international DESIGN JOURNAL
Print ISSN 2090-9632
Online ISSN 2090-9640

"Global and Local Approaches to Energy Efficiency in Green Building Certifications: A Comparative Analytical Study"

Hassan ELShahat Hassan Ahmed ELDib
Assistant Professor, Architecture Engineering Department-
Faculty of Engineering, Canadain International College, dr.hassan.aldeeb@hotmail.com

Abstract
This research explores the role of green building certification systems in promoting energy efficiency, focusing on internationally recognized frameworks such as LEED (Leadership in Energy and Environmental Design) and BREEAM (Building Research Establishment Environmental Assessment Method), alongside local systems like DGNB (German Sustainable Building Council) and Egypt's Green Pyramids Rating System. The research problem is the limited effectiveness of sustainable building systems and standards at the local level in achieving energy-efficient design and construction. The study aims to leverage insights from global sustainable building standards to enhance the efficiency of local systems in achieving energy savings. Using a comparative analytical approach to evaluate both global and local standards, the effectiveness of these systems is analyzed by examining their criteria and approaches to energy optimization. The study investigates the varying emphasis placed on energy efficiency across these certification systems, taking into account regional factors such as climate, resource availability, and local building practices. A SWOT analysis (strengths, weaknesses, opportunities, and threats) assesses the effectiveness of these systems in enhancing energy efficiency. Ultimately, the study provides recommendations to improve energy efficiency strategies within these frameworks, fostering a more sustainable built environment..

Keywords
Energy, Efficiency, Green building, Certification Systems

Paper received November 8, 2024, Accepted January 10 2025, Published on line March 1, 2025

1. Introduction
As the global urgency for sustainable development intensifies, the construction industry plays a pivotal role in mitigating environmental impacts, particularly regarding energy consumption. Buildings account for a significant portion of global energy use and greenhouse gas emissions, prompting the emergence of green building certification systems designed to promote energy efficiency and environmental sustainability. These frameworks, such as the Leadership in Energy and Environmental Design (LEED) and the Building Research Establishment Environmental Assessment Method (BREEAM), have gained international recognition for their structured approaches to assessing and certifying building performance in relation to energy efficiency. In parallel, localized certification systems, including DGNB (Germany's Deutsche Gesellschaft für Nachhaltiges Bauen) and Egypt's Green Pyramids Rating System, aim to address regional characteristics and challenges that influence energy performance in the built environment.

Despite the proliferation of various certification systems, there exists a significant disparity in how they emphasize energy efficiency, particularly in relation to localized factors such as climate and resource availability. The effectiveness of these systems in achieving tangible energy savings has become a critical area of inquiry for researchers and practitioners alike. This study seeks to investigate the role of these green building certification systems in fostering energy efficiency, with a specific focus on comparing the energy criteria of LEED and BREEAM against those of DGNB and the Green Pyramids Rating System. By analyzing the adaptability of these systems to distinct geographic contexts, the research aims to elucidate how they contribute to energy-efficient design across diverse climates.

To achieve its objectives, this research will address key questions regarding the efficacy of different certification frameworks in promoting energy-efficient practices and whether localized systems

CITATION
Hassan Eldib (2025), "Global and Local Approaches to Energy Efficiency in Green Building Certifications: A Comparative Analytical Study", International Design Journal, Vol. 15 No. 2, (March 2025) pp **587-603**

can more effectively tackle regional energy challenges. A comprehensive literature review will trace the evolution of green building certification systems, shedding light on their varied impacts on energy performance. Utilizing a SWOT analysis approach, the research methodology will incorporate the data analysis, facilitating an understanding of how these systems address energy efficiency concerns.

Ultimately, this study endeavors to provide actionable recommendations for enhancing energy efficiency strategies within existing green building certification frameworks. By critically assessing the effectiveness of these systems, the research aims to contribute to the ongoing discourse on sustainable building practices, fostering a more sustainable built environment that aligns with the pressing need for energy conservation and environmental stewardship.

1. Energy Efficiency at LEED

Introduction to LEED: (U.S. Green Building Council, n.d.)

Leadership in Energy and Environmental Design (LEED) is one of the most widely used green building rating systems in the world. Developed by the U.S. Green Building Council (USGBC), LEED provides a framework for building owners and operators to achieve high performance in key areas of environmental and human health, such as energy efficiency, water savings, sustainable site development, materials selection, and indoor environmental quality.

Energy efficiency plays a significant role in the LEED certification process, as buildings consume a large portion of the world's energy. LEED focuses on strategies that reduce energy use, limit greenhouse gas emissions, and ensure cost savings for building owners and occupants.

1.1. Key Components of Energy Efficiency in LEED

A. Energy and Atmosphere (EA) Category: LEED's Energy and Atmosphere (EA) category emphasizes strategies to reduce energy demand, improve energy performance, and ensure the use of renewable energy sources. Within this category, several credit points are awarded based on the building's energy-efficient design and performance.

Key Prerequisites and Credits in EA: (U.S. Green Building Council, n.d.)

- Fundamental Commissioning and Verification (Prerequisite): This ensures that building energy systems are designed and installed as intended, achieving optimal performance.
- Minimum Energy Performance (Prerequisite): Projects must meet minimum energy performance standards. Typically, this involves meeting or exceeding the ASHRAE 90.1 standard for energy efficiency.
- Building-Level Energy Metering (Prerequisite): Buildings must be equipped with systems to monitor and report energy usage, promoting transparency and accountability.
- Optimize Energy Performance (Credit): Points are awarded based on the percentage of energy cost savings achieved over a baseline. The more energy-efficient the design, the higher the number of points.
- Renewable Energy Production (Credit): Buildings that integrate on-site renewable energy systems (such as solar panels or wind turbines) receive additional points based on the percentage of energy generated.

B. Energy Modeling and Performance: LEED promotes the use of energy modeling software to predict energy consumption. Building energy simulations allow designers to optimize energy performance and evaluate the impact of various energy-saving measures. By using energy models, design teams can explore different combinations of heating, cooling, lighting, and insulation strategies to reduce overall consumption.

Approaches to Achieve High Energy Efficiency:

- Incorporating high-performance HVAC (heating, ventilation, and air conditioning) systems
- Optimizing building envelope design, including insulation, glazing, and shading
- Using energy-efficient lighting and appliances
- Incorporating natural daylighting and passive heating/cooling strategies
- Implementing energy recovery systems, such as heat exchangers and thermal storage.

(American Society of Heating, Refrigerating, and Air-Conditioning Engineers, n.d.) , (ASHRAE (2019).

C. Integration of Renewable Energy Sources: To further promote energy efficiency and reduce reliance on fossil fuels, LEED encourages the integration of renewable energy sources like solar, wind, geothermal, and biomass. This reduces the carbon footprint of the building and often results in significant long-term cost savings. Credits are awarded based on the percentage of building energy needs that are met by renewable sources.(AltEnergyMag, 2020)

D. Monitoring and Measurement: LEED places a strong emphasis on energy monitoring. Continuous tracking of energy usage through smart meters or Building Automation Systems (BAS) allows for performance optimization and early detection of inefficiencies. These systems can automatically adjust energy use in response to changing conditions or occupancy patterns, leading to more efficient operations (Accuenergy, n.d.).

1.2. Energy Efficiency Strategies for LEED Certification: (ASHRAE & U.S. Department of Energy, n.d.) and (Katipamula & Brambley, 2005).

To achieve higher levels of energy efficiency in LEED-certified buildings, several strategies are recommended:

- High-Performance Building Envelope: A well-insulated and sealed building envelope reduces the need for heating and cooling, improving overall energy performance. Energy-efficient windows and doors, along with appropriate insulation, reduce heat transfer, keeping the building comfortable with less energy input.
- Energy-Efficient HVAC Systems: HVAC systems are often the largest consumers of energy in a building. High-efficiency HVAC equipment, coupled with energy recovery ventilation and smart controls, can drastically reduce energy consumption. Variable speed drives and demand-controlled ventilation are also effective in optimizing energy use.
- Daylighting and Lighting Controls: Integrating natural daylight into the building reduces the need for artificial lighting. LEED encourages the use of daylight sensors, occupancy sensors, and energy-efficient lighting systems such as LEDs to reduce lighting energy consumption.
- Advanced Building Automation Systems (BAS): Building automation systems monitor and control building systems like HVAC, lighting, and security. With sophisticated algorithms and predictive controls, BAS can adjust energy consumption in real-time, maximizing energy savings without compromising comfort.
- On-site Renewable Energy Generation: Installing renewable energy systems, such as photovoltaic panels or wind turbines, can directly contribute to energy efficiency by offsetting traditional energy use. LEED awards additional points for on-site renewable energy generation, especially when it contributes to a significant portion of the building's energy needs.

1.3. Energy Efficiency Certifications and Performance Tiers: (U.S. Green Building Council, n.d.)

LEED certification comes in four levels: Certified, Silver, Gold, and Platinum. The level achieved is based on the total number of points earned across all categories, including energy efficiency. Projects aiming for higher certification levels typically focus on maximizing energy efficiency as it can contribute a substantial number of points.

Benefits of Energy Efficiency in LEED-Certified Buildings

- Cost Savings: Energy-efficient buildings reduce operational costs by lowering utility bills and improving system longevity. High-performance buildings often see rapid payback periods from energy-saving investments.
- Environmental Impact: By reducing energy consumption and incorporating renewable energy, LEED-certified buildings contribute to lowering greenhouse gas emissions, mitigating climate change, and conserving natural resources.
- Improved Occupant Comfort: Efficient energy systems and well-designed building envelopes create more stable and comfortable indoor environments, enhancing occupant well-being and productivity.
- Resilience: Energy-efficient buildings are better equipped to handle fluctuations in energy supply, increasing their resilience to energy price volatility and potential shortages.

Conclusion

Energy efficiency is a cornerstone of LEED certification, driving significant environmental and financial benefits. By promoting the use of energy-efficient systems, advanced building technologies, and renewable energy, LEED contributes to the global effort to reduce energy consumption and greenhouse gas emissions. As the world transitions to more sustainable and energy-efficient building practices, LEED continues to play a crucial role in shaping the future of energy-efficient design and construction.

2. Energy Efficiency at BREEAM

Introduction to BREEAM: (BREEAM, n.d., "Introduction" section)

The Building Research Establishment Environmental Assessment Method (BREEAM) is one of the world's most recognized sustainability assessment methods

for master planning projects, infrastructure, and buildings. Launched in 1990 by the UK's Building Research Establishment (BRE), BREEAM is used globally to evaluate the environmental performance of buildings, focusing on key areas like energy use, water consumption, materials, health and well-being, and pollution.

Energy efficiency is a core component of the BREEAM certification process, as it directly impacts the sustainability and carbon footprint of a building. BREEAM encourages the adoption of strategies that reduce energy demand, improve energy efficiency, and integrate renewable energy sources to minimize environmental impacts.

Key Components of Energy Efficiency in BREEAM : (BREEAM, n.d., "ENE 01 - Reduction of energy use and carbon emissions") and (O'Reilly, 2021, para. 4)

Energy efficiency within BREEAM is primarily assessed under the Energy category, with the objective of reducing a building's energy consumption and carbon emissions. This category aims to ensure that new and existing buildings operate with higher energy performance standards while reducing reliance on fossil fuels.

A. **Reduction of Operational Energy Use:**

BREEAM promotes strategies to minimize energy consumption during the operational phase of a building's lifecycle. Energy use for heating, cooling, lighting, and equipment is assessed, with projects expected to demonstrate reductions in energy demand through efficient building designs and systems.

Key aspects include:

- **Use of passive design techniques, such as orientation, shading, and natural ventilation, to minimize energy demand.**
- **Efficient use of energy for heating, ventilation, and air conditioning (HVAC) systems.**
- **Integration of smart building technologies and energy management systems to optimize energy use in real-time.**

B. Energy Modeling and Performance Assessment: (BREEAM, 2016, "New Construction / International / 03 - Energy") and (BREEAM, 2022, "Introduction" section)

BREEAM uses Building Energy Simulation (BES) to model energy consumption and carbon emissions. The assessment compares the energy performance of the proposed building against national and international standards, with points awarded based on improvements over a baseline scenario. This incentivizes projects to adopt advanced energy efficiency measures.

Simulation and modeling focus on:

- **Optimizing energy performance through improved building fabric (e.g., insulation, glazing, airtightness).**
- **Selection of high-performance mechanical and electrical systems, including energy-efficient lighting, heating, and cooling systems.**
- **Utilizing energy-efficient appliances and reducing energy loads from non-building services.**

C. **Energy Performance and Carbon Emissions: (Building Research Establishment Environmental Assessment Method [BREEAM], 2024)**

One of the primary goals of BREEAM is to reduce carbon emissions. Buildings are assessed based on their operational energy use and resulting carbon emissions, with performance benchmarks established according to national or international standards (such as the UK's Part L of Building Regulations or the EU's Energy Performance of Buildings Directive).

Energy Performance Ratios (EPR):

BREEAM includes the use of Energy Performance Ratios (EPR) that measure energy performance and carbon reduction. Points are awarded based on how much better the building performs compared to the baseline. This encourages the use of low-carbon technologies and renewable energy solutions.

D. **Integration of Renewable Energy Sources: (Stanford University, n.d.)**

BREEAM encourages the use of renewable energy technologies such as solar photovoltaic (PV) systems, wind turbines, biomass, and geothermal energy to offset traditional energy consumption. Projects that incorporate on-site renewable energy generation or utilize green power purchase agreements can receive additional credits.

Key renewable energy strategies:

- **Installing on-site renewable energy generation systems (solar panels, wind turbines).**
- **Using low-carbon energy sources for heating, such as combined heat and power (CHP) systems.**
- **Purchasing renewable energy from green energy suppliers to reduce the carbon**

footprint of the building's operation.

E. **Energy Monitoring and Smart Technologies: (Building Research Establishment, 2024)**

BREEAM emphasizes the importance of monitoring energy consumption to ensure ongoing performance optimization. By integrating Building Management Systems (BMS), smart meters, and real-time energy monitoring technologies, buildings can track and analyze their energy use. This enables building operators to identify inefficiencies, make data-driven adjustments, and ensure the building performs as designed over its operational life.

Energy monitoring systems typically include:

- **Smart meters that provide real-time feedback on energy use.**
- **Automated building controls to optimize lighting, heating, and cooling based on occupancy and external conditions.**
- **Predictive maintenance tools that help avoid energy losses from poorly maintained equipment.**

2.1. **Energy Efficiency Strategies for BREEAM Certification : (Kibert, 2016) and (Hafez et al., 2023)**

Achieving high levels of energy efficiency in BREEAM-certified projects requires careful consideration of building design, systems, and operations. Below are some common strategies employed to enhance energy efficiency in BREEAM projects:

A. **Building Envelope Design:**

A well-designed building envelope is critical to reducing heat loss and optimizing thermal performance. High-quality insulation, energy-efficient glazing, and minimizing thermal bridging all contribute to reducing the energy required for heating and cooling.

Key measures include:

- **High-performance insulation for walls, roofs, and floors.**
- **Energy-efficient windows with low-emissivity glazing and appropriate shading devices.**
- **Air-tightness measures to reduce heat loss and improve energy performance.**

B. **High-Efficiency HVAC Systems:**

HVAC systems typically account for a large portion of energy consumption in buildings. BREEAM encourages the use of energy-efficient HVAC systems that can be optimized through variable speed controls, demand-controlled ventilation, and heat recovery systems.

Best practices for HVAC efficiency include:

- **Using high-efficiency boilers and chillers with advanced controls.**
- **Incorporating heat recovery ventilation systems to capture waste heat.**
- **Zoning HVAC systems to reduce energy use in unoccupied areas.**

C. **Energy-Efficient Lighting:**

Lighting design is another important factor in energy efficiency. BREEAM encourages the use of energy-efficient lighting technologies like LED lighting, along with controls such as daylight sensors, motion detectors, and timers that automatically adjust lighting levels based on need.

D. **Day lighting and Passive Design:**

Maximizing natural daylight reduces the need for artificial lighting and improves occupant well-being. BREEAM supports the use of passive design principles, such as building orientation, window placement, and shading, to minimize reliance on artificial lighting and HVAC systems.

E. **On-Site Renewable Energy:**

Incorporating on-site renewable energy sources is encouraged under BREEAM, as it reduces the need for grid-supplied energy and lowers the building's carbon footprint.

Energy Efficiency Credits and Certification Levels : (Hoxha & Skenderi, 2018), (BREEAM, n.d.) and (CIM, 2024)

BREEAM certification is awarded on a point-based system, with energy efficiency being a critical category contributing to the overall score. BREEAM has five certification levels: Pass, Good, Very Good, Excellent, and Outstanding, with higher levels typically requiring significant improvements in energy efficiency.

Credits for energy efficiency are available across various criteria, including:

- **Reductions in regulated energy use and carbon emissions.**
- **The use of renewable energy.**
- **The adoption of passive design and energy-efficient systems.**
- **Ongoing monitoring and verification of energy performance.**

Benefits of Energy Efficiency in BREEAM-Certified Buildings

- Reduced Energy Costs: Energy-efficient buildings have lower operational costs due to reduced energy consumption, leading to significant long-term financial savings.
- Lower Carbon Emissions: By optimizing energy use and integrating renewable energy,

BREEAM-certified buildings reduce their carbon emissions, contributing to the global effort to combat climate change.

- Enhanced Building Value: Energy-efficient buildings often have higher market values and attract tenants or buyers who prioritize sustainability and operational savings.
- Improved Occupant Comfort: Energy-efficient systems create more comfortable indoor environments with better temperature control, air quality, and lighting, contributing to higher occupant satisfaction and productivity.

Conclusion

Energy efficiency is at the heart of BREEAM's sustainability framework, driving significant improvements in the environmental performance of buildings. By focusing on reducing energy demand, optimizing building systems, and integrating renewable energy, BREEAM-certified buildings achieve greater energy efficiency, lower operational costs, and reduced environmental impact. As sustainable building practices continue to evolve, BREEAM remains a leading global standard for energy-efficient and environmentally responsible buildings.

3. Energy Efficiency at DGNB

Introduction to DGNB Certification : (DGNB, n.d.) and (Hanga-Fărcaş, 2023)

The DGNB (Deutsche Gesellschaft für Nachhaltiges Bauen, or German Sustainable Building Council) certification is one of the world's leading systems for sustainable building certification. It was established in 2007 and focuses on a holistic approach to sustainability in the built environment. DGNB considers not only environmental aspects but also economic and sociocultural dimensions. The certification system is performance-oriented, relying on life cycle assessments to ensure that buildings contribute positively to overall sustainability.

Energy efficiency plays a crucial role in DGNB certification, forming one of the key pillars within the environmental quality section.

3.1. Energy Efficiency Criteria in DGNB Certification: (DGNB, n.d.)

The DGNB certification system assesses energy efficiency across multiple dimensions of a building's life cycle. The primary goal is to reduce energy consumption, mitigate environmental impact, and enhance the overall performance of the building. The energy efficiency criteria fall under the broader framework of "Environmental Quality" within the certification system. Key aspects of energy efficiency in DGNB certification include:

B. Primary Energy Demand (PED)

Primary energy demand is a core criterion in the DGNB system, calculated over the life cycle of the building. This includes the total energy required for operating the building and producing materials, which are then converted into primary energy demand using factors for renewable and non-renewable energy sources. Lowering the PED is essential to achieving higher DGNB ratings.

C. Operational Energy Efficiency

- The DGNB certification places a strong emphasis on reducing operational energy demand, covering the energy used for heating, cooling, ventilation, and lighting. Efficiency is measured not just by the building's performance on day one but by its sustained ability to reduce energy consumption over time.
- Buildings are expected to incorporate passive design strategies like optimal orientation, insulation, and the use of natural daylight to minimize energy needs.

D. Use of Renewable Energy Sources

- DGNB promotes the use of renewable energy sources to supply buildings. It encourages building designs that integrate renewable energy systems such as photovoltaic panels, solar thermal systems, and wind power. Projects that use renewable energy systems effectively can achieve higher energy efficiency scores.

E. Life Cycle Energy Assessment

- DGNB requires a life cycle energy assessment (LCEA) to quantify the total energy demand of a building throughout its life cycle, from construction and material production to decommissioning. This long-term view supports decision-making that minimizes environmental impact and encourages more sustainable building practices.

F. Building Envelope and Insulation

- A well-designed building envelope contributes significantly to energy efficiency by reducing heat losses and gains. DGNB certification evaluates the quality of insulation, window performance, and other elements that ensure minimal energy leakage and efficient thermal regulation.

G. Heating, Ventilation, and Air Conditioning (HVAC) Systems

- The efficiency of HVAC systems is another critical criterion under DGNB's energy efficiency framework. DGNB encourages the adoption of highly efficient heating, ventilation, and cooling systems that meet or exceed regulatory standards. Efficient heat recovery and smart control systems that adjust to real-time usage are also encouraged to improve energy efficiency.

H. Energy Monitoring and Control Systems

- The DGNB promotes the use of intelligent building management systems (BMS) to monitor and manage energy usage. These systems allow for the optimization of energy consumption in real time and contribute to long-term energy efficiency.

I. Future-Proofing for Energy Efficiency

- The DGNB certification encourages buildings to be adaptable and scalable in terms of energy performance. This includes ensuring that buildings are designed to accommodate future technological upgrades, such as advanced energy storage systems, grid interaction, or even carbon-neutral energy solutions.

3.2. Scoring System for Energy Efficiency

- Energy efficiency in DGNB certification is assessed through a point-based system. The certification grades projects across four levels: Bronze, Silver, Gold, and Platinum. Points are awarded based on how well the building performs against the energy efficiency criteria outlined above, with life cycle assessments, energy consumption forecasts, and actual performance data informing the scoring.

DGNB distinguishes itself from other rating systems by placing significant emphasis on the life cycle impact of buildings and on the reduction of energy use over the long term

3.3. Comparison with Other Green Building Certifications: (Hamedani & Huber, 2012)

DGNB, LEED and BREEAM these systems serve as tools for evaluating and promoting sustainable urban development, but they differ in their structure, focus, and criteria. DGNB as local system compared to other major green building rating systems, such as LEED (Leadership in Energy and Environmental Design) and BREEAM (Building Research Establishment Environmental Assessment Method), the notes are as follows: (Table : A)

Areas of Comparison	DGNB	LEED	BREEAM
Rating System	DGNB features a sophisticated rating system that evaluates projects across five main categories: ecological, economic, sociocultural, technical, and process quality. Each category has a designated weight, with ecological and economic factors receiving the highest emphasis. Unlike LEED and BREEAM, DGNB does not have mandatory credits, but projects must meet minimum score requirements in all categories to ensure a comprehensive approach to sustainability.	LEED, primarily used in the USA, focuses on aspects like site sustainability, water efficiency, and energy performance, with additional points available for innovation and regional priorities. It incorporates pre-requirements for specific criteria that must be met before a project can be certified. LEED’s rating system is relatively simpler than DGNB’s, making it widely accessible.	BREEAM has a regionally adaptive rating system, adjusting criteria weights based on the project's location in the UK. BREEAM covers multiple categories similar to LEED, including energy, water, and materials, but also has a strong focus on ecology and land use. The certification process uses predefined levels such as "Pass," "Good,"
Certification Process	DGNB is noted for its rigorous certification process. Projects must undergo a comprehensive evaluation with detailed analysis in each category, making it one of the strictest certification systems. This ensures that high standards are met across various sustainability factors, especially in urban	LEED is more streamlined and widely adopted, particularly in North America. It uses a points-based system where projects can aim for certifications at different levels: Certified, Silver, Gold, and Platinum. LEED is generally seen as more flexible and simpler to navigate than DGNB.	BREEAM, while less stringent than DGNB, provides a middle ground. Its flexibility and regional adaptability make it suitable for projects across different climates and contexts. It also offers a variety of certification

	development.		
Criteria Focus	DGNB places a stronger emphasis on economic and sociocultural aspects in addition to environmental sustainability, making it distinct from LEED and BREEAM, which prioritize environmental factors more heavily.	LEED emphasizes innovation and encourages projects to achieve higher scores by addressing regional issues, such as specific climate conditions or community needs. This flexibility allows for broader global applicability.	BREEAM places more weight on regional ecological factors and is known for its adaptability to local contexts, giving it a competitive edge in diverse geographical locations.
Summary of Findings:	**The comparison highlights that while DGNB is the strictest and most comprehensive system, particularly suitable for high-precision urban projects, LEED offers a more globally flexible and user-friendly system. BREEAM balances between the two, offering adaptability to regional needs while maintaining a strong focus on environmental factors. Each system has its strengths and weaknesses, and their effectiveness depends largely on the context and specific goals of the project in question**		

Conclusion

Energy efficiency is a cornerstone of the DGNB certification system, with a multi-faceted approach that spans operational energy use, life cycle assessments, and the integration of renewable energy sources. By setting high standards and encouraging innovative solutions for energy management, DGNB plays a vital role in promoting sustainable building practices and reducing the environmental footprint of buildings throughout their entire life cycle. Its comprehensive and forward-thinking framework positions it as a leading certification system in the global movement towards energy-efficient, sustainable architecture.

4. Energy Efficiency at GPRS

Introduction to the Green Pyramid Rating System (GPRS: (Housing and Building National Research Center, 2017) and (Dev, 2017)

The Green Pyramid Rating System (GPRS) is Egypt's national certification system for evaluating and certifying sustainable buildings. Launched by the Egyptian Green Building Council and endorsed by the Ministry of Housing, Utilities, and Urban Communities, GPRS is designed to address local environmental conditions and promote sustainability in the construction industry. This system evaluates buildings on various criteria, including energy efficiency, water efficiency, materials selection, and indoor environmental quality.

Energy efficiency plays a critical role in the GPRS, aligning with global standards for sustainable building practices while addressing Egypt's energy challenges. With energy demand rising due to population growth, urbanization, and climate factors, efficient energy use is imperative for Egypt's long-term sustainability goals.

4.1. Energy Efficiency Framework in GPRS: (GPRS, 2017), (Arafat et al., 2023) and (Daoud, Othman, Robinson, & Bayyatia, 2018)

Energy efficiency in the GPRS system is assessed through specific criteria aimed at reducing energy consumption and enhancing the overall performance of buildings. These criteria cover various aspects such as building design, energy management systems, and the use of renewable energy sources. Key components of the energy efficiency framework in GPRS include:

A. Building Envelope

The GPRS emphasizes the importance of the building envelope in controlling heat transfer and improving the thermal performance of structures. This includes:

- Insulation: High-performance insulation materials reduce heat gain in the summer and heat loss in the winter, minimizing the need for mechanical cooling and heating.
- Windows and Glazing: Energy-efficient windows and glazing systems reduce the transfer of heat, thereby improving indoor comfort and reducing the need for HVAC (Heating, Ventilation, and Air Conditioning) systems.
- Shading Devices: The use of shading devices, such as overhangs, blinds, and shutters, helps to mitigate solar heat gain, particularly in Egypt's hot climate.

B. Energy Management Systems

GPRS encourages the integration of advanced energy management systems that monitor, control, and optimize energy use in buildings. This includes:

- Smart Metering: Systems that track energy consumption in real-time and provide insights into usage patterns, enabling occupants to manage energy use more efficiently.

- Automation and Controls: Automated lighting, heating, and cooling systems that respond to occupancy or external weather conditions can significantly reduce energy waste.

C. HVAC Systems

The efficiency of HVAC systems is a major focus in energy efficiency standards under the GPRS. Recommendations include:

- Efficient HVAC Equipment: Utilizing energy-efficient air conditioning units, fans, and pumps with high Coefficient of Performance (COP) values, to reduce energy consumption.
- Proper Sizing of HVAC Systems: Ensuring HVAC systems are appropriately sized to meet the building's load requirements, thereby avoiding overconsumption of energy.
- Natural Ventilation: Incorporating natural ventilation strategies, when feasible, reduces reliance on mechanical systems for cooling and air circulation.

D. Lighting Systems

Energy-efficient lighting solutions are a key element of the GPRS's energy efficiency criteria:

- LED Lighting: The use of LED lighting is promoted due to its low energy consumption and long lifespan compared to traditional incandescent bulbs.
- Daylighting: Maximizing the use of natural daylight through building orientation, window placement, and skylights can reduce the demand for artificial lighting during the daytime.

E. Renewable Energy Integration

The GPRS encourages the integration of renewable energy sources to reduce reliance on conventional fossil fuel-based power. This includes:

- Solar Energy: Solar photovoltaic (PV) panels can be installed to generate clean electricity, and solar thermal systems can be used for water heating.
- Wind Energy: For projects in suitable areas, wind turbines can be considered as an additional renewable energy source.

Energy Performance Requirements: (GPRS, 2017) and (Bonna, El-Hakim, & El-Behairy, 2018)

To achieve GPRS certification, buildings must meet a minimum threshold of energy performance. The rating system follows a points-based approach, where the energy efficiency of a building contributes significantly to its overall rating. Projects are evaluated based on:

- Baseline Energy Consumption: A calculation of the building's projected energy consumption under conventional design compared to the more efficient design.
- Energy Reduction Targets: The GPRS sets reduction targets for energy consumption, with higher points awarded for greater reductions.
- Energy Modeling: A comprehensive energy model must be created to simulate the building's energy performance. This model accounts for factors like thermal loads, lighting, and HVAC system efficiency.

4.2. Energy Efficiency in Building Types

The GPRS is applicable to various building types, each with tailored energy efficiency requirements:

- Residential Buildings: Focus on reducing energy use through better insulation, efficient lighting, and renewable energy systems.
- Commercial Buildings: Require more advanced HVAC systems, energy management controls, and higher renewable energy integration due to their larger energy footprints.
- Public Buildings: Emphasize both operational efficiency and occupant education on energy conservation, given their high occupancy rates.

Government Incentives and Regulations

The Egyptian government, through the GPRS and other initiatives, offers incentives for energy-efficient buildings, including tax rebates and subsidies for the installation of renewable energy systems. Furthermore, building codes in Egypt are evolving to include mandatory energy efficiency standards, which complement the voluntary GPRS certification process.

Conclusion

Energy efficiency is a cornerstone of the Green Pyramid Rating System, aligning with Egypt's broader sustainability goals and addressing the urgent need for energy conservation in the face of growing demand. By encouraging the adoption of energy-efficient building designs, systems, and technologies, the GPRS is helping to shape a more sustainable built environment in Egypt.

The focus on reducing energy consumption not only cuts costs for building operators and occupants but also contributes to mitigating the environmental impacts of energy production, such as greenhouse gas emissions. As the GPRS continues to evolve, it is expected to further enhance energy efficiency standards, helping Egypt transition towards a greener, more energy-efficient future

5. SWOT analysis between Energy Efficiency at LEED, BREEAM, DGNB and Green Pyramid Rating System (GPRS) : (Table : B)

	LEED	BREEAM	DGNB	GPRS
Strengths	Comprehensive Approach: LEED provides a well-rounded framework that encourages a holistic view of energy efficiency. It addresses energy use in building design, construction, and operation. Market Credibility: LEED is a globally recognized certification sys tem that enhances the market value of buildings, attracting tenants and investors who prioritize sustainability. Integration with Technology: LEED encourages the adoption of energy-efficient technologies like smart lighting, HVAC systems, and renewable energy sources, improving operational efficiency. Operational Savings: Buildings certified under LEED often realize long-term cost savings through reduced energy consumption and operational efficiency. Carbon Footprint Reduction: LEED's energy efficiency standards contribute to lowering carbon	Long-Established Framework: BREEAM, developed in 1990, is one of the oldest and most established sustainability rating systems. Its credibility enhances the value of energy-efficient buildings. Flexibility: BREEAM allows projects to adjust and focus on different environmental aspects, including energy efficiency, based on local regulations, climate, and priorities. Lifecycle Approach: The BREEAM certification process evaluates energy efficiency throughout the entire lifecycle of the building—from design to construction to operation. Strong Focus on Carbon Emissions: BREEAM emphasizes reducing carbon emissions through energy-efficient designs and the use of renewable energy, contributing to global carbon reduction targets. Local Adaptability: BREEAM can be adapted to different countries and local regulations, making it easier for projects	Holistic and Life-Cycle Focus: DGNB is known for its comprehensive approach, emphasizing energy efficiency throughout the entire lifecycle of a building, from planning and design to construction, operation, and eventual deconstruction. Performance-Oriented: DGNB's focus on actual performance rather than design intent ensures that buildings achieve real, measurable energy efficiency results, not just theoretical ones. Strong European Integration: DGNB aligns well with European energy and sustainability regulations, making it a natural fit for projects in the EU that must comply with rigorous energy efficiency standards. Material and Resource Efficiency: DGNB goes beyond just energy use and considers how materials, resources, and operational strategies impact energy performance, providing a more well-rounded sustainability approach.	Regulatory Support: GPRS aligns with national policies promoting sustainable development and energy efficiency, ensuring governmental backing. Enhanced Building Performance: Adoption of energy-efficient measures leads to lower operational costs and improved building performance. Increased Awareness: The GPRS promotes awareness of energy-efficient practices among stakeholders, including architects, builders, and end-users. Attractive to Investors: Energy-efficient buildings often attract green financing and investment due to lower risk and operational costs.

	emissions, aligning with global environmental goals.	to comply with regional energy efficiency standards.	Innovation and Flexibility: DGNB encourages innovative solutions and the use of cutting-edge technologies to maximize energy efficiency, adapting to new advancements and local requirements.	
Weaknesses	High Initial Costs: The implementation of energy-efficient designs and technologies required by LEED often involves higher upfront costs, which can be a barrier for some developers. Complex Certification Process: Achieving LEED certification, especially for energy efficiency, can be time-consuming and requires extensive documentation and professional expertise. Lack of Adaptation to Local Context: While LEED is internationally recognized, it may not always align perfectly with local energy regulations, climate conditions, or resource availability. Performance Gap: In some cases, buildings designed to meet LEED standards may underperform in real-world operations, particularly if the building's operation and maintenance do	Perceived Complexity: The detailed and multifaceted nature of BREEAM's evaluation process can be seen as complex, requiring specialized expertise, which might deter smaller developers. Higher Upfront Costs: Achieving high energy efficiency ratings in BREEAM often requires considerable investment in advanced technologies and materials, which can increase project costs. Variability in Standards: Since BREEAM can be adapted for local contexts, there may be inconsistencies in how energy efficiency is evaluated across regions, making it difficult to compare buildings globally. Focus on Broader Environmental Aspects: Energy efficiency is just one aspect of BREEAM's broader environmental criteria, which can	Complex and Technical Process: The certification process can be highly technical and complex, requiring specialized knowledge and significant investment in expert consultants, which can be challenging for smaller projects. Limited Global Reach: Compared to LEED and BREEAM, DGNB is less widely recognized globally, which may limit its appeal outside of Europe and specifically Germany. High Initial Costs: Achieving energy efficiency under DGNB's stringent criteria often requires significant upfront capital investment in high-performance building systems and technologies. Focus on European Standards: Although adaptable, DGNB's close alignment with European regulations and standards may limit its relevance or appeal in non-European markets,	High Initial Costs: Implementing energy-efficient technologies can require significant upfront investment, which may deter some developers. Limited Knowledge: There may be a lack of awareness or understanding of energy-efficient practices among local builders and developers. Inconsistent Implementation: Variability in the application of GPRS standards can lead to inconsistent energy performance across projects. Monitoring Challenges: Difficulty in measuring and verifying energy savings can hinder performance assessments. (Dev, 2017)

	not follow through on energy efficiency plans. (Khoshbakht, Gou, & Dupre, 2017)	sometimes dilute the emphasis on energy-specific improvements compared to systems like LEED. (Apanavičienė, Maliejus, & Fokaides, 2020)	where energy codes and expectations differ. (López & Al-Mohammad, 2019)	
Opportunities	Increased Demand for Sustainable Buildings: Growing awareness of climate change and the financial benefits of energy efficiency presents significant opportunities for LEED certification in both new and existing buildings. Government Incentives: Various governments offer tax breaks, incentives, and grants for energy-efficient and LEED-certified buildings, making it easier for developers to offset initial costs. Advancements in Renewable Energy: LEED-certified buildings can capitalize on growing technological advancements in solar, wind, and geothermal energy, further enhancing energy efficiency. Corporate Social Responsibility (CSR) Trends: As businesses aim to enhance their CSR profile, energy-efficient LEED buildings are increasingly favored for corporate offices and other facilities.	Growing Demand for Sustainable Buildings: The increasing global demand for energy-efficient and eco-friendly buildings presents an opportunity for more BREEAM-certified projects. Advancements in Energy Technologies: New technologies, such as AI-driven energy management systems, energy-efficient building materials, and renewable energy sources, provide avenues for better performance under BREEAM's energy efficiency criteria. Alignment with Government Policies: Many governments are introducing regulations that align with BREEAM's energy efficiency standards, offering incentives, grants, and tax benefits for energy-efficient buildings. Climate Change and Carbon Reduction Commitments: As organizations strive to meet global climate targets, energy efficiency certifications like	Growing Demand for High-Performance Buildings: The global push for sustainable buildings with strong energy performance creates an opportunity for DGNB to grow, particularly in regions adopting stricter energy codes. Support for Innovation: DGNB's openness to innovative energy solutions provides opportunities for developers to adopt state-of-the-art technologies such as AI-driven energy management, green energy production, and smart building systems. International Expansion: DGNB could expand its influence by further adapting its certification to meet international standards, increasing its recognition in non-European markets. Aligning with ESG Trends: As companies increasingly prioritize Environmental, Social, and Governance (ESG)	Technological Advancements: New technologies (e.g., smart building systems, renewable energy sources) can enhance energy efficiency measures. Public-Private Partnerships: Collaborations between government and private sectors can foster innovation and funding for energy-efficient projects. International Collaboration: Partnerships with international organizations can bring in expertise and resources for implementing energy-efficient practices. Increased Demand for Sustainability: Growing public interest in sustainability can drive demand for energy-efficient buildings, leading to greater adoption of GPRS.

		BREEAM become more critical in demonstrating environmental responsibility.	factors, DGNB's focus on lifecycle energy efficiency positions it well to support organizations aiming for carbon neutrality and energy efficiency goals.	
Threats	Emerging Competitors: Other green building certification programs, such as BREEAM, Green Globes, and WELL, might compete for market share, offering different approaches to energy efficiency. Regulatory Changes: Sudden changes in government policies or building codes could potentially undermine or overlap with LEED standards, making certification less attractive or redundant. Economic Downturns: In times of financial uncertainty, developers and building owners may shy away from pursuing LEED certification due to the perceived additional costs. Technological Obsolescence: Rapid advancements in energy-efficient technologies may outpace LEED standards, making certified buildings less competitive unless upgrades are consistently made.	High Costs for Smaller Projects: The cost of achieving BREEAM certification, especially in terms of energy efficiency upgrades, may be prohibitive for smaller projects or developers with limited budgets. Competition from Other Certifications: Systems like LEED, Green Star, and WELL present competition, each offering a different focus on energy efficiency and sustainability, potentially reducing BREEAM's market share. Regulatory Shifts: Changes in local energy regulations or policies might render some BREEAM energy efficiency criteria less relevant or even conflicting with new codes. Economic Downturns: During periods of economic instability, developers may avoid the perceived added costs of achieving energy efficiency certifications, especially when these do not offer immediate returns.	Competition from Global Certifications: LEED and BREEAM are more widely recognized globally, particularly outside Europe, which poses a threat to DGNB's market share in the energy efficiency sector. Economic Uncertainty: In times of economic instability, the higher initial costs associated with energy-efficient DGNB certification may deter developers from pursuing it, especially in non-mandatory markets. Regulatory Overlap or Shifts: Changes in national or regional building codes, particularly outside the EU, could either supersede or conflict with DGNB's energy efficiency criteria, reducing the need for certification. Perception of Complexity: DGNB's highly technical and detailed assessment process might be seen as overly complex, particularly for projects outside Europe that are	Economic Fluctuations: Economic downturns may limit funding for energy-efficient projects, reducing participation in GPRS. Changing Regulations: Potential changes in governmental policies or regulations could impact the relevance and effectiveness of GPRS. Competition from Other Standards: Emerging or existing building rating systems may compete with GPRS, challenging its adoption. Climate Change Impacts: Extreme weather conditions can affect energy consumption patterns, complicating energy efficiency efforts.

			unfamiliar with its framework.	

Conclusion

This SWOT analysis highlights as follows:

How energy efficiency is a crucial and strategic element within the LEED framework but also comes with challenges related to cost, complexity, and evolving market conditions.

BREEAM's strong, adaptable, and lifecycle-based approach to energy efficiency, but it also reveals the challenges of high costs, complexity, and competition in the global green building certification market.

DGNB's strengths in its thorough and performance-driven approach to energy efficiency but also points to its challenges with complexity, cost, and competition in the international market.

The internal strengths and weaknesses of GPRS concerning energy efficiency, alongside the external opportunities and threats it faces in the evolving landscape of sustainable building practices.

6. Recommendations:

Based on the study, the below are recommendations to enhance energy efficiency in GPRS:

- **Incorporate Advanced Energy Efficiency Technologies**
  Encourage the use of modern energy-saving technologies such as smart meters, energy management systems, and IoT-enabled devices that allow real-time monitoring and optimization of energy use. This approach can help building owners and operators track and reduce energy consumption, aligning GPRS with the high-tech advancements found in LEED, BREEAM, and DGNB.
- **Introduce Performance-Based Energy Metrics**
  Shift from prescriptive methods (checklists) to performance-based energy metrics similar to DGNB, which measures actual energy savings post-construction and throughout the building's lifecycle. This would make GPRS more competitive and results-driven, demonstrating clear long-term energy savings to building owners and investors.
- **Provide Incentives for Renewable Energy Integration**
  Develop additional credits and incentives for integrating on-site renewable energy such as solar panels and wind turbines, or connecting to renewable energy grids.Egypt has significant solar potential, and providing incentives for renewables would reduce reliance on non-renewable energy sources, making buildings more energy independent and future-proof.
- **Focus on Energy Efficiency in Retrofitting Existing Buildings**
  Expand GPRS to offer a dedicated framework for energy retrofitting of older buildings, with strong energy efficiency incentives. Egypt has a large stock of existing buildings with poor energy performance. Focusing on retrofitting could significantly enhance overall energy efficiency across the sector, following BREEAM's approach to existing buildings.
- **Develop Regional Adaptation Strategies for Different Climates**
  Tailor energy efficiency criteria to suit different Egyptian climates (e.g., coastal, desert, urban areas) by adopting localized performance standards for heating, cooling, and insulation. BREEAM's strength is its ability to adapt to different local conditions, which would enhance GPRS's relevance across Egypt's diverse climate zones and reduce energy use specific to local needs.
- **Increase Awareness and Training Programs Partner with educational institutions and** government bodies to establish training programs for architects, engineers, and contractors to build expertise in energy-efficient design and construction practices. A major challenge for GPRS is the limited local expertise. Expanding knowledge will enhance adoption and effective implementation of energy-efficient solutions, leading to better building outcomes.
- **Strengthen Government Policy Integration and Incentives**
  Collaborate with government authorities to align GPRS energy efficiency standards with national energy policies and provide tax incentives or subsidies for developers meeting GPRS energy requirements. National energy policies are critical for driving market adoption. Government support in the form of financial incentives could accelerate adoption of energy-efficient practices.
- **Facilitate Third-Party Energy Audits and Certifications**
  Encourage third-party energy audits to verify actual energy performance post-construction and during building operations. This aligns with DGNB's focus on actual building performance and provides credibility to GPRS energy efficiency claims, thus building

confidence in the system.

- **Promote Low-Cost Energy Efficiency Measures for Affordable Housing**
  Develop a set of low-cost energy efficiency measures specifically designed for affordable housing projects, using passive design strategies like natural ventilation, day lighting, and appropriate insulation. Energy efficiency measures need to be accessible for all market segments, including affordable housing. This would improve GPRS's market reach and social impact while ensuring significant energy savings in low-income areas.
- **Enhance International Collaboration and Benchmarking**
  Build partnerships with international rating systems like LEED and BREEAM to establish joint initiatives, share best practices, and benchmark GPRS energy efficiency standards against global leaders. Learning from global standards can help GPRS improve its criteria and gain international recognition, attracting more foreign investments and elevating its energy efficiency standards.

Conclusion

To enhance the energy efficiency aspect of GPRS, the system should focus on leveraging Egypt's unique climatic advantages, promoting technological innovation, and aligning its strategies with global best practices. These recommendations, combined with strong governmental support, will improve GPRS's competitiveness and effectiveness in driving energy-efficient construction in Egypt.

References

1. U.S. Green Building Council. (n.d.). LEED v4: Building design + construction guide. U.S. Green Building Council. Retrieved from https://www.usgbc.org
2. U.S. Green Building Council. (n.d.). What is LEED certification? U.S. Green Building Council. Retrieved from https://support.usgbc.org/hc/en-us/articles/4404406912403-What-is-LEED-certification
3. American Society of Heating, Refrigerating, and Air-Conditioning Engineers. (n.d.). Standard 90.1: Energy standard for buildings except low-rise residential buildings.
4. ASHRAE. (2019). Energy modeling best practices and applications.
5. AltEnergyMag. (2020, December). Using renewable energy for LEED certification. AltEnergyMag. https://www.altenergymag.com/story/2020/12/using-renewable-energy-for-leed-certification/34241/
6. Accuenergy. (n.d.). LEED v4 for advanced energy metering. Accuenergy. https://www.accuenergy.com/articles/leed-v4-for-advanced-energy-metering/
7. ASHRAE, & U.S. Department of Energy. (n.d.). Advanced energy design guide for small to medium office buildings. American Society of Heating, Refrigerating and Air-Conditioning Engineers.
8. Katipamula, S., & Brambley, M. (2005). Building automation systems: Energy savings potential. Pacific Northwest National Laboratory (PNNL).
9. U.S. Green Building Council. (n.d.). LEED energy & atmosphere overview. U.S. Green Building Council.
10. BREEAM. (n.d.). BREEAM new construction. Retrieved October 18, 2024, from https://breeam.com/standards/new-construction/
11. BREEAM. (n.d.). BREEAM: [ENE 01 - Reduction of energy use and carbon emissions]. Retrieved October 18, 2024, from https://kb.breeam.com/wp-content/plugins/breeamkb-pdf/pdf/?c=838
12. O'Reilly, T. (2021, December 1). The decarbonization challenge: 4 passive strategies for energy-efficient building systems. ArchDaily. https://www.archdaily.com/994391/the-decarbonization-challenge-4-passive-strategies-for-energy-efficient-building-systems
13. BREEAM. (2016). BREEAM: [New Construction / International / 03 - Energy]. Retrieved October 18, 2024, from https://kb.breeam.com/wp-content/plugins/breeamkb-pdf/pdf/?c=816
14. BREEAM. (2022). GN32: Energy prediction and post-occupancy assessment – BREEAM UK new construction 2018 (v2.0). Retrieved October 18, 2024, from https://kb.breeam.com/knowledgebase/gn32-energy-prediction-and-post-occupancy-assessment/
15. Building Research Establishment Environmental Assessment Method (BREEAM). (2024, October 19). New construction/international/2016/03 - Energy/ENE 01 - Reduction of energy use and carbon emissions. https://kb.breeam.com/wp-content/plugins/breeamkb-pdf/pdf/?c=2862
16. Stanford University. (n.d.). Introduction to renewable energy. Stanford: Understand Energy. https://understand-energy.stanford.edu/energy-resources/renewable-energy/introduction-renewable-energy

17. Building Research Establishment. (2024). Ene 02 - Energy monitoring. BREEAM Knowledge Base. https://kb.breeam.com/wp-content/plugins/breeamkb-pdf/pdf/?c=965
18. HMC Architects. (2019, February 6). Energy-efficient building design: Thermal-efficient construction. HMC Architects. https://hmcarchitects.com/news/energy-efficient-building-design-thermal-efficient-construction-2019-02-06/
19. Kibert, C. J. (2016). Sustainable construction: Green building design and delivery (3rd ed.). John Wiley & Sons. (https://books.google.com.eg/books?hl=en&lr=&id=2xgWCgAAQBAJ&oi=fnd&pg=PR15&dq=Kibert,+C.+J.+(2016).+Sustainable+construction:+Green+building+design+and+delivery+(3rd+ed.).+John+Wiley+%26+Sons..&ots=GaVu9Jd-xy&sig=OmvxcLu4LrQPWi0cUqNerlvATK0&redir_esc=y#v=onepage&q&f=false)
20. Hafez, F. S., Sa'di, B., Safa-Gamal, M., Taufiq-Yap, Y. H., Alrifaey, M., Seyedmahmoudian, M., Stojcevski, A., Horan, B., & Mekhilef, S. (2023). Energy efficiency in sustainable buildings: A systematic review with taxonomy, challenges, motivations, methodological aspects, recommendations, and pathways for future research. Energy Strategy Reviews, 45, 101013. https://doi.org/10.1016/j.esr.2023.101013.
21. Hoxha, K., & Skenderi, A. (2018). The impact of energy efficiency measures on the BREEAM rating system. Journal of Building Performance, 9(1), 32-39. https://doi.org/10.21837/ebpj.v9i1.570.
22. CIM. (2024, March 1). The BREEAM rating system explained. CIM. https://www.cim.io/blog/the-breeam-rating-system-explained.
23. DGNB. (n.d.). DGNB certification. https://www.dgnb.de/en/certification/
24. DGNB. (n.d.). About the DGNB system. https://www.dgnb.de/en/certification/important-facts-about-dgnb-certification/about-the-dgnb-system
25. Hanga-Fărcaș, I. F. P. (2023). The building certification system - A tool of sustainable development of university campuses. Journal of Applied Engineering Sciences, 13(1), 105-112. https://doi.org/10.2478/jaes-2023-0014.
26. DGNB. (n.d.). Certification for buildings. Deutsche Gesellschaft für Nachhaltiges Bauen. Retrieved October 19, 2024, from https://www.dgnb.de/en/certification/buildings
27. Hamedani, A. Z., & Huber, F. (2012). A comparative study of DGNB, LEED and BREEAM certificate systems in urban sustainability. WIT Transactions on Ecology and the Environment, 155, 51–62. https://doi.org/10.2495/SC12011.
28. GPRS (Green Pyramid Rating System) (2017), "GPRS V2 for New Buildings and Major Renovation", Published May-2018, HBRC, Egypt. Dev, P. K. (2017, November 25).
29. Evaluating Green Pyramid Rating System: Potentialities & Revival. 1st International Conference on Towards a Better Quality of Life. Technical University Berlin Campus El Gouna. https://doi.org/10.2139/ssrn.3167435.
30. Arafat, M. Y., Faggal, A. A., Khodeir, L., & Refaat, T. (2023). Customizing the Green Pyramid Rating System for assessing university buildings' sustainability: A stakeholder-involved weighting approach. Ain Shams Engineering Journal. https://doi.org/10.1016/j.aej.2023.10.013.
31. Daoud, A. O., Othman, A. A. E., Robinson, H., & Bayyatia, A. (2018, March). Towards a green materials procurement: Investigating the Egyptian Green Pyramid Rating System. Paper presented at the Green Heritage International Conference (Chance - Change - Challenge), Cairo, Egypt. Retrieved from https://www.researchgate.net/publication/323588948_Towards_a_Green_Materials_Procurement_Investigating_the_Egyptian_Green_Pyramid_Rating_S.
32. Bonna, H., El-Hakim, A. S., & El-Behairy, H. S. (2018). The GPRS-V2-2017-NB National Rating System of Sustainable New Buildings and Major Renovation: A technical evaluation. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.3324044.
33. Khoshbakht, M., Gou, Z., & Dupre, K. (2017). Cost–benefit prediction of green buildings: SWOT analysis of research methods and recent applications. Procedia Engineering, 180, 167–178. https://www.academia.edu/79565998.
34. Apanavičienė, R., Maliejus, K., & Fokaides, P. (2020). Sustainability assessment of the building construction stage using building sustainability assessment schemes (BSAS). IOP Conference Series: Earth and Environmental Science, 410(1), 012064. IOP Publishing. https://doi.org/10.1088/1755-1315/410/1/012064.
35. López, A., & Al-Mohammad, A. (2019). Multiscalarity in international sustainable assessment systems: A qualitative comparison of LEED, CASBEE, BREEAM, DGNB and

ESTIDAMA on building, neighbourhood and city scale. IOP Conference Series: Earth and Environmental Science, 290, 012056. https://doi.org/10.1088/1755-1315/290/1/012056.
36. Dev, P. K. (2017). Evaluating green pyramid rating system: Potentialities & revival. In Proceedings of the 1st International Conference: Towards a Better Quality of Life (pp. 1-10). Technische Universität Berlin Campus El Gouna, Egypt.