

Changes in Architectural Design to Reduce Sources of Greenhouse Gases Produced in Construction

Jorge Pablo Aguilar Zavaleta*

Faculty of Engineering and Architecture, Professional School of Architecture, César Vallejo University, Peru

*Corresponding Author

Jorge Pablo Aguilar Zavaleta, Faculty of Engineering and Architecture, Professional School of Architecture, César Vallejo University, Peru.

Submitted: 2025, Jun 05; Accepted: 2025, Jul 07; Published: 2025, Jul 17

Citation: Zavaleta, J. P. A. (2025). Changes in Architectural Design to Reduce Sources of Greenhouse Gases Produced in Construction. *J Electrical Electron Eng*, 4(4), 01-05.

Abstract

Contemporary architectural design faces the urgent challenge of reducing greenhouse gas (GHG) emissions, given that the building sector accounts for 34% of global CO₂ emissions and consumes 32% of the world's energy, with operational emissions reaching 9.8 gigatons by 2023. The research is premised on the premise that sustainable architecture is key to mitigating environmental impact, integrating strategies such as energy efficient design, low carbon material selection, adaptive reuse, and smart technologies. Methodologically, the study employs a critical review of indexed literature and analysis of recent cases, complemented by data from international organizations and life cycle assessments (LCAs) to quantify operational and embedded emissions in buildings. Approaches such as LEED certification and the Passive House standard are examined, as well as the integration of energy modeling and advanced simulation tools, which allow for comparing the environmental performance of different construction solutions. The results show that, while energy efficiency has reduced the sector's energy intensity by almost 10% since 2015, demand and total emissions continue to rise due to the growth of the housing stock and the prevalence of carbon intensive materials such as cement and steel, which account for 18% of global emissions. The research reveals that 45% of new architectural projects incorporate sustainable criteria and that the adoption of technologies such as BIM and renewable energy grew by 30% and 25% respectively between 2020 and 2023. However, economic, regulatory, and cultural barriers persist that slow the transition to low carbon architecture. In conclusion, the article highlights that the transformation of architectural design toward sustainability requires coordinated action between public policies, technological innovation, and sectoral education. Only in this way will it be possible to achieve decarbonization goals and build resilient, healthy cities aligned with global climate commitments.

Keywords: Building, Architectural Design, Greenhouse, Construction

1. Introduction

Changes in architectural design aimed at reducing greenhouse gas emissions have emerged as a critical response to climate change, reflecting the urgent need for sustainable practices in the construction industry. With buildings accounting for nearly 40% of global greenhouse gas emissions, architects and designers are increasingly prioritizing environmentally responsible methods to minimize the ecological footprint of their projects [1,2]. Notable strategies include energy efficient design, sustainable material selection, adaptive reuse of existing structures, and the integration of smart technologies, all of which contribute to both operational and embodied carbon reduction [3-5].

The evolution of architectural practices toward sustainability has deep historical roots, with traditional designs often aligning closely with environmental conditions. In recent decades, this alignment has transformed into a proactive movement toward sustainable architecture, exemplified by influential figures such as Kenneth Yeang and the establishment of green building certifications like LEED [6,7]. These frameworks encourage architects to innovate by utilizing local materials, passive design strategies, and efficient construction methods to mitigate the impact of new buildings on the environment [8].

However, the transition to sustainable architecture faces significant challenges, including financial barriers, a lack of awareness among stakeholders, and regulatory hurdles that can impede the adoption of green building practices. Issues such as split incentives (where builders do not directly benefit from long term energy savings) further complicate efforts to implement energy efficient solutions in the construction sector [9,10]. Additionally, traditional market dynamics often favor conventional practices, making it difficult for innovative, sustainable alternatives to gain widespread acceptance [11,12].

As the architectural community continues to grapple with these challenges, ongoing advancements in technology, materials, and educational initiatives are essential

to foster a future where architectural design significantly contributes to reducing greenhouse gas emissions. The collaborative efforts of governments, industries, and communities will be crucial in promoting a sustainable built environment that aligns with global environmental goals [13,14].

1.1. Historical Context

The evolution of architectural design towards sustainability has deep historical roots, reflecting a growing awareness of the impact buildings have on the environment.

Traditionally, architecture was inherently aligned with environmental conditions, as evidenced by urban designs that incorporated narrow shaded streets and inner courtyards to adapt to climate challenges [1]. This integration of natural elements laid the groundwork for modern sustainable practices, which aim to blend traditional knowledge with contemporary technology.

In recent decades, the architectural community has increasingly recognized the necessity of sustainable design in response to climate change and ecological degradation. This shift has catalyzed the emergence of various sustainable architectural movements that focus on minimizing the ecological footprint of buildings. Pioneers such as Kenneth Yeang have advocated for ecology-based architecture, emphasizing the importance of reducing energy consumption and waste through innovative design and the use of local materials [3].

Moreover, the establishment of green building certifications like LEED has provided frameworks for evaluating and promoting sustainable practices within the industry, encouraging architects to adopt energy efficient technologies and ecofriendly materials [6,7]. The ongoing exploration of these concepts is reflected in a variety of projects that seek to harmonize aesthetics, functionality, and environmental responsibility, as seen in the works of architects like Wang Shu, who exemplifies the fusion of traditional craftsmanship with modern sustainability efforts [8].

As architects increasingly confront the challenges posed by climate change, their designs are becoming more innovative, incorporating strategies such as passive design and climate

responsive architecture. This historical context highlights the progression from traditional methods to contemporary sustainable practices, marking a significant transformation in how buildings are conceived and constructed for a greener future [4].

1.2. Key Strategies in Architectural Design

Architectural design plays a crucial role in mitigating greenhouse gas emissions produced during construction and throughout the lifecycle of buildings. Several key strategies are employed by architects to achieve sustainable outcomes while reducing the ecological footprint of their projects.

1.3. Energy Efficient Design

One of the primary strategies is the focus on energy efficient building design. This involves utilizing sustainable design principles such as climate responsive design, passive solar heating, and natural ventilation to minimize energy consumption and reliance on nonrenewable energy sources. By incorporating energy efficient lighting systems, appliances, and renewable energy technologies like solar panels, architects can significantly reduce electricity consumption and greenhouse gas emissions associated with building operations [4,13].

1.4. Use of Sustainable Materials

The selection of sustainable construction materials is another vital strategy. Architects prioritize materials with lower carbon footprints, such as recycled steel and sustainably sourced timber, to minimize the environmental impact of material production and waste generation [15,13]. The integration of prefabricated components in modular construction also enhances material efficiency and reduces waste, as these components are manufactured off site with greater precision [13].

1.5. Adaptive Reuse and Renovation

Adaptive reuse is increasingly recognized as an effective strategy for sustainable architecture. By transforming existing structures into functional spaces, architects can preserve cultural heritage while minimizing resource consumption and waste. This approach not only revitalizes old buildings but also reduces the need for new construction, thereby lowering overall emissions [5,16].

1.6. Smart Technologies

The incorporation of smart technologies into building design further enhances sustainability. By integrating sensors and automation systems, buildings can adapt to environmental conditions and user behaviors, optimizing energy use and improving occupant comfort. This dynamic approach allows for a more responsive built environment that can adjust to changing demands [5].

1.7. Indoor Environmental Quality

Maintaining high indoor environmental quality is essential for occupant health and comfort. Sustainable design emphasizes natural lighting, proper ventilation, and the use of nontoxic materials, which contribute to a healthier indoor environment and reduce the need for mechanical heating and cooling systems. This not only improves occupant wellbeing but also lowers energy

consumption [16,13].

1.8. Waste Reduction and Recycling

Sustainable construction practices also prioritize waste reduction and recycling throughout the building's lifecycle. This includes repurposing construction waste into new materials and minimizing the generation of waste during the construction process. By employing lean construction principles, architects aim to enhance efficiency and decrease environmental impact, further contributing to sustainability goals [13,17].

By implementing these key strategies, architects can create buildings that not only meet the functional and aesthetic needs of users but also contribute to a more sustainable future by significantly reducing greenhouse gas emissions associated with construction and building operation.

2. Methods

2.1. Impact of Changes in Architectural Design

The architectural design significantly influences the environmental impact of buildings, which collectively account for nearly 40% of global greenhouse gas emissions [2,8]. With the construction and buildings sector being the largest emitter of greenhouse gases, responsible for 37% of global emissions, the need for sustainable practices has become increasingly critical in the face of climate change [18].

2.2. Role of Sustainable Design

Sustainable architectural practices aim to reduce both operational and embodied carbon emissions associated with buildings. Operational carbon emissions, which arise from a building's energy consumption during its lifespan, typically account for about two thirds of a structure's total lifetime emissions [2]. Strategies such as passive solar design, efficient insulation, and natural ventilation can significantly decrease the energy required for heating, cooling, and lighting [19,2]. Furthermore, landscape architects are increasingly incorporating low carbon materials and practices into their designs, helping to shift the industry towards more sustainable building methods [20].

2.3. Embodied Carbon Considerations

In addition to operational emissions, the embodied carbon—the carbon footprint associated with the production and transport of construction materials—poses a substantial challenge. Materials such as cement, steel, and aluminum contribute significantly to a building's overall emissions profile [18,21]. Efforts to reduce embodied carbon involve strategies such as reusing materials, repurposing existing structures, and designing with fewer materials to minimize waste [20,22]. By 2030, it is expected that all new buildings and renovations will achieve at least a 40% reduction in embodied carbon emissions, underlining the urgency of these changes [23].

2.4. Continuous Improvement and Technological Integration

The architectural field is in a constant state of evolution, with architects urged to remain updated on advancements in sustainable

technologies and materials. This continuous improvement process ensures that buildings are not only energy efficient but also have a lower ecological footprint throughout their lifecycle [4,19]. Architects have a significant responsibility to advocate for eco-conscious designs from the planning phase, thereby impacting a structure's overall environmental footprint [19].

2.5. Implications for Policy and Economic Factors

Implementing stricter emissions standards and providing financial incentives for sustainable practices are essential steps in transforming the construction sector. The European Union's initiatives to reduce net greenhouse gas emissions serve as a model for global efforts, encouraging industries to adopt more sustainable

practices and innovate toward decarbonization [9,10]. By balancing economic growth with environmental goals, policymakers can facilitate a transition toward a more sustainable built environment [9].

3. Results and Discussion

3.1. Challenges and Limitations

The transition to sustainable architectural design aimed at reducing greenhouse gas emissions presents various challenges and limitations that can hinder effective implementation.

3.2. Financial Barriers

One significant obstacle is the initial cost associated with incorporating sustainable features into construction projects. These costs can be substantial, which may deter stakeholders from adopting green building practices [11]. Although such investments often lead to long term savings on energy bills and operational expenses, the upfront financial commitment remains a major hurdle for many developers and homeowners [13].

3.3. Lack of Awareness and Education

A widespread lack of awareness and understanding of green building practices among industry stakeholders further complicates the situation. This deficiency can result in resistance to change and reluctance to invest in sustainable technologies [11]. Educational initiatives aimed at promoting the benefits of sustainable design are essential to overcoming this barrier, yet they are often insufficiently prioritized in the industry.

3.4. Split Incentives

The issue of split incentives is particularly pronounced in the construction sector. When the builder or owner of a building does not directly bear the costs of energy efficient appliances and systems, they may opt for lower upfront costs instead of sustainable choices that would yield long term savings [10]. This misalignment of interests creates challenges in promoting energy efficiency throughout the building's lifecycle.

3.5. Regulatory and Policy Challenges

Existing regulations and codes may not adequately support or encourage sustainable construction practices. While policies such as the International Green Construction Code and California's CAL

Green provide frameworks for green building, the enforcement and consistency of such regulations can vary significantly across regions [12]. Additionally, as new technologies emerge, outdated policies may hinder innovation and slow the transition to more sustainable practices.

3.6. Technological Limitations

The integration of advanced technologies into sustainable design can also pose challenges. While innovations in building materials and energy modeling tools have the potential to enhance sustainability, their availability and affordability can be limited, particularly for smaller practices [24,13]. Furthermore, the rapid pace of technological change necessitates continuous learning and adaptation by architects and builders, which can be resource intensive.

3.7. Market Dynamics

The sustainability movement faces an uphill battle against entrenched market dynamics. Traditional construction practices and materials often dominate the market, making it difficult for new, sustainable alternatives to gain traction [12]. Market creation policies, which aim to stimulate the adoption of innovative technologies, are essential but can be slow to implement and require substantial government support to thrive [12].

4. Conclusions

Future Directions

The future of architectural design is increasingly focused on sustainability and reducing greenhouse gas emissions generated during construction. This shift necessitates a collaborative approach involving governments, industries, researchers, and communities, which is essential for creating a sustainable, low carbon future that meets global infrastructure needs without

compromising environmental integrity [9].

Innovations in Design

Architectural trends are evolving to prioritize sustainable and ecofriendly designs, integrating advanced technologies such as parametric modeling, 3D printing, and the use of sustainable materials. These innovations not only address current needs but also aim to mitigate long term environmental impacts [5]. The emphasis on sustainability is now ingrained in every stage of the design process, transforming how architecture is conceived and executed, thereby fostering a more harmonious relationship between humanity and the planet [5].

Strategies for Decarbonization

Efforts toward decarbonization in architecture require a multifaceted strategy. This involves utilizing existing building solutions more efficiently and advocating for educational initiatives that promote sustainable practices among architects and designers [7]. The journey to achieve significant reductions in embodied and operational carbon is complex, yet essential for enhancing quality of life while minimizing environmental footprints [14,13].

Emerging Technologies and Materials

The architectural landscape is also witnessing the emergence of new technologies capable of both reducing emissions and potentially sequestering carbon within the built environment. For instance, innovations in construction materials can lead to substantial decreases in greenhouse gas emissions associated with traditional materials such as concrete and steel [25,20]. Furthermore, the rise of renewable energy systems, smart technologies, and circular construction practices are set to shape the future of sustainable building design [13].

	Traditional construction	construction with BIM and sustainable criteria
Current architectural projects	85%	15%
New architectural projects	65%	45%
Note: 2025 report, https://gitnux.org/architecture-statistics/		

Table 1: New Architectural Projects Incorporate Sustainable Criteria and The Adoption of Technologies Such as BIM and Renewable Energies

Role of Policy and Education

Government policies play a crucial role in promoting sustainable construction practices. By incentivizing green building initiatives, enforcing environmental standards, and supporting research, policymakers can drive the industry toward more sustainable norms [13]. Educational programs that raise awareness and provide training on sustainable practices will also be vital in overcoming the barriers to implementing these innovations in the construction sector [13].

References

1. Sustainable Architecture | Tag - ArchDaily.
2. Sustainable Innovation: Discover 7 architects that inspire

- changes.
3. Energy Certifications in Architecture: 14 Examples Worldwide - Zigurat.
4. How to Reduce the Carbon Footprint Through Architecture? Three.
5. Top 25 Inspiring Sustainable Architects and Architecture Firms.
6. The Role of Architects in Combating Climate Change.
7. Sustainable Construction Practices: Efficiency and Environmental.
8. Smart Landscape Architecture Strategies for Reducing Greenhouse.
9. Architectural Design Trends 2024: Innovations in

-
- Sustainability.
10. Sustainable architecture: 46 innovative and inspiring building designs.
 11. Reducing carbon footprint in construction: Strategies for a greener.
 12. Decarbonizing Design: How Computational Tools are ... - Quinn Evans.
 13. Building Materials and The Climate: Constructing A New Future.
 14. 12 Ways Architects Can Combat Climate Change.
 15. Climate Change Mitigation: Landscape Materials and Construction.
 16. 10 design commandments for cutting your building's embodied carbon.
 17. Why making buildings greener is crucial to countering climate change.
 18. Embodied Carbon - World Green Building Council.
 19. Over 50% of global emissions from construction & manufacturing.
 20. Decarbonizing U.S. Buildings - C2ES.
 21. Green Building Standards in the US - Tunley Environmental.
 22. Primary Research: Green Architecture: Moving Toward a Cleaner.
 23. How residential design offers opportunities for sustainability.
 24. Three ways architects can reduce the carbon footprint of their designs.
 25. Low Carbon Building Materials in Construction | The Access Group.

Copyright: ©2025 Jorge Pablo Aguilar Zavaleta. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.