Building Energy Efficiency Codes (BEEC) for Zimbabwe

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Presented to:

The Government of Zimbabwe

Presented by:

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Abbreviations

BEEC	Building Energy Efficiency Codes
CO_2	Carbon dioxide
CFL	Compact Fluorescent Lightbulbs
CTCN	Climate Technology and Network
DCV	Demand-Controlled Ventilation
ERV	Energy Recovery Ventilation
HRV	Heat Recovery Ventilation
IAQ	Indoor Air Quality
LCA	Life Cycle Analysis
LEDs	Light emitting diodes
MEPS	Minimum Energy Performance Standards
SADC	Southern Africa Development Community
SAZ	Standards Association of Zimbabwe
SHGC	Solar Gain Heat Coefficient
SC	Shading coefficient
U4E	United for Efficiency
UNEP	United Nations Environment Programme
WWR	Window-to-Wall Ratio
WTE	Waste-to-Energy
ZERA	Zimbabwe Energy Regulatory Authority
ZGBC	Zimbabwe Green Building Council

0 Foreword

This document is titled "Building Energy Efficiency Codes" (BEEC) of Zimbabwe and is prepared with the support of the United Nations Environment Programme (UNEP) and the Climate Technology Centre and Network (CTCN).

The urgency of addressing climate change is now more evident than ever, and as we witness the increasing impacts on our environment, it is important for countries to take decisive action. In this context, the Government of Zimbabwe, in collaboration with the Climate Technology Centre and Network (CTCN), has embarked on the development of Green Building Standards aimed at supporting the transformation of the building sector, which accounts for a substantial portion of the country's greenhouse gas emissions.

The primary goal of this "Building Energy Efficiency Codes" is to provide the technical background needed to promote the construction of energy-efficient buildings that provide several co-benefits such as reduced emissions during construction, improved building quality and resilience, improved occupant health and comfort, and more.

Buildings in Zimbabwe contribute significantly to the nation's emissions profile by consuming over 50% of all electricity as well as large quantities of biomass, LPG, and other fuels. Added to this, the outdated building standards, coupled with rapid urbanization, have resulted in infrastructure development that often overlooks climate considerations.

The development of this Building Energy Efficiency Codes represents a forward-thinking approach to rectify these challenges, fostering a built environment that is in harmony with nature and conducive to the well-being of all Zimbabweans.

Further, this project aligns with Zimbabwe's commitments under the Paris Agreement and reflects the country's progress dedication to sustainable development. By establishing robust green building standards, the aim to enhance the climate performance of new buildings, reduce greenhouse gas emissions, and promote energy efficiency.

The process of developing these codes has aimed to be inclusive and collaborative, engaging a broad range of stakeholders from government ministries, local authorities, the private sector, and civil society. This collaborative approach ensures that the codes developed are widely accepted and can be effectively implemented.

The team that has developed the present document express its deepest gratitude to all the stakeholders and partners who have contributed to this initiative. Your commitment and cooperation are vital to the successful implementation of these codes.

The team behind the development of these codes invite all stakeholders to continue their support and active participation as we finalize and implement the Building Energy Efficiency Codes. Let us collectively strive towards a sustainable built environment that enhances the quality of life for present and future generations.

1 Scope and Application

The BEEC will provide descriptions and specifications for the for the following elements of Green Building Development:

- Minimum energy efficiency requirements and verification methods – this includes the key performance requirements for different aspects of building construction.
- Calculation methods and tools – this includes description of methodologies and tools to support the assessment of performance.
- Building energy performance certifications and energy efficiency incentives – This includes methods to certify, incentivize, and increase awareness of green buildings. This may include building labels, certification schemes, etc.
- Control and enforcement – Description of processes for market surveillance and regulatory enforcement.
- Qualification of experts – description of requirements for the different levels of expertise required for the successful implementation.
- Review and adaptation – description of the process to be followed for the periodic review and update of this BEEC to maintain it up-to-date and relevant.

The standards specified in the BEEC shall constitute the minimum requirement from which other energy-related regulations may be derived. Wherever any derived energy-related regulation is in conflict with any section of the BEEC, the provision in the BEEC prevails.

1.1 Building types covered by the BEEC.

This BEEC is defining the minimum design and construction requirements related to energy conservation and savings for the following types of buildings:

- Residential buildings
- Office buildings
- Commercial buildings

1.1.1 Residential buildings

Residential buildings are structures designed primarily for people to live in, including single-family homes, multi-family buildings like apartments and condominiums, and other dwelling units. These buildings are characterized by their focus on providing living space, amenities, and utilities tailored to meet the daily needs of individuals and families. Residential buildings typically include bedrooms, kitchens, bathrooms, and living areas, and they are designed to offer a safe, comfortable, and private environment.

Residential buildings can encompass a wide range of building types from multistory apartment buildings to single dwelling buildings over $60m^2$ in size.

In Zimbabwe, residential buildings are generally classified as follows:

- The high density stands range from $180m^2$ to $300m^2$, with the buildings leaving 3m from the front, 2.1m from the back and 1.5m from either side from the boundary.
- The medium density stands range from about $400m^2$ to $1000m^2$, with building sizes leaving and allowance of 2m – 5m from the front and 3m – 6m from the remaining sides of the building.

- The low-density suburbs have a stand area of at least 1000m^2, occupying at most 30% of the stand area. Cluster houses have floor spaces of about 500m^2 in medium density and about 800m^2 in low density.

1.1.2 Commercial buildings

Commercial buildings are structures primarily used for business and professional activities, encompassing spaces such as offices, retail shops, hotels, restaurants, and other service-oriented establishments. These buildings typically have high energy demands due to extended operational hours and the need for various amenities to support business activities. Implementing energy-efficient practices in commercial buildings can significantly impact overall energy consumption, reduce operational costs, and contribute to national efforts to lower greenhouse gas emissions.

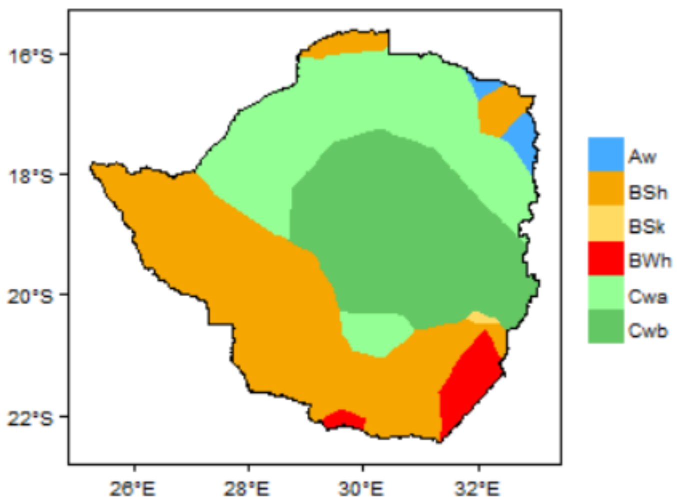
1.1.3 Office buildings

Office buildings are a subset of commercial buildings that are primarily used for business, administrative, and professional activities. These structures often have extended operational hours and require substantial energy for lighting, heating, cooling, and powering office equipment. Energy-efficient measures such as advanced HVAC systems, improved insulation, and the use of natural lighting can greatly decrease the energy demand of these buildings.

1.2 Climate zones

Zimbabwe, located in southern Africa, has a varied climate with different climate zones across the country. The climate zones are influenced by factors such as elevation, proximity to bodies of water, and topography. Here are the main climate zones in Zimbabwe:

Tropical Wet and Dry Climate (Aw):



This climate zone covers most of Zimbabwe and is characterized by distinct wet and dry seasons. Wet season: November to March, with the highest rainfall occurring from December to February. Dry season: April to October, with cooler temperatures and lower precipitation. This region includes major cities like Harare, Bulawayo, and Gweru.

Tropical High-Altitude Climate (Cwb):

This climate zone is found in the Eastern Highlands of Zimbabwe, including areas like Nyanga and Mutare. It is characterized by mild temperatures throughout the year due to the higher elevation. Rainfall is well-distributed, and the area receives more precipitation than the rest of the country. The Eastern Highlands have a pleasant climate and are known for their scenic beauty.

Semi-Arid Climate (Bsh):

Some parts of southern and southwestern Zimbabwe, including Beitbridge and parts of Matabeleland, experience a semi-arid climate. This region has hot temperatures, especially during the dry season, and receives lower rainfall compared to other areas in Zimbabwe. Droughts can be a concern in this climate zone.

Desert Climate (BWh):

The southwestern parts of Zimbabwe, particularly the area around Tsholotsho and Plumtree, can experience desert-like conditions. This zone is characterized by hot temperatures and very low rainfall, making it one of the driest regions in the country.

2 General Requirements

2.1 The overall objectives of the code, such as reducing energy consumption and promoting sustainability and Green Building Design.

The overall objectives of the BEEC for Zimbabwe are focused on reducing greenhouse gas (GHG) emissions, promoting sustainability, and enhancing energy efficiency in the built environment. These objectives align with global and national commitments to combat climate change, improve energy security, and foster sustainable development.

Reducing energy consumption is a primary objective of the BEEC, achieved through the implementation of energy-efficient design principles, high-performance materials, and advanced technologies. Optimized building design optimizing the utilization of natural light and ventilation, using high-performance building envelopes with materials that offer high thermal resistance, and the installation of efficient heating, ventilation, and air conditioning (HVAC) systems, along with energy-efficient lighting, further curtails energy consumption for temperature control and illumination.

Supporting renewable energy integration is crucial for further reducing GHG emissions and decreasing reliance on fossil fuels. The BEEC encourages the installation of on-site renewable energy systems, such as solar photovoltaic (PV) systems and solar water heaters, to generate clean energy. Preparing buildings for smart grid integration ensures efficient energy management and optimal utilization of renewable energy sources, enhancing overall energy resilience.

To ensure effective implementation, the BEEC includes robust compliance and enforcement mechanisms. This includes that regime that will assess plans prior to the development of the building and regular building inspections are conducted to verify compliance. To support inclusions in the industry, the BEEC will aim to ensure that the implementation and compliance processes do not negatively affect gender inequality issues.

It is understood that the concept of green buildings includes a wide range of performance concepts, but it is worth reiterating that this BEEC will only focus on the energy and climate and performance of buildings.

2.2 Performance goals and objectives for buildings.

This BEEC sets specific performance goals and objectives to ensure that buildings achieve high standards of energy efficiency and climate sustainability. The performance goals in this BEEC are aligned with national and global efforts to mitigate climate change, enhance energy security, and promote sustainable development.

Improving the overall building energy/climate performance involves setting stringent benchmarks for various building systems and ensuring that they operate at optimal efficiency. The performance metrics for individual building components will vary from an r value for insulation to a lux value for lighting, however, the resulting performance for different types of building can be summarized into the number of kilowatt hours per square meter per year (kWh/m^2/year) to indicate to the overall performance level of the building (Table 1).

Table 1: Minimum energy performance indices for different types of buildings in Zimbabwe in kWh/m^2/year. (Source: ZERA Draf Energy Conservation Code).

No,	Building type	BEEC minimum baseline energy performance (kWh/m^2/yr)
1	Office	175
2	Retail	300
3	Hotel	300
4	Hospital	300
5	University	150
6	Industrial Park	150

These levels of building performance are informed by the newly developed conservation codes by the Zimbabwe Energy Regulatory Authority (ZERA) as they are believed to be well suited to Zimbabwe and to ensure coherence between the different active policies in the country. These codes provide a comprehensive framework for energy conservation and efficiency, setting the benchmarks that buildings must achieve to comply with national energy performance standards.

It is important to note that is expected that buildings will meet the performance requirements for each individual component as well as the over figure in Table 1.

The BEEC promotes the use of energy management systems that can effectively integrate renewable energy sources with traditional energy systems, ensuring that buildings can maximize their use of clean energy.

The BEEC also emphasizes the importance of compliance and continuous improvement. Buildings must undergo regular inspections and audits to ensure they meet the established performance standards. The implementation of these codes is supported by a framework that includes incentives for compliance and penalties for non-compliance. This approach ensures that the performance goals and objectives are not only achieved but maintained over the long term.

3 Building Envelope

The building envelope is one of the most important components to achieve energy efficiency in buildings, playing a significant role in minimizing energy consumption and enhancing thermal comfort. Key variables influencing the building envelope's performance include U-value, Solar Heat Gain Coefficient (SHGC), and Window to Wall Ratio (WWR). The U-value measures thermal transmittance, indicating the rate of heat transfer through the building's walls, roof, and fenestration. Lower U-values indicate better insulation and reduced heat losses or gains between the outside environment and the inside of the building. SHGC measures the fraction of solar radiation admitted through windows, with lower values reducing cooling loads. WWR represents the proportion of the building's exterior wall covered by windows, which can greatly impact both thermal performance and natural lighting.

The importance of the building envelope lies in its ability to reduce the building's overall energy demand by mitigating unwanted heat gain in warm climates and heat loss in cooler climates. Effective design and the use of optimum material can lead to significant energy savings, reducing the reliance on heating, ventilation, and air conditioning (HVAC) systems. For instance, high-performance windows and well-insulated walls can minimize thermal bridging and improve the building's energy efficiency. In Zimbabwe, incorporating these measures into the building code is essential for promoting sustainable development and reducing greenhouse gas emissions. The integration of energy-efficient building envelope standards into national policies underscores the critical role these elements play in achieving energy conservation goals and enhancing the overall sustainability of the built environment.

Building orientation and site selection (where possible) are other important components for energy efficiency in Zimbabwe, affecting heat gains, shading, and natural light. Orienting buildings with their longer sides facing east and west can reduce solar heat gain, especially from intense afternoon sun, while maximizing north-facing windows provides consistent natural light. Effective shading through overhangs, awnings, and vegetation can further manage heat gain. Proper window placement and the use of light shelves can enhance daylighting, reducing the need for artificial lighting. Additionally, orienting buildings to facilitate natural cross-ventilation improves indoor air quality and reduces reliance on mechanical cooling. Integrating these orientation strategies with other design elements can create energy-efficient, comfortable, and sustainable buildings in Zimbabwe.

3.1 Key Factors in Building Orientation:

3.1.1 Maximize Solar Gain in Winter:

- **Orientation**: In Zimbabwe, orient buildings to capture maximum sunlight during winter months. Large windows facing north (in the Southern Hemisphere) allow for the best solar gain, as the sun is lower in the northern sky during winter.
- **Design Features**: Use large, unobstructed windows on the north side to allow sunlight to penetrate and warm interior spaces. Incorporate thermal mass elements such as concrete or stone floors to store this heat and release it slowly, maintaining warmth during the night.

3.1.2 Minimize Solar Gain in Summer

- **Shading Devices**: Install shading devices like overhangs, pergolas, or vertical fins to block excessive solar gain during summer. These should be designed to block the high-angle summer sun while allowing the lower-angle winter sun to penetrate.

- **Vegetation**: Plant deciduous trees on the north and west sides to provide natural shading in summer and permit sunlight in winter when they shed their leaves.

3.1.3 Natural Daylighting:

South and North Facades:

- **South Facade**: In Zimbabwe, windows on the north side (southern facade) should be maximized to allow ample natural light without excessive heat gain. Use light shelves and reflective surfaces to bounce light deeper into the building.
- **North Facade**: Windows on the south side (northern facade) provide consistent, diffuse light, reducing the need for artificial lighting. This orientation minimizes glare and heat gain, enhancing indoor comfort.

East and West Facades:

- **Minimize Window Areas**: Reduce window sizes on the east and west facades to minimize heat gain and glare from the low-angle morning and afternoon sun.
- **Shading**: Use vertical louvers, screens, or other shading devices to block direct sunlight, preventing overheating and glare.

3.1.4 Wind Patterns:

Natural Ventilation:

- **Prevailing Winds**: Orient buildings to take advantage of prevailing wind patterns for natural cooling and ventilation. In Zimbabwe, aligning buildings to maximize cross-ventilation can significantly reduce reliance on mechanical cooling systems.
- **Ventilation Design**: Design openings on opposite sides of the building to facilitate effective cross-ventilation, allowing fresh air to flow through and cool the interior spaces.

Wind Protection:

- **Landscaping**: Use trees, shrubs, and other landscaping elements to block harsh winds in colder climates. This can create a more comfortable microclimate around the building.
- **Building Forms**: Design building forms and layouts that protect against prevailing cold winds while allowing for natural ventilation during warmer months.

3.1.5 Thermal Mass:

Heat Storage:

- **Materials**: Incorporate materials with high thermal mass, such as concrete, stone, or brick, especially on the north side (southern exposure) of the building. These materials absorb heat during the day and release it slowly at night, providing a natural heating effect.
- **Placement**: Position thermal mass elements where they can receive direct sunlight in winter to store heat effectively.

Insulation:

- **Building Envelope**: Ensure that the building is well-insulated, particularly on the south side (northern exposure), to minimize heat loss during colder months. High-quality insulation materials in walls, roofs, and floors reduce the need for artificial heating.
- **Windows and Doors**: Use double-glazed windows and insulated doors to improve thermal performance and reduce heat loss.

3.1.6 Local Climate:

Climate-Specific Design: Tailor the orientation and design features to the specific climate zone. For example, in hot, arid climates, minimizing heat gain is critical, while in cold climates, maximizing solar gain is more important.

- **Hot, Arid Climates:** In regions with hot, arid climates, like much of Zimbabwe, minimizing heat gain is crucial. Use reflective roofing materials, light-coloured exterior finishes, and shading devices to keep buildings cool.
- **Cold Climates:** In cooler regions, prioritize maximizing solar gain to reduce heating needs. Incorporate large windows on the north side (southern exposure) and use thermal mass to store and distribute heat.
- **Humid Climates:** For areas with high humidity, focus on ventilation and shading to reduce moisture buildup and maintain comfort. Elevated buildings and wide eaves can help manage moisture and heat.

3.2 Requirements for the building's exterior components, including walls, roofs, windows, doors, and insulation.

Designing and constructing a building's exterior components with energy efficiency as the primary consideration involves careful selection of materials, construction methods, and design features. These elements are crucial in reducing energy consumption, enhancing thermal comfort, and minimizing environmental impact. The specific requirements can vary depending on local building codes, climate, and the building's purpose (e.g., residential, commercial, industrial). Below are the key considerations and requirements for each exterior component:

3.2.1 Walls

The key considerations for energy efficiency in walls are:

- **Insulation**: Use high-quality insulation within wall cavities or as an exterior layer to minimize heat transfer. Effective options include rigid foam boards, spray foam, or mineral wool, which help maintain indoor temperatures and reduce energy usage for heating and cooling.
- **Thermal Mass**: In climates with significant temperature fluctuations, materials with high thermal mass (e.g., concrete, brick) can stabilize indoor temperatures by absorbing heat during the day and releasing it slowly at night, reducing reliance on HVAC systems.

Functionality and Durability:

- **Material Selection**: Choose materials that offer strength, durability, and weather resistance, such as brick, concrete, stone, and modern composites. These materials should also support energy-efficient design principles.

- **Moisture Control**: Incorporate moisture barriers and drainage planes to prevent water infiltration and damage, ensuring the building's longevity and maintaining insulation effectiveness.

Aesthetic Appeal:

- **Finishes and Cladding**: Select finishes that enhance the building's aesthetic while providing additional weather protection. Options include stucco, siding, and decorative masonry.

3.2.2 Roofs

Energy Efficiency:

- **Insulation**: Install adequate insulation to reduce heat loss in winter and heat gain in summer. Reflective insulation and radiant barriers are particularly effective in hot climates, helping to maintain comfortable indoor temperatures.
- **Cool Roofs**: Use cool roofing materials that reflect more sunlight and absorb less heat, reducing cooling loads and improving energy efficiency.

Functionality and Durability:

- **Material Selection**: Choose roofing materials that provide durability and weather resistance, such as metal, tile, asphalt shingles, or green roofs.
- **Waterproofing**: Ensure proper waterproofing and drainage systems to prevent leaks and water damage, which can affect insulation and overall energy performance.

Aesthetic Appeal:

- **Design and Colour**: Select roofing designs and colours that complement the building's overall architectural style and surroundings.

3.2.3 Windows

Energy Efficiency:

- **Low-E Coatings**: Use low-emissivity (Low-E) coatings to reduce heat transfer while allowing natural light, enhancing both comfort and energy efficiency.
- **U-Value and SHGC**: Select windows with low U-values for better insulation and appropriate Solar Heat Gain Coefficients (SHGC) to control solar gain based on climate needs, reducing heating and cooling demands.

Functionality and Durability:

- **Frame Materials**: Use durable frame materials like vinyl, wood, aluminium, or fiberglass, which provide good thermal performance and longevity.
- **Glazing**: Choose high-performance glazing options like double or triple glazing, which **provide better insulation and noise reduction.**

Aesthetic Appeal:

- **Design and Placement**: Ensure window designs and placements enhance the building's architectural style and provide balanced natural lighting.

3.2.4 Doors

Energy Efficiency:

- **Insulated Doors**: Use doors with internal insulation cores to improve thermal performance and reduce energy loss.
- **Double Seals**: Incorporate double seals on exterior doors to enhance energy efficiency by preventing air leaks.

Functionality and Durability:

- **Material Selection**: Choose materials that offer security, durability, and weather resistance, such as wood, steel, fiberglass, and composite materials.
- **Weather Stripping**: Install high-quality weather stripping to seal gaps and prevent air and moisture infiltration, maintaining the building's thermal envelope.

Aesthetic Appeal:

- **Design and Finish**: Select door designs and finishes that complement the building's exterior and provide a welcoming entrance.

3.2.5 Insulation

Energy Efficiency:

- **R-Value**: Select insulation with appropriate R-values for walls, roofs, and floors based on the local climate and building codes. Higher R-values indicate better insulating properties, reducing energy consumption.
- **Continuous Insulation**: Consider using continuous insulation to cover all exterior surfaces, minimizing thermal bridging and enhancing the building's overall energy performance.

Functionality and Durability:

- **Material Selection**: Use durable insulation materials that maintain their thermal properties over time. Options include fiberglass, foam board, cellulose, and spray foam.
- **Installation Quality**: Ensure proper installation to avoid gaps, compression, and thermal bridges, which can reduce insulation effectiveness and compromise energy efficiency.

3.3 Minimum insulation and thermal performance requirements.

Minimum insulation values and thermal performance requirements are essential to enhance a building's energy efficiency, reduce heating and cooling costs, and ensure comfortable indoor environments. These requirements vary depending on factors such as location, building type, and local building codes. Below are key considerations and guidelines for establishing and meeting these requirements:

3.3.1 Location-Specific Requirements

Climate Zones:

- **Hot Climates**: In regions like Zimbabwe, where the climate can be hot and arid, insulation requirements focus on minimizing heat gain. Reflective insulation materials and radiant barriers are effective in reducing cooling loads.
- **Cold Climates**: In colder regions, the emphasis is on minimizing heat loss. Higher R-values for walls, roofs, and floors are necessary to maintain indoor warmth and reduce heating energy consumption.

Local Building Codes:

- **Compliance**: Building codes often specify minimum R-values for different building components (e.g., walls, roofs, floors). Compliance with these codes is mandatory to ensure energy efficiency and safety.
- **Updates**: Regular updates to building codes may occur to reflect advancements in building materials and technologies, ensuring that insulation standards remain effective and relevant.

3.3.2 Building Type Considerations

Residential Buildings:

- **Walls**: For residential buildings, wall insulation typically requires an R-value of at least R-13 to R-21, depending on the specific climate zone. Properly insulated walls help maintain a stable indoor temperature and reduce reliance on heating and cooling systems.
- **Roofs and Ceilings**: Roof and ceiling insulation in residential buildings should have higher R-values, often ranging from R-30 to R-60, to prevent heat loss through the attic or roof space.
- **Floors**: Insulation for floors, especially those above unconditioned spaces like basements or crawl spaces, should have an R-value of R-19 to R-30.

Commercial Buildings:

- **Walls**: Commercial buildings often have different insulation requirements due to their larger size and different usage patterns. Wall insulation may need to meet R-values of R-13 to R-20.
- **Roofs**: Flat roofs or those with minimal slope on commercial buildings require significant insulation, typically R-30 to R-49, to prevent heat gain and loss.
- **Floors**: Floors in commercial buildings, particularly those above unconditioned areas, should be insulated with an R-value of R-19 to R-30.

3.3.3 Insulation Materials and Installation

Material Selection:

- **Fiberglass**: Commonly used in both residential and commercial buildings, fiberglass insulation is affordable, easy to install, and provides good thermal resistance.
- **Spray Foam**: Spray foam insulation offers superior thermal performance and air sealing capabilities. It is ideal for filling gaps and creating a continuous insulation layer.
- **Rigid Foam Boards**: Rigid foam boards provide high R-values per inch of thickness and are suitable for insulating walls, roofs, and foundations.

- **Mineral Wool**: Mineral wool insulation is fire-resistant and provides good thermal and acoustic insulation properties.

Installation Quality:

- **Proper Installation**: Ensuring that insulation is correctly installed is crucial for achieving the desired thermal performance. Poor installation can lead to gaps, compression, and thermal bridging, reducing the effectiveness of the insulation.
- **Air Sealing**: Alongside insulation, proper air sealing is essential to prevent air leaks and drafts. This includes sealing around windows, doors, and any penetrations through the building envelope.

3.3.4 Thermal Performance Metrics

R-Value:

- **Definition**: The R-value measures a material's resistance to heat flow. Higher R-values indicate better insulating properties.
- **Requirement**: Building codes specify minimum R-values for different components (e.g., walls, roofs, floors) based on climate zones and building types.

U-Value:

- **Definition**: The U-value measures the rate of heat transfer through a building element (e.g., window, wall). Lower U-values indicate better insulation.
- **Application**: U-values are particularly important for windows and doors, where thermal performance can significantly impact overall building efficiency.

Thermal Bridging:

- **Mitigation**: Thermal bridging occurs when heat bypasses insulation through structural elements like studs or beams. To minimize thermal bridging, continuous insulation and advanced framing techniques can be used.
- **Impact**: Reducing thermal bridging improves the overall thermal performance of the building envelope, leading to lower energy consumption and enhanced comfort.

3.4 Window-to-wall ratio (WWR)

The window-to-wall ratio (WWR) is a term used in architecture and building design to describe the proportion of a building's exterior wall area that is occupied by windows. It is typically expressed as a percentage and is an important factor in determining a building's energy efficiency, aesthetics, and overall functionality.

A higher window-to-wall ratio means that a larger portion of the exterior walls is composed of windows, while a lower ratio means that there are fewer windows in proportion to the wall area. The choice of WWR can have significant implications for a building's performance and occupants' comfort.

The Window-to-Wall Ratio (WWR) is the fraction of the above grade wall area that is covered by fenestration, calculated as the ratio of the wall fenestration area to the gross above grade wall area.

$$WWR\ (\%) = \frac{\sum \text{Glazing area } (m^2)}{\sum \text{Gross exterior wall area } (m^2)}$$

3.4.1 Code requirements for window-to-wall ratio

Window to Wall Ratio for any orientation shall not exceed 20%. Where the design is such that this cannot be achieved, then all glazing elements on the relevant facades are to be adequately shaded[1].

3.5 Shading coefficient of windows

Shading and overhangs play a vital role in enhancing the energy efficiency of buildings by controlling solar heat gain and improving thermal comfort. These design features block direct sunlight during peak summer months, reducing the cooling load on air conditioning systems and lowering energy consumption. Overhangs, particularly on south-facing windows (in the Southern Hemisphere), are effective in preventing high-angle summer sun from entering the building while allowing lower-angle winter sun to penetrate and provide natural warmth. Additionally, shading devices such as pergolas, louvers, and strategically planted vegetation can mitigate glare and reduce indoor temperatures, creating a more comfortable environment. By optimizing natural light and minimizing overheating, shading and overhangs contribute to significant energy savings and enhance the overall sustainability of buildings. These elements are especially beneficial in regions with hot climates, like Zimbabwe, where managing solar exposure is crucial for maintaining energy-efficient and comfortable indoor spaces.

The shading coefficient (SC) of windows is a measure used in building design and energy analysis to quantify the effectiveness of window treatments or shading devices in reducing solar heat gain. It represents the fraction of solar heat that is transmitted through a window with shading compared to the solar heat transmitted through the same window without any shading. In other words, it measures how well a shading system can block or reduce the amount of solar radiation that enters a building through windows.

The shading coefficient is typically expressed as a dimensionless number between 0 and 1, where:

- An SC of 1 means that no shading is applied, and all the solar heat is transmitted through the window.
- An SC of 0 means that the shading system completely blocks all solar heat, so no heat is transmitted through the window.

Lower shading coefficients indicate better shading performance and can lead to reduced cooling loads in warm climates, as they help prevent excessive solar heat gain in a building's interior.

3.5.1 Shading and overhang

Shading and overhangs components are an important element of green building design, by optimizing the buildings' interactions with the environment and solar radiation they can have a significant role in enhancing energy efficiency and indoor comfort. These architectural elements

[1] World Green Building Council. (n.d.). *Daylighting the way to greener and healthier buildings*. World Green Building Council. Retrieved from https://worldgbc.org/article/daylighting-the-way-to-greener-and-healthier-buildings/

control solar heat gain, reduce cooling loads, and minimize glare, contributing to a more sustainable building environment. By blocking direct sunlight during peak summer months, shading devices and overhangs help maintain cooler indoor temperatures, reducing the reliance on air conditioning systems and lowering energy consumption.

Shading can also be achieved through various methods, including fixed overhangs, adjustable louvers, pergolas, and strategically planted vegetation. Each method has its benefits, such as fixed overhangs providing consistent protection and adjustable louvers offering flexibility based on seasonal changes. Vegetation like deciduous trees can provide natural shading in summer and permit sunlight during winter, further enhancing energy savings. In regions with hot climates, such as Zimbabwe, these strategies are especially beneficial as they help maintain a comfortable indoor environment while significantly reducing energy costs and carbon footprint

3.6 Roof insulation (R-value)

Roof insulation is a crucial component of a building's thermal envelope, which helps regulate indoor temperature and energy efficiency. It is installed in the roof or attic space to reduce heat transfer between the interior and exterior of a structure. Proper roof insulation provides several benefits:

- Energy Efficiency: Insulating the roof helps keep indoor temperatures stable, reducing the need for heating and cooling. This, in turn, lowers energy consumption and utility bills.
- Comfort: Insulation helps maintain a comfortable indoor environment by preventing heat from escaping during the winter and blocking heat from entering during the summer. This results in a more consistent indoor temperature and improved comfort.
- Noise Reduction: Insulation can also reduce external noise, such as traffic or rain, from penetrating into the living or working space.
- Moisture Control: Roof insulation can act as a barrier against moisture infiltration, preventing condensation and potential damage to the building structure.
- Longevity: Proper insulation can extend the life of a roof by reducing temperature-related stress and minimizing the expansion and contraction of roofing materials due to temperature fluctuations

3.6.1 Roof insulation requirement

All roof constructions are to include a layer of insulation with thermal resistance not less than 1.25 m^2K/W (R-value) in the warmer regions. For temperate or cooler areas, an R-value of 36 is recommended[2].

3.7 Sustainable building materials (embodied carbon)

Sustainable building materials are designed to minimize environmental impact throughout their entire lifecycle, from extraction and production to use and disposal. One critical aspect of assessing their sustainability is embodied carbon, which refers to the total greenhouse gas

[2] This is accordance with recommendations of the 2021 International Energy Conservation Code: International Code Council. (2021). *2021 International Energy Conservation Code (IECC)*. International Code Council. Retrieved from https://codes.iccsafe.org/content/IECC2021P1

emissions (expressed as carbon dioxide equivalent, CO_2e) associated with producing and processing these materials.

Embodied carbon encompasses all the CO_2 emissions from:

- Extraction of raw materials: Mining, logging, and other extraction processes often release significant amounts of CO_2.
- Manufacturing and processing: Converting raw materials into usable building products requires energy, often from fossil fuels.
- Transportation: Moving raw materials and finished products to the construction site also contributes to the carbon footprint.
- Construction and installation: Energy used during the building phase, including machinery and labor.
- Maintenance and replacement: Over the lifecycle of the building, materials may need maintenance or replacement, contributing to additional carbon emissions.
- End of life: Demolition and disposal or recycling of materials

To reduce embodied carbon, several strategies can be employed:

3.7.1 Material Selection

Low-Carbon Materials:

- **Sustainably Harvested Wood**: Using wood from sustainably managed forests can significantly reduce embodied carbon. For example, Cross-Laminated Timber (CLT) not only sequesters carbon but also requires less energy to produce compared to steel or concrete. Studies show that substituting CLT for conventional materials can reduce embodied carbon by up to 30%.[3,4]

3.7.2 Efficient Design

Optimization Techniques:

- **Modular Construction**: Prefabrication and modular construction techniques can minimize material use and waste. For example, prefabricated panels and modules are manufactured in controlled environments, reducing on-site waste and improving material efficiency. This approach can cut construction waste by up to 90% and reduce overall embodied carbon by 10-20%.[5]
- **Structural Efficiency**: Designing buildings with optimal structural efficiency reduces the amount of material needed without compromising strength. For instance, using advanced

3 5 Benefits of Building with Cross-Laminated Timber, Forest Biomaterials Research. Website: https://cnr.ncsu.edu/news/2022/08/5-benefits-cross-laminated-timber/

4 Building a Carbon Negative Future with Steel and Cross Laminated Timber. Website: https://coe.northeastern.edu/news/building-a-carbon-negative-future-with-steel-and-cross-laminated-timber/

5 Building a Carbon Negative Future with Steel and Cross Laminated Timber. Website: https://coe.northeastern.edu/news/building-a-carbon-negative-future-with-steel-and-cross-laminated-timber/

structural analysis and design software allows for precise material usage, resulting in up to 25% material savings and corresponding reductions in embodied carbon.[6]

3.7.3 Local Sourcing

Proximity and Availability:

- **Local Materials**: Sourcing materials locally reduces transportation emissions. For instance, using locally quarried stone or locally produced bricks can significantly cut down the carbon footprint. Transportation emissions can constitute up to 15% of the total embodied carbon, so local sourcing can lead to substantial savings.[7]
- **Traditional materials** like clay bricks and grass or hay roofing can offer sustainable building solutions that align with green building principles, particularly in the Zimbabwe context where traditional housing provide suitable solutions in rural areas. These materials are not only locally sourced and culturally relevant but also provide environmental benefits such as reduced energy consumption and minimal carbon footprint. They also promote the use of indigenous knowledge and practices, supporting sustainable development in the built environment. The performance of these materials can vary depending on the local manufacture, type, and quality of installation, but usually they have a solid energy performance, specially in the temperate climate that dominates Zimbabwe, these include:
    - **Clay Bricks** typically offers R-values ranging from 0.20 to 0.45 ($m^2 \cdot K/W$) depending on the density and type of brick. These values indicate moderate insulation properties, useful for stabilizing indoor temperatures in temperate climates.
    - **Hay/Grass** or thatch roofing generally have R-values between 1.5 and 2.5 ($m^2 \cdot K/W$), providing strong insulation as there is plenty of air trapped in the material, providing a strong barrier to heat transfer.
- **Climate-Suited Materials**: Utilizing materials naturally suited to the local climate, such as adobe in arid regions, can reduce the need for additional energy-intensive processing and transportation. Adobe construction has up to 50% lower embodied carbon compared to conventional building materials.

3.7.4 Recycled and Reused Materials

Incorporation of Recycled Content:

- **Recycled Steel**: Steel can be recycled multiple times without losing its properties. Using recycled steel can reduce embodied carbon by up to 75% compared to virgin steel.[8]

[6] Design guidance for reducing embodied carbon in structural systems. Website: https://se2050.org/resources-overview/structural-materials/lean-design-guidance/

[7] Building a Carbon Negative Future with Steel and Cross Laminated Timber. Website: https://coe.northeastern.edu/news/building-a-carbon-negative-future-with-steel-and-cross-laminated-timber/

[8] Cross laminated timber (CLT): overview and development. Website: https://link.springer.com/article/10.1007/s00107-015-0999-5

- **Reclaimed Wood**: Reusing wood from demolished buildings or other sources reduces the need for new timber. Reclaimed wood can cut embodied carbon by up to 50% compared to new lumber.[9]

3.7.5 Innovative Technologies

New Methods and Materials:

- **Low carbon cement**: Technologies like CarbonCure inject CO_2 captured from industrial processes into concrete, where it is permanently mineralized. This method can reduce the carbon footprint of concrete by up to 10%. Other technologies include cementitious materials that can proportionately replace Portland cement in concrete that can result in savings of 30 to 70%. Examples of these materials include Limestone Calcinated Cement (LC3) among others. [10,11]
- **Low-Carbon Binders**: Using alternative binders like fly ash or slag in place of traditional Portland cement can lower embodied carbon. For example, concrete made with 50% fly ash can reduce embodied carbon by 20-30%.[12]

3.7.6 Lifecycle Assessment (LCA)

Comprehensive Analysis:

- **Lifecycle Assessment Tools**: Tools like the Environmental Product Declaration (EPD) and Building for Environmental and Economic Sustainability (BEES) provide detailed insights into the environmental impact of materials. Conducting LCAs helps identify the stages with the highest carbon emissions and opportunities for improvement. Implementing LCA recommendations can lead to a reduction in embodied carbon by up to 30%.[13]

By focusing on these strategies, we can make more informed choices that promote sustainability, reduce greenhouse gas emissions, and enhance the long-term resilience of the built environment. For instance, substituting traditional concrete with a mix containing 30% recycled materials can save approximately 150 kg of CO_2e per cubic meter. Similarly, using local, sustainably sourced wood can reduce transportation emissions by up to 50%, significantly cutting the overall carbon footprint. These examples illustrate how integrating sustainable materials and practices into building construction can yield substantial environmental benefits and contribute to a more sustainable future.

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[9] Revisiting Wood and Embodied Carbon. Website: https://www.buildinggreen.com/op-ed/revisiting-wood-and-embodied-carbon
[10] Laying the foundation for zero-carbon cement. Website: https://www.mckinsey.com/industries/chemicals/our-insights/laying-the-foundation-for-zero-carbon-cement
[11] Why near-zero cement and concrete are crucial building blocks to reach net-zero Website: https://www.weforum.org/agenda/2023/11/near-zero-cement-concrete-net-zero/.
[12] Enhancing the sustainability of high strength concrete in terms of embodied energy and carbon emission by incorporating sewage sludge and fly ash. Website: https://link.springer.com/article/10.1007/s41062-022-00837-5
[13] 5 Benefits of Building with Cross-Laminated Timber, Forest Biomaterials Research. Website: https://cnr.ncsu.edu/news/2022/08/5-benefits-cross-laminated-timber/

3.7.7 Design considerations beyond materials and energy applications

Green building and energy efficient design encompasses a wide range of considerations beyond direct energy consumption, focusing on optimizing occupant experience, environmental impact, and overall building performance. These considerations include optimizing occupant movement, enhancing natural lighting, incorporating ergonomic design, and ensuring connectivity with the natural environment. The integration of these features can result in reduction of energy demand through reduce use of energy applications dues increased comfort or convenience. Some of these considerations include:

- Optimizing occupant movement and circulation within a building can result in enhanced productivity, reducing energy use, and improving overall comfort. Efficient circulation can minimize the use of elevators or escalators. As added co-benefits, this can promote active movement, such as using stairs instead of elevators, contributing to occupant health and well-being. These strategies include the placement of staircases in prominent, convenient, and inviting locations to encourage their use over elevators.
- Biophilic design principles look to incorporate elements of nature into the built environment to enhance occupant well-being and environmental performance. Features such as green walls, indoor plants, water features, and views of nature are not only aesthetically pleasing but also support mental and physical health. Green walls and roofs can significantly improve the insulation performance of buildings. Added to this, co-benefits include reduces stress of occupants, improved internal air quality, and improve overall occupant satisfaction which can result in improved productivity.
- Traditional and indigenous designs often feature passive cooling techniques, such as thick walls made from local materials, high ceilings, courtyards, and the strategic use of shade. For instance, traditional Zimbabwe rural architecture often includes features like thatched roofs and clay brick walls, which provide excellent insulation and ventilation. Similarly, indigenous designs present a stronger connection to the local environment, utilizing locally available resources and responding to the specific climatic conditions. Traditional design elements not only promote sustainability but also foster a sense of place and cultural continuity.

It is important to note that this standard does not look to replace all existing practices, rather build on the existing building practices and cultures to attain stronger energy performance. In the case of traditional buildings, they already present strong advantages, but considering recommendations from this document may provide significant improvements without losing the key features that identify them.

4 Heating, Ventilation, and Air Conditioning (HVAC)

Heating, Ventilation, and Air Conditioning (HVAC) systems are one of the most important in the context of green buildings as they are one of the largest energy consuming end-uses. HVACs also significantly impact their energy efficiency and indoor environmental quality. In sustainable architecture, the design and implementation of HVAC systems focus on reducing energy consumption, minimizing greenhouse gas emissions, and enhancing occupant comfort. Key strategies focus on the efficient HVAC system design, the use of energy-efficient equipment, advanced control systems, and integration with renewable energy sources. For instance, high-efficiency heat pumps, variable refrigerant flow systems, and smart thermostats are commonly employed to optimize performance.

Another key element for green buildings is incorporating and maximizing the use natural ventilation, proper insulation, and passive solar heating can further reduce the reliance on mechanical systems. Prioritizing these approaches can result in substantial energy savings, lower operational costs, and contribute to environmental sustainability.

Aside from technological options, the optimum design of HVAC systems is important in green buildings. This can encompass several critical aspects, from correctly sizing the equipment to strategic positioning and incorporating advanced technologies. Proper sizing ensures that HVAC systems operate efficiently without unnecessary energy consumption or wear. Positioning HVAC units to maximize airflow and minimize energy loss, while interacting with components of natural ventilation can result in significant savings.

4.1 Heating

Heating systems are used to maintain comfortable indoor temperatures in buildings during the colder times of the year. Given the relatively mild winters experienced in Zimbabwe, heating has traditionally represented a smaller component of household energy consumption. Heating is achieved through the use of electric heaters in electrified households and burning of biomass in both electrified and unelectrified homes. Biomass in the form of unprocessed wood and charcoal is the major source of fuel for heating due to loadshedding which usually intensifies during winter. During summer and dry season, heating is not usually done except in areas with tropical high-altitude climate.

For Green Buildings the heating component can leverage passive solar heating, which utilizes building orientation and materials to naturally warm indoor spaces during the day. For instance, north-facing windows can capture maximum sunlight, and thermal mass materials like concrete can store and slowly release heat.

High-efficiency heat pumps are also a viable option, providing both heating and cooling with significantly lower energy use compared to conventional systems. Ground-source (geothermal) heat pumps, which extract stable temperatures from the ground, can be particularly effective in the Zimbabwean climate, offering a renewable and reliable heating solution. Additionally, integrating solar water heaters for domestic hot water supply reduces reliance on electricity or fossil fuels.

Effective insulation is an important component that operates in tandem with the heating systems in buildings, reducing the need for additional heating. Insulating roofs, walls, and floors, and using double-glazed windows help prevent heat loss. Combining these strategies with advanced controls, such as programmable thermostats, ensures that heating systems operate only when needed, further enhancing energy efficiency.

4.2 Air conditioning

Energy efficient air conditioning systems are crucial for reducing energy consumption, lowering utility bills, and minimizing environmental impact. With advancements in technology, modern air conditioning units are now more efficient than ever, providing comfortable indoor climates while using less energy. The air conditioners in Zimbabwe are used mostly in non-residential buildings and consuming up to 70% of electricity for office buildings, commercial buildings and hotels. Zimbabwe has plans to implement energy efficient and climate friendly air-conditioners under the Cooling minimum energy performance standards (MEPS) project for refrigerators and air-conditioners.

Energy efficient air conditioning systems not only reduce energy consumption and lower utility bills but also contribute to a more sustainable environment by decreasing greenhouse gas emissions. By choosing the right type of system, incorporating advanced features, and following best practices for maintenance and usage, homeowners and businesses can achieve optimal cooling efficiency and comfort.

4.2.1 Features of Energy Efficient Air Conditioners

- Inverter technology: Adjusts the compressor speed to maintain the desired temperature, reducing energy consumption and providing more consistent comfort.
- Variable speed motors: Fan and compressor motors that can adjust speeds to meet cooling demands more efficiently than single-speed models.
- Smart thermostats and controls: Devices that allow for precise temperature control, scheduling, and remote access via smartphones. Smart thermostats can learn user preferences and optimize cooling schedules.
- Energy saving mode: Reduces power consumption by operating the unit at a lower capacity or cycling the compressor on and off.
- High-efficiency filters: Improve indoor air quality and maintain system efficiency by ensuring proper airflow and reducing strain on the system.

4.2.2 Strategies for Improving Air Conditioning Efficiency

- Appropriate sizing: Ensure the air conditioning unit is appropriately sized for the space. An oversized unit will cycle on and off frequently, wasting energy, while an undersized unit will struggle to cool the space.
- Regular maintenance: Clean or replace filters regularly, check and clean coils, and ensure proper refrigerant levels to maintain efficiency.
- Seal and insulate: Ensure ducts are sealed and insulated properly to prevent air leaks. Additionally, insulate the building to reduce cooling demand.
- Use ceiling fans: Fans can help distribute cool air more evenly and allow you to set the thermostat a few degrees higher without sacrificing comfort.
- Set optimal temperatures: During cooling seasons, set the thermostat to the highest comfortable setting. Each degree higher can save significant energy.
- Utilize natural ventilation: When outdoor temperatures are cooler, use windows and fans to ventilate and cool the space naturally.

- Energy audits: Conduct an energy audit to identify inefficiencies in the cooling system and building envelope.
- Reasonable AC temperature settings: Setting AC temperatures to warm yet comfortable indoor temperatures such as 25ºC will save energy compared to cool temperature settings that make the AC operate for much longer time and at a higher capacity causing waste and high energy consumptions.

4.2.3 Air conditioning requirements

The minimum required performance of air conditioning units installed in Zimbabwe should adhere to the MEPS for AC currently under development by the Government of Zimbabwe, which should be regularly updated to keep pace with technology development.

While the MEPS are under development, the Southern Africa Development Community (AFDC) (which includes Zimbabwe) approved harmonized standards for ACs should serve as a minimum requirement for ACs installed in the country.

It is also highly recommended that the strategies for optimal utilization of AC units above should be followed.

4.3 Ventilation and indoor air quality.

Ventilation and air quality directly impact the effectiveness of energy appliances and the health, comfort, and well-being of occupants. Effective ventilation systems ensure a consistent supply of fresh outdoor air while removing indoor pollutants, thereby maintaining high indoor air quality. In green buildings, ventilation strategies are designed to be energy-efficient and environmentally sustainable. This includes the use of natural ventilation, mechanical ventilation with heat recovery systems, and advanced filtration technologies. By optimizing airflow and reducing indoor contaminants such as volatile organic compounds (VOCs), dust, and allergens, these systems create healthier indoor environments.

4.3.1 Key Factors in Ventilation and Air Quality

Types of Ventilation

- Natural Ventilation: Utilizes natural forces (wind and thermal buoyancy) to circulate air without mechanical systems. This includes strategically placed windows, vents, and open spaces.
- Mechanical Ventilation: Uses fans and ductwork to control air flow. This can be part of HVAC (Heating, Ventilation, and Air Conditioning) systems and includes exhaust fans, supply fans, and balanced systems.
- Hybrid Systems: Combine natural and mechanical ventilation to optimize air quality and energy efficiency.

Indoor Air Quality (IAQ)

- Pollutant Removal: Effective ventilation removes indoor pollutants, including VOCs (volatile organic compounds), CO2, and particulate matter.
- Humidity Control: Maintaining optimal humidity levels (30-60%) prevents mold growth and improves indoor comfort.
- Filtration: High-efficiency filters in mechanical systems capture airborne contaminants.

Energy Efficiency in Ventilation

- Heat Recovery Ventilation (HRV) and Energy Recovery Ventilation (ERV): These systems capture heat (and sometimes humidity) from exhaust air to pre-condition incoming fresh air, reducing heating and cooling loads.
- Demand-Controlled Ventilation (DCV): Adjusts ventilation rates based on occupancy or air quality sensors, ensuring ventilation is provided only when needed.
- Efficient Fans and Motors: Use high-efficiency fans and motors with variable speed drives to minimize energy consumption.

Design for Natural Ventilation

- Window Placement and Size: Place operable windows on opposite sides of the building to promote cross-ventilation.
- Stack Ventilation: Utilize vertical spaces like atriums to enhance airflow through thermal buoyancy.
- Ventilation Towers: Integrate features like ventilation shafts or towers to drive natural airflow.

Optimize Mechanical Ventilation

- Zoning: Divide the building into zones with separate ventilation controls to match ventilation to specific needs and occupancy patterns.
- Ventilation Rates: Ensure ventilation rates meet or exceed standards such as ASHRAE 62.1, balancing air quality and energy use.
- Sealing and Insulation: Ensure ductwork is well-sealed and insulated to prevent energy loss and maintain efficiency.

Energy Recovery:

- HRV and ERV Systems: Install these systems to reclaim energy from exhaust air, reducing the load on heating and cooling systems.
- Climate Considerations: Choose HRV for colder climates (to reclaim heat) and ERV for more humid climates (to reclaim both heat and moisture).

Energy-Efficient Components

- Variable Speed Drives: Install variable speed drives on fans and pumps to adjust airflow and pressure as needed.
- Efficient Motors: Use high-efficiency motors to reduce energy consumption in mechanical ventilation systems.

4.3.2 Ventilation requirements

Buildings in the scope of these standards must include consider elements of ventilation that minimize the needs for active space conditioning (heating and cooling) and consider the above options. In particular, natural ventilation and energy efficient forms of ventilation.

Moreover, commercial and office buildings must be equipped with building controls that adjust ventilation rates based on occupancy, temperature, and air quality. This is often achieved through demand-controlled ventilation (DCV), which uses sensors such as CO2 detectors to modulate airflow according to the actual needs of the space[14].

5 Lighting

5.1 Scope

Energy efficient lighting is an essential component of sustainable building practices and also one of the components with the easiest path to achieve high performance due to the ready availability of LED technologies for most building lighting applications. Advances in lighting technology have made it possible to achieve significant energy savings while maintaining or even enhancing lighting quality through the use of LED technologies.

Energy efficient lighting is a simple yet impactful way to reduce energy consumption, lower utility bills, and decrease greenhouse gas emissions.

Benefits of Energy Efficient Lighting

- Reduced Energy Consumption: Energy efficient lighting uses significantly less electricity than traditional lighting options, leading to lower energy bills and reduced demand on power plants.
- Lower Greenhouse Gas Emissions: By consuming less electricity, energy efficient lighting helps reduce the carbon footprint associated with electricity generation, which is often powered by fossil fuels.
- Cost Savings: Although energy efficient bulbs can be more expensive upfront, their longer lifespans and lower energy use result in cost savings over time.
- Improved Light Quality: Modern energy efficient lighting options provide better light quality, with various color temperatures and brightness levels to suit different needs.
- Reduced Heat Emission: Energy efficient lighting produces less heat than traditional incandescent bulbs, contributing to lower cooling costs, especially in warm climates.

5.1.1 Strategies for Implementing Energy Efficient Lighting

- Upgrade to LEDs: Replace incandescent and CFL bulbs with LED options to maximize energy savings and longevity.
- Use Lighting Controls:
- Dimmers: Adjust light levels to suit needs and save energy when full brightness is not necessary.
- Occupancy Sensors: Automatically turn lights on and off based on room occupancy, reducing wasted energy.
- Daylight Harvesting: Adjust artificial lighting based on natural light availability, reducing energy use during daylight hours.
- Install Timers: Use timers to ensure lights are turned off during unoccupied hours, such as overnight in commercial buildings.
- Optimize Lighting Design: Ensure that lighting is designed to meet the specific needs of the space without over-illumination. Use task lighting where needed and reduce general ambient lighting levels.

[14] This is accordance with recommendations of the 2021 International Energy Conservation Code: International Code Council. (2021). *2021 International Energy Conservation Code (IECC)*. International Code Council. Retrieved from https://codes.iccsafe.org/content/IECC2021P1.

- Regular Maintenance: Clean fixtures and replace bulbs as needed to maintain optimal efficiency and light quality.

5.2 Requirements for energy-efficient lighting, including lighting power density limits and controls. LUX and Lumen for various building typologies

The recommended lux levels for various rooms depend on the activities typically performed in those spaces. Lux is a measure for illuminance, indicating how much light is cast on a given area. The following are general guidelines for recommended lux levels in different types of rooms and spaces.

5.2.1 Residential Spaces:

- Living Room: 100-300 lux
- Kitchen: 300-750 lux (higher levels for task areas like countertops)
- Dining Room: 150-300 lux
- Bedroom: 100-300 lux (lower levels for relaxation areas, higher for reading areas)
- Bathroom: 200-750 lux (higher levels for grooming areas)
- Hallways and Stairs: 100-200 lux
- Home Office/Study: 300-500 lux

5.2.2 Commercial Spaces:

- Office Areas: 300-500 lux (higher levels for detailed tasks)
- Conference Rooms: 300-500 lux
- Reception Areas: 200-300 lux
- Corridors and Staircases: 100-200 lux
- Retail Stores: 500-1000 lux (higher levels for display areas)
- Workshops and Manufacturing Areas: 300-1000 lux (depending on the precision of tasks)
- Warehouses: 100-300 lux (higher for packing and inspection areas)

5.2.3 Educational Institutions:

- Classrooms: 300-500 lux
- Lecture Halls: 300-500 lux
- Libraries and Reading Areas: 500-750 lux
- Laboratories: 500-1000 lux

5.2.4 Healthcare Facilities:

- General Wards: 100-300 lux
- Examination Rooms: 500-1000 lux
- Operating Theatres: 1000-2000 lux
- Nurse Stations: 300-500 lux
- Waiting Rooms: 200-300 lux

5.2.5 Hospitality:

- Hotel Lobbies: 200-300 lux
- Restaurants and Dining Areas: 150-300 lux
- Guest Rooms: 100-300 lux
- Bathrooms: 200-750 lux

5.2.6 Public and Community Spaces:

- Museums and Galleries: 200-500 lux (lower for preservation of sensitive exhibits)
- Sports Facilities: 300-750 lux (higher levels for detailed tasks like scorekeeping)
- Auditoriums: 150-300 lux

5.2.7 Outdoor Areas:

- General Outdoor Areas: 20-100 lux
- Pathways and Walkways: 5-30 lux
- Parking Lots: 30-75 lux
- Building Entrances: 100-200 lux

5.2.8 Special cases:

- **Task Lighting**: In areas where specific tasks are performed, such as reading, cooking, or sewing, additional task lighting may be needed to achieve the required lux levels.
- **Ambient Lighting**: General lighting to ensure overall illumination and safety.
- **Accent Lighting**: Used to highlight specific areas or objects, not necessarily related to the overall lux levels but important for aesthetics.

6 Water Heating

Water heating is another main component of energy demand and GHG emissions in the buildings sector. Both for the residential cooking, hydration, and sanitation use as well as commercial use for sanitation in hospitals, various uses in restaurants, and more. As such, water heating is another important component in the design of Green Buildings significantly influencing energy consumption and sustainability. In eco-friendly structures, the goal is to provide efficient and reliable hot water while minimizing energy use and environmental impact. Current practices often rely on electric geysers, which are energy-intensive and contribute to higher electricity bills and increased carbon footprints.

In Zimbabwe, the climate offers ample sunlight, making solar water heating a highly viable and efficient solution. Current practices often rely on electric geysers, which are energy-intensive and contribute to higher electricity bills and increased carbon footprints. According to the National Energy Policy (2012), strategies to improve energy usage and conservation in urban households should include water storage tank and pipe insulation.

Solar water heaters harness the abundant solar energy available in Zimbabwe, providing a renewable and virtually zero-cost source of hot water. These systems can significantly reduce reliance on the grid, lower energy bills, and decrease greenhouse gas emissions. Additionally, heat pump water heaters, which extract heat from the air or ground, offer an efficient alternative to traditional electric or gas water heaters. They work well in Zimbabwe's climate, providing reliable hot water with lower energy consumption.

Another effective solution is the use of tankless (on-demand) water heaters. These units heat water only when needed, eliminating the energy waste associated with maintaining a large reservoir of hot water. This technology is particularly beneficial in regions where electricity supply can be inconsistent, ensuring hot water availability without continuous energy use.

Integrating these advanced water heating technologies with smart controls and energy management systems further enhances their efficiency and performance. By adopting these sustainable practices, Zimbabwe can achieve significant energy savings, reduce greenhouse gas emissions, and provide reliable hot water to occupants, aligning with broader goals of environmental sustainability and energy efficiency.

Another strategy widely used in green building standards includes the reduction of hot water demand through technology and behavioral means. This includes the implementation of awareness campaigns to promote lower use through shorter showers, reduced washing, etc. Green building buildings will also make use of technology options including:

- Low-Flow Showerheads:
    - Reduce water usage by up to 50% compared to conventional models by limiting the flow rate without sacrificing performance.
    - Significantly lower the volume of hot water needed, saving energy used for heating.
- Water-Efficient Clothes Washers:
    - Use advanced technologies to clean effectively while using up to 40% less water and 25% less energy than standard models.
    - Energy Star-rated appliances provide substantial water and energy savings.
- Water-Efficient Dishwashers:
    - Designed to clean effectively with less water, reducing water use by significant amounts compared to traditional models.
    - Energy-efficient dishwashers save both water and energy, contributing to lower utility bills and environmental conservation.

These types of technologies can be applied to different levels of demand such as residential and commercial requirements to general significant savings for the sectors.

6.1 Requirements for energy efficiency for water heating systems.

The following technologies are recommended for adoption in Zimbabwe:

1. Heat Pump Water Heaters:

   Mandate: Encourage the use of heat pump water heaters, particularly in regions with less sunlight.

   Performance Standard: Systems should have a minimum coefficient of performance (COP) of 3.0.

2. Tankless (On-Demand) Water Heaters:

   Mandate: Promote the use of tankless water heaters in both residential and commercial buildings.

   Performance Standard: Systems must have an energy factor (EF) of 0.82 or higher.

3. Low-Flow Fixtures:

   Mandate: Require the installation of low-flow showerheads and faucets in all new constructions and major renovations.

   Performance Standard: Showerheads with a flow rate of no more than 7.6 liters per minute (L/min) and faucets with a flow rate of no more than 5.7 L/min.

4. Water-Efficient Appliances:

   Mandate: Installation of water-efficient clothes washers and dishwashers in new residential buildings.

   Performance Standard: Clothes washers with a water factor (WF) of 5.5 or less and dishwashers with an EF of 0.75 or higher.

5. Insulation of Hot Water Pipes:

   Mandate: Insulate all hot water pipes in new buildings to minimize heat loss.

   Performance Standard: Insulation must have a minimum R-value of 3.0.

6. Smart Controls and Timers:

   Mandate: Integration of smart controls and timers in water heating systems to optimize usage based on occupancy and time of day.

   Performance Standard: Systems should include programmable thermostats and smart meters.

6.2 Requirements for solar water heating

Solar water heaters are one of the most effective ways of implementing renewable energy harvesting for direct use. As such it is recommended that they should be implemented as follows:

1. Solar Water Heaters:

   Mandate: Installation of solar water heaters for all new residential and commercial buildings.

   Performance Standard: Systems must meet a minimum solar fraction of 50%, meaning at least 50% of the water heating demand must be met by solar energy.

7 Renewable Energy

Renewable energy is a cornerstone of sustainable development, offering a clean, inexhaustible, and increasingly cost-effective alternative to fossil fuels. Harnessing natural resources such as sunlight, wind, water, and geothermal heat, renewable energy technologies can significantly reduce greenhouse gas emissions and mitigate the impacts of climate change.

In the context of green building design, renewable energy systems like solar panels, wind turbines, and geothermal heat pumps play a pivotal role in achieving energy efficiency and reducing the carbon footprint of buildings. As the world transitions towards a more sustainable future, the adoption and expansion of renewable energy are essential to meet global energy demands while protecting the environment for future generations.

Zimbabwe has targeted renewable energy in the building sector through the Renewable Energy Policy (2019) that promotes the installation of solar water heaters. The solar thermal technology roadmap and implementation plan targets the growth rate of collector area to reach 0.1 m^2 per capita by 2030.

7.1 Recommendations / mandates for the use of renewable energy sources, such as PV and solar thermal.

All buildings in Zimbabwe must be designed and built with the ability to support the installation of solar water heating or solar PV.

All buildings subject to these standards must have installed solar water heating devices as per section 6.2.

In the case of solar PV, it is strongly recommended that building developers install PV panels in an economic and robust manner.

7.2 Solar water heaters

Solar water heaters collect solar thermal energy to heat water that meets a significant component of hot water demand in buildings. This results in significant energy cost and emissions reductions.

The optimum utilization of solar water systems requires an appropriate system design and sizing for the needs of each building. Other recommendation on the use of this technology include:

- Effective insulation of storage tanks and pipes reduces heat loss.
- Avoid shading collectors.
- Regular cleaning of collectors and using anti-reflective coatings to improve performance.
- Absorbers should have a high absorptivity rating, and concentrating collectors should have high reflectivity to enhance performance.

7.3 Solar PV

Photovoltaic (PV) systems, commonly known as solar panels, can also play a significant role in reducing energy demand in buildings and reducing reliance on non-renewable energy sources.

7.3.1 Renewable Energy Source:

- PV systems convert sunlight directly into electricity, providing a clean, renewable source of energy that reduces the dependence on fossil fuels.
- Reduction in Energy Costs:
- By generating electricity on-site, PV systems can significantly lower electricity bills. Excess energy can often be sold back to the grid in a process known as net metering, further reducing costs.

7.3.2 Integration of PV Systems of buildings in Zimbabwe:

The integration of solar PV systems requires optimum design to maximize benefits while minimizing cost and waste. This includes the following design characteristics:

- The efficiency of a PV system is highly dependent on its orientation and tilt. For optimum design, panels should face North and be tilted at an angle equal to the latitude of the location to maximize sun exposure. It is recommended that tracking panels are considered during the design stage.
- Shading should be minimized to avoid significant drops in energy production.
- Incorporating storage (batteries) allows for the storage of excess energy produced during peak sunlight hours, which can be used during periods of low sunlight or at night. This increases the overall efficiency and reliability of the energy supply.
- Smart energy management systems can optimize the use of electricity generated by PV systems. They can prioritize the use of solar power for high-energy tasks during peak generation times and switch to stored or grid power when solar output is low.
- Building automation systems can optimize energy use based on generation patterns, further enhancing efficiency.
- The efficiency of solar panels themselves is a critical factor. High-efficiency panels generate more electricity from the same amount of sunlight compared to lower-efficiency panels.
- The inverter converts the direct current (DC) produced by the panels into alternating current (AC) used by most household appliances. High-efficiency inverters reduce energy loss during this conversion.
- Conduct a thorough site assessment to evaluate solar potential, including roof orientation, tilt, shading, and structural integrity.
- Size the PV system according to the building's energy consumption patterns and future energy needs.
- Hire qualified professionals for installation to ensure safety and optimal performance. Regular maintenance, such as cleaning panels and checking electrical components, is essential for maintaining efficiency.

7.4 Waste-to-energy

Waste-to-energy (WTE) technologies offer another (largely recognized) renewable energy solution, particularly for residential buildings while at the same time presenting a sustainable way to manage organic waste. Integrating WTE into green building standards promotes circular economy principles, enhances resource efficiency, and supports energy resilience.

The technical feasibility of this technology is proven, but its implementation in buildings will require an assessment of the economic and practical applicability based on the building's scale and waste output.

The key technology for this application is the use of anaerobic digestors that break down organic waste in the absence of oxygen to produce biogas, which can be used for space and water heating, cooking, and even electricity generation. It's suitable for buildings with significant organic waste, such as residential complexes, commercial kitchens, or facilities with food processing.

7.5 Requirements for waste-to-energy

It is recommended that this technology should be considered for suitable buildings, and that the benefits of energy generation as well as waste management should be included in the economic assessment.

8 Building Systems and Controls

Building systems and controls are advanced computerized systems linked the building's energy using systems such as HVAC, lighting, and water heating that aim to optimize the supply of these services to match the demand through intelligent management technologies. This minimizes losses and waste such as having unused parts of the building cooled or lit.

Smart thermostats, programmable lighting systems, movement sensors, and automated shading devices adjust operations based on occupancy and environmental conditions, ensuring optimal performance while minimizing energy consumption. Examples of this include:

- Water heating systems with smart controls and timers optimize usage, reducing waste and energy demand.
- Integration of renewable energy sources, such as solar panels and wind turbines, is facilitated through advanced control systems that manage energy production and storage.
- Additionally, water-efficient fixtures and appliances, combined with real-time monitoring and leak detection systems, further conserve resources.

The automation and optimization in the operation of HVAC, lighting, and water heating systems, can achieve an average of nearly 30% energy savings in commercial buildings[15]. This is accomplished by optimizing settings based on real-time occupancy patterns, automating the adjustment of heating and cooling systems, and enhancing the sequencing of operations to ensure systems run only when necessary.

These systems can also be supported by integrating fault detection and diagnostics (FDD) modules into building control systems to identify and rectify inefficiencies and malfunctions promptly, preventing energy losses and ensuring optimal system performance.

8.1 Requirements for building automation systems and controls to optimize energy use.

To enhance energy efficiency in Zimbabwe's buildings, it is important to establish requirements for buildings to include a robust set of building automation systems and controls during their design and permitting stage, or during the significant retrofits of existing buildings. The following minimum requirements are recommended:

1. HVAC Systems and Controls
    1. **Smart Thermostats**:
       Requirement: Install programmable or smart thermostats in all buildings.
       Function: Optimize heating and cooling schedules based on occupancy patterns and weather conditions.

[15] Impacts of Commercial Building Controls on Energy Savings and Peak Load Reduction Website: https://buildingretuning.pnnl.gov/publications/PNNL-25985.pdf

Energy Savings: Can reduce HVAC energy consumption by up to 10%[16].

2. **Variable Speed Drives (VSDs)**:
Requirement: Equip HVAC systems with VSDs on motors and pumps.
Function: Adjust motor speed to match load requirements, enhancing efficiency.
Energy Savings: Can achieve energy savings of 30-50% compared to fixed speed systems[17].

3. **Zone-Based Heating and Cooling**:
Requirement: Implement zoning systems in larger buildings.
Function: Provide targeted heating and cooling to different areas, reducing energy waste.
Energy Savings: Can save up to 20% on energy costs[18].

2. Lighting Systems and Controls
   1. **Daylight Harvesting**:
   Requirement: Install daylight sensors and automated shading devices.
   Function: Adjust artificial lighting based on natural light availability.
   Energy Savings: Can reduce lighting energy consumption by 20-60%[19].

   2. **Occupancy Sensors**:
   Requirement: Integrate occupancy sensors in common areas and offices.
   Function: Automatically turn lights on and off based on occupancy.
   Energy Savings: Can reduce lighting energy usage by up to 30%[20].

3. Water Heating Systems and Controls
   1. **Solar Water Heaters**:
   Requirement: Mandate the use of solar water heaters for all new residential and commercial buildings.
   Function: Utilize solar energy to heat water, reducing reliance on electric or gas water heaters.
   Energy Savings: Can meet 50-80% of a building's hot water demand[21].

   2. **Heat Pump Water Heaters**:
   Requirement: Encourage the use of heat pump water heaters in regions with less sunlight.
   Function: Extract heat from the air or ground to heat water efficiently.

[16] Understanding How Building Controls Can Save Energy. Website: https://www.facilitiesnet.com/buildingautomation/article/Understanding-How-Building-Controls-Can-Save-Energy--19490
[17] The Advantages and Disadvantages of an Inverter AC. Website: https://consumer-voice.org/ac/the-advantages-and-disadvantages-of-an-inverter-ac/
[18] Saving energy through advanced control strategies. Website: https://www.mdpi.com/1996-1073/6/9/4769
[19] Saving energy through advanced control strategies. Website: https://www.mdpi.com/1996-1073/6/9/4769
[20] Impacts of Commercial Building Controls on Energy Savings and Peak Load Reduction Website: https://buildingretuning.pnnl.gov/publications/PNNL-25985.pdf
[21] Impacts of Commercial Building Controls on Energy Savings and Peak Load Reduction Website: https://buildingretuning.pnnl.gov/publications/PNNL-25985.pdf

Energy Savings: Use up to 60% less energy than conventional electric water heaters[22].

3. **Smart Water Heaters**:
   Requirement: Install smart water heaters with programmable timers and thermostats. Function: Optimize heating schedules and reduce standby energy consumption.
   Energy Savings: Can reduce water heating energy use by up to 15%[23].

4. Energy Management Systems (EMS)
   1. **Building Automation Systems (BAS)**:
      Requirement: Integrate BAS in all large commercial and institutional buildings.
      Function: Centralize control of HVAC, lighting, and other systems for optimal performance.
      Energy Savings: Can improve overall building energy efficiency by 20-30%[24].

   2. **Energy Monitoring and Reporting**:
      Requirement: Implement real-time energy monitoring systems with data analytics.
      Function: Track energy usage, identify inefficiencies, and generate reports for continual improvement.
      Energy Savings: Provides actionable insights that can lead to significant energy savings.

5. Renewable Energy Integration
   1. **Solar PV Systems**:
      Requirement: Promote the installation of solar photovoltaic (PV) systems for on-site electricity generation.
      Function: Generate renewable electricity to offset grid consumption.
      Energy Savings: Can provide substantial energy cost savings and reduce carbon emissions depending on size of the system and building demand patterns.

   2. **Battery Storage**:
      Requirement: Integrate battery storage systems with renewable energy installations.
      Function: Store excess energy generated during peak production times for use during low production periods.
      Energy Savings: Enhances the reliability and efficiency of renewable energy systems.

[22] Saving energy through advanced control strategies. Website: https://www.mdpi.com/1996-1073/6/9/4769
[23] Impacts of Commercial Building Controls on Energy Savings and Peak Load Reduction Website: https://buildingretuning.pnnl.gov/publications/PNNL-25985.pdf
[24] US Department of Energy – Building controls. Website: https://www.energy.gov/eere/buildings/building-controls

9 Energy Performance Calculations

9.1 Methods for calculating a building's energy performance, including energy modeling and compliance documentation.

Building energy performance calculations are essential to evaluate and optimize the energy efficiency of buildings. These calculations help in estimating energy consumption, carbon emissions, and cost-effectiveness of different design options. Here's a breakdown of key aspects and methods involved in building energy performance calculations:

9.2 Energy Modeling

Energy modeling is used to simulate how energy is used in a building. Various software tools, such as **EnergyPlus**, **eQUEST**, and **DesignBuilder**, are used for this purpose. These tools consider a range of factors, including:

- **Building geometry** (floor area, volume)
- **Material properties** (U-values, insulation, glazing)
- **Lighting systems**
- **HVAC systems**
- **Occupancy patterns**
- **Weather data** (temperature, humidity, solar radiation)

9.3 Key Performance Metrics

Building energy performance is assessed using specific metrics, such as:

- **Energy Use Intensity (EUI)**: Total energy used per square meter (kWh/m²/year).
- **Heating/Cooling Load**: Amount of energy required to maintain comfortable indoor temperatures.
- **CO_2 Emissions**: Carbon footprint of the building based on its energy consumption.
- **Thermal Comfort**: Evaluation of indoor temperature, humidity, and airflow

9.4 Building Envelope Performance

The building envelope (walls, roofs, windows) plays a critical role in energy performance. Insulation, airtightness, and window glazing are key factors influencing the thermal performance. Commonly, U-values (thermal transmittance) are used to assess the heat loss through the building envelope.

9.5 Renewable Energy Integration

For buildings incorporating renewable energy systems (solar panels, wind turbines), performance calculations also include energy generation from these sources. The energy contribution from renewables is subtracted from the total consumption to determine the net energy use or the building's energy balance.

9.6 Standards and Certifications

Energy performance is often assessed based on standards like:

- **ASHRAE 90.1**: Provides guidelines for energy-efficient building design.
- **LEED** (Leadership in Energy and Environmental Design): Certification that includes energy performance criteria.
- **BREEAM**: A UK-based sustainability assessment method that also considers energy performance.

9.7 Energy Simulation Tools

- **EnergyPlus**: A detailed building energy simulation tool for whole-building performance analysis.
- **eQUEST**: A user-friendly tool for energy analysis.
- **IES VE**: Integrated Environmental Solutions Virtual Environment for dynamic energy simulation.

10 Compliance Pathways

The compliance processes for building energy related standards are a key step in ensuring that construction practices meet the requirements prescribed in the BEEC for energy efficiency performance. A robust compliance pathway can streamline the implementation of these standards by offering clear guidelines and methodologies that builders and developers can follow and support greater level of compliance.

Common ways to achieve compliance include:

1. **Prescriptive pathways** involve adhering to specific requirements outlined in building codes, such as material specifications and construction techniques
2. **Performance-based** pathways focus on meeting defined outcomes, such as energy savings or indoor air quality levels, allowing for flexibility in how these goals are achieved.
3. **Third-party certification** involves independent verification that a building meets established standards by a recognized certification provider. Examples of a certification include LEED (Leadership in Energy and Environmental Design) or BREEAM (Building Research Establishment Environmental Assessment Method).

For this BEEC, it is recognized that the Zimbabwe Energy Regulatory Authority (ZERA) has produced an Energy Conservation Building Code in 2023. This BEEC aims to expand (but not replace) on the measures and pathways provided in the ZERA EC Regulations. As such, the compliance pathways recommended for this BEEC mirror follow the same process.

10.1 Options for compliance, prescriptive requirements, performance-based approaches, or a combination of both.

As per section **4 – Compliance Mechanism** of the Electricity (Energy Conservation Building Code) Regulations, 2023:

"(1) The compliance of energy performance of a building shall be ensured by the owner by following either of the following methods, namely: -

a) Prescriptive Method. – The building shall comply with the mandatory requirements and prescriptive requirements as specified in the Code for envelope components, comfort systems and controls, lighting and controls, electrical and renewable energy systems.

b) Whole Building Performance Method. – The building shall comply with all mandatory measures and the requirements specified in the whole building performance method of the Code and the energy performance index of the proposed design under this method shall be the same or less than the energy performance index of the standard baseline design of building as follows:

$$energy\ performance\ index\ ratio = \frac{energy\ performance\ index\ of\ the\ building}{energy\ performance\ index\ of\ standard\ baseline\ design} \leq 1$$

(2) The summary covering building envelope, comfort systems and controls, lighting and controls, and electrical and renewable energy systems and their checklists under Prescriptive Method and Whole Building Performance Method shall be as specified in the Second Schedule of the Code.

(3) The energy performance index of standard baseline design shall be based upon figures provided in the Third Schedule of the Code."

11 Inspection and Testing

Inspection and testing are some of the most important tools of the compliance process for building standards, ensuring that construction practices meet regulatory requirements and achieve intended performance outcomes.

These processes serve not only as tools to verify that all aspects of a building (materials, systems, etc.) conform to the codes, but also provide builders with checkpoints to identify and remedy arising issues. Inspections are conducted at various stages of construction, from initial groundwork to final completion, to identify and rectify any deviations from the specified standards. Testing involves evaluating the performance of building systems, such as HVAC, electrical, plumbing, and structural integrity, to confirm they operate as designed and meet efficiency and safety criteria.

Common inspection and testing practices include visual inspections, functional testing, performance testing (such as blower door tests for air leakage), and commissioning of building systems.

In the case of this BEEC, as section 10 indicated, it is recommended to follow the requirements set in the Electricity (Energy Conservation Building Code) Regulations, 2023.

11.1 Procedures for verifying compliance, including inspections, testing, and certification processes.

As per section **5 – Procedure for erection of Code compliant building** of the Electricity (Energy Conservation Building Code) Regulations, 2023:

"(1) Every owner who intends to erect or re-erect a building or make alterations or additions in any building under this Code shall submit to the Authority, an application in ECBC Form I in the First Schedule accompanied by-

(a) construction documents duly signed by the owner together with an undertaking in ECBC Form II in the First Schedule;

(b) construction documents shall ensure –

(i) *compliance with the applicable building by-laws in force;*

(ii) *building design incorporates energy conservation measures and best national and international practices having regard to the climatic conditions of the site and specific needs of the building so as to optimise the energy performance index ratio of the building;*

(iii) *that all the data, building features, identified energy conservation measures under various building components and systems are shown in detail and in the manner specified in the applicable by-laws;*

(iv) *the drawing of plan, colour of plan, dimensions of plan, scale of plan as per requirements of the applicable by-laws in force;*

(c) compliance documents covering the construction of components and systems of the Code,

Duly certified by Energy Assessors including the following, namely: -

(i) *energy performance index ratio report in respect of the proposed building at the design stage;*

(ii) *certificate in ECBC Form III by Energy Assessors certifying the compliance documents as specified in Second Schedule of the Code;*

(iii) *have been scrutinized or verified in respect of the identified energy conservation measures; and*

(iv) *an application with heading super scribed "Application for permission to erect/re-erect an Energy Conservation Building Code Compliant Building", duly signed by the owner seeking building Approval from the concerned Authority before starting construction work in respect of the proposed building.*

(2) *The Authority may require submission of documents in electronic ECBC Form or hard copy of the documents, referred to in sub-section (1) above.*

(3) *The Energy Assessors, at the design stage, shall follow the following procedure of inspection, namely: –*

(a) *scrutinize the construction documents with respect to–*

(i) *floor area;*

(ii) *window area;*

(iii) *wall area;*

(iv) *roof area of the building;*

(v) *built-up area of the proposed design of the building;*

(b) *scrutinize the Code compliance documents and the checklist as specified in the Second Schedule of the Code and identify -*

(i) *the energy conservation measures that are applicable to the proposed design of building;*

(ii) *insulation quantities in walls and roof, and the construction assemblies, solar heat gain coefficient, visible light transmittance and thermal transmittance (U-factor) for window assemblies.*

(iii) *heating, ventilation and air-conditioning component tables for air-handling equipment, refrigeration equipment, condensing equipment and air-flow summaries;*

(iv) *heating, ventilation and air-conditioning equipment efficiencies and control equipment;*

(v) *tables showing lighting equipment schedules;*

(vi) *lighting power density calculations in the design documents;*

(vii) *lighting controls;*

(viii) *motor efficiencies and controls;*

(ix) *findings of the document review to match with the energy model inputs for the proposed building by using the simulation tool approved by the Authority;*

(c) *scrutinize energy performance index ratio projected at the design stage;*

(d) *verify and certify the items from 5(3)(b) and 5(3)(c);*

(e) *fill the checklist as specified in the Second Schedule of the Code and issue correction list in case the design documents of the proposed design of building provide inadequate information or do not meet the requirements of this Code and shall-*

(i) *communicate his findings in ECBC Form IV to the owner of the building under intimation to the Authority*

(ii) *give specified time to the owner to implement its findings;*

(iii) *satisfy himself that the communication received from the owner within the specified time, meet the findings and fulfil the shortcomings.*

(f) *record his/her approval and complete the checklist conforming compliance with the Code and issue the certificate of approval in ECBC Form V to the owner under intimation to the Authority.*

(4) *The Authority on receipt of application under sub-section (1) for issue of Approval for construction of proposed building shall-*

(i) approve the design and sanction building plan only after it has received a certificate in ECBC Form II or ECBC Form IV from the Energy Assessors;

(ii)grant Approval to erect or re-erect the building or add to or make alterations in the building to carry out the construction works subject to the following conditions in its sanction letter, namely: -

(A) *the construction work shall be in accordance with the sanctioned plan and requirement under the Code and this Code;*

(B) *the compliance with this Code shall be achieved during construction-in-progress;*

(C) *the building shall not be occupied before issuance of occupancy certificate to the owner;*

(D) *the Authority may, at any stage, revoke the Approval on receipt of noncompliance report from the Energy Assessors or on the notice of any misrepresentation of material facts in the application in respect of the provisions of this Code or the Code after giving a reasonable opportunity of being heard to the owner.*

(5) *After receiving the Approval, the owner shall-*

(a) *give notice of his intention to start the construction work of the building in ECBC Form VI;*

(b) *undertake construction of energy conservation measures incorporated in the construction documents in terms of sub-clause (ii) of clause (b) of sub-section (1);*

(c) *have flexibility in constructing the building components and systems covered in the construction documents referred to in clause (a) of sub-section (1) to most effective use of energy by deploying best practices in such components and systems to optimize the energy performance index ratio;*

(d) *take the approval of the Energy Assessors before undertaking such construction referred to in clause (c) if the components and systems proposed to be constructed are other than those incorporated in the construction and compliance document.*

(6) *The Energy Assessors, at construction stage, shall review, verify the specifications of the parameters specified in sub-section (3) and, -*

(a) *fill out the checklist specified in the Second Schedule of the Code, provide comments if the proposed design of building does not meet the construction requirements and specify the shortcomings in compliance to the Code, this Code and sanctioned plan, and shall-*

(i) *communicate its shortcomings and finding to the owner.*

(ii) *give specified time to the owner to implement its findings.*

(iii) *satisfy himself that the communication received thereafter from the owner meets the specified findings and fulfil shortcomings;*

(b) *record his approval and complete the checklist indicating compliance with the Code and this Code and issue a certificate of compliance in ECBC Form VII to the owner under intimation to the Council having jurisdiction.*

(c) *where it is determined at any stage that construction is not proceeding in accordance with the sanctioned plan or is in violation of any of the provisions of the Code and this Code, Energy Assessors shall notify the owner, and request for additional information with respect to his findings or on the short comings identified by him as per ECBC Form VIII;*

(d) *in case the Energy Assessors is satisfied with the additional information provided by the owner, he shall record the same in the certificate of compliance in ECBC Form VII and communicate the same to the owner under intimation to the Council having jurisdiction.*

(e) *in case the Energy Assessor is not satisfied with the additional information submitted by the owner he shall report the same to the Authority to ensure that all further construction is stayed until correction has been effectuated and a certificate of compliance has been issued by Energy Assessors.*

(7) *Every owner shall submit a notice of completion of the building in ECBC Form IX to the Authority on the completion of work including the works related to energy conservation measures specified in the sanctioned Building Approval along with the certificate in ECBC Form X issued by the Energy Assessors certifying the completion of the building accompanied by -*

(a) *the duly completed compliance ECBC Forms together with checklist of various components covered under section (3) at the completion stage which shall include the followings-*

(i) *review of heating, ventilation and air-conditioning component tables for air-handling equipment, refrigeration equipment, condensing equipment, air-flow summaries, tables showing lighting equipment specifications, and tables showing motor specifications.*

(ii) *inspection of lighting equipment compliance to standards according to the type of usage in the building to determine lighting power density;*

(iii) *review the required lighting controls such as manual switching off perimeter, day lighting circuits, automated occupancy-based control, photo sensor controls, and automated timer-based controls;*

(iv) *review of coefficient of performance values of installed heating, ventilation and air-conditioning equipment and control equipment;*

(v) *review of efficiencies of installed motor and controls;*

(vi) *review of power factor and power distribution losses;*

(vii) *review the required check metering and monitoring system.*

(b) *a list of the energy related building features in the proposed design, if any, which are different from the sanctioned or standard baseline design;*

(c) *all documents and invoices in support of the construction undertaken with respect to all energy conservation measures including insulation, fenestration, heating, ventilation and air-conditioning, lighting and electrical systems, water heating systems of the building.*

(8) *If the energy performance index ratio at the completion stage is less than or equal to one as compared to the sanctioned plan of the building, it shall be deemed to have complied with the Code and this Code.*

(9) *If there is deviation in the energy performance index ratio of the sanctioned plan that, is it is more than one as compared to the sanctioned plan of the building, Energy Assessors shall record its findings in ECBC Form XI and communicate the same to the owner and seek compliance of the same through incorporation of additional energy conservation measure. The Energy Assessor shall render technical assistance to the owner to ensure that the proposed design of building becomes compliant with this Code.*

(10) *The owner shall neither occupy nor allow any other person to occupy the building or part of the building covered under this Code for any purpose until such building or such part thereof has been granted occupancy certificate under the by-laws of the Council having jurisdiction.*

(11) *The owner shall give notice of completion of the building and seek permission for occupancy.*

(12) *The Authority on receipt of such notice by the owner accompanied by a certificate by the Energy Assessors, issue the occupancy certificate in ECBC Form XII incorporating inter alia the following conditions, namely: -*

1. *that the energy performance of the building shall be monitored and verified by the Authority.*

2. *that the owner through the Energy Assessors shall submit to the Authority, an energy performance index report as per ECBC Form XIII under intimation to Authority for two consecutive years after the building has been fully operational;*
3. *in case the energy performance index ratio of the building is more than one, the Authority may issue a provisional Energy Performance Certificate subject to the condition that the owner shall undertake energy audit of the building to identify additional energy conservation measures to achieve the energy performance index ratio of the building approved in the sanctioned plan or Building Approval within a period of two years;*
4. *if the owner fails to achieve the energy performance index ratio as specified in 5(12)(iii) within a period of twelve(12) months from the date of occupancy of the building the Authority shall place the matter before the Energy Conservation Building Code Technical Grievances Redressal Committee, which shall hear the owner and the Energy Assessors and make recommendations in the matter accordingly and the Authority shall comply with such recommendations.*

(13) *The process shall be continued repeatedly till energy performance index ratio of the building comes to less than one or equal to one and Energy Assessors shall fill and submit the compliance documents, as specified in First Schedule of the Code, of various energy conservation measures at each stage namely, design, construction and completion, to achieve conformity with the Code and this Code.*

(14) *The simulation tool referred in sub-section (3) shall be based on the standard method of test for the evaluation of building energy analysis computer program.*

(15) *The owner may approach the Energy Conservation Building Code Compliant Technical Grievances Redressal Committee for redressal of any grievance under the provisions of this Code."*

12 Enforcement and Penalties

To complete the compliance pathways, the regulatory mechanisms require enforcement and penalties for non-compliance cases, ensuring adherence to regulations and promoting the construction of safe, efficient, and sustainable buildings. Enforcement involves the application of the BEEC, as set in the regulation, and standards by the relevant authorities to all the buildings, new and significant retrofits, that fall within its purview. Penalties, on the other hand, serve as deterrents against non-compliance, providing consequences for non-compliance that range from fines and project delays to revocation of permits and mandatory corrective actions.

Enforcement mechanisms ensure that building standards are not merely guidelines but mandatory requirements that must be followed. Authorities, such as building inspectors and code enforcement officers, play a key role in this process by conducting inspections at various stages of construction, reviewing plans, and verifying that materials and methods meet the required standards.

Penalties for non-compliance vary depending on the severity of the violation but are designed to encourage adherence to building codes and standards. Common penalties include monetary fines, which can escalate based on the nature and frequency of the violations; orders to cease construction activities until compliance is achieved; and, in severe cases, demolition of unauthorized or unsafe structures.

In the case of this BEEC, as section 10 indicated, it is recommended to follow the requirements set in the Electricity (Energy Conservation Building Code) Regulations, 2023.

12.1 How the code will be enforced and the penalties for non-compliance.

12.1.1 Roles

The implementation and enforcement of a green building standard requires the coordination of several agencies/stakeholders to fulfil a key set of identified roles. This chapter presents a perspective to main roles identified, the key stakeholders involved to date, and it provides a recommended workflow to operationalize the Standards.

1. Developing the regulation that sets the requirements and provides an enforcement procedure to be flowing by enforcement agencies.
2. Compliance and enforcement agencies that receive the building plans to provide a license for construction and perform inspections and audits during construction to ensure compliance, and finally issue an operating permit upon completion of the construction.
    a. Compliance inspectors are a key component of this type of programme. Inspectors will determine the level of compliance and recommend the issuing of permitting or the enforcement of penalties. Inspectors will usually be members of compliance and permitting agencies such are city and local councils.
3. Legal advisors to develop legal guidance for compliance, grounds for enforcement, and ensure that penalties are observed.
4. Training and education providers to capacitate compliance inspectors, educate stakeholders about the standards and compliance requirements, and provide capacity buildings to other related professional practitioners.
5. Awareness raising and communication between regulators, enforcement agencies, the construction industry, and building professionals to ensure standards are understood and implemented correctly. This role is often fulfilled by NGOs, industry organizations, education organizations and more.

12.1.2 Stakeholders to address the identified roles

The application of the roles above for the implementation and enforcement of the Green Building Standards involves a collaborative approach among several key stakeholders at different levels of government (local, regional, national), each with a key role in the implementation and compliance of a green building standard. The principal implementing agency will be the Ministry of National Housing and Social Amenities with responsibility for:

- Design and maintain the standards to ensure that they remain up to date and relevant for the national context.
- Design the implementation process with the support of the related agencies such as regional governments, the ministry of justice, etc.
- Ensure that the standard is being enforced and the objectives of the standard are being met and make the necessary adjustments to correct deviations from expectations.

Other important agencies should be included in the process of enforcement and maintenance of the standards are:

- The Ministry of Environment, Climate, and Wildlife as key support policy agency and ensuring the policy aligns with national policies.
- The Ministry of Energy and Power Development as key support policy agency and ensuring the policy aligns with national objectives and policies.
- Zimbabwe Energy Regulatory Agency (ZERA) as an expert regulatory agency and that will also be implementing the enforcement of an energy conservation code.

- City and regional building departments operationalize the GBS such as issuing permits and ensuring compliance through inspections and audits.
- Standards association of Zimbabwe to support the development and maintenance of the standards, supporting the interactions with other regulatory bodies, and provide technical support and training to industry professionals on implementing standards.

Aside from the government agencies mentioned above, several possible stakeholders from civil society include academia, NGOs, and industry bodies. This includes but is not limited to:

- Zimbabwe Green Building Council to provide technical support for the development and promotion green building policies, tools, and regulations. The ZGBC will also advocate for green building practices and engage with stakeholders to drive adoption. The Council can also develop a certification scheme around the GBD such as such as the Green Star rating to validate sustainable construction efforts.
- Industry associations (Architects, Engineers, Contractors) to provide a technical and commercial perspective on green buildings including the design and construction of green buildings. Associations can also support the compliance process and the development of awareness and market development for green buildings.
- Developers and building owners engage in the process of development of standards with technical and economic insights, support compliance activities, and increase awareness to develop a market for Green Buildings and more.

These key stakeholders are able to fulfill key roles and responsibilities that support, not only a full implementation of the green building standards, but also to support other industry-related activities that support the implementation and leveraging to these technologies to maximize benefits.

12.1.3 Operationalization process

The key process proposed for the implementation of the Green Buildings Standards is as follows:

1. Permitting and Approvals: Building plans must demonstrate adherence to the standards before they begin construction to receive a permit that allows the builder to begin construction. This will require the submission of detailed documentation and plans demonstrating building performance in accordance with the standards. An approval (and therefore a license to build) is contingent upon meeting these criteria.
2. Inspections and Audits: Throughout the construction phase, a schedule of inspections will be developed and executed by the regulatory agency to ensure compliance with the standards. Inspections will focus on key areas of the standards such as insulation, renewable energy, and overall building performance. Auditors use a checklist aligned with the standards to verify that all requirements are met, and they provide feedback or corrective actions if deficiencies are found.
3. Penalties and Incentives: To enforce compliance, a system of penalties for non-compliance and incentives for exceeding standards is established. A dual approach leveraging penalties for non-compliance and rewarding diligence or exceeding compliance is a proven approach to maximize impacts. A proposed set of penalties include:

i. Upon initial non-compliance, the initial approach for non-compliance will include a verbal and written request for requirements to be met within set timelines.
ii. For repeat non-compliance events or disregard for written notices, imposing fines based on the degree of non-compliance.
iii. For more extreme cases, the order to halt construction activities or delaying approvals for subsequent project phases should come in effect until compliance is demonstrated.
iv. In the more egregious cases, a revocation of permits and/or withdrawal of occupancy permits will need to be issued until compliance issues are resolved.
v. Orders for corrective actions, such as retrofitting buildings to meet standards, will need to be considered in cases where work has proceeded outside of the initial scope of the building.
vi. In severe cases, non-compliance can lead to legal actions, including lawsuits or injunctions that compel compliance or impose additional penalties.
vii. Public disclosure of non-compliance and increased scrutiny for future projects should also be considered as penalties for repeat offenders. This can damage the reputation of developers or building owners.

Similarly, it is proposed that regulators offer incentives for diligence in meeting or exceeding the standard requirements. The type and level of incentives will need to be decided by regulators based on the available resources. Incentives for this include the following:

viii. Offering tax reductions, rebates, or credits for meeting or exceeding the requirements set in the standards. Similarly, offering lower licensing fees for building permits to projects that comply with the standards can be used.
ix. Providing financial assistance or grants for projects that meet or exceed requirements.
x. Expediting the approval process for buildings that exceed requirements or for developers with a history of meeting or exceeding the requirements.
xi. Awarding certifications or public recognition, such as green building ratings, can enhance the marketability and value of the property.
xii. Providing access to special loans or favorable financing terms for projects that meet green building standards.
xiii. Allowing increased building heights, densities, or other zoning advantages for projects that demonstrate superior environmental performance.

4. Post-construction, buildings are recommended to be regularly monitored or audited to ensure they continue to meet the requirements over time.

13 Updates and Amendments

A recognized and regular process for the update and amendment of the BEEC is required to ensure that BEEC remains relevant by keeping pace with advancements in technology, changes in environmental standards, and evolving climate conditions. Regular updates to the BEEC will incorporate the latest innovations in materials, building techniques, and energy management systems, leading to greater energy savings and reduced greenhouse gas emissions.

Additionally, periodic revisions help rectify any gaps or weaknesses identified, not only with the performance requirements, but also with enforcement and penalties of the existing BEEC to improve its effectiveness and compliance.

13.1 Update and amendment process

13.1.1 Purpose and Scope

The purpose of this chapter is to establish a systematic approach for the regular updating and amending of the BEEC to ensure they reflect the latest advancements in technology, changes in environmental standards, and evolving climate conditions.

13.1.2 Frequency of Updates

- **Mandatory Review Cycle**: The BEEC must undergo a comprehensive review and update every three to five years.
- **Interim Amendments**: Provisions must be made for interim amendments to address urgent issues, incorporate significant technological innovations, or respond to new regulatory requirements as they arise.

13.1.3 Stakeholder Involvement

- **Advisory Committee**: An advisory committee must be established for the update and amendment process comprising representatives from relevant government agencies, industry experts, environmental organizations, academic institutions, and other stakeholders. The committee will provide recommendations for the update process.
- **Public Consultation**: Conduct public consultations to gather input from a broad range of stakeholders, including builders, developers, architects, engineers, and the general public. This ensures transparency and inclusiveness in the update process.

13.1.4 Review and Approval Process

- **Initial Review**: The advisory committee conducts an initial review of the existing codes and identifies areas that require updating or amending based on new data, technologies, and regulatory changes. The review needs to include information on the latest technology and policy developments, but it must also include information relating to the implementation and enforcement of the BEEC to address arising issues.
- **Draft Amendments**: Develop draft amendments that incorporate the advisory committee's recommendations. These drafts should outline specific changes, the rationale for these changes, and anticipated impacts on energy efficiency and compliance.
- **Public Comment Period**: Release the draft amendments for public review and comment for a period of no less than 60 days. Collect and analyse feedback to refine the proposed changes.
- **Final Approval**: Submit the refined amendments to the appropriate regulatory body for final approval. This body reviews the proposed changes, considers public feedback, and formally adopts the amendments.

13.1.5 Documentation and Publication

- **Comprehensive Documentation**: Maintain detailed documentation of the review process, stakeholder consultations, and rationale for each amendment. This ensures transparency and provides a record for future reviews.

- **Official Publication**: Publish the updated codes and amendments in an accessible format, ensuring that all stakeholders are informed of the changes. Provide training and resources to support the implementation of new standards.

13.1.6 Implementation and Compliance

- **Transition Period**: Allow a transition period for stakeholders to comply with new requirements. This period should provide sufficient time for industry adaptation and capacity building.
- **Enforcement Mechanisms**: Update enforcement mechanisms to align with new standards. Ensure that building inspectors and compliance officers are trained on the updated codes and equipped to enforce them effectively.

13.1.7 Continuous Improvement

- **Feedback Mechanism**: Establish a continuous feedback mechanism to monitor the implementation of the updated codes and identify areas for further improvement. Regularly collect data on compliance rates, energy savings, and other relevant metrics.
- **Ongoing Research**: Support ongoing research and development in building energy efficiency technologies and practices. Encourage innovation and the adoption of emerging technologies through pilot programs and incentives.

14 Accessibility and Adoption

14.1 How the code will be made accessible to builders, designers, and the public.

Ensuring that the updated building energy efficiency standards are accessible to all relevant stakeholders is an essential aspect of a transparent and democratic society for successful implementation and compliance. The following measures will be taken to disseminate the standards effectively:

14.1.1 Official Publication:

The full text of the standards will be published on official government websites, including the Ministry of Public Works and National Housing, and the Environmental Management Agency. This will provide a central, easily accessible location for stakeholders to download the documents.

Printed copies of the standards will be available at government offices, libraries, and other public institutions for those who may not have internet access.

14.1.2 Digital Platforms:

The standards will be hosted on dedicated online portals for building and construction regulations, providing downloadable versions in multiple formats (PDF, HTML).

Relevant stakeholders, including professional associations, construction firms, and educational institutions, will receive digital copies via email to ensure they are informed promptly.

14.1.3 Workshops and Training Sessions:

Workshops and training sessions will be carried out to educate builders, developers, architects, engineers, and inspectors on the new standards. This may include online webinars and instructional videos that explain the key changes and requirements of the new standards, making it accessible to remote stakeholders.

14.1.4 Public Awareness Campaigns:

A campaign of public awareness that may involve traditional media (news organizations, radio, TV) and social media platforms to announce the release of the new standards and direct stakeholders to where they can access the information will be planned.

The key enforcing agency will issue press releases and engage with industry magazines and journals to reach a broader professional audience.

14.1.5 Industry Partnerships:

Professional associations such as the Zimbabwe Institute of Architects (ZIA) and the Zimbabwe Institute of Engineers (ZIE) will be engaged to support the dissemination of the standards to their members.

Similarly, major construction firms, architects, and developers ensure the standards are integrated into their training programs and project planning processes.

14.2 Effective date of the code and the process for its adoption by local authorities.

The BEEC will become effective on Jul 1, 2025. This effective date allows for a transition period during which all stakeholders, including builders, developers, architects, and engineers, can familiarize themselves with the new requirements and ensure compliance. The transition period will include training sessions, dissemination of updated guidelines, and support resources to facilitate the smooth implementation of the standards.

15 References and Standards

15.1 Lists of relevant industry standards and reference documents that are incorporated into the code.

The Standard Association of Zimbabwe (SAZ) is responsible for the compilation and development of standards for any activities, products and measures used or installed in any businesses or organizations in Zimbabwe. As a member of the International Standard Organization (ISO) several of the nationally adopted standards are from ISO.

Below list includes scope and title of national standards specifically relevant to the BEEC. SAZ has information centers located in Harare, Bulawayo and Mutare from where standards can be purchased. When commencing a design phase of a new building project – or in connection with larger building renovations - it is important to review existing or available standards and make sure that these are followed. Especially, it is important to check whether obligatory codes refer to such available standards.

Table 2: Table of standards used as sources for the development of this BEEC.

Standard scope and title	Code no.
Thermal storage electric water heaters	ZWS 213:1997
Safety of household and similar electrical appliances stationary instantaneous electrical water heaters	ZWS 283:1984
Immersion heaters for electric water heaters	ZWS 557: 1997
Code of practice for the installation of solar water heaters	ZWS 744:2003
Design, sizing and installation of battery based photovoltaic systems	ZWS 536:1998
Solar batteries	ZWS 522:2017
Energy management systems – Requirements with guidance for use	ZWS ISO 50001:2018
EMS – Guidance for the Implementation, Maintenance and Improvement of ISO 50001.	ZWS ISO 50004:2020
Energy Management system and energy savings – Building energy data management for energy performance – Guidance for s systemic data exchange approach.	ZWS ISO 50008:2018
Part of the National Building Regulations, this standard focuses on energy usage in buildings, setting minimum requirements for energy efficiency, including thermal performance and insulation levels	SANS 10400-XA
Provides specific guidelines for energy efficiency in buildings, detailing design requirements for naturally ventilated, mechanically ventilated, and air-conditioned buildings. It outlines performance parameters and compliance methods through rational design or deemed-to-satisfy rules.	SANS 204
Solar Water Heaters—guidelines for the design, installation, and maintenance of solar water heating systems.	SANS 10106
Energy Efficiency for Electrical and Electronic Apparatus—sets requirements for energy efficiency and labeling of appliances that impact overall building energy use.	SANS 941
Lighting and Ventilation—requirements that impact the energy efficiency of lighting and HVAC systems in buildings.	SANS 10400-O
It provides certification for buildings that meet high standards of environmental sustainability across various categories, including	Green Star

energy efficiency, water usage, indoor environmental quality, and materials.

16 Appendices and Supporting Materials

16.1 Modelling guidelines to assess building performance

The **Modelling Guidelines** provide a structured approach to evaluating building energy performance. The document outlines the standards and methodologies for modelling energy consumption and efficiency in buildings, ensuring compliance with the proposed BEEC. The key focus areas include modelling the building envelope, HVAC systems, lighting, and other internal loads.

Key Elements of the Guidelines:

1. **Scope and Purpose**: The guidelines set out standard inputs and assumptions for modelling energy performance, including operational usage, occupancy profiles, and climatic data.
2. **General Methodology**: The guidelines emphasize using certified thermal modelling software to simulate both the proposed building and a reference building with similar geometry and functionality. The simulations will account for representative climate data, operating schedules, and energy loads to ensure comparable performance assessments.
3. **Energy Performance Reporting**: Energy performance is reported as annual energy consumption per square meter of net floor area, expressed in kilowatt-hours per square meter per annum (kWh/m²/year). This metric, referred to as annual energy intensity, provides a standardized measure of energy efficiency across different building designs.
4. **Specific Modelling Requirements**: The document outlines detailed requirements for modelling various building components, including:
    - **Building Envelope**: Specific parameters for modelling the geometry, insulation, glazing, and other elements of the building envelope are defined for both the reference and proposed buildings.
    - **HVAC Systems**: All HVAC components must be modelled according to the actual design specifications, including equipment capacities and energy consumption by fans and pumps.
    - **Naturally Ventilated Buildings**: For areas without artificial heating or cooling, theoretical energy consumption must be calculated to ensure comfort within prescribed temperature ranges.
    - **Reference Building Cooling Systems**: A standard cooling system is modelled in the reference building for consistent comparison, even if the proposed building does not include cooling equipment.
5. **Schedules of Operation**: The guidelines provide recommended schedules of operation for both residential and non-residential buildings. These schedules help standardize the input data for energy simulations, ensuring consistency in how equipment usage, lighting, and HVAC operations are modelled throughout a typical year.

16.2 Assessment tool

In order to support the implementation of the green standards, the development of an assessment tool to ensure uniformity and support regulatory bodies with the burden.

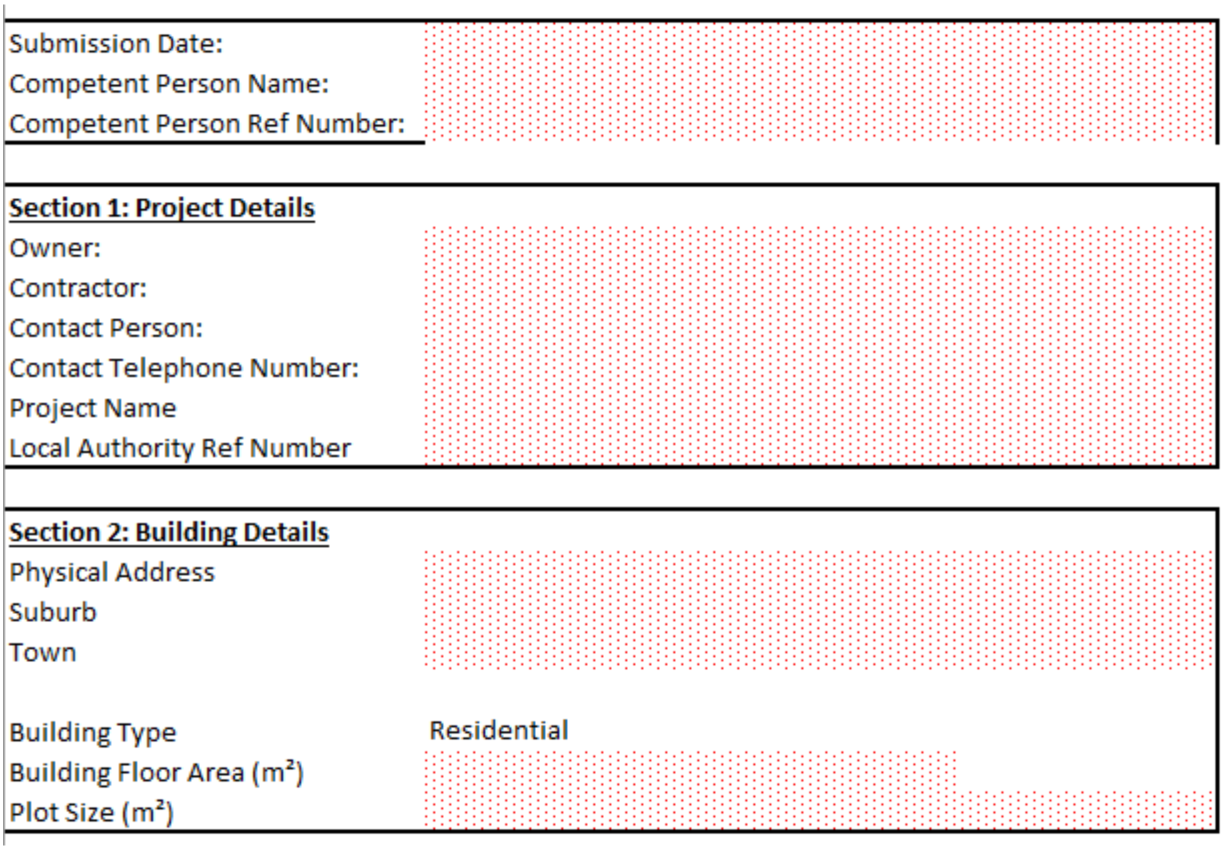
This section provides an overview of a tool for this purposes that serves another jurisdiction. The images illustrate the tool and the simplicity of its operation.

The spreadsheet is designed to assess the suitability of different aspects of the green buildings code such as insulation, WWR, and other. The tool includes a series of drop-down menus and self-calculations to estimate the suitability of different building aspects with the requirements.

The key inputs include the following:

- Building Characteristics: Includes sections for inputting details about the building's geometry, such as floor area, number of floors, and window-to-wall ratios.
- Material Properties: Allows input of insulation levels, thermal properties of walls, roofs, and glazing specifications to model the building envelope.
- HVAC Systems: Inputs for heating, ventilation, and air conditioning equipment, including types, efficiency ratings, and operational schedules.
- Lighting and Equipment: Sections for entering lighting power density, equipment loads, and their usage schedules to account for internal energy demands.

Figure 1 illustrates the sections for the input of basic information of the building to be assessed.



Submission Date:
Competent Person Name:
Competent Person Ref Number:

Section 1: Project Details
Owner:
Contractor:
Contact Person:
Contact Telephone Number:
Project Name
Local Authority Ref Number

Section 2: Building Details
Physical Address
Suburb
Town

Building Type: Residential
Building Floor Area (m^2)
Plot Size (m^2)

Figure 1: Screenshot of the basic building information sections.

Figure 2 illustrate the section of the tool that determines the building general compliance based on the average performance of the building.

Section 3: Method of Compliance

Method	Performance
Software Used	

Section 3b: Performance-based Metrics

Note: Only complete this section if the performance method has been selected

	Reference	Proposed Building	
Lighting [kWh/m2/yr]			**Not Compliant**
Cooling [kWh/m2/yr]			
Total	0	0	
% Improvement over BEEC		0%	

Figure 2: Illustrates the section where main compliance determination is made based on the performance of the building.

Figure 3 Illustrates the specific sections on the assessment of wall insulation and wall-to-window ratios.

Section 4: Insulation Thickness			
K-value W/mK	Design Thickness mm	Minimum Threshold mm	Status
		0	**Compliant**
Supporting documentation attached			

Section 5: Window to Wall Ratio				
Orientation	Above-Grade Wall Area (m^2)	Vertical Glazing Area (m^2)	Vertical Glazing Area (%)	Status
North	450	50	11.1%	**Compliant**
East	350	45	12.9%	**Compliant**
South	250	44	17.6%	**Compliant**
West	200	20	10.0%	**Compliant**
TOTAL COMPLIANCE	**Compliant**			
Supporting documentation attached				

Section 5 b) For any Non-Compliance in Section 5, show compliance here.					
Number of Windows		1			
	Reference	Window Height	Height of Overhang Above Window	Length of Overhang	Status
Window 1		0	0	0	Compliant
+ Add Window					
Supporting documentation attached					

Figure 3: Illustration of the checks on insulation and wall to window ratio.

Finally, Figure 4 illustrates the final sections on assessing air conditioning and lighting power density.

Section 6: Air Conditioning

Drawing Ref	Model Ref	Rated Cooling Capacity (kW)	Rated Input Power (kW)	EER/COP	Inverter Compressor	Status
				0.0	No	Not Compliant
+ Add						
Supporting documentation attached						

Section 7: Lighting Power Density

Drawing Ref	Description	Light Fitting Total W	Quantity	Total W
+ Add				
Total Installed Lighting (kW)				**0.00**
Total Building Area (m²)				**0**
Total Lighting Power Density (W/m²)				**area?**
Not Compliant				
Supporting documentation attached				

Figure 4: Assessment tool sections on AC and lighting.