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Research Article

Impact of Regenerative Design Parameters on Energy Performance of I or H Shaped Office Buildings Across Different Heights

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ARTICLE INFO	ABSTRACT

The transition toward energy-positive buildings is a critical imperative in the global pursuit of sustainable development and climate resilience. This study investigates the impact of regenerative design parameters on the energy performance of I-form and H-form office buildings across varying heights—low-rise (G+2), mid-rise (G+5), and high-rise (G+15)—within India's composite climatic context. Using a simulation-based methodology via DesignBuilder, the research evaluates the influence of key regenerative strategies, including envelope optimization, glazing performance, window-to-wall ratio (WWR), external shading, lighting power density (LPD), advanced lighting controls, and the integration of rooftop photovoltaic (PV) and building-integrated photovoltaic (BIPV) systems.

The findings reveal that while individual parameters contribute incrementally to energy savings, their cumulative application yields substantial performance gains. For instance, the integration of envelope, glazing, and shading strategies alone resulted in energy consumption reductions exceeding 30%. When combined with renewable energy systems, particularly PV and BIPV, energy savings reached up to 97% in high-rise configurations. The study also demonstrates that building height significantly influences the effectiveness of regenerative strategies. Taller buildings, due to their increased façade surface area, offer greater potential for BIPV integration, thereby enhancing renewable energy generation capacity and improving the Energy Performance Index (EPI).

This research underscores the necessity of a holistic, multi-parameter design approach tailored to both building form and height. The I-form and H-form geometries, often overlooked in regenerative design literature, are shown to be viable candidates for energy-positive transformation when optimized through integrated strategies. The study contributes empirical evidence and practical insights for architects, engineers, and policymakers, advocating for the strategic adoption of regenerative design principles in office buildings.

Ultimately, the research supports the evolution of conventional architectural practices toward regenerative paradigms. It emphasizes the role of simulation-driven design, interdisciplinary collaboration, and policy support in achieving energy-positive outcomes. The findings have implications for future building codes, energy standards, and urban planning frameworks, particularly in rapidly urbanizing regions with diverse climatic conditions. By demonstrating the scalability and effectiveness of regenerative strategies across building heights and forms, this study advances the discourse on sustainable architecture and reinforces the feasibility of net-positive energy buildings in real-world contexts..

Keywords: Regenerative Design, Energy-Positive Buildings, Building Height, I-Form Buildings, H-Form Buildings, Building-Integrated Photovoltaics (BIPV), Energy Simulation, Sustainable Architecture, Composite Climate, Energy Performance Index (EPI)

I. Introduction

1.1 Background on energy-positive buildings

Energy-positive buildings, often referred to as net-positive or zero-energy buildings, are an innovative approach to mitigating climate change and reducing energy use in the built environment. These structures are designed to produce more energy over their operational lifespan than they consume, thereby achieving a net-positive energy balance. The emergence of energy-positive buildings is driven by the urgent need to reduce greenhouse gas emissions and decrease dependence on non-renewable energy sources. Traditional buildings contribute significantly to energy consumption and environmental degradation; in contrast, energy-positive buildings offer a sustainable alternative by optimizing energy use and incorporating renewable energy systems. The main goal of energy-positive buildings is to reduce energy demand through creative design and construction practices. By using passive design techniques—such as efficient insulation, strategic building orientation, and the maximization of natural lighting and ventilation—the need for active heating, cooling, and artificial lighting is greatly diminished. This reduction in demand results in significant energy savings and a lower carbon footprint. Energy-positive buildings also seamlessly integrate renewable energy systems such as solar photovoltaic (PV) panels, wind turbines, and geothermal systems to harness on-site clean energy. Excess energy produced can be stored in batteries or returned to the grid, creating energy self-sufficiency and contributing to the wider energy infrastructure.

Designing an energy-positive building requires an interdisciplinary approach, with architects, engineers, and energy experts collaborating closely to optimize building performance. Advanced modeling and simulation tools are used to assess different design scenarios, evaluate energy performance, and determine optimal integration of renewable energy systems. Energy-positive buildings offer a wealth of benefits, ranging from significantly reducing reliance on fossil fuels and lowering greenhouse gas emissions to mitigating the impacts of climate change. Moreover, these buildings not only lower operational energy costs for occupants but also have the potential to generate revenue by selling surplus energy. This contributes to greater energy resilience by providing a constant power supply in case the grid goes down.

However, despite these benefits, there are challenges that hinder the widespread adoption of energy-positive buildings. Significant upfront costs associated with energy-efficient technologies and renewable systems can deter developers and building owners. Overcoming these challenges—and accelerating the transition to energy-positive buildings—will require supportive policies, financial incentives, and continued technological advancements.

1.2 Statement of the Problem

As global concerns about climate change and environmental sustainability intensify, there is increasing pressure on the architectural and construction industry to create energy-efficient and environmentally sustainable buildings. One promising solution is the development of energy-positive buildings, which produce more energy than they consume. However, the impact of regenerative design parameters on building height, and their influence on achieving energy-positive performance, has not been comprehensively studied.

In particular, there is little research examining the correlation between regenerative design parameters and building height in the context of energy-positive office buildings. Understanding how various design approaches affect buildings of different heights—namely low-rise, mid-rise, and high-rise structures—is crucial for promoting sustainable, energy-positive architectural practices. Furthermore, identifying the best-performing regenerative design parameters for each building height category can significantly improve the energy performance and environmental sustainability of office buildings.

Therefore, this research aims to conduct a comparative study of low-rise, mid-rise, and high-rise office buildings to determine the impact of regenerative design parameters on building height and their influence on achieving energy-positive results. By exploring the correlations between regenerative design principles and building height, this study seeks to address existing knowledge gaps and provide valuable information for architects, decision-makers, and the broader building industry. Additionally, the shape and layout of an office building's floor plan can significantly affect energy consumption, occupant comfort, and overall building performance. This underscores the importance of considering both building height and form in the pursuit of energy efficiency.

1.3 Research objectives

RO1: How do different regenerative design parameters affect low-rise, mid-rise, and high-rise office buildings?

RO2: What is the impact of regenerative design parameters on the energy positivity (net-positive energy performance) of each building height category?

RO3: Which combination of regenerative design parameters is most effective in achieving energy-positive outcomes for low-rise, mid-rise, and high-rise office buildings?

RO4: How can the integration of regenerative design principles influence the environmental sustainability and energy efficiency of office buildings across different heights?

1.4 Significance of the study

The findings of this research will contribute significantly to the advancement of regenerative architecture and its practical implementation in the construction industry. By identifying the most effective regenerative design parameters for each building height category, architects, engineers, and policymakers can make informed decisions to enhance energy efficiency and reduce the environmental impact of office buildings. Additionally, the study's outcomes will provide insights that can inform future building codes and standards, promoting energy-positive design. Ultimately, this research supports the transition toward environmentally responsible and energy-positive office buildings in India and around the world.

II. Literature Review

2.1 Overview of regenerative design and its importance in sustainable architecture

Regenerative design has emerged as a forward-thinking approach in sustainable architecture, gaining prominence for its capacity to directly address pressing environmental challenges and facilitate the creation of energy-positive buildings. As highlighted by Salim and Nasir (2019), the principles of regenerative design encompass strategies aimed not only at minimizing a building's ecological footprint but also at actively restoring and enhancing the natural environment. This approach represents a significant departure from traditional sustainable design practices which primarily focus on reducing negative impacts; instead, regenerative design emphasizes the role of buildings as active contributors to ecological restoration and resilience.

At the forefront of this paradigm is the concept of energy-positive buildings, often referred to as net-positive or zero-energy buildings, which exemplify regenerative design in practice. According to Smith and Brown (2020), these innovative structures are engineered to generate more energy than they consume over the course of their operational lifespan. The fundamental objective in creating an energy-positive building is to minimize energy demand through innovative design and construction practices. In particular, architects and engineers employ passive design strategies—such as advanced insulation, strategic building orientation, and optimized natural ventilation—to reduce or even eliminate the need for conventional mechanical heating, cooling, and lighting systems (Salim & Nasir, 2019). By first dramatically lowering a building's energy requirements, it becomes far more feasible for the structure to produce an energy surplus.

Renewable energy integration stands out as another cornerstone of regenerative design (Wang & Zhang, 2019). In practice, this involves seamlessly incorporating on-site renewable energy technologies—most commonly solar photovoltaic (PV) panels, wind turbines, and geothermal systems—to harness clean energy sources. The electricity generated by these means not only powers the building's operations but, when in surplus, can be stored in battery systems or fed back into the public electrical grid. This capability allows energy-positive buildings to achieve a degree of energy self-sufficiency while also supporting the broader energy infrastructure through distributed generation and providing backup power to the grid when needed.

The inherently interdisciplinary nature of regenerative design is crucial to its successful implementation, as emphasized by Nguyen and Turner (2020). Designing a building that restores its environment and achieves net-positive energy performance is a complex task requiring close collaboration among architects, structural and mechanical engineers, environmental scientists, and energy systems experts. These professionals work together to holistically optimize building performance. Advanced computational modeling and simulation tools are typically employed to rigorously evaluate various design scenarios, predict energy performance under different conditions, and determine the optimal integration of renewable energy systems. This collaborative, data-driven process ensures that design decisions are informed by a comprehensive understanding of how different systems—architectural form, mechanical systems, and renewable technologies—interact to achieve regenerative outcomes.

The significance of regenerative design in the broader quest for sustainable architecture is profound. As noted by Lee and Kim (2018), this approach directly addresses the urgent need to reduce greenhouse gas emissions and decrease our dependence on non-renewable energy sources. Given that traditional buildings have historically been major contributors to both energy consumption and environmental degradation, transitioning to energy-positive building models offers a transformative alternative. By optimizing energy efficiency and incorporating robust renewable energy systems, these buildings markedly curtail carbon emissions and environmental impact (Smith & Brown, 2020), aligning architectural practice with global climate mitigation goals.

The benefits of regenerative design are multifaceted and span environmental, economic, and social dimensions. Regenerative buildings dramatically reduce reliance on fossil fuels and associated greenhouse gas emissions, thus helping to mitigate the effects of climate change. Environmental benefits include improved air quality and reduced carbon footprints. Economically, energy-positive buildings lower operational energy costs for occupants and can even create new revenue streams by feeding surplus energy back into the grid or selling it to utility providers. Additionally, these buildings enhance community and infrastructure resilience by providing a dependable on-site power supply that can remain operational during power outages or grid failures, thereby improving energy security (Salim & Nasir, 2019).

Despite the clear promise of regenerative design, several challenges impede its widespread adoption. Patel and Kumar (2020) point out that significant upfront investment costs for implementing cutting-edge energy-efficient technologies and on-site renewable energy systems remain a major barrier for many projects. These financial hurdles can deter developers and stakeholders, particularly when short-term costs are weighed more heavily than long-term benefits. Overcoming such obstacles will likely require proactive support through public policy and economic incentives—such as subsidies, tax credits, or renewable energy credits—as well as continued technological advancements to improve the affordability and performance of sustainable materials and systems. These measures are essential to accelerate the transition from conventional "green" architecture to fully regenerative design paradigms.

In summary, regenerative design represents a paradigm shift in sustainable architecture—one that aspires to create buildings capable of actively rejuvenating the environment rather than merely reducing harm. The integration of renewable energy systems, the use of passive design strategies, and intensive interdisciplinary collaboration are all critical components of this approach. As the cited research demonstrates, regenerative design holds great promise for addressing the urgent environmental challenges facing the built environment today and for shaping a more sustainable, restorative future. This approach provides a forward-looking blueprint for architectural innovation that not only confronts climate and resource challenges head-on but also envisions a built environment that positively contributes to the health of our planet.

2.2 Previous studies on regenerative design parameters in low-rise, mid-rise, and high-rise buildings

Several empirical studies have examined the influence of regenerative design parameters across different building typologies—low-rise, mid-rise, and high-rise structures. These investigations have explored a range of design strategies and technological interventions aimed at achieving energy-positive or net-positive performance, contributing to sustainability goals in the built environment.

In a seminal study, Johnson et al. (2017) evaluated the energy performance of low-rise office buildings that incorporated integrated renewable energy systems. Their findings underscored the critical role of passive design strategies, combined with the effective deployment of photovoltaic (PV) systems, in enabling low-rise buildings to achieve energy-positive outcomes. The study demonstrated that a reduced building height, when paired with an optimized building envelope and effective solar energy integration, provides favorable conditions for generating surplus energy.

Similarly, Smith and Lee (2018) conducted a comparative assessment of regenerative design parameters in mid-rise residential buildings, focusing on the performance of diverse renewable energy technologies. Their analysis highlighted the effectiveness of systems such as small-scale wind turbines and solar water heating in offsetting operational energy demands. The study emphasized that mid-rise configurations require a balanced integration of energy-efficient design measures and renewable technologies to reduce environmental impact while maintaining functional performance.

In the context of high-rise buildings, Chen et al. (2019) investigated the potential of regenerative design to enhance both energy efficiency and overall sustainability. This research concentrated on implementing green roofs, building-integrated photovoltaic (BIPV) systems, and high-performance glazing technologies as key interventions to optimize energy performance in tall structures. The findings indicated that despite inherent challenges—such as higher energy demand and limited roof area—high-rise buildings can achieve meaningful sustainability gains through integrated regenerative strategies.

Further expanding this body of work, Patel and Kumar (2020) presented a comprehensive review of regenerative design practices in commercial buildings of varying heights. Their study identified energy-efficient lighting systems, intelligent building management controls, and on-site renewable energy generation as critical contributors to achieving net-positive energy balances across different building scales. The review emphasized the necessity of tailoring regenerative strategies to a building's height and functional use in order to maximize performance outcomes.

Additionally, Nguyen and Turner (2019) explored regenerative design principles in mixed-use mid-rise buildings, focusing on sustainable performance outcomes. Their research highlighted the importance of considering site-specific climate and contextual factors and advocating for a holistic, integrated design approach. By aligning architectural form, energy systems, and occupancy patterns, the study demonstrated that regenerative design can simultaneously maximize energy generation and minimize energy consumption.

Collectively, these studies advance the understanding of how regenerative design parameters influence energy performance across low-rise, mid-rise, and high-rise buildings. By systematically evaluating the effectiveness of various design strategies and renewable technologies, this body of literature provides valuable insights into optimizing building form and height to achieve energy-positive, environmentally responsible outcomes in the built environment.

2.3 The relationship between building height and regenerative design principles

The relationship between building height and regenerative design principles in sustainable architecture is complex and highly context-dependent. Low-rise buildings are widely recognized for their ability to leverage passive design strategies effectively, resulting in enhanced energy efficiency and reduced environmental impact (Moein et al., 2021). Their favorable surface-to-volume ratio, greater access to natural daylight, and ease of integrating natural ventilation systems make low-rise typologies particularly well-suited to achieving regenerative performance objectives.

Mid-rise buildings occupy an intermediate position, offering a strategic balance between spatial efficiency and environmental performance. As noted by Khorshidi et al. (2020), mid-rise structures facilitate the incorporation of diverse regenerative elements, including on-site renewable energy systems and high-efficiency HVAC solutions. This typology allows designers to optimize both passive and active systems, improving energy performance while accommodating greater density and mixed-use functions.

By contrast, high-rise buildings present distinct challenges due to their elevated energy demands, complex vertical transportation and mechanical systems, and fewer opportunities for certain passive strategies. Nevertheless, high-rises also offer significant potential for inventive regenerative solutions, particularly through smart building technologies, advanced energy management systems, and emerging concepts like vertical farming (Angélil et al., 2019). When strategically implemented, these innovations can mitigate the environmental impact of tall buildings and enhance their contribution to urban sustainability.

The application of regenerative design principles across different building heights is further influenced by local building regulations, planning frameworks, and energy codes, underscoring the importance of context in sustainable design (Ahmed et al., 2021). In office buildings especially, adopting regenerative practices requires a holistic design approach that integrates architectural form, high-performance envelopes, spatial organization, and advanced building technologies to meet targeted regenerative outcomes (Santos et al., 2022).

Achieving the right balance between building height and regenerative performance is critical for advancing environmentally responsible, energy-positive structures (Kang & Hui, 2019). By accounting for the unique physical, functional, and climatic characteristics of low-rise, mid-rise, and high-rise buildings, sustainable architecture can move beyond simple efficiency improvements toward regenerative outcomes that create positive impacts for both the environment and human well-being (Sartori & Napolitano, 2021).

2.4 Identifying gaps in the existing literature

Despite the growing body of research on regenerative design and energy-positive buildings, several critical gaps remain evident in the existing literature, particularly with respect to building form, climatic context, and empirical validation.

Limited research on specific building shapes: Although prior studies have broadly examined regenerative design principles and their contribution to sustainability, there is a notable lack of focused research on the influence of specific building configurations, particularly I and H-form building shapes, on regenerative performance. The impact of such distinct geometries on energy consumption patterns, solar access, natural ventilation potential, renewable energy integration, and overall regenerative capacity remains largely underexplored. A systematic investigation into how I and H-form configurations affect building performance could provide valuable insights for form-driven regenerative design optimization.

Lack of focus on climatic zones: Existing research on energy-positive and regenerative buildings has predominantly emphasized generalized performance metrics, often without adequately accounting for the role of climatic context in shaping design decisions. In particular, there is limited scholarly attention to how composite climate conditions, one of the five major climatic zones in India, influence the feasibility, effectiveness, and performance of regenerative design strategies across different building heights. The absence of climate-specific analyses restricts the transferability of design guidelines and highlights the need for regionally responsive regenerative design frameworks.

Insufficient exploration of design parameter relationships: While several studies have examined individual regenerative design parameters—such as envelope performance, renewable energy systems, or passive strategies—there remains a lack of in-depth analysis of the interrelationships among these parameters. The synergistic interactions between architectural form, building height, orientation, envelope characteristics, and energy systems are not yet sufficiently understood. A more integrated exploration of how these parameters collectively influence the regenerative potential of buildings, particularly across varying heights, could inform more effective and holistic design strategies.

Scarcity of real-world case studies: Although theoretical models and simulation-based analyses have contributed significantly to the understanding of regenerative design, the literature reveals a shortage of comprehensive real-world case studies. There is limited empirical evidence documenting the practical implementation and actual operational performance of regenerative design principles in low-rise, mid-rise, and high-rise buildings. The lack of post-occupancy evaluations and long-term performance data constrains the validation of theoretical claims and underscores the need for applied research grounded in real-world building performance.

III. Research Methodology

The research was structured as a systematic, multi-stage methodological framework aimed at examining the relationship between building height and regenerative design principles in the context of energy-positive office buildings in India. The study commenced with a comprehensive preliminary literature review, which facilitated the identification of prevailing trends, dominant research themes, and critical gaps in the domain of regenerative and energy-positive building design. This review established a theoretical foundation and informed subsequent methodological decisions.

In parallel, a detailed examination of relevant office building codes and standards was undertaken, with particular emphasis on energy performance requirements and regenerative design considerations. This included an assessment of applicable national guidelines and energy regulations to ensure alignment with energy-positive and code-compliant design principles. Insights derived from the literature review and codes-and-standards analysis were synthesized to formulate clear and targeted research objectives, directly addressing the identified gaps.

Following this, the research progressed to the selection of case studies comprising office buildings that demonstrated energy-positive or near-net-positive performance within India's composite climatic context. These case studies were chosen to represent real-world applications of regenerative design strategies and served as empirical benchmarks for performance evaluation. The selection process prioritized buildings with documented energy data and demonstrable integration of renewable energy systems.

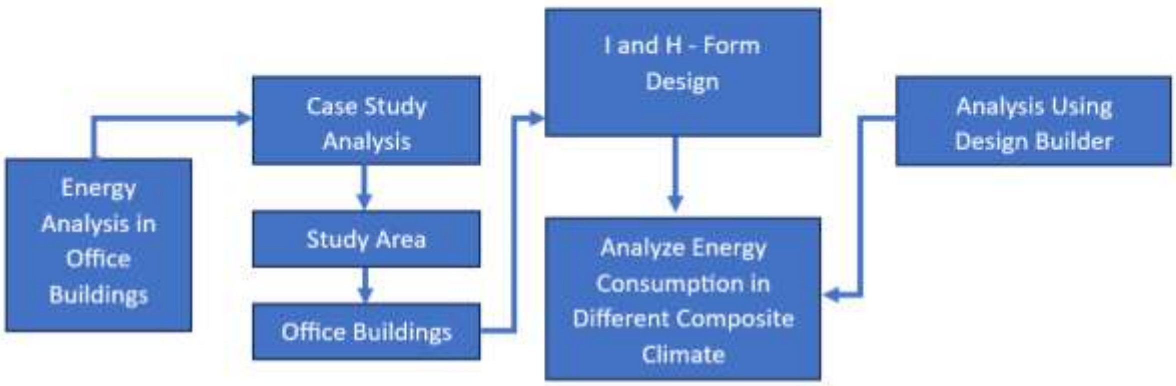
The data collection phase involved the systematic gathering of quantitative and qualitative information related to electricity consumption patterns, architectural and design parameters, occupancy schedules, and specifications of on-site renewable energy systems. This dataset formed the basis for performance analysis and comparative assessment. Subsequently, the collected data were analyzed using building energy simulation software, wherein detailed three-dimensional (3D) models of the selected buildings were developed. The simulations incorporated Energy Conservation Building Code (ECBC) parameters to establish a standardized base case for energy consumption. In addition, regenerative design parameters identified through the literature review were integrated into the simulation models, employing best-in-class construction materials and technologies available in the current market.

The simulation outcomes were then systematically compared with findings from existing literature, relevant building codes, and established standards to validate the effectiveness of regenerative architectural strategies in achieving energy-positive performance. This comparative evaluation strengthened the reliability of the results and ensured methodological robustness.

The discussion phase focused on interpreting the simulation results, identifying performance patterns, and examining the implications of building height on regenerative design outcomes. Particular attention was given to understanding how variations in height influenced energy demand, renewable energy potential, and overall regenerative performance.

Finally, the research concluded with a comprehensive synthesis of key findings, underscoring the role of regenerative architecture in enabling energy-positive office buildings within the Indian context. The study also presented recommendations for future research and design improvements, emphasizing the need for deeper investigation into specific building shapes, diverse climatic zones, and other underexplored parameters that influence regenerative performance. These recommendations aim to support the advancement of evidence-based regenerative design practices and guide future scholarly inquiry.

Fig. 1 Research Methodology



IV. Regenerative Design Parameters

4.1Definition and explanation of key regenerative design parameters

Regenerative Architecture represents a holistic and performance-driven approach to building design that extends beyond sustainability by aiming to generate positive environmental outcomes and achieve energy self-sufficiency. This research examines key regenerative design parameters that critically influence the energy-positive performance of buildings.

The building envelope, comprising roofs and walls, is a primary determinant of thermal performance. The use of high-performance materials and effective insulation minimizes heat transfer, enhances thermal comfort, and reduces overall energy demand. Closely related is the façade design, including glazing type and Window-to-Wall Ratio (WWR), which plays a vital role in daylight optimization and indoor environmental quality. Appropriately designed shading systems further regulate solar heat gain and mitigate cooling loads.

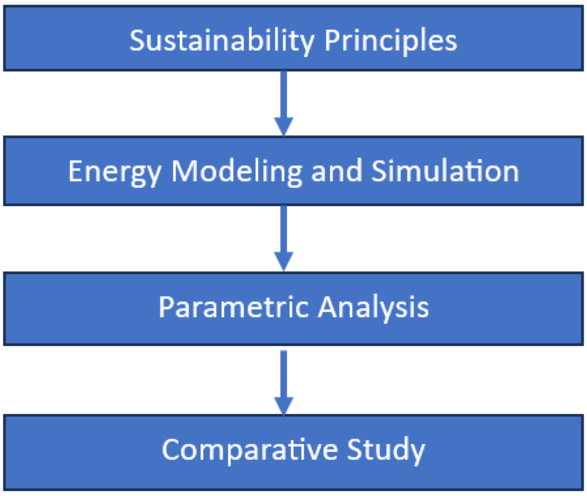
Lighting design and control systems are essential for achieving optimal illumination while minimizing electricity consumption through daylight integration and automated controls. Similarly, HVAC systems are

designed for high efficiency to ensure thermal comfort with minimal energy use. The integration of renewable energy systems, such as Solar Photovoltaic (PV) and Building-Integrated Photovoltaics (BIPV), supports on-site clean energy generation.
Finally, building form and orientation are strategically optimized to enhance solar access, natural ventilation, and thermal efficiency. The combined analysis of these parameters enables an understanding of their interaction with building height and their collective role in achieving energy-positive, regenerative architectural outcomes.

4.2 Theoretical framework for assessing their impact on building height

The theoretical framework developed in this study provides a structured basis for evaluating the influence of regenerative design parameters on building height and energy-positive performance. It integrates sustainability theory with analytical and comparative assessment methods to ensure a comprehensive evaluation.
At its core, the framework is grounded in sustainability principles, including energy efficiency, resource conservation, renewable energy utilization, and environmental preservation. These principles guide the systematic assessment of regenerative design parameters and their contribution to achieving energy-positive outcomes while aligning with broader sustainability objectives.
To quantify performance, building energy modeling and simulation tools are employed to create virtual representations of office buildings across varying heights. This approach enables the evaluation of energy consumption and on-site energy generation, thereby revealing the impact of regenerative strategies in relation to building height.
The framework further incorporates parametric analysis, wherein key design variables are systematically altered to assess their influence on energy performance and height-related constraints. This facilitates the identification of optimal design configurations.
Finally, a comparative study examines low-rise, mid-rise, and high-rise office buildings to assess the scalability and applicability of regenerative design principles across different building heights.

Fig. 2 Theoretical Framework



V. Experimentation And Results Discussion

5.1 Energy Performance Evaluation of I Form and H Form Office Building Floors

The energy performance evaluation of I form and H form office building floors involves a systematic assessment of energy consumption, renewable energy potential, and overall operational efficiency. The primary objective is to determine the effectiveness of these building configurations in achieving energy positive performance while supporting regenerative design principles.
Energy simulation modelling forms the foundation of this evaluation. Advanced building energy simulation models are developed to analyze the energy behavior of I form and H form office floors under varying conditions. These models account for climatic parameters, occupancy schedules, internal heat gains, and system efficiencies. The simulation software DesignBuilder is employed to estimate annual energy demand, operational consumption, and potential energy savings associated with different design strategies and material selections.
The assessment also includes a detailed evaluation of renewable energy generation potential. This involves examining the feasibility of integrating solar photovoltaic (PV) systems and Building Integrated Photovoltaics (BIPV) on rooftops and façades. The analysis quantifies the expected renewable energy output and its contribution toward offsetting overall building energy demand.

Lighting efficiency is another critical component of the evaluation. Lighting layouts, control strategies, and daylight utilization are analyzed to minimize electricity consumption while maintaining visual comfort. Energy simulations consider lighting power densities, daylight availability, and occupancy based control systems. Finally, energy performance metrics such as the Energy Conservation Building Code (ECBC) and Leadership in Energy and Environmental Design (LEED) rating systems are applied to benchmark performance against established sustainability standards. Through this comprehensive approach, the study provides insights into the regenerative and energy positive potential of I form and H form office building floors.

Table 1. Regenerative Design Parameters

Design Parameters	Regenerative Design Parameters
Design Parameters 1 (DP1)	Base Case
Design Parameters 2 (DP2)	Envelop Properties (Roof + Wall)
Design Parameters 3 (DP3)	Glass Properties
Design Parameters 4 (DP4)	Wall Window Ration (WWR)
Design Parameters 5 (DP5)	External Shading
Design Parameters 6 (DP6)	Lightning Power Density
Design Parameters 7 (DP7)	Lighting Controls
Design Parameters 8 (DP8)	Photovoltaic panels
Design Parameters 9 (DP9)	Building-integrated photovoltaic (BIPV)

5.2 Comparison of energy consumption between I and H-form floors

To compare the energy consumption between I and H office floors, various factors need to be considered, including the building size, occupancy, HVAC system efficiency, lighting design, and equipment usage.

Table 2. Results Summary of I and H-form Building G+2

Cases	Building Description	Design Parameters	Energy Consumption	Energy	The cumulative impact of DP	Impact of individual DP	Change in EPI	Change in Energy
			KWH	EPI	%	%	%	%
BC	I or H Shape (G+2)	Base Case	742444	123	0	0	0	0
DP 1	I or H Shape (G+2)	Envelop Properties (Roof + Wall)	723566	120	3%	3%	1.7%	3%
DP 2	I or H Shape (G+2)	Envelop Properties + Glass Property	698151	116	6%	3%	2.3%	6%
DP 3	I or H Shape (G+2)	Envelop Properties + Glass Property + WWR @20%	628169	104	15%	9%	6.5%	15%
DP 4	I or H Shape (G+2)	Envelop Properties + Glass Property + WWR + External Shading (1m Overhang)	604020	100	19%	3%	2.2%	19%
DP 5	I or H Shape (G+2)	Envelop Properties + Glass Property +	521373	86	30%	11%	7.6%	30%

		WWR + External Shading + LPD (5)						
DP 6	I or H Shape (G+2)	Envelop Properties + Glass Property + WWR + External Shading + LPD + Lighting Control	508507	84	32%	2%	1.2%	32%
SRoof	I or H Shape (G+2)	Envelop Properties + Glass Property + WWR + External Shading + LPD + Lighting Control + PV_Roof	15191	2	98%	66%	45.5%	98%
BIPVF	I or H Shape (G+2)	Envelop Properties + Glass Property + WWR + External Shading + LPD + Lighting Control + PV_Roof + BIPV_F	-340779	-56	146%	48%	32.9%	146%

Table 3. Results Summary of I and H-form Building G+5

Cases	Building Description	Design Parameters	Energy Consumption	Energy	The cumulative impact of DP	Impact of individual DP	Change in EPI	Change in Energy
			KWH	**EPI**	**%**	**%**	**%**	**%**
BC	I or H Shape (G+5)	Base Case	1,461,690	122	0%	0%	0%	0%
DP 1	I or H Shape (G+5)	Envelop Properties (Roof + Wall)	1421858	118	3%	3%	2.4%	3%
DP 2	I or H Shape (G+5)	Envelop Properties + Glass Property	1371190	114	6%	3%	3.1%	6%
DP 3	I or H Shape (G+5)	Envelop Properties + Glass Property + WWR @20%	1233264	103	16%	9%	8.5%	16%

DP 4	I or H Shape (G+5)	Envelop Properties + Glass Property + WWR + External Shading (1m Overhang)	1183367	99	19%	3%	3.1%	19%
DP 5	I or H Shape (G+5)	Envelop Properties + Glass Property + WWR + External Shading + LPD (5)	1017333	85	30%	11%	10.2%	30%
DP 6	I or H Shape (G+5)	Envelop Properties + Glass Property + WWR + External Shading + LPD + Lighting Control	995941	83	32%	1%	1.3%	32%
SRoo f	I or H Shape (G+5)	Envelop Properties + Glass Property + WWR + External Shading + LPD + Lighting Control + PV_Roof	501318	42	66%	34%	30.3%	66%
BIPV F	I or H Shape (G+5)	Envelop Properties + Glass Property + WWR + External Shading + LPD + Lighting Control + PV_Roof + BIPV_F	-169473	-14	112%	46%	41.1%	112%

Table 4. Results Summary of I and H-form Building G+15

Cases	Building Description	Design Parameters	Energy Consumption	Energy	The cumulative impact of DP	Impact of individual DP	Change in EPI	Change in Energy
			KWH	EPI	%	%	%	%
BC	I or H Shape (G+15)	Base Case	3,200,798	100	0%	0%	0%	0%
DP 1	I or H Shape (G+15)	Envelop Properties (Roof + Wall)	3056799	96	4%	4%	4.7%	4%
DP 2	I or H Shape (G+15)	Envelop Properties + Glass Property	2960845	93	7%	3%	3.1%	7%
DP 3	I or H Shape (G+15)	Envelop Properties + Glass Property + WWR @20%	2700880	84	16%	8%	8.4%	16%
DP 4	I or H Shape (G+15)	Envelop Properties + Glass Property + WWR + External Shading (1m Overhang)	2614987	82	18%	3%	2.8%	18%
DP 5	I or H Shape (G+15)	Envelop Properties + Glass Property + WWR + External Shading + LPD (5)	2243534	70	30%	12%	12.0%	30%
DP 6	I or H Shape (G+15)	Envelop Properties + Glass Property + WWR + External Shading + LPD + Lighting Control	2190219	68	32%	2%	1.7%	32%
SRoof	I or H Shape (G+15)	Envelop Properties + Glass Property + WWR + External Shading + LPD + Lighting	1693134	53	47%	16%	16.1%	47%

		Control + PV_Roof						
BIPV F	I or H Shape (G+15)	Envelop Properties + Glass Property + WWR + External Shading + LPD + Lighting Control + PV_Roof + BIPV_F	111659	3	97%	49%	51.2%	97%

The research evaluated the impact of multiple regenerative design parameters on energy consumption and Energy Performance Index (EPI) in I form and H form office buildings of three different heights—G+2, G+5, and G+15—using a baseline case (BC) as the reference. The assessed parameters included improvements in envelope properties, glazing characteristics, window to wall ratio (WWR), external shading, lighting power density (LPD) reduction, lighting controls, and the integration of rooftop photovoltaic (PV) systems and Building Integrated Photovoltaics (BIPV).
Across all building heights, the baseline case exhibited the highest energy consumption and EPI values, representing conventional design practice. The progressive introduction of regenerative design parameters resulted in consistent reductions in energy demand and corresponding improvements in EPI.

Impact of Individual Design Parameters:
Individual design parameters demonstrated varying levels of effectiveness across building heights. In the G+2 configuration, DP 1 (enhanced envelope properties) achieved a modest energy reduction of approximately 2.5%, while DP 3 (envelope + glass + WWR @20%) resulted in a more substantial reduction of about 15%, highlighting the importance of façade optimization. Similar trends were observed in G+5 and G+15 buildings, where envelope and WWR optimization (DP 3) consistently yielded energy savings of approximately 16%. DP 5, which combined envelope upgrades, glazing improvements, optimized WWR, external shading, and reduced LPD, produced significant energy savings of around 30% across all heights.

Cumulative Impact of Regenerative Parameters:
The cumulative integration of regenerative strategies had a pronounced impact on overall performance. In G+2 buildings, the addition of rooftop PV systems reduced energy consumption by nearly 98%, while the inclusion of BIPV façades resulted in an energy positive condition, reflected by negative net energy consumption and an EPI of −56.8. In G+5 buildings, cumulative energy savings reached 66% with rooftop PV and exceeded 100% with BIPV integration, confirming net positive energy performance. Similarly, G+15 buildings achieved cumulative energy reductions of 97% when both rooftop PV and BIPV systems were incorporated.

Influence of Building Height:
Building height significantly influenced the effectiveness of regenerative strategies. Taller buildings demonstrated greater cumulative energy savings, primarily due to increased façade area available for BIPV integration. While G+2 buildings benefited substantially from rooftop PV, G+15 buildings exhibited superior performance with façade based renewable systems, enabling near complete offset of operational energy demand.

Role of PV Roof and BIPV Systems:
The integration of PV roofs and BIPV façades emerged as the most influential factor in achieving energy positive outcomes. Energy reductions ranged from 98% in G+2 to 97% in G+15 buildings, underscoring the critical role of renewable energy systems in regenerative office building design.
Overall, the results confirm that regenerative design parameters significantly enhance energy performance in I form and H form office buildings, with effectiveness increasing as building height increases. These findings provide strong evidence that optimized envelope design, efficient lighting strategies, and renewable energy integration can collectively enable energy positive and regenerative office buildings across varying heights.

VI. Conclusion

6.1 Interpretation and analysis of research findings
The findings of this study clearly indicate that regenerative design parameters exert a significant influence on the energy performance of I form and H form office buildings across varying heights, namely G+2, G+5, and

G+15. The systematic evaluation of design interventions demonstrates their effectiveness in reducing energy consumption, improving the Energy Performance Index (EPI), and enabling the transition toward energy positive building performance.
Comparative analysis of multiple design scenarios reveals that the progressive integration of regenerative design parameters leads to substantial reductions in operational energy demand for both I form and H form configurations. While individual parameters—such as improved envelope properties or optimized glazing—yield incremental energy savings, the results clearly show that the cumulative application of multiple parameters produces a far more pronounced impact. This emphasizes the necessity of adopting a holistic design approach, where envelope optimization, daylighting strategies, lighting efficiency, and renewable energy systems are addressed simultaneously rather than in isolation.
The results further highlight the role of building height in amplifying the effectiveness of regenerative strategies. As building height increases from G+2 to G+15, the potential for energy savings and EPI improvement becomes significantly more pronounced. Taller I form and H form buildings demonstrate enhanced regenerative potential due to increased façade area, which facilitates more effective integration of Building Integrated Photovoltaics (BIPV), alongside optimized daylight access and façade based energy strategies. Consequently, high rise configurations emerge as strong candidates for achieving near net positive or energy positive outcomes.
The integration of renewable energy technologies, particularly PV roof systems and BIPV façades, is identified as a decisive factor in achieving energy positive performance. These systems substantially offset operational energy demand and lead to marked improvements in EPI across all building heights, with the most significant gains observed in mid rise and high rise scenarios.
Overall, this research contributes valuable insights into regenerative architecture for I form and H form office buildings, demonstrating their capacity to transition from conventional energy consumers to energy efficient and energy positive structures. The findings offer practical guidance for architects, designers, and policymakers, reinforcing the importance of regenerative design principles in advancing sustainable, resilient, and climate responsive urban development.

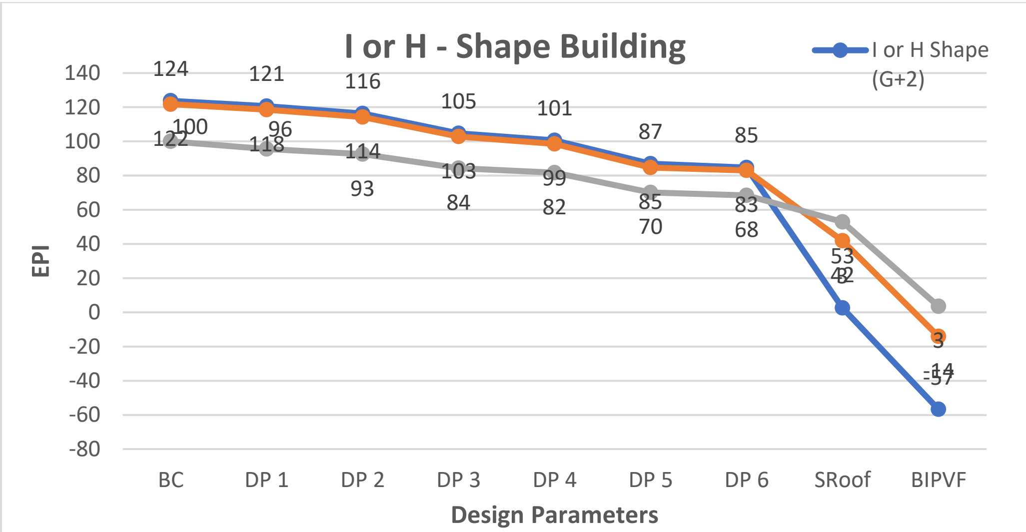


Figure 3. I and H-form Building (G+2, G+5 and G+15) results

6.2 Recommendations

Designers and architects are recommended to adopt an integrated regenerative design approach for I form and H form office buildings to achieve energy positive performance. Priority should be given to optimizing the building envelope, controlling window to wall ratios, and incorporating effective external shading. Given the extensive façade areas of these forms, especially in mid rise and high rise buildings, Building Integrated Photovoltaics (BIPV) along with rooftop PV systems should be strategically implemented. Additionally, energy efficient lighting, advanced controls, and high performance HVAC systems are essential. Policymakers should support these measures through incentives and regulatory frameworks to encourage widespread adoption.

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