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Structural Evaluation and Sustainable Practices in the Construction Industry withing the Framework of Saudi Vision 2030

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Abstract

Buildings and infrastructure are major contributors to environmental degradation due to high energy use, water pollution, construction waste, and greenhouse gas emissions. Aligned with Saudi Vision 2030, the Kingdom aims to reduce these impacts in the construction sector to promote environmental, social, and economic sustainability. While several buildings have obtained LEED (Leadership in Energy and Environmental Design) is a global system evaluating buildings' environmental performance, including energy, water, and material efficiency, though sustainable practices remain limited. Green building principles focus on minimizing environmental impacts through energy efficiency, water conservation, and sustainable materials. LEED and similar rating systems are key tools for assessing building performance, yet their application in Saudi Arabia faces challenges, mainly due to a strong emphasis on energy efficiency and limited consideration of local climatic, socioeconomic, and cultural factors. Additionally, the connection between structural performance, LEED scoring is unclear, limiting its integration into sustainability assessments. This study analyzes LEED's implementation in the Saudi construction market, identifies barriers to broader adoption, and proposes practical recommendations to adapt the system to local conditions, supporting the sustainability goals of Vision 2030.

Key words: Structural evaluation; Sustainable construction; Green building; LEED certification; Saudi Vision 2030; Energy efficiency.

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1. Introduction

The Kingdom of Saudi Arabia is facing growing environmental challenges due to rapid urban expansion, which places significant pressure on natural resources, particularly water and energy. In this context, Saudi Vision 2030 serves as an ambitious roadmap aimed at achieving sustainable development and environmental preservation through the adoption of ecofriendly building technologies, improved resource efficiency, and widespread environmental awareness [1]. Buildings play a central role in environmental impact, as they heavily rely on materials extracted from natural resources and transported over long distances. This results in increased fuel consumption, road congestion, and higher carbon emissions from transportation. During the construction phase, high levels of noise and pollution negatively affect the quality of life in surrounding areas. Once operational, buildings contribute to the consumption of large amounts of water and energy, generating wastewater, solid waste, and ongoing carbon emissions. At the end of a building's lifecycle, demolition produces significant waste that requires effective management to mitigate environmental harm [2]. Through the integration of sustainable practices initiatives in the construction sector, the Kingdom aims to reduce resource consumption, lower pollution levels, and minimize waste generation supporting the broader goal of building a green economy and a sustainable environment that ensures a superior standard of living for current and future generations.

Although structural performance plays a critical role in building safety and long-term sustainability, in this study, "structural evaluation" refers to assessing the overall performance of the built structures rather than detailed structural design. The connection between such structural evaluation and LEED scoring remains unclear, which may limit the integration of structural efficiency and material optimization in sustainability assessments. Clarifying this relationship is essential to ensure that structural aspects of buildings are effectively reflected in overall sustainability evaluations, particularly in contexts like Saudi Arabia where environmental and climatic conditions significantly affect building performance

1.1 The significance of becoming "green"

The importance of becoming "green" in the Kingdom of Saudi Arabia has significantly increased, especially with the rising electricity and fuel consumption over the past two years. With growing urban populations and expanding industrial activities, fuel consumption remains high due to the transportation and industrial sectors, contributing substantially to greenhouse gas emissions. Therefore, adopting green practices such as enhancing energy efficiency in buildings, promoting

renewable energy sources, and encouraging sustainable transportation is essential to reduce environmental impacts, lower carbon emissions [3], and support the goals of Saudi Arabia's Vision 2030 for a sustainable and diversified economy. Table 1 presents key activities and their environmental impacts, emphasizing the link between human activities and environmental degradation. This aligns with Saudi Vision 2030, which prioritizes sustainability and encourages actions that reduce environmental harm while supporting long-term development goals [1].

Table 1: Main Activity and Environmental Impacts

Activity	Environmental Impacts	Responsiveness to comply with Vision 2030
Mining / Drilling / Extraction	• Vegetation Loss • Displacement of communities • Soil erosion • Water pollution	• Promotes sustainable land use and ecosystem protection • Promote sustainable mining • Regulate natural resource use • Expand reforestation and environmental protection programs
Manufacturing / Assembly	• High energy consumption • Industrial waste generation	• Shift toward green industries • Improve energy efficiency • Support recycling and circular economy initiatives
Transportation / Distribution	• Fossil fuel consumption • CO_2 emissions • Overuse of packaging materials	• Expand electric and sustainable transport networks • Enhance logistics and distribution efficiency • Encourage local production
Construction / Building	• CO_2 emissions • Pollution from materials and technology • Environmental degradation around construction sites	• Enforce green building codes • Improve energy and water efficiency in buildings • Implement the Saudi Sustainable Building Code
Maintenance / Building Life Cycle	• Continuous energy use • Ongoing emissions • Resource depletion • Material wear and tear	• Promote smart and preventive maintenance • Use long lasting, high efficiency materials • Integrate digital facility management
Recycling / Waste Management	• Landfill decomposition • Groundwater contamination • Methane gas emissions	• Develop national recycling centers • Promote waste segregation at the source • Invest in waste to energy technologies

Connection to Saudi Vision 2030

Saudi Arabia's Vision 2030 places environmental sustainability at the heart of its national transformation plan. The Vision aims to:

- Enhance the quality of life by ensuring a clean and healthy environment.
- Diversify the economy through the development of green industries.

- Reduce dependency on fossil fuels by promoting renewable energy sources.
- Increase the efficiency of resource consumption across all sectors.

By aligning construction, industrial, and waste management practices with these goals, the Kingdom is working toward building a sustainable future that protects its natural resources and enhances the wellbeing of future generations [1].

1.2 LEED (leadership in energy and environmental design)

The concept of "sustainability" gained strong international momentum following the 1992 United Nations Conference on Environment and Development in Rio de Janeiro, underscoring the necessity of integrating environmental considerations into all stages of design and construction. One of the LEED systems that have proven particularly relevant is LEED-EB (Existing Buildings), which applies to structures already in use including offices, laboratories, dormitories, and schools and emphasizes actual building performance and environmental impact. LEED-EB also accommodates buildings that were originally certified under LEED-NC, offering opportunities to improve operational efficiency and reduce recurring costs. discusses how LEED-EB certification assists in resolving operational inefficiencies and lowering building operating expenses [4].

To implement LEED-EB effectively, designers must perform comprehensive sustainability assessments. Recent studies highlight BIM as a tool that can enhance LEED evaluations, streamline documentation, and reduce time and cost. Techniques include third-party software, cloud-based BIM, and API plug-ins, or combining BIM with optimization and machine learning to improve LEED credits and energy efficiency. These examples are provided for context; BIM integration is not part of this study. [5]

Additionally, it is required that any project seeking LEED certification include a minimum level of commissioning. A LEED-accredited professional often guides the project team through a re-commissioning management guide to ensure sustained performance over time emphasized this requirement to safeguard against performance decay after initial certification. Moreover, LEED-EB version 4.1 has introduced performance-based re-assessment and offers bonus points for buildings previously certified under other LEED categories, encouraging continuous performance compliance [6].

1.2.1 challenges of implementing leed in saudi arabia

1. **Lack of Expertise and Multidisciplinary Skills**

A major barrier to the implementation of green building projects is the limited availability of professionals with expertise in sustainable construction. Forming project teams with multidisciplinary knowledge of sustainability remains difficult.

2. **High Initial Costs**

Developers often identify the higher upfront costs of sustainable materials and green technologies, compared to conventional alternatives, as a significant barrier to implementing green building projects.

3. **Harsh Desert Climate and Extreme Weather Conditions**

High heat, low humidity, and frequent sandstorms affect both building performance and maintenance, thus requiring materials and designs that tolerate severe environmental conditions.

4. **Water Scarcity and Water Sustainability**

Given the Kingdom's limited water resources, green building projects face added pressure to apply water saving systems, efficient irrigation, and technologies that reduce water usage.

5. **Weak or Insufficient Regulatory Frameworks**

Although interest in sustainability is growing, there are still gaps in national legislation or building codes that mandate sustainable building practices, resulting in inconsistent adoption.

6. **Limited Awareness and Professional Education**

Many architects, engineers, and contractors are not fully familiar with LEED requirements or the benefits of green building, which hinders wider uptake across the building sector.

7. **Complex Documentation and Administrative Burden**

The process of gathering required documentation for LEED certification is often complex and time consuming, discouraging some teams from fully committing to the certification process [7].

1.2.2 advantages & opportunities of adopting leed in Saudi Arabia

1. **Pioneering Achievements Such as KAPSARC**

The King Abdullah Petroleum Studies and Research Center (KAPSARC) in Riyadh has achieved five LEED-EBOM Platinum certifications for its existing buildings, totaling approximately 52,284 square meters, establishing it as a local benchmark in sustainable building performance [8].

2. **Enhanced Environmental Reputation and Investment Attraction**
   LEED certified buildings provide a marketing edge and attract international investors who prioritize environmentally responsible projects.
3. **Growing Government Support and Alignment with Vision 2030**
   The objectives of Vision 2030 align well with promoting sustainability in the built environment, opening up opportunities for incentives, facilitation, and supportive policies for green projects [1].
4. **Long Term Operational Cost Savings**
   Buildings that meet high sustainability standards tend to use less energy and water, resulting in significant reductions in operating costs over their lifecycle.
5. **Boosting Innovation in Green Technologies and Materials**
   LEEDEB adoption drives demand for advanced materials and technologies, which encourages local industries to invest in research and development in sustainability.

1.2.3 practical suggestions to strengthen leed implementation in Saudi Arabia

1. **Professional Training and Workshops**

Organize specialized training sessions and workshops for architects, engineers, and contractors to deepen their understanding of LEED standards and sustainable design practices. World Business Council for Sustainable Development (WBCSD)

2. **Financial Incentives**

Provide government support, tax reductions, or subsidies to projects aiming for LEED certification to lower the financial burden of initial investments.

3. **Development of Local Guidelines for LEED in Saudi Conditions**

Create guiding documents and best practices that account for desert climate, water scarcity, and regional material availability to ensure consistent application across all regions.

4. **Integration of Modern Technologies and Smart Monitoring Systems**

Employ sensors and real time performance monitoring tools to ensure continual compliance with LEED requirements and assess building behavior after occupancy.

5. **Strengthening Laws and Regulations**

Embed sustainability criteria into the Saudi Building Code and consider mandating certain green certifications or standards, especially in government-initiated projects.

6. **Showcase or Pilot Projects**

Establish pilot or showcase green building projects in major cities to demonstrate the economic, environmental, and technical feasibility of LEED, serving as examples for wider adoption.

1.3 Terminologies “green versus sustainable”

While the terms “green” and “sustainable” are often used interchangeably, they carry distinct meanings, especially in the context of environmental design and construction. A “green building” typically refers to structures designed to reduce environmental impact by improving energy efficiency, conserving water, and utilizing ecofriendly materials. The focus is primarily on minimizing harm to the environment throughout the building's lifecycle from design to operation [9].

On the other hand, “sustainability” is a broader and more holistic concept that extends beyond environmental concerns to include economic viability and social responsibility**.** Sustainable buildings these are initiatives that not only minimize environmental impact but also generate long-term economic value and improve the quality of life for both occupants and surrounding communities. In essence, all sustainable buildings are green, but not all green buildings can be considered truly sustainable [10].

As Saudi Arabia moves forward with its Vision 2030**,** understanding the difference between “green” and “sustainable” becomes increasingly important. Integrating both approaches into the construction and development sectors is vital Aiming to create buildings that are environmentally responsible, economically viable, and socially beneficial, thereby contributing to a more resilient and future-ready Kingdom [1].

Theory #1:

Figure 1 illustrates the distinctions between commonly used terms, focusing on energy consumption and environmental impact regenerative design represents the highest sustainability level, followed by reconciliation and restorative approaches, while sustainability reflects a neutral environmental impact. Green practices achieve relative improvement through rating systems such as LEED, whereas conventional practice is limited to legal compliance. The progression of environmentally conscious design, as shown in the figure, follows an encouraging upward trajectory moving from traditional design to green design, and ultimately toward fully restorative and regenerative approaches. In this context, adopting green practices can be seen as an important step on the path to achieving true sustainability [11].

The distinctions between commonly used terms in environmentally conscious design, such as “green” and “sustainable,” can be understood through their relative impacts on energy consumption and

environmental footprint. The evolution from traditional building practices to green design, and ultimately to sustainable and regenerative design, represents a progressive improvement in minimizing ecological harm and enhancing resource efficiency. Green building is often considered an important step toward sustainability, focusing on reducing energy and water use, minimizing site disturbances, and improving indoor environmental quality compared to conventional buildings. This includes careful consideration of lifecycle impacts, from material selection and construction to operation and end of life reuse or disposal. Sustainability, however, encompasses a broader philosophy, emphasizing the balance between environmental stewardship, economic viability, and social wellbeing to ensure that future generations can enjoy a comparable quality of life It involves not only using resources efficiently but also creating resilient systems and communities that can thrive over the long term. Therefore, while all green buildings aim to reduce environmental impacts, truly sustainable projects integrate economic and social dimensions to support lasting benefits for people and the planet [12].

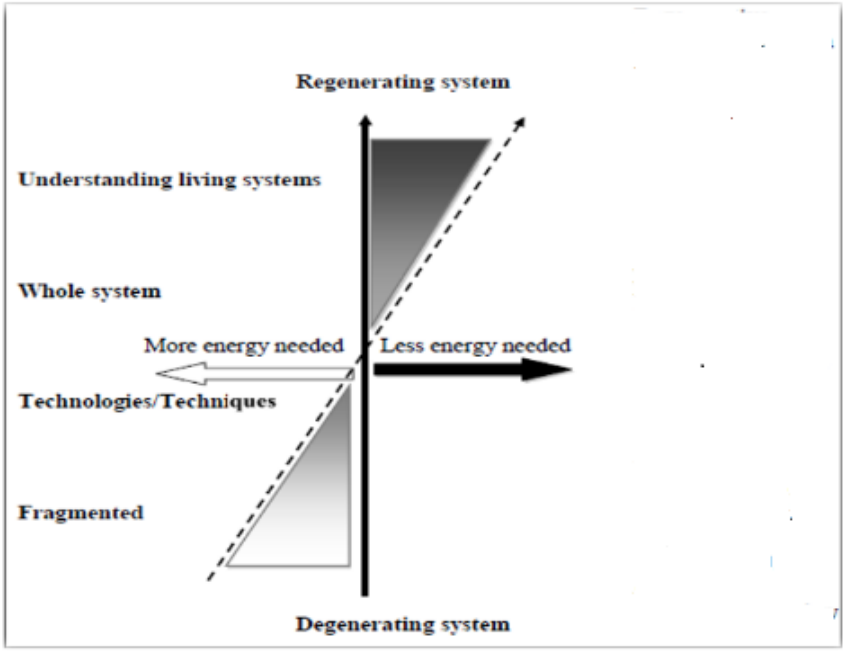


Fig. 1. Illustrates The Differences Between Commonly Used Terminologies Based On Energy Consumption and Environmental Impact. [11]

Theory #2:

From an alternative perspective, the relationship between sustainability and green design is illustrated in Figure 2. In this depiction, sustainability encompasses environmentally stable, technologically advanced, materially efficient, and ecologically responsible building design. Conversely, the term "green" is viewed more abstractly, integrating concepts of ecology, performance, and sustainability [13]. Within this framework, ecology refers to how a building interacts with and maintains harmony with the natural environment. It is possible, therefore, for a building to be sustainable and stable yet not necessarily "green" if it exhibits poor environmental performance or negative ecological impact. Similarly, a building may demonstrate high performance but lack ecological balance or long term stability, underscoring the nuanced distinction between these concepts. Devoid of stability, ecology, etc. [14].

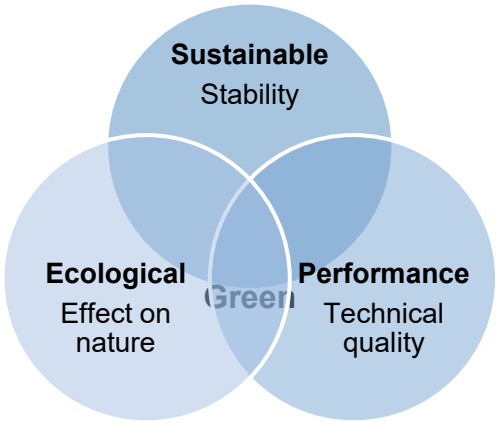


Fig. 2. Relationship Between Green, Sustainability, Ecology, And Performance [13]

2. Research Objective

The primary objective of this paper is to evaluate selected construction projects in the Kingdom of Saudi Arabia that have obtained LEED certification, with a particular focus on identifying the weaknesses that affect their scoring. To date, numerous construction projects in major cities such as Riyadh, Jeddah, and Dammam have been awarded LEED certifications, reflecting the Kingdom's growing commitment to sustainable building practices. Figure 3, illustrates the geographic distribution of these certified projects across various regions of the Kingdom, highlighting the progress and challenges in implementing green building standards nationwide.

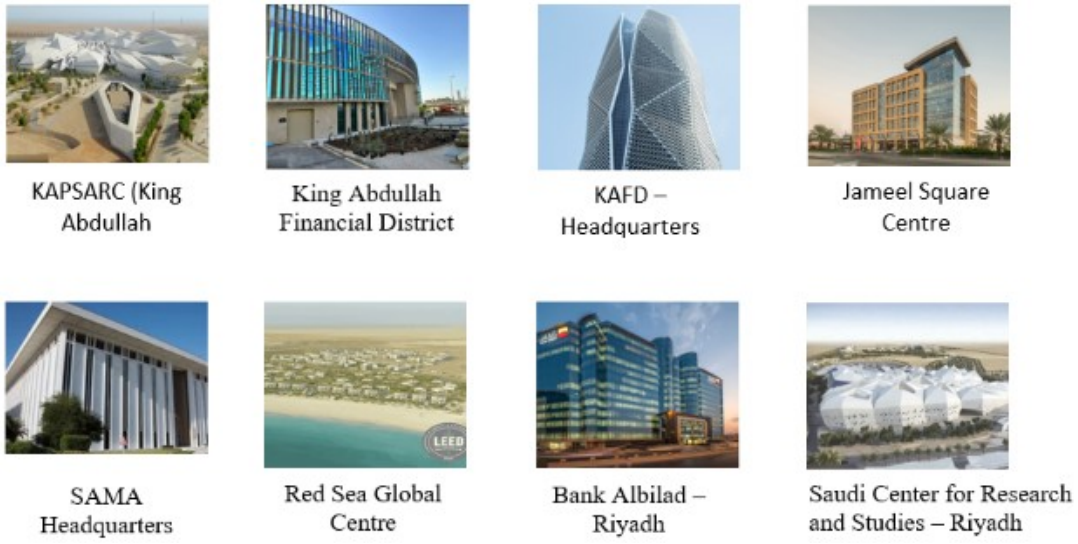


Fig. 3. Several Construction Projects in The Kingdom of Saudi Arabia Have Achieved LEED Certification (All images sourced from the Internet and official building websites.)

3. Methodology

Figure 4 illustrates the detailed research methodology applied in this study, which consists of five main steps. First, a selection of construction projects in Saudi Arabia was identified based on their LEED certification status, and relevant data, including building type, size, and LEED scorecards, were collected to form the study dataset. Next, the collected data were examined for completeness and consistency, and preliminary assessments were conducted to evaluate project compliance with LEED criteria across all relevant categories. Each project was then scored according to the LEED rating system, and scores were categorized by performance areas (e.g., Energy & Atmosphere, Sustainable Sites, Water Efficiency) to facilitate comparative analysis. Statistical analysis was applied to the evaluation results to determine overall project performance, identify trends, and quantify strengths and weaknesses in each LEED category. Finally, the findings were summarized, gaps and recurring weaknesses in current project practices were highlighted, and practical recommendations were proposed to improve the accuracy of the scoring system and enhance the implementation of sustainable strategies in future projects.

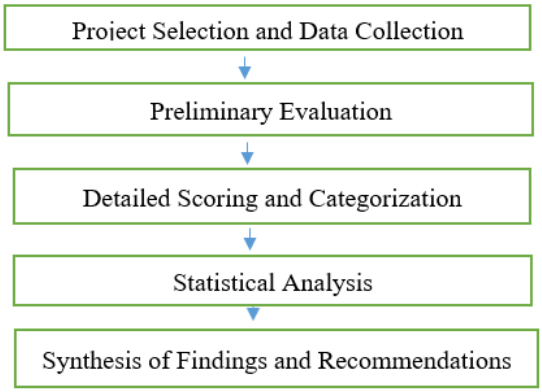


Fig. 4. Research Methodology

Statistics show a significant variation among Middle Eastern countries in the number of projects certified under the **LEED** (Leadership in Energy and Environmental Design) system as show in figure 5. The Kingdom of Saudi Arabia leads with 1,029 certified projects, reflecting its growing commitment to sustainability and alignment with the goals of Saudi Vision 2030. It is followed by the United Arab Emirates, which has 749 certified projects, benefiting from an early adoption of green building standards, particularly in Dubai and Abu Dhabi. Qatar ranks third with 162 projects, many of which are part of modern infrastructure and sustainable stadium developments. Egypt has achieved 46 certified projects, amid growing efforts to implement sustainability standards in national development projects. Meanwhile, Kuwait has 23 certified projects, indicating room for further expansion in the prospective implementation of green building practices [15].

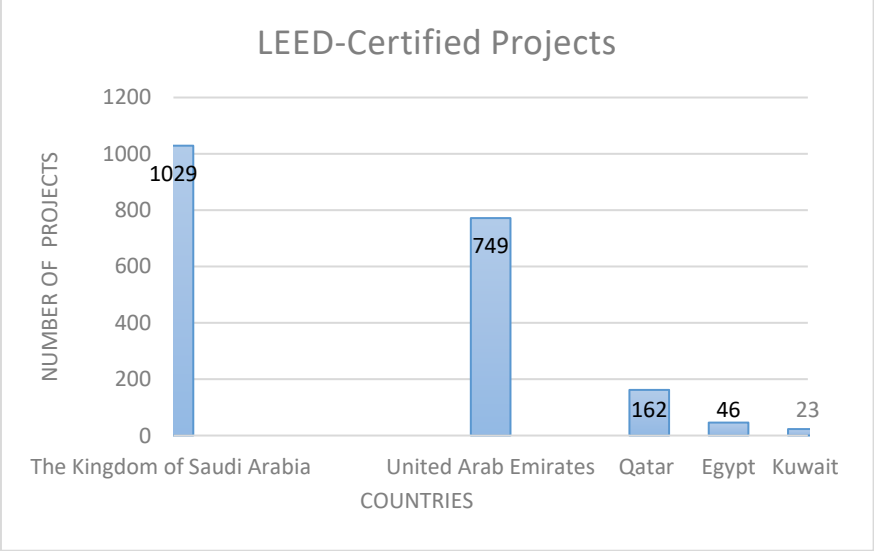


Fig. 5. Comparison Between Some Middle Eastern Countries to Obtain LEED

As show in figure 6, the number of projects certified under the LEED (Leadership in Energy and Environmental Design) system in the Kingdom of Saudi Arabia has reached 1,029 projects, reflecting the country's growing commitment to sustainability in the construction and urban development sectors.

These certifications are distributed across various levels: 240 projects achieved Platinum certification, the highest level, 174 received Gold, 569 were awarded Silver, and 46 projects obtained basic Certification [15]. This research aims to increase awareness and understanding of the LEED system and its importance in promoting energy efficiency and environmental sustainability, as well as to encourage the development of more certified projects in alignment with Saudi Vision 2030, which seeks to build a sustainable future and achieve comprehensive development across all sectors.

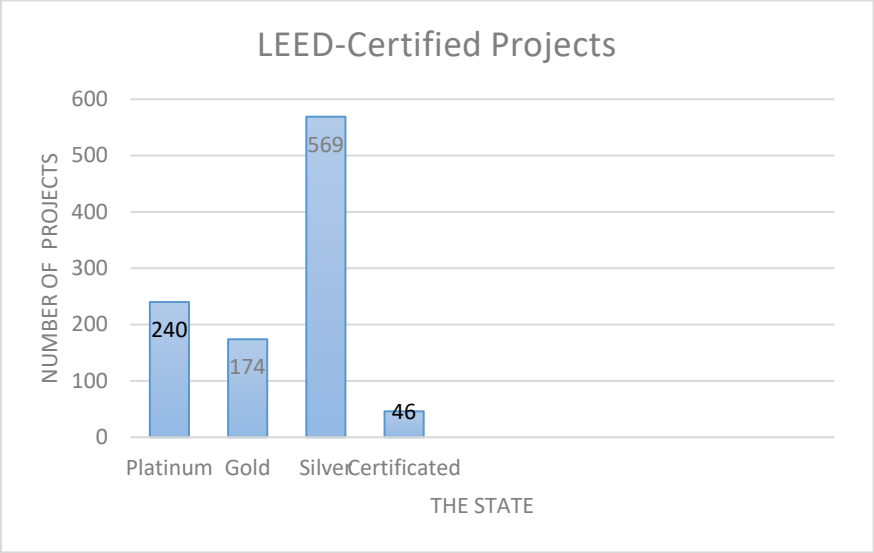


Fig. 6. Classification of LEED Certified Projects in The Kingdom of Saudi Arabia.

This study will analyze the projects certified under LEED in the Kingdom of Saudi Arabia, aiming to gain a deeper understanding of these projects and to develop recommendations that contribute to improving environmental performance and future sustainability of buildings. The projects have been classified into three main categories: Gold, Silver, and Certified, with the objective of identifying shortcomings and challenges within each category, and striving to achieve the higher. The selected projects were chosen randomly, based on the availability of necessary data for analysis. Detailed information about these projects is presented in the following tables, which serve as the foundation for the analysis and conclusions of this study.

As shown in the following tables, Table 2 includes projects with LEED Certified status, presenting individual scores for key sustainability categories such as Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality, Sustainable Sites, Water Efficiency, and Innovation in Design, highlighting strengths and areas for improvement. Table 3 presents projects that attained LEED Silver certification, with a breakdown of scores in the same categories to assess environmental performance. Table 4 showcases projects that achieved LEED Gold certification, detailing scores across all major categories to emphasize achievements and potential improvements. Additionally,

Table 5 presents fifteen LEED Gold projects, Table 7 shows eight LEED Silver projects, and Table 9 includes seven LEED Certified projects, all with detailed category scores. This presentation provides a clear evaluation of environmental performance and supports strategies to enhance sustainability outcomes and achieve higher LEED ratings [15].

Table 2: Projects Certified LEED Gold in The Kingdom of Saudi Arabia and Total Score Achieved

#	**Project & Address**	**Project Certification Level**	**Scoring**
1	**KAAUH Riyadh # Airport Road, Riyadh, Saudi Arabia, 11552**	Gold	60
2	**4HP9R9R Al Khams's Rd Road Fanateer, Al Jubal, Saudi Arabia, 35811**	Gold	70
3	**VOX Cinema sin the Esplanade Mall The Esplanade Mall, Riyadh, Saudi Arabia, 12371**	Gold	69
4	**VOX Cinema sin The Roof in Riyadh King Abdul-Aziz Rd Al Burj, Riyadh, Saudi Arabia, 18278**	Gold	69
5	**DAR Engineering Al Olay a, Riyadh, Saudi Arabia, 11642**	Gold	62
6	**Dr Suleiman Al Habib Al Qassim Al Safra Unit1 Buraydah, Al Qassim, Saudi Arabia, 52381**	Gold	67
7	**Dr Suleiman Al Habib Al Khobar King Fahad Bin Abdul-Aziz Road Banda, Al Khobar, Saudi Arabia, 34423**	Gold	65
8	**DrSulaimanAlHabibAlOlayaWadiHanifaOlayaUnit42Riy, Riyadh, Saudi Arabia, 12214**	Gold	62
9	**VOX Cinema sin Roshn Front Riyadh, Riyadh, Saudi Arabia,**	Gold	60
10	**Olaya Towers by Osool –Al Olaya Street, Riyadh, Saudi Arabia, 12213**	Gold	71
11	**Jamel Square Prince Mohammed Bin Abdul-Aziz St Al and, Jeddah, Saudi Arabia, 23326**	Gold	63
12	**Bank Al Bilad Tower Al Mutamarat 8229 Building No23952, Riyadh, Saudi Arabia, 12711**	Gold	60
13	**Mon shaat Head Office 7739OlayaSt Al Ghadir247013311https:mon shaatgovsa, Riyadh, Saudi**	Gold	67
14	**Saudi Electricity Company HQ Abha 68303129Almahalah Abha62561, Abha, Saudi Arabia, 62561**	Gold	72
15	**King Abdul-Aziz Center for World Culture Dhahran Jubail Highway Saudi Arabia, Dhahran, Saudi Arabia, 31311**	Gold	72

Table 3: Projects Certified LEED Silver in The Kingdom of Saudi Arabia and Total Score Achieved

#	Project & Address	Project Certification Level	Scoring
1	**NEOM SATCO Layd own office Wade Ainounah Neom, Neom, Saudi Arabia, 49637**	silver	51
2	**Panda202 ArRawdah District, Jeddah, Saudi Arabia, 23434**	silver	59
3	**KAUST RP Mosque 4700 King Abdullah University, Jeddah Thuwal, Saudi Arabia, 23955**	silver	55
4	**IPSO911Riyadh Storage Building Salboukh Road, Riyadh, Saudi Arabia**	silver	50
5	**KFMC Rehabilitation Hospital Al Sulay maneyya Riyadh, Riyadh, Saudi Arabia, 11525**	silver	55
6	**Asharqia Chamber Tower Plotnumber6DBlocknumber1Masterp, Dammam, Saudi Arabia,**	silver	50
7	**U.S. Consulate General Dhahran 889 Salah Elden Al Ayoubi St, Al Andalus, Al Khobar, Saudi Arabia, 31261**	silver	55
8	**KAUST RP Administration Building 4700 King Abdullah University, Jeddah Thuwal, Saudi Arabia, 23955**	silver	52

Table 4: Projects Certified LEED The Kingdom of Saudi Arabia and Total Score Achieved

#	Project & Address	Project Certification Level	Scoring
1	**Al Woroud City Admin Building Al Sail Road Taif, Taif, Saudi Arabia, 26311**	certified	49
2	**The VUE Obhor, Jeddah, Saudi Arabia, 23734**	certified	41

3	**Ministry of Environment Water and Agric. Ministry of Environment Water and Agric., Riyadh, Saudi Arabia,**	certified	47
4	**Diyar Al Salam Jeddah, Jeddah, Saudi Arabia, 21411**	certified	44
5	**NGHA Jeddah Neuroscience Hospital NGHA Jeddah Campus, Jeddah, Saudi Arabia,**	certified	48
6	**SABIC Academy Building Saudi Arabia, Riyadh, Saudi Arabia,**	certified	46
7	**Tamer Group Main Distribution Center Kumar Area, King Faisal Road, Near Old Check Point, Jeddah, Saudi**	certified	47

The LEED rating system is one of the most prominent global standards for assessing sustainable buildings. It is used to measure how well projects adhere to environmental sustainability criteria. Certifications are awarded based on the total number of points a project earns through the implementation of sustainable design and construction strategies. LEED certification is divided into four main levels:

- Certified: Awarded to projects that earn between 40 and 49 points.
- Silver: Awarded to projects that earn between 50 and 59 points.
- Gold: Awarded to projects that earn between 60 and 79 points.
- Platinum: The highest level, awarded to projects that earn 80 points or more [15].

These certification levels reflect the building's commitment to environmentally responsible practices, encouraging reduced environmental impact, improved resource efficiency, and the creation of healthy and sustainable indoor environments.

The LEED rating system evaluates projects based on a set of fundamental environmental criteria, which are divided into several main categories. Projects earn points in each category, and the total number of points determines the final level of certification. These categories include:

- Sustainable Sites: Assesses site selection and development strategies that minimize environmental impact, such as preserving natural habitats and reducing pollution.
- Water Efficiency: Focuses on methods and technologies that reduce water consumption both indoors and outdoors.
- Energy and Atmosphere: Addresses energy efficiency, the use of renewable energy sources, and the optimization of heating, cooling, and ventilation systems.

- Materials and Resources: Evaluates the use of sustainable, recycled, and regionally sourced materials, as well as waste reduction practices during construction.
- Indoor Environmental Quality: Assesses indoor air quality, lighting, thermal comfort, and acoustic performance to promote healthier indoor environments.
- Innovation in Design: Awards additional points to projects that implement innovative strategies exceeding standard sustainability practices.
- Regional Priority: Provides extra points for addressing specific environmental concerns relevant to the project's geographic location.

Points earned across all categories are totaled to determine the final certification level, encouraging designers and developers to adopt integrated solutions that enhance long term environmental sustainability.

As shown in the following tables, Table 6 focuses on projects that achieved LEED Gold certification, showing each item's score as a percentage of the total possible points, which highlights the categories that contribute most to Gold-level certification and indicates areas with the greatest impact on sustainability performance. Table 8 presents the relative scores for projects with LEED Silver certification, allowing for comparison across categories to identify both strengths and areas that require improvement to meet Silver-level requirements. Table 10 illustrates the relative scores for projects with LEED Certified status, providing insight into the most influential categories at the Certified level and supporting targeted strategies to enhance environmental performance.

Table 5: Presents The Fifteen Projects That Have Achieved LEED Gold Certification, along with The Separated Scores for Each Individual Scoring Category

#	Project Adress	Project Certification Level	scoring	SUSTAINABLE SITES (4)	WATER EFFICIENCY (15)	ENERGY & ATMOSPHERE (35)	MATERIAL & RESOURCES (9)	INDOOR ENVIRONMENTAL QUALITY (22)	INNOVATION (1)	LOCATION & TRANSPORTATION (14)
1	KAAUH-Riyadh # Airport Road, Riyadh, Saudi Arabia, 11552	Gold	60	0	6	20	7	15	0	12
2	4HP9R9RAlKhameesRdRoadFanateer, AlJubayl, Saudi Arabia, 35811	Gold	70	0	9	21	7	20	1	12
3	VOXCinemasintheEsplanadeMall-TheEsplanadeMall, Riyadh, Saudi Arabia, 12371	Gold	69	0	8	19	7	22	1	12
4	VOXCinemasinTheRoofinRiyadh- KingAbdulazizRdAlBurj, Riyadh, Saudi Arabia, 18278	Gold	69	0	9	17	7	22	1	13
5	DAREngineering-AlOlaya, Riyadh, Saudi Arabia, 11642	Gold	62	0	9	24	7	19	0	10
6	nanAlHabibAlQassim-AlSafraUnit1Buraydah, AlQassim, Saudi Arabi	Gold	67	0	9	25	4	17	1	11
7	DrSulaimanAlHabibAlKhobar-KingFahadBinAbdulazizRoadBanda, AlKhobar, Saudi Arabia, 34423	Gold	65	0	11	19	5	17	1	12
8	anAlHabibAlOlaya-WadiHanifaOlayaUnit42Riy, Riyadh, Saudi Arabi	Gold	62	0	7	21	8	16	1	9
9	VOXCinemasinRoshnFront - Riyadh, Riyadh, Saudi Arabia, 00000	Gold	60	0	11	14	5	20	1	9
10	OlayaTowersByOsool -AlOlayaStreet, Riyadh, Saudi Arabia, 12213	Gold	71	0	10	28	5	15	1	12
11	JameelSquare Address: PrinceMohammedBinAbdulazizStAlAnd, Jeddah, Saudi Arabia, 23326	Gold	63	0	9	19	6	18	1	10
12	BankAlBiladTower Address: AlMutamarat8229BuildingNo23952, Riyadh, Saudi Arabia, 12711	Gold	60	1	9	21	6	12	0	11
13	MonshaatHeadOffice Address: 7739OlayaStAlGhadir2470133111https:monshaatgovsa, Riyadh, Saudi	Gold	67	1	12	22	6	15	0	11
14	SaudiElectricityCompanyHQAbha Address: 68303129AlmahalahAbha62561, Abha, Saudi Arabia, 62561	Gold	72	0	11	24	7	17	1	12
15	KingAbdulazizCenterforWorldCulture Address: DhahranJubailHighwaySaudiArabia, Dhahran, Saudi Arabia, 31311	Gold	72	4	11	16	8	20	1	12

Table 6: The Relative Score of Each Scoring Item of LEED Gold

	Sustainable Sites	**Water Efficiency**	**Energy & Atmosphere**	**Material & Resources**	**Indoor Environmental Quality**	**Innovation**	**Location & Transportation**
sum	6	141	310	95	265	11	168
total sum	60	225	525	135	330	15	210
relative score	0.1	0.6266	0.5905	0.7037	0.8030	0.7333	0.8

Table 7: Presents The Eight Projects That Have Achieved LEED Silver Certification, along with The Separated Scores for Each Individual Scoring Category

#	Project Adress	Project Certification Level	scoring	LOCATION & TRANSPORTATION (14)	SUSTAINABLE SITES (4)	WATER EFFICIENCY (15)	ENERGY & ATMOSPHERE (35)	MATERIAL & RESOURCES (9)	INDOOR ENVIRONMENTAL QUALITY (22)	INNOVATION (1)
1	NEOMSATCOLayd own office WadiAinounahNeom, Neom, Saudi Arabia, 49637	silver	51	8	0	12	16	5	9	1
2	Panda202 ArRawdahDistrict, Jeddah, Saudi Arabia, 23434	silver	59	10	0	10	17	3	19	0
3	KAUST RP Mosque 4700 King Abdullah University, Jeddah-Thuwal, Saudi Arabia, 23955	silver	55	11	1	9	16	6	11	1
4	IPSO911Riyadh Storage Building SalboukhRoad, Riyadh, Saudi Arabia	silver	50	9	0	11	14	5	10	1
5	KFMC Rehabilitation Hospital AlSulaymaneyyaRiyadh, Riyadh, Saudi Arabia, 11525	silver	55	14	1	8	15	6	11	0
6	Asharqia Chamber Tower Plotnumber6DBlocknumber1Masterp, Dammam, Saudi Arabia,	silver	50	9	0	12	14	6	8	1
7	U.S. Consulate General Dhahran 889 Salaheddin Al Ayoubi St, Al Andalus, Al Khobar, Saudi Arabia, 31261	silver	55	10	1	10	13	7	13	1
8	KAUST RP Administration Building 4700 King Abdullah University, Jeddah-Thuwal, Saudi Arabia, 23955	silver	52	11	0	9	12	6	13	1

Table 8: The Relative Score of Each Scoring Item of LEED Silver

	Sustainable Sites	**Water Efficiency**	**Energy & Atmosphere**	**Material & Resources**	**Indoor Environmental Quality**	**Innovation**	**Location & Transportation**
Sum	3	81	117	44	94	6	82
Total sum	32	120	280	72	176	8	112
Relative score	0.09375	0.675	0.4179	0.6111	0.5341	0.75	0.7321

Table 9: Presents The Seven Projects That Have Achieved LEED Certificated Only, along with The Separated Scores for Each Individual Scoring Category

#	Project Adress	Project Certification Level	scoring	location & transportation (20)	sustainable sites (10)	water efficiency (11)	Eenergy & atmosphere (20)	material & resources (13)	indoor environmental quality (16)	Regional priority credits (4)	innovation (6)
1	Al Woroud City Admin Building AlSailRoadTaif, Taif, Saudi Arabia, 26311	certified	49	3	1	9	18	0	8	4	6
2	The VUE Obhor, Jeddah, Saudi Arabia, 23734	certified	41	5	2	5	7	5	9	3	5
3	Ministry of Environment Water and Agric Ministry of Environment Water andAgric, Riyadh, Saudi Arabia,	certified	47	12	3	5	13	4	6	2	2
4	Diyar Al Salam Jeddah, Jeddah, Saudi Arabia, 21411	certified	44	13	7	2	3	5	8	3	3
5	NGHA - Jeddah Neuroscience Hospital NGHA Jeddah Campus, Jeddah, Saudi Arabia,	certified	48	5	5	8	9	5	11	4	1
6	SABIC Academy Building Saudi Arabia, Riyadh, Saudi Arabia,	certified	46	5	5	8	11	1	7	5	4
7	Tamer Group - Main Distribution Center Kohmra Area, King Faisal Road, Near Old Check Point, Jeddah, Saudi	certified	47	7	7	7	11	1	5	5	4

Table 10: The Relative Score of Each Scoring Item of LEED Certificated

	Sustainable Sites	**Water Efficiency**	**Energy & Atmosphere**	**Material & Resources**	**Indoor Environmental Quality**	**Innovation**	**Location & Transportation**
Ssum	30	44	72	21	54	25	50
Total sum	70	77	140	91	112	42	140
Relative score	0.4286	0.5714	0.5143	0.2308	0.4822	0.5953	0.3572

4. Analysis of result

4.1. Analysis of performance results for leed gold certified projects

The analysis of the relative scores across the fifteen LEED Gold certified construction projects reveals notable variations in performance across the different sustainability categories. The relative score for each category is as follows: Sustainable Sites: 6/60 = 0.10, Water Efficiency: 141/225 = 0.63, Energy & Atmosphere: 310/525 = 0.59, Materials & Resources: 95/135 = 0.70, Indoor Environmental Quality: 265/330 = 0.80, Innovation: 11/15 = 0.73, Location & Transportation: 168/210 = 0.80. These results indicate strong performance in categories such as Indoor Environmental Quality, Location & Transportation, and Innovation, each achieving over 70% of the possible points. The Materials & Resources and Water Efficiency categories also demonstrate solid performance, with scores above 60%.

However, the Sustainable Sites category shows a significant underperformance, achieving only 10% of the total possible points (6 out of 60), the low score (10% for Gold projects) in the Sustainable Sites category is mainly due to Saudi Arabia's arid climate, scarce vegetation, and water scarcity, which limit landscaping and irrigation options. Urban density and site constraints further restrict sustainable site practices. LEED criteria, designed for temperate regions, are not fully adapted to desert conditions. Locally tailored strategies, such as drought-resistant plants, water reuse, and reduced impervious surfaces, are needed to improve performance in this category, supporting Vision 2030 sustainability goals, which heavily affects the overall certification score.

Additionally, the Energy & Atmosphere category, despite being a critical aspect of environmental performance, scored only 59% for gold projects, indicating room for improvement. This relatively low score is primarily attributed to Saudi Arabia's hot and arid climate, which significantly increases cooling demands, conventional building designs that limit the use of passive energy strategies, and the limited adoption of renewable energy systems. Overall, the cumulative performance across all categories did not exceed 50% of the total possible points, highlighting the need for strategic interventions, particularly in site selection and energy management. Addressing these weaknesses can enhance overall environmental efficiency and increase the potential for achieving higher LEED certification levels in future projects

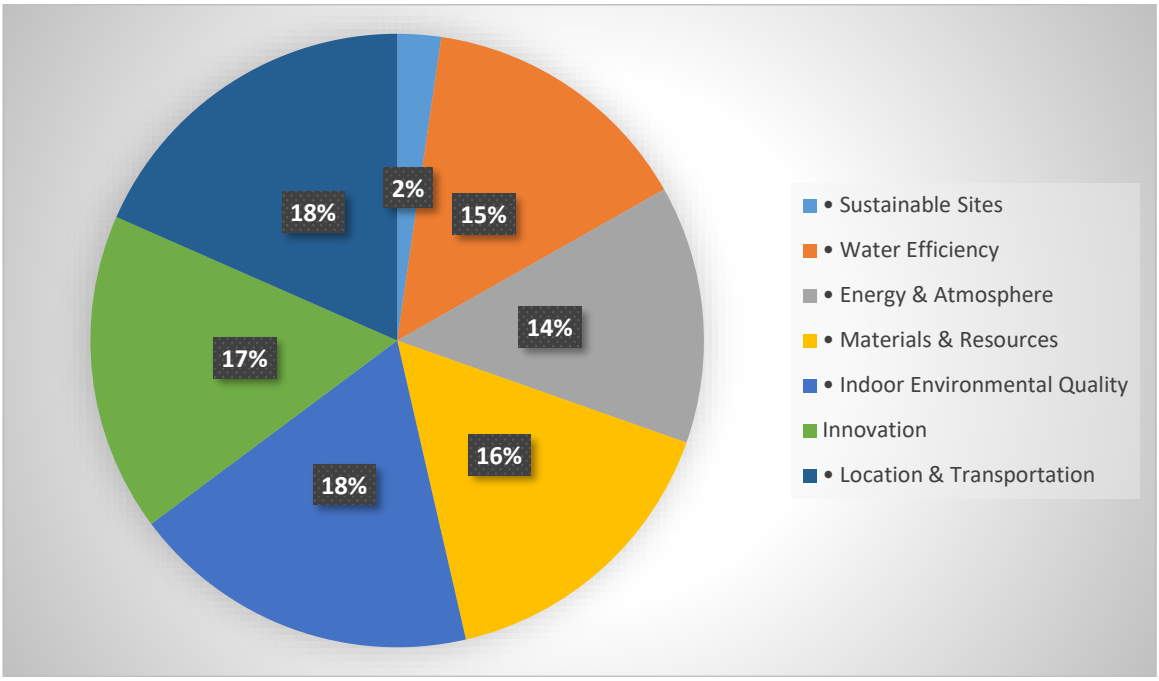


Fig. 7. Scoring Leeds Items Percentage for LEED Gold Certified Projects.

Figure 7 illustrates the percentage distribution of LEED scoring across various sustainability categories for projects that achieved LEED Gold certification. The breakdown is as follows: Sustainable Sites: 2.3% Water Efficiency: 14.5% Energy & Atmosphere: 13.6% Materials & Resources: 16% Indoor Environmental Quality: 18.4% Innovation: 16.4% Location & Transportation: 18.4% This distribution reveals a clear imbalance in score contribution among the evaluated categories. Notably, Sustainable Sites received the lowest percentage (2.3%), which indicates either underperformance in site selection and ecological integration or a strategic reprioritization of this category in design and planning phases. In contrast, Indoor Environmental Quality and Location & Transportation both scored the highest at 18.4%, reflecting strong attention to occupant health, comfort, connectivity, and access to sustainable mobility. The relatively high scores in Innovation (16.4%) and Materials & Resources (16%) suggest that these projects incorporate advanced construction strategies and place value on responsible material usage, potentially including recycled and locally sourced components. However, the moderate score in Energy & Atmosphere (13.6%), which is typically one of the most critical categories in determining a building's sustainability performance, points to room for improvement in energy efficiency measures, renewable integration, and overall carbon footprint reduction. This aligns with sustainable design principles discussed in literature. For instance, [12] highlights the importance of practical, performance driven housing design that incorporates tight construction, high insulation, controlled ventilation, and energy recovery systems all of which contribute to lower carbon emissions and enhanced energy efficiency. Such strategies are not only effective but also accessible and replicable, allowing widespread adoption of sustainable building practices.

4.2. Analysis of performance results for leed silver certified projects

An evaluation of the relative scores for the eight construction projects certified under the LEED Silver level highlights noticeable disparities in performance across the various sustainability categories. The relative score for each category is as follows: Sustainable Sites: 3/32 = 0.09, Water Efficiency: 81/120 = 0.675, Energy & Atmosphere: 117/280 = 0.42, Materials & Resources: 44/72 = 0.61, Indoor Environmental Quality: 94/176 = 0.54, Innovation: 6/8 = 0.75, Location & Transportation: 82/112 = 0.73

Key Observations

Sustainable Sites (0.09)

This category demonstrates the lowest relative score (9%), indicating a major weakness in site planning and ecological considerations. This underperformance may result from poor integration of sustainable land use practices, minimal efforts to mitigate site disruption, or lack of prioritization during project design.

Water Efficiency (0.675) and Materials & Resources (0.61)

These two categories show strong performance, reflecting effective implementation of water saving fixtures, landscape strategies, and responsible material selection potentially including recycled and locally sourced materials.

Location & Transportation (0.73) and Innovation (0.75)

These are the topper forming categories, suggesting that the projects focused on connectivity, walkability, public transportation access, and also incorporated creative or forward thinking sustainability strategies that exceed standard LEED requirements.

Energy & Atmosphere (0.42)

Despite being one of the most critical categories in environmental performance, this score is relatively low, revealing opportunities for improvement in energy optimization, renewable energy integration, and HVAC system efficiency.

Indoor Environmental Quality (0.54)

This is a moderate score, indicating some effort to ensure thermal comfort, air quality, and lighting control. However, there is still room for enhancement to meet higher occupant wellbeing standards.

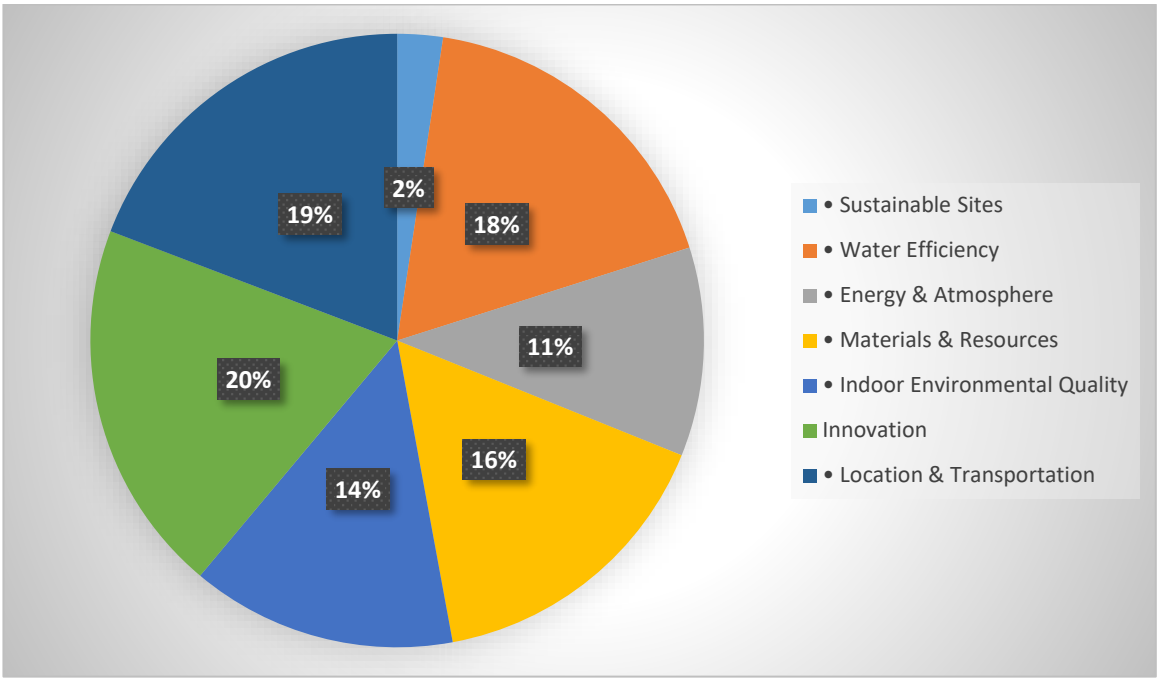


Fig. 8. Scoring Leeds items percentage for LEED Silver Certified Projects

Figure (8) illustrates the relative distribution of scores across the various sustainability categories for projects certified under LEED Silver. The highest percentages were recorded in the categories of Innovation (19.7%) and Location & Transportation (19.2%), indicating a strong focus on integrating creative solutions and effective urban connectivity that supports sustainable mobility and access to public transportation. This success reflects the adoption of design strategies that exceed standard LEED requirements and can be leveraged to enhance performance in other categories. In contrast, moderate performance was observed in Indoor Environmental Quality (14%) and Water Efficiency (17.7%), suggesting a reasonable level of attention to indoor comfort, air quality, and water saving technologies. However, there remains room for improvement in natural ventilation, the use of high efficiency plumbing fixtures, and water efficient irrigation systems. The Energy & Atmosphere category scored just 11%, which is relatively low given its critical role in reducing carbon emissions and improving energy efficiency. This weakness highlights the need to strengthen the integration of renewable energy technologies, as well as the performance of HVAC systems and thermal insulation. On the other hand, the Sustainable Sites category recorded the lowest score at 2.4%, indicating significant shortcomings in site planning and selection regarding environmental impact mitigation and resource preservation. Therefore, it is essential to prioritize site choices that protect ecosystems, reduce urban pollution, and support sustainable land development practices in future projects. Overall, the score distribution demonstrates clear variation in performance across the categories, emphasizing the importance of

adopting a balanced approach that addresses areas of weakness particularly in energy and site sustainability while maintaining excellence in innovation and urban connectivity.

4.3. Analysis of performance results for leed certified projects

The relative score evaluation of seven construction projects certified at the LEED Certified level reveals clear disparities in performance across various sustainability categories. The relative scores for each category are as follows: Sustainable Sites: 30/70 = 0.43, Water Efficiency: 44/77 = 0.57, Energy & Atmosphere: 72/140 = 0.51, Materials & Resources: 21/91 = 0.23, Indoor Environmental Quality: 54/112 = 0.48, Innovation: 25/42 = 0.6, Location & Transportation: 50/140 = 0.36

Category Performance Overview

- **Materials & Resources (0.23):** This category has the lowest score, indicating weak implementation of sustainable material selection and recycling practices.
- **Location & Transportation (0.36):** A relatively low score, reflecting limited integration with public transport infrastructure or selection of sites that do not support urban sustainability.
- **Sustainable Sites (0.43):** A moderate performance level, indicating some environmental considerations in site planning, but without strong results in reducing environmental impact.
- **Indoor Environmental Quality (0.48):** Also a moderate score, suggesting partial implementation of air quality, thermal comfort, and indoor environmental standards.
- **Energy & Atmosphere (0.51):** This score reflects average performance, with some application of energy efficiency strategies, though lacking robust renewable energy use or advanced HVAC systems.
- **Water Efficiency (0.57):** A relatively strong category, showing clear attention to water conservation both indoors and outdoors.
- **Innovation (0.60):** The highest scoring category, reflecting the integration of creative, beyond standard LEED strategies within project designs

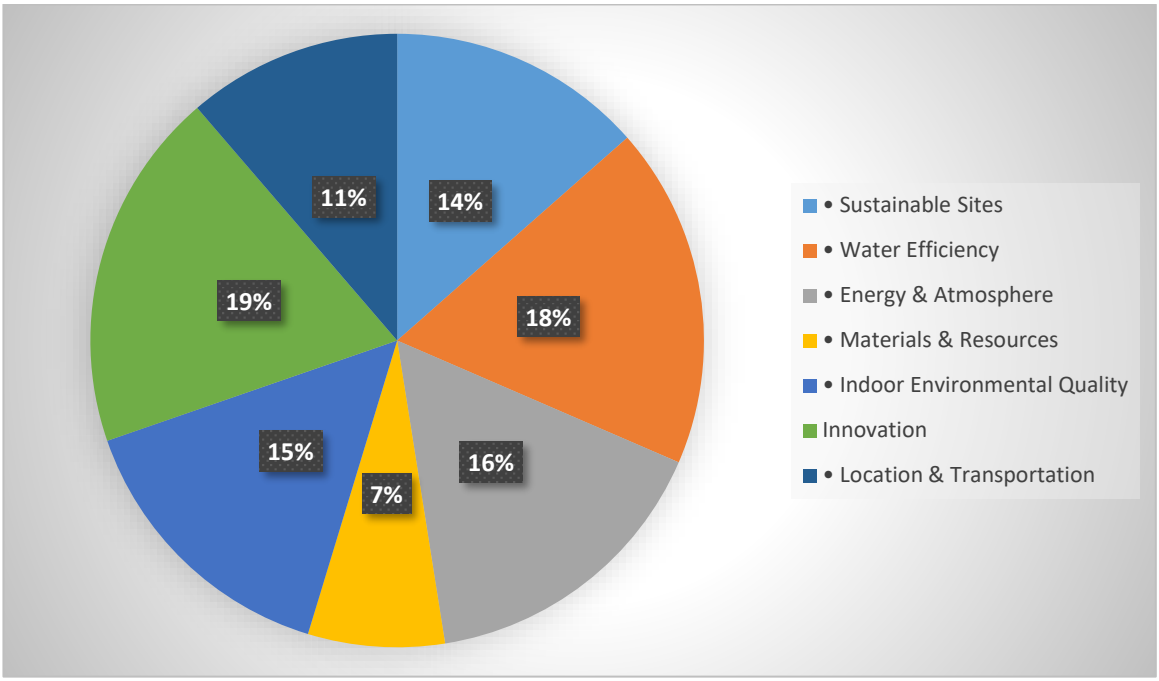


Fig. 9. Scoring Leeds Items Percentage for LEED Certified Projects

Figure 9 illustrates the relative percentage distribution of scores achieved across the sustainability categories for projects certified under LEED. The results are as follows: The Sustainable Sites category scored 13.5%, indicating a moderate level of attention to site planning, selection, and environmental impact reduction. Water Efficiency achieved a good percentage of 18%, reflecting the implementation of effective water saving strategies. The Energy & Atmosphere category scored 16%, a moderate level that shows efforts to improve energy efficiency and reduce emissions, though there is room for greater improvement in the use of renewable energy sources and HVAC systems. Materials & Resources recorded the lowest score at 7.2%, reflecting a clear weakness in the use of sustainable materials and waste management. Indoor Environmental Quality scored 15%, indicating noticeable efforts to enhance indoor air quality and thermal comfort. Innovation ranked highest at 19%, demonstrating that the projects adopt innovative solutions that go beyond traditional standards. Finally, Location & Transportation scored 11.3%, indicating a need to strengthen connectivity with sustainable transportation and improve accessibility. Overall, the distribution reveals disparities in performance among the categories, with clear strengths in innovation and water efficiency, and weaknesses in materials management and location & transportation, highlighting the need to adopt balanced strategies to enhance overall sustainability.

5. Conclusion

The analysis of LEED Gold certified projects showed varied performance across sustainability categories. Strong results appeared in Indoor Environmental Quality and Location and Transportation, while weaknesses were noted in Sustainable Sites and Energy and Atmosphere. This highlights the need for balanced improvement across all categories to achieve holistic sustainability and higher certification levels in the future.

Silver certified projects demonstrate clear strengths in Innovation and Location & Transportation. However, there is a noticeable weakness in the Energy & Atmosphere and Sustainable Sites categories. Strengthening performance in these areas while leveraging modern building science and design principles will be essential to advancing toward higher LEED certification levels such as Gold or Platinum

The results indicate that LEED Certified projects exhibit varied performance across sustainability categories, with notable strengths in Innovation and Water Efficiency, and significant weaknesses in Materials & Resources and Location & Transportation. This imbalance highlights the need for a more holistic and evenly distributed application of sustainable strategies to reach higher certification levels in future developments.

To improve the Sustainable Sites category, future projects should implement advanced storm water management, increase green and permeable areas, optimize site orientation for natural ventilation and daylight, preserve native vegetation, and enhance connectivity to public transportation.

In addition, improving Energy & Atmosphere, Materials & Resources, and other weaker categories alongside Sustainable Sites will help projects achieve higher LEED scores and contribute to more sustainable and resilient built environments

6. Recommendations for improvement

- Improving Site Planning: Focus on careful site selection and enhancing integration with the natural environment to reduce environmental impact.
- Enhancing Energy Efficiency: Strengthen thermal insulation and adopt renewable energy sources to improve performance in the Energy and Atmosphere category.
- Developing Water Conservation Systems: Continue adopting smart irrigation and water saving technologies to achieve higher performance in the Water Efficiency category.
- Promoting the Use of Sustainable Materials: Increase reliance on recycled and low carbon materials in the Materials and Resources category.
- Maintaining Indoor Environmental Quality: Continue prioritizing user comfort and indoor air quality in building design.
- Maintaining Integration with Sustainable Transportation: Continue selecting sites with easy access to public transportation.
- Leveraging Innovation: Utilize innovative solutions to enhance the performance of weaker categories and achieve overall balance in environmental performance

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Data Availability Statement

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Conflicts of Interest

The authors declare no conflict of interest.

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