DEVELOPMENT OF GREEN BUILDING STANDARDS FOR GHANA

BASELINE ASSESSMENT REPORT

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Abbreviations

CTCN	Climate Technology Centre and Network
EPA	Environmental Protection Agency
GhIE	Ghana Institution of Engineering
GSA	Ghana Standards Authority
HVAC	Heating, Ventilation, and Air Conditioning
IEQ	Indoor Environmental Quality
LCC	Life Cycle Cost
MRV	Monitoring, Reporting, and Verification
MWH	Ministry of Works and Housing
NZEB	Net-Zero Energy Building
NEEAP	National Energy Efficiency Action Plan
NDC	Nationally Determined Contributions
SWG	Stakeholder Working Group
ZEB	Zero Energy Building

1 Introduction

To support a transition towards a more sustainable and climate-friendly building environment, the Government of Ghana, through its designated entity, the Environmental Protection Agency (EPA), sought support from the Climate Technology Centre and Network (CTCN) and the German Ministry for Economic Cooperation and Development (Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung – BMZ) to develop a Green Building Standard for the country.

The technical assistance project includes the development of a set of deliverables that provide the necessary tools to develop and implement Green Building Standards, which include:

- Baseline assessment of current building performance, existing policies and regulations, existing building practices, and an assessment of gaps and options to fill the gaps.
- Development of draft green building standards and policy guidelines.
- The generation of implementation mechanisms such as an MRV framework, a training program, and support tools.

This report responds to the first item above, presenting an in-depth report of the findings from project activities 2.1 and 2.2, aimed at establishing a comprehensive background and baseline for developing Ghana's Green Building Standards. The main components covered are:

- Policy and Regulatory Analysis: This analysis examines Ghana's current efforts to enhance or enforce building performance, with an emphasis on energy efficiency. It includes a review of building codes, policy frameworks, industry strategies, and municipal by-laws, aiming to understand current requirements and assess potential future directions.
- Baseline Building Performance Analysis: This section evaluates the existing energy demand in buildings, assessing the presence or absence of design features and energy-using appliances to establish the sector's average energy consumption. Additionally, it projects growth trends in building energy use and emissions over time, providing a baseline to gauge potential energy savings achievable through Green Building Standards.
- Identification of International Best Practices: This part identifies effective energy-saving measures across various stages of the building lifecycle, providing examples and comparisons to the current state. This analysis supports the selection of practices for Ghana's Green Building Code and helps estimate the savings achievable from their implementation.

Together, these components lay the foundations of information required for the design of Green Building Standards, offering a foundation for advancements in building technologies, sustainable design practices, and policies that promote and support green building development.

2 Green building concepts

2.1 Definition of green buildings

Green buildings, often described as structures that reduce their environmental footprint throughout their lifecycle, encompass various designs, practices, and technologies to optimize resource efficiency, minimize waste, and reduce or avoid GHG emissions. While definitions vary globally, Bungau et al. (2022) emphasize that green buildings not only aim to lower energy and water consumption but also consider occupant health and comfort by using non-toxic materials and biophilic elements. This holistic approach supports not only environmental goals but also the well-being and productivity of occupants, highlighting the balance green buildings strive to achieve between ecological and human-centred design principles.

The Green Building Council and other bodies advocate that green buildings are essential to addressing the climate crisis through the application of sustainable construction practices that involve integrating renewable energy sources, improving energy efficiency, and selecting materials with low embodied carbon. Standards like LEED, BREEAM, and the WELL Building Standard provide frameworks that reinforce these principles, offering guidance on everything from material selection to indoor environmental quality.

Green buildings thus represent a shift from traditional construction toward a lifecycle perspective, which, aside from climate objectives, is closely aligned and has been described as important to achieving sustainability goals. Thoughtful design, resource conservation, and occupant-centred practices achieve outcomes beyond climate friendliness, supporting a more sustainable future. As Bungau et al. note, the goal is not simply to create energy-efficient buildings but to cultivate spaces that actively contribute to environmental sustainability and human health.

However, this project will focus on the climate-related components of green buildings, particularly energy efficiency, renewable energy integration, and the use of low-carbon materials. Energy efficiency strategies, like advanced insulation, high-performance windows, passive design, and smart HVAC systems, reduce the energy demand of buildings, making them more sustainable and affordable to operate. On the other hand, renewable energy, such as solar and wind, decreases energy demand from electrical grids, which in turn reduces demand for fossil fuels, enabling ambitious developers to aim for net-zero or even net-positive energy building performance. Lastly, the use of low-carbon materials, such as recycled steel, bamboo, and reclaimed wood, minimises the embodied carbon associated with construction processes [USGBC, 2022]. This climate-focused approach not only addresses the urgent need to reduce emissions but also sets the foundation for resilient, future-ready building practices.

It should be noted that buildings built to a strong, energy-efficient standard tend to generate other benefits associated with green buildings for users. This includes a quiet and dry indoor environment from the building's insulation and air-tightness considerations. Also, keeping a comfortable home tends to be easier in climate-friendly buildings, resulting in positive outcomes for health, productivity, and other social outcomes. The project strongly believes that the implementation of energy-efficiency standards is a first, and important, step in the transition towards green buildings in Ghana.

2.2 Key features of green buildings

Green buildings incorporate sustainable practices aimed at reducing environmental impact, promoting energy efficiency, and enhancing occupant well-being throughout a building's lifecycle. Key features of sustainable buildings include energy efficiency, water efficiency, sustainable site selection and land use, material selection, indoor environmental quality (IEQ), waste management, and green infrastructure. While this project will discuss each feature, the primary focus will be on energy efficiency, complemented by a look at materials and design choices that reduce overall energy demand.

2.2.1.1 Energy Efficiency

As much human activity takes place in buildings, they account for around 34% of energy-related emissions, more than any other sector [UNEP, 2025]. Buildings use a large amount of energy to cool or warm their interiors, cooking, lighting, appliances and equipment, water heating, and plug loads to power electric appliances and equipment. Much of this energy is produced using fossil fuels. Green buildings aim to minimise energy use in buildings through the incorporation of design strategies that optimise natural lighting, ventilation and insulation, thereby reducing the need for artificial lighting, heating, and cooling and hence, reducing energy consumption. The implications for the policy and regulatory framework for this are that policies and regulations should provide necessary guidelines, standards and incentives that encourage the adoption of sustainable building practices.

2.2.1.2 Material Selection and Resource Efficiency

Green buildings prioritise using sustainable, low-emission, and recycled materials that are sourced responsibly and manufactured to reduce environmental impacts and support long-term sustainability. This includes materials such as responsibly harvested timber, reclaimed materials, eco-friendly insulation, recycled plastics, and advanced alternatives to standard concrete. These options generally produce far fewer emissions compared to conventional materials like concrete and steel, which require substantial energy for extraction and processing. Efficient resource use throughout a building's life—from construction to demolition—focuses on minimising consumption, cutting waste, and optimising material use. To support these practices, policies and regulations should establish guidelines, standards, incentives, and frameworks that promote the development and maintenance of sustainable, energy-efficient buildings. Policy frameworks that incentivise the use of sustainable materials encourage innovation in low-impact building materials, responsible sourcing, and fostering practices that support a circular economy within the construction industry [UNEP, 2025].

2.2.1.3 Sustainable Site Selection and Land Use

Green buildings consider the environmental impact of site selection and land use. They are designed to minimise disturbances to natural habitats and to protect biodiversity. Thus, when choosing a location for a building, factors such as the presence of sensitive ecosystems or endangered species should be considered to avoid causing harm to these areas. Additionally, green buildings aim to reduce reliance on vehicles because they contribute to air pollution and greenhouse gas emissions, which are harmful to the environment. Green buildings integrate amenities such as parks, recreational areas, and commercial facilities within walking distance to reduce the need for long-distance travel and encourage physical activity [BREEAM, 2023]. The policy and legal framework implications are that policies should consider instruments and tools that discourage building development at inappropriate sites and encourage the reduction of the environmental impact from the location of a building on the site.

2.2.1.4 Green Infrastructure

Green infrastructure integrates natural systems with built environments to improve environmental performance, enhance human well-being, and manage stormwater. Features such as green roofs, permeable pavements, rain gardens, and living walls contribute to urban biodiversity, reduce heat islands, and support sustainable water management. By incorporating green infrastructure, buildings reduce their environmental impact and foster resilience to climate change. Policy frameworks supporting green infrastructure are instrumental in establishing guidelines that promote its adoption, such as incentives for sustainable landscaping and infrastructure.

2.2.1.5 Indoor Environmental Quality (IEQ)

A green building's indoor environmental quality (IEQ) addresses aspects like air quality, lighting, and thermal comfort, all of which impact occupant health and productivity. High IEQ is achieved through natural lighting, non-toxic materials, and efficient HVAC systems that maintain optimal air circulation and temperature. Regulations like the WELL Building Standard emphasise occupant well-being, setting guidelines for air quality, natural light exposure, and thermal comfort to create healthier indoor spaces (WELL, 2023). Policy and regulatory frameworks ensure that buildings uphold IEQ standards, reducing health risks and supporting sustainable practices.

2.2.1.6 Waste Management

Green buildings incorporate waste management practices aimed at reducing construction and operational waste through recycling, reuse, and sustainable disposal. Effective waste management, including strategies for waste reduction, segregation, and recycling, contributes to a circular economy by decreasing landfill waste and optimising material reuse (BREEAM, 2023). The integration of efficient waste management strategies in green buildings contributes to the creation of more sustainable built environments.

3 Review of internationally recommended practice

3.1 International setting

The building sector's energy demand, encompassing both construction-related energy and the energy services required during a building's operational phase—such as heating, cooling, lighting, and appliance use—accounts for over one-third of global energy consumption. It is also responsible for 26% of energy-related GHG emissions worldwide, divided roughly into direct emissions from buildings, accounting for 8% and indirect emissions tied to the electricity and heat produced for building operations, accounting for 18% [IEA, 2021]. In Ghana, electricity demand from the residential and commercial sectors accounts for approximately 57% of the country's electricity use and contributes 18% of its energy-related emissions [IEA, n.d.]

As urbanisation accelerates and floor areas expand, especially in developing regions, the sector faces rising energy pressures. Increased prosperity in these areas also drives higher adoption rates for energy-intensive appliances like air conditioners, which, without intervention, could substantially increase future emissions [IEA, 2021]. Given the long lifespan of most buildings and their heating, cooling, and electrical systems, the design and purchasing decisions made today will lock in energy usage and carbon emissions for decades.

To mitigate these impacts and achieve net-zero emissions by 2050, governments and international bodies are advancing a range of policy measures and technical standards. These include establishing minimum energy performance standards (MEPS) that set baseline efficiency requirements for appliances and equipment used in buildings, building energy efficiency codes that set standards for new constructions and/or major renovations, ensuring the resulting buildings meet increasingly ambitious energy performance criteria, and mechanisms to support their implementation [UNEP, 2025; World GBC, 2020]. Policy frameworks such as the Zero-Carbon Building Standard advocate for new buildings to be zero-carbon-ready by 2030 and for the sector to achieve substantial decarbonization by mid-century.

Some governments have also introduced incentive programs, like tax breaks or grants, for energy-efficient retrofits, while others are expanding green certification systems to encourage sustainable practices. In some cases, countries are incorporating net-zero energy building (NZEB) policies to reduce reliance on to promote on-site renewable energy production. Added to this, some international initiatives such as the European Green Deal and U.S. Federal Energy Performance Standards seek to address both **operational** and **embodied** carbon in buildings by setting aggressive targets for emissions reductions through stringent building codes, efficient technologies, and increased renewable energy integration [World GBC, 2020].

Despite progress, the sector still requires accelerated change to align with the Net Zero Emissions by 2050 Scenario. This decade is crucial for implementing these measures, with a view to enabling net-zero-ready energy buildings as soon as possible. This project will support policymakers, industry stakeholders, and private operators to collectively advance these policies, technologies, and sustainable practices and turn Ghana into a regional leader in the subject.

3.2 International certification schemes for Green Buildings

Building certifications, while often tailored to specific national standards, have increasingly aligned with internationally recognised frameworks that emphasise sustainability, resource efficiency, and environmental responsibility in both the construction and operation of buildings. Certifications such as LEED (Leadership in Energy and Environmental Design), BREEAM (Building Research Establishment Environmental Assessment Method), and EDGE (Excellence in Design for Greater Efficiencies) have established comprehensive standards that are voluntary in most countries but encourage developers to adopt more sustainable practices. The certification process typically involves a series of steps, including submitting architectural and operational plans to a certifying organisation, inspections during construction to ensure compliance with sustainability benchmarks, and, ultimately, official certification once these standards are met. This multi-step approach helps ensure that a project is not only planned sustainably but is also implemented with accountability.

One of the primary motivations for pursuing these certifications is their marketability. Properties that have received recognised certifications tend to command higher market values, as they signal a commitment to sustainability and often lead to reduced operational costs over time. This increase in value can help offset the sometimes-higher costs of sustainable construction, which may include using energy-efficient systems, renewable materials, or advanced water management solutions. For building owners and operators, certified buildings frequently lead to lower long-term utility costs due to improved energy efficiency and may qualify for tax incentives, grants, or other financial benefits depending on regional policies. Thus, the initial investment in certification can often be recouped through these long-term savings.

Beyond financial incentives, certified green buildings also tend to offer enhanced health and well-being for occupants. Many certification programs include criteria that address indoor air quality, natural daylighting, and noise reduction, which contribute to a healthier and more comfortable indoor environment. Research has shown that occupants of green-certified buildings report higher levels of satisfaction and well-being, which can lead to improved productivity in workspaces and an overall higher quality of life for residents and occupants. As awareness of the environmental impact of buildings continues to grow, certifications not only support ecological goals but also meet an increasing demand for healthier, more sustainable living and working environments.

Table 1 - Examples of leading green building certification schemes internationally.

#	**Branding**	description
1	U.S. GREEN BUILDING COUNCIL LEED USGBC	**LEED** from the US Green Building Council provides a framework for healthy, highly efficient, and cost-saving green buildings. It offers various certification levels based on points earned across several categories, including sustainable site development, water efficiency, energy performance, materials selection, and indoor environmental quality.
2	CODE FOR A SUSTAINABLE BUILT ENVIRONMENT BREEAM BRE GLOBAL	**BREEAM** (Building Research Establishment Environmental Assessment Method): This standard is widely used in the United Kingdom and several other countries. BREEAM assesses the environmental performance of buildings, including their design, construction, and operation.
3		**Green Star**: This is an Australian-based rating system for sustainable building design and construction. It evaluates a building's environmental performance across various categories and has gained recognition in several countries.
4		Living Building Challenge: The Living Building Challenge, administered by the International Living Future Institute, goes beyond just energy and water efficiency. It aims to create buildings that are "regenerative" and produce more energy and resources than they consume.

#	Branding	description
5		Passivhaus (Passive House): Originating in Germany, Passivhaus focuses on extreme energy efficiency and is designed to reduce a building's energy consumption significantly. It's applicable in many countries and regions.
6		**Estidama**: This is the sustainability rating system used in the United Arab Emirates, with a particular focus on the environmental performance of buildings in the desert environment
7		GRIHA (Green Rating for Integrated Habitat Assessment): Developed in India, GRIHA assesses the environmental performance of buildings and infrastructure projects in the Indian context.
8		Green Mark: Singapore's green building rating system, Green Mark, evaluates and rates the environmental performance of buildings in the city-state.
9		Excellence in Design for Greater Efficiencies (EDGE): Used in over 100 countries, EDGE is a free software and an international green building certification system. A green building solution created by the International Finance Corporation (IFC), a member of the World Bank Group, EDGE empowers you to optimise your designs to use less energy, water, and embodied energy in materials.

3.3 Building Energy Efficiency Codes (BEEC)

The effectiveness and impact of building energy efficiency codes (BEEC) depend on several operational conditions and market dynamics, including the specific requirements outlined within the codes, the compliance level within the construction industry, and the government's capacity to monitor and enforce such standards. Key aspects of BEEC generally cover energy-efficient insulation, minimum requirements for heating and cooling systems, lighting, ventilation, and even renewable energy integration.

The benefits of BEEC extend beyond energy conservation to include reduced operational costs, enhanced occupant comfort, and resilience against energy price fluctuations. For building owners and developers, compliance can increase property values and, in many cases, qualify them for tax incentives or financial subsidies. For instance, the U.S. federal government offers tax deductions for commercial buildings that meet or exceed energy efficiency requirements, thus reinforcing the market's interest in compliance [US DOE, 2020]. However, BEEC's success relies heavily on the implementation and enforcement mechanisms in place, as well as the support provided to the construction industry through training, financial incentives, and clear regulatory guidance.

To achieve broad compliance and maximise impact, energy efficiency codes must adapt to changing technologies, regional climate needs, and building types, which requires ongoing updates and revisions. Codes that prioritise (and embed in the law) periodic code updates are better equipped to align with evolving climate goals and market conditions.

This chapter highlights the key elements that a BEEC needs to address to make it successful, flexible, resilient and effective.

3.3.1 Ambition

Ambition is at the centre of building energy efficiency that aims to achieve substantial reductions in energy consumption and emissions across different regions and economic contexts. High-performance standards set rigorous requirements for key building elements, such as insulation, HVAC systems, and lighting, to minimise energy demand and maximise energy efficiency, which is essential for progress toward climate goals. Setting ambitious yet feasible energy standards can motivate the use of innovative technologies and high-efficiency practices that provide long-term savings and environmental benefits.

In developing regions with varying access to reliable and affordable electricity, ambitious energy codes can face challenges in implementation, but they remain valuable in driving progress. For example, in regions where energy access is limited or costly, stringent efficiency standards can reduce dependence on electricity, encouraging energy conservation and making buildings more resilient to fluctuations in power availability. Countries that incorporate gradual, adaptable standards—adjusting to regional climates and resource access—can achieve greater compliance and acceptance, allowing more regions to benefit from energy savings while addressing affordability and practical needs.

In the case of Ghana, the ambition of a BEEC should balance high performance with practical, region-specific goals that reflect the country's energy needs, climate, and economic constraints. Ghana's warm and humid climate, combined with rising energy demand for air conditioning and cooling, highlights the need for efficient insulation, shading, and ventilation requirements to reduce cooling loads. Incremental implementation, beginning with foundational energy-saving measures and progressing toward higher efficiency targets over time, can help encourage market compliance and affordability [GIZ, 2021; MCC, 2021].

3.3.2 Scope

Energy efficiency codes address multiple components of building design and construction, each contributing to reduced energy use and a more sustainable built environment. The objective of each component is to look at how to best meet occupants' needs while supporting the overall achievement of the standards. Key elements include:

- **Building Envelope Quality**: The building envelope, comprised of walls, roof, windows, doors, and foundation, forms the barrier between the indoor environment and the exterior. It plays a critical role in protecting indoor air quality and regulating indoor temperature, reducing energy requirements for heating and cooling by minimizing unwanted heat exchange with the environment.
- **Insulation**: Effective insulation retains desired indoor temperatures by keeping heat indoors during winter and preventing heat gain in summer. This reduces dependence on heating and cooling systems, making it a central aspect of energy efficiency codes.
- **Heating, Ventilation, and Air Conditioning (HVAC) Efficiency**: Energy efficiency codes often specify minimum standards for HVAC systems, ensuring they provide comfortable indoor temperatures efficiently and sustainably. Such standards help lower energy consumption by encouraging the use of advanced, energy-saving HVAC technology.
- **Lighting Systems:** Codes set requirements for lighting that is appropriate for building use, specifying energy-efficient solutions like LED technology. Lighting standards may vary by space, as task-specific lighting, such as for desk work or industrial settings, demands different levels of brightness.
- **Renewable Energy Integration**: In some regions, codes require buildings of certain types to generate a portion of their energy on-site using renewable technologies, such as solar

photovoltaics (PV), to reduce demand from the grid and support a transition to cleaner energy sources.

Other considerations include how building design can be optimised or incorporate passive principles to significantly reduce the need for active energy use in heating, cooling, and lighting, which contributes to overall energy efficiency. Passive design strategies work with natural resources—such as sunlight, shade, and ventilation—by optimising the building's orientation, layout, and materials to regulate indoor climate without relying heavily on mechanical systems. Similarly, design features may look to enhance occupants' experiences, while encouraging healthy activities such as strategically placing stairs and other accessibility features to encourage collaboration while increasing physical movement.

The scope of these codes can vary significantly. Some countries adopt comprehensive codes that apply to all building types, ensuring that residential and commercial structures alike contribute to national energy savings. Other regions may focus on high-energy buildings above certain sizes, such as large commercial buildings, while single-family residences are sometimes excluded from mandates [IEA, 2021]. Additionally, efficiency codes often target areas with the highest potential energy savings at the lowest cost, such as requiring LED lighting in all buildings, regardless of their type or use.

3.3.3 Compliance and enforcement

Once the development of the BEEC performance requirements and application mechanisms is completed, the majority of the resources of the activity will focus on ensuring compliance throughout the construction and retrofitting processes. Effective enforcement mechanisms are essential to verify adherence to BEEC requirements and drive meaningful energy savings. Common enforcement strategies include:

- Inspections: Trained inspectors monitor the development of buildings to ensure that construction meets energy efficiency standards. For effective inspections, building officials need specific technical skills and training in BEEC requirements and energy-efficient technologies.
- Permits: Issued by local authorities, permits certify that construction companies and individuals meet BEEC minimum requirements before starting or continuing construction. Permit requirements help maintain standards consistency across new projects and retrofits.
- Penalties for Non-Compliance: Penalties often involve fines for failing to meet BEEC minimum requirements, though more severe violations may lead to site closures, license revocations, or even imprisonment for contractors or developers. Such penalties emphasise the importance of compliance and the high stakes of sustainable building.
- Incentives for Compliance: Some jurisdictions offer financial incentives or other benefits for meeting or exceeding BEEC standards. For instance, developers may receive financial rewards per square meter of energy-efficient building space, or be allowed design concessions, like additional floor space in height-restricted areas, for meeting higher standards. These incentives encourage greater adoption and implementation of BEECs.

In developing countries, which often encounter significant challenges in these are due to resource and capacity constraints, international organisations often support BEEC formulation and implementation. However, a strong focus on capacity building is critical, as the availability of skilled and experienced inspectors, permit issuers, and enforcement staff directly impacts the effectiveness of BEECs.

3.3.4 Flexibility and adaptability

A level of flexibility and adaptability needs to the included in the development of BEECs to address the wide range of building types, climate conditions, and construction practices found globally. This flexibility is critical for ensuring that residential, commercial, and industrial buildings can each achieve the desired level of energy efficiency without compromising their functional requirements. To remain relevant, BEECs must also respond to changing technologies, energy costs, and environmental priorities. Regular updates allow BEECs to incorporate advanced building materials, new technologies, and align with shifts in environmental policies, keeping the standards practical and effective in reducing energy demand and emissions [UNEP, 2025].

To keep BEECs aligned with these evolving conditions, monitoring and evaluation systems are an essential component of the implementation mechanisms. These systems not only ensure compliance with existing codes but also provide valuable data on building performance under diverse conditions. By analysing trends and performance outcomes, regulators can refine and update the codes to reflect advancements in building technologies and shifting environmental needs. Additionally, building industry professionals benefit from ongoing education in building science, which equips them to implement updated standards effectively and stay ahead of technological developments.

For effective implementation, the review and updating process for BEECs should be embedded in the regulatory framework. This includes specifying the review methodologies, setting clear priorities, identifying responsible stakeholders, and assigning an agency to oversee the process. This structured approach to BEEC updates ensures that regulations remain rigorous and effective, addressing both current needs and future demands in sustainable building practices.

3.3.5 Cost effectiveness

Although building energy efficiency standards may increase initial construction costs, these upfront investments are generally offset by substantial long-term savings and benefits. Energy-efficient and green buildings utilise higher-quality materials and advanced technologies that significantly reduce energy consumption, resulting in lower operational costs for utilities and maintenance. Over the life of the building, the lower cost of energy and maintenance contributes to an overall lower total cost of ownership, making green buildings financially advantageous compared to standard structures [IEA, 2021; UNEP, 2025].

However, one barrier to green building adoption is the split-incentive issue, where the costs of building energy-efficient properties primarily affect developers, while the benefits accrue to future occupants or operators who enjoy lower operational costs and improved quality. To bridge this gap, some green building incentive programs enable developers to capitalise on improved building performance. For instance, programs may offer direct subsidies, allow additional floor space in height-restricted areas, or provide certification that increases market value, thereby making green development more attractive.

In addition to financial benefits, green buildings often enhance the health, comfort, and productivity of occupants. Features like improved indoor air quality, thermal comfort, and daylighting contribute to better overall well-being, with evidence showing productivity gains in workplaces and reduced health costs for residents. Effective insulation and airtight designs in green buildings also reduce noise and moisture issues, contributing to healthier indoor environments and fewer health-related costs over time.

3.3.6 Climate impact

It is well understood that buildings play a significant role in reducing the overall climate impact of the built environment, as there is a potential to significantly lower GHG emissions and energy consumption. According to the World GBC [2000], green buildings can achieve energy savings of up to 50% compared to standard buildings, primarily by incorporating efficient HVAC systems, lighting, insulation, and renewable energy sources such as solar or wind power. What is more, with the incorporation of renewable energy into the latest energy-efficient materials and designs, the industry is able to generate net-zero carbon buildings.

Furthermore, green buildings help to alleviate urban heat islands, which are caused by dense developments that trap heat. By using reflective materials, green roofs, and vegetation, green buildings can lower surrounding temperatures, reducing the energy demand for cooling and improving urban air quality. Additionally, these buildings often incorporate water-saving technologies that reduce the need for energy-intensive water treatment processes. By reducing both energy and water consumption, green buildings provide a holistic approach to sustainability that mitigates climate impacts and enhances resilience against climate-induced stresses, such as heat waves and water scarcity.

3.3.7 Market transformation, public awareness, and education

The implementation of energy efficiency building codes supports a wider transition in the markets by transforming the construction industry and markets through the adoption of sustainable technologies, materials, and design practices. By setting high standards, these codes not only lower energy consumption in new buildings but also catalyse a growing demand for advanced building materials, such as high-performance insulation, energy-efficient HVAC systems, and smart building management solutions. This demand encourages manufacturers and industry stakeholders to increase investment in research and development, resulting in innovative products and practices that continue to push the boundaries of energy-efficient design. These standards stimulate a competitive market that incentivises continuous improvement and refinement in building technologies.

Further, as markets become more aware and used to the benefits of high-quality and efficient buildings, demand for them will increase, as will the expectations of a more knowledgeable consumer.

As such, the success of energy codes in achieving large-scale market transformation will rely heavily on effective implementation and widespread public engagement. Builders, architects, homeowners, and tenants must understand the benefits and specific requirements of these codes to drive compliance and adoption. Public awareness campaigns and educational programs, including community workshops, online webinars, and accessible resources, play a critical role in illustrating the practical benefits of energy-efficient building practices, such as cost savings and enhanced comfort. Targeted training for industry professionals also ensures they are equipped with the skills to apply these standards effectively. Through sustained educational efforts, energy codes foster a well-informed public and industry, cultivating a culture that values sustainability and integrates energy efficiency as a standard in both new construction and retrofitting.

3.3.8 Global harmonisation

Harmonisation of BEECs across regions or globally is an important component to support the creation of unified expectations and practices that benefit markets for materials, technologies, and skilled labour. Unified or compatible standards allow manufacturers to develop products, such as insulation, energy-efficient HVAC systems, and renewable energy solutions, that meet multiple markets' requirements, thereby reducing costs through economies of scale and simplifying compliance. This alignment fosters an interconnected market where materials and technologies are not only more widely available but also more affordable, making energy-efficient building practices accessible to a broader audience. By aligning standards, regions can promote innovation and stimulate the development of cutting-edge materials and construction methods that adhere to energy efficiency principles and reduce overall emissions in the construction sector [IEA, 2022].

Harmonised codes also address the growing demand for skilled professionals with expertise in sustainable building practices, creating a global standard that encourages consistency in education, training, and certification programs. Shared standards enable educational institutions and professional training programs to design curricula that prepare architects, engineers, and construction workers with the skills needed to implement energy-efficient technologies across different regions.

Unified energy efficiency standards simplify public messaging around sustainable building practices, allowing governments, NGOs, and industry stakeholders to deliver consistent educational content and outreach initiatives. This consistency helps communities understand the benefits of green buildings, such as lower utility costs and improved indoor air quality, encouraging broader acceptance and demand.

Lastly, harmonised codes promote international cooperation on climate goals by setting shared benchmarks and tracking mechanisms that allow countries to measure and compare progress on energy efficiency in buildings. Such coordination supports the establishment of global policies that combat climate change through unified efforts, ensuring that building standards are a key tool in reducing carbon emissions worldwide. By creating an integrated framework, harmonised codes help ensure that sustainable building practices contribute meaningfully to climate action, bridging the gap between regional standards and global environmental objectives.

Green building certification programmes generally look to improve harmonisation by following their requirements. For example, the global Green Building Council programme.

3.4 BEEC global status

BEECs typically outline minimum requirements that fall into two types of requirements:

- **Prescriptive requirements** specify a minimum level of performance or specific technological applications for individual components of the building, such as lighting and HVAC systems, establishing benchmarks for energy consumption at the component level. For instance, prescriptive lighting standards might require specific wattage per square meter to ensure adequate illumination for different types of activities, such as schools, offices, and hospitals. Alternatively, there can be requirements that all lighting should use LED technologies where available. These standards are often based on internationally accepted guidelines that offer consistency across various regions.
- **Performance-based standards** look at the building as a whole, setting limits on total energy consumption per square meter per year (e.g., kWh/m^2/year). This approach allows builders and designers to meet efficiency targets flexibly, using different combinations of materials and technologies to achieve the overall goal. In this system, the performance requirements are also set according to the main activities of buildings, allowing different levels of consumption for schools, offices, hospitals, homes, etc. Performance-based standards also often require simulations and comprehensive data on building materials, insulation, and systems to evaluate how the building performs over time. This holistic assessment is increasingly common in developed countries, where advanced tools and detailed specifications are available to support such evaluations [World GBC, 2020].

The enforcement of BEECs varies widely across regions, with some countries making the BEEC a mandatory requirement forcing all relevant parties to comply, while others offer voluntary schemes where building owners can opt into energy assessments and receive some form of certification or recognition regarding compliance or building performance to help potential buyers or tenants make informed choices and providing a market advantage to building developers that meet the voluntary standards. Similarly, the voluntary recognition schemes aim to increase awareness and demand for energy-efficient buildings. International programs like LEED and BREEAM offer globally recognised rating systems that can supplement national standards, allowing for comparability and alignment with best practices worldwide.

The status of global implementation is illustrated in Figure 1 demonstrating the increasing levels of BEEC implementation in the world. However, it also illustrated that Africa is falling behind in this regard, making this project an important step for progress in the region. Currently, 71 countries have implemented a mandatory BEEC in at least one region (light green), although in most of them, it is a national requirement. A further 17 countries have some form of standards, but do not have a comprehensive national BEC. It is of note that some countries were not included in the research represented in Figure 1 due to geopolitical conflict (e.g. Russia and Belarus) [World Bank, 2024].

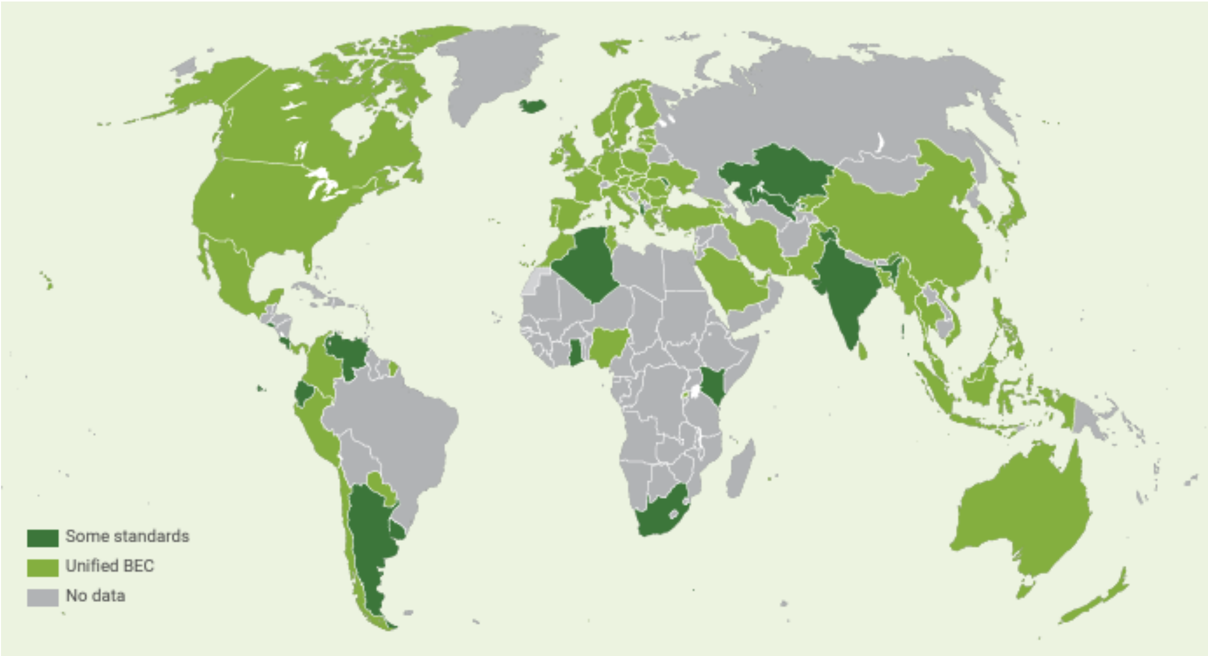


Figure 1 - Global status of BEEC implementation (Source: World Bank 2024)

3.5 International policy context

When developing a BEEC in countries with limited regulatory experience in the subject, such as Ghana, two primary approaches are commonly considered. The first approach involves adapting codes from other countries with similar climate and building practices or using international standards, such as those provided by ASHRAE or IECC. This method is efficient, as it leverages existing frameworks and adapts them to the local context, enabling quicker implementation. For this approach to succeed, however, a comprehensive understanding of local construction techniques and climate impacts is essential, as well as reliable energy performance data across various building types.

The second approach is a baseline analytical method, starting with an assessment of existing design and construction practices to identify potential savings from available energy-efficient technologies. In Ghana, where green building initiatives are expanding, this method would involve collecting data on the current energy performance of different building types to establish efficiency benchmarks. This baseline data would then inform specific targets that are both ambitious and achievable in the Ghanaian market. For example, Ghana's warm and humid climate could benefit from standards emphasising passive cooling techniques, such as natural ventilation and shading, as well as reflective materials to reduce heat gain.

If current data is insufficient for a thorough analytical approach, capacity building becomes a priority. Ghana could implement awareness campaigns, energy audit training, and monitoring mechanisms to foster a foundational understanding of energy-efficient building practices. Building a skilled workforce in energy management and green construction techniques would support the future enforcement of BEECs. Partnering with local organisations, such as the Ghana Green Building Council, could facilitate the development of a sustainable BEEC framework that aligns with Ghana's environmental goals and economic needs. To support the first approach, various global, regional, and national policies that promote action in green buildings and their impact on Ghana are reviewed in the following sections.

3.5.1 Global policies on Green Buildings

Globally, buildings account for 37% of total carbon emissions and 30% of final energy demand (United Nations Environment Programme, 2024). Other environmental impacts include unsustainable materials consumption, biodiversity loss, land, water, and air pollution, and resource depletion. To mitigate these impacts, several countries around the world have developed policies, regulations, and programmes to promote action in green buildings. Every country or region has its approach to policy development, implementation, monitoring, verification, and enforcement. Global policies, therefore, become crucial for driving action and delivering transformative change in the building sector at the global scale. Major policies include the United Nations Framework Convention on Climate Change (UNFCCC) (1992), Paris Agreement to the UNFCCC (2016), UN Sustainable Development Goals (SDGs), New Urban Agenda, Global Policy Principles for a Sustainable Built Environment, and Green Building Principles: The Action Plan for Net-Zero Carbon Buildings.

Table 2: Global policies that promote action in green buildings and their impacts in Ghana.

#	Policies	Provisions	**Comment / Analysis**
1	United Nations Framework Convention on Climate Change (UNFCCC) (1992)	Article 2	Achieve stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.
		Article 4	Sets out commitments such as requiring parties to develop, periodically update, and publish national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, using comparable methodologies to be agreed upon by the Conference of the Parties.
2	Paris Agreement to the UNFCCC (2016)	Articles 2, 4, 7, and 10	A legally binding international treaty on climate change signed in 2016, its aim, as described in Article 2, is to strengthen the response of the world to the threat of climate change. A key goal is to hold "the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change". To achieve this goal, as described in Article 4, parties aim to achieve greenhouse gas emissions peaking as soon as possible. Parties must communicate actions they will take to reduce their greenhouse gas emissions in nationally determined contributions (NDCs). They must also communicate actions they will take to build resilience to adapt to the impacts of climate change. As a party to the Paris Agreement, Ghana communicates NDCs, committing to 31 mitigation and adaptation actions across seven economic sectors (Cooke, 2021). Article 7 emphasizes the global need for adaptation actions and establishes the goal of improving adaptive capacity, strengthening resilience and reducing vulnerability to climate change. It recognizes the adaptation actions of developing countries, such as Ghana. To implement the mitigation and adaptation actions under the Agreement, technology development and deployment are important, as stressed in Article 10.
3	Sustainable Development Goals (SDGs)	Goal 3: Good health and well-being	This SDG aims to ensure healthy lives and promote well-being for all at all ages. Protecting vulnerable populations and regions with high disease burdens is a priority. To contribute to this SDG, Ghana needs to promote green buildings. The health and well-being benefits of green buildings are closely linked with this SGD.
		Goal 6: Clean water and sanitation	This SDG aims to ensure the availability and sustainable management of water and sanitation for all. One of the targets is to substantially increase water-use efficiency across all sectors by 2030. By reducing the amount of water buildings use and the amount of waste buildings generate, green buildings play a significant role in achieving the goal and targets of this SDG.

		Goal 7: Affordable and clean energy	Aims to ensure access to affordable, reliable, sustainable and modern energy for all. Green buildings not only support energy efficiency through energy conservation measures, but they can also use renewable energy, making them cheaper or affordable to run. With the abundance of renewable energy resources, e.g., solar power, in Ghana, the country has a huge potential to contribute to this SDG through the use of renewable energy for green buildings development.
		Goal 11: Sustainable cities and communities	The goal is to make cities and human settlements inclusive, safe, resilient and sustainable. Buildings are an inevitable part of cities and communities. Sustainable green buildings can make cities and communities inclusive, safe, resilient, and equitable. All citizens benefit when there is access to high-quality, healthy, affordable housing or when cities and human settlements are climate-resilient and can withstand extreme climate hazards.
		Goal 12: Responsible consumption and production	Focuses on ensuring sustainable consumption and production patterns. In green buildings, resources are not wasted, following circular economy principles. This ensures sustainable consumption and production patterns, where resource use is optimized, waste to landfills is avoided, and the regeneration of nature is supported.
		Goal 13: Climate action	Focuses on taking urgent action to combat climate change and its impacts. Green buildings are widely known to produce fewer greenhouse gas emissions, helping to combat climate change and its impacts. They do this by using low-carbon materials in their design, reducing operational energy use through energy conservation measures, and using renewable energy. Thus, for Ghana to meet its climate goals in the NDCs, it is important to promote green buildings.
4	New Urban Agenda	Paragraph 53	A commitment to promoting safe, inclusive, accessible, green and quality public spaces as drivers of social and economic development, to sustainably leverage their potential to generate increased social and economic value, including property value, and to facilitate business and public and private investments and livelihood opportunities for all. This is similar to the goal of SDG 11 described above.
		Paragraph 63	Under the broader theme of environmentally sustainable and resilient urban development, it is recognised that the way cities, including buildings, are planned, designed, built, operated, governed, managed, and financed has a direct impact on resilience and sustainability.
		Paragraph 64	Uban centres and their inhabitants worldwide, especially in developing countries, such as Ghana, are especially vulnerable to the adverse impacts of climate change hazards, such as air and water pollution, storms, heatwaves, flooding, droughts, water scarcity, and sea level rise, making high-performance green buildings urgently needed in such developing countries.
		Paragraphs 71, 79 and 88.	According to Paragraph 71, there is a need to strengthen the sustainable management of resources, including energy, water, land, materials, and forests. Circular economy principles

			should be implemented to minimise waste and facilitate ecosystem conservation, regeneration, restoration and resilience in the face of new and emerging challenges. This is similar to SDG 12 described above. There is also a need to reduce climate and air pollutants and noise. Paragraph 79 links to the Paris agreement goal of "holding the increase in the global average temperature to well below 2°C above preindustrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels. While enabling policy frameworks are crucial for achieving the transformation commitments set out in the New Urban Agenda, the importance of integrated approaches to urbanisation cannot be underestimated, as highlighted in Paragraph 88.
5	Global Policy Principles for a Sustainable Built Environment	Carbon Principle	Prioritise renovation of existing buildings and eliminate both operational and embodied carbon emissions across the lifecycle of all buildings. In a developing country such as Ghana, where there is a huge demand for new construction in the coming years, new building construction should be prioritised.
		Resilience Principle	Enhance the ability of homes and communities to respond to external shocks and stressors by integrating climate resilience and promoting adaptation.
		Circularity Principle	Drive waste out of the construction value chain and minimise the use of primary materials by optimising the use of resources and materials.
		Water Principle	Conserve and protect water resources and guarantee equitable access to potable water and sanitation.
		Biodiversity Principle	Regenerate natural systems and restore biodiversity loss by avoiding development on land with high biodiversity, and by prioritising nature-based solutions that enhance, expand, and protect the natural environment.
6	Green Building Principles: The Action Plan for Net-Zero Carbon Buildings	Principles 1–10	A roadmap and a vision for sustainable, resilient, liveable, and affordable buildings and cities of the future was developed by the World Economic Forum. It sets out ten Green Building Principles: (1) calculate a robust carbon footprint of your portfolio in the most recent representative year to inform targets; (2) set a target year for achieving net-zero carbon by 2050 at the latest, and an interim target for reducing at least 50% of these emissions by 2030; (3) measure and record embodied carbon of new developments and major refurbishments; (4) maximize emissions reductions for all new developments and major refurbishments in the pipeline to ensure delivery of net-zero carbon (operational and embodied) by the selected final target year; (5) drive energy optimization across both existing assets and new developments; (6) maximize supply of on-site renewable energy; (7) ensure 100% off-site energy is procured from renewable-backed sources, where available; (8) engage with stakeholders with whom you have influence in your value chain to reduce Scope 3 emissions; (9) procure high-quality carbon offsets to compensate for residual emissions; and (10) engage with stakeholders to identify joint endeavours and equitably share costs and benefits

			of interventions. These principles have major implications for green building development in Ghana and worldwide.

3.5.2 Regional policies on Green Buildings

At the regional level, Africa has developed several policies that are pertinent to Green Buildings. These include Agenda 2063 and the Common Market for East and Southern Africa (COMESA) Regional Strategy on Renewable Energy and Energy Efficiency (2019–2030). The Economic Community of West African States (ECOWAS) is a regional economic and political union of 15 West African countries (commonly referred to as ECOWAS member states). The ECOWAS region faces acute energy, housing, and climate change challenges. The building sector alone consumes 25% to 30% of the total electricity supply in the region for cooling and hot water heating (ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE), 2024). To address the energy challenges in the buildings, energy, and other sectors, ECREEE was established in 2007 as a specialised agency of the ECOWAS Commission. ECREEE is tasked with the responsibility of developing and promoting renewable energy and energy efficiency in the ECOWAS. ECREEE delivers this responsibility through such initiatives as policy development, knowledge management and awareness creation, capacity building, and investment and business promotion. Under the policy development arm, ECREEE has developed several policies that are pertinent to green buildings and impact the ECOWAS member states, including the ECOWAS Energy Efficiency Policy (EEEP) (2012, 2015), ECOWAS Renewable Energy Policy (EREP) (2012, 2015), ECOWAS Energy Policy (2023), ECOWAS Gender Mainstreaming in Energy Access Policy, ECOWAS Bioenergy Policy (2017), and Energy Efficiency in Buildings Program. Because Ghana is a member state of the ECOWAS and hence impacted by these policies, these policies are reviewed in this section.

Table 3: Regional and African policies that promote action in green buildings and their impacts in Ghana.

#	Policies	Provisions	Comment / Analysis
1	ECOWAS Energy Efficiency Policy (EEEP) (2012, 2015)	The policy had the overall objective to improve energy efficiency in the ECOWAS region, of which Ghana is a member state, to levels of international standards by 2020.	Specific targets included: • Implementing efficiency measures that free up 2000 MW of power generation capacity by 2020. • Phasing out inefficient incandescent lamps by 2020. • Reducing average losses in electricity distribution from the current levels of 15 - 40% to the world standard levels of below 10% by 2020. • Achieving universal access to safe, clean, affordable, efficient and sustainable cooking for the entire population of ECOWAS by 2030. • Developing and adopting region-wide standards and labels for major energy equipment before the end of 2020. • Developing and adopting region-wide efficiency standards for buildings (e.g. building codes).

			• Creating instruments for financing sustainable energy, including carbon finance, in the short term, and in the longer term, establish a regional fund for the development and implementation of sustainable energy projects.
2	ECOWAS Renewable Energy Policy (EREP) (2012, 2015)	Aims to promote the achievement of universal access to sustainable energy services in the ECOWAS region by 2030.	Specific objectives included: • Improving energy sustainability and energy security. • Providing solutions for domestic cooking energy. • Creating a favourable environment to attract the private sector and use renewable energy as an engine for industrial development, fostering socioeconomic development. • Mainstreaming gender in renewable energy-related issues, especially associated with women's productive roles. • Reducing the negative environmental externalities of the current energy system, such as air, soil and water pollution and greenhouse gas emissions.
3	ECOWAS Energy Policy (2023)	One of the recent energy policies in the ECOWAS region, its vision is to transform the region into "a community with access to modern, affordable, reliable and sustainable energy services for improved living standards and socio-economic development".	Six strategic objectives for 2050 have been set to include the following: • Improving the governance and performance of the energy sector. • Ensuring universal access to adequate, affordable, reliable and sustainable electricity services. • Improving the security, reliability and quality of energy supply. • Diversifying the energy mix through greater integration of renewables, natural gas, nuclear and all other forms of clean energy, including hydrogen. • Promoting energy efficiency and conservation. • Increasing the population's access to modern and clean energy for cooking. Like most policies in the ECOWAS/African region, this policy focuses more on the energy sector rather than buildings. While there is a broader objective to improve energy efficiency and conservation, this objective has not been set in relation to the buildings sector.
4	ECOWAS Gender Mainstreaming in Energy Access Policy	Transforming ECOWAS into a world where men and women enjoy equal access to modern energy services that are easily available, affordable and contribute to high levels of standards of living and economic development.	• Achieving widespread understanding of energy and gender considerations at all levels of society. • Ensuring that all energy policies, programmes and initiatives, including large energy infrastructures and investments, are non-discriminatory, gender-inclusive, gender-balanced and directed towards addressing inequalities, particularly energy poverty, differentially affecting men and women in the region. • Increasing women's public sector participation in energy-related technical fields and decision-making positions. • Ensuring that women and men have equal opportunities to enter and succeed in energy-related fields in the private sector. • Establishing and maintaining a comprehensive gender-responsive monitoring, accountability and review framework.

			This policy highlights why it is important to account for gender and social inclusion considerations in the development and implementation of green building standards in Ghana as an ECOWAS member state.
5	ECOWAS Bioenergy Policy (2017)	This policy has the vision to transition to sustainable production, transformation, trade and utilisation of biomass to ensure universal access to modern energy services with a view of creating added value, jobs, increasing food security, mitigating environmental impacts and overall sustainable development in ECOWAS.	This policy seeks to promote a modern, sustainable and vibrant bioenergy sector in the ECOWAS region by creating an enabling environment that can unlock the potential by removing the institutional, legal, financial, social, environmental and capacity gaps and barriers. It is aimed at addressing the needs and constraints of the governments, the private sector and the local communities in using existing resources, including household, agricultural and industrial processing wastes and residues. It aims to encourage the utilisation of Bioenergy resources to provide sustainable energy access. Policy targets are set for 2020 and 2030. It is important to assess whether the 2020 targets were achieved, to inform actions toward the achievement of the 2030 targets.
6	Energy Efficiency in Buildings Program	The main goal is to achieve energy demand reductions in buildings to reduce the impacts of poor grid infrastructure and urban development.	• Development and implementation of ECOWAS Building Energy Efficiency Code (EBEEC). • Development and implementation of Energy Performance Certification • Avoid energy consumption using building design: correct building orientation; shading of windows and walls. • Reduce energy consumption through more efficient technologies that provide the same service with less energy consumption. • Substitute electricity from fossil fuels with renewables. • Use electricity only where it is necessary: replace electric water heaters with solar water heaters. This is one of the few programs specifically focused on energy efficiency in buildings in the ECOWAS region. Adequate support needs to be provided for the implementation of the building energy efficiency guidelines in member states.

3.6 Scope of building energy efficiency codes

3.6.1 Building envelope

The building envelope plays a primary role in determining a building's energy use, as it is the main barrier separating the outside environment from inside spaces. As such, the design of the building envelope is the key element to control and minimise energy demand by controlling the flow of heat, air, and moisture between the interior and exterior of the building.

The key elements that comprise the building envelope are walls, windows, doors, roofs, and floors. By enhancing the performance of these components, buildings can achieve substantial reductions in energy consumption, lower utility costs, and lessen their environmental footprint. Depending on the standards in place, envelope requirements are typically set either as prescriptive measures or as whole-building performance requirements.

Climate and location significantly influence the optimal design of the building envelope. In tropical, low-elevation regions, for instance, air conditioning is often needed year-round, and effective envelope design can help reduce cooling demands. In such climates, building orientation can play an important role, with a north-south orientation generally preferred to minimise direct sunlight exposure on the east and west facades, which would otherwise increase heat gain through windows. Additional measures can include reflective roofing, shade structures, and high-performance windows to reduce thermal gains, minimise internal losses, resulting in high energy performance and high occupant comfort.

3.6.1.1 Insulation

Insulation is one of the key concepts needed to create comfortable and energy-efficient indoor environments, as it reduces heat exchange between a building's interior and the outdoors. The primary goal of insulation is to minimise heat loss during colder seasons and prevent heat gain in warmer ones, thus reducing reliance on active heating and cooling systems. International standards recommend various techniques and materials for insulation in walls, roofs, and floors, depending on climate needs. For instance, insulation in temperate climates emphasises retaining indoor heat during winter, while in tropical climates, it focuses on preventing excessive heat penetration.

Central to insulation effectiveness is the R-value, a metric that measures a material's resistance to heat transfer. Materials with higher R-values provide better thermal resistance, making them more effective in maintaining indoor comfort by resisting heat flow. In temperate climates, like parts of Europe and North America, insulation with high R-values, such as double-layer fibreglass or spray foam, helps trap heat indoors, reducing heating needs and energy costs. These materials adapt well to seasonal changes, ensuring that homes remain comfortable year-round without excessive energy use.

Conversely, in tropical climates, like those in Southeast Asia or the Caribbean, the challenge is to keep out the intense heat and humidity. Here, reflective or radiant barriers are often used in conjunction with shading, building orientation, and traditional insulation materials to minimise heat gains from the sun. These barriers, often installed in roofs, possess high R-values and act effectively to reduce heat gain, ensuring cooler indoor environments without over-reliance on air conditioning systems.

In the context of Ghana, the country has a tropical climate dominated by high temperatures throughout the year, making cooling demand a priority. There are some regional differences with the coastal and southern regions experiencing higher temperatures and humidity year-round, while the northern savannah regions have hot, dry seasons and slightly cooler nights during the Harmattan season.

With this high level of heat throughout the year, therefore, insulation materials and building designs should be oriented to effectively reduce indoor heat gain during the hotter months and maintain a level of thermal comfort. It is of note that while occasionally, there are colder temperatures registered in the records, these are very sporadic, with the **mean daily minimum** temperatures in the northern city of Tamale still averaging around 20 °C (Climate Change Knowledge Portal,2025), making demand for heating or maintaining heat irrelevant. Similarly, the vast majority of the Ghana population lives in the southern, warmer regions.

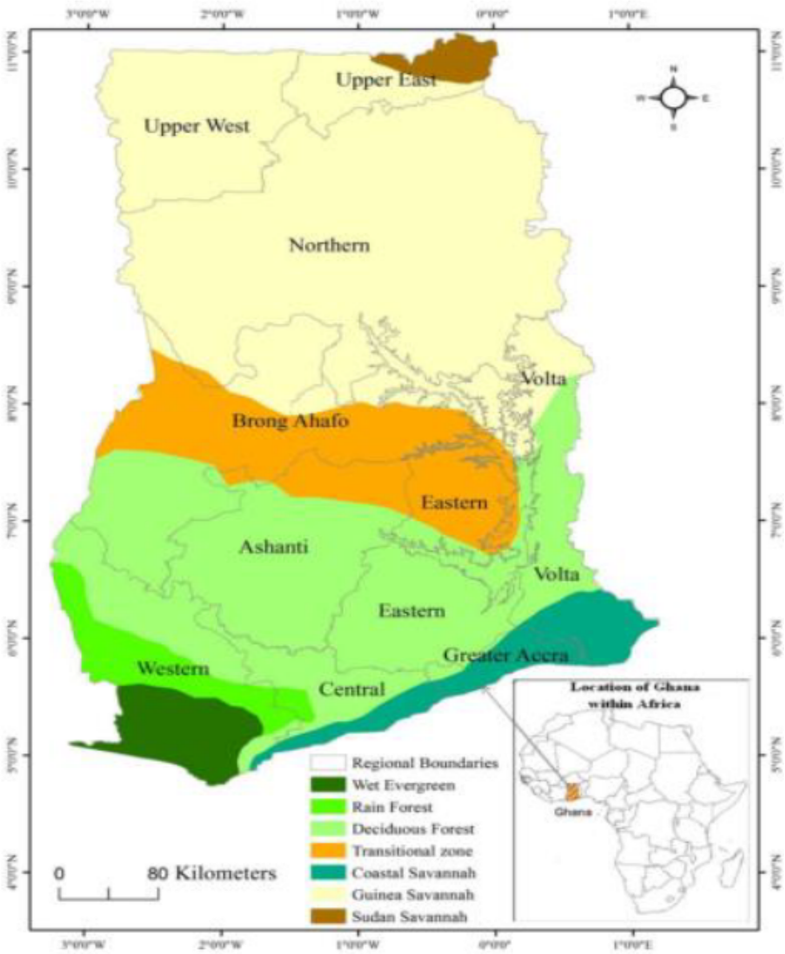


Figure 2: Map depicting the general ecological zones in Ghana.

As such, insulation solutions that focus on minimising heat gain are ideal, like reflective barriers or radiant barriers are recommended for roofs to deflect solar radiation and prevent excessive heat from entering the interior. Combining these barriers with shading strategies, such as extended roof eaves and awnings, enhances indoor comfort while lowering the cooling needs.

In the northern regions, where the climate can have more significant seasonal temperature swings, minimising heat gains will also be key as daily temperatures regularly surpass 30 °C, but making use of natural ventilation during the cooler parts of the year can be beneficial. A combination of insulated roofing and high-R-value wall insulation can help balance temperature fluctuations and reduce the need for additional space conditioning. Using locally available materials like compressed earth blocks, which have natural thermal mass properties, may also serve as an efficient and cost-effective approach to insulation in these areas.

3.6.1.2 Air sealing

Air leakage is another large source of unwanted thermal exchanges, increasing demand for active space conditioning. As such, air sealing through the building envelope will help to maintain a comfortable indoor environment and reduce heating and cooling loads. Some of the key actions to minimise air leakage include sealing gaps, cracks, and joints with weatherstripping, caulking, and sealants help to minimise air infiltration.

These practices are all standard in the development of high efficiency buildings, but depending on local climate conditions, there might be special conditions that promote a design of buildings that are more "open" to support ventilation or natural cooling that may be supported due to optimum local conditions.

3.6.1.3 High-performance windows

As a key element in building construction, windows can significantly impact the energy performance of green buildings, as they impact natural lighting, ventilation, heat transfer, and occupant comfort. Strategically designed and placed windows can reduce a building's energy consumption significantly. High-performance windows can lower a building's annual energy consumption by around 15% when compared to traditional single-pane windows.

Daylighting through windows also reduces the need for artificial lighting, which can account for up to 10% of a building's energy use in commercial structures. Advanced window technologies, such as low-emissivity (low-e) coatings, multi-pane glass with inert gas fill, and thermally broken frames, significantly improve the insulation properties of windows, helping to maintain comfortable indoor temperatures with minimal energy consumption. These types of high-performance windows can lead to energy savings of up to 50% in buildings where heating and cooling costs are substantial [IEA, 2021].

The wall-to-window ratio (WWR) is another factor directly influencing a building's envelope energy performance. The WWR is the proportion of the building's exterior wall area that is occupied by windows, typically expressed as a percentage. Higher WWRs allow for greater daylight penetration, which can reduce the need for artificial lighting and enhance occupant well-being. However, high WWRs can also increase unwanted heat gain or loss, particularly if windows are not adequately insulated, thereby increasing energy demands for heating or cooling.

Optimising the WWR depends on climate conditions, building orientation, and the performance of window materials. In hot climates, a lower WWR on sun-exposed facades, paired with high-performance glazing, can help minimise solar heat gain while still allowing for natural light. It is suggested that a WWR of around 20-40% often strikes a good balance in energy-efficient buildings, providing adequate daylight without significantly increasing thermal loads. For instance, a study found that a WWR of 25% in tropical buildings reduced annual energy use by approximately 15% compared to higher ratios, as it limited solar gain while still providing sufficient daylight [Journal of Sustainable Architecture and Civil Engineering, 2019].

Additionally, advancements in window technology, such as low-emissivity coatings and multi-pane glass, can allow for slightly higher WWRs without compromising energy efficiency. There are also strong interactions between WWR and shading devices, like overhangs or louvres, on larger windows, further mitigating heat gain.

3.6.1.4 Thermal mass

The use of materials with high thermal mass, such as concrete and masonry, in building design can significantly improve energy efficiency by stabilising indoor temperatures. Thermal mass allows these materials to absorb heat during the day, preventing excess warmth from entering the building, and release it gradually as temperatures cool at night. This process helps maintain a consistent indoor environment and reduces the need for heating and cooling systems, ultimately saving energy and lowering utility costs. For instance, a concrete wall can absorb substantial heat during hot daytime hours, cooling the interior, and later release that stored warmth during cooler nighttime hours, reducing reliance on HVAC systems.

However, there are environmental considerations associated with high thermal mass materials, particularly concrete, which has a high carbon footprint due to the energy-intensive cement production process. To balance these impacts, green building practices can integrate recycled concrete or combine high thermal mass materials with bio-based options like timber, which sequester carbon. By combining sustainable sourcing, improved production processes, and innovative material use, buildings can benefit from the thermal properties of materials like concrete while reducing their overall environmental impact. This balanced approach helps maximise the energy-saving benefits of thermal mass while minimising carbon emissions associated with construction.

3.6.1.5 Reflective roofing

Cool or reflective roofing materials are another building element that has been proven effective to enhance the energy performance of buildings, particularly in areas that experience high temperatures and intense sunlight. These specialised roofing materials are designed to reflect more sunlight and absorb less heat compared to traditional roofing products. By doing this, they significantly reduce the amount of heat transferred into a building, which can drastically lower cooling loads and decrease overall energy consumption during hot weather.

When implementing cool or reflective roofing, it's necessary to take into account local climate conditions. In warm, sunny climates, highly reflective, light-coloured roofs effectively reduce heat absorption. This is particularly beneficial in tropical or subtropical regions, where reflective roofing helps prevent excessive heat buildup in buildings.

Green roofs, also known as living roofs, are another rooftop system that incorporates vegetation over a waterproofing layer, providing both environmental and building performance benefits. They help insulate buildings and provide other co-benefits such as managing stormwater runoff as they absorb rainfall, lessening the burden on urban drainage systems and reducing the risk of flooding.

In Ghana, where the climate is largely hot and humid, cool or reflective roofing materials can provide considerable energy-saving advantages. With year-round high temperatures, especially in coastal and savannah zones. This approach is also beneficial in more urbanised areas, such as Accra and Kumasi, where reflective roofs help alleviate the urban heat island.

3.6.1.6 Shading and overhangs

Shading and overhangs are energy efficiency features that manage solar heat gain, enhance natural lighting, and improve occupant comfort. Properly designed shading systems, including overhangs, louvres, and shades, prevent excess heat from entering buildings while allowing daylight to illuminate interiors. These elements reduce the need for artificial cooling and lighting, which translates to lower energy consumption and utility costs. Shading is particularly effective in climates with high solar exposure, where controlling sunlight can reduce cooling demands significantly.

Overhangs, one of the simplest and most effective shading methods, are tailored to a building's orientation and local conditions. In hot climates, overhangs positioned above south-facing windows block high-angle summer sun while allowing low-angle winter sun to enter, providing passive solar heating during cooler months. Adjustable or retractable shading systems, such as louvres or external blinds, offer additional flexibility, allowing occupants to adapt shading based on seasonal and daily variations in sunlight. Studies indicate that well-designed shading can reduce cooling loads by up to 30%, depending on the building's orientation and window size [NREL, 2019].

Vegetative shading, using trees or green screens, also plays a role in sustainable shading. Trees planted strategically around buildings can block up to 70% of summer sunlight on south and west facades, improving comfort and reducing heat island effects in urban areas. Green walls, which incorporate climbing plants on building exteriors, offer an added layer of insulation and reduce solar heat gain, making them an energy-efficient alternative to mechanical cooling systems.

In Ghana's hot and humid climate, shading and overhangs are valuable features in green building design, as they help control solar heat gain, reduce indoor temperatures, and lower energy costs for cooling. Properly implemented shading systems, such as overhangs, awnings, and external louvres, can prevent direct sunlight from entering buildings during the hottest parts of the day, particularly in south and west-facing facades. Studies suggest that shading can decrease cooling demand by 20-30%, depending on building orientation and window size, making it an effective strategy for energy savings in Ghana's urban areas, such as Accra and Kumasi [IEA, 2021].

3.6.1.7 Passive solar design

Passive solar design leverages natural solar energy to maintain comfortable indoor temperatures, reducing reliance on mechanical heating and cooling systems. In hot climates, passive solar techniques, such as orientation, shading, thermal mass, and ventilation, can optimise sunlight exposure and regulate indoor temperatures effectively. For instance, positioning a building to face north-south can reduce direct sunlight on east and west walls, where solar gain is typically the highest. This orientation strategy, combined with shading elements like overhangs, trees, or louvred panels, helps to prevent excessive heat gain while still allowing natural light to illuminate interiors.

Thermal mass materials, such as concrete or stone, are often used in passive solar buildings to absorb, store, and slowly release heat, stabilising indoor temperatures through day-night cycles. In cooler regions, this approach allows buildings to retain warmth, while in hot climates, it can moderate daytime heat and release it during cooler nights, reducing the need for air conditioning. Cross-ventilation designs, which encourage airflow by aligning windows and doors across a structure, further enhance passive cooling.

In Ghana, passive solar design can be applied by orienting the building along a north-south axis to minimise direct sunlight, reducing indoor temperatures and the need for air conditioning. This approach is especially beneficial in urban areas, such as Accra, where cooling demand is high. Also, combining shading with thermal mass materials, such as concrete, can further stabilise indoor temperatures. Cross-ventilation, facilitated by strategically placed windows and doors, supports natural airflow, helping to cool interiors and improve air quality.

3.6.1.8 Ventilation

Optimum ventilation design helps control humidity, remove pollutants, and introduce fresh air, creating a healthier and more comfortable indoor environment. Green buildings use a combination of natural ventilation and mechanical systems to optimise airflow, with natural ventilation reducing the need for energy-intensive cooling systems in moderate climates. Strategies such as cross-ventilation, stack ventilation, and hybrid systems (where natural and mechanical methods are combined) allow green buildings to adapt to different climates and meet varying air quality requirements efficiently.

In Ghana’s hot and humid environment, natural ventilation supports indoor comfort and reduces energy costs associated with cooling. Green buildings in Ghana often incorporate ventilation strategies that align with local climate conditions, such as cross-ventilation through carefully positioned windows and open floor plans that facilitate airflow. In regions with high humidity, such as along Ghana’s coast, ventilation systems are designed to enhance airflow without exacerbating indoor moisture levels.

3.6.1.9 Advanced building materials

Advanced materials in green building design are transforming the industry by enhancing energy performance, durability, and sustainability of buildings. Some of the key materials in this category include high-performance insulation, phase-change materials (PCMs), aerogels, and engineered wood, among others, to reduce the energy needed for heating and cooling. Some examples include:

- High-performance insulation materials like aerogels and vacuum-insulated panels provide superior thermal resistance with minimal thickness, making them ideal for energy-efficient buildings where space is limited.
- Aerogels, for example, are lightweight and highly porous, providing up to four times the insulating capacity of conventional materials.

- Phase-change materials (PCMs) are another innovation that enhances energy efficiency by storing and releasing thermal energy as they change from solid to liquid. PCMs can be incorporated into walls, floors, or ceilings to absorb heat during the day and release it at night, thus stabilising indoor temperatures.
- Engineered wood products such as cross-laminated timber (CLT) offer both structural strength and environmental benefits. CLT is manufactured by layering wood panels crosswise, which enhances its load-bearing capacity while using less material. As wood sequesters carbon, using engineered timber as a construction material helps reduce the carbon footprint of buildings, especially when sourced from sustainable forests. CLT also offers natural insulation properties, contributing to lower energy demands.

3.6.2 Energy modelling and analysis

Conducting energy modelling and simulations of the detailed performance of the building during the design phase is a powerful method for architects and engineers to create buildings with optimal energy performance. This approach uses software tools to simulate various design scenarios, examining factors like insulation quality, window placement, and thermal bridging potential. By visualising energy flows and internal temperature patterns before construction, designers can detect inefficiencies and make pre-emptive design adjustments, ensuring that the building's envelope—its walls, roof, windows, and doors—minimises energy waste. Such foresight avoids costly post-construction modifications and ensures the building performs efficiently from day one, reducing long-term operational costs and environmental impact.

Energy modelling also aids in decision-making by identifying the most effective technologies and design strategies for a specific project. For example, simulations may indicate that boosting insulation in specific areas would significantly reduce heating loads or that orienting the building to maximise natural light could reduce reliance on artificial lighting. In diverse climate conditions, energy modelling allows architects to tailor designs to local conditions, such as high humidity or intense sunlight, to enhance indoor comfort and minimise cooling demands.

3.6.3 Climate conditions and zones

The development of the requirements of a BEEC requires the careful consideration of prevailing climate conditions to ensure that the buildings perform as expected and provide the needed services, comfort, and utility to occupants. For this, the concept of degree days serves as a metric for estimating the heating and cooling needs specific to a region. Degree days measure temperature differences between outdoor conditions and a baseline "comfortable" temperature, often set at 18°C or 20°C, over a defined period, such as a day or season. These measurements are divided into two types: Heating Degree Days (HDD), which quantify heating needs when outdoor temperatures drop below the comfort threshold, and Cooling Degree Days (CDD), which assess cooling requirements when temperatures exceed this level. Degree days are widely used in building design, energy modelling, and sizing HVAC systems, as they provide a straightforward means to quantify seasonal heating and cooling demands.

To define tailored energy efficiency requirements becomes crucial that match regional conditions. Metrics such as HDD and CDD, along with other climatic factors like maximum and minimum temperatures, humidity, and seasonal extremes, support the design of energy requirements that account for variations. For example, South Africa's BEEC is divided into six climate zones, each with specific requirements suited to local conditions, ensuring that building designs in warmer coastal zones differ from those in colder inland areas (South African National Energy Development Institute, 2020). This zoning approach enables building codes to meet region-specific energy needs more accurately. In the case of Ghana, a similar approach to climate zoning and energy modelling could help align building practices with key regional variations, although 6 distinct zones may not be required.

3.6.4 Advancing the establishment of a GBS in Ghana

When developing BEECs in countries where no prior codes exist, two primary approaches are often used. The first approach involves adapting existing codes from countries with similar climates and construction practices or using international standards like the ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) standards or the IECC (International Energy Conservation Code). This method allows for relatively quick adoption by aligning with established best practices and benchmarks from comparable regions. However, for effective adaptation, detailed knowledge of the local building design, construction techniques, and performance levels across various building types is crucial.

The second approach, often analytical, begins with defining the baseline for current national design and construction practices and identifying potential energy savings achievable through locally available technologies. This method involves evaluating the energy performance of existing building stock, which is essential for setting realistic efficiency targets tailored to the local market. In Ghana, where green building practices are evolving, reliable data on building performance is necessary for either method to be effective, as it informs energy targets that are both ambitious and achievable.

If baseline data is insufficient, building awareness and training around energy efficiency are crucial. This may include activities like capacity building, energy auditing training, and developing mechanisms for enforcement over time. Additionally, where data limitations exist, Ghana could look to regional examples, like the South Africa case mentioned above. By leveraging both regional and international standards, Ghana could develop a code that balances international best practices with local environmental and market needs, gradually building up the data and technical capacity needed for detailed, long-term code enforcement.

4 Ghana policy and regulatory framework review

4.1 General overview

Climate change mitigation and adaptation are a top priority in Ghana's national development agenda (Environmental Protection Agency, 2021). Ghana's updated Nationally Determined Contribution (NDC) under the Paris Agreement (2020 - 2030) covers 19 policy areas and 47 adaptation and mitigation programmes of action. These actions are expected to generate an absolute reduction in greenhouse gas emissions of 64 $MtCO_2e$, among other goals, by 2030 (Environmental Protection Agency, 2021). To achieve this ambitious goal, Ghana is increasingly taking actions to enhance energy efficiency in the built environment, one of the major energy-consuming and greenhouse gas-emitting sectors. The country has developed several policies, regulations, and laws to guide development and set objectives, such as the NDC. However, buildings do not feature prominently in most of these policies, regulations, and laws. The NDC policy actions, for example, include promotion of energy efficiency in homes, industry and commerce, and promotion of clean rural household lighting, but do not include measures and targets to achieve these goals. Other key policies aimed at enhancing energy efficiency in various sectors, including the buildings sector, include:

- **National Energy Policy (2021):** Although this policy focuses predominantly on the energy sector, it highlights the importance of reducing wastage in the energy sector through energy-efficient buildings.
- **Renewable Energy Act 2011 (Act 832):** This act can influence and promote the deployment of renewable energy in buildings, reducing the use of unsustainable energy and carbon emissions.
- **Ghana National Climate Change Policy (2013):** While a national climate change policy should have implications for the buildings sector, the strategic focus areas of this policy exclude buildings.
- **National Energy Transition Framework (2022-2070):** This framework, aimed at achieving carbon neutrality in the energy sector by 2070, recommends a policy option to promote the

development of energy-efficient buildings. Even though carbon neutrality must be achieved by mid-century to avoid the catastrophic impacts of climate change, Ghana aims to achieve this target two decades later, which may be too late for the environment and human survival.

- **National Energy Efficiency Action Plan (NEEAP) (2015-2020):** Provides energy efficiency targets from 2010 to 2020 for energy efficient lighting, high-performance distribution of electricity, energy efficiency standards and labels, and industries. It does not provide energy efficiency targets for buildings specifically.
- **Climate Action Roadmap for Buildings and Construction (2024):** Provides a strategic policy framework that outlines a pathway to achieving a net-zero, climate-resilient built environment by 2050 through regulatory reform, sustainable materials, capacity building, and green procurement.

These policies and action plans have outlined the vision, goals, and strategies to increase energy efficiency in Ghana, but they are not legally binding. Ghana is in its infancy stage of building energy efficiency. At this stage, a comprehensive legal and regulatory framework is needed to significantly drive mandatory action. The country has yet to have a comprehensive and dedicated national building energy code that mandates energy efficiency requirements. Only limited effort has been made, which centres mainly on two key documents:

- **Ghana Building Code (2018):** Ghana's Building Code, as a Building Code, must have mandated the requirements set in it. However, the requirements are currently not mandatory. Although the code includes energy efficiency and sustainability, and green building requirements, it is not as comprehensive or detailed as in dedicated and mature building energy codes in other countries. The code focuses largely on ensuring safety and structural integrity rather than energy efficiency, which may be attributed to the difficult challenge of building collapse Ghana has been facing over the past few years (Boateng, 2020).
- **Building Regulation 2022 (L.I. 2465):** A significant legislative instrument aimed at enforcing and mandating the requirements in the Ghana Building Code (2018). Ghana does not have comprehensive building performance standards, making it difficult to enforce the building code requirements. To effectively enforce the code, there is a need to build performance standards that provide detailed guidance on how to meet the requirements specified in the code. Codes, regulations, and standards work hand in hand to significantly promote building energy efficiency.

The Energy Commission of Ghana is the national regulatory body responsible for the implementation of energy efficiency regulations. The Energy Commission is leading efforts by raising awareness, educating stakeholders, and enhancing knowledge of energy efficiency requirements through various programs and legislative instruments. The Commission also provides practical guidance on constructing energy-efficient buildings, ensuring compliance with local requirements, and fostering a unified effort towards achieving energy efficiency goals. To streamline these efforts, building energy codes, regulations, and standards should be developed, and their enforcement and compliance must be ensured.

To date, there are limited policies or regulations providing guidance on absolute levels of performance relating to energy consumption in the life cycle of buildings in Ghana. The recently published Ghana Climate Action Roadmap for the Buildings and Construction Sector (Ministry of Works and Housing, 2024) provides an overview of current and projected carbon emissions in buildings, but limited guidance and insights into energy consumption. It is crucial to tackle energy consumption to achieve carbon emissions reductions. Similarly, the institutional arrangements for the implementation and enforcement of existing policies, codes, regulations, and laws have several gaps, limitations, and poor coordination, leading to a high level of non-compliance. For example, metropolitan, municipal and district assemblies lack the logistical capacity to enforce the requirements in the Ghana Building Code (2018), while compliance is not systematically tracked, and penalties for non-compliance are not consistently applied (Ministry of Works and Housing, 2024).

This report provides a review of the current policies and regulatory framework for green building in Ghana, with relatively more emphasis on building energy efficiency. This is against the background that, despite acknowledging that green building contributes to global efforts to mitigate climate change, reduce energy and water consumption and waste generation, promote resources, and a circular economy (Darko et al., 2017; Darko & Chan, 2016, 2018), the policy and legal framework does not comprehensively respond to the need to support green building and building energy efficiency in Ghana. Likewise, the adoption of green building, energy efficiency, and sustainability practices still faces various barriers and challenges, including a lack of awareness, standards, and regulations (Chan et al., 2018; Djokoto et al., 2014; Felix Anzagira et al., 2024). Therefore, it is important to review the policy and legal framework for green building and energy efficiency in Ghana to identify gaps, best practices, and opportunities for improvement. The report provides a review focusing on the following aspects: the existing legal and regulatory frameworks that have a bearing on green buildings and building energy efficiency, gender and social inclusion considerations, enforcement mechanisms of the existing legal and regulatory frameworks, impact of the policy and regulatory enforcement, and gaps and limitations in the existing framework.

The gaps and limitations identified in the current frameworks governing the construction and operations of buildings to improve energy efficiency include:

- Absence of a comprehensive legal and regulatory framework specifically for the built environment.
- Inadequate monitoring and enforcement.
- Insufficient collaboration among key stakeholders.
- Limited awareness, knowledge, expertise, and capacity; and
- Low demand.

This report provides recommendations to address these gaps and limitations to promote the wider adoption of green building, sustainability, and energy efficiency in the Ghanaian built environment sector, supporting Ghana's climate change mitigation and adaptation goals in the national development agenda. It is hoped that the report will be useful to key stakeholders, including the Ministry of Works and Housing, metropolitan, municipal and district assemblies, Energy Commission, Environmental Protection Agency, and Ghana Green Building Council.

4.2 Ghana policy context

At the national level, the relevant policies that are pertinent to Green Buildings include the Ghana Building Code (2018), Building Regulation 2022 (L.I. 2465), National Energy Policy (2021), National Energy Efficiency Action Plan (NEEAP) (2015-2020), Renewable Energy Act 2011 (Act 832), National Energy Transition Framework (2022-2070), Ghana National Climate Change Policy (2013), and The National Rooftop Solar Programme (2016). These policies are reviewed in the table below. It should be noted that apart from these policies, the Energy Commission of Ghana has launched several Legislative Instruments (L.I.s) for energy efficiency and renewable energy. However, these L.I.s are mainly focused on promoting energy efficiency at the energy and appliance levels. While they do not directly focus on buildings, some of them may be directly applicable to buildings. For example, L.I. 2458 sets out minimum energy performance standards for air conditioners that are major building energy systems. Although these L.I.s are important, their minimum energy performance standards were not set in the context of meeting green building performance goals or certification requirements. The L.I.s also do not consider carbon emission reduction requirements. Most importantly, the L.I.s show that energy efficiency and renewable energy are important to the country. These issues warrant the development of dedicated and comprehensive green building standards.

Table 4: National policies and regulations affecting the building sector in Ghana.

#	Policies	Provisions	Comment / Analysis
1	Ghana Building Code (2018)	• A modified adoption of the International Building Code, the code establishes minimum requirements that buildings must meet. • Based on prescriptive and performance-related provisions, and encourages the use of new materials and new building designs.	• Part 14 of the code sets out requirements and recommendations for energy efficiency and sustainability in lighting systems, mechanical ventilation systems, refrigeration equipment, and hot water systems. It is observed that 'active' building energy efficiency measures are prioritised, while 'passive' measures such as highly efficient windows, building envelope, thermal insulation, orientation, and occupant behaviour, and the critical role they play in building energy efficiency and sustainability are largely ignored. Renewable energy is also largely overlooked. Comprehensive green building codes or standards are necessary for addressing all essential areas of building energy efficiency and sustainability. There is also a need for stricter and concrete requirements regarding minimum energy performance levels of electrical appliances and plug load efficiency. • Part 37 of the code sets out green building requirements for private office and commercial/industrial buildings, public buildings, and residential buildings that are above certain specified gross floor areas. While this part addresses some of the limitations of Part 14 by touching on some passive measures, there is no clear definition of green building, and renewable energy and occupant behaviour are still largely overlooked, with a limited mention of solar photovoltaic for certain building types. In addition, the basis for the green building requirements and whether these requirements are informed by a specific green building certification, or other government requirements or certifications, remains unknown. The code specifies a prescriptive compliance path for the green building requirements. However, due to the lack of a green building certification system in Ghana, the code specifies that an international green building certification of a building shall be considered a replacement for all prescriptive requirements of the code. This can be problematic given that green building is highly context- or country-specific, and green building certification systems are usually developed based on the sustainability priorities and needs of that specific context or country. There is a need to develop and use a Ghana-specific green building standard or certification system in the building code. Moreover, it is not very clear whether the energy efficiency and sustainability requirements in Part 14 and the green building requirements in Part 37 apply to new construction only, existing buildings only, or both new construction and existing buildings. Parts of the code seem to claim that the requirements are focused on existing buildings, but other parts seem to claim that they apply to new buildings. Clarity regarding the scope of application of the code in the whole building life cycle is needed. • The code does not regulate building carbon emissions. Although the energy efficiency requirements in Parts 14 and 37 can help to deal with operational carbon emissions in existing buildings to some extent, whole life carbon and embodied carbon emissions may need comprehensive green building standards to address. This is essential if the goals of the Ghana National Climate Change Policy (2013) (reviewed below) are to be achieved.

2	Building Regulation 2022 (L.I. 2465)	• The goal of this regulation is to ensure the safety of property and life and to ensure the general welfare of people, public health, and environmental protection in the construction of buildings.	• Aims to achieve its goals through such measures as energy efficiency and conservation, green building, ensuring structural stability and strength of a building, and providing means of escape and access to facilities of a building. It is a regulatory instrument including the energy efficiency and sustainability, and green building requirements set out in the Ghana Building Code (2018). • This law's energy efficiency provisions aim to put climate and user wellbeing considerations at the top of the considerations in the development of the building industry. It does not include building performance thresholds or specific requirements on technologies. However, it does set the scene for the development of standards that this project aims to generate.
3	National Energy Policy (2021)	• Intended to guide the development and management of Ghana's energy sector, transforming the energy sector into a sustainable, climate-resilient, and low-carbon energy economy.	• The policy focuses on removing the barriers constraining the promotion and implementation of energy efficiency and conservation measures, yet does not categorically promote energy efficiency in buildings. The key challenge the policy aims to address is "how to increase the energy supply and also sustainably expand the energy infrastructure in the country in line with the global energy transition." This is a good goal, focusing on the energy supply side. However, the demand side has a big impact on the supply side. When energy demand is high, the cost and amount of energy supply to meet such high demand can be significant. Green buildings play a critical role in reducing the energy demand to meet the goals of this policy; thus, the policy needs to work hand in hand with comprehensive green building standards. Although the policy has an objective "to reduce wastage in the energy sector through energy-efficient buildings", it did not provide requirements, standards, measures, incentives, or targets for such buildings.
4	National Energy Efficiency Action Plan (NEEAP) (2015-2020)	• Provides baseline data on the status of energy efficiency development in Ghana and proposes attainable energy efficiency targets. It also provides an overview of laws, incentives, and measures to achieve the energy efficiency targets.	• NEEAP provides energy efficiency targets from 2010 to 2020 for energy efficient lighting, high-performance distribution of electricity, energy efficiency standards and labels, and industries. It does not provide energy efficiency targets for buildings specifically because it states that at the time of preparation/publication of the action plan (2015), no targets had been set for energy efficiency in buildings. It appears that such targets still do not exist currently. It also highlights the lack of an established process of energy auditing in buildings in Ghana. There is also no baseline data available, nor have projections been made for building energy performance and efficiency in the country. NEEAP proposes measures to promote energy efficiency in buildings and develop standards, highlighting the need for green building standards. Despite the useful recommendations for building energy efficiency, building carbon emissions were not discussed.
5	Renewable Energy Act 2011 (Act 832)	• Seeks to promote the development, management, and utilisation of renewable energy sources to produce heat and power in an efficient and environmentally friendly manner.	• The act does not make any explicit reference to buildings. However, buildings are critical sites for renewable energy implementation. In addition, renewable energy plays a critical role in green buildings for meeting building energy demand and offsetting carbon emissions through the production of zero-carbon or carbon-free energy.
6	National Energy Transition Framework (2022-2070)	• A roadmap on Ghana's transition pathways to ensure sustainable development. • A framework for decarbonising the energy sector and reaching net-zero emissions by 2070.	• The framework has five specific objectives centred around identifying pathways to achieve carbon neutrality within a secure and efficient energy sector by 2070, achieving fair and equitable energy transition, evaluating impacts of energy transition, developing targets and policies for achieving a carbon neutral economy by 2070, and estimating the costs of implementing the framework and identifying financing options for achieving the objectives of the framework. As one of the first carbon neutrality policies in Ghana, just like most of Ghana's

			energy policies, the focus is largely on the energy sector (i.e., the supply side) rather than the demand side, which includes buildings. However, one of the policy options recommended for consideration is to "encourage the construction of energy-efficient buildings". This provides impetus and opportunities for the development of green building standards. • The Energy Transition targets over the next five decades include an ambitious target of electrifying more than 95% of households by 2030, more than 90% of household electrical appliances being best in class by 2050, more than 50% of water heating systems being solar heaters by 2050, more than 98% of all appliances and cooling systems being best in class by 2070, and renewable energy constituting 20% of electricity generation capacity by 2070. These targets have implications for green building standards development. However, the framework does not provide any targets, requirements, and standards for green and energy-efficient buildings development.
7	Ghana National Climate Change Policy (2013)	• Provides a pathway for dealing with the challenges of climate change within the socio-economic context of Ghana.	• The vision of the National Climate Change Policy is to ensure a climate-resilient and climate-compatible economy while achieving sustainable development through equitable low-carbon economic growth for Ghana. Interestingly, the strategic focus areas of the policy do not include buildings but areas such as agriculture and food security, and energy.
8	The National Rooftop Solar Programme (2016)	• Seeks to deploy solar PV systems on the rooftops of homes and commercial buildings to supply power, especially during peak periods.	• Seeks to address the barrier of high initial cost to the uptake of solar PV technology. • A Capital Subsidy Scheme under which beneficiaries are given a capital subsidy to cover the cost of the solar panel component of a solar PV system. • The main objective is to install 200,000 solar PV systems on rooftops in the country to reduce peak load (lighting load and critical loads) up to 200MW in the medium term. • Targeted at residential, public, commercial and industrial sectors. • Renewable energy target of 10% in the energy mix by 2020. • Increasing the development of green buildings provides opportunities for meeting the aims of this programme, and more such incentive programmes are needed for the uptake of green building requirements.
9	Climate Action Roadmap for Buildings and Construction (2024)[1]	• Achieve net-zero operational and embodied carbon emissions in the building and construction sector by mid-century. • Mainstream green building principles across policy, design, and implementation.	• Support the strengthening of regulatory reforms through the introduction and enforcement of mandatory energy efficiency and green building codes (like the proposed BEEC) tailored to the climate zones and local market conditions in Ghana. • Promote a material transition through the use of low-carbon, locally sourced materials such as bamboo, compressed earth blocks, and recycled construction materials to reduce embodied carbon. • Transform public procurement and provide leadership through government-led projects as pilots for green buildings by integrating sustainability criteria in public procurement, setting an example for the private sector.

[1] Ministry of Works and Housing (2024), Climate Action Roadmaps for Building and Construction Ghana. Link: https://globalabc.org/resources/publications/climate-action-roadmaps-buildings-and-construction-ghana

			• Ensure the strong implementation of capacity building & education through training programs for architects, engineers, contractors, and government staff to implement sustainable design, construction, and operations practices, institutional capacity and regulatory frameworks to support long-term climate goals.

The summary in Table 4 highlights that Ghana has several policies and regulations for energy efficiency and renewable energy aimed at meeting the challenges of development in a climate-constrained setting. The National Energy Efficiency Action Plan (NEEAP) (2015-2020) has reviewed several of these policies and indicated that "energy efficiency and conservation is regarded as the 'low-hanging fruit' in protecting the energy resources available in Ghana." The country believes in the notion that it is cheaper to conserve energy than to build power plants to meet high energy demands, leading to the launch of several energy efficiency policies and regulations in the country. However, most of these policies and regulations are focused on the energy sector and some selected electrical appliances, such as refrigerators, air conditioners, and lighting systems. Policies and regulations specifically focused on energy efficiency and carbon emissions in the buildings and construction sector are difficult to find, not to mention Building Performance Standards (BPS) and Building Energy and Carbon Codes. The most relevant one seems to be the Ghana Building Code (2018), which is partly enforced through the Building Regulations, 2022 (L.I. 2465).

The Ghana Building Code is Ghana's first comprehensive building code (Osei-Agyekum, 2024) that provides requirements and recommendations for energy efficiency, green building, and sustainability in buildings. It aims to regulate the activities of the building and construction industry sector to increase energy efficiency, green buildings, and sustainability in Ghana. Despite the usefulness of the code, there are gaps that warrant the development of more comprehensive green building standards and policy guidelines.

The code is a 'big' code covering the broader buildings and construction sector. As such, it is not a 'dedicated' building energy code, green building code, or sustainability code, nor is it a 'dedicated' building energy standard, green building standard, or sustainability standard. This restricts the coverage of energy efficiency and sustainability requirements to broader requirements, giving rise to the need for a more specific effort on energy efficiency that can be enforced through the processes of the existing code.

Energy efficiency requirements and recommendations are incorporated in the code Part 14, which includes the following key provisions:

- It requires that mechanical services and equipment in buildings should be as energy efficient as practicable. These include the installation, alterations, repairs, and replacement of parts for ventilation, heating, cooling, air conditioning and refrigeration systems, incinerators and other energy-related systems.
- For many of these systems, the code requires that they only be installed where they are essential for human comfort or the function of the building. Although these requirements are hard to enforce as "needs" can vary, especially in a warming and developing setting where comfort is taking a more important role, the Code places a strong emphasis on **conservation** as well.
- Similarly, the code promotes the use of natural energy services such as ventilation and lighting where possible, even in some locations where it is customary to use mechanical appliances.
- For combustion water heating, there are requirements for combustion efficiency and for minimum insulation of storage tanks.
- The code also requires that appliances be correctly sized and installed to avoid waste and maximise efficiency.
- The use of "renewable energy" is also encouraged through solar PV, solar hot water heating, and even the recovery of wasted heat for heating water, among others.
- In areas where energy services are demanded through appliances, the Code encourages compliance with the existing MEPS (where available), but this does make the requirements a minimum with significant potential for improvement.

- The code does not underestimate the roles of the building envelope with requirements around window-to-wall ratio (WWR), the solar heat gain coefficient (SHGC) of the glazing, and exterior shading. However, the treatment of thermal insulation for walls and windows is generalised.

Following this thorough review and analysis of the regulation of the building sector in Ghana, a number of gaps and observations are made for consideration in the development of a robust BEEC:

- The code and existing regulations don't have energy performance requirements for buildings.
- There are no requirements for carbon emissions, standards, and targets (e.g., carbon intensity targets). The need for life cycle assessment (LCA) and low-carbon passive design should be considered.
- Lack of energy efficiency targets (e.g., energy intensity targets). An energy goal must be set for the project early in the design or retrofit process.
- Lack of energy and carbon audit and benchmarking requirements and procedures.
- Lack of renewable energy requirements at the project level and the buildings sector level.
- There is no requirement on the climate performance of building materials or requirements for local sourcing.
- Lack of requirements specifically focused on new construction and those specifically focused on existing buildings. The Ghana Building Code appears to have a mixed focus.
- There are no requirements for building management systems (BMS) or building automation systems (BAS) and associated requirements.
- Current practices do enforce commissioning and verification requirements.

While these gaps are not meant to be exhaustive, they demonstrate that comprehensive green building standards for both new construction and existing buildings in Ghana are urgently needed to drive increased energy efficiency and carbon emissions reduction. There is also a need for policy guidelines for the implementation of green building standards in Ghana. For example, guidelines that establish a reasonable amount of time for the standards to remain voluntary before transitioning into mandatory requirements would be useful to the government. The benefits that such a transition may bring to energy efficiency and carbon emissions reduction in the country should be projected for informed decision-making. The policy guidelines may also highlight incentive policies that can be used to promote the adoption of the green building standards.

4.3 Enforcement of building and energy efficiency regulations

As can be seen from previous sections, Ghana has enacted many policies, regulations, and laws to directly or indirectly regulate the building sector. Most of these regulations and laws were influenced by environmental management, spatial planning, economic planning, safety, and risk-related issues. They were not primarily designed with a commitment to efficient energy use or decarbonization of the building sector in mind. Therefore, one of the biggest obstacles to promoting energy efficiency, leading to a more sustainable and decarbonised built environment, in Ghana is the absence of a comprehensive legal and regulatory framework. To fully harness the energy-saving potential in buildings, a robust policy, regulatory, and legal framework is needed to mandate energy efficiency requirements.

The Ghana Building Code (GS 1207, 2018) and the new building regulation L.I. 2465 are significant steps towards addressing the gaps in the built environment. These regulations have positively shaped Ghana's construction landscape by enhancing safety and structural integrity. However, further measures are needed to achieve comprehensive energy efficiency and sustainability. A critical element that is still lacking is the Building Energy Efficiency Standards. These standards are essential as they complement codes by providing comprehensive and detailed guidelines for enhancing energy efficiency in buildings. Currently, the absence of these standards leaves energy efficiency decisions to the discretion of building developers, architects, contractors, or owners. The building code specifies what is required, while the building standards specify how these requirements should be met. By understanding how these terms interrelate, we can appreciate the comprehensive approach needed to achieve energy efficiency and sustainability in the building sector.

In Ghana, a policy is defined as a broad principle, strategic guideline or course of action adopted by an organisation or the government to guide decision-making and achieve rational outcomes. Building policies are not legally binding, but they significantly influence the direction of building practices. The purpose of these policies is to set out the vision, goals, and strategies to address specific issues such as energy efficiency, sustainability, and other building standards.

The regulatory framework bridges policy-making and practical implementation by translating high-level goals into actionable requirements. Building regulations are detailed rules that govern the design, construction, maintenance and other building practices. Regulations are legally binding and enforced by authorities to ensure compliance and maintain high standards within the construction industry. The primary goal is to set specific standards, procedures, and requirements for all stakeholders in the construction industry, ensuring buildings are safe, sustainable, and energy efficient. Clear regulations enable authorities to enforce standards and monitor compliance. Regulation includes codes, standards, and administrative procedures. Based on this definition, the Ghana Building Code (2018) is supposed to be a mandatory code to ensure enforcement and compliance. However, the code has been left voluntary since its introduction. Because of this, implementation and enforcement of the code have been an issue. In addition, the code was meant to be updated after three years of implementation. Due to a lack of monitoring and enforcement of its implementation, there has been no helpful feedback and data to inform its appropriate update to date.

Building codes (also known as technical standards) set specific and minimum requirements for the design, construction, alteration, materials, maintenance, and performance of buildings and their systems. While building standards (also known as technical guidelines) complement codes by providing detailed guidance on how to execute the requirements specified in the codes. They may also provide guidance in areas not covered by the code. Standards set out specifications and procedures designed to ensure products, services, and systems are safe, reliable and consistently perform the way they were intended to. Key elements of Building Energy Efficiency Standards include the following:

- Energy Efficiency requirements for evaluating compliance with the Building Code (Standard Calculation Methodology designed to ensure buildings meet prescribed energy performance criteria).
- Energy Performance Certification and labelling criteria: Ensuring transparency and accountability in energy use.
- Inspection and Compliance: Establish regular inspections and compliance checks to ensure buildings meet the required standards.

Ghana's journey towards energy efficiency in the built environment is still in its initial stages. The Energy Commission is leading efforts by raising awareness, educating stakeholders, and enhancing knowledge of energy efficiency requirements through the latest building regulations, such as the Ghana Building Code (GS 1207, 2018) and Building Regulation (L.I. 2465).

The Commission provides practical guidance on constructing energy-efficient buildings, ensuring compliance with local requirements, and fostering a unified effort towards achieving energy efficiency goals. This foundational work sets the stage for more extensive implementation and enforcement efforts in the future.

With continued efforts, Ghana aims to achieve substantial improvements in energy efficiency and sustainability in its built environment, paving the way for a greener and more resilient future.

4.3.1 Impact of the policy and regulatory enforcement

The building sector plays a major role in energy consumption and carbon emissions in Ghana. According to the International Energy Agency (IEA), the residential sector is the second largest sector, after the transport sector, in final energy consumption in Ghana, accounting for 37% of total final energy consumption (IEA, 2024). A recent study on electricity consumption and household structure in Ghana also indicated that "Ghana has a rising residential electricity consumption of 47% of total generation" (Amoako et al., 2023). Such a high energy usage in the residential sector significantly contributes to the high energy-related carbon emissions of 20 Mt CO2 (IEA, 2024). While biofuels and waste account for 76% of energy in the residential sector, there is a lack of data on the energy intensity of residential buildings in the country (IEA, 2024).

Regulations, especially mandatory regulations with enforced compliance measures, are important for reducing the negative impacts of the buildings sector. They significantly influence building owners to improve energy efficiency, reduce carbon emissions, and promote overall sustainability in their buildings. Non-compliance is often punished through appropriate penalties and fines. By setting mandatory energy consumption and carbon emissions targets and requirements, regulations push building owners to implement better, highly efficient building envelope and energy system measures to drive significant energy savings. These energy savings resulting from regulatory enforcement and compliance impact climate change mitigation and adaptation efforts through the reduction of energy-related carbon emissions. Strict regulations can also promote the wider adoption of renewable energy technologies to electrify buildings, offsetting their carbon emissions. Property values are increased when there is high demand for more energy-efficient and carbon-efficient buildings due to regulations. In addition, as building owners pursue solutions to meet regulatory requirements, there is a greater chance of enhancing technology adoption and innovation. The adoption of new green, energy-efficient building practices and technologies often faces barriers because of perceived risks. Regulations can be instrumental in removing such barriers.

Despite these benefits of policy and regulatory enforcement, as discussed in the preceding section, Ghana lacks a comprehensive mandatory legal and regulatory framework for the built environment. The regulations that exist are suffering from a lack of enforcement and compliance, with no penalties and fines imposed for non-compliance. In fact, most regulations created to govern the Ghanaian built environment have been ineffective (Appiah, 2007). There has been no monitoring and measurement of the implementation, performance, and impact of existing policy and regulatory enforcement, since the enforcement itself is lacking. Thus, there is a lack of data on the impact of existing policies and regulations on building performance. However, the number of registered and certified green buildings in Ghana has increased from one in 2009 to over 30 in 2024 (Table 5). The One Airport Square, certified in 2009, is the first green commercial office building in West Africa (Figure 2) (ArchDaily, 2024), while the Ridge Hospital, certified in 2016, is the first LEED-certified green hospital in Africa (Figure 3) (Leber, 2017). Various green measures and technologies, such as rainwater harvesting, natural ventilation, and solar water heating, were implemented in these projects. Most of these projects adopted green building measures and pursued certification out of their own volition, not because of specific mandatory regulations in the country. In a study on the strategies to promote green building technologies adoption in Ghana (Darko & Chan, 2018), it was found that strategies that encourage voluntary adoption were ranked higher than mandatory regulations. This may be due to the lack and enforcement of such regulations in Ghana, not to mention the lack of data on the impact of existing regulations. Although there currently exists a lack of knowledge on how existing regulations have impacted building performance in terms of energy efficiency and sustainability, launching building-specific energy efficiency, green building, and sustainability regulations can have a positive impact, uplifting building performance and the number of green buildings in Ghana. Ensuring efficient, effective, and consistent implementation and enforcement of these regulations is, however, necessary to realise the positive impact.

Table 5: Summary of registered and certified green buildings in Ghana.

SN	Building name	Building type	Sector	Type of certification (level) - Year
1.	One Airport Square	Office Building	Private	Green Star South Africa-Ghana - 2009
2.	Cantonment City Tower - Goldkey Properties Ltd, Ghana	Serviced Apartment	Private	Preliminary EDGE Certification – 2023
3.	Heritage 100	Serviced Apartment	Private	Preliminary EDGE Certification – 2023
4.	Rehoboth Palm	Homes	Private	Preliminary EDGE Certification – 2021
5.	Rehoboth Knightsbridge	Homes	Private	Preliminary EDGE Certification – 2021
6.	Earlbeam One Place	Mixed Use	Private	Preliminary EDGE Certification – 2022
7.	Crown Forest Safari and Hotel	Hospitality	Private	Preliminary EDGE Certification – 2022
8.	Ultimo Gardens	Homes	Private	Preliminary EDGE Advanced Certification – 2022
9.	The Genesis Residences	Homes	Private	Preliminary / Final EDGE Certification – 2022 / 2024
10.	National Homeownership Fund Estates (Model Community 22 Project)	Homes	Public	Preliminary Advanced / Final EDGE Certification – 2022 / 2024
11.	Cal Bank Head Office Tower	Offices	Private	Final EDGE Certification – 2019
12.	World Bank Group Office Accra	Offices	Private	Final EDGE Certification – 2019
13.	EY Office Building	Offices	Private	Final EDGE Certification – 2022
14.	Lahagu Housing Project	Homes	Private	Final EDGE Certification – 2021
15.	International Warehousing Company	Industrial	Private	Final EDGE Certification – 2024
16.	Standard Chartered Bank, Ghana	Offices	Private	Final EDGE Certification – 2022
17.	Achimota Mall Retail Centre	Retail	Private	Final EDGE Certification – 2023
18.	Takoradi Mall	Retail	Private	Final EDGE Certification – 2018
19.	Ecobank Ghana Plc Head Office	Offices	Private	Final EDGE Certification – 2023
20.	Accra Financial Centre	Offices	Private	Final EDGE Certification – 2023
21.	SU Tower	Offices	Private	Final EDGE Certification – 2023
22.	335 Place	Offices	Private	Final EDGE Certification – 2023
23.	Ghana Infectious Disease Centre	Hospitals	Public	Final EDGE Certification – 2020
24.	MBU at Komfo Anokye Teaching Hospital	Hospitals	Joint	Final EDGE Advanced Certification – 2018
25.	Atlantic Tower	Mixed Use	Private	Final EDGE Advanced Certification – 2018
26.	Tema Port – Terminal Three	Industrial	Joint	Final EDGE Advanced Certification – 2019
27.	Tesano Lofts	Homes	Private	Final EDGE Advanced Certification – 2022
28.	Ridge Hospital	Healthcare	Public	LEED v2009 NC (Silver Certified) – 2016
29.	Google Office Ghana	Office (Commercial Interiors)	Private	LEED v4 ID+C IC (Gold Certified) – 2022
30.	CONSAR Ltd. New Head Office Accra, Ghana	Office	Private	LEED v4 BD+C NC (Registered) – 2017
31.	GNPC Research and Technology Centre	Office	Public	LEED v4 BD+C NC (Registered) – 2018
32.	GNPC Operational Head Office Building	Office	Public	LEED v4 BD+C NC (Registered) – 2020
33.	GNPC Head Office	Office	Public	LEED v4 BD+C NC (Registered) – 2023
34.	NPA Head Office Building Annexe	Office	Public	LEED v4 BD+C NC (Registered) – 2023
35.	Guinness Ghana Achimota Brewhouse	Industrial	Private	LEED v4 BD+C NC (Registered) – 2020
36.	Silver Breezes	Lodging	Private	LEED v2009 BD+C NC (Registered) – 2011

Note: LEED v4 BD+C NC – LEED v4 for Building Design and Construction; LEED v4 ID+C IC – LEED v4 for Interior Design and Construction.

Figure 3One Airport Square (Source: ArchDaily, 2024).

Figure 4: Ridge Hospital (Source: MyjoyOnline, 2024).

4.4 Existing research on energy efficiency in buildings in Ghana

Several research studies on green, energy-efficient, or climate-friendly buildings in Ghana have been conducted over the past years. As the topic is still relatively new to the country, most of the existing research studies have focused on the challenges, strategies, policies, and interventions to promote the adoption of energy-efficient building technologies and practices (Addy et al., 2014; Agyarko et al., 2020; Chan et al., 2018; Darko et al., 2017; Felix Anzagira et al., 2024; Johansson & Winge, 2023). These studies have reported several financial, market, knowledge, political, technical, and institutional barriers to building energy efficiency in Ghana, such as difficulty in accessing financing for building energy efficiency improvement projects, lack of energy-efficient technologies on the local market, lack of knowledge on long-term benefits of energy efficiency technologies and practices, weak institutional collaboration between government institutions to promote energy efficiency, and the government's politicization of the energy rather than the buildings sector (Agyarko et al., 2020). To remove these barriers and drive energy efficiency innovations and knowledge in the buildings sector in Ghana, four key sectors of society, government, academia, industry, and public/media, need to play a pivotal role.

Researchers have attempted to develop building energy efficiency assessment tools for Ghana (Addy et al., 2017; Nii et al., 2017). The variables necessary for effective assessment of building energy efficiency in Ghana include glaze ratio of the wall, thermal properties of the building envelope, HVAC facilities, use of shading devices, and airtightness of the envelope. Efforts have also been made to conduct energy audits and measure the actual electricity consumption of some selected energy systems and electrical appliances in public tertiary institutions and commercial buildings in Ghana using power quality analysers (Opoku et al., 2019, 2020). Power consumption data generated and analysed indicated that retrofitting the ventilation fans, lighting systems, and air-conditioners could lead to a total electricity saving of 163,400 kWh ± 5% per month, which translates to electricity cost reductions of about US$37,880 per month and US$69.1 million over 20 years. (Opoku et al., 2020). Another key insight from these studies is that over 85% of air-conditioners used in Ghana exist in the lowest energy efficiency ratio category (1-star), and the remaining percentages are in the next lower categories (2 and 3-stars) (Opoku et al., 2019), which is no good news if the country is to achieve its climate goals. Energy efficiency regulations must be enforced to move the air-conditioner market in Ghana into higher energy efficiency ratio categories.

Building energy simulation models have been used to assess the energy performance of buildings in Ghana. These models predict the energy-saving potentials from the adoption of energy-efficient designs, energy retrofits, practices, and technologies, providing valuable insights for policymakers and practitioners. The study of Ohene et al. (2022), for example, investigated the feasibility of net-zero energy buildings and proposed retrofit guidelines to achieve net-zero energy targets for existing buildings in the tropical climate of Ghana. A two-storey residential building with eight apartments located in Kumasi was analysed systematically using parametric building energy simulation models in Rhino Grasshopper software. It was identified that it is possible to turn the existing residential buildings in Ghana into net-zero and even net-positive energy buildings using retrofit measures across passive design, active, and renewable energy measures.

This review has identified that the topic of building energy efficiency in Ghana has been reasonably well researched and understood from various perspectives. The level of research does not match the level of actual implementation. While most studies have focused on issues concerning the adoption and promotion of building energy efficiency, such as challenges, strategies, policies, motivations, and interventions, few studies have focused on assessing and improving the actual existing building stock performance through, for example, retrofits. These studies have generated data and analysis that help to understand the energy performance of some selected building energy systems and electrical appliances in certain types of buildings (institutional, residential, and commercial office buildings). Most of the studies have been limited to individual buildings, limiting the understanding of the existing building stock performance on a large, national scale. Further studies are needed to develop national energy performance benchmarks for buildings.

4.5 Gender and social inclusion considerations in Ghana's policy

Gender is one of the most important elements within society, caused by the socially constructed roles given to male and female members. In the contemporary world, the patriarchal society introduces gender issues and women's rights as problems of sustainability. These problems are multi-faceted with different corresponding aspects, architecture being one of them. Although the role of architecture in gender issues is sometimes ignored, its reflection can be seen in the built environment in many different instances, as it has the responsibility to address gender issues to aid in meeting the needs of a sustainable society. Sustainable societies are defined as structures that include different elements in balance to remain healthy over the long term. They consist of a mixture of users with various interests, needs, and abilities. Gender mainstreaming is fundamental to any project and does not necessarily signify additional costs; instead, it could increase the efficiency and effectiveness of the project and influence the project outcome. Greed (2005) argues that the integration of gender into spatial policy making would result in a more sustainable, equal, and accessible built environment for all members of society. Therefore, the development of a Gender Action Plan introduces gender considerations into decision-making elements such as the development of green building standards.

The Paris Agreement, which acknowledges the importance of human rights and specifically names gender equality as a priority in the global climate agreement, has been signed by all 54 African countries. As part of the agreement, these African countries have agreed to a gender-equitable implementation of the agreement, including an assessment of gender differences, the establishment of baseline data, analysis of existing policies and strategies regarding gender issues, and gender responsive budgeting within climate change policies, action plans, strategies and frameworks. Climate change is a threat to all humanity, and women disproportionately suffer from its consequences, many of which interact with our built environments in some way. Women make up approximately 80 % of the people who are displaced from their homes by climate change-related factors, such as extreme weather events, natural disasters, and environmental degradation (United Nations Development Programme). When disaster strikes, women and children are 14 times more likely than men to die. A real example is the 230,000 people killed in the 2004 Indian Ocean Tsunami, of which 70 % were women (Asako Okai, UN Assistant Secretary-General and Director, UNDP Crisis Bureau, 2022).

Buildings contribute to about 40% of global energy consumption and about one third of greenhouse gas emissions, figures that are predicted to continue increasing; and while around 2.1 billion people who live in low and middle income countries experience energy poverty, household air pollution was also reported to be responsible for an estimated 3.2 million deaths per year in 2020, including over 237 000 deaths of children under the age of 5. Women and children are more likely to die of indoor air pollution due to their traditional roles in many societies where they spend more time near sources of pollution like wood, coal and kerosene for cooking and doing household chores in poor lighting (WHO, 2024). To meet COP26 targets, the energy efficiency of buildings will have to improve by 30% by 2030. But if that's to happen, gender needs to be considered.

In the wider West African region, Ghana is often seen as an energy success story, with over 80% of the population having access to grid electricity. Yet, 50% of rural areas live without this access, while 'dumsor' (load shedding) poses an ongoing challenge for those connected. In terms of gender equity, national energy policy recognises the need for gendered responses to improving energy access. Ghana's Energy Policy 2010 indicates that women are some of the most important actors in the energy sector, in terms of their use and management of household energy, including renewable sources. It therefore seeks to mainstream energy-related gender concerns and align them with wider health and safety as well as environmental standards. Similarly, the Renewable Energy Master Plan1 (Energy Commission, 2019) indicates that the development of policies and strategies should always seek to ensure equitable participation and delivery of energy services to men, women, children and the vulnerable (Energy Access and Gender, 2021).

Women are key users, suppliers and innovators within energy systems, and their empowerment is crucial in achieving sustainable energy goals (Winther et al., 2017). Dr Chris Foulds's project on gender and energy access in developing countries has uncovered three key factors that result in women not having the same access to energy compared to men – a situation that makes achieving sustainability even more challenging. The four case study countries: Nigeria, Ghana, India, and Pakistan, were selected based on current energy access rates and their performance in the 2019 SDG Gender Index.

These key factors are:

- Inadequate gender-specific data showing how and when women need energy.
- The underrepresentation of women in the energy sector.
- The marginalisation of women's energy needs in gender neutral energy policies.

"Women constitute about 50% of the users of the built environment, yet they have a negligible influence on their architectural forms" (Weisman, 2000). Buildings that are designed without considering gender often benefit men and disadvantage women by default, impacting energy efficiency (Energy Research and Social Science: volume 96, 2023) Even today, in most societies across the world, men tend to be considered the heads of their households and are frequently the breadwinners for their families. Yet women are responsible for at least 2.5 times more unpaid domestic work than men (UN Women, 2017). They undertake most household chores, which is where most of their energy is used. Therefore, without a doubt, green buildings can play a significant role in facilitating gender equality by addressing various aspects of the built environment that impact women's lives, such as indoor air quality and energy efficiency.

Green building- i.e. the practice of creating structures and using environmentally responsible processes and resource-efficient practices throughout a building's life cycle from siting to design, construction, operation, maintenance, renovation and deconstruction (US EPA), should be gender sensitive to reflect the differing needs of all users. Gender-sensitive architectural design acknowledges the inherently non-neutral spaces of buildings and aims to address the diverse needs of users based on their gender, age, and abilities. The Handbook for Gender-Inclusive Urban Planning and Design by the World Bank draws attention to the importance of integrating gender perspectives into urban and architectural planning to combat spatial inequities and ensure inclusivity. This practice expands and complements the classical building design concerns of economy, utility, durability, and comfort. All the design features of a green building help to "future proof" it from the risks of climate change and resource scarcity. At the same time, green building principles benefit occupants' health and well-being while providing cost savings. Nearly 50%, or 13, of the 28 heads of established Green Building Councils are women (World Green Building Council, 2024a). Despite this, the sector does not prescribe any specific gender equality standards to be applied across the supply chain. Most of the sustainability standards are voluntary and require the supply chain to meet basic human rights, worker health, and safety regulations, with no explicit focus on gender equality. It is therefore important to establish appropriate gender equality considerations within individual bond frameworks to ensure inclusivity and safety.

Despite the importance of gender in building development, the current Ghana building code does not cover any gender considerations. The Building Code, which is the first comprehensive building code for Ghana, and also doubles as a modified adoption of the International Building Code, lays down the essential requirements that buildings must conform, yet it lacks the inclusion of gender aspects that can help reduce gender gaps in the building industry, and ultimately be responsive to the needs of every user. Gender is an important and essential issue for society, but the perspective in architecture is still under development, especially in developing countries, as seen in the building code under review.

The role of women in the work-life environment has been changing under new economic and social conditions. In the past, the nature of the working woman was mostly secretarial duties that required open offices and common spaces, as the men were working behind closed doors and in privacy, as they were the decision-makers (Spain, 2000). Nowadays, the situation has changed, and especially among the white-collar workers, the equality between women and men has been established. Accordingly, the physical environment in the workspaces has changed to meet the needs of working women. There is more room for personalisation or socialisation, and workspaces are more suitable for multiple functions. The transformation of workspaces, which is based on the changes in women's way of living and getting more engaged in public life, also requires the transformation of the urban spaces as they are the socialisation areas for all workers and other members of society. Therefore, their physical qualities need to answer the needs of all groups.

Well-designed green buildings can incorporate safety measures such as well-lit pathways, secure parking areas, and access control systems, creating a safer environment for women. Enhanced building accessibility often emphasises universal design principles, making them more accessible to people of all ages, abilities, and genders. By incorporating features like ramps, elevators, wider doorways, and barrier-free spaces, green buildings can ensure equal access and mobility for women with disabilities, elderly women, and caregivers. The work-life balance for women can also be supported by incorporating amenities such as flexible workspaces, childcare facilities, lactation rooms, and recreational areas. These features can enable women to balance their professional and personal responsibilities more effectively, fostering greater gender equality at home and in the workplace. Green buildings often incorporate communal spaces, such as parks, gardens, and shared facilities, that promote social interaction and community engagement. These spaces can provide opportunities for women to connect, collaborate, and participate in decision-making processes, thus empowering them within their communities.

The reflections of the changes in society are visible in the built environment. Nowadays, the urban public space becomes a stage for the cultural and social exchange of knowledge, regardless of age, ethnicity, or gender of the users. The relationship between the built environment and the user is mutual. Space defines the people in it, as the presence of individuals in space determines its nature (Ardener, 2000). Energy, gender and space are closely interlinked. Only by investigating how they intersect can we truly begin to move towards creating sustainable societies.

4.6 Gaps and limitations in the existing framework

Following the comprehensive review and analysis of the current policies, regulations, and practices on energy efficiency, green building, and sustainability in the building sector in Ghana, several gaps and limitations in the existing regulatory framework have been identified. The key barriers are (1) the absence of a comprehensive legal and regulatory framework specifically for the built environment, (2) inadequate monitoring and enforcement, (3) insufficient collaboration among key stakeholders, (4) limited awareness, knowledge, expertise, and capacity, and (5) low demand. These barriers have been identified through the policy analysis and stakeholder engagement facilitated by the inception meeting of this project, as well as one-on-one meetings with key stakeholders such as the Energy Commission of Ghana.

1. **Absence of a comprehensive legal and regulatory framework specifically for the built environment**

One of the biggest barriers to building energy efficiency and sustainability in Ghana is the inadequate government support and promotion in the form of a comprehensive legal and regulatory framework (Chan et al., 2018; Djokoto et al., 2014). Government support and promotion are critical to promoting building energy efficiency and sustainability in any jurisdiction. The government can usually support the promotion of building energy efficiency and sustainability through two main initiatives: (1) mandatory policies and regulations, and (2) incentive policies – i.e., "carrot-and-stick approach" (GeeksforGeeks, 2024). This approach to motivation is a well-known and effective strategy that combines rewards ("carrot") and punishments ("stick") to encourage desired behaviours. In the context of building energy efficiency, green building, and sustainability, the stick refers to policies and regulations that mandate energy efficiency requirements, with non-compliance punished by penalties and fines. The carrot refers to financial and non-financial incentives (such as tax rebates, gross floor area concessions, expedited permitting, and low-interest loans) that reward compliance. Ghana has a building code (Ghana Building

Code (2018)) but does not have Building Performance Standards (BPS). This is a significant limitation in the existing regulatory framework because it is difficult to enforce the requirements in the code without BPS, which provides guidance on how to execute the requirements specified in the code. The code is also voluntary rather than mandatory. In a market where stakeholders perceive several challenges and risks in implementing new energy efficiency measures and technologies, the lack of mandatory building codes and regulations can significantly impede action. Another key limitation is that there is a lack of adequate financial and non-financial incentives for implementing these new measures and technologies in the Ghanaian market. These two limitations combined go a long way in preventing energy efficiency and sustainability improvements in the Ghanaian built environment sector. A comprehensive legal and regulatory framework that uses a mix of mandatory and incentive policies and regulations is needed to encourage energy efficiency and sustainability improvements in the Ghanaian built environment sector.

2. Inadequate monitoring and enforcement

Having mandatory and incentive policies and regulations is one thing, and monitoring and enforcing their implementation is another thing. While Ghana generally lacks building energy and sustainability policies and regulations, specifically, the few that currently exist are not being consistently and efficiently enforced. Because most of them are non-mandatory, there are no punishments for non-compliance.

3. Insufficient collaboration among key stakeholders

To ensure full implementation and enforcement of energy efficiency in buildings, appropriate institutional enforcement systems are needed. However, a critical limitation in the existing regulatory system is insufficient coordination and collaboration among key stakeholders, such as the Ministry of Works and Housing, Local Government Services (i.e., Local Authorities), Energy Commission, Environmental Protection Agency, and Ghana Green Building Council. There has been insufficient support for these institutions to work together effectively to promote energy efficiency in buildings. Most of these institutions prefer to work within their boundaries with limited opportunities for information sharing and collaboration. To promote building energy efficiency, an enabling environment should be established to breakdown such silo mentality to allow these institutions to work together in developing and implementing relevant requirements and guidelines. The Ghana Green Building Council, for example, has been established since 2009, but the country still lacks its green building standard or assessment tools. The lack of support and collaboration between the Ghana Green Building Council and other key stakeholders, such as the Government, plays a key role in this shortfall. Moreover, there are instances where Metropolitan Assemblies consider the inclusion of building energy efficiency requirements and guidelines in their bylaws without engagement with the Energy Commission, which has the mandate to enact and enforce energy efficiency requirements in the country. There is a lack of coordination among initiatives that are being implemented by various institutions to promote building energy efficiency. Strong collaboration between relevant government institutions and local authorities should be established to enact, implement, and enforce building energy efficiency provisions.

4. Limited awareness, knowledge, expertise, and capacity

Another challenge to building energy efficiency in Ghana is limited awareness and knowledge of energy efficiency measures/technologies and their benefits. Even among key stakeholders such as local authorities/assemblies who are required to enforce the building code and conduct inspections, there is a lack of awareness of the energy efficiency provisions in the code. As building energy efficiency is still in its infancy stage in Ghana, only a few professionals have the technical knowledge, expertise, and capacity to effectively implement energy efficiency measures. Building owners lack information about measures to achieve energy efficiency in their buildings, and the costs and benefits associated with improving energy efficiency.

5. Low demand

The above-mentioned gaps and limitations in the existing regulatory framework work together to impede demand for building energy efficiency in Ghana. Insufficient policy incentives to encourage the adoption of energy efficiency measures, lack of awareness of the benefits, perceived high upfront costs, unclear return on investment, and lack of capacity are well-known to be factors that can lead to a low adoption rate of energy efficiency measures and technologies. Without a better understanding of the benefits of energy efficiency and how to implement energy efficiency measures, it would be difficult to drive demand among building owners.

4.7 Policy conclusions and recommendations

The buildings sector is a major energy and electricity consumer in Ghana. The residential sector alone accounts for 37% of total final energy consumption (IEA, 2024)and 47% of electricity consumption (Amoako et al., 2023). To address climate and sustainability challenges in the country, it is urgent to cut energy consumption from the building sector. Hence, Ghana has enacted many policies, regulations, and laws to directly or indirectly regulate the sector. An analysis and review of the existing regulatory framework has revealed that most of these policies, regulations, and laws were not primarily designed with a commitment to efficient energy use or decarbonization of the buildings sector in mind. The focus has predominantly been on the energy sector (the supply side) rather than the buildings sector (the demand side). The Ghana Building Code (2018) and the Building Regulation 2022 (L.I. 2465) are the two most relevant instruments aiming to drive forward energy efficiency, sustainability, and green building requirements in the Ghanaian built environment sector. However, their implementation and enforcement have not been monitored, consistent, and effective. Nevertheless, the number of registered and certified green buildings in Ghana has increased from one in 2009 to over 30 in 2024. While this can be considered limited in a period of 15 years, it may still suggest some building performance improvement. Based on the analysis, the following key gaps and limitations in the existing regulatory framework have been identified:

- Absence of a comprehensive legal and regulatory framework specifically for the built environment.
- Inadequate monitoring and enforcement of existing regulations.
- Insufficient collaboration among key stakeholders.
- Limited awareness, knowledge, expertise, and capacity.
- Low demand.

To address existing gaps and limitations, the following recommendations are put forward:

- A comprehensive legal and regulatory framework that uses a mix of mandatory and incentive policies and regulations is needed to encourage energy efficiency and sustainability improvements in the Ghanaian built environment sector. Compliance should be rewarded with financial incentives (such as low-interest loans and subsidies) and non-financial incentives (such as expedited permitting and technical assistance), and non-compliance should be strictly punished with fines and penalties.
- Consistent and effective enforcement of building codes and regulations. There should be regular inspections and compliance checks to ensure buildings meet the code and regulatory requirements. The Ministry of Works and Housing and Local Authorities/Metropolitan Assemblies should effectively play their role in this regard. In addition, Building Performance Standards (BPS) (such as green building standards or rating tools) are needed and should include requirements for evaluating compliance with the building codes or a Standard Calculation Methodology designed to ensure buildings meet prescribed energy performance criteria. The Ghana Green Building Council and other key stakeholders (Ministry of Works and Housing, Local Authorities/Metropolitan Assemblies, Energy Commission, and Environmental Protection Agency) should work together to develop and implement these BPS. The building codes and regulations should mandate meeting the requirements in the BPS. This is one of the best ways

that the building codes and regulations, and BPS work together to promote building energy efficiency.

- Energy performance benchmarks should be established to gauge the level of performance in the sector.
- Increasing knowledge and awareness of energy efficiency measures and technologies and their benefits through relevant educational campaigns and programs. Education and training are needed to build the capacity and technical know-how of the industry to implement energy efficiency in buildings. The Energy Commission's Building Efficiency Initiative program aims to provide information about energy efficiency in buildings to increase the awareness of key stakeholders, including all the Metropolitan Assemblies in Ghana, and provide technical support.
- Considering energy efficiency as part of the requirements to be met before a building permit is issued. This and the above recommendations will help to increase demand for building energy efficiency.

5 Building performance baseline assessment

5.1 Overview

The objective of assessing the baseline energy performance of buildings in Ghana is to establish a comprehensive understanding of how energy is currently consumed within the built environment. This evaluation serves as a critical foundation for identifying energy inefficiencies and developing strategies for improving energy use. By determining the baseline energy performance, stakeholders can better gauge the energy intensity of buildings, compare it to international standards, and set realistic targets for energy efficiency improvements. In Ghana, where the energy sector is under pressure due to rising demand, this assessment is particularly important for supporting national efforts toward sustainable energy use, reducing operational costs, and mitigating the environmental impact of buildings. Moreover, it provides key insights for policymakers, developers, and building owners to prioritise energy-saving interventions, invest in renewable energy technologies, and promote green building practices across the country.

5.2 Methodology

Methodology for Determining Baseline Performance of Existing Buildings in Ghana Using Simulation of Real Building Samples.

To establish the baseline performance of existing buildings in Ghana, this study employs a simulation-based methodology that integrates real-world building data with advanced modelling techniques. The process involves a series of steps designed to accurately assess the energy performance, thermal comfort, and overall sustainability of typical Ghanaian buildings. The methodology includes the following key phases:

1. Selection of Building Samples

The first step involves the selection of a representative sample of existing buildings. The buildings chosen for this study are selected based on their geographical location, building type, construction materials, age, and occupancy patterns. To capture the diversity of building stock in Ghana, the sample includes a range of:

- Residential (single-family homes, apartment complexes).
- Commercial (retail spaces).
- Office (government and private buildings).

Data on each building's physical characteristics (e.g., floor area, wall and roof construction, window-to-wall ratio) is gathered from architectural plans and drawings.

2. Data Collection on Building Performance

To accurately simulate the performance of the selected buildings, detailed data is collected on several parameters that affect energy use and comfort, including:

- Building envelope properties (U-values of walls, windows, roofs, etc.).
- Internal loads, such as lighting, HVAC systems (types of cooling and ventilation systems) and various electrical appliances and equipment.
- Occupant behaviour (occupancy schedules, lighting and appliance use patterns).
- Utility data (monthly energy and water usage if available). Where the data for building performance was made available, the comparison of simulated and actual performance is made explicit.

Climatic data specific to Ghana, including temperature, humidity, solar radiation, and wind patterns, is also collected from a publicly available weather database. This ensures that the simulations reflect the actual environmental conditions that buildings experience.

3. Building Energy Modelling and Simulation

The baseline performance of the selected buildings is simulated using advanced building energy modelling (BEM) software called BSim. This tool is chosen for its ability to accurately model the thermal behaviour of buildings under different conditions. The simulation process includes:

- Creating digital models of each building, based on the collected physical and operational data.
- Defining baseline operation scenarios, which assume the most common usage patterns and existing equipment.
- Running simulations over a typical meteorological year (TMY) to capture seasonal variations in performance.
- Analysing key performance indicators (KPIs), such as energy consumption, indoor temperature, occupant thermal comfort, and energy intensity per square meter.

4. Calibration of Simulation Models

To ensure that the simulation results accurately reflect real-world performance, the models are calibrated using actual utility data (where available) and in situ measurements (temperature, humidity, indoor air quality, etc.). This step involves comparing the simulated energy use with actual data from the buildings and adjusting the models to minimise discrepancies. The calibration process ensures that the models provide a realistic representation of the building's performance.

5. Benchmarking and Baseline Determination

The final stage involves analysing the simulation outputs to determine the baseline performance of the selected building stock. This is done by:

- Aggregating the results to provide an average or typical energy use intensity (EUI) for different building types.
- Identifying key factors that influence energy performance, such as insulation levels, shading devices, HVAC efficiency, and occupant behaviour.

This baseline data will serve as a reference point for future performance improvement measures, such as retrofitting or implementing energy efficiency interventions in existing buildings.

6. Sensitivity and Scenario Analysis

To provide a comprehensive understanding of building performance under varying conditions, additional sensitivity analyses can be conducted. These analyses test the impact of changes in key variables, such as insulation levels, window glazing, or HVAC system efficiency, on the building's overall energy consumption and comfort. Additionally, different future climate scenarios are simulated to assess how building performance might shift under climate change, providing valuable insights for long-term planning and adaptation strategies.

7. Reporting and Policy Implications

Finally, the results of the baseline performance analysis are compiled into detailed reports. The findings are presented in a way that highlights actionable insights for policymakers, building owners, and designers. The reports focus on:

- Identifying buildings or building types with the highest potential for energy savings,
- Recommending policy interventions, such as mandatory energy performance standards, retrofitting programs, and awareness campaigns,
- Providing guidelines for improving the sustainability of Ghana's building sector, in alignment with national and global energy efficiency goals.

This methodology ensures a robust understanding of the current performance of Ghana's building stock, serving as a foundation for energy efficiency improvements and supporting the transition towards more sustainable, low-carbon buildings.

5.3 Building performance and design practices

While buildings can vary in size, materials, and designs, there are significant commonalities that tend to dominate the market. This section aims to provide a general overview of these practices and provide the results of building performance simulations based on the described practices. The aim is to provide a baseline for the development of the GBS.

5.3.1 Lighting

In Ghana, there are certain common practices and standards for lighting in buildings, which aim to ensure both functionality and safety. These practices are guided by regulations and building codes, often influenced by both local and international standards. Here are some of the key aspects:

1. Adequate Lighting for Safety and Functionality

Lighting must be sufficient to ensure safety and proper functioning in all areas of a building. This includes adequate illumination in hallways, staircases, and exits to prevent accidents and enhance visibility, especially in commercial and residential buildings.

2. Energy-Efficient Lighting

Given the growing awareness of energy consumption and sustainability, energy-efficient lighting, such as LED lights, is commonly used in many buildings. This practice helps reduce energy costs and supports environmental sustainability.

3. Natural Light Considerations

Many buildings in Ghana make provisions for natural light, especially in residential homes. Proper placement of windows and use of translucent materials help reduce dependence on artificial lighting during the day. This practice helps with energy conservation.

4. Lighting Controls and Automation:

The use of lighting controls like motion sensors, dimmers, and timers is becoming more common in commercial buildings to reduce energy wastage. Automated systems help regulate lighting based on occupancy or time of day.

5. Compliance with Building Codes

Ghana has building codes, including the Ghana National Building Regulation (L.I. 1630), which guide the installation and design of lighting systems. These codes ensure proper wiring, use of quality materials, and adherence to electrical safety standards.

6. Use of Standard Fixtures and Equipment

Fixtures and electrical equipment used in buildings often follow specific standards to guarantee safety and reliability. This includes ensuring that lighting installations comply with electrical load requirements to avoid overloading circuits.

7. Cultural and Aesthetic Considerations

In both residential and commercial settings, lighting design often takes into account cultural and aesthetic preferences. Traditional lighting methods, such as using lanterns or oil lamps, may still be used in some areas, though modern electric lighting predominates.

8. Fire Safety Measures

Lighting in buildings, especially commercial or high-rise buildings, often includes emergency lighting systems that are activated in case of power failure. These systems are part of fire safety regulations, ensuring that exit routes are illuminated during an emergency.

These practices are largely influenced by the need to ensure safety, reduce energy costs, and comply with building codes. Additionally, with growing awareness around sustainability, more buildings in Ghana are incorporating energy-efficient lighting solutions like LEDs and solar-powered systems.

5.3.2 Air conditioning

The use of air conditioning (AC) in buildings varies depending on factors like location, type of building, socioeconomic status, and environmental conditions. The following provides an overview of common practices:

1. Residential Buildings

- Urban Areas: In major cities like Accra, Kumasi, and Tema, air conditioning is common in middle- and upper-income households. Homes are often fitted with split-unit air conditioners or window units, particularly in bedrooms and living rooms. Given the tropical climate, many households in urban areas rely on AC for comfort, especially during the hotter months.
- Rural Areas: In rural areas, AC is less common due to cost and the availability of reliable electricity. Most homes rely on natural ventilation (windows, fans) to cool living spaces. AC is considered a luxury in these areas.

2. Commercial Buildings

- Offices: Most modern office buildings, particularly in business districts in cities like Accra, are equipped with centralised or split-unit air conditioning systems. AC is a standard feature in corporate offices, banks, hotels, and government buildings. Maintaining a cool environment in workspaces is considered essential for productivity, especially in Ghana's hot and humid climate.

- Shops and Malls: Large shopping malls, supermarkets, and high-end retail stores in cities are fully air-conditioned. Smaller shops and local markets often rely on natural ventilation or electric fans unless they are catering to higher-end clients.

3. Public Buildings

- Government Offices: In urban areas, government offices and institutions are typically equipped with AC systems. However, in rural government offices, air conditioning might not be as common or consistent due to budgetary constraints.
- Schools: While air conditioning in schools is generally rare, especially in public schools, some private schools, particularly international ones, may have air-conditioned classrooms.

4. Hotels and Hospitality

Air conditioning is standard in most hotels, guesthouses, and hospitality facilities that cater to tourists, particularly in urban and coastal areas. High-end hotels offer AC as part of basic amenities, while budget hotels may offer it as an optional service.

5. Energy and Cost Considerations

- Electricity Costs: Electricity prices in Ghana are relatively high, which impacts the use of air conditioning. Many households and businesses manage AC usage carefully to control costs. As a result, some buildings may only use air conditioning during the hottest parts of the day or in select rooms.
- Energy Efficiency: Increasingly, there is a focus on energy-efficient AC units, especially in commercial buildings, due to the rising costs of electricity and environmental concerns. Some newer buildings are designed with energy efficiency in mind, using natural ventilation alongside air conditioning to reduce energy consumption.

6. Power Supply Issues

- Power Outages: Ghana has faced power supply challenges in the past, with periodic outages. This has affected the consistent use of air conditioning, particularly in residential settings. During outages, many households and businesses switch to fans or generators if available.

7. Cultural Practices

In some settings, particularly in traditional or older buildings, there is a preference for natural ventilation over air conditioning. Buildings designed with high ceilings, wide windows, and open courtyards are more conducive to passive cooling, which can reduce reliance on air conditioning.

While air conditioning is widely used in urban areas and in commercial and hospitality sectors, natural ventilation and fans are still common in less affluent or rural settings. Electricity costs and power reliability remain key factors influencing the use of AC in Ghana.

5.3.3 Electrical appliances

The installation and use of electrical appliances in buildings is influenced by socioeconomic status, urbanisation, and the availability of reliable electricity. An overview of common practices concerning electrical appliances in various types of buildings is provided in the following:

1. Residential Buildings

Urban Areas:

In cities like Accra, Kumasi, and Tema, where electricity is more stable, many homes are equipped with a variety of electrical appliances. Some common ones include:

- Refrigerators and Freezers: Standard in middle- and upper-income households. These are essential for food storage due to the tropical climate. Some households, especially in urban areas, have both refrigerators and deep freezers to store perishables.
- Televisions: Almost every household, regardless of income level, has at least one television, usually connected to a satellite TV device or digital services. In wealthier homes, smart TVs are becoming more popular.
- Air Conditioners (AC): Common in higher-income households, particularly in living rooms and bedrooms. Fans are more common in lower-income homes or in situations where electricity is expensive or unreliable.
- Microwave Ovens: Widely used in middle- and upper-class households. Microwaves are convenient for reheating food, especially in fast-paced urban life.
- Electric Stoves/Ovens: In urban areas, electric stoves and ovens are common, though gas stoves are also used due to concerns about electricity outages and the high cost of electricity. More energy-efficient cooking devices, such as induction cooktops, are gradually gaining popularity.
- Water Heaters: Some homes, especially modern ones, have water heaters for bathrooms. Solar water heaters are also becoming more common in urban areas due to their energy efficiency.
- Washing Machines: Middle- to high-income households often have washing machines.
- Electric Irons: Irons are standard in most homes, and people often use them daily to press their clothes before going to work or school.

Rural Areas:

In rural areas, the use of electrical appliances is less widespread due to lower incomes and unreliable electricity access. Most homes in rural areas typically have fewer electrical devices, such as:

- Radios: Very common as a primary source of news and entertainment. Battery-operated radios are widely used due to frequent power outages.
- Electric Fans: Basic ceiling or standing fans are often used where electricity is available, but fans are less common than in urban areas.
- Televisions: While less common than in urban areas, many rural homes have a television, often powered by an external antenna or satellite dish.

2. Commercial Buildings (incl. public buildings)

Offices:

Modern offices in Ghana, particularly in urban areas, are equipped with a variety of electrical appliances to support daily operations:

- Computers and Printers: Desktop computers, laptops, and printers are essential for daily business operations. Internet connectivity is also common in offices, particularly in major cities.
- Air Conditioners: Centralised or split-unit air conditioning systems are common in offices to maintain a comfortable working environment.
- Photocopiers and Scanners: These are standard in most offices for document handling.
- Telecommunication Equipment: Phones, routers, and other communication devices are essential for business operations.

Shops and Retail Spaces:

- Refrigeration Units: In supermarkets and convenience stores, refrigerators and freezers are widely used for storing perishable goods.
- Cash Registers and POS Systems: Larger retail stores and malls use electronic cash registers and point-of-sale (POS) systems for processing transactions.

Restaurants and Hospitality:

- Kitchen Appliances: Restaurants are equipped with refrigerators, freezers, ovens, microwaves, and other kitchen appliances to serve their customers. High-end restaurants may use more sophisticated appliances like dishwashers, espresso machines, and food processors.
- Air Conditioners: In urban restaurants and hotels, air conditioning is a standard feature to enhance customer comfort.

3. Public and Government Buildings

- Lighting: Most public buildings are equipped with standard fluorescent or LED lighting. Energy-efficient lighting is increasingly being adopted in government offices and public institutions as part of energy conservation efforts.
- Computers and Communication Equipment: Public offices typically have computers, printers, telephones, and internet connectivity to handle administrative tasks.
- Air Conditioners: Common in urban government offices and institutions. In rural areas, the use of AC is less frequent, with ceiling fans or no cooling systems used instead.

4. Schools

- Projectors and Computers: In some urban schools, especially private and international ones, projectors and computers are used in classrooms to facilitate digital learning. However, public schools, particularly in rural areas, may lack these resources.
- Fans: Electric fans are used in many schools to cool classrooms, though some rural schools rely on natural ventilation.

5. Energy and Cost Considerations

Ghana's electricity tariffs are relatively high, which can impact the usage of electrical appliances. In some homes and businesses, energy-efficient appliances (e.g., LED lighting, inverter air conditioners) are preferred to reduce energy costs.

Frequent power outages have historically been an issue in Ghana. This has led to the use of backup generators, uninterruptible power supply (UPS) systems, and solar energy solutions to ensure the continuous operation of electrical appliances in homes and businesses.

In August 2023, the Public Utilities Regulatory Commission (PURC)[2] announced new electricity tariff adjustments due to various factors, including the rising costs of fuel, currency depreciation, and inflation. The tariff increase in 2023 was approximately:

- 27% increase for residential consumers.
- 30% increase for non-residential consumers (commercial and small businesses).
- 31% increase for industrial consumers.

These increases were attributed to the need to recover the cost of power generation and distribution, which has been affected by global energy price volatility.

6. Solar and Alternative Energy

Due to intermittent electricity supply and rising energy costs, there is a growing trend toward solar energy use in Ghana. Solar panels are increasingly used in rural homes, schools, and even some urban households to power basic appliances like lights, fans, and water heaters.

Some households and businesses use inverters and batteries to store electricity and power essential appliances during outages.

7. Cultural and Traditional Practices

In some homes, particularly in rural areas, people still use traditional cooking methods, such as coal pots or firewood, alongside electrical appliances like electric stoves, especially in regions with unreliable electricity.

The use of electrical appliances reflects the country's urban-rural divide, with urban areas having wider access to modern appliances, while rural areas may use fewer electrical devices or rely on more basic alternatives. Electricity costs, availability, and energy efficiency are key factors in determining appliance usage.

8. Envelope materials

Wall materials: The choice of wall materials has a significant impact on the thermal performance of buildings. Adobe bricks, laterite bricks, and burnt clay bricks are well-suited to the climate due to their low thermal conductivity and high thermal mass, which help regulate indoor temperatures. Sandcrete

[2] https://www.purc.com.gh/

blocks and concrete walls, while more widely used in urban areas, tend to have higher thermal conductivity, making them less energy-efficient without additional insulation or ventilation measures.

To optimise thermal comfort in buildings, it's common to combine materials with shading devices, ventilation systems, and light-coloured finishes that reduce heat absorption and improve the energy efficiency of the structure.

Tropical Climate Considerations: In Ghana's hot and humid climate, wall construction often considers thermal insulation to keep interiors cool; however, these considerations are not part of the building code, so it can (and is) often ignored by developers. Thicker walls made from materials like laterite, adobe, or burnt bricks offer natural insulation and keep buildings cooler during the day.

Ventilation: Many buildings are designed with wide windows, ventilation blocks, or louvre systems to enhance airflow and reduce the need for air conditioning.

9. Roofing materials

Roof construction is a critical element of building design, particularly due to Ghana's hot and humid climate. Roof materials not only protect against the weather but also significantly influence the thermal comfort inside buildings. The right choice of roof materials can help manage indoor temperatures, reduce heat gain, and improve energy efficiency.

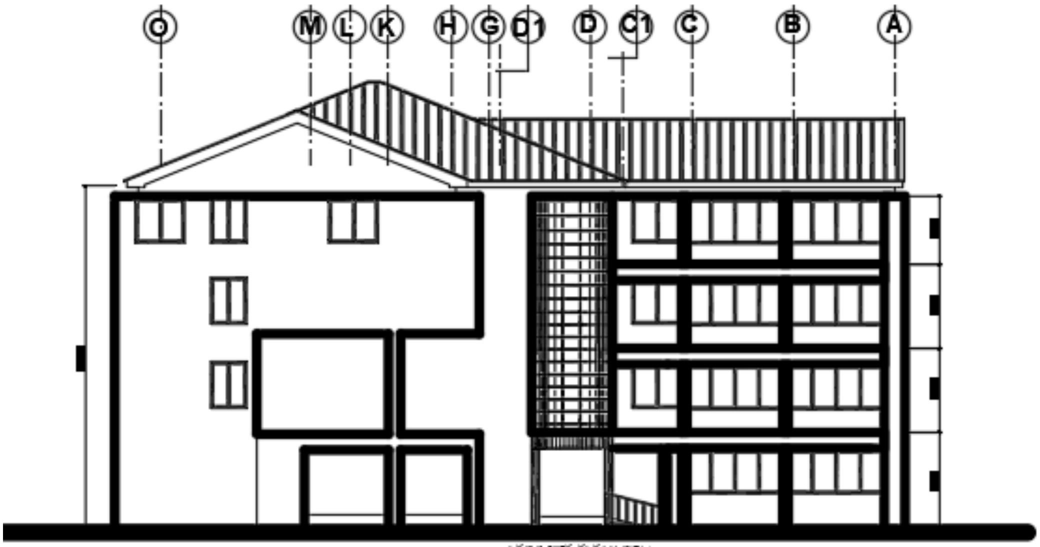
The thermal properties of roofing materials play a key role in the comfort and energy efficiency of buildings in Ghana's tropical climate. Metal roofing sheets, while popular due to their durability and cost-effectiveness, require additional insulation to reduce heat gain. Clay tiles, thatch, and green roofs provide excellent thermal performance due to their natural insulation and heat-regulating properties, making them well-suited to the climate. Concrete roofs can also perform well if properly insulated. For all roofing types, ventilation and light-coloured coatings are critical for improving thermal comfort and reducing the need for artificial cooling.

5.3.4 Office building baseline performance simulation

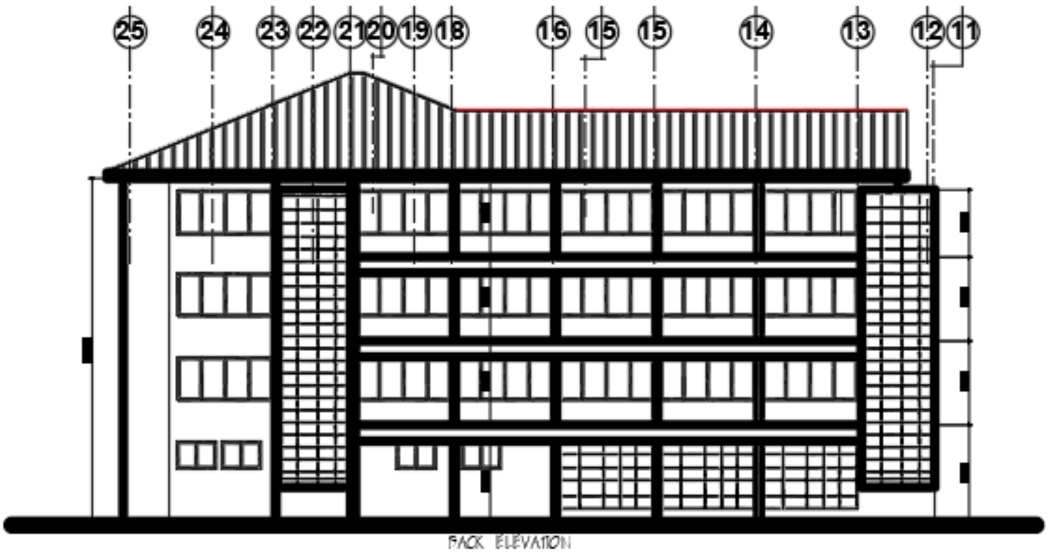
To generate a baseline assessment, some typical examples of office buildings in Ghana have been selected for a detailed analysis of their energy performance. The cross-section of the selected office building is presented in Table 6.

Table 6: Simulated office building drawing and specifications.

Project Name	EPA Amasaman
Building category	Office
Total floor area (conditioned)	2.235 m2



LEFT SIDE ELEVATION

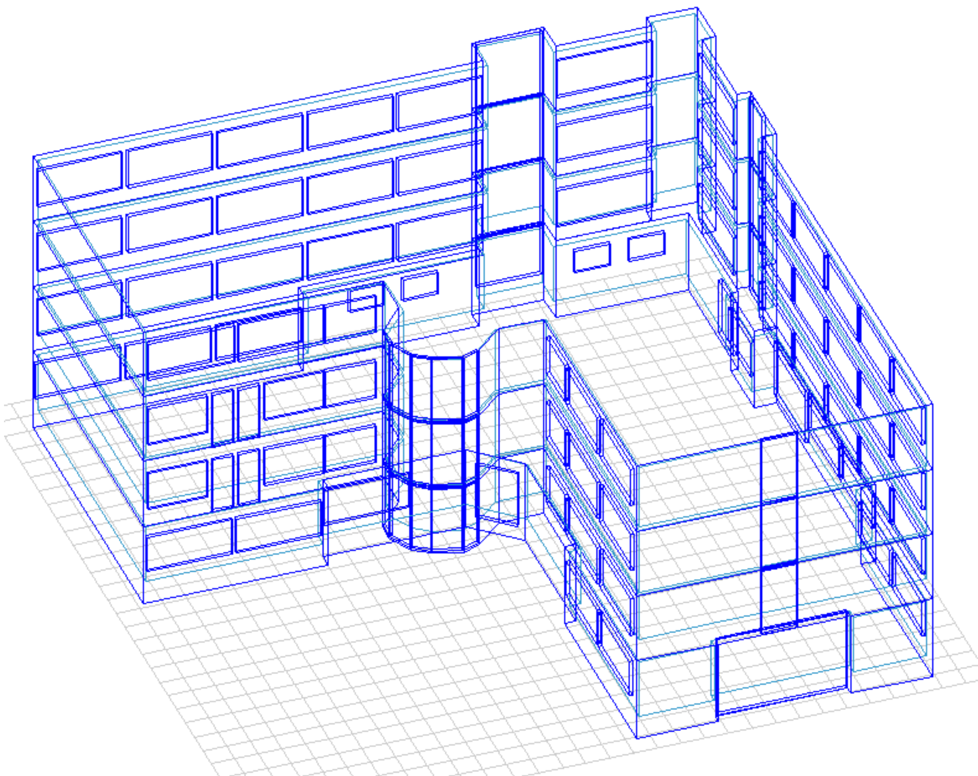


BACK ELEVATION

Below is the baseline data for the building's structures

Parameter	Office	Note
Exterior wall construction	4.35 W/m²K	150 mm reinforced concrete
Roof	5.0 W/m²K	150 mm reinforced concrete
Floor	0.58 W/m²K	600 mm sand foundation layer 150 mm reinforced concrete
Vertical glazing performance	5 W/m²K	6 mm hard-coated glass Frame of wood, steel or plastic

The model outline



Inputs for the building's internal loads and installations:

Parameter	Office	Note
Indoor design temperature setpoint	Cooling setpoint of 24 °C	Assumed cooling effect: 3 W/m² on the building.
Occupancy	150 persons	Each person has a heat emission of 100 W
Internal lightning	7.15 W/m²	
Equipment allowance	3.5 W/m²	Assumptions: 8000 W
Fresh air rates (Infiltration)	0.5 h-1	
Office hours	From 8:00 AM to 5:00 PM	Break with 50% load from 12:00 to 1:00 PM.

Another key set of assumptions to assess building performance involves an understanding of how much and when the key energy services operate. The assumptions are shown in Table 7.

Table 7: Assumed schedule of operation of key energy services in the simulated office building.

Hour of the day	Lightning	Equipment	HVAC
1	0.1	0.05	0
2	0.1	0.05	0
3	0.1	0.05	0
4	0.1	0.05	0
5	0.1	0.05	0
6	0.5	0.5	0
7	0.8	0.8	1
8	1.0	1.0	1
9	1.0	1.0	1
10	1.0	1.0	1
11	1.0	1.0	1
12	1.0	1.0	1
13	1.0	1.0	1
14	1.0	1.0	1
15	1.0	1.0	1
16	1.0	1.0	1
17	1.0	1.0	1
18	0.5	0.5	1
19	0.1	0.05	0
20	0.1	0.05	0
21	0.1	0.05	0
22	0.1	0.05	0
23	0.1	0.05	0

As per the simulation results below, the building consumes approximately a total of 4,500 kWh per month. On an annual basis, this is equal to 53,000 kWh, and when considering the total conditioned floor area, this results in an Energy Use Index (EUI:- kW/m^2/y) at 23.9 kWh/m^2/y. From an international perspective, this EUI is considered not high.

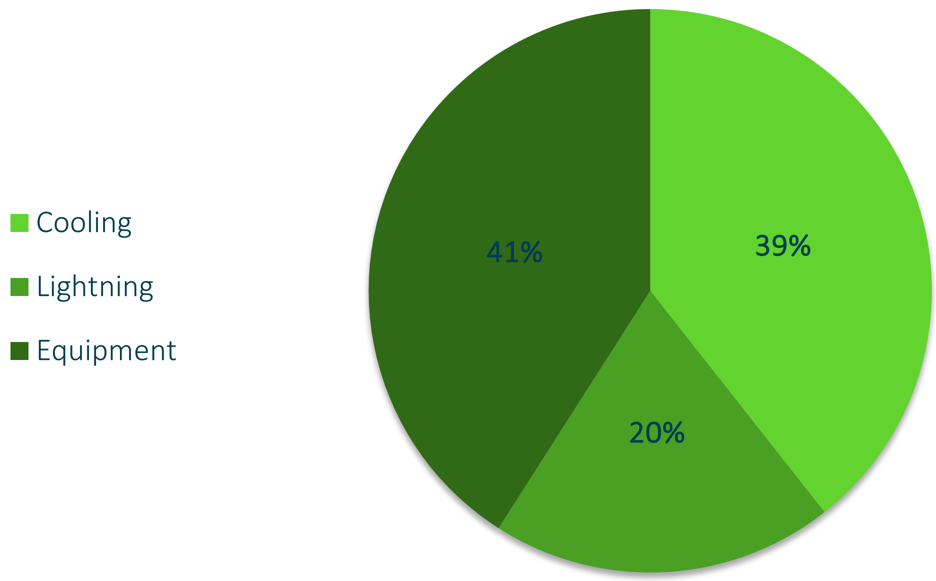


Figure 5: Summary of end-use shares of electricity consumption for the simulated office building.

The graph below shows how the simulated results compare to the measured electricity consumption. It is observed that there is a variation between the two curves, which can be explained by the weather data that is standard for one calendar year and not specific to the period of the measured data covering 2023-24.

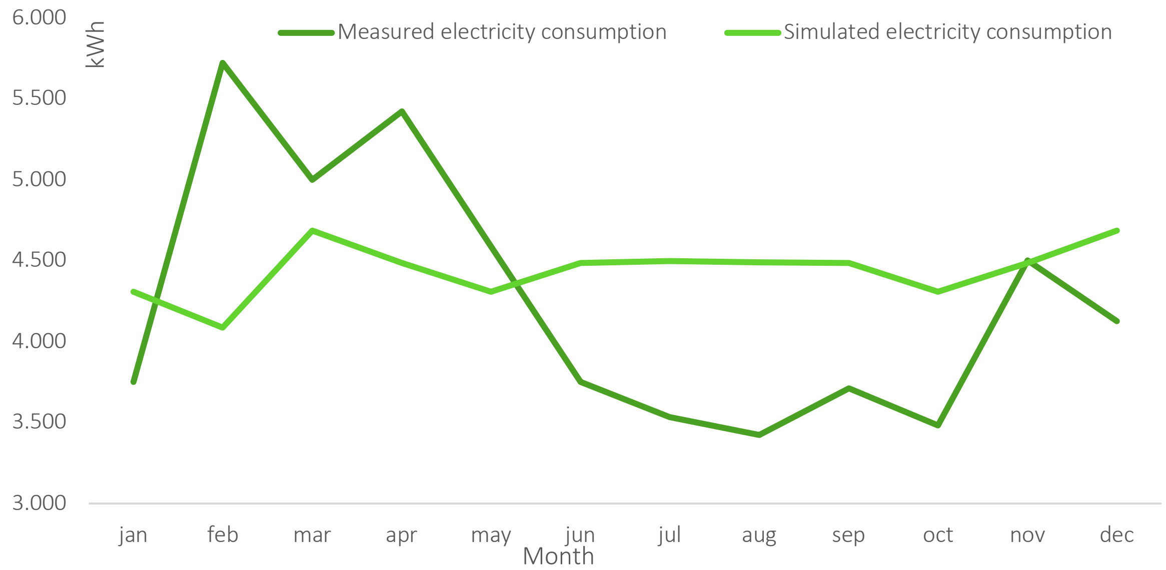


Figure 6: Measured vs Simulated electricity consumption for the simulated office building for one year (kWh).

It also appears that the actual consumption varies more month by month than the simulation estimated. This can be a result of either the variability of weather conditions for the period or special events convened at the building that impact the demand for energy services, which cannot be realistically captured in a set of assumptions for long-term performance.

The results of the simulation indicate that this office building is less sensitive to variations imposed by climate conditions over the period of the analysis. The observed variations (in actual consumption) are likely the results of conditions that fall outside normal operations for the buildings, such as hosting an event that increases occupancy, or weather that falls outside the norm. The variations due to these events are difficult to address through energy-efficient building designs, but well-designed buildings will perform better than the alternative. In this case, the building presents an EUI of around 25 kWh/m^2/y, which is considered energy efficient.

Correlation between measured and simulated data

The correlation factor between the measured data and the simulated data is 0.33. This indicates a relatively weak correlation between the two sets of data, suggesting that there are notable discrepancies between the measured and simulated values over the entire dataset. However, when focusing on the average value for the year, the simulation aligns quite well with the measured data. This means that while there are significant deviations on a more general level, the overall trend and yearly average are captured accurately by the simulation.

In summary, although the simulation may not replicate individual data points closely, it effectively approximates the general trend when considering the yearly average, suggesting that the model performs reasonably well at an annual consideration.

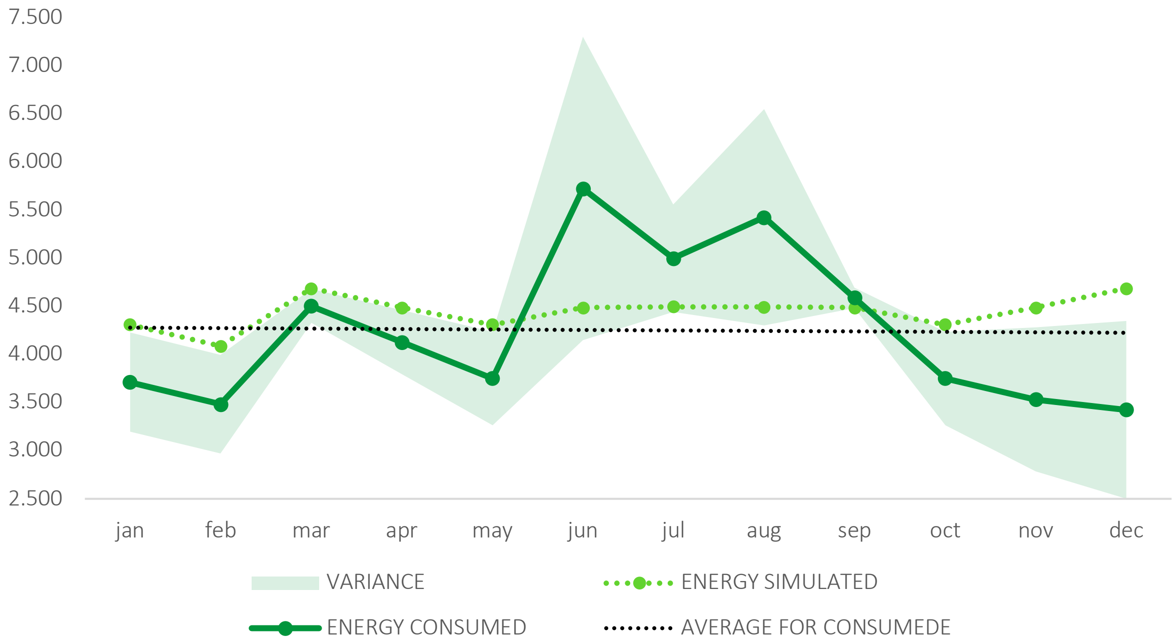


Figure 7: Correlation between measured and simulated data (source: HEAT Analysis)

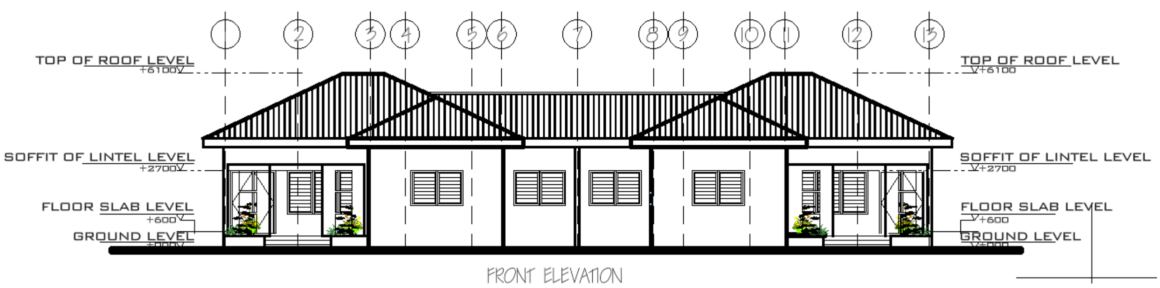
5.3.5 Residential building baseline performance simulation

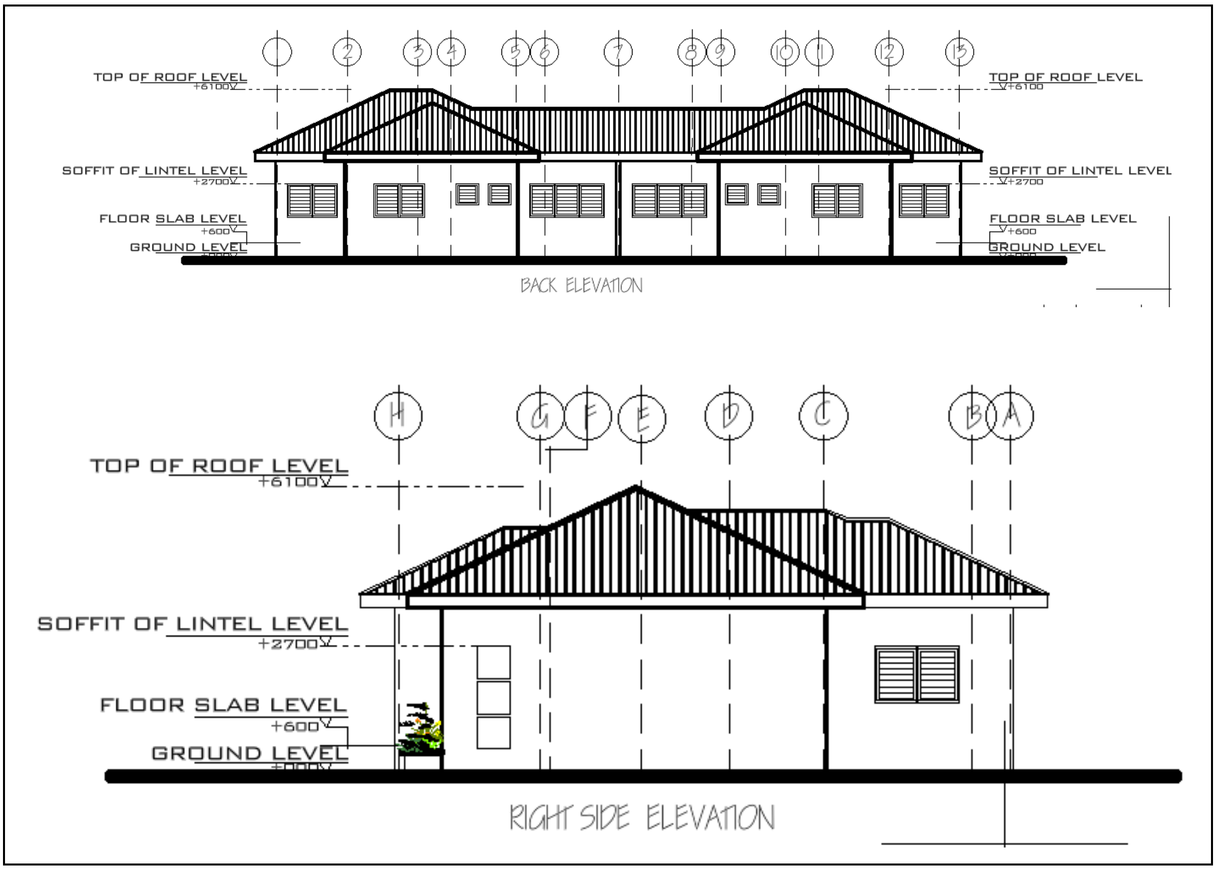
Two typical residential buildings in Ghana have been selected for detailed analysis of their energy performance. The two building types are a *single-floor residential* and a *multiple-storey apartment building*.

Single-floor residential

The cross section of a single-floor residential and a multiple-story apartment building is presented below.

Table 8: Simulated residential building drawing and specifications.

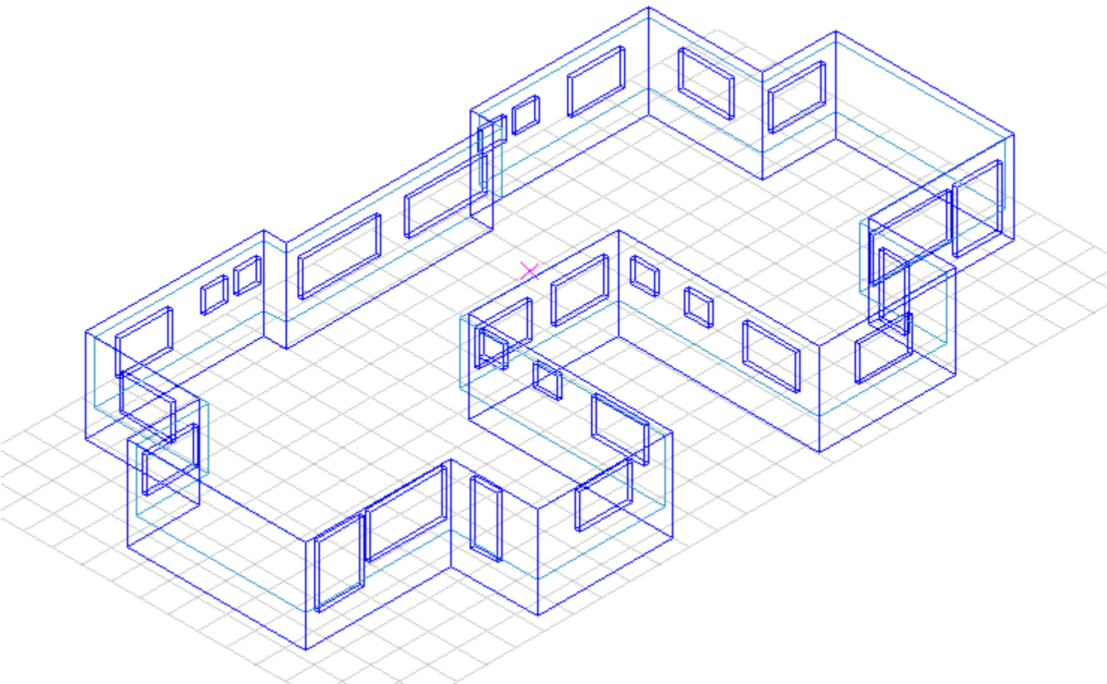
Project Name	Police service 2-bedroom – semi-detached
Building category	Residential
Total floor area (conditioned)	215 m²
	


TOP OF ROOF LEVEL
+6100
SOFFIT OF LINTEL LEVEL
+2700
FLOOR SLAB LEVEL
+600
GROUND LEVEL
BACK ELEVATION
TOP OF ROOF LEVEL
+6100
SOFFIT OF LINTEL LEVEL
+2700
FLOOR SLAB LEVEL
+600
GROUND LEVEL
RIGHT SIDE ELEVATION

Below is the baseline data for the building's structures

Parameter	Office	Note
Exterior wall construction	4.35 W/m² K	150 mm reinforced concrete
Roof	5.0 W/m² K	150 mm reinforced concrete
Floor	0.58 W/m² K	600 mm sand foundation layer 150 mm reinforced concrete
Vertical glazing performance	5 W/m²K	6 mm hard-coated glass Frame of wood, steel or plastic

The model outline



Inputs for the building's internal loads and installations:

Parameter	Office	Note
Indoor design temperature setpoint	Cooling setpoint of 24 °C	Assumed cooling effect: 3.5 W/m² on the building.
Occupancy	10 persons	Each person has a heat emission of 100 W
Internal lightning	3.25 W/m²	
Equipment allowance	3,255 W/m²	Total = 700 W

The assumed residential energy services schedule of operation for the simulated single-floor residential building is illustrated in Table 9.

Table 9: Assumed schedule of operation of energy services in the simulated residential building.

Hour of the day	Cooling		Lightning		Equipment	
	Weekdays	Weekends	Weekdays	Weekends	Weekdays	Weekends
1	1.00	1.00	0	0	1.00	1.00
2	1.00	1.00	0	0	1.00	1.00

Hour of the day	Cooling		Lightning		Equipment	
	Weekdays	Weekends	Weekdays	Weekends	Weekdays	Weekends
3	1.00	1.00	0	0	1.00	1.00
4	1.00	1.00	0	0	1.00	1.00
5	1.00	1.00	0	0	1.00	1.00
6	1.00	1.00	0	0	1.00	1.00
7	0	1.00	0	0	1.00	1.00
8	0	1.00	0	0	0.2	1.00
9	0	1.00	0	0	0.2	1.00
10	0	1.00	0	0	0.2	1.00
11	0	1.00	0	0	0.2	1.00
12	0	1.00	0	0	0.2	1.00
13	0	1.00	0	0	0.2	1.00
14	0	1.00	0	0	0.2	1.00
15	0	1.00	0	0	0.2	1.00
16	0	1.00	0	0	0.2	1.00
17	1.00	1.00	1.00	1.00	1.00	1.00
18	1.00	1.00	1.00	1.00	1.00	1.00
19	1.00	1.00	1.00	1.00	1.00	1.00
20	1.00	1.00	1.00	1.00	1.00	1.00
21	1.00	1.00	1.00	1.00	1.00	1.00
22	1.00	1.00	1.00	1.00	1.00	1.00
23	1.00	1.00	0	0	1.00	1.00

According to the simulation results below, the single-floor residential uses approximately 350 kWh per month in total. On an annual basis, this equals 4,300 kWh, and when considering the total conditioned floor area, this results in an Energy Use Intensity (EUI:- kW/m^2/year) of 20.1 kWh/m^2/year. In an international context, this EUI is considered not high.

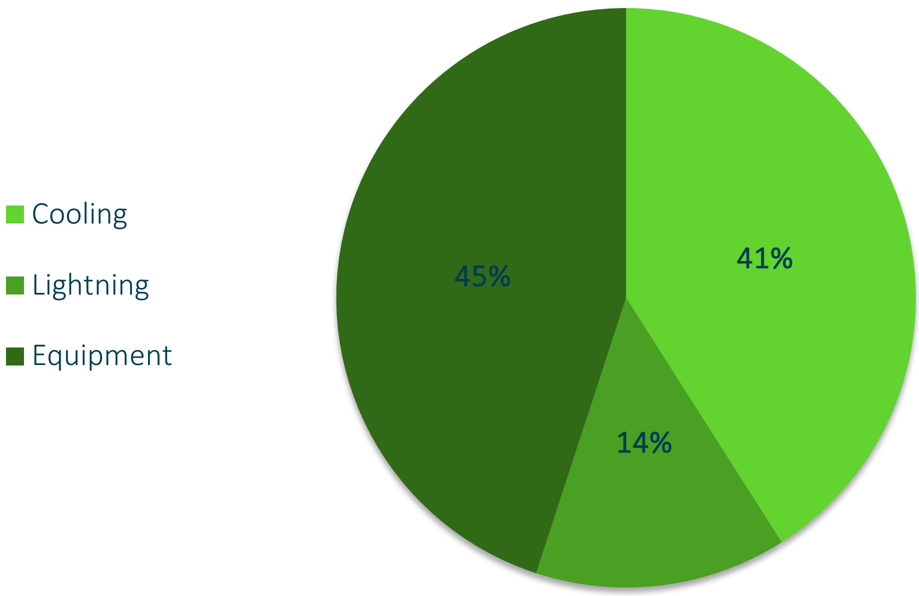


Figure 8: Summary of end-use shares of electricity consumption for the simulated single-storey residential building.

The graph below shows the simulated results for the building based on the specified inputs. The weather data used is standard for a calendar year and not specific to the period of the measured data.

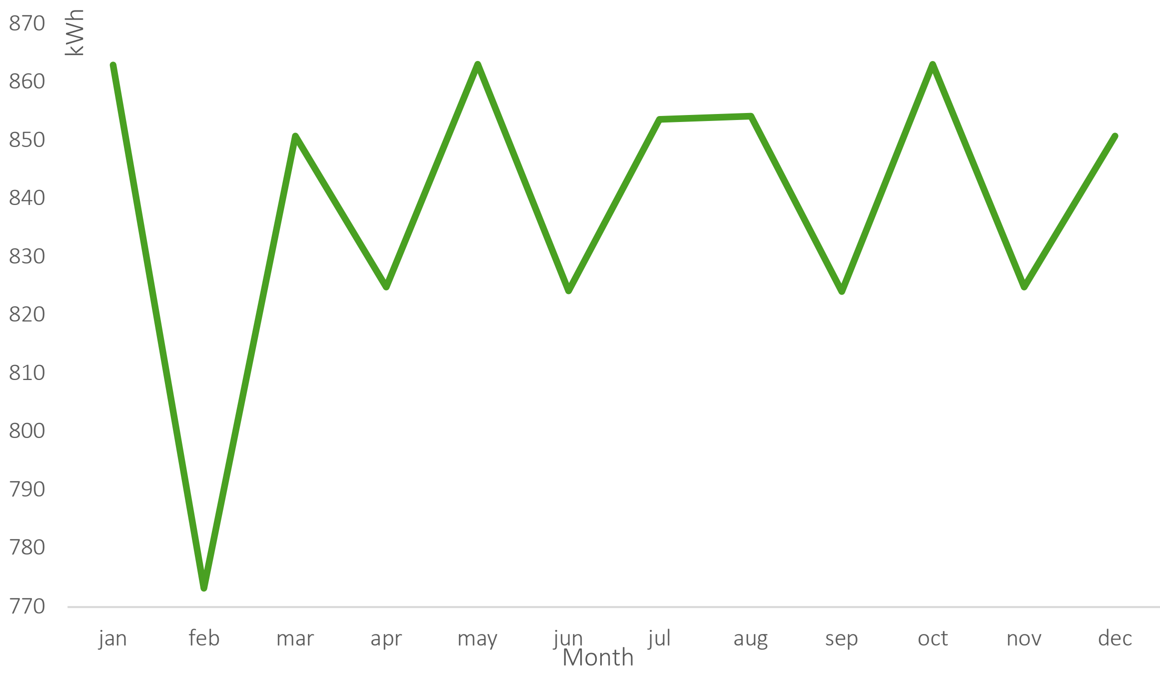
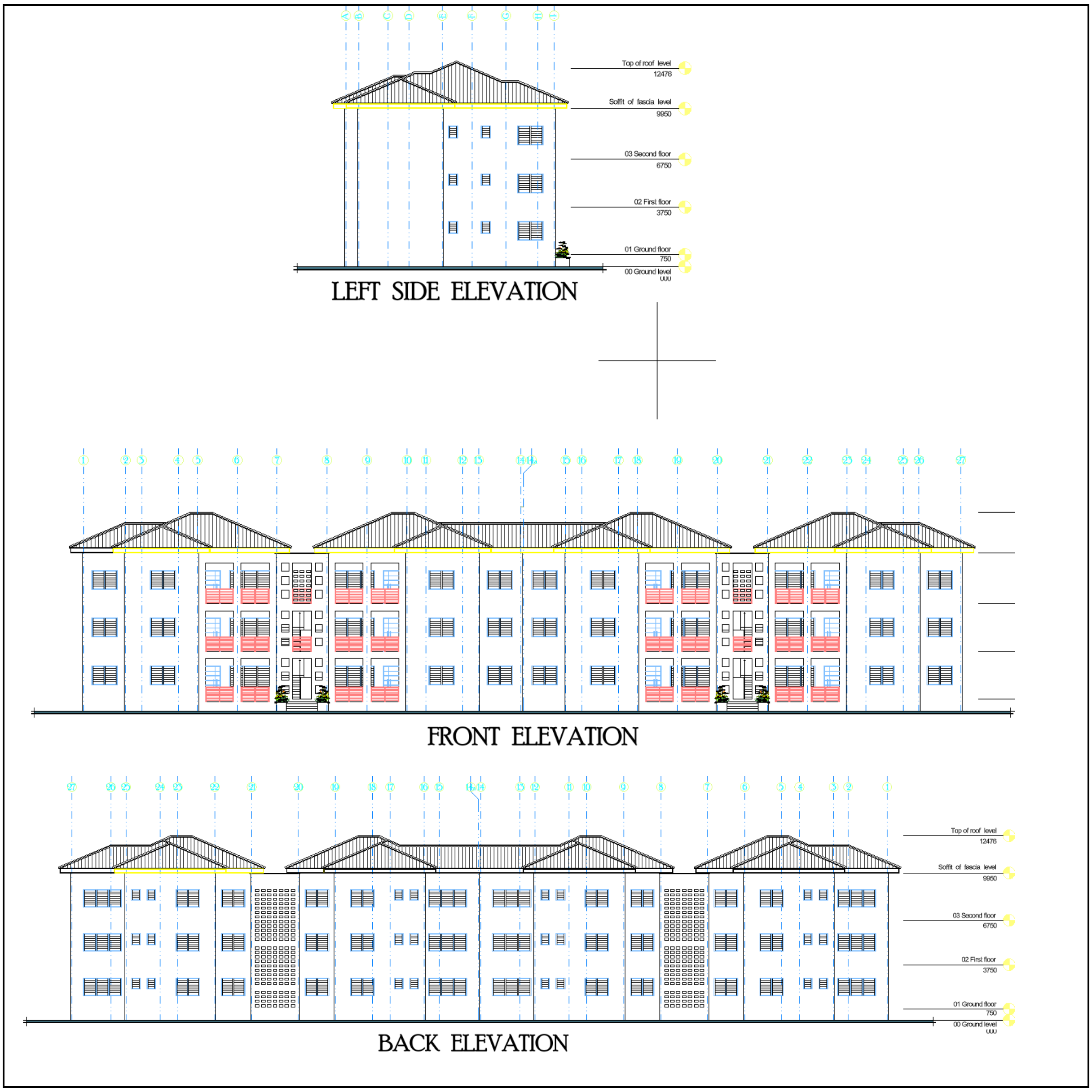


Figure 9: Simulated electricity consumption for a single-floor residential (kWh)

The simulation results indicate that this building is less sensitive to variations in climate conditions, but variations in cooling demand, equipment, and lighting have a significant impact. In this case, the electricity used in the building is evenly distributed among these parameters. The building has an EUI of 31.2 kWh/m^2/year.

Table 10: Technical drawings and specifications of the simulated multistorey building.

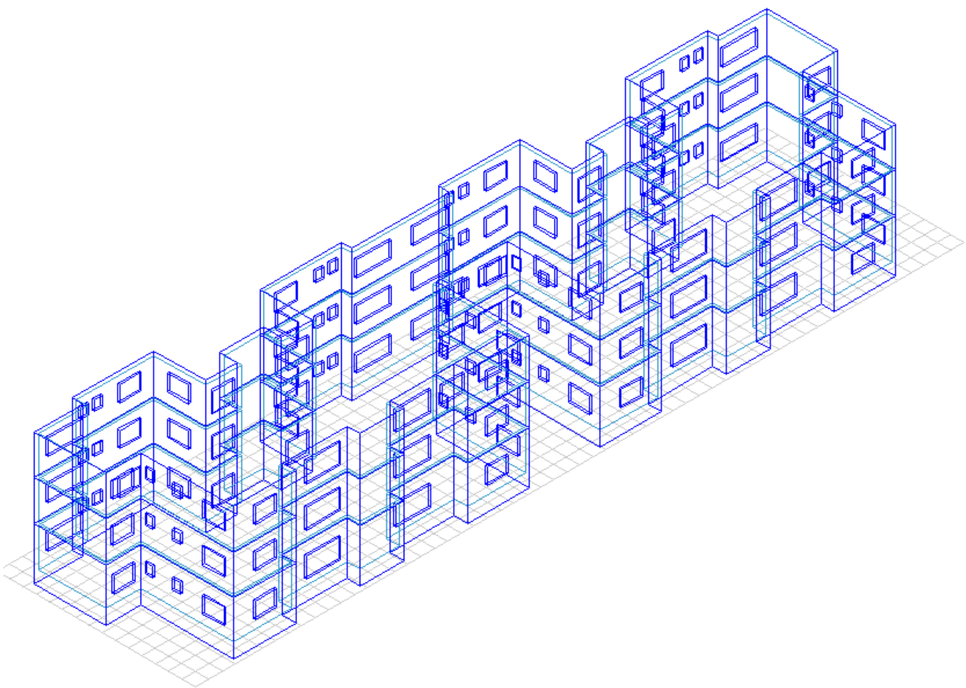
Project Name	Multiple-story apartment building
Building category	Residential
Total floor area (conditioned)	1,623 m^2


Top of roof level
12476
Soffit of fascia level
9950
03 Second floor
6750
02 First floor
3750
01 Ground floor
750
00 Ground level
UUU
LEFT SIDE ELEVATION
FRONT ELEVATION
Top of roof level
12476
Soffit of fascia level
9950
03 Second floor
6750
02 First floor
3750
01 Ground floor
750
00 Ground level
UUU
BACK ELEVATION

Below is the baseline data for the building's structures

Parameter	Office	Note
Exterior wall construction	4.35 W/m² K	150 mm reinforced concrete
Roof	5.0 W/m²K	150 mm reinforced concrete
Floor	0.58 W/m²K	600 mm sand foundation layer 150 mm reinforced concrete
Vertical glazing performance	5 W/m²K	6 mm hard-coated glass Frame of wood, steel or plastic

The model outline



Inputs for the building's internal loads and installations:

Parameter	Office	Note
Indoor design temperature setpoint	Cooling setpoint of 24 °C	Assumed cooling effect: 2 W/m² on the building.
Occupancy	50 persons	Each person has a heat emission of 100 W
Internal lightning	2.34 W/m²	
Equipment allowance	2.59 W/m²	Total = 4,200 W

The assumed residential energy services schedule of operation for the simulated multistorey residential building is illustrated in Table 11.

Table 11: Assumed schedule of operation of energy services for the simulated multistorey residential building.

Hour of the day	Cooling		Lightning		Equipment	
	Weekdays	Weekends	Weekdays	Weekends	Weekdays	Weekends
1	1.00	1.00	0	0	1.00	1.00
2	1.00	1.00	0	0	1.00	1.00
3	1.00	1.00	0	0	1.00	1.00
4	1.00	1.00	0	0	1.00	1.00
5	1.00	1.00	0	0	1.00	1.00
6	1.00	1.00	0	0	1.00	1.00
7	0	1.00	0	0	1.00	1.00
8	0	1.00	0	0	0.2	1.00
9	0	1.00	0	0	0.2	1.00
10	0	1.00	0	0	0.2	1.00
11	0	1.00	0	0	0.2	1.00
12	0	1.00	0	0	0.2	1.00
13	0	1.00	0	0	0.2	1.00
14	0	1.00	0	0	0.2	1.00
15	0	1.00	0	0	0.2	1.00
16	0	1.00	0	0	0.2	1.00
17	1.00	1.00	1.00	1.00	1.00	1.00
18	1.00	1.00	1.00	1.00	1.00	1.00
19	1.00	1.00	1.00	1.00	1.00	1.00
20	1.00	1.00	1.00	1.00	1.00	1.00
21	1.00	1.00	1.00	1.00	1.00	1.00
22	1.00	1.00	1.00	1.00	1.00	1.00
23	1.00	1.00	0	0	1.00	1.00

Based on the simulation results provided below, the building consumes approximately 2,900 kWh per month. On an annual basis, this totals 34,000 kWh, and when accounting for the total conditioned floor area, the Energy Use Intensity (EUI:- kW/m^2/year) is 21 kWh/m^2/year.

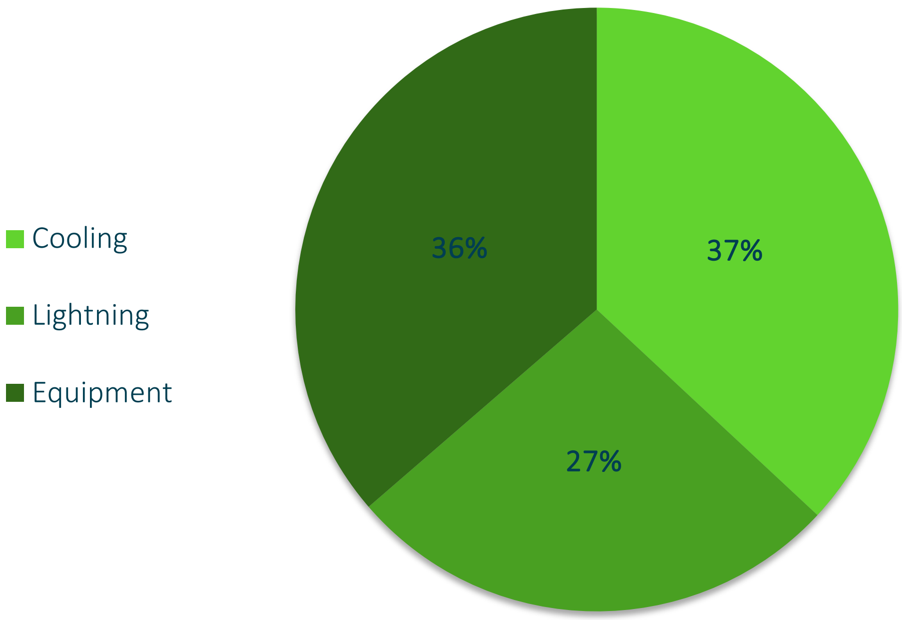


Figure 10: Summary of simulation results for a typical multiple-storey residential building.

The graph below illustrates the simulated results for the building, based on the specified inputs. Standard weather data for a calendar year was used, rather than data specific to the period of the measured information.

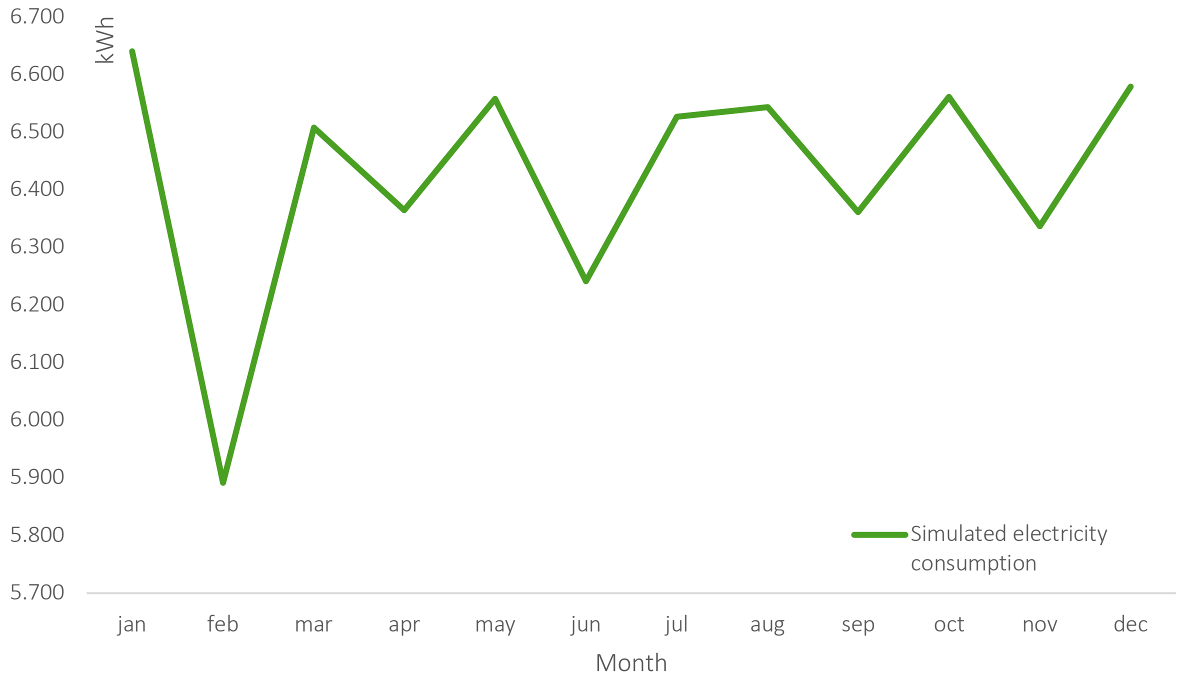


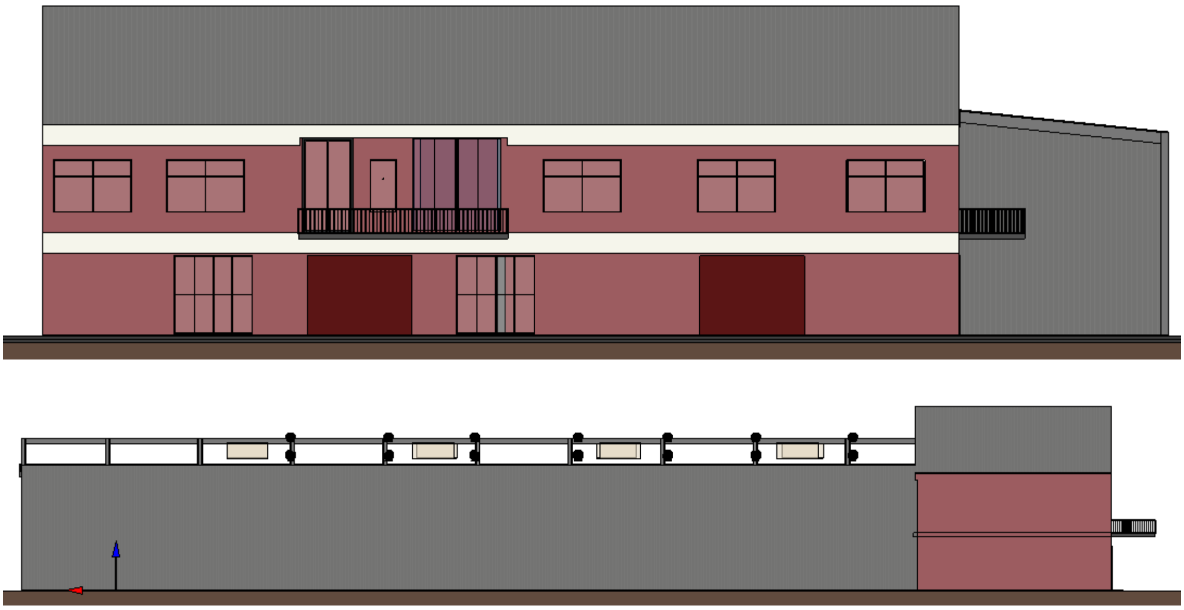
Figure 11: Simulated electricity consumption for a multiple-apartment building (kWh)

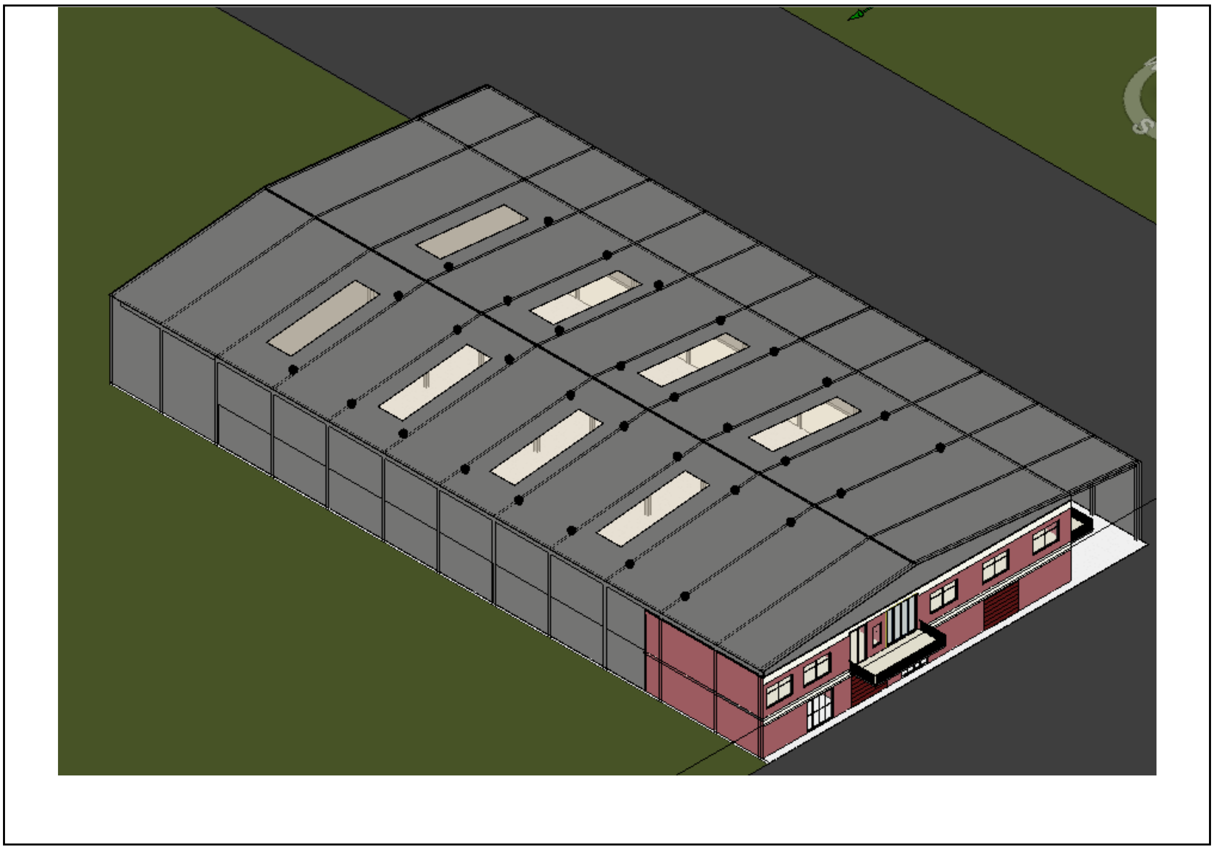
The simulation results suggest that the building's energy consumption is evenly distributed among cooling, equipment, and lighting, resulting in an EUI of 47.5 kWh/m^2/year.

5.3.6 Commercial building baseline performance simulation

A typical commercial building has been assumed based on a similar project in Africa, and the key building attributes have been transferred to the Ghana climate and context to simulate performance. It is assumed that the building specifications for this type of building are similar in Ghana, which forms the basis for a detailed analysis of its energy performance.

Table 12: Technical drawing and specifications of the simulated commercial building.

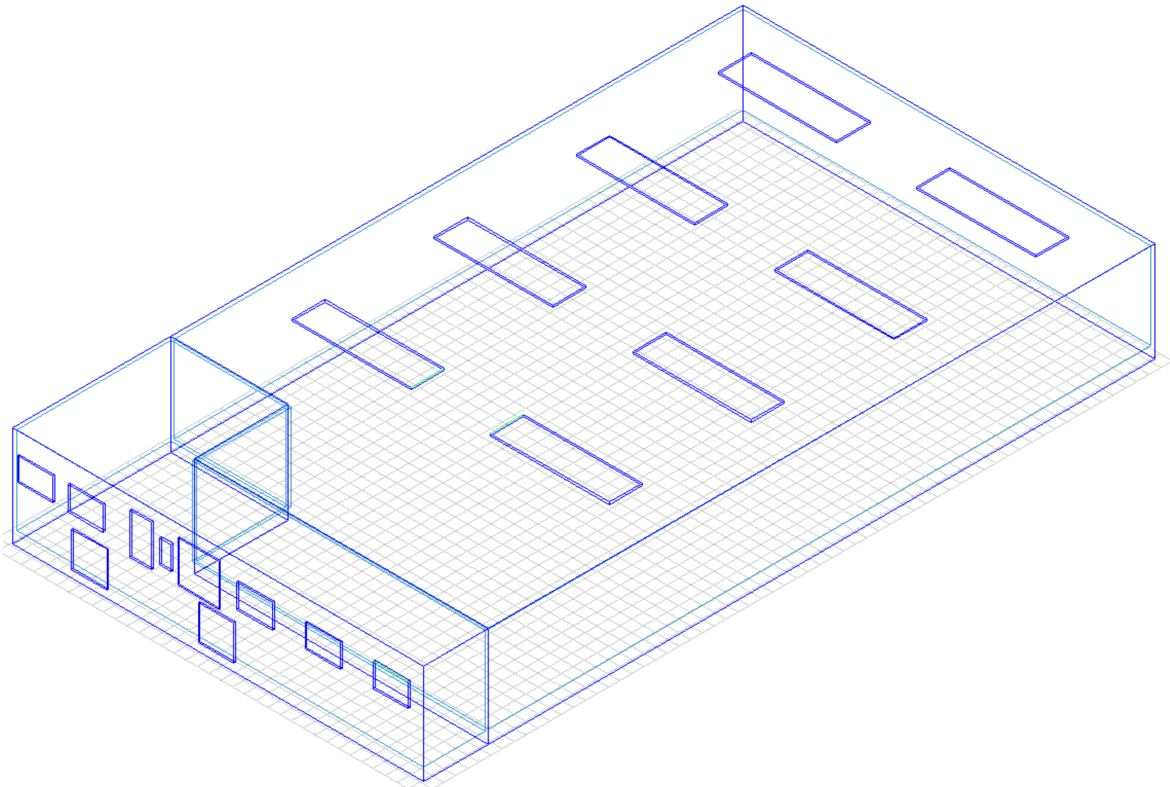
Project Name	Commercial building
Building category	Commercial
Total floor area (conditioned)	2,415 m^2
	



Below is the baseline data for the building's structures

Parameter	Office	Note
Exterior wall construction	4.35 W/m²K	150 mm Steel structure
Roof	5.0 W/m²K	150 mm Steel structure
Floor	0.58 W/m²K	600 mm sand foundation layer 150 mm reinforced concrete
Vertical glazing performance	5 W/m²K	6 mm hard-coated glass Frame of wood, steel or plastic

The model outline



Inputs for the building's internal loads and installations:

Parameter	Office	Note
Indoor design temperature setpoint	Cooling setpoint of 24 °C	Assumed cooling effect: 6 W/m² on the building.
Occupancy	600 persons	6 m² pr. Person Each person has a heat emission of 100 W.
Internal lightning	6.21 W/m²	
Equipment allowance	2.07 W/m²	Total = 5,000 W

The assumed commercial energy services schedule of operation for the simulated multistorey residential building are illustrated in Table 13.

Table 13: Assumed schedule of operation of energy services in the simulated commercial building.

Hour of the day	Cooling	Lightning	Equipment	Person load
1	0	0	0.05	0
2	0	0	0.05	0
3	0	0	0.05	0
4	0	0	0.05	0
5	0	0	0.05	0
6	0	0	0.05	0
7	0	0	0.5	0
8	0	0	0.5	0
9	1.0	1.0	1.0	0.1
10	1.0	1.0	1.0	0.3
11	1.0	1.0	1.0	0.3
12	1.0	1.0	1.0	0.5
13	1.0	1.0	1.0	0.6
14	1.0	1.0	1.0	0.6
15	1.0	1.0	1.0	0.8
16	1.0	1.0	1.0	1.0
17	1.0	1.0	1.0	0.8
18	1.0	1.0	1.0	0.5
19	1.0	1.0	1.0	0.2
20	0	0	0.5	0
21	0	0	0.05	0
22	0	0	0.05	0
23	0	0	0.05	0

The simulation results below indicate that the single-floor residence consumes around 8,000 kWh of energy each month. This translates to 97,000 kWh annually, and when the total conditioned floor area is factored in, it gives an Energy Use Intensity (EUI:- kW/m^2/year) of 40.2 kWh/m^2/year. From an international perspective, this EUI is considered relatively low.

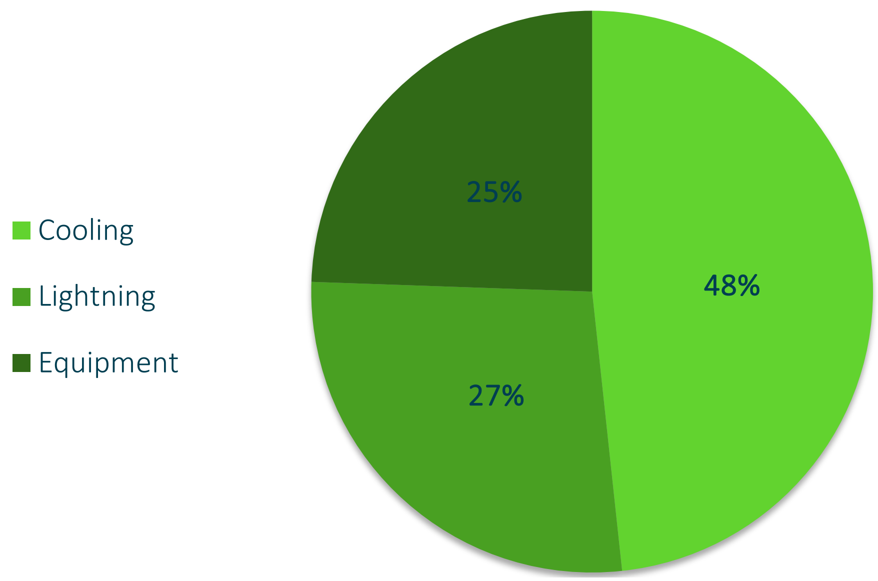


Figure 12: Summary of electricity demand end-uses for the simulated commercial building

The graph below shows the simulated results for the building based on the specified inputs. The weather data used is standard for a calendar year and not specific to the period of the measured data.

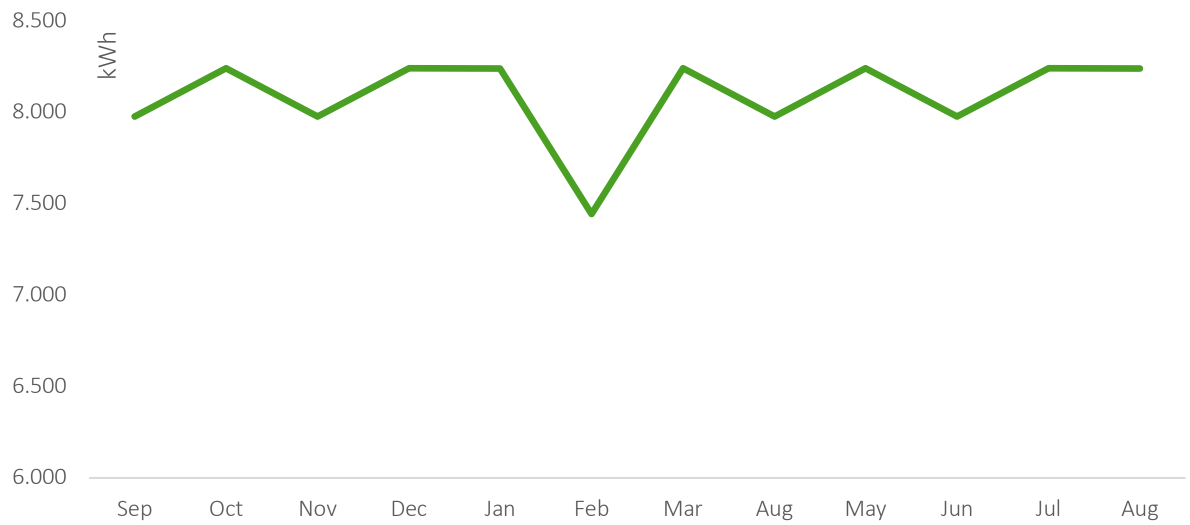


Figure 13: Simulated electricity consumption for a commercial building (kWh)

The simulation results show that the building is not highly affected by changes in climate conditions. However, fluctuations in cooling requirements, equipment usage, and lighting have a notable effect. In this instance, electricity consumption within the building is distributed fairly evenly across these factors. The building's Energy Use Intensity (EUI) stands at 40.2 kWh/m^2/year.

5.3.7 Analysis of performance in different climate zones

A simulation has been carried out for the office building presented under section 6.3.4, applying weather data representing the climate for the location of Tamale. The result of this simulation is presented in the figure below and shows that there are only very small differences in the monthly electricity consumption compared with those measured and simulated for Accra, and the annual consumption differs by less than 0.1%.

This indicates that in relation to the task of developing minimum energy efficiency standards/requirements for Ghana, nationwide minimum requirements are realistic and applicable for the whole country and even with the climate variations that can be experienced on some occasions.

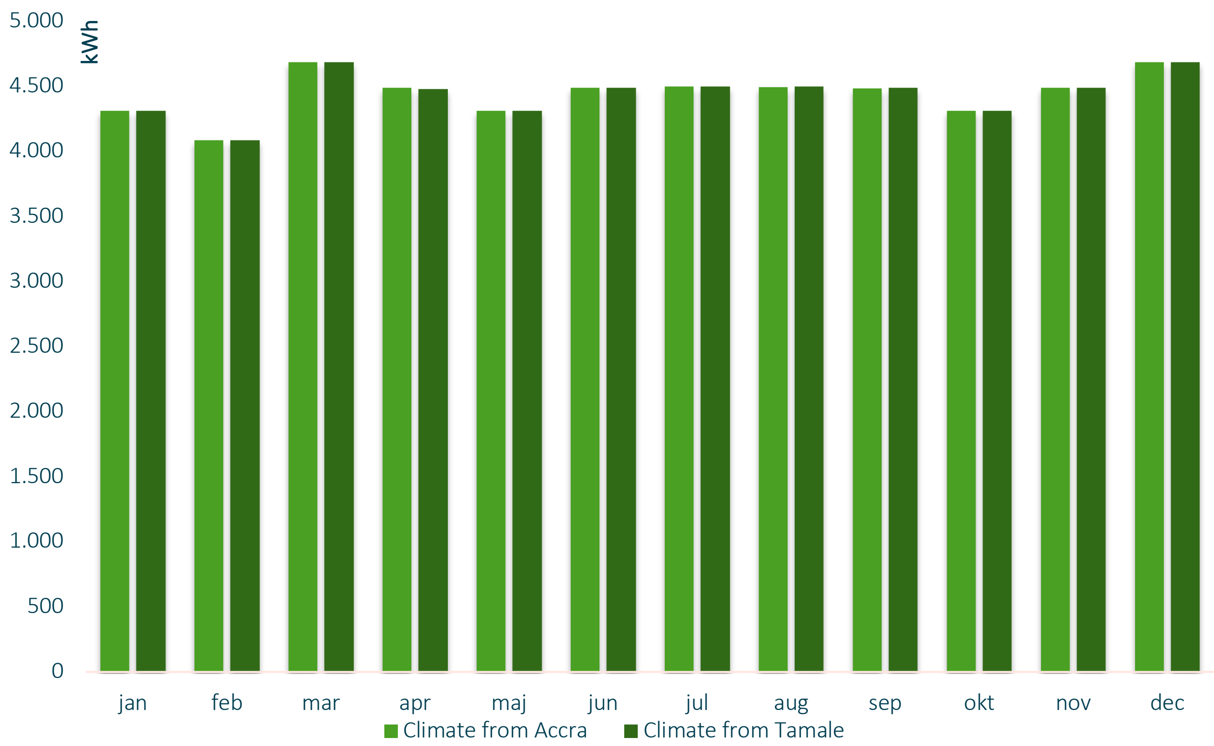


Figure 14: Electricity consumption in an office building located in two different climate zones (Accra vs Tamale).

5.4 Energy performance of buildings in Ghana

Considering that the proposed GBS does not encompass the entire building sector in Ghana, a top-down methodology was deployed, utilising macroeconomic data such as GDP, population statistics, and overall energy demand statistics, and it was enriched with results from the building simulations presented in section 5.3. While the general application of top-down methodologies usually is unable to provide detailed building-specific insights, in this case, the availability of building-specific performance simulation results provides another source of data to strengthen the results and increase the accuracy and value of the results.

This makes it particularly valuable for developing energy demand projections and emissions reduction scenarios, as well as informing the generation of the Green Building Standard.

The key data employed for the implementation of this methodology include the following:

1. Population statistics:
    a. Total population – World Bank.
    b. Population projections until 2050 – World Bank.
    c. Number of people per household – Ghana Statistical Service.
2. Economic statistics

a. Constant price GDP – World Bank

b. GDP growth assumptions – Estimated and assumed from the available GDP statistics.

3. Electricity statistics

a. Total electricity generation – Ghana profile of the IEA.

b. Consumption by sector (residential and commercial, including public buildings) – Ghana profile of the IEA.

c. Assumptions of electricity demand increases by sector (residential and commercial) – Assumed from population and economic statistics.

d. Electrification rates – World Bank

e. Price of electricity – Statista.

4. Emission factors

a. Grid emissions factor for Ghana – IGES.

The methodology begins by analysing electricity consumption in the commercial and residential sectors to estimate total electricity demand per household. This calculation is based on the overall electricity generation total and the residential sector's share of this total, divided by the estimated number of households in the country. It assumes that electricity demand will grow proportionally with the increase in the number of households and, as household incomes rise with national development, per-household electricity consumption will also increase.

The growth in energy demand is estimated by examining overall commercial electricity consumption. This figure is then adjusted using a growth factor linked to GDP growth, assumed to be 3% based on historical trends. This rate accounts for both periods of high growth and years of economic downturn over the past decade.

The projections presented focus exclusively on electricity consumption, reflecting the assumption that the benefits of the Green Building Standard (GBS) will primarily influence electricity-dependent end uses, such as air conditioning, lighting, and other building systems. These uses are directly aligned with the energy efficiency improvements targeted by the GBS. In contrast, other energy uses in the residential and commercial sectors, such as cooking and water heating, are expected to be less affected by the implementation of the GBS, as these activities often rely on other energy sources or are not directly addressed by the standard's measures. This focused scope ensures that the projections remain aligned with the primary areas of impact anticipated under the GBS framework.

5.4.1 Energy demand in buildings in Ghana

While 87% of households in Ghana are electrified (IEA, 2024), over three-quarters of energy demand in Ghanaian households is in the form of wood and charcoal for cooking, water heating and some lighting (ISSER, 2021). Added to this, LPG is widely used in urban areas for cooking and water heating. However, it is essential to consider that the usually inefficient use of fuel and charcoal would result in significantly increased total demand for these fuels compared to the other end-uses.

The continued reliance on traditional biomass for energy is both unsustainable and environmentally detrimental, contributing to issues like land degradation, deforestation, and the destruction of biodiversity habitats. Furthermore, this dependence exacerbates poverty and gender inequality, as significant time and labour, primarily from women, are required for collecting these resources. Such demands on women’s time limit opportunities for education, income generation, and social mobility. Given these challenges, development policies, including the Green Building Standards (GBS), are expected to prioritise transitioning from traditional biomass to greener, modern energy solutions such as electricity. This shift has the potential to alleviate environmental pressures, promote gender equity, and support sustainable development.

The combined demand for electricity of the commercial and residential sectors (buildings sector) accounts for over 57% (41% residential and 17% commercial) of the country's total, accounting for just over 10,000 GWh in 2022. Assuming a 479 tCO2e per GWh emissions factor, electricity demand from buildings represents emissions of around 4.82 $MtCO_2e$.

The residential component of this total is 7,107 GWh, which, divided among the 8.1 million households, indicates an average electricity demand per household of around 875 kWh per year in 2022. The residential demand for electricity has been increasing at a CAGR of 5.4% since 2010, almost doubling demand. However, the increases in population and electrification rates meant that the total number of households demanding electricity increased at a faster pace (6.7%), resulting in an overall decrease in electricity demand at a household level between 2010 and 2022. This may be explained by a lower level of consumption of the households that have been most recently added to the electricity system.

In terms of commercial electricity demand, electricity demand increased at a CAGR of 4.5% compared to a GDP growth rate of 5.7%, indicating that the general economic growth of Ghana is more associated with the primary (agriculture/mining) and the secondary (manufacturing/industrial) sectors rather than commercial services. However, it should be expected that commercial sector energy demand will follow economic growth in the country.

The robust implementation of GBS in this context can have a transformative effect to transition to a more sustainable economic growth path, addressing the dual challenges of rapid population growth and economic expansion. By integrating energy-efficient designs, renewable energy technologies, and resource-conscious construction methods, green buildings can significantly reduce energy demand, lower greenhouse gas emissions, and minimise waste. This is particularly impactful in urban areas where the surge in housing and commercial developments often leads to sprawling, inefficient infrastructure.

5.4.2 Projections to 2050

To project electricity demand and the related emissions out to 2050, the methodology considers the population growth, economic growth, and electricity demand per household. For this, the projected population in 2050[3] is over 52 million, a 56% increase from the 2022 levels, which is accompanied by an observed pattern of household size reduction and the continued electrification, resulting in a significant increase in the number of households connected to the grid to an estimated 15.5 million households. This assumes that household size reduces gradually to 3.2 persons per household by 2050 and that electrification rates reach 95%.

At the same time, the demand for electricity per household increases to 1,525 kWh per year (a 74% increase on the 2022 total) as households increase demand for electricity services such as cooling, electronic equipment, and appliances, as well as slowly transition away from traditional biomass. This is a conservative estimate assuming that the transition away from traditional biomass is not accelerated through government interventions.

In the case of commercial growth, an average GDP growth rate of 4% was assumed, considering the aggressive growth observed in the last decade (aside from the COVID years). Further, a 1% annual intensity increase was also assumed to account for increased demand for electricity services by businesses as they become wealthier, formalise, and look to emulate commercial buildings in developed countries.

Based on this, total energy demand from the building sector increases from 10,072 GWh in 2022 to 35,265 GWh by 2050, a 350% increase over the period. In terms of the residential sector, electricity demand increases to 23,640 GWh, a 330% increase, while the commercial sector increases at a faster pace (nearly 400%) to 11,626 GWh (Figure 15).

[3] World Bank data- *https://databank.worldbank.org/source/population-estimates-and-projections#*

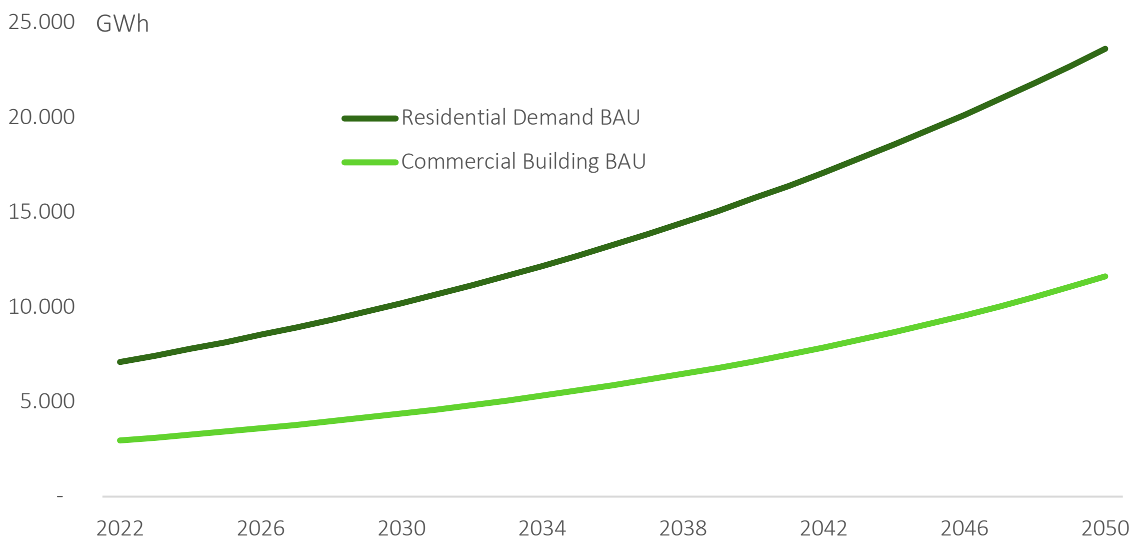


Figure 15: Electricity consumption trend in buildings in Ghana 2022-2050 (Source: HEAT Analysis).

5.4.3 Emissions reduction potentials

The potential energy and emissions reductions from the implementation of a GBS can be very significant, as the technologies exist for the development of zero energy buildings that effectively draw no energy from the grid through a combination of design elements, energy efficient technologies, and renewable energy on-site [US DOE, 2015]. However, it is not reasonable to expect this from a nationally implemented programme in an emerging economy. As such, savings between 20 and 30% have been assumed for these projections in line with the suggested impacts seen in the literature (Opuku et. Al, 2019) and follow logical premises including:

- The ambition of the initial GBS is not expected to be as high as leading standards, and it is not practical to go from no standards to leading standards.
- The ability to enforce the standards will be limited in the beginning, leading to lower gains that would otherwise be possible.

Considering the 20% reduction assumption, and assuming that the building stock is generally replaced every 50 years, the projected energy demand reductions for the buildings sector are 5,991 GWh by 2050 or a 17% reduction from BAU. This results in the reduction of GHG emissions of 2.9 million tonnes of CO_2 equivalent.

The residential sector is projected to contribute 3,980 GWh to the overall reduction in electricity demand through the implementation of a Green Building Standard (GBS), resulting in a reduction of 1.9 $MtCO_2e$, or two-thirds of the total emissions reductions projected compared to the Business as Usual (BAU) scenario for 2050.

In contrast, the commercial sector is projected to achieve demand reductions of 2,011 GWh and 963 $ktCO_2e$ in emissions savings. Due to the significantly larger initial demand of the residential sector during this period, its energy and emissions savings are much greater. While these figures are indicative, the trends they represent are considered reliable and reflect a realistic development scenario for the building sector.

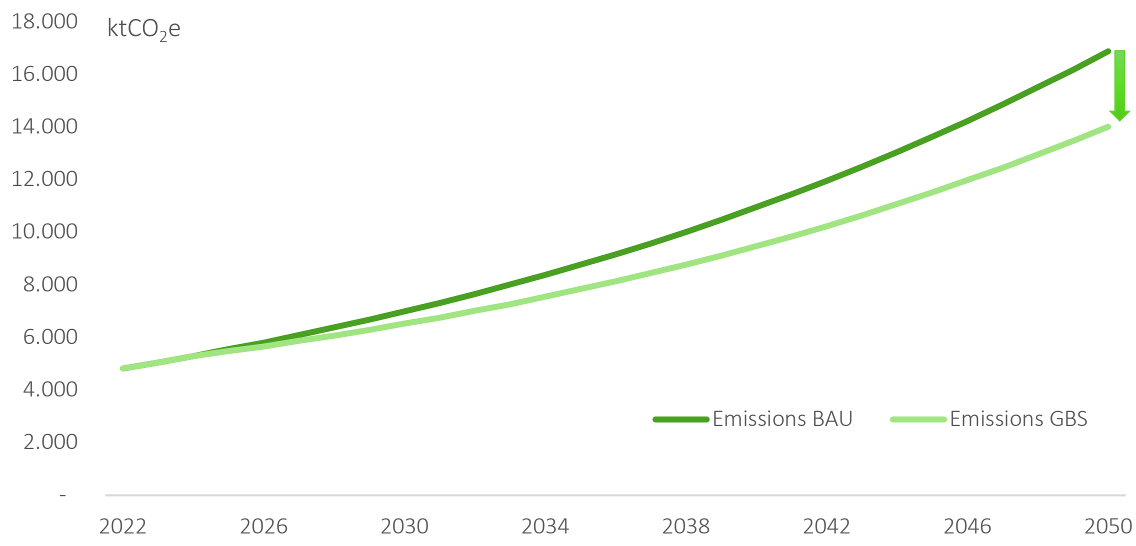


Figure 16: GHG Emissions projections for the building sector BAU vs GBS scenario 2022-2050 (source: HEAT Analysis).

6 Advanced energy efficiency building materials and technologies database

This GBS represents a significant step toward improving building performance and improving the sustainability of the country's building environment. As one of the largest energy-consuming sectors in Ghana (and globally), particularly electricity and biomass, it is important to adopt advanced technologies that enhance energy efficiency, reduce greenhouse gas emissions, and align with global climate goals. The GBS emphasises energy efficiency and conservation across various building components, including the building envelope, HVAC systems, lighting, water heating, renewable energy integration, and the implementation of building systems and controls.

For this, a database has been developed to provide an overview of advanced technologies that are aligned with the standards outlined in the code. These technologies are intended to guide architects, engineers, builders, and developers in selecting and integrating energy-efficient solutions that meet or exceed the performance requirements of the BEEC.

6.1 Purpose of the database

The purpose of this database is to serve as a practical resource for stakeholders involved in the design, construction, and operation of buildings in Ghana. It offers detailed information on state-of-the-art technologies that can be applied across various components of a building to enhance energy efficiency, reduce operational costs, and promote environmental sustainability.

Each entry in this database includes the following key details:

- **Technology Name:** The specific name of the technology.
- **Component**: The relevant building component (e.g., HVAC, Lighting, Renewable Energy).
- **Description**: A brief explanation of how the technology works and its benefits.
- **Application**: Practical applications of the technology within different building types.
- **Impact**: The environmental and economic impacts of implementing the technology.

- **Certification/Standard Alignment**: This sector shows alignment with the BEEC and other well-recognised international green building standards such as LEED and BREEAM.

6.2 Scope and structure

The database is structured around the key energy components that are outlined in the BEEC, reflecting the critical areas where energy savings and efficiency can be maximised:

- **Building Envelope**: Technologies that improve the insulation, glazing, and overall thermal performance of building exteriors.
- **HVAC Systems**: Advanced heating, ventilation, and air conditioning solutions that reduce energy consumption and enhance indoor comfort.
- **Lighting**: Energy-efficient lighting technologies and controls that reduce electricity usage while maintaining optimal lighting quality.
- **Water Heating**: Systems that provide efficient and sustainable hot water solutions, leveraging renewable energy where possible.
- **Renewable Energy**: Integration of renewable energy sources such as solar PV and battery storage to reduce reliance on non-renewable energy.
- **Building Systems and Controls**: Automation and control systems that optimise the operation of building energy systems to minimise waste and improve performance.

It is important to note that this database is not intended as a final, static component, but rather a living document that is maintained to reflect changes in technology, changes in the BEEC, changes in the key priorities of the government of Ghana, and changes in the building environment.

6.3 Options to integrate the database into the standards development and implementation

As a repository of knowledge, the use and integration of this database into the development and implementation of the BEEC can take several practical forms, depending on the desired regulatory approach. Below are some potential ways this integration can be realised:

- The database can serve as a **voluntary reference tool** for architects, builders, and developers to aid their knowledge. They can consult the compendium to explore the latest energy-efficient technologies, sustainable building materials, and design strategies.
- It can be positioned as a guideline that would detail the methods, technologies, and materials recognised as best practices recommended for achieving energy efficiency requirements in the BBEC. This would provide clear avenues on how to comply with regulations without being a mandatory component of the standard itself. This would not be mandatory, but it would form part of the implementation documentation and ensure that all of these are considered during the building construction process.
- For more stringent enforcement, the database could become a mandatory component of building standards. Developers would be required to reference or incorporate the technologies and practices listed to meet regulatory approval. This could be tied to specific building permits, with authorities checking compliance against the database as part of the permitting and inspection process.
- The database could provide a framework for buildings to be certified based on the technologies and practices they use. It could offer specific benchmarks for energy consumption, emissions reduction, and other performance metrics, where buildings are assessed and awarded points for meeting specific green benchmarks. This would enable the establishment of a clear, objective measure of sustainability that can guide building projects and encourage higher levels of performance.

- The database could be structured to include feedback from ongoing projects and real-time data on the performance of green building solutions. This feedback loop would allow building standards to evolve based on actual performance data, helping to refine existing standards and adapt them to new technologies. Building professionals could contribute their experiences, which would be incorporated into the database for future users, creating a dynamic and continuously improving resource.

It is recommended that Ghana evaluates the value of such a tool, including the possibility of expanding on it, as well as the regulatory appetite to define a way to integrate it into the formal BEEC enforcement process.

6.4 GBS Database

6.4.1 Building insulation

This category comprises advanced insulation materials with high R-values, providing superior thermal resistance, thereby reducing heat loss in cold climates and heat gain in warm climates. Key examples include:

Type	Examples	Description	Application	Performance
High-performance insulation material	Aerogel Insulation	Aerogel is a lightweight material with high insulating properties, consisting of over 90% air trapped in a silica matrix. It has one of the highest R-values per inch of any insulation material, making it ideal for applications where space is limited but high insulation performance is required.	Used in walls, roofs, and floors in both new construction and retrofit projects. It's particularly effective in building envelopes and areas requiring minimal thickness. Significantly reduces thermal bridging and overall heat transfer, contributing to lower energy consumption for heating and cooling.	R-10 to R-30 per inch of thickness.
Spray foam insulation (open-cell and closed-cell)	Expanding foam insulation	Spray foam insulation expands upon application, filling gaps and providing a continuous barrier that reduces air leakage. Closed-cell spray foam is denser and offers a higher R-value per inch, making it suitable for areas where space is at a premium. Open-cell spray foam is less dense and offers soundproofing benefits along with insulation.	Commonly used in walls, roofs, and floors, particularly in irregular spaces where traditional insulation might not fit well. Provides superior air sealing, reducing thermal bridging and improving overall building energy efficiency.	• Open-Cell: R-3.5 to R-4.0 per inch. • Closed-Cell: R-6.0 to R-7.0 per inch.
Vacuum insulated panels (VIPs)	High-Performance Insulation Panels	VIPs consist of a core of fumed silica encased in a gas-tight envelope, creating a vacuum that	Used in walls, roofs, and floors, particularly in retrofits where	R-25 to R-30 per inch

Type	Examples	Description	Application	Performance
		provides outstanding thermal insulation. These panels are thin yet highly effective, making them ideal for applications where space is limited.	adding thick insulation might be impractical. Reduces heat transfer, making it possible to meet strict energy codes without sacrificing interior space.	
Rigid foam insulation (polyisocyanurate, extruded polystyrene, expanded polystyrene)	Rigid Board Insulation	Rigid foam insulation boards are available in various types, each offering different levels of thermal resistance and moisture control. Polyiso has the highest R-value per inch among rigid foams and is often used in above-grade walls and roofs. XPS and EPS offer good insulation with varying levels of moisture resistance.	Suitable for walls, roofs, and foundations. They are often used in continuous insulation applications to reduce thermal bridging.	• Polyisocyanurate (Polyiso): R-6.0 to R-6.5 per inch • Extruded Polystyrene (XPS): R-5.0 per inch • Expanded Polystyrene (EPS): R-3.6 to R-4.0 per inch
Mineral wool insulation	Fibrous insulation material	Mineral wool, made from natural or recycled materials, offers both thermal insulation and fire resistance. It is available on batts or rigid boards and is known for its ability to withstand high temperatures.	Ideal for walls, roofs, and floors where both thermal and fire resistance are important. It is also commonly used in acoustic insulation. Provides a balance of thermal performance, soundproofing, and fire protection, contributing to overall building safety and energy efficiency.	• R-3.7 to R-4.2 per inch
Reflective insulation and radiant barriers	Reflective Foil Insulation	Reflective insulation and radiant barriers use reflective materials to reduce heat transfer by reflecting radiant heat rather than absorbing it. These materials are particularly effective in hot climates, where they help to keep buildings cool by reflecting solar radiation away from the building envelope.	Commonly used in attics, walls, and roofs, particularly in regions with high solar exposure. Reduces cooling loads in hot climates, contributing to lower energy consumption and increased occupant comfort.	It varies, primarily reducing radiant heat gain.

6.4.2 Windows

Windows affect not only the aesthetics of a building but also its energy efficiency, indoor comfort, and overall environmental impact. Choosing the right type of window glazing—whether double or triple glazing—can significantly influence a building's thermal performance, daylighting, and energy costs.

Type	Examples	Description	Application	Performance
Double-glazed windows		Double-glazed windows consist of two panes of glass separated by a spacer filled with air or inert gas (such as argon or krypton). This design reduces heat transfer through the window by trapping air between the glass layers, which acts as an insulator. Low-E (low emissivity) coatings can be applied to one or more panes to further reduce heat loss and improve energy efficiency. Double glazing improves energy efficiency, soundproofing, and daylighting, although not as effectively as triple glazing, but provides significant gains at a lower cost.	Often applied to residential and commercial buildings to achieve moderate energy savings while maintaining affordability.	**U-Value:** Typically, 1.6 to 3.0 W/m²K. Lower U-values indicate better insulation. **Solar Heat Gain Coefficient** (SHGC): Usually ranges from 0.3 to 0.6, balancing solar heat gain with natural light.
Triple Glazing		Triple-glazed windows consist of three panes of glass with two spacers filled with air or inert gas. This design provides even greater insulation than double glazing, making it ideal for buildings in colder climates or those aiming for very high energy efficiency standards. Low-E coatings and gas fillings (argon or krypton) further enhance the performance by reducing heat transfer and improving overall energy efficiency.	**Residential Buildings**: Used in high-performance homes, such as passive houses, where maximum energy efficiency is a priority. **Commercial Buildings**: Installed in office buildings and educational facilities, aiming for the highest energy performance standards, particularly in colder climates or noise-sensitive areas.	**U-Value**: Typically, 0.15 to 1.2 W/m²K, offering superior insulation. **Solar Heat Gain Coefficient (SHGC)**: Typically ranges from 0.2 to 0.4, providing better control over solar heat gain.
Wall-to-window ratio (WWR)	Building design feature.	WWR is the proportion of a building's exterior wall area that is made up of windows. This	Residential and commercial buildings: Relevant for all building types,	For energy efficiency, a WWR of 30-40% is recommended in

Type	Examples	Description	Application	Performance
		ratio is a critical factor in the thermal performance of a building's envelope, as windows generally have lower insulation values (higher U-values) compared to walls. Optimising the WWR involves balancing natural light and views with energy efficiency, ensuring that the building minimises heat loss in colder climates and reduces heat gain in warmer climates.	especially in climates with significant temperature variations or where energy efficiency is a priority. The WWR should be carefully considered during the design phase to optimise both daylighting and thermal performance.	many climates. This allows for adequate daylight while minimising excessive heat loss or gain. Higher WWRs (e.g., above 40%) increase the need for enhanced glazing options, such as double or triple glazing, to maintain energy efficiency. Lower WWRs (below 30%) may reduce the need for advanced glazing but limit natural light, increasing lighting needs.
Dynamic glazing (electrochromic windows)	Electrochromic Glazing (Smart Windows)	Dynamic glazing allows windows to change their tint in response to light conditions, heat, or even manual controls. This technology enables users to optimise the amount of light and heat entering a space without the need for blinds or shades. The glass can darken to reduce solar heat gain during the day or clear to allow maximum light during cloudy conditions.	**High-Performance Buildings**: Used in buildings where control over solar gain and glare is critical, such as office buildings with large glass facades. **Commercial and Institutional Buildings**: Ideal for spaces where occupant comfort and energy efficiency are high priorities, such as educational institutions and healthcare facilities.	**U-Value**: Typically, 0.29 to 0.5 W/m²K depending on the base glazing used (double or triple glazing). **Solar Heat Gain Coefficient** (SHGC): Variable, ranging from 0.1 to 0.5, depending on the level of tint.

6.4.3 Cool Roofs

Cool roofs are another strategy for improving the energy efficiency of buildings, particularly in warm climates like Ghana's. These roofs are designed to reflect more sunlight and absorb less heat than standard roofs, which can significantly reduce the cooling load on buildings, lower indoor temperatures, and enhance occupant comfort.

The key performance metrics are:

- **Solar Reflectance Index (SRI)**: SRI is the key performance metric that combines solar reflectance and thermal emittance into a single value. In the Ghana context, cool roofs with an SRI of 78 or higher for flat roofs and 29 or higher for sloped roofs are ideal. The higher the SRI, the better the roof is at reflecting solar radiation and staying cool.
- **Thermal Emittance**: This is the ability of the roof material to release absorbed heat. High thermal emittance indicates that the roof does not retain heat.

Type	Examples	Description	Application	Performance
Reflective coatings	Acrylic-based reflective coating	Reflective coatings are applied to existing roofs to improve their solar reflectance. These coatings are typically white or light-coloured and contain special reflective pigments that can bounce back a significant portion of the sun's rays.	Suitable for both new and existing buildings, especially those with flat or low-sloped roofs. Reflective coatings can be applied to a variety of roofing materials, including asphalt, metal, and concrete.	Can achieve a Solar Reflectance Index (SRI) of 78 or higher, significantly reducing roof surface temperatures by up to 50°C compared to standard roofs
Cool roof membranes	Thermoplastic Polyolefin (TPO) Membrane	These are prefabricated roofing materials made from single-ply membranes, such as thermoplastic olefin (TPO) or polyvinyl chloride (PVC), that are naturally reflective. They are typically installed on flat or low-sloped roofs.	Ideal for commercial and institutional buildings with flat roofs. These membranes are durable and offer high reflectivity and thermal emittance.	Typically, they have an SRI of 82 or higher, providing excellent solar reflectance and reducing the need for air conditioning.
Cool roof shingles	Asphalt Shingles with Reflective Granules	Cool roof shingles are similar to standard asphalt shingles but are manufactured with specially coated granules that provide better solar reflectance.	Commonly used in residential buildings with sloped roofs. Cool shingles are easy to install and provide a familiar aesthetic while offering improved energy performance.	SRI values typically range from 29 to 60, making them more reflective than standard shingles but less than membranes or coatings
Cool metal roofing	Pre-Painted Metal Roofing Panels	Metal roofing materials, such as aluminium or steel, can be finished with reflective coatings to enhance their solar reflectance. These roofs are durable and can be designed to reflect a significant portion of solar radiation.	Suitable for both residential and commercial buildings, particularly in areas where long-term durability and low maintenance are desired.	Metal roofs can achieve SRI values of 70 or higher, making them highly effective at reducing heat gain.

6.4.4 HVAC

Heating, Ventilation, and Air Conditioning (HVAC) systems are an essential component of building design as they are required to maintain comfortable indoor environments, particularly in climates like Ghana's, where temperatures can vary significantly between day and night. Aside from that, HVAC systems are a major energy consumer and as such, a key consideration of the BEEC to help reduce energy consumption and improve indoor air quality and occupant comfort.

The key performance metrics in HVAC systems are:

- **Coefficient of Performance (COP)** is a measure of a heating or cooling system's efficiency. It is calculated as the ratio of useful heating or cooling provided to the electrical energy consumed. A higher COP indicates greater efficiency.
- **Energy Efficiency Ratio (EER)** measures the efficiency of cooling systems, calculated as the ratio of cooling output (in BTUs per hour) to the electrical input (in watts). A higher EER represents better energy efficiency under specific conditions.
- **Heat Recovery Efficiency** indicates the percentage of heat recovered from exhaust air and transferred to incoming fresh air in a Heat Recovery Ventilation (HRV) system. Higher percentages mean more energy is reclaimed, reducing heating or cooling loads.
- **Natural Ventilation Rate (ACH- Air Changes per Hour)** is a measure of how many times the air within a space is replaced with fresh air in one hour. It indicates the effectiveness of passive or mechanical ventilation systems in providing adequate fresh air.
- **Cooling Seasonal Performance Factor (CSPF)** CSPF is a comprehensive metric that measures the seasonal efficiency of an air conditioning system, particularly in variable climates. It is calculated as the ratio of the total annual cooling provided (in watt-hours) to the total annual energy consumed (in watt-hours) by the system. A higher CSPF indicates better overall efficiency throughout the cooling season.

6.4.5 Lighting

Lighting also directly influences both energy consumption and occupant comfort. Advances in lighting technologies have made it possible to significantly reduce energy use while enhancing the quality of light in buildings. Among these technologies, LED (Light Emitting Diode) lighting stands out as the most efficient and sustainable option, and it should be a priority in all green building projects. Generally speaking, LEDs are not only more energy efficient, but they are also more durable, and the costs are now more accessible.

Type	Examples	Description	Application	Performance
Advanced HVAC Systems	Variable speed drives Variable refrigerant flow	Variable Refrigerant Flow (VRF) systems allow for precise control of refrigerant and power flow to multiple indoor units, enabling individual temperature control in different zones of a building, depending on occupancy, temperature, etc. VRF systems are highly efficient because they can adjust each indoor unit based on the current demand, which	**Commercial Buildings**: Ideal for office buildings, hotels, and large commercial spaces with diverse thermal needs across multiple zones. **Residential Buildings:** Increasingly popular in large homes or apartment complexes where	Coefficient of Performance (COP): Can range from 3.5 to 5.0, indicating high energy efficiency. Energy Efficiency Ratio (EER): Typically, between 12 and 20, depending on system configuration and

Type	Examples	Description	Application	Performance
		reduces energy wastage. These systems can provide both heating and cooling, and they are capable of simultaneous operation, meaning some zones can be cooled while others are heated.	zone temperature control is beneficial.	operating conditions.
Heat recovery ventilation (HRV) systems	N/A	Heat Recovery Ventilation (HRV) systems are designed to improve indoor air quality by providing continuous ventilation while minimising energy loss. HRV systems work by capturing heat from the stale exhaust air and using it to preheat the incoming fresh air, reducing the load on the heating system. This is particularly beneficial in climates where there is a significant difference between indoor and outdoor temperatures.	Residential and Commercial Buildings: Suitable for any building type, especially those in cooler regions of Ghana or in urban areas where air quality is a concern.	Heat Recovery Efficiency: Typically exceeds 70-80%, meaning most of the heat from the exhaust air is recovered.
Passive ventilation	Designs from the design stage rather than specific technology.	Passive Ventilation relies on natural forces, such as wind and thermal buoyancy, to circulate air throughout a building without the use of mechanical systems. This design strategy takes advantage of building orientation, window placement, and venting systems to maximize airflow and maintain comfortable indoor temperatures.	**Residential Buildings**: Especially effective in single-story homes, where cross-ventilation can be easily achieved. **Commercial Buildings**: Can be integrated into the design of offices, schools, and public buildings through the use of atriums, vented facades, and high ceilings.	Typically measured in air changes per hour (ACH), effective passive designs can achieve adequate ventilation rates (e.g., 5-10 ACH) depending on the building design and external conditions.
High-efficiency Chillers	Chillers for larger AC systems in commercial buildings.	High-efficiency chillers are used in larger buildings to provide cooling. These systems use advanced technologies, such as variable speed drives (VSDs) and magnetic bearing compressors, to improve energy efficiency.	Commercial Buildings: Commonly used in large commercial buildings, hospitals, and industrial facilities where substantial cooling is required. Institutional Buildings: Suitable	COPs of high-efficiency chillers can achieve 6.0 to 7.0 or higher, depending on the system design and conditions. The EER of these chillers can reach 20 or more, particularly when

Type	Examples	Description	Application	Performance
			for schools, universities, and government buildings where reliability and energy efficiency are critical.	operating under part-load conditions.

6.4.6 Water heaters

Water heating is a significant energy-consuming activity in both residential and commercial buildings. Implementing energy-efficient water heating technologies is crucial for reducing overall energy consumption, lowering greenhouse gas emissions, and improving the sustainability of a building. Below are key water heating technologies that green buildings should prioritise.

Type	Examples	Description	Application	Performance
Tankless (on-demand) water heaters	N/A	Tankless Water Heaters, also known as on-demand water heaters, heat water only when it is needed, rather than storing hot water in a tank. These systems use gas or electricity to heat water directly as it flows through the unit, providing an endless supply of hot water without the standby energy losses associated with traditional tank heaters.	Residential and commercial buildings: suitable for homes, apartments, and businesses with varying hot water demand. Particularly effective in small spaces where the footprint of a storage tank is a concern.	The energy factor: Typically ranges from 0.8 to 0.95 for gas models and 0.98 or higher for electric models, indicating high efficiency.
Heat pump water heaters (HPWHs)	N/A	Heat pump water heaters work by transferring heat from the surrounding air or ground to heat water, rather than generating heat directly. These systems are much more efficient than conventional electric or gas water heaters, especially in moderate climates.	Residential and Commercial Buildings: Ideal for buildings in moderate climates or where solar water heating is less feasible. It is commonly used in residential settings, hotels, and small commercial buildings.	COPs of HPWHs typically have a COP of 3.0 to 4.5, meaning they produce three to four times more heat than the electrical energy they consume. Energy Factor: Typically ranges from 2.0 to 3.5, indicating overall efficiency
Low-flow fixtures	Conservation measure	Low-flow fixtures include faucets, showerheads, and aerators designed to reduce water flow without compromising performance. By restricting the amount of	Residential and Commercial Buildings: Suitable for bathrooms, kitchens, and any	Low-flow showerheads typically have flow rates of 5.7 to 7.6 litres per minute (L/min), compared to standard

Type	Examples	Description	Application	Performance
		water that flows through, these fixtures significantly reduce the amount of hot water used, thereby decreasing the energy required to heat it.	area where hot water is used regularly.	showerheads, which can use up to 9.5 L/min or more. Low-flow faucets typically reduce flow to 1.9 to 5.7 L/min.
Hot water recirculation systems	Efficient water distribution	Hot water recirculation systems circulate hot water through the plumbing system so that it is always readily available at the tap. This minimises the time spent running water while waiting for it to heat up, thereby reducing both water and energy waste. These systems can be controlled by timers, sensors, or demand-based controllers to further optimise efficiency.	Residential and commercial buildings: Particularly useful in large buildings or homes with long plumbing runs, where it takes a significant time for hot water to reach the fixtures.	Energy savings: Modern systems with efficient pumps and controls can reduce water heating energy use by 10-30%.
Insulating hot water pipes	Conservation measure	Pipe insulation involves wrapping hot water pipes with insulating materials to reduce heat loss as water travels through the plumbing system. This helps maintain water temperature, reduces the energy needed to reheat water, and minimises wait times for hot water at the tap.	Residential and Commercial Buildings: Applicable to all types of buildings, especially those with long plumbing runs or where pipes are exposed to cooler environments.	Energy savings: Can reduce heat loss by 25-45%, depending on the thickness and material of the insulation.
Temperature control settings	Thermostat adjustment	Adjusting the thermostat on water heaters to a lower, more efficient temperature can significantly reduce energy use. The recommended temperature for most domestic hot water systems is 49°C. This temperature is sufficient for most household needs and reduces the risk of scalding, while also minimising energy consumption.	Residential and commercial buildings: Applicable in all settings where hot water is used, particularly in households, hotels, and institutional buildings.	Energy savings: Lowering the water heater temperature by 5.5°C can reduce energy use by 3-5%. Safety: Reduces the risk of scalding injuries, especially in homes with children or elderly residents.

Type	Examples	Description	Application	Performance
Water heater timers	Energy management device	Water heater timers allow users to control when their water heater is active, ensuring it only operates during times of high demand. This prevents energy wastage during periods when hot water is not needed, such as overnight or during work hours.	Residential and commercial buildings: Ideal for homes and businesses where hot water demand can be predicted or scheduled.	Energy Savings: Can reduce water heating energy use by 5-12%, depending on the building's occupancy patterns and hot water usage.

6.4.7 Renewable energy systems in green buildings

Renewable energy systems are an important element of green building design, helping to reduce reliance on fossil fuels, lower greenhouse gas emissions, and achieve energy independence. Solar energy, in particular, offers a versatile and abundant resource that can be harnessed in various ways to meet a building's energy and water heating needs. Below is an overview of key solar technologies that should be prioritised in green building projects.

Type	Examples	Description	Application	Performance
Solar Photovoltaic (PV) Systems	PV Panels PV Windows	Solar Photovoltaic (PV) Systems convert sunlight directly into electricity using semiconductor materials, typically silicon-based solar cells. These systems can be installed on rooftops, building facades, or ground-mounted arrays, and are suitable for both on-grid and off-grid applications. Solar PV systems can be designed to meet part or all of a building's electricity needs, significantly reducing dependency on grid electricity. There are different technological options for the implementation of PV, including the blending of PV components into roofing, windows, and other materials.	Residential, Commercial, and Institutional Buildings: Ideal for homes, offices, schools, and industrial facilities. PV systems are versatile and can be scaled according to the energy demands of the building.	Panel efficiency: Modern solar PV panels achieve efficiencies of 15-22%, with some advanced technologies exceeding 22%. Annual energy production: In Ghana, a well-designed PV system can produce over 1,650 kWh/m²/year, depending on location and solar radiation levels.
Solar water heating (SWH) systems	Solar thermal applications.	SWH Systems uses solar collectors to capture and transfer solar thermal energy to heat water. These systems typically	Residential and commercial buildings: Suitable for homes, hotels, hospitals, and any	Solar fraction: Typically provides 50-80% of a building's hot water needs.

Type	Examples	Description	Application	Performance
		consist of flat-plate collectors or evacuated tube collectors and a storage tank. Solar water heaters can be used in both residential and commercial buildings to provide a significant portion of the hot water demand.	building with high hot water demand. Particularly effective in sunny climates like Ghana.	Efficiency: High-performance systems can achieve efficiencies of 60-70%, converting a significant portion of solar energy into usable heat.
Solar tubes or tubular daylighting devices (TDD)	Solar daylight applications	Solar tubes or TDDs capture and channel natural sunlight through reflective tubes into interior spaces. These devices are highly efficient in bringing natural light into areas that lack direct access to windows, reducing the need for artificial lighting during the day and thereby saving energy.	Residential and commercial buildings: Ideal for interior rooms, hallways, bathrooms, and spaces with limited access to natural light.	Light output: TDDs can deliver the equivalent of up to 1,000 watts of incandescent light during peak daylight hours. Energy Savings: Solar tubes can significantly reduce the need for artificial lighting, leading to substantial energy savings, especially during daytime hours.

6.4.8 Building sensors and controls for energy efficiency

Building sensors and controls are an important component in the management of modern green buildings, enabling precise monitoring, control, and optimisation of energy use across a variety of systems (importantly, HVAC, lighting, and water heating). These technologies enhance energy efficiency by ensuring that heating, ventilation, air conditioning (HVAC), lighting, and other building systems operate only when and as needed. Whole-building management systems integrate these controls to provide comprehensive oversight and optimisation of a building's energy performance.

Type	Examples	Description	Application	Performance
Building energy management systems (BEMS)	Whole-building energy management	Building energy management systems (BEMS) are integrated systems that monitor and control a building's energy consumption across all end-uses, including HVAC, lighting, water heating, and other systems. BEMSs collect data from various sensors installed throughout the building and use this	Commercial, industrial, and large residential buildings: BEMS are ideal for complex buildings with multiple systems requiring coordinated control to optimise energy use.	Energy savings: BEMS can reduce overall energy consumption by 10-30% by ensuring systems operate at peak efficiency. Real-time monitoring: Provides continuous data on energy use,

Type	Examples	Description	Application	Performance
		information to optimise the operation of energy-consuming systems. This can involve adjusting settings based on occupancy, time of day, weather conditions, and energy demand.		enabling proactive management and quick identification of inefficiencies.
Occupancy Sensors	Lighting and HVAC controls	Occupancy sensors detect the presence or absence of people in a room and automatically adjust lighting, HVAC, and other systems accordingly. These sensors use infrared, ultrasonic, or microwave technologies to detect occupancy and can be used to turn off lights, reduce HVAC operation, or adjust other systems when spaces are unoccupied.	All building types: Commonly used in offices, conference rooms, restrooms, corridors, and any area with variable occupancy.	Energy savings: Occupancy sensors can reduce lighting and HVAC energy use by 20-50%, depending on the building's occupancy patterns. Response time: Modern sensors provide near-instantaneous response to changes in occupancy, minimising energy wastage.
Smart thermostats	HVAC Control	Smart Thermostats provide advanced control over HVAC systems by learning user preferences and automatically adjusting heating and cooling based on occupancy, weather, and other factors. These thermostats can be controlled remotely via mobile devices and often integrate with BEMS or other smart home systems.	Residential and commercial buildings: Suitable for any building where precise control of HVAC systems can improve energy efficiency and comfort.	Energy savings: Smart thermostats can reduce heating and cooling energy use by 10-20% by optimising system operation based on real-time conditions. Learning algorithms: Many smart thermostats learn user behaviour over time, further enhancing energy efficiency and comfort.
Daylight sensors	Lighting control	These sensors (or daylight harvesting sensors) automatically adjust the intensity of artificial lighting based on the amount of natural light available. These sensors help maintain consistent lighting levels while	Commercial and institutional buildings: particularly effective in office spaces, schools, and retail environments where daylight can be harnessed to	Energy savings: Can reduce lighting energy use by 20-60%, depending on the amount of natural light available.

Type	Examples	Description	Application	Performance
		minimising the use of electric lights during daylight hours.	reduce energy consumption.	Lighting quality: Ensures optimal lighting levels are maintained, improving occupant comfort and productivity.
Advanced metering systems	Energy monitoring and reporting	Advanced metering systems provide detailed monitoring of energy consumption for electricity, gas, water, and other utilities. These systems enable real-time tracking of energy use, identifying inefficiencies and areas for improvement. They are often integrated with BEMS for comprehensive energy management.	All building types: Suitable for buildings of all sizes, particularly those aiming for high levels of energy efficiency and sustainability certification.	Energy savings: Advanced metering can help identify and eliminate inefficiencies, potentially reducing overall energy use by 5-15%. Data accuracy: Provides precise, real-time data that can be used to optimise energy use and reduce costs.

6.4.9 Low-carbon building materials

Low-carbon building materials are essential in green building design, significantly reducing the carbon footprint associated with construction and building operations. These materials are characterised by their low embodied energy, minimal greenhouse gas emissions during production, and often by their ability to sequester carbon. Utilising locally sourced and sustainable materials further enhances their environmental benefits by reducing transportation emissions and supporting local economies. Below are key low-carbon building materials, with a focus on those that are locally relevant and sustainable.

Type	Examples	Description	Application	Performance
Compressed stabilised earth blocks (CSEB)	Locally sourced and manufactured building material	CSEB are made from a mixture of soil, sand, and a small amount of cement or lime, which is then compressed into blocks. CSEB offers a sustainable alternative to traditional fired bricks, with much lower energy requirements for production. These blocks can be produced on-site or near the construction site, reducing the need for transportation and associated emissions.	Residential and commercial buildings: Ideal for walls, partitions, and load-bearing structures in residential and low-rise commercial buildings. CSEB is particularly suitable for buildings in regions with abundant natural soil resources, such as rural areas of Ghana.	Thermal insulation: CSEB offers good thermal mass, helping to regulate indoor temperatures by absorbing and slowly releasing heat. Significantly lower embodied carbon compared to fired bricks or concrete blocks, as the production process requires minimal energy.

Type	Examples	Description	Application	Performance
				CSEB supports local industries and reduces the environmental impact of transporting materials over long distances
Recycled aggregates	Recycled building material	Recycled aggregates are made from crushed concrete, bricks, and other demolition waste. These materials can be used in new concrete production, road bases, and other construction applications. Using recycled aggregates reduces the need for virgin materials, conserves natural resources, and decreases the environmental impact of construction activities.	Infrastructure, Residential, and Commercial Buildings: Used in concrete production, road construction, and as a base material for foundations and pavements.	Strength: Recycled aggregates can achieve comparable strength and durability to traditional aggregates when properly processed and used in the right proportions. Sustainability: By reusing construction waste, recycled aggregates reduce the environmental impact of both waste disposal and the extraction of natural resources.
Low-carbon concrete	Sustainable construction material	Low-Carbon Concrete incorporates alternative materials and production methods to reduce its carbon footprint. This includes the use of supplementary cementitious materials (SCMs) such as fly ash, slag, and silica fume, which partially replace Portland cement, one of the most carbon-intensive components of traditional concrete. Low-carbon concrete can also include recycled aggregates and innovative techniques such as carbon capture and storage during production.	Residential, Commercial, and Infrastructure Projects: Used in foundations, slabs, columns, and other structural components where traditional concrete is commonly applied.	Carbon footprint: Reduces embodied carbon by up to 30-50%, depending on the proportion of SCMs and other low-carbon technologies used. Resource efficiency: Promotes the use of industrial by-products and reduces reliance on virgin materials.
Recycled steel	Recycled building material	Recycled steel is steel that has been recovered and reprocessed from old	Commercial, industrial, and residential buildings:	Reduces embodied carbon by up to 70% compared to

Type	Examples	Description	Application	Performance
		buildings, vehicles, and other sources. Using recycled steel significantly reduces the energy required for production compared to producing new steel from iron ore. Recycled steel can be used in the same applications as new steel, including structural frameworks, reinforcements, and building components.	Commonly used in structural framing, reinforcements, roofing, and cladding.	new steel production, as recycling steel requires significantly less energy. Reduces the need for mining and processing raw materials, promoting the circular economy.
Green steel (low-carbon steel)	Low-carbon construction material	Green steel refers to steel produced using processes that significantly reduce carbon emissions compared to traditional steelmaking methods. This can be achieved through several innovative approaches, such as using hydrogen instead of carbon as a reducing agent in steel production, utilising renewable energy sources for electric arc furnaces, and incorporating carbon capture and storage (CCS) technologies. Green steel aims to maintain the high performance and durability of conventional steel while minimising its environmental impact.	Residential, commercial, and industrial buildings: Used in structural frameworks, reinforcements, roofing, cladding, and various other construction applications where steel is typically employed.	Significantly reduces embodied carbon by up to 90% compared to traditional steelmaking. Contributes to decarbonising the construction industry, which is crucial for achieving global climate goals. Green steel production also encourages the development of sustainable supply chains.

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