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Comparing the Amount of CO_2 Emissions from a Commercial Building with a Traditional Design and a Sustainable Design

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Abstract: The building sector's substantial contribution to global CO2 emissions necessitates the urgent adoption of sustainable construction practices. This study employs life cycle assessment (LCA) methodology through One Click LCA software to quantitatively compare the environmental performance of conventional versus sustainable commercial buildings, while also evaluating three prominent certification systems: BREEAM, LEED, and DGNB. Results demonstrate that the sustainable design achieved an overall CO_2 emission reduction of 49.7% (from 961 to 483 kg CO_2/m_2) compared to the traditional design. This included 42% lower operational CO_2 emissions and 28% decreased embodied carbon. Certification assessments revealed notable disparities: the building scored 78% under BREEAM (which gives significant weight to energy efficiency), 85% under LEED (which emphasizes operational energy and renewable energy), and received approximately 15% lower ratings under DGNB, reflecting DGNB's comprehensive lifecycle approach and strong focus on embodied carbon (25% material weighting). These variations highlight fundamental methodological differences in sustainability evaluation that may affect market perceptions and policy effectiveness. The findings provide empirical evidence for two critical conclusions: sustainable building design delivers measurable environmental benefits, and current certification systems exhibit inconsistent assessment frameworks that could hinder standardized progress toward net-zero targets. This research underscores the need for greater alignment among certification methodologies to ensure consistent, transparent evaluation of building sustainability and offers valuable insights for architects, policymakers, and certification bodies.

Keywords: Sustainability, Green Building, CO_2 Emissions, BREEAM, DGNB, LEED.

Introduction

The construction sector is one of the largest contributors to human-caused CO_2 emissions, accounting for approximately 40% of global annual emissions [1]. This significant environmental impact comes from two main sources: operational emissions (28%) from building functions like heating, cooling, and lighting; and embodied carbon (11%) from material production and construction processes [2,3]. Rapid urbanization and population growth are driving unprecedented demand for new infrastructure, urgently requiring the industry to transform its practices and dramatically reduce its carbon footprint.

A particularly pressing concern is the sector's heavy reliance on concrete – the world's most widely used construction material. Cement production alone generates about 6% of global CO_2 emissions, with nearly one ton of CO_2 released for every ton of cement produced due to the energy-intensive clinker manufacturing process [4,5]. This striking 1:1 emission ratio highlights the critical need to develop low-carbon alternative materials and implement innovative construction methods to mitigate concrete's substantial environmental impact.

The construction industry faces several challenges in reducing CO_2 emissions, including a heavy reliance on carbon-intensive traditional materials like concrete and steel. Additionally, the sector is often slow to adopt new technologies and practices due to high upfront costs, limited awareness, and resistance to change. Furthermore, the embodied carbon of buildings—emissions associated with material extraction, manufacturing, and transportation—is frequently overlooked in favor of operational carbon reductions, despite its significant contribution to buildings' overall carbon footprint [6].

Recent advancements in technology and materials offer promising solutions for reducing CO_2 emissions in the construction industry. For example, the use of low-carbon materials such as cross-laminated timber (CLT), hempcrete, and recycled steel can significantly lower the embodied carbon of buildings. Additionally, innovative construction techniques like BubbleDeck a method that uses hollow plastic spheres to reduce the amount of concrete in floor slabs and 3D printing are helping to minimize material use and associated emissions [7, 8]. The integration of solar panels, geothermal heating and cooling systems, and smart building technologies can also drastically reduce a building's operational carbon footprint [9].

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The 2015 Paris Agreement marked a pivotal moment in global efforts to combat climate change, with countries committing to achieve net-zero CO_2 emissions by 2050 [10,11], meeting these ambitious targets requires transformative changes in the construction sector, particularly through the adoption of sustainable building practices and materials.

Numerous opportunities exist to reduce CO_2 emissions through the adoption of sustainable design principles and emerging technologies. Green buildings, designed to minimize environmental impact and maximize resource efficiency, play a crucial role in this transition. According to the World Green Building Council, a green building "reduces or eliminates negative impacts, and can create positive impacts, on our climate and natural environment" [12]. These buildings not only conserve resources but also enhance human well-being by providing healthier, more comfortable living and working environments.

To promote sustainable construction practices, several green building certification systems have been developed, including BREEAM (Building Research Establishment Environmental Assessment Method), LEED (Leadership in Energy and Environmental Design), and DGNB (German Sustainable Building Council). These systems provide frameworks for assessing and improving the environmental performance of buildings, covering aspects such as energy efficiency, water management, material selection, and indoor environmental quality. However, the weighting of these parameters varies across systems, leading to differences in certification outcomes [13, 14]. While these leading certification systems like BREEAM, LEED, and DGNB are widely adopted, their disparate weighting of crucial parameters, particularly operational versus embodied carbon, can lead to inconsistent sustainability assessments and potentially obscure the most effective pathways for genuine CO2 reduction. This inconsistency creates a research gap concerning a clear, comparative understanding of how these systems perform in practice when evaluating holistic carbon reduction strategies.

This study aims to address this gap by quantitatively comparing the effectiveness of these three leading green building certification systems BREEAM, LEED, and DGNB in evaluating sustainable versus traditional commercial building designs, with a particular emphasis on their capacity to drive substantial CO2 emission reductions. The research focuses on assessing the comprehensive environmental impact of a commercial building designed according to conventional practices versus one incorporating advanced sustainability principles, utilizing the One Click LCA program [15]. By applying the distinct evaluation criteria of BREEAM, LEED, and DGNB to both design scenarios, the study seeks to identify which certification system, and which underlying methodological priorities, most effectively support robust and verifiable carbon reduction strategies. This comparative analysis will offer critical insights into the relative strengths, limitations, and potential biases of each system in achieving measurable CO2 reductions and advancing broader environmental objectives. The findings aim to inform architects, engineers, and policymakers in their efforts to promote low-carbon construction practices through the strategic selection and potential refinement of certification frameworks.

Green building certification systems provide structured methodologies for assessing and enhancing the environmental performance of buildings. Among the most widely adopted systems are BREEAM, LEED, and DGNB, each of which evaluates buildings based on criteria such as energy efficiency, water usage, material selection, and indoor environmental quality. However, these systems differ in the weighting and prioritization of these parameters, leading to varying certification outcomes. These differences may significantly affect their effectiveness in reducing CO_2 emissions. Therefore, a direct comparison of these systems is essential to understanding their relative performance in supporting carbon mitigation goals [15].

BREEAM: Introduced in 1998, BREEAM (Building Research Establishment Environmental Assessment Method) has become a global benchmark for sustainable building design. It evaluates buildings across categories such as energy, health and comfort, materials, and innovation, with energy efficiency carrying the highest weight (19%) [16]. Studies have shown that BREEAM-certified buildings tend to perform well in energy and water efficiency but may lag in areas such as waste management and innovation [17, 18].

The credit categories used in the BREEAM certification system are presented in Figure 1. The weighting of these categories is as follows: Management (12%), Energy (19%), Health and Comfort (14%), Water (6%), Materials (12%), Waste (8%), Pollution (6%), Innovation (10%), Ecology (10%), and Risk (1%) [19].

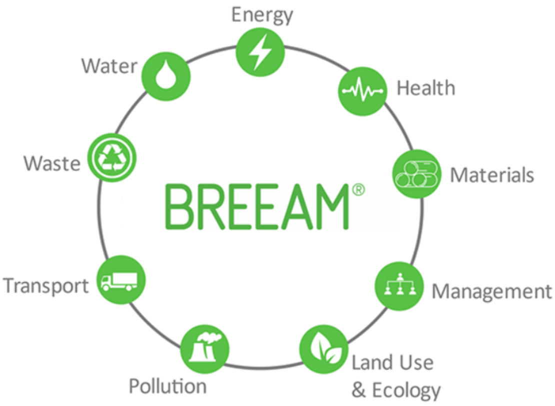


Figure (1): Key elements considered in the BREEAM certification system.

LEED: Developed by the U.S. Green Building Council, LEED (Leadership in Energy and Environmental Design) is the most widely adopted green building certification system worldwide. It offers a building's performance across different categories including sustainable sites, water efficiency, energy and atmosphere [20]. Research indicates that LEED-certified buildings often excel in energy efficiency and indoor environmental quality but may face challenges in achieving high scores in the materials and resources category, primarily due to the complexities of sourcing sustainable materials [21].

There are technically 110 points in the LEED certification system. A project must receive 40 points to receive LEED certification. Depending on the points obtained in the project, the following types of certificates are given to a project:

- 40-49 points – LEED Certified
- 50-59 points – LEED Silver
- 60-79 points – LEED Gold
- 80-110 points – LEED Platinum

DGNB: The German Sustainable Building Council's DGNB certification system is distinguished by its holistic approach, incorporating environmental, economic, and social factors. DGNB assesses buildings based on life cycle assessment (LCA) principles, placing particular emphasis on reducing embodied carbon and promoting long-term sustainability [22]. Comparative studies have found that DGNB-certified buildings often outperform those certified by BREEAM and LEED in terms of overall sustainability, particularly with respect to embodied carbon reduction [23].

In order to make sustainable construction applicable in a practical manner, measurable and thus comparable, the DGNB has developed its own certification system. The system was first introduced to the market in 2009 and has been continuously developed since then, and is now not only considered the most advanced in the world, but is also internationally recognized as the Global Benchmark for Sustainability [24].

In particular, the certification systems mentioned above attach great importance to the use of sustainable materials. The choice of sustainable building materials plays a critical role in reducing the carbon footprint of construction projects. While traditional materials such as concrete and steel are highly carbon-intensive, alternative materials and innovative construction techniques offer promising solutions. The best examples of sustainable materials today are green concrete (low carbon emission), wood-based materials and recycled materials.

Low-Carbon Concrete: Researchers have explored various methods to reduce the carbon footprint of concrete, including the incorporation of supplementary cementitious materials (SCMs) such as fly ash and slag, which partially replace cement in concrete mixtures. These materials not only lower CO_2 emissions but also enhance the durability and performance of concrete [25]. In addition, geopolymer concrete—utilizing industrial by-products as binders instead of traditional cement—has emerged as a sustainable alternative with significantly lower embodied carbon [26].

Wood materials and Cross-Laminated Timber (CLT): Wood is gaining traction as a sustainable alternative to concrete and steel, particularly in the form of cross-laminated timber (CLT). CLT is lightweight, renewable, and has a substantially lower carbon footprint compared to traditional materials. Studies have demonstrated that buildings constructed with CLT can achieve significant reductions in embodied carbon, especially when coupled with efficient design and construction practices [27].

Recycled and Reused Materials: The adoption of circular economy principles in construction—such as the use of recycled concrete aggregate (RCA) and reclaimed steel—can further reduce the environmental impact of building materials. These practices not only decrease embodied carbon but also minimize waste generation and reduce the need for resource extraction [28].

In addition to sustainable materials, the use of innovative technology is one of the effective issues recommended by many certification systems in terms of reducing material use, increasing energy efficiency and minimizing waste providing radical changes in the construction sector. The applications that stand out as innovative technologies in the construction sector can be listed as prefabricated or 3D printing technologies, smart building technologies and composite/hybrid product production [29,30].

Methods

This study compares the CO_2 emissions of a commercial building designed using traditional methods versus a sustainable design approach, utilizing the One Click LCA program. This section outlines the methodology, including the application of the One Click LCA tool, the building design scenarios, and the specific parameters and assumptions adopted for the analysis. The analysis is conducted within the frameworks of three major green building certification systems.

The One Click LCA program is a building lifecycle assessment software that allows for the calculation of carbon footprint, lifecycle cost, and other environmental parameters. It is widely used for eco-design, green building certification, and carbon-neutral construction projects. The software is compatible with over 40 green building certification programs, including BREEAM, LEED, and DGNB, making it an ideal tool for this study. [31]

For this analysis, generic datasets available within One Click LCA were used to represent construction materials. Specifically, we were selected for key materials such as concrete, steel, insulation, and glazing, ensuring compliance with ISO 14025 and EN 15804 standards. Where available, Turkish or regional European datasets were prioritized to reflect local construction practices more accurately. The system boundaries for the assessment follow a cradle-to-grave approach, encompassing the product stage (A1–A3), construction process stage (A4–A5), use stage (including maintenance and renovation, B2–B5), and end-of-life stage (C1–C4). The loads beyond the system boundary (D stage) were excluded from this analysis.

Software Settings and Input Parameters

The following settings and input parameters were used in the One Click LCA program to ensure accurate and consistent analysis:

Building Type: The building analyzed in this study is a commercial structure with two underground floors and four above-ground floors, totaling 6,781.06 square meters of floor area. It also includes a 3,000 square meter car park.

Location: Sakarya, Turkey, was selected as the geographic location for the analysis. The program utilizes location-specific data for energy mix, transportation, and material sourcing.

Life Cycle Assessment (LCA) Scope: The analysis covers the entire life cycle of the building, including material production, construction, operation, and end-of-life stages. A 60-year assessment period standard for commercial building LCA studies is applied.

Carbon Footprint Calculation: The program calculates both embodied carbon (CO_2 emissions associated with materials and construction) and operational carbon (CO_2 emissions from energy use during the building's operation). Results are expressed in kg $CO_2e/m^2/year$ (kilograms of carbon dioxide equivalent per square meter per year).

Material Inputs: Detailed material specifications were provided, including:

Concrete: Type and quantity, including cement content and any supplementary cementitious materials (SCMs) such as fly ash or slag.

Steel: Quantity and type used in structural elements.

Insulation: Type and thickness of insulation materials in walls, floors, and roofs.

Finishing Materials: Materials for interior and exterior finishes, such as plasterboard, tiles, and paints.

Energy Use: The building's energy consumption including heating, cooling, lighting, and other electrical loads was input into the program. The local energy mix for Sakarya, Turkey, was used to calculate associated CO_2 emissions.

Transportation: Transportation of materials to the construction site was modeled using default distances and transport modes based on the building's location.

Assumptions

The following assumptions were made during the analysis:

Material Lifespan: All materials are assumed to have a lifespan of 60 years, aligning with the building's assessment period. Materials requiring replacement during this period (e.g., roofing, insulation) are incorporated into the life cycle analysis.

Energy Mix: The energy mix for Sakarya, Turkey, is based on national averages, reflecting a significant reliance on fossil fuels. This assumption influences the calculation of operational carbon emissions.

Construction Waste: A 10% waste factor for construction materials was assumed, consistent with typical commercial construction practices.

End-of-Life Scenario: At the end of the building's life, it is assumed that 50% of materials are recycled, while the remaining 50% are sent to landfill. This assumption impacts the calculation of end-of-life emissions.

Building Design Scenarios

This study evaluates three design scenarios for the commercial building, each representing a different level of sustainability:

First Design (Traditional Design): This scenario represents a conventional commercial building constructed using standard materials and traditional construction techniques. The primary materials include conventional concrete and steel, with minimal insulation and no integration of renewable energy systems.

Second Design (Intermediate Sustainable Design): This scenario incorporates sustainability-oriented modifications, including the use of BubbleDeck technology for floor slabs and wooden joist floors with mineral wool insulation in specific areas. These enhancements reduce concrete consumption while improving the building's thermal performance.

Third Design (Advanced Sustainable Design): This scenario represents a highly sustainable building, integrating low-carbon materials such as cross-laminated timber (CLT) and recycled steel. It also includes advanced insulation systems and renewable energy technologies. Additionally, smart building systems are implemented to optimize energy consumption and enhance operational efficiency.

In this stand, the British classification system is used to assess the levels and degree of evaluation of carbon dioxide emissions, as outlined in Figure 2.

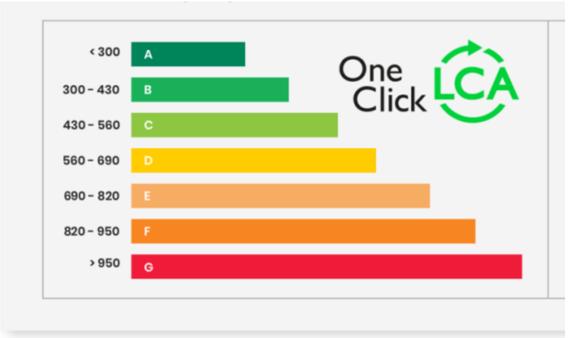


Figure (2): Levels of carbon dioxide emissions

The classification follows the Carbon Heroes Benchmark, as integrated into the program. The Carbon Heroes Benchmark gives you benchmark analysis from thousands of buildings that have used One Click LCA to record their life cycle analysis.

Software Validation and Study Limitations

The One Click LCA software is a widely recognized and validated tool for building life cycle assessment (LCA), conforming to key international standards such as EN 15978, ISO 14040/44, and other relevant frameworks. To strengthen the contextual accuracy of this study, core material carbon factors especially for regionally common materials were cross-verified using available data from Turkish national construction databases and relevant regional Environmental Product Declarations (EPDs). Nonetheless, one key limitation of this study is the partial reliance on high quality generic EPDs and EN 15804 compliant datasets from the One Click LCA database. This was necessary in cases where verified, Turkey-specific EPDs were unavailable for certain materials at the time of analysis. While this approach is aligned with standard LCA practices, it inevitably introduces a degree of generalization and may not fully reflect regional production methods or material supply chains.

Additional limitations include the assumption of a standardized 60-year lifespan for the building, as recommended in LCA protocols. In reality, building operational durations and material durability may differ, which could shift the balance between embodied and operational carbon impacts. For instance, shorter lifespans may amplify the significance of embodied emissions relative to operational energy use. Operational energy assumptions were based on typical consumption profiles for buildings located in Sakarya, Turkey, and may not encompass variations in actual building performance, management practices, or user behavior. Likewise, end-of-life scenarios including assumptions around material recycling, reuse, or landfill rates were modeled using current common practices and regional data, which are expected to evolve as waste management systems and circular economy policies improve in the future.

Results And Discussion

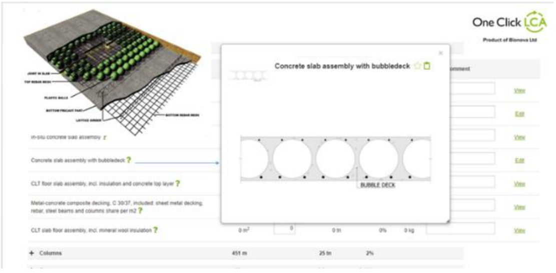
The primary objective of this study is to compare the carbon dioxide (CO_2) emissions of a commercial building with a traditional design versus a sustainable design, and to assess the associated social costs using three prominent green building certification systems: BREEAM, LEED, and DGNB. The analysis was conducted in three stages, each corresponding to a different level of sustainability in the building's design.

First Design (Traditional Design): After analyzing the data in the program, the total carbon dioxide emissions for the first design, which represents the traditional baseline scenario, amounted to 961 kg CO_2e/m^2. Based on the PERM classification system, this design falls under Level G, indicating the highest environmental impact among the alternatives. The total embodied carbon for all building components in this design is detailed in the table1.

Second Design (Intermediate Sustainable Design): In the second design, improvements were made to the quality of construction in certain parts of the concrete structure. Notably, two key changes were implemented:

- Concrete Slab Assembly with BubbleDeck: As shown in Figure 3, BubbleDeck technology was used to reduce the amount of concrete in the floor slabs. This innovation contributed to a 12% reduction in carbon emissions for the concrete slab assembly.
- Wooden Joist Floor with Mineral Wool Insulation: In certain areas of the building, a 278mm wooden joist floor was installed, incorporating 225mm of mineral wool insulation (Figure 4). This change resulted in a 14% reduction in carbon emissions.

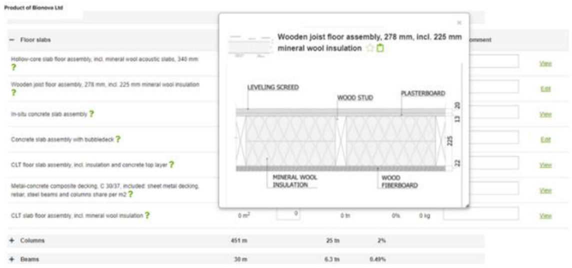
These modifications significantly reduced the overall carbon footprint of the building compared to the traditional design.



Concrete slab assembly with bubbledeck

In-situ concrete slab assembly ?
Concrete slab assembly with bubbledeck ?
CLT floor slab assembly, incl. insulation and concrete top layer ?
Metal-concrete composite decking, C 30/37, included: sheet metal decking, rebar, steel beams and columns share per m2 ?
CLT slab floor assembly, incl. mineral wool insulation ? 0 m² 0 0 tn 0% 0 kg
+ Columns 451 m 25 tn 2%

Figure (3): Concrete slab assembly with bubbledck.



Wooden joist floor assembly, 278 mm, incl. 225 mm mineral wool insulation

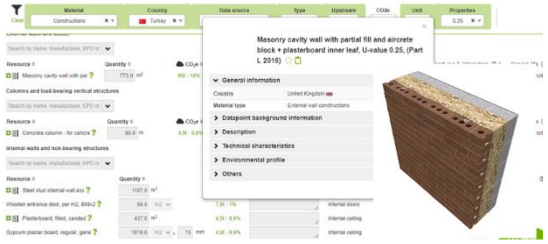
− Floor slabs
Hollow-core slab floor assembly, incl. mineral wool acoustic slabs, 340 mm ?
Wooden joist floor assembly, 278 mm, incl. 225 mm mineral wool insulation ?
In-situ concrete slab assembly ?
Concrete slab assembly with bubbledeck ?
CLT floor slab assembly, incl. insulation and concrete top layer ?
Metal-concrete composite decking, C 30/37, included: sheet metal decking, rebar, steel beams and columns share per m2 ?
CLT slab floor assembly, incl. mineral wool insulation ? 0 m² 0 0 tn 0% 0 kg
+ Columns 451 m 25 tn 2%
+ Beams 30 m 6.3 tn 0.49%

Figure (4): wooden joist floor 278mm, inci 225mm mineral wool insulation.

For the second design, the total carbon dioxide emissions were calculated to be 588 kg CO_2e/m². According to the PERM system, this corresponds to Level D, reflecting a moderate environmental impact. The emissions associated with all construction elements in this design are presented in the comparison table1.

Third Design (Advanced Sustainable Design): In the third design, modifications were made to the walls to enhance the building's thermal performance. The finishing system was designed to conserve the internal temperature of the building. The specific changes included:

Masonry Cavity Wall with Partial Fill and Aircrete Block: This wall system, featuring a plasterboard inner leaf and a U-value of 0.25 (according to Part L 2016), contributed to a significant reduction in carbon emissions. This modification led to an 18% reduction in carbon emissions, as shown in Figure 5. These adjustments further improved the building's overall sustainability, reducing both embodied and operational carbon footprints.



Masonry cavity wall with partial fill and aircrete block + plasterboard inner leaf, U-value 0.25, (Part L 2016)

Country: United Kingdom
Material type: External wall constructions

Resource Quantity
Masonry cavity wall with par ? 773.0 m²
Columns and load-bearing vertical structures
Concrete column - for concre ? 80.0 m
Internal walls and non-bearing structures
Steel stud internal wall ass ? 1107.0 m²
Wooden entrance door, per m2, 809x2 ? 58.0 m2 7.8t - 1% internal doors
Plasterboard, filled, sanded ? 437.0 m² 4.5t - 0.9% internal ceiling
Gypsum plaster board, regular, gene ? 1019.0 m2 15 mm 4.5t - 0.9% internal ceiling

Figure (5): Masonry cavity wall with partial fill and aircrete block + plasterboard inner leaf, U-value 0.25, (Part L 2016),

The third design yielded total emissions of 483 kg CO_2e/m² after analysis in the program. This result places the design in Level C of the PERM classification, which is the lowest acceptable performance level. The total embodied carbon of this design is also provided in the table1.

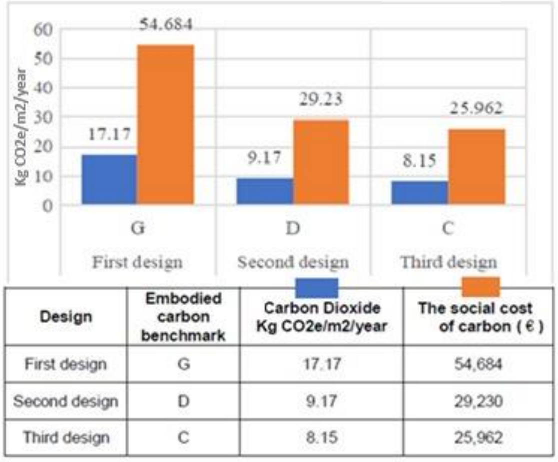
Table1: Comparative Levels of Carbon Dioxide Emissions by Design.

Design	CO_2 Emissions (kg CO_2e/m²)	Emission Class
1	961	G
2	588	D
3	483	C

Notably, while BubbleDeck technology continued to deliver a 12% reduction in slab emissions, the use of CLT walls in Design 3 had the most significant individual impact, achieving an 18% emissions reduction.

Conclusion

After entering data for the commercial building and examining carbon emissions under baseline construction conditions, the study compared emissions with those resulting from adjustments to the proportions of additives and alternative materials. The results, including the carbon footprint and associated costs, were assessed using the BREEAM system assessment criteria. The energy class of the building, carbon emissions per m2 and the social costs of carbon emissions for three different designs are shown in Figure 6.

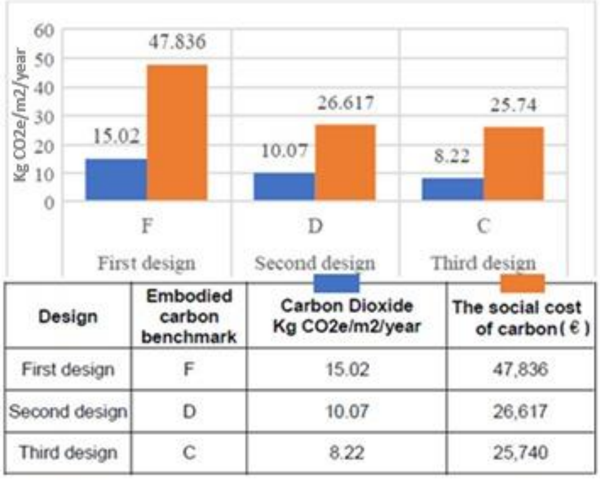


Design	Embodied carbon benchmark	Carbon Dioxide Kg CO2e/m2/year	The social cost of carbon (€)
First design	G	17.17	54,684
Second design	D	9.17	29,230
Third design	C	8.15	25,962

Figure (6): Comparison of Cost and Annual Carbon Quantity Design by Breeam System.

Transitioning from a G-rated to a C-rated design halves both emissions and social costs. The largest gains occur between the First and Second designs—indicating that moderate sustainable upgrades yield substantial environmental and economic benefits. Incremental improvements from the Second to Third design still deliver meaningful reductions, underscoring the value of advanced materials and systems for deeper carbon savings.

The resulting carbon footprint and associated costs for the LEED system are presented in Figure 7.

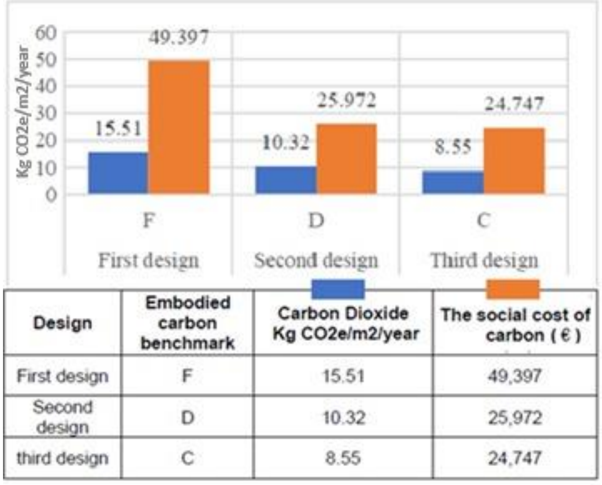


Design	Embodied carbon benchmark	Carbon Dioxide Kg CO2e/m2/year	The social cost of carbon(€)
First design	F	15.02	47,836
Second design	D	10.07	26,617
Third design	C	8.22	25,740

Figure (7): Comparison of Cost and Annual Carbon Quantity Design by LEED System.

Moving from an F-rated to a C-rated design results in a significant reduction, nearly cutting both emissions and social costs in half. The largest gains occur between the First and Second designs as in the breeam certificate indicating that moderate sustainable upgrades yield substantial environmental and economic benefits.

The analysis of the carbon footprint and associated costs of carbon within the DGNB system framework is presented in Figure 8.



Design	Embodied carbon benchmark	🟦 Carbon Dioxide Kg CO2e/m2/year	🟧 The social cost of carbon (€)
First design	F	15.51	49,397
Second design	D	10.32	25,972
third design	C	8.55	24,747

Figure (8): Comparison of Cost and Annual Carbon Quantity Design by DGNB System.

The analysis results obtained from the DGNB assessment align closely with those of the LEED system. Transitioning from an F-rated to a C-rated design nearly halves both carbon emissions and social costs. Similar to the findings under the BREEAM certification, the most significant improvements are observed between the First and Second designs, highlighting that moderate sustainable upgrade can achieve substantial environmental and economic benefits. Further enhancements from the Second to the Third design continue to deliver notable reductions, emphasizing the importance of advanced materials and systems in achieving deeper carbon savings.

The comparative analysis revealed significant variations in carbon emission assessments across the three certification systems (BREEAM, LEED, and DGNB), stemming from their distinct evaluation frameworks and weighting methodologies. BREEAM places a strong emphasis on operational energy efficiency, LEED employs a flexible credit-based system, and DGNB focuses on comprehensive life cycle assessments. Despite these methodological differences, all three systems consistently showed that the third design incorporating advanced sustainable materials and energy-efficient technologies achieved markedly lower CO_2 emissions compared to conventional designs (Figure 9). This consensus highlights the effectiveness and resilience of sustainable design principles in reducing environmental impact, irrespective of the certification system applied.

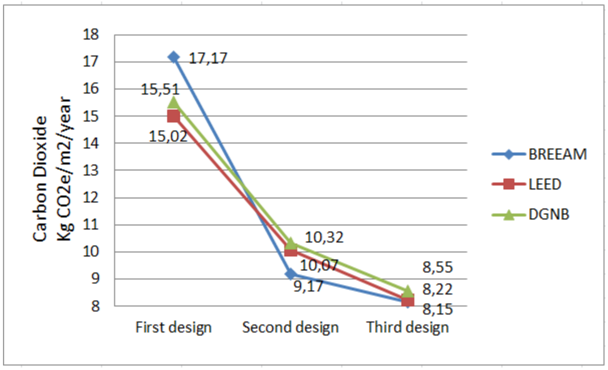


Figure (9). Carbon emission graph of three different designs according to certification systems.

These differences in assessment outcomes can be attributed to the varying weightings assigned to key sustainability parameters within each certification system. As shown in Table 2, LEED places the greatest emphasis on operational energy (35%), while DGNB assigns the highest importance to embodied carbon (25%). In contrast, BREEAM applies a more balanced approach, with 19% weighting for operational energy and 12% for embodied carbon. These distinctions explain why certain design strategies may perform better under one certification system than another and highlight the importance of selecting appropriate sustainability goals when choosing an assessment framework.

Table (2): Comparison of Parameter Weightings Across Certification Systems.

Parameter	BREEAM (Weight)	LEED (Weight)	DGNB (Weight)
Operational Energy	19%	35%	20%
Embodied Carbon	12%	10%	25%

This paper provides a structured guide for selecting certification systems based on project-specific CO_2 emission priorities. By synthesizing existing tools and frameworks, it helps stakeholders navigate the increasing complexity of low-carbon construction choices. The inclusion of recent findings on life cycle assessment (LCA) methodologies [32–33,35–37], environmental benefits of alternative construction materials such as geopolymer concrete [34], and decision-support tools for comparing certification schemes [36], positions this study as a timely and practical resource for project managers, policy-makers, and sustainability consultants.

Recommendations

This study highlights the critical role of embodied carbon in the total emissions profile of commercial buildings, underscoring the need for systemic changes in both policy and practice. Based on the analysis, the following targeted recommendations are proposed to support the transition toward low-carbon construction and to align with global climate objectives:

Implement Mandatory Carbon Emission Limits Informed by Life Cycle Assessment (LCA)

Given that embodied emissions represent a substantial share of a building's total carbon footprint, policymakers should establish enforceable carbon limits for new construction. These thresholds should be derived from LCA data and embedded within updated national building codes to ensure early-stage emissions reductions.

Prioritize Green Building Certification Systems with Strong LCA Integration (e.g., DGNB)

The comparative evaluation of certification schemes reveals that systems like DGNB, which incorporate detailed LCA methodologies, offer superior guidance for embodied carbon reduction. Policymakers should prioritize and promote such systems through targeted incentives.

Introduce Construction-Specific Carbon Pricing Mechanisms

As material selection and construction practices significantly influence embodied emissions, carbon pricing mechanisms such as taxes or cap-and-trade—should be implemented within the construction sector. These policies can drive market preferences toward low-carbon materials and techniques by internalizing the environmental cost of emissions.

Enhance Incentives for High-Performance Green Buildings

Projects achieving top-tier certifications (e.g., LEED Platinum, BREEAM Outstanding) demonstrate consistent reductions in life-cycle emissions. Expanding financial incentives, including tax rebates or expedited permitting, for such projects can accelerate their adoption and contribute to broader emissions mitigation goals.

Together, these recommendations provide a practical roadmap for reducing CO_2 emissions in commercial buildings and promoting more sustainable construction practices. Aligning regulatory, financial, and market-based strategies with findings from LCA-driven analysis is essential to achieving measurable climate outcomes.

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- **Funding:** No funning was awarded
- **Conflicts of interest:** The authors declare that there is no conflict of interest regarding the publication of this article

Open Access

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