Planning Framework for Net Zero Energy Residential Neighborhoods in Hot Climate Cities

A THESIS

Submitted in partial fulfilment of the requirements for the award of the degree

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by

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under the supervision of
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I hereby certify that the work which is being presented in the thesis entitled "**PLANNING FRAMEWORK FOR NET ZERO ENERGY RESIDENTIAL NEIGHBORHOODS IN HOT CLIMATE CITIES**" in partial fulfillment of the requirements for the award of the Master of Planning (Housing) and submitted in the Department of Architecture and Planning of the Maulana Azad National Institute of Technology, Bhopal is an authentic record of my own work carried out during the period from 14/07/2025 to 10/07/2026 under the supervision of Dr. Anupama Sharma, Professor, Department of Architecture and Planning, Maulana Azad National Institute of Technology, Bhopal.

The matter presented in this thesis has not been submitted by me for the award of Any other degree of this or any other Institution.

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Date :10/07/2026

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ABSTRACT

Urbanization in hot cities is happening quickly. This fast growth leads to higher energy use and more damage to the environment. It also makes homes less comfortable. In India, more people need housing because of programs like Pradhan Mantri Awas Yojana (PMAY). The challenge is to build homes that are energy-efficient and can handle climate changes. Green Infrastructure (GI) and passive design strategies are key solutions for creating neighborhoods with Net Zero Energy (NZE) in hot areas. Green Infrastructure includes things like green roofs and walls, which help cool the city. These features can reduce the Urban Heat Island (UHI) effect and support nature. For example, planting trees along streets can cool down neighborhoods and provide shade. Passive design uses natural elements to save energy. This includes how buildings are placed, using shading, and allowing natural air flow. Together, these methods help people rely less on-air conditioning. The research uses different methods to gather information. It includes looking at books, studying specific cases, and testing ideas. For instance, BedZED in the UK shows how eco-friendly designs work. These studies help create a plan that fits cities like Indore and Ahmedabad. The goal is to provide guidelines that match India's housing and energy needs. This includes programs like PMAY and Smart Cities Mission. It also focuses on making homes affordable and strong against climate changes. This research aims to create neighborhoods that use energy wisely and adapt to the environment. An example of this is a community that installs solar panels on rooftops to generate electricity. The aim is to build homes that are self-sufficient and inclusive. This aligns with global goals for sustainability and India's push for low-carbon growth. By using these ideas, we can create better living spaces for everyone.

सारांश

तेज़ी से बढ़ते शहरीकरण ने गर्म जलवायु वाले शहरों में ऊर्जा मांग में वृद्धि, पर्यावरणीय क्षरण और आवासीय पड़ोसों में तापीय आराम में गिरावट को बढ़ावा दिया है। भारत में, जहाँ प्रधानमंत्री आवास योजना (PMAY) जैसी पहलों के तहत आवास की मांग तेजी से बढ़ रही है, ऊर्जा-कुशल और जलवायु-लचीले विकास को हासिल करना एक बड़ी चुनौती है। यह अध्ययन हरित अवसंरचना (Green Infrastructure - GI) और निष्क्रिय डिजाइन रणनीतियों के एकीकरण की जांच करता है, जिन्हें गर्म जलवायु क्षेत्रों में नेट-ज़ीरो एनर्जी (NZE) आवासीय पड़ोस के विकास के लिए प्रमुख दृष्टिकोण माना जाता है।

ग्रीन इंफ्रास्ट्रक्चर जैसे ग्रीन रूफ, ग्रीन वॉल और शहरी वनस्पति सूक्ष्म जलवायु स्थितियों को बेहतर बनाती है, अर्बन हीट आइलैंड (UHI) प्रभाव को कम करती है और पारिस्थितिक संतुलन को समर्थन देती है। इसके पूरक के रूप में निष्क्रिय डिजाइन रणनीतियाँ भवन अभिविन्यास, छायांकन, प्राकृतिक वेंटिलेशन, और थर्मल मास जैसे जलवायु-प्रतिक्रियाशील तत्वों का उपयोग करके ऊर्जा खपत को न्यूनतम करती हैं। संयुक्त रूप से, ये दृष्टिकोण सक्रिय शीतलन प्रणालियों पर निर्भरता को कम करने और समग्र रहनेयोग्यता को बढ़ाने के लिए एक समग्र ढांचा तैयार करते हैं।

यह शोध साहित्य समीक्षा, केस स्टडी विश्लेषण, सिमुलेशन-आधारित सत्यापन, और नीतिगत समीक्षा सहित मिश्रित-पद्धति दृष्टिकोण अपनाता है। BedZED (यूके), Vauban (जर्मनी), और Masdar City (यूएई) जैसे केस स्टडी, इंदौर और अहमदाबाद जैसे भारतीय संदर्भों के लिए एक एकीकृत ढांचा विकसित करने में सहायक हैं। अनुसंधान का उद्देश्य भारत की आवास और ऊर्जा नीतियों (PMAY, ECBC, स्मार्ट सिटीज मिशन) के अनुरूप डिजाइन और योजना दिशानिर्देश तैयार करना है, जिसमें वहनीयता, विस्तारयोग्यता और जलवायु-लचीलापन पर जोर दिया गया है।

अंततः, यह अध्ययन सतत शहरी आवास के विमर्श में योगदान देता है और एक पुनरावृत्त मॉडल का प्रस्ताव करता है जो पारिस्थितिक प्रणालियों और जलवायु-प्रतिक्रियाशील डिजाइन को एकीकृत करता है। यह ऐसे आवासीय पड़ोसों की कल्पना करता है जो ऊर्जा की दृष्टि से आत्मनिर्भर, पर्यावरणीय रूप से अनुकूलनशील और सामाजिक रूप से समावेशी हों जो वैश्विक सतत विकास लक्ष्यों (SDG 11 और SDG 13) तथा भारत की कम-कार्बन शहरी विकास प्रतिबद्धताओं के अनुरूप हैं।

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CERTIFICATE OF PLAGIARISM

This is to certify that the Thesis entitled "**Planning Framework for Net Zero Energy Residential Neighborhoods in Hot Climate Cities**" is a piece of research work carried out by **Yamini Vaskale**, Scholar No.**24209021101** under my guidance and supervision for the degree of Master of Planning (Housing) from the Department of Architecture and Planning of Maulana Azad National Institute of Technology, Bhopal (M.P.) India

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LIST OF ABBREVIATIONS

Abbreviation	Definition
NZEB -	Net Zero Energy Building
PV -	Photovoltaic
PVT -	Photovoltaic-Thermal System
WT -	Wind Turbine
REC -	Renewable Energy Contribution
EUI -	Energy Use Intensity
LHS -	Latin Hypercube Sampling
ML -	Machine Learning
ANN -	Artificial Neural Network
MLR -	Multiple Linear Regression
GWR -	Geographically Weighted Regression
MGWR -	Multi-Scale Geographically Weighted Regression
MOOA -	Multi-Objective Optimization Algorithm
TOPSIS -	Technique for Order Preference by Similarity to Ideal Solution
RSR -	Rank Sum Ratio
LCCE -	Life-Cycle Cost Evaluation

CHAPTER 1

INTRODUCTION

1.1. Introduction

Rapid urban growth, together with increasing energy needs, has brought the housing sector to the fore in the global sustainability debate. According to UN DESA (2018), it is estimated that about 68% of the world's population will move into urban areas by 2050, the most significant increases taking place in Asia and Africa. This demographic shift has led to increased pressure on housing, energy systems, and urban ecosystems in recent years in India, but particularly in cities lying within hot climate zones such as Indore, Ahmedabad, and Chennai (Warden et al., 2022). These cities have more significant energy requirements for cooling, which further exacerbates the Urban Heat Island (UHI) effect, lack of vegetation, and dense building forms (Imam & Banerjee, 2016).

GI and passive design strategies now offer new opportunities to overcome these challenges. GI comprises vegetated roofs, walls, urban greenery, and permeable surfaces that help in modifying microclimate conditions, reducing heat stress, and enhancing biodiversity (Jim 2015; Galagoda et al. 2018). At the same time, passive design strategies utilize climatic factors such as orientation, shading, ventilation, and thermal mass in reducing cooling needs and thereby reducing the consumption of energy. These may be mixed together to be able to allow a shift towards NZE residential areas where annual energy consumption is matched by the renewable energy created.

Initiatives in India, such as PMAY to ensure affordable housing and ECBC for energy-efficient buildings, are mainly standalone building efficiency-oriented. Some key initiatives include the Pradhan Mantri Awas Yojana for affordable housing and the Energy Conservation Building Code for energy-efficient buildings (MoHUA 2021; BEE 2017). But these remain individual building-centric and lack an integrated approach to ecological and passive systems design at the neighbourhood level. The latter is of prime importance in the context of climate resilience, energy efficiency, and social inclusivity.

This current research investigates how green infrastructure integrated with passive design can create a replicable model for setting up NZE residential neighbourhoods within hot climate cities. With a significant view to both environmental performance and occupant wellness, it redefines sustainable housing as a system that strikes a balance in affordability, resilience, and energy neutrality. (Priya & Senthil, 2024 Basu and Nagendra 2021).

1.2. Background of the Topic

The housing industry now stands at the crossroads of rapid urban growth, changes in climate, and sustainable practices. According to (UN DESA, 2018), it is expected that close to 68% of the world's population will be living in urban areas by the year 2050, driven largely by rapid growth in Asia and Africa. Also, in India, the cities are subjected to unprecedented population growth; due to this, there is tremendous pressure on infrastructure, energy systems, and environmental resources. This is a population and spatial shift that has ushered in an unprecedented increase in energy consumption within the residential sector-one that already takes centre stage in urban electricity consumption, especially in hot-climate cities where air conditioning and mechanical cooling dominate (Banister, 2011).

The Urban Heat Island effect, with increased ambient temperatures arising from concentrated built environments, asphalt surfaces, and lack of vegetation, is a critical issue in hot climate cities. UHI can increase heat stress and peak energy demands for cooling. Studies have reported that core urban areas in Indian cities like Chennai and Delhi have urban surface temperatures of about 3-5 °C above surrounding rural areas (Wardeh et al., 2022). Yet, these worsening conditions decrease living standards and exacerbate inequities in access to comfortable housing. Therefore, greater recognition is placed on the importance of planning approaches that incorporate GI and passive design strategies in achieving climate resilience and sustainable housing.

Green Infrastructure represents a nature-based solution that integrates vegetation and ecosystem services into urban settings, from large-scale urban parks and water systems to building-scale interventions such as green roofs, living walls, balcony gardens, and tree-lined streets. GI improves air quality, reduces UHIs, increases biodiversity, and promotes

psychological well-being by bringing citizens closer to nature. Recent studies in the tropics and subtropics have emphasized that residential levels of vegetation-even on very small or microscales, which would include balconies, terraces, and small gardens-play a much more significant role in reducing indoor cooling demands and improving thermal comfort (Priya & Senthil, 2024). In highly populated urban cities with very little open space, greening that is integrated into building designs is often the most viable option. However, high upfront costs, maintenance requirements, and simple lack of awareness often hinder widespread acceptance (Radić et al., 2019).

Green infrastructure (GI), when combined with passive design strategies, provides an effective approach to improving building performance while reducing operational energy demand. Passive design takes advantage of local climatic conditions by incorporating features such as appropriate building orientation, natural ventilation, external shading, thermal mass, reflective roofing materials, and daylight optimization. These principles have long been employed in vernacular architecture in hot climates through elements such as courtyards, verandas, and wind catchers, which naturally regulate indoor temperatures without relying heavily on mechanical cooling systems (Givoni, 1998; Olgyay, 2015). Adapting these traditional concepts to contemporary residential developments through climate-responsive design guidelines can significantly improve thermal comfort while lowering energy consumption and associated carbon emissions (Banister, 2011).

The integration of passive design with green infrastructure is particularly important in the planning of Net Zero Energy (NZE) residential neighbourhoods. NZE developments seek to balance annual energy consumption with renewable energy generation while minimizing environmental impacts and improving long-term sustainability. Although successful NZE neighbourhoods such as BedZED in the United Kingdom and Vauban in Germany demonstrate the feasibility of this concept, implementing similar developments in hot climates presents additional challenges, including increased cooling requirements, limited water resources, and affordability constraints (Torcellini et al., 2006; UNEP, 2020). In these climatic conditions, green infrastructure contributes by mitigating the urban heat island effect, improving outdoor thermal comfort, and enhancing stormwater management, while

passive design strategies reduce cooling loads through climate-responsive architectural planning. Together, these complementary approaches establish a practical and scalable framework for developing sustainable and energy-efficient residential neighbourhoods in regions with hot climates.

Despite the implementation of national programmes such as the Pradhan Mantri Awas Yojana (PMAY) and the Energy Conservation Building Code (ECBC), the primary emphasis has remained on providing affordable housing and improving the energy performance of individual buildings. Comparatively less attention has been given to incorporating ecological planning principles at the neighbourhood scale, including green infrastructure, biodiversity conservation, and climate resilience. This highlights a significant research gap, suggesting that affordable housing developments should be evaluated not only for their energy efficiency but also for their ability to function as environmentally resilient and socially sustainable communities (BEE, 2021; Ministry of Housing and Urban Affairs, 2015).

Previous studies conducted in Tamil Nadu further indicate that residents generally express positive attitudes toward the inclusion of vegetation on balconies, terraces, and other semi-private spaces. Such findings demonstrate that community acceptance and participation are essential factors influencing the long-term success of green infrastructure interventions. Therefore, behavioural preferences and user engagement should be integrated into neighbourhood planning to ensure the continued effectiveness and maintenance of sustainable design strategies (Sanyé-Mengual et al., 2015).

This research is based on the premise that rapidly urbanizing cities in hot climatic regions face two interconnected challenges: increasing residential energy demand and growing vulnerability to climate change. Addressing these issues requires neighbourhood-scale planning approaches that combine energy-efficient design with ecological resilience. The study proposes that affordable residential developments can move toward net-zero energy performance by integrating passive design strategies with green infrastructure, while simultaneously promoting social inclusiveness and climate adaptability. Such an approach provides a practical framework for developing housing communities that satisfy

environmental objectives without compromising the need for affordable and equitable urban development in India. The concept of a Net Zero Energy Building (NZEB) is illustrated in (Figure 1).

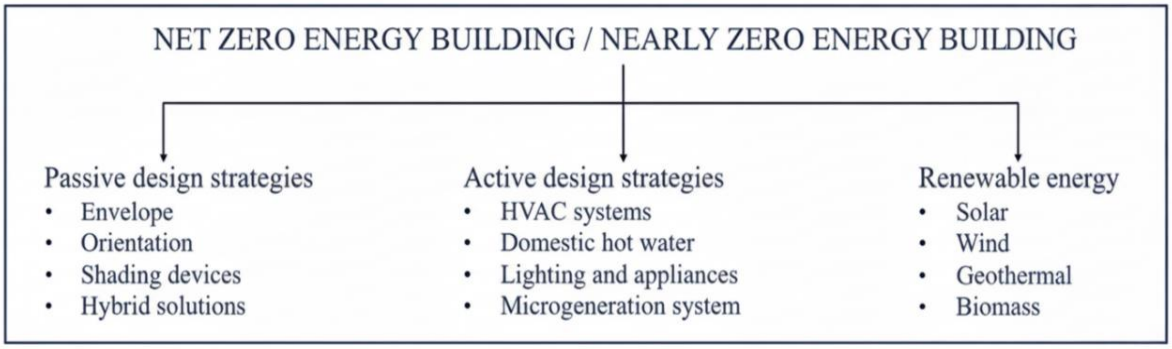

Figure 1: Strategies for attaining NZEB/nZEB. (source author)

1.3. Need for the Study

Rapid urbanization in hot-climate regions, particularly in India, has intensified the demand for housing while simultaneously placing considerable stress on energy resources and the urban environment. The rapid expansion of residential neighbourhoods has resulted in higher cooling energy requirements, reduced availability of green and open spaces, and declining outdoor thermal comfort. According to the United Nations Department of Economic and Social Affairs (UN DESA, 2018), nearly 68% of the world's population is expected to reside in urban areas by 2050; a significant proportion of this growth will occur across Asia and Africa. This trend is already evident in Indian cities such as Indore, Ahmedabad, and Chennai; where increasing urban density is accompanied by rising ambient temperatures and a growing intensity of the Urban Heat Island (UHI) effect (UN DESA, 2018).

Conventional residential developments generally prioritize maximizing built-up area while minimizing construction costs; however, this approach frequently overlooks sustainable design measures that could improve environmental performance and occupant comfort. The incorporation of Green Infrastructure (GI), including green roofs, vertical gardens, urban trees, and landscaped open spaces, offers multiple environmental benefits; these include reducing surface temperatures, mitigating the Urban Heat Island effect, improving air quality, supporting biodiversity, and enhancing the overall resilience of urban neighbourhoods (Gill

et al., 2007; EPA, 2023). Likewise, passive design strategies that respond to local climatic conditions such as appropriate building orientation, natural ventilation, solar shading, daylight optimization, and the use of thermal mass can substantially reduce dependence on mechanical cooling systems and lower operational energy consumption (Givoni, 1998; Olgyay, 2015).

Although the environmental and economic benefits of Green Infrastructure and passive design have been widely documented, their adoption within affordable housing developments remains limited. Key barriers include inadequate awareness among stakeholders; concerns regarding initial investment costs; insufficient technical expertise; and the absence of comprehensive planning policies and regulatory frameworks that encourage neighbourhood-scale implementation. Addressing these challenges is essential for promoting sustainable residential communities that are both energy-efficient and resilient to future climatic conditions (Chang et al., 2024).

This study becomes relevant because there is an imminent need to align mass housing expansion with the goals of sustainability. Flagship housing schemes for India, like PMAY, though have the objective of providing affordable housing, actually fall short in integrating energy efficiency and climate resilience into the design of their buildings. On the other hand, the ECBC looks at individual structures but fails to cover planning at the neighborhood level (Bureau of Energy Efficiency [BEE], 2017). This gap must be addressed to ensure that the growth of affordable housing is not detrimental to urban environmental issues.

User perception studies also reveal a high inclination towards greenery even within highly populated cities through the use of balconies, potted plants, and vertical gardens (Priya & Senthil, 2024). Despite these, none have provided systematic frameworks which can integrate these user-driven preferences along with passive design methods within NZE neighborhood models for hot climate regions.

Therefore, this research work is important to develop a holistic and scalable framework of integration between green infrastructure and passive design strategies within residential areas

that would, in turn, foster energy savings, climate resilience, better health and wellbeing, and innovative policies to make future housing development in hot climate cities both affordable and sustainable (Chang et al., 2024).

CHAPTER 2
LITERATURE REVIEW

The reviewed studies indicate that neighbourhood-level planning plays a fundamental role in determining the thermal performance of urban residential environments, particularly in regions characterized by hot climatic conditions. Planning decisions related to street orientation, building spacing, block configuration, and the provision of ventilation corridors significantly influence solar exposure and natural air movement; consequently, these factors contribute to improved microclimatic conditions and reduced heat accumulation. Well-designed urban layouts promote effective airflow and create shaded outdoor environments, thereby mitigating the Urban Heat Island (UHI) effect and lowering the cooling energy requirements of adjacent residential buildings. These findings highlight that climate-responsive planning should be incorporated during the initial stages of neighbourhood development to enhance thermal comfort and overall energy efficiency (Oke, 1987; Emmanuel & Krüger, 2012).

The literature further identifies Green Infrastructure (GI) as one of the most effective passive cooling strategies for residential neighbourhoods. Vegetation elements such as street trees, landscaped courtyards, shaded pedestrian pathways, urban parks, and green corridors improve environmental performance through shading and evapotranspiration; these natural processes reduce both surface and ambient air temperatures while enhancing outdoor thermal comfort. The comparative results presented in (Table 1**)** demonstrate that strategically planned vegetation can generate measurable reductions in urban temperatures, reinforcing its importance in developing climate-responsive and environmentally sustainable residential communities (Bowler et al., 2010; Gill et al., 2007).

The concept of Net Zero Energy (NZE) neighbourhoods has become a key objective in contemporary sustainable urban planning, particularly for cities located in hot climatic regions. An NZE neighbourhood is designed so that its annual energy demand is balanced by renewable energy generated within the development; however, achieving this objective requires a substantial reduction in cooling demand before renewable energy technologies are

incorporated. Consequently, recent research emphasizes passive cooling as a primary design strategy for minimizing operational energy consumption. Mohammed et al. (2023) reported that the application of climate-responsive passive design measures in regions experiencing prolonged periods of high temperatures and intense solar radiation can reduce cooling energy demand by up to 60%. Such reductions improve the feasibility of integrating photovoltaic systems, battery energy storage, and decentralized renewable energy microgrids, thereby facilitating the successful implementation of Net Zero Energy residential neighbourhoods (Chang et al., 2024).

The form of a town shapes how it breathes. The layout at neighbourhood scale controls the building layout, street, and block structure; sun exposure; shade; and wind flow. Research indicates that parameters such as building tightness, street orientation, height-to-width ratio, and block grid all have direct impacts on heat gain on façades, cooling opportunities, and ventilation (Haggag & Elmasry, 2011). On one hand, good compact design can provide mutual shading among buildings, reducing solar heat on surfaces. On the other hand, if compactness is associated with poor ventilation, warm air may be stagnant and the urban heat island effect will be aggravated. There is a high agreement that aligning buildings and streets with prevailing winds enhances natural ventilation indoors and outdoors, hence improving comfort and reducing the demand for mechanical cooling (Garde et al., 2012). Such results represent an emerging paradigm shift toward holistic neighbourhood-scale energy approaches rather than building-scale approaches in isolation.

Green infrastructure also plays a crucial role. Features like urban trees, green corridors, and landscaped courtyards have the potential to reduce surface temperatures by approximately 2-6°C through the processes of shading and evapotranspiration, which in turn reduces cooling demands in the immediate vicinity (Li et al., 2023). Vegetation affects not only air temperature but also wind patterns and shading, improving the potential for cooling at pedestrian level. Field studies further confirm that urban greenery offers both daytime shade and nighttime radiative cooling, thus representing one of the most flexible passive climate-control options designers have (Oshio et al., 2022). These findings emphasize the need to incorporate green networks into house designs to maximize microclimate control.

At the building scale, passive envelope design is widely recognized as one of the most effective approaches for achieving Net Zero Energy (NZE) performance. Among the various passive techniques, external solar shading systems including overhangs, vertical fins, louvers, and shading screens have been extensively investigated because of their ability to reduce unwanted solar heat gain. Simulation-based studies demonstrate that appropriately designed shading devices can decrease direct solar radiation on east- and west-facing façades by as much as 80% during peak summer conditions; consequently, cooling energy demand is significantly reduced. Similar findings have been reported by Uwa and Pourvahidi (2024), who concluded that external shading systems not only improve energy efficiency but also enhance indoor visual comfort by limiting excessive summer solar radiation while permitting beneficial winter daylight (Lombardi et al., 2011).

The literature also highlights the importance of thermal mass as a passive design strategy, particularly in hot-arid climatic regions. Building materials with high heat storage capacity absorb excess heat during daytime hours and gradually release it when outdoor temperatures decline; this process moderates indoor temperature fluctuations and contributes to improved thermal comfort (Mohammed et al., 2023). Furthermore, the performance of thermal mass can be enhanced when combined with night-time natural ventilation, commonly referred to as night flushing; this strategy dissipates the heat stored within the building envelope during cooler night-time conditions, thereby reducing peak cooling loads and improving the overall energy performance of residential buildings (Givoni, 1998; Mohammed et al., 2023).

Cool roofs and reflective materials further reduce building-level heat. High-albedo roofs can potentially reduce roof surface temperatures by 20-35°C, reducing cooling energy consumption by as much as 15% (Li et al., 2023). Insulation of roof and walls resists heat transfer, thereby maintaining comfort and reducing energy consumption. Combined, these methods of shading, thermal mass, insulation, and reflective materials encompass a suite of passive envelope strategies that current literature widely recognizes as integral to net-zero design. Natural ventilation remains basic for passive cooling in hot climates.

The techniques represented by cross-ventilation, stack ventilation, and wind-driven airflow can markedly improve indoor thermal comfort with a reduction in reliance on mechanical cooling, according to many different studies (Garde et al., 2012). Solar chimneys, wind catchers, and operable windows have long been utilized to capture and channel natural airflow, especially in arid regions with large diurnal temperature swings. Contemporary interpretations of these techniques exploit computational fluid dynamics (CFD) and optimized opening designs to maximize ventilation potential while maintaining security and daylighting. In hot-humid climates, natural ventilation cannot be relied upon as a sole solution, and hybrid systems combining natural ventilation with low-energy fans have been deployed (Grassie et al., 2021). Such configurations yield unbroken airflow, higher indoor air quality, and decreased consumption of active cooling energy with less reliance on mechanical air conditioning.

Traditional vernacular architecture provides valuable insights into the development of climate-responsive passive design strategies for contemporary buildings. Across hot climatic regions, indigenous construction techniques evolved in direct response to local environmental conditions, incorporating design elements such as internal courtyards, wind towers, thick masonry walls, perforated shading screens, natural ventilation shafts, and strategically positioned openings. These architectural features utilize prevailing wind directions, diurnal temperature variations, and solar movement to maintain comfortable indoor conditions while minimizing dependence on mechanical cooling systems (Givoni, 1998; Olgyay, 2015).

Recent research has explored the integration of these traditional passive design principles with modern building technologies to improve the performance of energy-efficient residential developments. Contemporary applications combine vernacular concepts with advanced materials and façade systems, including phase-change materials (PCMs), ventilated building envelopes, and adaptive external shading devices. This hybrid approach enhances thermal performance, reduces operational energy consumption, and supports occupant comfort while preserving regional architectural identity and cultural character. Consequently, the combination of traditional climate-responsive design and modern technological innovations

offers an effective pathway toward developing sustainable and Net Zero Energy residential buildings in hot climatic regions (Ascione et al., 2016; Mohammed et al., 2023).

The literature also underlines the need for combining passive strategies with renewable energy systems to achieve net-zero performance at the neighbourhood scale. (Tortellini et al. 2020) believe that passive design has to be in the forefront and not after the sizing of active systems, which avoids oversized and costly renewables. Reducing cooling loads by passive means increases the efficiency of deploying PV, microgrids, and shared storage. Community-scale renewables enable the sharing of loads among buildings, enhancing reliability by reducing energy waste. LCZs have emerged as a practical tool for climatic analysis, hence helping planners map thermal conditions and tailor passive and active strategies to specific urban forms. (Eshraghi et al.,2024) reinforce that the above connection between energy planning and climatic and morphological characteristics exists.

Despite rich research, the gaps in studies still exist. Single-building studies dominate over neighbourhood interaction analyses, even though the microclimate factors that would be significant in impacting energy performance include street canyons, building layout, and vegetation distribution. Indeed, occupant behaviour is also of essence to the success of passive systems, especially in natural ventilation and in allowing for adjustable shading (Grassie et al., 2021). Further study is needed in passive materials' embodied energy, especially of the high-thermal-mass variety, so as to ensure net-zero goals cover both operational and lifetime carbon. Passive design promotion barriers within hot-climate housing include policy and implementation issues such as outdated building codes, weak incentives, and low public awareness. In short, the literature robustly supports green, passive design as integral to net-zero energy residential neighbourhoods in hot climates. From urban planning to building science and landscape architecture, through renewable energy, the message is one: passive cooling, smart urban form, vegetation integration, natural ventilation, and traditional design principles matter. Where applied comprehensively and coupled with appropriate renewables, neighbourhoods become more resilient, thermally comfortable, and energy-efficient. These references support the goals of this thesis on sustainable housing in hot-climate regions with a strong theoretical framework (Lombardi et al., 2011).

Table 1 : Literature survey

S.No	Title of the Paper	Author Name	Objective	Methodology	Identification of Gaps	Findings Or Results
1	**Energy performance analysis of a net zero energy house in Oman**	Omed Akber Abbass, Ahmed Ghareeb, Mahmood Sh. Suwaed, Tarik Alkharusi	The primary objective of this research is to conduct a comprehensive energy performance analysis of a unique, fully operational Net Zero Energy House in Muscat, Oman, using a complete year of monitored data. The study aims to assess the building's energy generation, consumption patterns, and thermal comfort to validate the feasibility of the NZEB concept in a hot, desert climate and offer valuable insights for sustainable housing design in the region.	Case Study: A two-story, 220 m2 home with high-performance insulation and a solar power system. Data Acquisition: A data logging system recorded energy production, consumption (HVAC and non-HVAC), and climate variables for the full year of 2015. Analysis: The study compared energy generation vs. consumption, analyzed thermal comfort, and calculated avoided CO 2 emissions	There is a lack of long-term empirical data on fully operational NZEBs in the hot, arid climate of the Middle East, despite extensive studies from Europe and North America. Additionally, gaps remain between simulated and actual NZEB performance, underscoring the need for year-long, real-world case studies to validate designs and establish reliable benchmarks.	The house operates as a net-positive energy building, producing a large solar energy surplus compared to its yearly demand. HVAC use represents the main load, significantly higher than all other loads. Energy demand peaks in summer due to cooling needs, while solar production is highest during periods of strong sunlight. The design helps reduce roughly 23 tons of CO_2 emissions annually. Indoor temperatures remain stable and within a comfortable range of 23–27°C, showing good thermal performance.
2	**Urban morphology and residential building net-zero energy performance: A global meta-analysis**	Hengyu Li, Jie Zheng, Yukun Zhang, Rui Zhang	The objective is to establish a comprehensive quantitative framework for understanding morphology-energy relationships in residential blocks with integrated PV systems.	The methodology involves a systematic review of 39 studies and a meta-analysis using random-effects statistical models with the coefficient of determination (R2) as the standardized effect size measure. The analysis focuses on 17 morphological parameters across two scales: site planning and architectural geometry.	The key gap identified is the lack of a comprehensive meta-analysis that synthesizes findings from multiple studies to create a unified framework for understanding morphology-energy relationships for net-zero energy goals.	Morphological building parameters demonstrate stronger and more consistent correlations with photovoltaic potential than with energy-use intensity, indicating that the configuration of building form plays a more significant role in enhancing solar energy performance. Architectural geometric variables—such as roof-to-floor area ratio and surface-to-volume ratio—exert greater influence than site-planning parameters. Collectively, increases in roof-to-envelope ratio, roof-to-floor ratio, surface-to-volume ratio, and sky-view factor substantively improve photovoltaic potential while contributing to reductions in net energy-use intensity across diverse climatic contexts.
3	**Adoption of Net Zero Energy Building Concepts and Energy Performance in Residential Buildings: A Sustainable Strategy in Affordable Housing Projects in Nairobi, Kenya**	Abel K. Njogu, Erick K. Ronoh, Kipchumba Cherono	The objective is to bridge the knowledge gap by investigating the current level of NZEB integration, the associated challenges, and opportunities within government-led affordable housing projects in Nairobi, Kenya.	The methodology uses a mixed-methods survey research design, gathering data from 120 stakeholders (residents, architects, engineers, property managers) through questionnaires, interviews, and observations from two projects: one private (Tilisi) and one government-led (Pangani). The data analysis includes descriptive analysis and multiple linear regression to examine relationships between NZEB concepts and adoption/energy performance.	A key gap identified is the lack of research on NZEB integration in government-led affordable housing projects in Kenya and the direct relationship between various NZEB concepts and actual energy performance in a local context.	Awareness and Adoption: Most respondents lacked knowledge of NZEBs, with 95% unfamiliar and only 7% fully applying NZEB features. Heating and Cooling: All participants used some form of heating technology, indicating general acceptance of energy-efficient heating. For cooling, 59% relied on passive methods, while only 25% used mechanical systems. Statistical Findings: Regression results showed that "Responsible Heating Controls" and "Controlling Cooling" both positively influenced NZEB performance. In contrast, "Personal Control over Cooling" showed no significant effect

4	**Towards net-zero energy buildings: Real-time monitoring, data-driven, and machine learning optimization**	Ali Farahmandfar, Ayat Gharehghani, Jabraeil Ahbabi Saray	The primary objective is to configure and optimize an innovative HRES for a mechanical engineering faculty building in Tehran to achieve NZEB status and self-sufficiency.	Simulate the building and its loads (electrical, heating, cooling) using the Trnsys3D plugin in SketchUp Pro and TRNBuild. Model the HRES, including photovoltaic-thermal (PVT) panels, vertical-axis wind turbines (WT), electrolyzers, fuel cells, a hydrogen storage tank, a diesel generator, and a methanation system, within the TRNSYS simulation environment. Develop a novel Artificial Neural Network (ANN) and a Multi-Objective Grey Wolf Optimization (MOGWO) algorithm to find the optimal configuration.	The identified gap is the lack of research on integrated systems capable of simultaneously supplying electricity, domestic hot water, cooling, heating, and natural gas demands, especially in a large institutional building like a university faculty.	The system produces 683,943.4 kWh annually from PVT and WT, with WT supplying the largest share. Cooling demand is higher than heating demand. The optimal setup—72 PVT panels and 7 WT—achieves a 93.97% renewable contribution, 74.41% system efficiency, CO_2 emissions of 36,824.22 kg, and a cost of 8.31 EUR/hr. The ANN model shows excellent accuracy, with R-values near 1 for all objectives.
5	**Examining spatial variations in the relationship between domestic energy consumption and its driving factors using multiscale geographically weighted regression: a case study in Nottingham,**	Yuan Feng, Ying Miao, and Ed Turner	The study aims to examine the spatial variations and different spatial scales of the relationship between domestic energy consumption and its driving factors in Nottingham, England, using a local spatial statistical modeling technique, specifically Multiscale Geographically Weighted Regression (MGWR).	The methodology involves using a Multiple Linear Regression (MLR) model as a baseline, followed by a GWR model, and finally an MGWR model to provide the most nuanced understanding. The study uses public datasets from Census 2021 and other sources at the Lower Layer Super Output Area (LSOA) level.	A critical gap is the lack of research using local spatial statistical modeling techniques, such as geographically weighted regression (GWR), in the UK context to understand how the relationship between energy consumption and its drivers varies geographically.	The MGWR model achieved the strongest performance, with an adjusted R^2 of 0.754, outperforming both the global MLR and single-scale GWR models. Domestic energy use varies across spatial scales, influenced by heterogeneous local conditions. Higher energy consumption is linked to larger dwellings, unemployment, and terraced housing, while lower consumption is associated with social-rented housing and district heating. Other factors including energy efficiency, income, household size, fuel poverty, and renewable energy show varied impacts across local areas.
6	**Validation of energy simulations for multi-family residences with photovoltaic power and gas cogeneration: Case study on balancing energy efficiency and resident health**	Hikari Harasaki, Kan Shindo, Shin-ichi Tanabe, Toru Shiba, Shun Kawakubo, Takashi Akimoto, Toshiharu Ikaga	The objective is to demonstrate a methodology for wellness-centric performance validation by building a simulation model of an actual ZEH-certified dwelling and validating it with real-world data.	Constructing a simulation model using the Building Energy Simulation Tool for Housing (BEST-H) and validating it against HEMS data (30-min interval energy consumption and indoor temperature records) from the winter of 2024. Incorporating actual lifestyle behaviors gathered from resident interviews into the model. Conducting case studies to analyze the impact of different scenarios (e.g., varied thermal insulation, optimized behaviors) on operational energy, well-being (indoor temperature and estimated morning blood pressure), and bills (utility and medical).	A critical gap identified is the lack of integrated research that simultaneously evaluates an advanced energy system (PV and gas cogeneration) in a multifamily building from both an energy and a resident health perspective.	The model showed good agreement with measured winter data, though actual lighting and gas use were higher due to occupant behavior. Poor insulation ($55) led to higher morning blood pressure and inadequate indoor temperatures even with continuous heating. Behavioral adjustments in lighting, appliances, and hot water use can lower energy consumption by up to 15% and improve economic efficiency by 33%, with additional savings even under 24-hour heating.

7	**Low-carbon retrofit of rural dwellings in the dabie mountain region of China based on life-cycle assessment**	Bo Wang, Hui Xi, Wanjun Hou, Yueyao Li	The study's objective is to develop and apply a comprehensive MOO framework to find optimal low-carbon retrofit solutions for rural dwellings in the Dabie Mountain region.	1.Conduct a field survey to assess architectural and energy-use features of rural dwellings. 2. Develop a prototype dwelling model and generate 500 retrofit scenarios using LHS. 3. Build a dataset through building simulations and LCCE calculations. 4. Train and compare nine ML models to predict key optimization objectives. 5. Integrate the best ML model with advanced MOOAs to obtain Pareto-optimal solutions. 6. Use MCDM methods (TOPSIS, RSR, VIKOR) to rank and select optimal retrofit strategies.	A key gap is the absence of a systematic comparative analysis of MOO methodologies, including the selection of machine learning (ML) algorithms, optimization of model performance, evaluation of Pareto fronts, and implementation of different multi-criteria decision-making (MCDM) methods.	Option 1 (Passive Retrofit): This option, which maintains reliance on conventional energy, achieved a 5.1% reduction in LCCE and a 17.6% decrease in EUI. However, it was not economically viable, with a negative NPV of -22,730 CNY. Option 2 (Renewable Energy): This option, which introduced renewable energy systems, achieved a 36% reduction in LCCE, a 24% decrease in EUI, and a significant improvement in thermal comfort (81.6%). Critically, it yielded a positive NPV of 48,070 CNY, confirming its economic feasibility.
8	**Reducing the Energy Use in Unconditioned Residential Buildings in a Warm Humid Climate: A Case Study in Guwahati, India**	Shrutismita Talukdar, Tomosree Deb, Subhrajit Dutta	The study's objective is to reduce the energy use intensity (EUI) of an unconditioned residential building by optimizing its passive design through a metamodel-based design optimization approach.	Developing a parametric model with four passive design variables: orientation, window-to-wall ratio (WWR), shading depth, and shading angle. Using a metamodel based on the design of experiments (DoE) and statistical validation to approximate the relationship between design variables and energy consumption. Employing a genetic algorithm (GA) to perform the optimization and identify the optimal values for the design variables that minimize total energy consumption. Conducting a sensitivity analysis to determine the influence of each design variable on energy consumption.	The identified gap is the need for a scheme that specifically addresses how passive design optimization can reduce energy consumption in unconditioned residential buildings in a warm, humid climate.	Optimization Results: The optimization process, using the identified optimal design variables (0° orientation, 5% WWR, 0.749m shading depth, 41° shading angle), yielded a total energy consumption of 256.48 kWh. This represents a significant decrease of 31.77% compared to the existing design's 375.95 kWh. Energy Performance: The achieved annual EUI of the building was 2 kWh/m2, which is well below the passive house standard of 15 kWh/m2. Sensitivity Analysis: The sensitivity analysis revealed that WWR is the most influential design variable on total energy consumption, followed by shading angle.

9	**Urban Green Spaces and Collective Housing: Spatial Patterns and Ecosystem Services for Sustainable Residential Development**	Zuzana Vinczeová, Attila Tóth	The study's objective is to develop a theoretical framework for categorizing green open spaces in Slovakia's residential areas, based on their spatial characteristics, and to provide recommendations for their integration and management.	To review the literature on green space–housing estate relationships and analyze existing Slovak housing typologies. To identify dominant housing types in Slovakia and assess their spatial configuration and accessibility. To conduct field surveys in the Chrenová housing estate (Nitra) and selected residential areas in Šaľa. To develop a typology of six residential green space types and propose suitable design recommendations..	A key gap is the lack of a theoretical framework for categorizing green open spaces based on their spatial characteristics in the Slovak context, which is dominated by post-war housing estates.	The study developed a typology of six green residential space types and linked them to housing forms based on accessibility and density levels. Green space access varies by housing typology, with point buildings and open structures typically offering public access, while ridge developments and open courtyards provide semi-public access. Recommendations include using green roofs for point buildings and community gardens for courtyard types, with open courtyards identified as offering a strong balance between density and green space quality.
10	**A Whole-Life Carbon Assessment of a Single-Family House in North India Using BIM-LCA Integration**	Deepak Kumar, Kranti Kumar Maurya, Shailendra K. Mandal, Nandini Halder, Basit Afaq Mir, Anissa Nurdiawati, Sami G. Al-Ghamdi	To develop a BIM-LCA integrated cradle-to-grave methodology to quantify the environmental impacts of a typical single-family house in Northern India and provide recommendations for reducing its carbon footprint.	The total carbon footprint over a 60-year lifespan was approximately 5884 kg CO_2. Operational energy use was the biggest driver, accounting for 87% of emissions, while embodied carbon contributed about 11%. Cement-based components (mortar and concrete) and steel were the largest embodied carbon contributors. A sensitivity analysis showed that future grid decarbonization alone could lead to a >95% reduction in operational carbon emissions by 2050 under the Sustainable Development Scenario.	This gap is critical as India is experiencing rapid urbanization and needs a tailored approach to sustainable building practices.	The study used a BIM-based LCA framework applied to a 110 m2 single-family dwelling over a 60-year lifespan. Autodesk Revit was used for modeling, and One Click LCA was used for lifecycle inventory and impact assessment. The operational performance was simulated using cove.tool software with New Delhi climate data. A sensitivity analysis was conducted using three future electricity grid mix scenarios.
11	**Enhancing Energy Efficiency in Egyptian Middle-Income Housing: A Study of PV System Integration and Building Envelope Optimization in Sakan Masr**	Ehsan Raslan, Samah Elkhateeb, Ramy Ahmed	To evaluate the combined effect of passive envelope improvements and rooftop PV systems on a typical housing model from the Sakan Masr project in Egypt, and to provide evidence-based recommendations for improving energy performance.	Passive strategies such as improved glazing and shading enhanced thermal comfort by up to 10% and reduced cooling loads. East-west PV arrays outperformed south-facing ones by producing over 14% more electricity and achieving up to 50% in cost savings. The East-West PV systems for the entire Sakan Masr project avoided up to 168 tons of CO_2 emissions annually.	There is a critical gap in understanding the combined effect of passive strategies and PV systems on energy use, thermal comfort, and affordability specifically within the country's middle-income housing sector.	The study followed a four-phase methodology: 1) identifying dominant building orientations in Sakan Masr, 2) simulating electricity demand and thermal comfort using DesignBuilder, 3) optimizing the building envelope with passive measures, and 4) simulating PV system performance for south-facing and east-west configurations using PV-SOL.

12	**Evaluating the Effectiveness of Regulatory Frameworks for Transitioning to Net-Zero Energy Buildings in a Tropical Desert Climate**	Motaz Mestarehi and Osama Omar	To assess the impact of Bahrain's building regulations on energy consumption and to evaluate the potential for a typical residential unit to achieve net-zero energy status by following these regulations and using onsite power generation.	The study determined that domestic electricity consumption could be reduced by up to 52% by adhering to the updated building regulations and using efficient materials. This reduction, combined with onsite photovoltaic (PV) power generation of 12,500 kWh/year, can facilitate the Kingdom's attainment of net-zero energy status. The simulation results for Scenario III, using the highest-rated materials, resulted in an overflow of approximately 2000 kWh of solar-generated energy annually.	there is a significant gap in research that evaluates the effectiveness of specific government-mandated regulatory frameworks in a tropical desert climate like Bahrain. The study also notes a lack of a clear framework for how to achieve NZE status with commercially accessible materials and systems.	The study used DesignBuilder software with EnergyPlus 9.4 to model and simulate a typical housing unit (T8) in Bahrain. Three scenarios were created: a baseline model (pre-2012 regulations), a second scenario adhering to updated 2019 regulations, and a third using the most efficient materials available on the market. Simulation results were validated against real-world electricity consumption data and then compared with established rooftop PV power generation data for the same unit.
13	**Calibration of Building Performance Simulations for Zero Carbon Ready Homes: Two Open Access Case Studies Under Controlled Conditions**	Christopher Tsang, Richard Fitton, Xinyi Zhang, Grant Henshaw, Heidi Paola Díaz-Hernández, David Farmer, David Allinson, Anestis Sitmalidis, Mohamed Dgali, Ljubomir Jankovic, and William Swan	To develop and validate a standardized, evidence-based calibration workflow for Dynamic Thermal Simulation (DTS) models using high-quality measurements from two modern homes built in a climate-controlled chamber.	The calibrated Dynamic Thermal Simulation (DTS) models achieved very low performance gaps (0.5% for "The Future Home" and 0.6% for "eHome2"), significantly outperforming the SAP model, which had a discrepancy of 2.6% and 4.3%. The study found that incorporating as-built U-values and air permeability rates, along with detailed modeling of ground temperature and sub-floor voids, was crucial for achieving high accuracy.	This study identifies a gap in standardized guidance for calibrating DTS models, especially with detailed, open-access datasets.	The study used two zero-carbon-ready homes ("The Future Home" and "eHome2") constructed inside the University of Salford's Energy House 2.0. The whole-house heat transfer coefficient (HTC) was measured using a controlled aggregate heat loss test. The homes were modeled in DesignBuilder, and a series of evidence-based calibration steps were performed to align the simulated HTC with the measured values. The study specifically investigated the impact of as-built U-values, air permeability, roof ventilation, ground temperature, and sub-floor voids.
13	**Impact of Urban Expansion on the Formation of Urban Heat Islands in Isfahan, Iran: A Satellite Base Analysis (1990-2019)**	Zohreh Golestani, Reza Borna, Mohammad Ali Khaliji, Hosein Mohammadi, Kamran Jafarpour Ghalehteimouri, Farideh Asadian	To investigate the impact of urban expansion on the formation of the urban heat island in Isfahan, Iran, and to lay the basis for implementing strategies to mitigate its effects.	The study found a noticeable increase in the city's size at the expense of agricultural lands and pastures. This expansion led to a rise in UHI intensity from 2.8∘C in 1990 to 3.9∘C in 2019. Urban areas consistently exhibited higher temperatures and lower vegetation cover compared to other land use types. A strong negative correlation was found between the Normalized Difference Vegetation Index (NDVI) and Land Surface Temperature (LST), indicating that areas with more vegetation have lower temperatures.	studies have primarily focused on urbanization and urban development without fully integrating various human activities and historical satellite data, creating a gap that this research addresses by providing a comprehensive, localized analysis.	The research used a satellite-based analysis over a 30-year period (1990-2019). It collected Landsat ETM imagery and employed ENVI software to analyze land surface temperature (LST), normalized difference vegetation index (NDVI), and normalized difference built-up index (NDBI). The methodology also included a supervised classification to create land use maps and a statistical analysis to quantify the relationship between these environmental indicators.

14	**A Study on the Effect of Green Plot Ratio (GPR) on Urban Heat Island Intensity and Outdoor Thermal Comfort in Residential Areas**	Jian Zheng, Zilong Li, Bohong Zheng	To analyze the impact of GPR on urban heat island intensity and outdoor thermal comfort in residential areas.	Increasing the GPR was found to effectively reduce UHI intensity and improve thermal comfort, but with diminishing returns after GPR exceeded 2.5 during the day. A GPR of 3.5 was recommended as the ideal value for mitigating daytime UHI intensity. However, an increased GPR also exacerbated the nocturnal warming effect, as plants trap long-wave radiation. The cooling effect varied by space type, with the east-west street space showing the most significant improvement in thermal comfort.	However, it identifies a noticeable gap in research that analyzes the impact of greenery on the thermal environment from a three-dimensional perspective. A few design standards have begun to incorporate the Green Plot Ratio (GPR) as a metric, but there is a lack of research on how different GPR values actually affect the outdoor thermal environment and whether an optimal range exists.	The study selected a typical residential area in Changsha, China, as a case study. Six scenarios with varying GPR values (0, 0.5, 1.5, 2.5, 3.5, and 4.5) were established by adjusting the number of plants. The outdoor thermal environment was analyzed using the ENVI-MET simulation model, which was validated with on-site measurements. Data was extracted for air temperature and physiological equivalent temperature (PET) for four types of spaces (street, courtyard, and building overhead) to evaluate the impact of GPR during both daytime and nighttime.
15	**Assessing the Equity of Accessibility to Urban Green Space: A Study of 254 Cities in China**	Yingxue Rao, Yi Zhong, Qingsong He, Jingyi Dai	To evaluate the accessibility and equity of urban green space in 254 cities in China at a community scale, and to explore the relationship between housing prices and UGS accessibility equity.	The study found a large gap in UGS accessibility among Chinese cities. Inequities were most severe at walking/cycling distances (1 km and 2.5 km), with a Gini coefficient typically above 0.6 ("dangerous" level). As the search radius expanded to 10 km (driving), accessibility improved, but some cities still showed dangerous levels of inequality. The study found a significant relationship between high housing prices and UGS accessibility, indicating that higher-income areas are more likely to have greater access to green spaces.	For China, research has been limited to a few metropolitan areas (e.g., Beijing, Shanghai), which do not represent the full diversity of Chinese cities. This narrow focus fails to capture the heterogeneity of small- and medium-sized cities and makes it difficult to compare UGS accessibility and equity across different spatial scales. This research gap highlights the need for a comprehensive, national-scale study on this issue.	The study used the two-step floating catchment area (2SFCA) method, combined with the Gini coefficient, to build an evaluation system. Data on UGS locations and areas were collected, along with community data (households, housing prices) from a real estate network platform. The accessibility was measured at four search radii (1 km, 2.5 km, 5 km, and 10 km), representing different modes of transport.
16	**Analysis of urban residential greening in tropical climates using quantitative methods**	Udayasoorian Kaaviya Priya, Ramalingam Senthil	To quantitatively explore users' perceptions and preferences regarding residential greening in urban and suburban regions of Tamil Nadu, India, with a focus on Chennai.	About 90% of respondents were interested in having a garden. In urban Chennai, the most available space for greening was a balcony (45%), while in suburban areas, it was front and back gardens. The most preferred greenery types were potted plants (30%) and climbers (20%). The primary perceived challenges were installation and maintenance costs. The most influencing factors on preference were house typology, ownership, and site location.	A significant gap exists in understanding user preferences and perceptions of residential greenery at the individual building level, particularly in private green spaces like balconies and terraces. This research aims to fill this gap for a tropical urban context.	The study used a structured questionnaire survey of 578 respondents in Tamil Nadu, with nearly half from the city of Chennai. The survey collected data on respondents' demographics, residential characteristics, and preferences for different types of greenery and green wall systems. The data was analyzed using descriptive statistics, the chi-squared test, and crosstabulation analysis to identify significant relationships between variables.

17	**Towards net-zero futures: Modular Passivhaus design as a solution to meeting national carbon targets for new housing**	Raine Estales and David Coley	To develop and demonstrate a new time-series based whole-life carbon analysis methodology to inform sustainable design choices. The main hypothesis is that a mass rollout of modular Passivhaus construction can meet the UK's housing target while staying within the 2050 carbon budget.	A model for UK housing demand predicts that a modular Passivhaus approach can meet the national housing target of 300,000 homes per year while staying within 90% of the allocated carbon budget by 2050. The operational energy of the Passivhaus was a net negative value, and the whole-life embodied carbon was significantly lower than for traditional homes. However, the study found that the carbon budget would be exceeded by 2053 if the construction rate continued, suggesting that the rate of housing provision must also decrease in the long run to reach net-zero.	The paper notes a gap in methodologies that combine time-series analysis of both operational and embodied carbon, especially when considering the decarbonization of the electricity grid. It also identifies a lack of data on the comparative benefits of modular construction against traditional methods.	The study used a whole-life carbon analysis methodology for a 3-bedroom detached modular Passivhaus house in Bristol. It used ZEBRA software to model operational energy and IStructE's 'Structural Carbon Tool' for embodied carbon. The model was then scaled up to a UK-wide housing demand of 300,000 homes per year, and the cumulative emissions were projected until 2050. The results were compared against 'business-as-usual' and RIBA targets.
18	**Perceptions of volume home builders and the transition to net zero emissions housing in Australia**	Turlough F. Guerin	To understand the perceptions of the volume home builder sector to identify interventions, including from the government, that could help them deliver more sustainable homes and increase the proportion of NZE homes.	The interviews revealed that volume builders have a limited appetite for NZE homes due to low consumer demand, a risk-averse culture, and supply chain inertia. They prefer government incentives ("carrot") over regulations ("stick"). The study found that while the supply chain has some capability, there is a clear skills and knowledge deficit among designers, salespeople, and tradespeople. The participants supported the idea of a government-led buyers' group to increase demand and reduce costs.	frameworks like Strategic Niche Management (SNM) and the Multi-Level Perspective (MLP) provide theoretical insights, there are no specific published studies on the perceptions of Australia's volume home-building sector. This is a critical gap, as this sector shapes both supply and demand and acts as the bridge between research and application in the marketplace.	The study used a mixed-methods approach involving one-on-one interviews with 10 volume builders, 4 developers, and 4 industry experts. This was followed by a workshop with an expanded group of 30 stakeholders to validate the findings and develop targeted recommendations. The research used a human centered design approach and analyzed the findings through the lens of SNM, MLP, and coevolutionary frameworks.
19	**Reducing the Energy Use in Unconditioned Residential Buildings in a Warm Humid Climate: A Case Study in Guwahati, India**	Shrutismita Talukdar, Tomosree Deb, Subhrajit Dutta	To minimize the total energy consumption in an existing unconditioned multistoried residential building in Guwahati, India, by optimizing passive design variables.	The study used a metamodel-based design optimization approach with a workflow of five phases. A parametric model was created using four passive design variables: orientation, window-to-wall ratio (WWR), shading depth, and shading angle. Energy performance simulations were run in Grasshopper (a plugin for Rhinoceros) with weather data from ASHRAE. A genetic algorithm (GA) was then used to perform the optimization, and a sensitivity analysis was conducted to determine the influence of each variable.	The key research gap is the absence of a comprehensive scheme that specifically addresses how passive design optimization can reduce energy consumption in unconditioned residential buildings in a warm, humid climate like Guwahati.	The study successfully developed a parametric scheme that reduced the total energy consumption of the case study building by 31.77% compared to its original design. This resulted in an annual Energy Use Intensity (EUI) of 2 kWh/m2 , well below the passive house standard of 15 kWh/m2 . A sensitivity analysis revealed that the window-to-wall ratio (WWR) was the most influential design variable, followed by the shading angle.

2.1. Summary from Scopus Database

The data taken from Scopus for the thesis topic "Green passive design strategies for NetZero residential neighbourhood housing in hot climate cities" identifies a clear trend: this is a suddenly emergent field that is very timely. From 190 documents published between 2013 and 2025, a significant shift in scholarly attention can be found (figure 2).

From 2013 through 2022, the activity was modest and somewhat volatile, with only two papers in 2018, signalling an early tentative stage of exploration at this intersection. Then, starting in 2023, the publication counts really started to rise decisively, going from 21 papers to 30 in 2024.

Most striking is the projected leap for 2025-an expected 77 documents. That volume would be nearly 2.5 times the 2024 total and would account for more than 40% of the entire dataset. This sharp rise suggests that practical, scalable approaches which marry Net Zero objectives with passive design for hot-climate urban areas are becoming a priority in global research. The trend underlines the timeliness of the current study and frames its findings as a concrete contribution to a rapidly evolving and highly relevant scholarly and professional conversation (Lombardi et al., 2011).

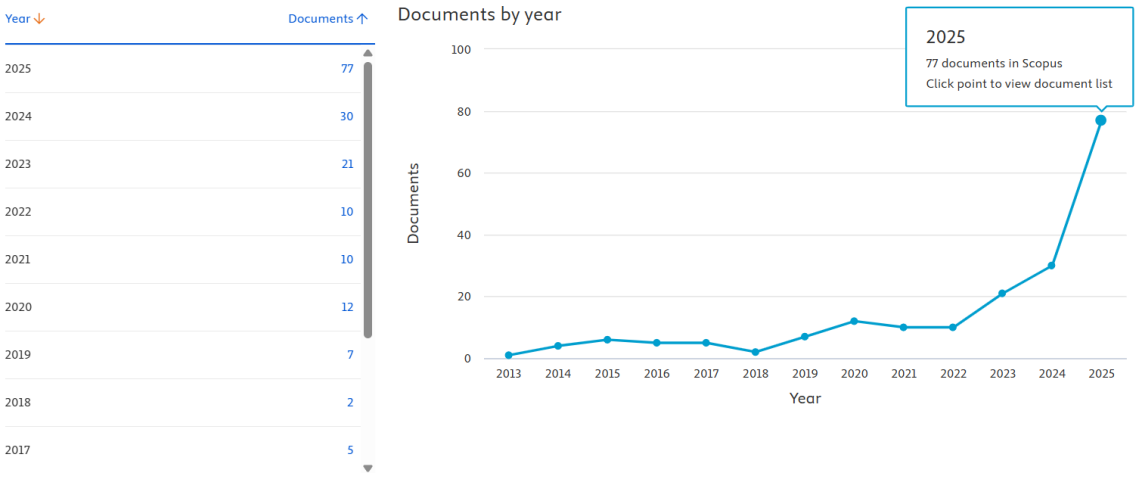

Figure 2: Documents by Year (Source: SCOPUS Database)

The data indicate that Sustainability Switzerland and Sustainable Cities and Society lead the pack, having each issued 16 documents. Remarkably, a chart would demonstrate a clear and steep rise of relevant publications in major journals starting from approximately 2021, with a peak in 2024-2025 (see figure 3). This trend illustrates the salience of NetZero urban design research nowadays. Steadily increasing output from specialized journals such as Urban Climate and Remote Sensing is an indicator of shifts toward more sophisticated methodologies climate modelling and geospatial analysis, respectively. Thus, the source base for the future literature review will be comprised of recent articles by high-output sources alone, which is within the last five years, in order to ground the synthesis in the most up-to-date knowledge.

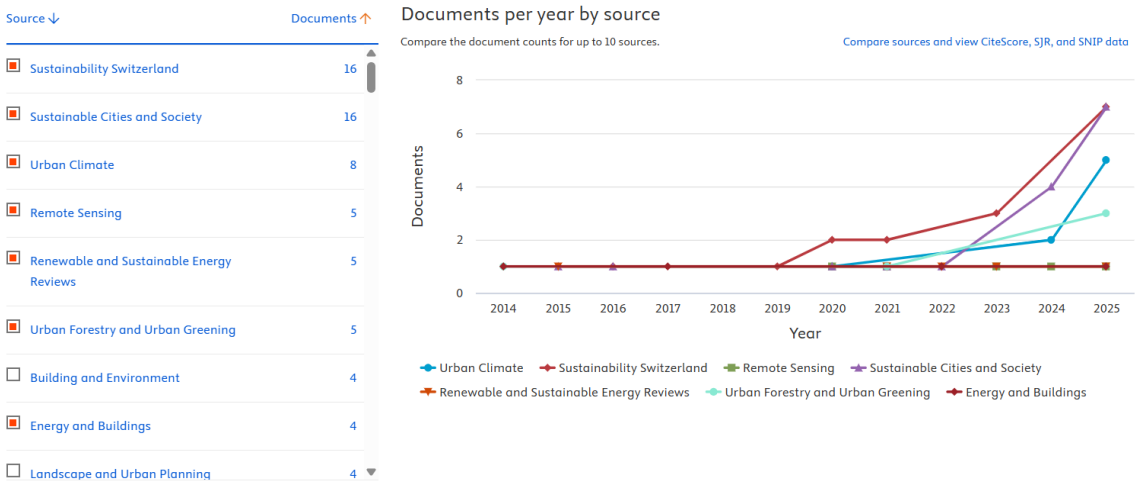

Figure 3: Documents per Year by Source (Source: SCOPUS Database)

Turning to geography, the analysis of the 190 documents is key in that it roots the study of housing in hot-climate cities within relevant climatic contexts. China leads with 22 documents and the United States with 19, illustrating their strong methodological and technological influence on NetZero building science. But the relevance of the topic is magnified by the notable output from the hot-climate regions: Australia (16), India (13), Spain (11), and Saudi Arabia (9). The research from these countries is bound to bring practical case studies and climate-specific passive strategies that are suited for hot-arid and

hot-humid climates. Thus, the literature review should integrate the broad volume of global research with the essential and climate-relevant findings from these countries in order to make sure that the proposed strategies are both cutting edge and regionally validated.

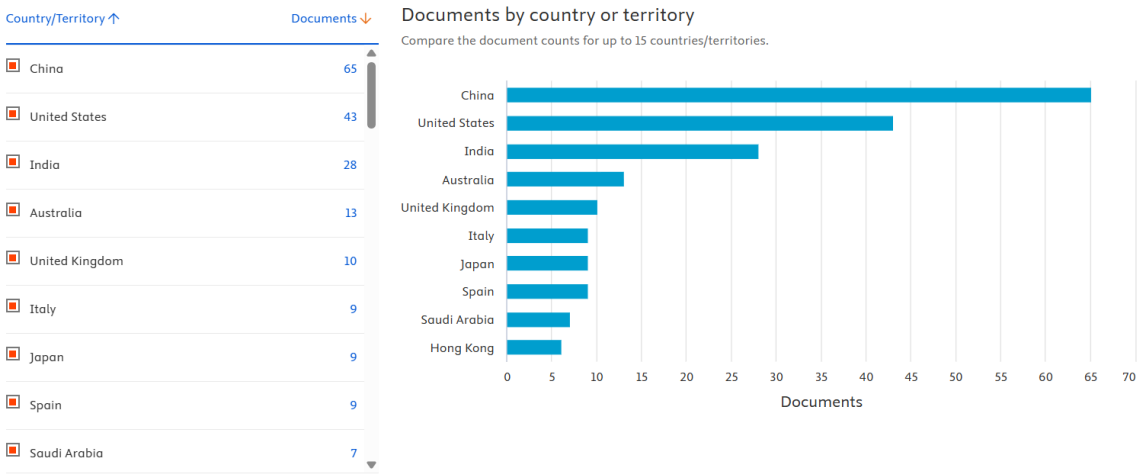

Figure 4: Document by country or territory (Source: SCOPUS Database)

This is further supported by the Scopus subject-area breakdown, which shows this field to be inherently interdisciplinary, cantered around three core domains. Engineering leads with 108 documents, Environmental Science next with 104, and Energy with 93. The actual overlap among these counts indicates that most papers merge technical solutions (Engineering), performance modelling (Energy), and sustainability goals (Environmental Science). Engineering's presence speaks to practical implementation and performance of built systems. Noticeably, Social Sciences are represented with 33, and Computer Science with 29, adding significant texture: Social Sciences cover policy, economic viability, and occupant behaviour; whereas Computer Science reflects the heavy use of advanced simulation and modelling for urban microclimate performance prediction (see figure 5). Together, this disciplinary mix calls for a holistic literature review that integrates findings across the technical and contextual fields.

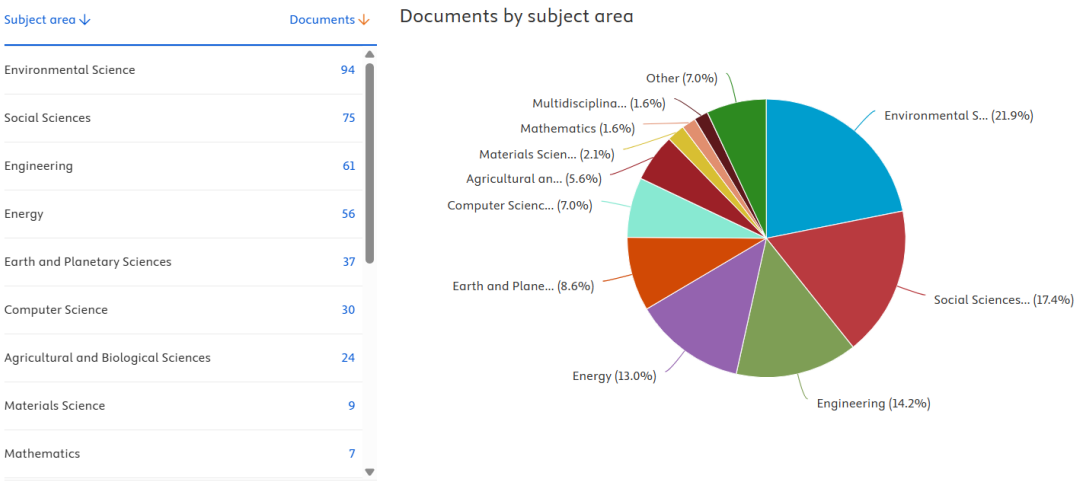

Figure 5: Document by subject area (Source: SCOPUS Database)

An analysis of the major funding sponsors puts into perspective how institutions and governments set priorities for research in this area. The data indicate intense support from government agencies and established universities. The NSFC-National Natural Science Foundation of China-leads with eight documents, closely followed by the European Commission with seven and the US Department of Energy with six. The dominance of these three funders indicates that the global drive toward NetZero is a top-down process, facilitated by significant amounts of public money in Asia, Europe, and North America. Furthermore, China's funding campaign is highlighted through the Fundamental Research Funds for the Central Universities with five documents and the National Key R&D Program of China with four documents, underlining a coordinated national effort to drive technological solutions for sustainable building, as illustrated in figure 6. Taken as a whole, this funding landscape suggests that the research published is based on thorough, large-scale, policy-informed agendas that aim at providing practical, scalable solutions for high-performance residential neighbourhoods.

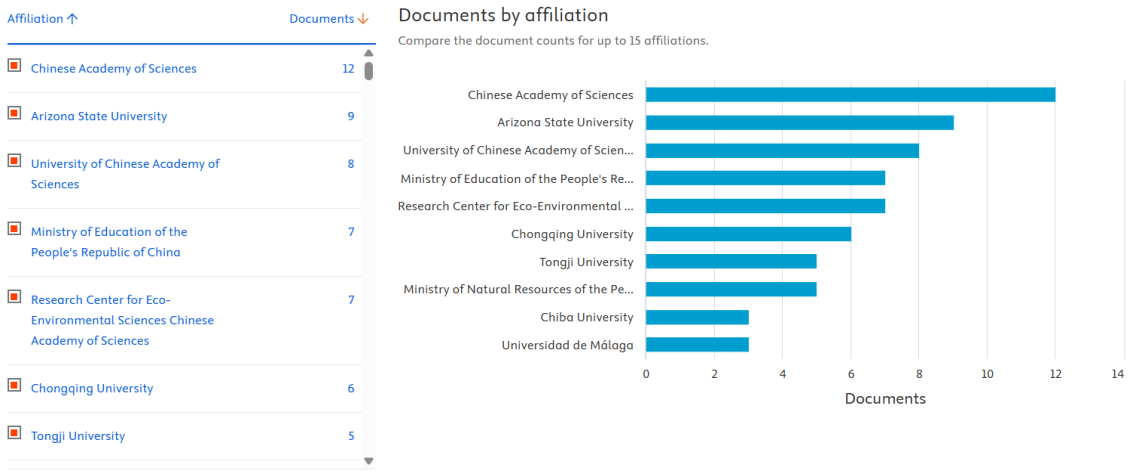

Figure 6: Document by affiliations (Source: SCOPUS Database)

2.2. Research Gap

The efforts towards integrating GI and passive design at the residential neighbourhood scale have gained wide acceptance across the globe in sustainable housing research. However, there are significant gaps that persist, especially for hot-climate cities and developing economies like India (Reiche, 2010).

First, much of the literature on urban greening for housing deals exclusively with developed nations such as Germany, the UK, and Japan, where high-tech, higher affordability, and strong regulation make green solutions more feasible to conduct (Francis & Jensen, 2017; Melo et al., 2020). In sharp comparison, developing countries have to struggle with cost barriers, scant technical knowledge, and weak policy support for the broad GI adoption in big housing projects (Zinia & McShane, 2018).

Research shows that GI can reduce urban heat island effects and improve thermal comfort, think green roofs, green walls, and balcony greening. However, most studies have focused on city or neighbourhood-scale interventions (Gunawardena et al., 2017; Jeganathan et al., 2016). For how to green individual buildings, within mass housing, only a few studies exist. This is a major knowledge gap for hot-climate cities characterized by vertical growth and dense living (Priya & Senthil, 2024).

This also brings out a noticeable chasm between the passive design practices and the GI method in research as well as practice. All too often, these strategies are assessed piecemeal, missing the potential gains from integrating them for cutting cooling loads and pushing toward Net Zero Energy or NZE (Susca et al., 2022).

In India, research is still limited regarding user perceptions and challenges to adoption. A study undertaken in Tamil Nadu revealed that almost 90% of residents favoured greener homes; however, stumbling blocks such as cost, lack of awareness, and issues of post-construction maintenance were significant. Community preferences are not yet being translated into design frameworks that aim at affordable housing (Reiche, 2010).

In India, the policy research gaps are evident. Programs like the Energy Conservation Building Code of India and National Mission on Sustainable Habitat encourage energy efficiency; however, it targets majorly individual buildings and gives less scope for neighbourhood-level GI and passive-design integration within the ambit of affordable housing initiatives like PMAY (Basu & Nagendra, 2021).

CHAPTER 3
RESEARCH DESIGN

3.1. Aim

A framework is being developed that merges green infrastructure with passive design tactics to reach Net Zero Energy in residential neighborhoods found in hot climates, focusing on how it can be utilized within India.

3.2. Research Questions

- How would green infrastructure enhance thermal comfort and reduce energy demands in hot-climate residential areas?
- Which passive design tactics prove most effective for net zero energy performance in hot-climate housing?
- What are the synergies between building-level design and neighbourhood-scale systems that can help increase overall energy efficiency?
- How can these approaches be adapted and mainstreamed in the affordable housing sector in India?

3.3. Objectives

Phase 1:

1. Review and analyse main concepts of Net Zero Energy Housing and neighbourhood-scale planning in hot climates.
2. Explore how green infrastructure can improve urban microclimates and reduce energy use.
3. Evaluate the effect of passive design strategies on enhancing thermal comfort and reducing cooling loads.
4. Examine the housing typologies and case studies of India to identify opportunities and challenges in integrating NZEH.

Phase 2:

1. Derive a framework/model which couples green infrastructure with passive design at the neighbourhood scale under the NZEH principle.

2. Evaluate the proposed planning framework by comparing GRIHA performance before and after the proposed interventions.

3. Suggest guidelines for design and planning of NZE neighbourhoods that are focused on affordability, scalability, and resilience.

4. Suggest policy and implementation strategies in line with national housing and energy missions.

3.4. Research Methodology

The study adopts a combined approach of literature review, analysis of case studies, and development of frameworks:

- Literature Review
    - Systematic survey of global and Indian scholarship on net zero energy housing, green infrastructure, and passive design.
    - Detail theoretical frameworks, sustainability indicators, and performance metrics pertaining to hot climates.
- Data Collection
    - Primary Data: climate-responsive design parameters such as temperature, humidity, solar radiation, and wind for the selected hot-climate contexts; stakeholder insights through expert consultations among urban planners, architects, and housing authorities.
    - Secondary Data: national policies on ECBC, NBC 2016, and Affordable Housing Mission; case studies of international experiences; performance benchmarks of NZEH.
- Case Studies & Comparative Analysis

    - Review selected national and international projects: BedZED, UK; Masdar City, UAE; Infosys Pune; IIT Ropar Net Zero Campus.
    - Compare based on energy balance, passive strategies, community integration, and affordability.
- Framework Development
    - Develop an integrated planning framework combining passive design principles, green infrastructure, renewable energy strategies, and sustainable neighbourhood planning.
    - Formulate planning interventions based on GRIHA assessment results and lessons from case studies.
    - Reassess the proposed neighbourhood using the same GRIHA criteria.
    - Compare existing and proposed GRIHA performance to demonstrate improvements in sustainability, energy efficiency, environmental quality, and resilience.
- Recommendations
    - Planning and design guidelines for application in Indian housing projects. - Policy-level recommendations to scale NZEH approaches.

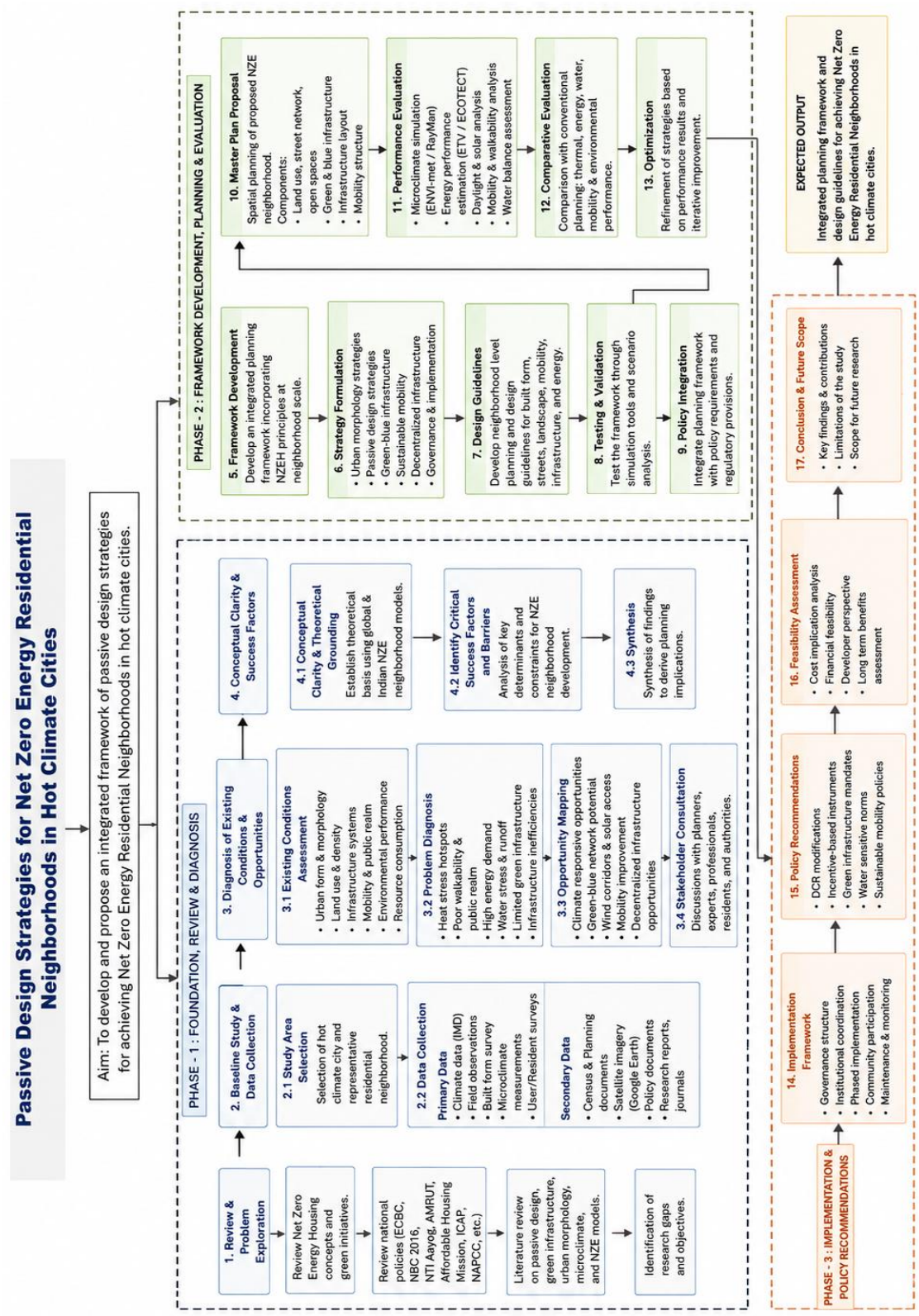

Figure 7: Methodology Flowchart (source by author)

3.5. Scope of the Study

i. Thematic, geographical, and methodological boundaries confine the scope of this research in order to provide focused and practical results.

ii. This research focuses on GI and Passive Design Strategies in the planning and development of NZE residential neighbourhoods. It highlights the interactions between ecological systems green roofs, green walls, urban vegetation, and rainwater harvesting landscapes with climate-responsive architectural techniques like shading devices, orientation, natural ventilation, and thermal mass. The active energy technologies are recognized, but the core focus is to be on nature-based solutions and passive design strategies that reduce energy demand prior to developing active systems (Jim, 2015; Safikhani et al., 2014; Priya & Senthil, 2024).

iii. The study is situated within the context of hot-climate Indian cities, representing some of the main challenges related to high levels of solar radiation, long summer seasons, urban heat islands, and water scarcity issues, among other concerns (Wardeh et al., 2022). Indore, Madhya Pradesh, will be the primary case context in view of the rapid growth of its urban area, increasing housing needs, and sensitivity to the extremes of climate. However, valuable lessons can also be learnt from other hot-climate cities like Ahmedabad and Chennai that provide relevant examples of energy-efficient housing and green infrastructure initiatives (Imam & Banerjee, 2016; Anand & Bhattacharya, 2024).

iv. The focus is precisely on residential neighbourhoods, with more emphasis on affordable mass housing, plotted developments, and group housing projects. High-rise commercial or mixed-use buildings are excluded, unless transferable insights could be gained on GI and passive design (Santamouris, 2015). This aligns with housing solutions for urban populations and government programs such as Pradhan Mantri Awas Yojana and the Smart Cities Mission (MoHUA, 2021).

v. A multi-scalar methodology guides the work by combining literature review, case study analysis, simulation-based energy modelling, and user perception surveys. Both neighbourhood-scale considerations (layout, open spaces, infrastructure) and

building-scale factors such as orientation, envelope design, and green integration are considered herein. The focus is maintained mainly upon the design and planning frameworks rather than on minute construction technologies or financial-investment modelling (Galagoda et al. 2018; Gupta & De, 2024).

vi. It addresses current and emerging housing challenges relevant in the next 10 to 20 years, in line with India's goals on climate action and international agreements such as the Paris Agreement and SDGs. UN DESA (2018)

vii. In short, this should yield a replicable, flexible framework for planning and design that enables the integration of green infrastructure and passive strategies in urban housing in hot climates while prioritizing sustainability, affordability, and resilience (Santamouris, 2015).

3.6. Limitations of the Study

i. The research confines to hot climate cities like Indore and Ahmedabad, results from which may not directly apply to composite or temperate climates without adjustments in context (Gupta & De, 2024).

ii. It deals with residential neighbourhoods (affordable housing, group housing, plotted developments); other urban forms such as commercial and mixed-use buildings are excluded, though they are a significant contributor in the energy use contribution – (UN DESA, 2018).

iii. Primary data from perception surveys may also be affected by respondents' limited knowledge of green infrastructure and passive design components. Previous studies show that user preference often focuses on aesthetics and cooling benefits, while there is less interest in maintenance and structural issues (Priya & Senthil, 2024).

iv. Cost benefit estimates depend partly on secondary sources - government housing reports and construction-cost indices - which makes affordability figures more indicative than precise (Imam & Banerjee, 2016).

v. While guidelines are laid down regarding design and planning, actual implementation is by housing boards, development authorities, and private developers, and institutional, regulatory, and political barriers are outside the core focus area of the

present research work. vii. Given the time constraints, long-term post-occupancy evaluation regarding energy performance cannot be done; hence, the study focuses on framework development rather than extended monitoring for extensive empirical validation (Basu & Nagendra, 2021).

3.7. Expected Outcomes

The research is expected to offer significant insights into sustainable housing design and policy within hot climate cities. The anticipated outcomes are detailed below:

3.7.1. Framework for Net Zero Energy Neighbourhoods

This work aims at developing a holistic framework that integrates green infrastructure with passive design strategies in order to reduce energy consumption both at building and neighbourhood levels (Santamouris, 2015). The framework will be used to direct urban planners and designers in site orientation, developing open areas, and implementing green initiatives in the form of green roofs, green walls, tree-shaded street canyons, and shared interior courts that contribute cumulatively to reduced energy demands and enhanced resilience. There is a growing need for such an approach in mass housing built using the affordable principle, where cost factors generally override environmental performance (Priya & Senthil, 2024).

3.7.2. Reduction in Energy Demand and Thermal Stress

It foresees high energy savings, primarily by reducing cooling loads through passive design and GI integration. Literature proves that green walls and roofs could reduce ambient temperatures by 1.6-8 °C and enhance indoor comfort even in tropical regions (Galagoda et al., 2018; Priya & Senthil, 2024). Other savings are from passive strategies: optimal orientation, shading, and natural ventilation steer us to achieve the goal of net zero energy.

3.7.3. Improved Microclimate and Environmental Quality

On a community level, GI is supposed to temper urban heat island effects, support biodiversity, and improve air quality. For example, in Taiwan, research showed that

balcony green curtains cut PM2.5 exposure and lowered indoor temperatures by 0.6 °C with air conditioning running (Chang et al., 2024). Vertical greening systems have also been shown to cut CO_2 by 5-50% while lowering annual building energy use by about 20% (Yungstein & Helman, 2023). These gains emphasize health and ecological benefits of GI at the micro scale.

3.7.4. User-Centric Adoption Insights

Additionally, the study will provide insights into residents' attitudes and preferences regarding the adoption of GI. Data from Tamil Nadu indicates that almost 90% of residents showed a preference for residential greenery, with balconies and potted plants as the most favoured options (Priya & Senthil, 2024). By identifying obstacles such as installation costs, maintenance issues, and gaps in awareness, the research will suggest strategies to increase community engagement and acceptance.

3.7.5. Policy Recommendations for Affordable Housing

Policy Guidance on Affordable Housing The policy implications will advocate for the integration of GI and passive design into government housing programs, including PMAY and the Smart Cities Mission. It will be recommended in line with the Energy Conservation Building Code and SDGs 11 and 13 to make housing developments climate-resilient, inclusive, and energy-efficient based (Ratti et al., 2005).

3.7.6. Scalable and Replicable Models

Scalable and Replicable Solutions These results will help in identifying cheap, modular approaches such as balcony greening, shared courtyards, traditional methods of shading, and rooftop gardens, which can be easily replicated in different types of housing. The aim would be to extend sustainable practices beyond premium projects to mass housing (Basu & Nagendra, 2021).

3.7.7. Academic and Professional Contribution

Academic and Professional Impact Ultimately, the research will integrate green infrastructure, passive design, and NZE into one coherent framework for hot-climate

cities. The insights will support architects, planners, and policymakers in the development of future housing models that balance affordability and energy efficiency with climate resilience.

3.8. Case Studies

The global push for net-zero energy neighbourhoods underlines how important passive design, green infrastructure, and renewable energy are becoming in urban housing. These approaches cut both operational energy use and boost thermal comfort and climate resilience. Next, we look at standout case studies-BedZED in London, the Vauban District in Freiburg, Masdar City in Abu Dhabi, Auroville in Tamil Nadu, and Infosys Net Zero Campus in Pune-that collectively show diverse paths to sustainable residential neighbourhoods. Each case reflects a unique climate, culture, and technology backdrop and offers critical lessons for the design of net-zero housing in hot-climate cities like those in India.

3.8.1. BedZED, London

Completed in 2002 by Bioregional and the Peabody Trust, the Beddington Zero Energy Development (BedZED) was the UK's first large-scale carbon-neutral housing project. The project takes an integrated approach to architecture, ecology, and community engagement to reduce energy use and minimize resource waste.

Completed in 2002 by Bioregional and the Peabody Trust, the Beddington Zero Energy Development (BedZED) was the UK's first large-scale carbon-neutral housing project (BioRegional & Peabody Trust, 2002; Lombardi et al., 2011). The project takes an integrated approach to architecture, ecology, and community engagement to reduce energy use and minimize resource waste (Lombardi et al., 2011). The buildings have a southern orientation to maximize winter sun, while triple glazing, thick insulation, and high-thermal-mass materials help maintain a consistent indoor temperature. The prominent wind cowls encourage natural ventilation and minimize mechanical systems. Together, these passive approaches achieved approximately an 88% reduction in space-heating energy compared with typical UK homes (BioRegional, 2009; Lombardi et al., 2011).

The project also encompasses green roofs, rainwater harvesting, and constructed wetlands to enhance biodiversity and manage stormwater sustainably (BioRegional, 2009). Just as important is the social sustainability emphasis in BedZED: active community involvement car-sharing, composting, and shared green spaces supports long-term environmental performance (Banister, 2011; BioRegional, 2009).

Situated in a temperate climate, BedZED nonetheless offers a replicable model of integrated design around passive strategies and community involvement and can be adapted to hot climates with proper shading and cooling modifications (Lombardi et al., 2011). Monitoring results indicate BedZED is providing significant energy savings: space heating demand is 88% lower compared to UK standards, hot water use is 57% lower compared to the average UK home, and electricity consumption is around 3 kWh per person per day, with approximately 11% generated on-site through photovoltaics (BioRegional, 2009).

Mains water consumption is 50% lower than average and 67% lower than for a household with a power shower (BioRegional, 2009). Travel-wise, residents' car mileage decreased by approximately 65% compared with regional averages. Electricity use also declined from about 130 kWh/week before BedZED to around 51 kWh/week per household during the monitored phase (BioRegional, 2009).

These findings demonstrate that combining passive design with sustainable lifestyles can significantly reduce operational energy, water consumption, and transport-related emissions. Similar strategies could be adapted for hot-climate urban developments by prioritizing passive cooling, water conservation, and energy-efficient design (Lombardi et al., 2011; Banister, 2011).

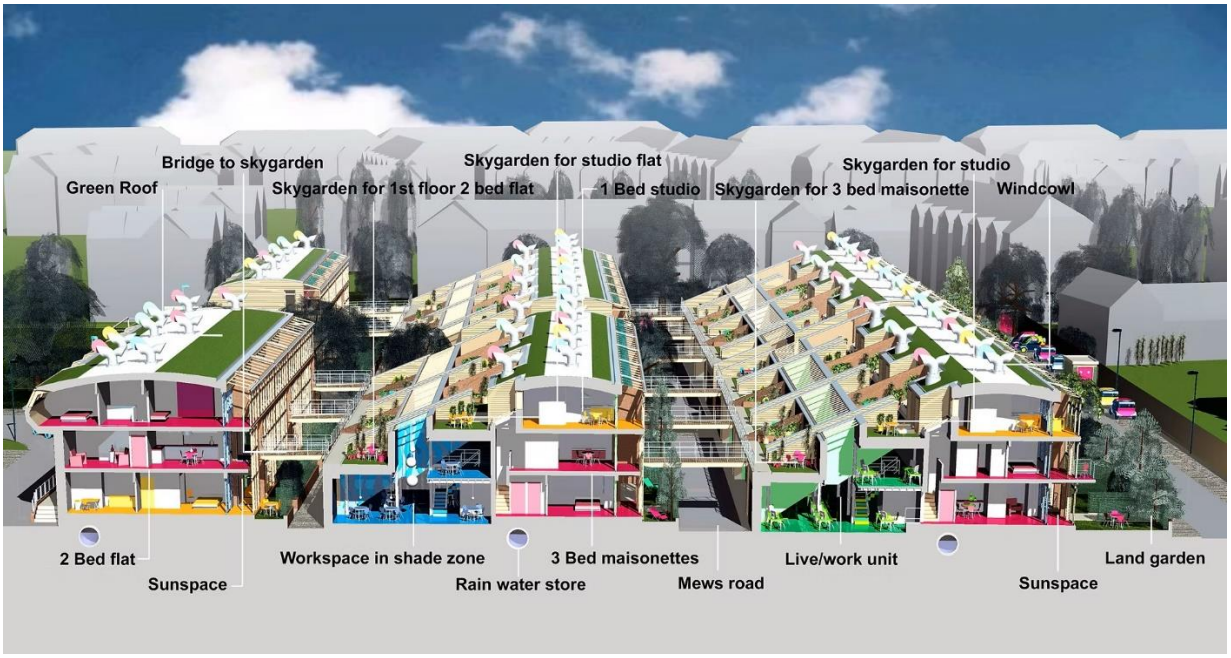

Figure 8: BedZED Sectional Perspective

Monitoring results indicate BedZED is providing significant energy savings: space heating demand is 88% lower compared to UK standards, hot water use is 57% lower compared to the average UK home, and electricity consumption is in the range of 3 kWh per person per day-some 25% below the UK average, with approximately 11% of that generated on-site through photovoltaics. Mains water consumption is 50% lower than average-and 67% lower than for a household with a power shower.

Travel-wise, the residents' car mileage within the development went down by 65% compared to the regional norms. A closer look at the use of electricity across three phases shows that in Phase 3, it had reached an average of 51 kWh/week/house, from 130 kWh/week pre-BedZED.

Together, these metrics indicate how passive design combined with behavioral controls can reduce operational energy not just for heating but also water and transportation. In hot-climate city settings, where heating is less of a driver, it is cooling and water conservation that take on more importance, suggesting the use of similar targets-such as cooling reduction percentages and water reuse goals-to guide design and behavior.

3.8.2. Vauban District, Freiburg

The Vauban district in Freiburg, Germany, is widely recognised as one of the world's leading examples of sustainable urban development. Developed between 1995 and 2006, the neighbourhood was designed to combine energy-efficient buildings, renewable energy systems, environmentally friendly transport, and active community participation. The urban layout follows an east-west orientation, allowing buildings to receive maximum southern sunlight during winter while improving natural daylight inside homes. High levels of insulation, shared building walls, and compact urban form reduce heat loss, while green corridors and open spaces encourage natural ventilation and improve the local microclimate (Scheurer & Newman, 2009; Coates, 2013).

Renewable energy plays a central role in Vauban's sustainability strategy. District heating supplied by a biomass combined heat and power (CHP) plant is supported by solar thermal collectors and rooftop photovoltaic systems. Several residential developments, including the well-known Solar Settlement, were designed to achieve very low or even passive-house energy standards (Scheurer & Newman, 2009).

Transport planning is another defining feature of the district. Private vehicle use is intentionally limited, while walking, cycling, and public transport are prioritised. This integrated approach reduces energy consumption and carbon emissions while creating a healthier urban environment. Community participation and cooperative housing initiatives have also strengthened residents' commitment to long-term environmental sustainability **(**Banister, 2011; Scheurer & Newman, 2009).

Performance data further demonstrate the success of Vauban's sustainable planning. Buildings were required to meet a maximum heating demand of 65 kWh/m²/year, with many achieving the Passive House standard of approximately 15 kWh/m²/year. The biomass CHP system supplies district heating and contributes around 73% of the area's renewable energy, while renewable sources account for more than 90% of the district's total energy supply. Green infrastructure, passive design measures, and renewable technologies collectively reduce carbon emissions by an estimated 40,000 tonnes annually. In addition, photovoltaic

systems generated approximately 1.235 million kWh of electricity in 2016 across 132 installations (Scheurer & Newman, 2009; Coates, 2013).

Although Vauban is located in a temperate climate, its integrated planning approach demonstrates how building efficiency, renewable energy generation, sustainable mobility, and community engagement can work together to create a low-carbon neighbourhood. These principles can be adapted to hot-climate cities by focusing on passive cooling, renewable energy, and reduced dependence on private vehicles (Scheurer & Newman, 2009; Coates, 2013).

Key points:

- Buildings had to achieve at least a low-energy standard of 65 kWh/m²/year for heating; many blocks did much better than this and some achieved the Passive House benchmark of about 15 kWh/m²/year.
- The wood-chip CHP plant provides all district heating and accounts for approximately 73% of total renewable energy.
- More than 90% of the district's energy comes from renewable sources.
- Greening and passive strategies cut Vauban's CO_2 emissions by an estimated 40,000 metric tonnes per year.

Solar PV produced approximately 1.235 million kWh in 2016 across 132 installations. Even in Freiburg's temperate climate, Vauban shows how neighbourhood-scale energy targets, on-site renewables, and reduced car usage can converge toward a net-zero vision. For hot-climate cities, the takeaway is clear: set ambitious energy envelopes, embrace on-site generation, and rethink transport in tandem with building design (Scheurer & Newman, 2009; Coates, 2013).

3.8.3. Masdar City, Abu Dhabi

Masdar City, located in Abu Dhabi, was launched in 2006 as one of the world's first urban developments designed to achieve net-zero sustainability in a hot desert climate. Developed by the Abu Dhabi Future Energy Company and master-planned by Foster + Partners, the project integrates climate-responsive architecture, renewable energy technologies, and

sustainable urban management to reduce environmental impacts (Reiche, 2010; Masdar, 2022).

The city's layout has been carefully planned to respond to the extreme climatic conditions of the region. Narrow streets, compact building arrangements, and deep façades reduce direct solar exposure throughout the day, while the orientation of the street network captures prevailing north-west winds to improve natural ventilation. These passive design measures help lower outdoor temperatures by approximately 5-10°C compared with the surrounding desert environment (Reiche, 2010; Masdar City, 2024).

To further improve energy performance, buildings incorporate high-performance glazing, external shading elements, and reflective materials that minimise heat absorption. Courtyards and shaded pedestrian pathways create comfortable outdoor spaces, while native vegetation, drought-resistant landscaping, and greywater recycling reduce water consumption and support evaporative cooling (Masdar, 2022).

Masdar City also combines passive strategies with advanced energy technologies. A district cooling network supported by solar photovoltaic systems supplies energy efficiently across the development, reducing dependence on conventional cooling methods. In addition, the city operates a digital Environmental, Social and Governance (ESG) monitoring system that continuously evaluates indicators such as energy consumption, water reuse, and overall environmental performance to support sustainable urban management (Masdar City, 2024).

Overall, Masdar City demonstrates how passive design, renewable energy integration, efficient water management, and smart monitoring technologies can work together to create a resilient and energy-efficient urban environment. The strategies adopted in the project provide valuable guidance for future net-zero residential developments in hot and arid regions.

Building exteriors utilize high-performance glazing, Rabiya shading, and high-albedo materials to reflect heat. Similarly, courtyards and shaded walkways are stitched together to enhance outdoor thermal comfort even more. Green infrastructure is within its DNA: native plants, low-water landscaping, and greywater reuse work in harmony to balance evaporative cooling with conservation needs. The city makes use of a district cooling system partly powered by solar PV, marrying passive and active strategies in a leap toward net-zero

operation. Masdar also runs a data-driven ESG monitoring system, keeping tabbed key metrics such as energy intensity and water reuse efficiency (figure 9).

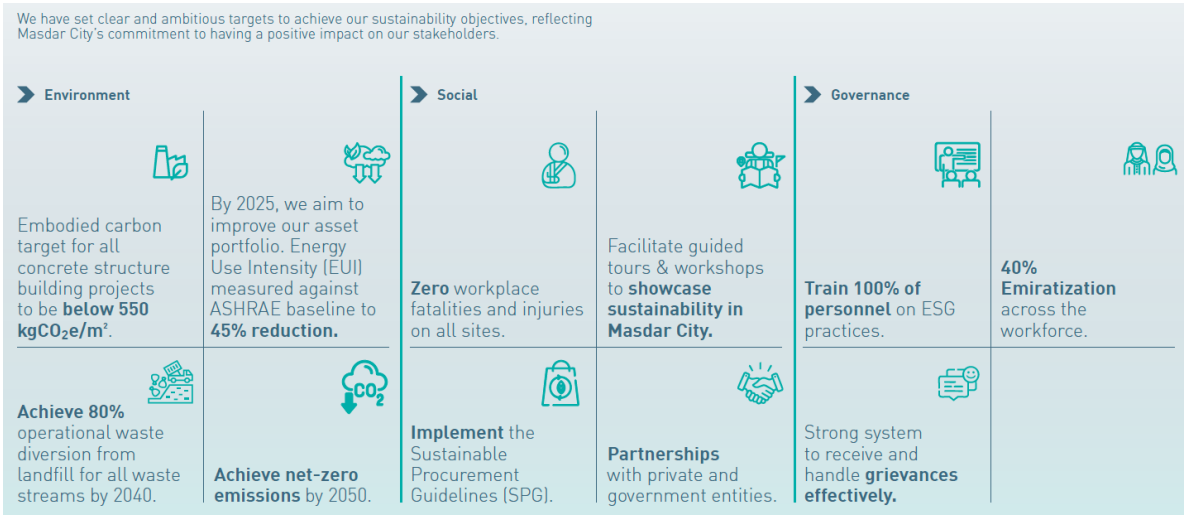

Figure 9: ESG Goals (source: Masdar City 2024 ESG Report)

A study related to Masdar's Eco Plaza considered the cooling effect of shading, green roofs, misting systems, and reflective paving. In some locations, these strategies reduced ambient temperatures by as much as 6°C. In a separate study, researchers found that green parks in Masdar can reduce the local ambient temperature by approximately 2.2°C. A micro-climate study for Abu Dhabi, with Masdar included, concluded that vegetated inner-city spaces reduced urban temperatures by 4-6°C compared to more no vegetated or urban ones. These ambient and micro-climate temperature reductions demonstrated that passive and green approaches will have significant impacts in hot, dry urban environments where cooling demands are relatively high. These approaches will decrease demands on mechanical cooling and, therefore, energy consumption. This can be used to establish targets for cooling-load reductions or microclimate enhancements (Reiche, 2010; Masdar City, 2024).

3.8.4. Auroville Township, Tamil Nadu

Located in Tamil Nadu, just outside Puducherry, Auroville Township represents one of the earliest models of sustainable community design and ecological living. Born in 1968 as an international township, Auroville embraces vernacular and passive architectural strategies attuned to India's hot, humid tropical climate. Many buildings in Auroville rely on earth-

based materials such as CSEB and lime plaster, providing strong thermal mass at low embodied energy. The layouts and forms are tuned for cross-ventilation, with overhangs, courtyards, and protected verandas that reduce solar heat gain (Auroville Earth Institute, 2018).

On a larger scale, this project integrates green corridors, rainwater harvesting, and planting of trees in order to enhance local microclimates and improve the level of groundwater recharge. Energy and water resources management within the community are also aligned with daily living and environmental objectives. Likewise, the Auroville Earth Institute trains and researches in sustainable building, paving ways for knowledge sharing and self-sufficiency. This model exemplifies how the integration of traditional passive techniques with ecological planning can yield energy-efficient, thermally comfortable houses without reliance on advanced technology-this is a model that would work very well in affordable housing within hot climates (Auroville Earth Institute, 2018).

Although exact energy metrics are not widely published within the reviewed sources, Auroville is well-documented in terms of its use of CSEB, vernacular passive design features (such as courtyards, verandas, cross-ventilation), and green corridors/afforestation. The key takeaway is that, in a hot-humid Indian environment, low-tech materials and passive design provide real thermal benefits, making these strategies highly relevant for affordable housing in warm climates. (Auroville Earth Institute, 2018).

3.8.5. Infosys Net Zero Campus, Pune

The Infosys Net Zero Campus in Pune represents a state-of-the-art Indian example of putting passive energy efficiency at the forefront in a large-scale mix of offices and housing. Conceived for a hot, mixed climate, the campus uses intelligent building orientation, exterior shading, and natural ventilation to cut cooling demands by about 30% versus typical commercial buildings. Exterior building envelopes feature high-performance glazing and insulated roofs, while internal courtyards and landscaped areas further contribute to a generally cooler microclimate (Infosys Limited, 2021).

Green features run deep: dense tree canopies, rainwater harvesting, and recycled-water irrigation all help curb the urban heat island effect. Rooftop solar panels, energy-efficient HVAC, and intelligent monitoring keep the campus operating at near-net-zero energy performance. This project shows that a mix of passive strategies with green technology can also work in advanced corporate settings and provides a replicable model for hot-climate urban housing when supported by solid governance and long-term upkeep (Infosys Limited, 2021).

Publicly available data is somewhat limited and largely derived from corporate reports, but the campus clearly demonstrates about a 30% reduction in cooling loads due to thoughtful orientation, shading, natural ventilation, and landscaping. It also has rooftop photovoltaics, water-harvesting systems, and a dense tree canopy to manage the microclimate and resources effectively (Infosys Limited, 2021).

3.8.6. Key Learnings

A detailed analysis of these five case studies indicates that effective net zero energy neighbourhoods possess three key characteristics: a focus on passive design, the integration of green infrastructure, and active governance or community involvement.

- BedZED and Vauban illustrate the connection between architectural design and social dynamics, emphasizing the importance of resident engagement in achieving lasting energy efficiency (BioRegional, 2009; Lombardi et al., 2011).
- Masdar City showcases how passive urban layout and flexible technologies can lead to significant cooling and energy savings, even in extremely hot conditions.
- In India, Auroville and the Infosys Pune Campus demonstrate how traditional knowledge and bioclimatic design can be adapted to modern contexts, confirming that passive strategies are still relevant in contemporary constructions (Auroville Earth Institute, 2018).
- Documented reductions include: 88% reduction in heating (BedZED), 90% renewable energy sourcing (Vauban), and an ambient temperature decrease of up to 6°C (Masdar). (BioRegional, 2009; Lombardi et al., 2011).
- The metrics span various domains, including heating/cooling, water management, mobility, CO_2 reductions, and microclimates.

- For hot climates and affordable housing scenarios, it may be beneficial to convert these metrics into targets for cooling-load reduction, tree shading and green canopy metrics, water collection and irrigation savings, and reduced community mobility (Auroville Earth Institute, 2018).

- Overall, these examples confirm that key passive strategies such as orientation, ventilation, shading, and vegetation can effectively mitigate cooling demands in hot climates. Additionally, the incorporation of renewable technologies, water-sensitive designs, and community governance encourages sustained performance and resilience. The lessons learned from these case studies provide a conceptual basis for establishing affordable net zero energy residential neighbourhoods in India's hot urban areas, where energy security and thermal comfort are increasingly critical (BioRegional, 2009; Lombardi et al., 2011).

3.9. Conclusions

Research has proved that combining GI with Passive Design Strategies is not only feasible but a necessary approach toward the development of NZE residential areas in hot-climate cities. A review of the existing literature, case studies, and climate factors reveals that GI practices like green roofs, green walls, and extensive urban greenery can significantly enhance microclimates, reduce urban heat island phenomena, and increase thermal comfort. If these measures are integrated with passive design principles like proper orientation, efficient shading, natural ventilation, and thermal mass, the outcome would be a significant reduction in cooling demand and, ultimately, energy consumption (Auroville Earth Institute, 2018; Masdar City, 2024).

Case studies like BedZED, Vauban, Masdar City, Auroville, and Infosys Pune show that neighbourhood-scale planning combined with active community participation and nature-based solutions can achieve significant reductions in temperature, energy use, and carbon emissions. These international and Indian examples strengthen the argument that a passive-first, integrative ecological approach is fundamental to sustainable neighbourhood design (Auroville Earth Institute, 2018; Masdar City, 2024)

Results in the Indian context show that existing housing initiatives, such as PMAY, and policy frameworks, like ECBC and Smart Cities Mission, focus on efficiency but mostly miss ecological integration opportunities at the neighbourhood level. There is a definite preference for green spaces among residents, while main barriers are cost, awareness gaps, and maintenance issues. What is required is an integrated approach that merges architectural design, policy, affordability, and community involvement for implementation to be feasible (Auroville Earth Institute, 2018; Masdar City, 2024).

Thus, the takeaways are clear: NZE neighbourhoods in hot-city contexts are attainable through a layered, holistic strategy that aligns ecological systems with passive design to boost energy efficiency, climate resilience, affordability, and long-term liability. This kind of integrated approach has great potential to guide future mass housing projects toward low-carbon, inclusive, and environmentally resilient urban growth.

3.10. Takeaways

3.10.1. Tool Study

- **ENVI-MET**

  Facilitated the assessment of outdoor microclimates, the impact of urban heat islands (UHI), surface temperatures, and the cooling potential of green infrastructure such as green roofs, walls, and vegetation corridors.
- **EnergyPlus / HAP**

  Permitted the simulation of energy loads at the building level, with a particular focus on reducing cooling demands through passive design techniques.
- **GIS + 3D Morphology Analysis**

  Aided in mapping vegetation, built density, shading, and neighbourhood geometry to comprehend spatial relationships that affect thermal comfort.
- **Scopus Database + VOSviewer**

  Contributed to bibliometric examination, revealing research trends, prominent authors, keywords, organizations, and global collaboration networks related to net zero energy (NZE) housing.

Tool-based assessments revealed that the combination of green infrastructure and passive design significantly impacts microclimate enhancement, energy savings, and thermal performance, thereby reinforcing the framework for developing NZE neighbourhoods.

3.10.2. Analysis Study

The analytical investigation established that effective net zero neighbourhoods depend on passive design strategies, renewable systems, and active community participation, as illustrated by worldwide examples such as BedZED, Vauban, and Masdar City. These case studies demonstrated quantifiable improvements in energy efficiency, thermal comfort, and microclimate conditions. Indian instances like Auroville and the Infosys Net Zero Campus highlighted the importance of traditional techniques, landscape buffers, and climate-responsive architectural characteristics that improve comfort while decreasing energy consumption. Literature findings indicated that elements of green infrastructure could lower ambient temperatures by 2-8°C, enhance air quality, promote biodiversity, and help mitigate urban heat island effects (Auroville Earth Institute, 2018; Masdar City, 2024).

Passive strategies consistently reduced cooling needs, underscoring the significance of orientation-based planning, shading, ventilation, and thermal mass in hot climate settings. Policy evaluations showed that despite Indian initiatives like PMAY and ECBC promoting energy efficiency, comprehensive ecological planning at the neighbourhood level remains limited. User perception studies also revealed that residents strongly favoured balcony greenery, potted plants, and vertical gardens, albeit with concerns regarding expenses, maintenance, and structural limitations. In summary, the analysis highlighted that integrating green features and passive strategies provides a promising route for diminishing energy consumption and enhancing liability in residential neighbourhoods' situated in hot climates (Lemoine-Rodríguez et al., 2022).

CHAPTER 4
PROPOSED PLANNING FRAMEWORK AND DESIGN STRATEGIES

The formulation of the proposed planning framework represents the core outcome of the research because it translates theoretical understanding, case study learnings, climatic analysis, and site assessment into a practical neighborhood-scale planning approach suitable for hot-climate cities (UN-Habitat, 2020; IPCC, 2023). The framework has been developed to address the limitations of conventional residential development patterns which are characterized by excessive heat gain, automobile dependency, fragmented public spaces, ecological degradation, and increasing operational energy demand (Gehl, 2010; UN-Habitat, 2020).

The proposed framework shifts the focus of sustainability from isolated building-scale interventions toward integrated neighborhood-scale systems involving climate-responsive urban morphology, ecological infrastructure networks, sustainable mobility systems, decentralized environmental infrastructure, and implementation-oriented planning mechanisms (Rogers & Gumuchdjian, 1997; Calthorpe, 1993). The framework therefore establishes how passive planning strategies can function simultaneously at urban, neighborhood, street, and public realm levels to reduce operational energy demand and improve environmental performance (Olgyay, 2015; Givoni, 1998).

The planning framework has been specifically developed for residential neighborhood planning within hot-climate Indian cities were increasing urbanization, rising temperatures, and infrastructure pressure require environmentally responsive planning systems (Government of India, 2015; IPCC, 2023). The framework also attempts to address practical implementation concerns raised within contemporary planning discourse, particularly regarding governance integration, planning regulations, developer participation, and economic feasibility (UN-Habitat, 2020; World Bank, 2021).

4.1. Planning Vision

The idea behind this plan is to create neighborhoods that're good for the climate and use very little energy. These neighborhoods should be comfortable for people to live in and help the environment. We want to make neighborhoods where people can live in a way that's good for the earth (UN-Habitat, 2020; IPCC, 2023).

The plan thinks of neighborhoods as systems that work with the environment. This includes how the neighborhood is laid out how people get around the parks and green spaces and how resources like energy and water are used. All these things should work together to help the environment and make sure the neighborhood can handle problems that may come up in the future (Rogers & Gumuchdjian, 1997; Calthorpe, 1993; Givoni, 1998).

The main goal of this plan is to make neighborhoods that're not just good for the environment but also nice places for people to live (Gehl, 2010; UN-Habitat, 2020). We do not just want to build neighborhoods that're energy efficient we want to build neighborhoods that are good for people and the environment (Olgyay, 2015; IPCC, 2023). These neighborhoods should be able to adapt to the climate and be responsive to the needs of the people living there (World Bank, 2021; UN-Habitat, 2020). The Net Zero neighborhoods should be a place to live and good for the earth, at the same time (IPCC, 2023; Government of India, 2015).

4.2. Planning objectives of the proposed framework

The new plan is based on these goals:

1. To reduce neighborhood-level operational energy consumption through climate-responsive urban planning, passive design principles, and context-sensitive spatial organization (Olgyay, 2015; Givoni, 1998).
2. To enhance outdoor thermal comfort and mitigate the Urban Heat Island (UHI) effect by integrating green infrastructure, shaded public spaces, and climate-responsive landscape strategies (UN-Habitat, 2020; IPCC, 2023).

3. To minimize transportation-related energy consumption and carbon emissions by promoting mixed land use, walkable neighbourhoods, compact urban form, and sustainable mobility systems (Calthorpe, 1993; Gehl, 2010).
4. To strengthen environmental resilience through integrated water resource management, renewable energy utilization, ecosystem conservation, and sustainable environmental infrastructure (World Bank, 2021; Government of India, 2015).
5. To establish an implementation-oriented planning framework supported by governance integration, planning regulations, stakeholder participation, and development incentives that facilitate the successful realization of climate-responsive neighbourhood planning (UN-Habitat, 2020; Rogers & Gumuchdjian, 1997).

4.3. Conceptual Planning framework

The plan for a city is based on five parts that work together:

• Designing cities that work well with the climate
• Systems that help the environment without using a lot of energy
• Systems that combine green spaces and water
• Planning for transportation that is good for the environment
• Systems for managing resources and making decisions that are spread out

These components function together to improve environmental performance and reduce neighborhood-scale energy consumption. The proposed framework recognizes that urban energy performance and environmental sustainability depend not only on building efficiency but also on urban form, transportation systems, public spaces, ecological networks, and governance mechanisms. Therefore, the framework adopts a holistic neighborhood-scale approach to sustainability rather than focusing solely on individual buildings (UN-Habitat, 2020; IPCC, 2023).

Research has demonstrated that urban morphology significantly influences energy consumption. According to Ratti, Baker, and Steemers (2005), factors such as urban density, building orientation, street configuration, and transportation patterns directly affect heating, cooling, and transportation energy demand (Ratti et al., 2005). Similarly, Beatley (2012)

emphasized that environmentally sustainable neighborhoods require integrated transportation systems, interconnected green infrastructure, compact urban development, and coordinated ecological planning (Beatley, 2012).

Accordingly, the proposed planning framework integrates climate-responsive urban form, sustainable transportation systems, high-quality public spaces, ecological infrastructure, and environmental service networks into a unified planning approach. These interrelated components collectively contribute to reducing energy demand, enhancing climate resilience, improving environmental quality, and supporting the development of sustainable net-zero neighborhoods **(**Rogers & Gumuchdjian, 1997; Calthorpe, 1993; Givoni, 1998).

4.4. Climate Responsive Urban Morphology

4.4.1 Compact Mixed- Use Development

The plan is to use mixed-use development to reduce the need for transportation, make better use of land, and make neighborhoods more walkable (Calthorpe, 1993; Gehl, 2010). This kind of development means that people do not have to travel far to get to where they need to go, and it also means that less infrastructure is required (UN-Habitat, 2020).

Mixed-use planning makes neighborhoods nicer to live in because people can do things like go to the store or to school without having to travel very far. The Institute for Transportation and Development Policy (2017) stated that neighborhoods with mixed-use development can use 20 to 40 percent less transportation energy than neighborhoods that are more spread out (Institute for Transportation and Development Policy [ITDP], 2017).

Accordingly, the proposed planning framework provides homes, community centers, stores, parks, and other essential facilities within walking distance of each other (Gehl, 2010). In cities where it is very hot, it is important not to make neighborhoods too dense because excessive density can increase heat accumulation and reduce natural airflow. If neighborhoods are too dense, heat can become trapped, making outdoor environments uncomfortable (Givoni, 1998; Olgyay, 2015).

Therefore, the framework proposes compact development without excessive density while incorporating parks and other green spaces that help keep neighborhoods cool and comfortable (Beatley, 2012; UN-Habitat, 2020). This approach improves neighborhood livability while reducing the need for transportation, thereby benefiting both the environment and residents (IPCC, 2023). Compact mixed-use development is an effective strategy for creating more walkable, climate-responsive, and comfortable neighborhoods, and it forms an integral component of the proposed planning framework (Calthorpe, 1993; Rogers & Gumuchdjian, 1997).

4.4.2 Orientation and Street Network Planning

Street orientation and urban layout play a role in how much sun buildings and streets get and how hot they get (Olgyay, 2015; Givoni, 1998). The proposed plan suggests that streets should run north-south to avoid too much sun from the east and west during the hottest part of the summer (Koenigsberger et al., 1974). Streets that run east-west get a lot of sunlight in the morning and afternoon, which makes the area heat up and makes it uncomfortable for people walking around (Olgyay, 2015).

This is a problem because it can make the streets feel hot. The proposed plan tries to avoid east-west streets that get too much sun and instead includes shaded areas for people to move around in public spaces (UN-Habitat, 2020). The plan for the streets also aims to help the wind move through the area and provide ventilation within residential neighborhoods. Open streets and connected public spaces help air move through the area and prevent it from getting stuck (Givoni, 1998; Koenigsberger et al., 1974). The plan also focuses on making streets more shaded and compact with plants and covered walkways to make it more comfortable outside and make public areas more usable. This includes adding vegetation systems and shaded pedestrian infrastructure to improve thermal comfort and public realm usability (Gehl, 2010; Beatley, 2012; IPCC, 2023).

4.4.3 Thermal Responsive Public Realm

The public realm in this plan is made to work like a system that helps the environment, not just as a way to get people around. This includes streets, plazas, community spaces, and walkways for people on foot. These are all connected with plants, shady paths, and permeable ground cover that lets water through to make people feel more comfortable when it is hot outside (Beatley, 2012; UN-Habitat, 2020).

The United States Environmental Protection Agency (2021) found that shaded areas within cities can be significantly cooler than areas exposed to direct sunlight, with surface temperatures reduced by approximately 11 to 25°C (U.S. Environmental Protection Agency [EPA], 2021). Therefore, this plan includes trees along pedestrian pathways and shaded areas where people can walk comfortably (Gehl, 2010).

People can easily walk to these spaces because they are located close together. These spaces provide opportunities for social interaction while also helping to keep the neighborhood cool and improving environmental quality (Gehl, 2010; Calthorpe, 1993).

This plan makes neighborhoods better places to live, helps reduce the risk of excessive heat exposure, and improves overall environmental performance. The public realm is an essential component of this planning framework because it creates neighborhoods that are more comfortable, climate-responsive, and environmentally sustainable (IPCC, 2023; UN-Habitat, 2020).

4.5 Green- Blue Infrastructure Systems

4.5.1 Urban Green Infrastructure

Green infrastructure is a part of the proposed planning framework because plants and trees help make cities more comfortable, support biodiversity, manage rainwater, and strengthen environmental resilience (Beatley, 2012; UN-Habitat, 2020). The main green infrastructure components included in the framework are:

- Green corridors
- Urban tree cover

- Neighborhood parks
- Community open spaces
- Green buffers
- Vegetated pedestrian pathways
- Green roofs

Plants help keep cities cool by providing shade and releasing water vapor into the air through evapotranspiration (Olgyay, 2015; Givoni, 1998). The U.S. Environmental Protection Agency states that increasing urban tree canopy coverage by approximately 10% can reduce local air temperatures by about 1°C to 2°C (U.S. Environmental Protection Agency [EPA], 2021).

The proposed framework includes green corridors along major roads to improve pedestrian comfort while strengthening ecological connectivity and supporting urban biodiversity (Beatley, 2012). Community parks and open spaces also improve neighborhood livability and provide opportunities for social interaction (Gehl, 2010; Calthorpe, 1993). The framework further incorporates green buffers around major roads and infrastructure corridors to reduce heat accumulation, improve air quality, and minimize environmental pollution (IPCC, 2023; UN-Habitat, 2020).

4.5.2 Water- Sensitive Urban Planning

Water-sensitive planning systems are incorporated to improve resource efficiency and support environmental sustainability (Fletcher et al., 2015; UN-Habitat, 2020). Conventional urban development relies heavily on centralized water infrastructure, which often leads to excessive surface runoff, groundwater depletion, and increased flood risks (World Bank, 2021).

The proposed planning framework includes the following components:

- Rainwater harvesting systems
- Bioswales

- Permeable paving
- Recharge landscapes
- Decentralized wastewater reuse systems
- Ecological drainage corridors

The use of permeable landscapes and bioswales helps reduce stormwater runoff while enhancing groundwater recharge (Fletcher et al., 2015). The U.S. Environmental Protection Agency (2021) reported that green stormwater infrastructure can reduce stormwater runoff by approximately 50–90%, depending on site conditions (U.S. Environmental Protection Agency [EPA], 2021).

Water-sensitive planning also contributes to mitigating urban heat because vegetated areas and permeable surfaces remain cooler than conventional impervious surfaces (Givoni, 1998; Olgyay, 2015). These planning systems improve environmental performance, strengthen resource efficiency, and enhance urban resilience. By integrating water-sensitive planning strategies, cities can become more sustainable, climate-responsive, and livable (IPCC, 2023; UN-Habitat, 2020).

4.6 Sustainable Mobility Framework

4.6.1 Walkability and Pedestrian Infrastructure

The new plan is to make neighborhoods that people can walk around in. This will help reduce the amount of energy we use for transportation and make our neighborhoods better places to live. When we have neighborhoods that're easy to walk around people do not need to use their cars as much. This also helps people meet each other and is better for the environment (ITDP, 2017).

The way we plan neighborhoods is to have paths with shade that connect where people live with schools, community centers, stores, parks and public transportation. We design these paths to be comfortable for people to walk on even when it is hot outside. We know that when

it is hot people do not like to walk much. So we use trees, shaded paths and plants to make walking more comfortable (EPA, 2021).

The ITDP said in 2017 that neighborhoods with a mix of homes, stores and other things that people can walk to really help reduce the need for cars and make people healthier (ITDP, 2017). Pedestrian-oriented planning is what we need to make our neighborhoods better. Pedestrian-oriented planning is the key, to reducing transportation energy demand and improving neighborhood livability.

4.6.2 Cycling Infrastructure

Cycling is a part of making our cities better for the environment. We need to have roads just for bikes and make sure they are all connected. This helps people get around without using a lot of energy. It is good for the earth. Cycling is also a way to get people to use public transportation and walk in nice areas with shade (ITDP, 2017).

We should have places to park our bikes and special areas in neighborhoods where people can easily get around without using cars. Cycling makes our cities better. Helps us get around in a way that is good, for the environment. The plan is to make cycling a part of how we get and to work with public transportation and nice walking areas. Cycling and walking are important. We should have good systems in place to support them (NACTO, 2014; ITDP, 2017).

4.6.3 Transit-Oriented Planning

Transit-oriented planning helps reduce our reliance on cars and makes it easier to get around. We plan areas near public transportation and mobility corridors so people can walk to buses and trains (Calthorpe, 1993; ITDP, 2017).

The plan suggests combining transit with mixed-use development to reduce the need, for long commutes. By reducing parking needs and improving transportation we can lower emissions and energy use related to transportation (Calthorpe, 1993; ITDP, 2017).

4.7 Decentralized Infrastructure Systems

4.7.1 Renewable Energy Integration

The proposed framework integrates renewable energy systems at neighborhood scale to reduce dependency on conventional energy sources. Rooftop solar photovoltaic systems are proposed across residential and institutional structures (MNRE, 2021).

According to the Ministry of New and Renewable Energy (2021), central Indian cities receive high solar radiation potential suitable for decentralized solar energy systems (MNRE, 2021).

Renewable energy integration is combined with passive planning strategies to reduce overall operational energy demand before introducing technological energy systems (UN-Habitat, 2020).

4.7.2 Decentralized Water and Waste Systems

Decentralized infrastructure systems are really good, for the environment. They help us use resources in a way and make our communities stronger when it comes to dealing with natural disasters. This is because we do not have to rely much on the big systems that are usually found in cities (UN-Habitat, 2020).

The new plan puts together a few things, including:

- Decentralized wastewater treatment systems
- Greywater reuse
- Organic waste composting
- Community-level waste segregation
- Localized stormwater management systems

These Decentralized infrastructure systems help us make the most of our resources and they also take some pressure off the big utility systems that serve entire cities. Decentralized infrastructure systems are a way to make our cities more sustainable (UNEP, 2019; UN-Habitat, 2020).

4.8 Governance and Implementation Framework

One big problem with planning neighborhoods is that there's no clear way to make it happen. So the plan we're suggesting includes working with different groups and making a plan thats focused on getting things done (UN-Habitat, 2020).

The plan suggests:

- Building rules that take climate into account
- Giving rewards for planning that works
- Allowing more building space for green projects
- Speeding up approvals for eco-friendly developments
- Requiring green spaces
- Teamwork, between public and private groups

The plan also stresses that different experts need to work together like city planners, environmental groups, infrastructure teams, housing people and local communities. Working together is key because you can't just design a neighborhood and expect it to happen (IPCC, 2022; UN-Habitat, 2020).

4.9 Proposed Planning Framework Matrix

The proposed framework establishes relationships between planning issues, environmental concerns, and planning interventions.

Table 2: Proposed Planning Framework

Planning Issue	Proposed Strategy	Expected Outcome
Excessive heat gain	Orientation optimization and vegetation systems	Improved thermal comfort
Automobile dependency	Walkable mixed-use planning	Reduced transportation energy demand

Surface runoff	Permeable landscapes and bioswales	Improved groundwater recharge
Poor public realm	Shaded pedestrian corridors and public spaces	Improved livability
High energy demand	Passive planning and renewable integration	Reduced operational energy consumption
Ecological degradation	Green-blue infrastructure systems	Improved environmental resilience

CHAPTER 5
MASTER PLAN PROPOSAL AND PLANNING STRATEGIES

The master plan proposal is a plan that shows how to use the planning framework in a situation. This framework was developed by looking at what other people have written, studying cases checking the climate and examining the site. The proposal takes the ideas about planning neighborhoods that work well with the climate. Turns them into a model for building homes in Indian cities where it is hot.

The proposal is a plan for a neighborhood that uses systems that do not need a lot of energy mixes homes and businesses combines natural systems with built ones creates ways for people to get around without cars and manages resources in a way that does not rely on one central point. This is different from the way of planning homes, which mostly focuses on dividing up land and building roads. The master plan proposal prioritizes how well the environment works how comfortable people are when it is hot how easy it is to walk and how well the city will work in the long term.

The proposal also thinks about how to make these plans happen including working with the government using resources efficiently making sure it is possible to develop the area and following planning rules. The strategies for planning were created to be practical and to guide how homes will be built in cities in the future not just as ideas about being sustainable. The master plan proposal is a plan for the Climate-Responsive Neighborhood Planning, which's the main goal of this proposal and it is, about the master plan proposal itself which is the main topic here.

5.1 Planning concept

The master plan is based on an idea: making neighborhoods that work well with the climate. This means thinking of the neighborhood as a system that keeps people comfortable and does not hurt the environment. The neighborhood is designed so that the way it is laid out the parks

and green spaces the roads and walkways and the basic services like water and energy all work to use less energy and make the air and water cleaner.
The plan is built on some ideas:

- Making neighborhoods that fit the climate
- Building homes and shops close together
- Designing neighborhoods that are easy to walk around
- Adding spaces and water features to cool the neighborhood
- Creating spaces that are comfortable in hot or cold weather
- Providing services like water and energy in a way that does not rely on big central systems
- Reducing the need for cars and trucks
- Using energy from sources like sun and wind

The proposal understands that making a neighborhood sustainable is not just about using new technology but also, about planning the neighborhood in a way that works with the climate the natural environment and the people who live there. Climate-Responsive Integrated Neighborhood Planning is what this is called. It is the foundation of the master plan.

5.2 Land Use Planning Strategy

5.2.1 Mixed-Use Neighborhood structure

The proposed master plan uses a mix of homes, shops and community spaces to reduce the need for transportation and make it easier to get to activities. Residential areas are combined with shops, community centers, schools, parks and recreation areas that are close by and easy to walk to.

This mix of uses helps reduce the need for commutes and makes it easier for people to connect with their neighbors. A report by the Institute for Transportation and Development Policy in 2017 found that neighborhoods with a mix of uses and compact design use energy for

transportation and are more walkable. The proposed plan organizes homes around community hubs that are connected by paths and public spaces.

Shops and businesses are located along paths and near public transportation to reduce the need for cars within the neighborhood. Community facilities, like schools, healthcare services, social spaces and recreation areas are spread out evenly across the neighborhood to make it easier for people to access them and feel included.

5.2.2 Residential Cluster Planning

The homes in this project are designed with the weather in mind. They are built in groups around shady yards and public spaces that are not too open. This helps people stay cool get to know their neighbors and have air.

The way these groups of homes are laid out reduces the amount of surfaces like concrete that are directly in the sun. This creates areas within the neighborhood. The buildings are also arranged to get the amount of sunlight and to let the breeze blow through.

The homes are built together but not too close. This way we can fit a lot of homes in an area without hurting the environment. When homes are built close together without thinking about the weather it can get very hot and the air does not move well. So this project uses a number of homes per area and includes open spaces that let the air move and plants that help keep the air clean.

This way of building homes in groups also helps people get to know each other and makes the neighborhood a nicer place to live. Development and residential zones and housing clusters and cluster planning all work together to make this happen. Residential development is very important, in this project.

5.3 Urban Morphology and Climatic Response

5.3.1 Orientation Strategy

The homes in this project are designed with the weather in mind. They are built in groups around shady yards and public spaces that are not too open. This helps people stay cool get to know their neighbors and have air.

The way these groups of homes are laid out reduces the amount of surfaces like concrete that are directly in the sun. This creates areas within the neighborhood. The buildings are also arranged to get the amount of sunlight and to let the breeze blow through.

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This way of building homes in groups also helps people get to know each other and makes the neighborhood a nicer place to live. Development and residential zones and housing clusters and cluster planning all work together to make this happen. Residential development is very important, in this project.

5.3.2 Ventilation Corridors

Ventilation corridors are part of the master plan to make the air move better and reduce the heat that gets stuck. We have green corridors and public spaces that are connected to each other and this helps the wind move around the places where people live.

The way cities are built has an effect on how well the air moves. When buildings are close together and there are no gaps it stops the airflow and makes the heat worse as seen in the work of (Oke, 1987). So the plan we have includes buildings that're not too tall open spaces that are connected and ecological corridors to make the air better in the neighborhoods.

The ventilation corridors do two things at the time. They help the environment and they are also public spaces where people can go. This makes the whole area better for the environment and, for the people who live there.

5.3.3 Street Section design

Street sections were designed with the weather and peoples comfort in mind, not cars.
The proposed street sections include:

- Walkways with shade
- Streets lined with trees
- Bike tracks
- Roads made with permeable material
- Special grassy areas called bioswales
- Narrower roads

Trees along the street provide a lot of shade which helps to keep the area cooler and makes it more comfortable to be outside. The Environmental Protection Agency says that shaded areas can be 11°C to 25°C cooler than areas without shade. These streets are not just, for moving people they also help the environment. They act like corridors. The proposed streets help to make the area a nicer place to be.

5.4 Green- Blue Infrastructure Proposal

5.4.1 Green Network Planning

The new plan for the area includes a network of green spaces that connect all the parks, special areas that help the environment, public spaces, community areas with grass and walking paths with shade. The green system does a lot of things to help the environment, including:

- Reducing heat
- Managing storm water

- Helping plants and animals
- Making the air cleaner
- Making people feel comfortable
- Making public spaces more fun

The plants and trees help keep the air cooler by releasing water into the air and giving shade. Some people, like Bowler and others found out in 2010 that having plants in cities can make a difference in how hot it feels outside and make it more comfortable for people.

The parks and green areas are placed in a way that makes sure everyone has a chance to enjoy them no matter where they live. There are also green areas along the roads to reduce the heat and pollution from cars. The green spaces are really important for the environment and, for people. The green system and the green spaces all work together to make the area a nicer place to live.

5.4.2 Water- Sensitive Infrastructure

The proposal is about making cities better with water- urban planning. This means we want to use water in a way and help the environment at the same time. When we build cities the way it can cause problems like too much water running off into the streets and not enough water in the ground. This happens because we cover much of the land with hard surfaces like pavement and we do not have good systems to handle the water.

The new plan includes some things like:

- Rainwater harvesting systems
- Recharge landscapes
- Bioswales
- Retention ponds
- Permeable surfaces
- Decentralized greywater reuse systems

Bioswales and permeable landscapes are good because they slow down the water that runs off and help put more water back into the ground. The Environmental Protection Agency said in 2021 that using landscapes can really cut down on water running off into the streets and make stormwater management work better.

Water-sensitive systems are also good for the air around us because they reduce the heat that gets trapped when the sun hits surfaces. This makes the city a comfortable place to be. Water-sensitive urban planning systems, like these can make a difference. Water-sensitive systems are a part of this proposal.

5.5 Sustainable Mobility Proposal

5.5.1 Walkable Neighborhood structure

The neighborhood plan we have in mind focuses on making it easy for people to walk around. This way we can reduce the need for cars. Lower the energy used for transportation. We are grouping homes together. Linking them with shaded walkways that have green spaces and areas where people can gather.

- Schools, parks, shops and community centers are all close by so people do not have to drive too much.
- We want to make sure people can walk to the places they use every day without having to travel
- When designing walkways, we think about how to keep people comfortable in the heat.
- In cities that get very hot people do not like to walk if it's too hot.
- So, we add trees, shaded paths and places to sit and rest.

A researcher named Gehl said that when public spaces are good for walking people interact more with each other the environment is better and cities are more pleasant to live in. Gehls work in 2010 showed that walkable public environments really help. Walkable neighborhoods make a difference, in how people live and interact. They help create an urban environment.

5.5.2 Cycling Infrastructure

The neighborhood has roads just for cycling. These roads are connected to the sidewalks, parks and bus stops. This makes it easy for people to get around without a car.

The cycling roads help people not use their cars much. This makes it easier for people to get where they need to go. It is better for the environment. There will be places to park bicycles, near shops and bus stops. This will make people want to ride their bicycles. The neighborhood wants to make cycling a popular way to get around.

5.5.3 Transit Integration

Transit-oriented planning is used to make it easier to get around and reduce the use of vehicles. Transit hubs are placed along roads and residential areas are kept close to public transportation. Parking spaces are limited in areas to encourage people to use other modes of transport. Parking facilities are built on the outskirts and shared transportation systems are proposed to make use of land and improve the environment. By combining transit-oriented planning and mixed-use development people have to commute and neighborhoods become more accessible.This approach helps to reduce the need, for vehicles and promotes a more sustainable way of living. The goal is to create neighborhoods where people can easily walk, bike or use transportation.

5.6 Decentralized Infrastructure Systems

5.6.1 Renewable Energy Systems

The neighborhood plan includes panels on rooftops and solar-powered public services. Bhopal gets a lot of sunlight with radiation ranging from 5 to 5.5 kWh/m²/day which makes using solar power very possible in new residential areas. The plan is to reduce the energy needed to run buildings by designing them to use less energy.

This approach believes that making buildings use energy and planning for a comfortable environment should come before adding technology to generate energy. The neighborhood will also have solar-powered street lights, community buildings and public services. The use

of power and energy-efficient design are key to the neighbourhood plan. The neighbourhood aims to use power and other renewable energy sources to meet its energy needs. Bhopal high solar radiation makes it an ideal place to use power. Reducing energy demand through design is a priority. The plan includes solar-powered street lighting and community infrastructure. The goal is to create a neighborhood that uses energy and has a low impact, on the environment.

5.6.2 Decentralized Waste and Water Systems

The proposed neighborhood uses power and other renewable energy sources through rooftop solar panels and solar-powered public utilities. Bhopal gets a lot of sunlight with 5 to 5.5 kWh/m²/day of radiation making it easy to use solar power in homes (MNRE, 2021).

To make the most of energy we first reduce the energy needed by planning the neighborhood carefully. This means using design strategies that don't need a lot of energy to keep the neighborhood running. We think that making the neighborhood energy-efficient and environmentally friendly should come before adding technology to generate energy. The neighborhood also uses power for street lights, community buildings and public utilities. The proposal includes systems that are not connected to a central network, such as:

- Reusing greywater
- Composting organic waste
- Treating wastewater
- Segregating waste in the community
- Recharging stormwater

These systems help recover resources and reduce the load on the citys infrastructure. By managing waste people, in the neighborhood become more aware of the environment and participate more in sustainability practices.

5.7 Governance and Implementation Strategies

One of the goals of the research was to solve real problems with building sustainable neighborhoods. So the proposed master plan includes planning tools that help with governance. The proposal suggests:

- Building rules that consider the climate
- Giving benefits for planning approvals that work
- Extra floor space for buildings that include green spaces
- Special walkways for pedestrians that are shaded
- Rules for green spaces
- Mandatory use of renewable energy
- Working together with private companies

The proposal also suggests that different groups work together during the project. These groups include planning authorities, environmental agencies, infrastructure departments, housing boards and developers. Making sustainability a part of planning rules makes it more likely that the project will work, than just adding it on as an extra environmental measure.

The sustainable neighborhood development and planning regulations are key to making the project successful. The research on neighborhood development helps to support the proposal. The proposal, for neighborhood development includes many important aspects.

5.8 Environmental and Planning Outcomes

One of the goals of the research was to solve real problems with building sustainable neighborhoods. So the proposed master plan includes planning tools that help with governance. The proposal suggests:

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- Giving benefits for planning approvals that work
- Extra floor space for buildings that include green spaces
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The sustainable neighborhood development and planning regulations are key to making the project successful. The research on neighborhood development helps to support the proposal. The proposal, for neighborhood development includes many important aspects.

CHAPTER 6
IMPLEMENTATION FRAMEWORK, POLICY RECOMMENDATIONS

The successful implementation of climate-responsive Net Zero residential neighborhoods depends not only on physical planning interventions but also on governance systems, institutional coordination, regulatory mechanisms, financial feasibility, and policy integration. One of the major criticisms associated with sustainable neighborhood development is that many proposals remain theoretical because of inadequate implementation frameworks and lack of integration with existing urban development systems.

The present chapter therefore focuses on translating the proposed planning framework into implementable planning mechanisms applicable within the context of Indian cities. The chapter addresses issues related to development regulations, institutional coordination, economic feasibility, developer participation, policy integration, and implementation strategies. The chapter further establishes how climate-responsive neighborhood planning can be integrated within existing urban planning and housing development processes. The final section summarizes the overall research findings and conclusions derived from the study.

6.1 Need for Implementation-Oriented Planning

When we think about making residential areas more sustainable, we usually just focus on the buildings themselves. Do not think about the bigger picture. This means we do not consider things like how people move the natural environment the shape of the city and how the government works together with other groups. Because of this many sustainable developments do not work well together. Do not help the environment in the long run.

Indian cities are growing quickly which is making environmental problems worse. This includes things like cities getting too hot people using energy to cool their homes traffic jams, the natural environment being damaged water underground being used up and public spaces

not being nice anymore. The Ministry of Housing and Urban Affairs said this in 2021. Now the people who plan cities often prioritize making money from land and building more infrastructure but they do not think enough about how to respond to the climate and help the environment.

So, it is very important that we have a plan in place to make sure that we are using strategies that help the environment and creating neighborhoods in a systematic way when we build new residential areas.

The proposed plan is trying to connect the ideas of sustainability with the process of developing cities by bringing together rules, incentives, coordination, between institutions and a system to implement things in phases. This way we can make sure that residential development and sustainability go hand in hand.

6.2 Institutional Framework for Implementation

6.2.1 Role of Planning Authorities

People who plan cities have a job to do when it comes to making sure that homes and neighborhoods are safe from really bad weather. The city planning people and the government agencies are in charge of making plans, for how neighborhoods should be built. They decide what the streets and houses will look like they make sure the water and electricity systems work. They enforce the rules so that everything gets built correctly. Urban planning authorities do this by making sure that urban planning is done in a way that considers the climate and what Urban planning authorities can do to help.

The proposed framework recommends that planning authorities incorporate climate-responsive neighborhood planning principles within statutory planning documents including:

- Development Plans
- Local Area Plans
- Town Planning Schemes
- Development Control Regulations

- Transit-Oriented Development Policies

The integration of environmental planning parameters within statutory planning systems ensures long-term implementation continuity and regulatory enforcement. Planning authorities should also establish climate-responsive planning guidelines focusing on:

- Orientation regulations
- Mandatory green infrastructure provisions
- Shaded pedestrian infrastructure
- Permeable surface requirements
- Water-sensitive planning systems
- Renewable energy integration
- Mixed-use neighborhood planning

According to (UN-Habitat, 2020), institutional integration and planning governance are essential for implementing sustainable urban development strategies effectively.

6.2.2 interdisciplinary Coordination

Climate-responsive neighborhood planning requires coordination between multiple institutions including:

- Urban planning departments
- Environmental agencies
- Housing authorities
- Transportation departments
- Water supply agencies
- Energy departments
- Municipal corporations
- Private developers

Fragmented governance structures often lead to planning of infrastructure and environmental issues. This results in inefficiency. The proposed framework focuses on coordinating planning across areas. It aims to combine mobility systems, ecological infrastructure, renewable energy systems and public space planning into one development approach. When planning is coordinated in a way it works better and reduces conflicts. This is because it brings together infrastructure systems and environmental goals. It helps to implement plans efficiently. Coordination makes sure that infrastructure and environmental objectives work together.

6.3 Development Regulations and Planning Controls

6.3.1 Climate- Responsive Development control Regulations

One of the suggestions from the research is to include climate-friendly features in Development Control Regulations (DCRs). Many Indian cities have rules that mainly focus on things like building setbacks, how much floor area can be used (FAR) and road sizes. These rules do not do enough to ensure buildings are comfortable in terms of temperature perform environmentally or work well with nature. The research again highlights that incorporating climate- parameters within Development Control Regulations (DCRs) is crucial.

In Indian cities existing regulations focus on setbacks, FAR distribution and road widths. However, they often overlook aspects such as thermal comfort, environmental performance and ecological integration. The incorporation of climate- parameters, within DCRs can help address these issues.The proposed framework recommends the inclusion of:

- Orientation-based planning controls
- Mandatory tree plantation ratios
- Green cover requirements
- Maximum hardscape limits
- Permeable paving regulations
- Shading requirements for pedestrian corridors

- Ventilation corridor preservation
- Water-sensitive infrastructure provisions

Such planning controls would ensure that sustainability becomes an integral part of urban planning approvals rather than an optional environmental intervention. According to the National Building Code of India (NBC, 2016), climate-responsive planning regulations significantly improve environmental performance and operational energy efficiency within urban developments.

6.3.2 FAR and Incentive- based Mechanisms

One of the major implementation concerns raised within real estate development is the perception that sustainable planning reduces commercially saleable area. Therefore, the research proposes incentive-based planning mechanisms to encourage developer participation.

The proposed incentives include:

- Additional FAR incentives for green infrastructure integration
- Fast-track approvals for climate-responsive developments
- Tax rebates for renewable energy integration
- Reduced infrastructure charges for decentralized systems
- Density bonuses for transit-oriented mixed-use developments

Incentive-based systems improve economic feasibility while encouraging developers to integrate sustainability measures within residential projects. According to the World Bank (2022), financial incentives and regulatory flexibility significantly improve private-sector participation within sustainable urban development projects.

6.4 Economic Feasibility and Developer Participation

6.4.1 Long-Term Economic Benefits

Although sustainable neighborhood development may involve higher initial investment in environmental infrastructure systems, long-term operational savings significantly improve economic feasibility.

Passive environmental planning reduces operational cooling demand and energy consumption. Green infrastructure systems improve stormwater management efficiency and reduce infrastructure maintenance costs. Walkable mixed-use planning further reduces transportation expenditure for residents.

Research conducted by the International Energy Agency (2021) indicates that energy-efficient urban planning systems generate long-term economic benefits through reduced operational costs and improved infrastructure efficiency.

The proposed framework therefore emphasizes life-cycle environmental and economic performance rather than short-term construction cost evaluation.

6.4.2 Market Transformation and Value Enhancement

People care more and more about the environment how easy it is to walk the quality of public spaces and how comfortable it is outside when they are looking for a place to live in cities. This means that neighborhoods that are good at dealing with the climate will be more valuable in the run. Quality and climate-responsive neighborhoods are important to people.

Projects that include spaces with shade, green areas and ways to get around that are good for the environment often make the area nicer to live in and better for the environment than areas that are made for cars.

The plan shows that being sustainable is not a limitation for businesses but a way to make cities more valuable in the run and environmental quality and sustainability are key, to this.

6.5 Policy Recommendations

6.5.1 Integration with National and State Policies

The proposed framework recommends integration with existing national and state-level sustainability policies including:

- National Action Plan on Climate Change
- Smart Cities Mission
- AMRUT Mission
- National Transit-Oriented Development Policy
- Energy Conservation Building Code
- Urban and Regional Development Plans Formulation and Implementation Guidelines

Policy integration strengthens implementation feasibility and enables institutional support for climate-responsive neighborhood planning. According to MoHUA (2015), integrated planning approaches are essential for improving urban sustainability and infrastructure efficiency within rapidly urbanizing Indian cities.

6.5.2 Climate- Responsive Neighborhood Planning Guidelines

The study recommends preparation of dedicated climate-responsive neighborhood planning guidelines for hot-climate Indian cities.

The guidelines should include:

- Climatic orientation principles
- Green-blue infrastructure standards
- Thermal comfort benchmarks
- Mobility integration systems
- Public realm design standards
- Ecological infrastructure planning
- Decentralized infrastructure systems

- Renewable energy integration mechanisms

Such guidelines would assist planners, architects, developers, and planning authorities in implementing sustainable neighborhood systems systematically.

6.6 Environmental Performance Assessment

The proposed planning framework is expected to improve environmental performance through multiple integrated systems.

The expected outcomes include:

- Reduction in cooling energy demand
- Reduction in Urban Heat Island intensity
- Improved outdoor thermal comfort
- Increased walkability
- Reduced transportation emissions
- Improved groundwater recharge
- Enhanced biodiversity
- Improved environmental resilience
- Reduced stormwater runoff
- Increased renewable energy utilization

Research by (Bowler et al. 2010) demonstrates that integrated urban greening strategies significantly improve urban thermal performance and environmental quality. Similarly, compact mixed-use planning integrated with sustainable mobility systems substantially reduces transportation energy demand and carbon emissions (ITDP, 2017).

6.7 Limitations of the Study

Although the research establishes a comprehensive planning framework for climate-responsive Net Zero residential neighborhoods, certain limitations remain within the scope of the study.The research primarily focuses on planning-level strategies and does not include:

- Detailed building-scale engineering analysis
- Structural system design
- Detailed energy simulation modeling
- Financial cost-benefit analysis
- Detailed policy drafting
- Construction-level technical detailing

Additionally, implementation feasibility may vary depending on local governance conditions, economic structures, climatic variations, and urban development patterns.The study nevertheless establishes a strong planning-oriented framework capable of guiding sustainable residential neighborhood development within hot-climate cities.

CHAPTER 7
DESIGN GUIDELINES FOR CLIMATE-RESPONSIVE NET ZERO RESIDENTIAL NEIGHBORHOODS

Design guidelines are a part of the research. They help turn planning ideas and theories into rules that people can use when they are planning and building neighborhoods. The last chapters talked about the ideas and plans for the neighborhood. This chapter is about making rules for planning and designing neighborhoods that are good for the environment and do not hurt the climate. These neighborhoods are for cities that're very hot.

We made these rules by reading a lot of books and papers studying what other people have done looking at the weather and making a plan. This chapter has ideas for planning neighborhoods. It talks about how the streets and parks should look how to make the neighborhood friendly, to the environment and how to get around without hurting the climate.

The goal of these rules is to help the people who plan and build neighborhoods make choices. These people include city planners, designers, housing agencies, builders and government officials. They want to build neighborhoods that're good for the environment and nice to live in especially in cities that are getting bigger and hotter.

7.1 Urban Form and Density Guidelines

7.1.1 Compact Mixed- Use Development

Residential neighborhoods should adopt compact mixed-use planning principles to reduce transportation demand, improve land-use efficiency, and strengthen neighborhood accessibility. Compact development minimizes infrastructure distribution requirements while improving walkability and reducing commuting distances.

Mixed-use integration should include:

- Residential development

- Local commercial facilities
- Educational infrastructure
- Community facilities
- Recreational spaces
- Public amenities

Daily-use facilities should ideally remain within 400-800 meters walking distance from residential clusters to encourage non-motorized movement systems (ITDP, 2017). However, density optimization within hot-climate cities should maintain adequate airflow and thermal comfort. Excessively dense built forms without climatic consideration may obstruct ventilation and intensify Urban Heat Island conditions. Therefore, moderate compact density integrated with ventilation corridors and ecological systems is recommended for climate-responsive neighborhood planning.

7.1.2 Building Orientation Guidelines

Building orientation significantly influences solar heat gain, daylight access, and thermal comfort. Residential blocks should preferably be aligned along north-south axes to minimize excessive east-west solar exposure.

East-west facades receive intense solar radiation during morning and afternoon periods, increasing cooling demand and thermal discomfort (Givoni, 1998). Therefore, long exposed east-west building facades should be minimized within residential layouts. Street orientation should similarly reduce prolonged solar exposure within pedestrian movement corridors and public spaces.

Orientation guidelines should include:

- North-south Street alignment preference
- Minimized exposed west-facing facades
- Solar-responsive block spacing
- Shaded pedestrian corridors
- Controlled solar exposure within public spaces

Such orientation systems improve passive cooling performance while reducing operational energy demand.

7.2 Public Realm and Street Design Guidelines

7.2.1 Climate- Responsive Street Sections

Street sections should be designed according to climatic responsiveness and pedestrian comfort principles rather than conventional automobile-oriented planning standards.

The proposed street sections should integrate:

- Continuous shaded pedestrian pathways
- Dedicated cycling infrastructure
- Tree-lined streets
- Bioswales
- Permeable paving systems
- Reduced hardscape exposure
- Traffic-calming measures

According to the Environmental Protection Agency (2021), shaded urban surfaces can remain approximately 11°C to 25°C cooler than exposed paved surfaces. Therefore, continuous tree canopy systems should be integrated across pedestrian corridors and public movement networks. Street widths should also be proportionally designed to maintain thermal comfort and reduce excessive solar exposure within public spaces.

7.2.2 Pedestrian- Oriented Public Spaces

Public spaces should function as environmental and social infrastructure systems rather than merely residual open spaces.

Neighborhood-level public spaces should include:

- Shaded plazas
- Community parks

- Courtyard systems
- Pocket parks
- Interactive public spaces
- Community gathering zones

Public spaces should be distributed equitably across residential neighborhoods to improve accessibility and social interaction. Vegetation systems and water-sensitive landscaping should be integrated within public spaces to improve microclimatic conditions and thermal comfort. According to (Gehl, 2010), high-quality pedestrian-oriented public spaces significantly improve neighborhood livability and social interaction.

7.3 Green- Blue Infrastructure Guidelines

7.3.1 Urban Vegetation Systems

Green infrastructure should function as a primary environmental system within climate-responsive neighborhood planning.

Vegetation systems should include:

- Urban tree canopies
- Green corridors
- Community parks
- Ecological buffers
- Green roofs
- Shaded pedestrian corridors
- Native landscape systems

Tree species selection should prioritize native drought-resistant vegetation capable of surviving hot-climate conditions with low maintenance requirements. According to (Bowler et al., 2010), urban vegetation significantly reduces localized ambient temperatures and improves outdoor thermal comfort conditions. Continuous green corridors should be

ntegrated along mobility networks and public spaces to strengthen ecological continuity and environmental performance.

7.3.2 Water- Sensitive Urban design Guidelines

Water-sensitive urban planning systems should be integrated to reduce runoff, improve groundwater recharge, and strengthen environmental resilience.

The proposed systems should include:

- Rainwater harvesting systems
- Bioswales
- Permeable paving
- Retention ponds
- Recharge landscapes
- Decentralized greywater reuse systems
- Ecological drainage systems

Impervious surface coverage should be minimized within residential neighborhoods to reduce heat retention and stormwater runoff. The Environmental Protection Agency United States Environmental Protection Agency (EPA, 2021) indicates that permeable landscape systems significantly improve runoff management and groundwater recharge performance.

7.4 Sustainable Mobility Guidelines

7.4.1 Walkability Standards

Neighborhood planning should prioritize walkability to reduce transportation energy demand and automobile dependency. The following planning measures are recommended:

- Continuous pedestrian pathways
- Shaded movement systems
- Universal accessibility
- Safe pedestrian crossings

- Reduced vehicular dominance
- Mixed-use accessibility
- Traffic-calming infrastructure

Pedestrian movement corridors should maintain thermal comfort through tree canopies, shaded arcades, and vegetation systems because excessive heat exposure significantly discourages walking behavior within hot-climate cities. Walkability should further be integrated with public transit accessibility and public activity zones.

7.4.2 Cycling Infrastructure Standards

Cycling systems should be integrated as primary mobility infrastructure within residential neighborhoods.Recommended planning measures include:

- Dedicated cycling tracks
- Shaded cycling corridors
- Bicycle parking infrastructure
- Connectivity with transit systems
- Reduced vehicular conflict zones

Cycling systems significantly reduce transportation emissions while improving neighborhood accessibility and mobility efficiency.

7.4.3 Transit- Oriented Development Guidelines

Residential areas should have planning systems that focus on transport to reduce the need for cars.This kind of planning should include:

- Corridors with a mix of homes, shops and offices that're easy to reach by public transport
- Areas around transit stops where people can walk to get to the bus or train
- Fewer parking spaces
- Shared transportation systems like carpooling or ride-sharing
- Places where people can easily switch between different types of transportation

- Sidewalk and public transport systems that work well together

According to the Institute for Transportation and Development Policy Institute for Transportation and Development Policy (ITDP, 2017), neighborhoods with a mix of homes, shops and public transport really help make transportation more sustainable and use energy.

7.5 Infrastructure and Resource Management Guidelines

7.5.1 Renewable Energy Integration

We need to use energy systems but first we have to reduce the amount of energy we use every day. We can do this by planning things in a way that saves energy. The renewable energy systems we are talking about include:

- Rooftop photovoltaic systems
- Solar-powered utilities
- Solar street lighting
- Community energy infrastructure

The Ministry of New and Renewable Energy (MNRE, 2021) said in 2021 that cities in the middle of India get a lot of sunlight, which is great for renewable energy systems that are not controlled by one central point. So, when we plan neighborhoods we should make sure they are good, for energy and have rooftops that can support renewable energy systems like renewable energy systems to generate more renewable energy.

7.5.2 Decentralized Waste and Water Systems

Climate-responsive neighborhoods should use infrastructure systems to make better use of resources and improve environmental resilience. Recommended systems include:

- Greywater recycling
- wastewater treatment
- Organic waste composting

- Waste segregation systems
- Community recycling infrastructure
- Stormwater recharge systems

Decentralized systems help reduce the load on big infrastructure networks and make neighborhoods more sustainable in the long run. This approach helps neighborhoods prepare for climate challenges. Improves their environmental sustainability. Decentralized infrastructure systems are key, to achieving these goals. They make neighborhoods more resilient and sustainable.

7.6 Governance and Regulatory Guidelines

7.6.1 Planning Regulation Integration

We need to think about how we plan our cities so that they work well with the climate. This means we should put climate-responsive planning principles into the systems that govern how we build things. This includes things like Development Plans, Local Area Plans, Development Control Regulations, Town Planning Schemes and Transit-Oriented Development policies (National Building Code of India, 2016). When we plan we should make sure to include some rules about the environment. These rules should include things like:

• Minimum green cover requirements
• Maximum hardscape limits
• Shading provisions
• Permeable surface requirements
• Renewable energy integration
• Water-sensitive infrastructure standards

The National Building Code of India (2016) says that following climate-responsive planning principles is a good idea. It can really help our cities work better and be more friendly to the environment (National Building Code of India, 2016).

7.6.2 incentive- Based Planning Mechanisms

To get companies to participate we should offer some benefits. Here are a few ideas:

- We can give them incentives to build green infrastructure
- We can approve their development projects quickly
- We can give them tax benefits if they use renewable energy systems
- We can help them with subsidies for building decentralized systems
- We can give them density incentives if they build near train or bus stations

These things will make it easier to get things done and get developers to participate in building homes that're good for the climate and the people who live in them. The main goal is to get developers to build climate- residential developments so we need to make sure we give them the right incentives, like these benefits, for green infrastructure and renewable energy systems.

7.7 Framework for Implementation Prioritization

The proposed design guidelines should be implemented through phased planning systems.

Phase 1

- Climatic analysis
- Land-use planning
- Mobility framework preparation
- Ecological infrastructure identification

Phase 2

- Street and public realm development
- Green-blue infrastructure integration
- Decentralized infrastructure planning

Phase 3

- Renewable energy integration
- Smart environmental systems

- Community participation systems
- Monitoring and evaluation

Phased implementation improves financial feasibility and institutional coordination during project execution.

CHAPTER 8
DESIGN DEVELOPMENT AND SPATIAL INTERVENTIONS

The design development stage is where we turn the plan into things that can happen in a neighborhood. Before this we talked about the ideas and strategies for planning. Now we are looking at how to make the neighborhood a better place to live especially when it comes to dealing with the heat in cities with hot weather. We want to make neighborhoods that're good for the environment and use very little energy, which is what we call Net Zero residential neighborhoods.

This part of the book explains how we can organize the neighborhood to make it a nice place to live. We think about how the streetsre laid out how we can help the environment and how we can make sure people have nice public spaces to enjoy. We also think about how to get around the neighborhood without using cars and how to make the air and water cleaner.

When we were designing the neighborhood we thought about a lot of things like how to keep people cool how to make the neighborhood a nice place to live and how to make it easy for people to get around. We tried to fix some problems that we found when we were researching like neighborhoods getting too hot people relying too much on cars and public spaces being separated. We also wanted to reduce the amount of energy people use help the environment and make the streets better, for people walking.

8.1 Design Approach

The design approach adopted for the proposed neighborhood was based on the principle of “Environmental Integration through Spatial Planning.” The proposal treats the neighborhood as an interconnected climatic and ecological system where urban form, public spaces, movement systems, and infrastructure collectively contribute toward reducing environmental impact and improving thermal comfort.

The design development process was guided by the following principles:

- Climatic responsiveness
- Passive environmental planning
- Compact mixed-use development
- Pedestrian prioritization
- Ecological continuity
- Thermal comfort enhancement
- Sustainable mobility integration
- Resource-efficient infrastructure planning

Unlike conventional residential layouts that prioritize road infrastructure and plot subdivision, the proposed design prioritizes environmental performance and public realm quality.

8.2 Spatial Structure of the Proposed Neighborhood

8.2.1 Neighborhood Structure

The neighborhood we are planning will have a lot of things close together. We want people to be able to walk to places they need to go. The neighborhood will be set up so that people do not have to travel far to get where they want to go. This will make it easier for people to get around the neighborhood. People will live in areas that're close to:

- Community parks
- Public open spaces
- Places where they can buy things they need
- Schools
- Places where they can have fun
- Streets where they can catch buses and trains

This way people can meet each other and get to know one another. They will not have to drive much. Gehl (2010) states that neighborhoods where people can walk to places are really nice to live in. The neighborhood we are planning will be designed for people, not cars. We also want to make sure the neighborhood is good for the environment. The neighborhood will have paths that let air move through and help keep the neighborhood cool (Gehl, 2010).

8.2.2 Hierarchy of Open Spaces

The open space system is like a team working together to make the environment better. It is not a bunch of separate areas for people to have fun. The open space system has a lot of parts including:

- Neighborhood parks
- Community greens
- Semi-public courtyards
- Pocket parks
- Green corridors
- Ecological buffers
- Shaded pedestrian plazas

All these open spaces are connected and that helps people feel more comfortable when they are outside. The open space system also helps the environment by making it easier for plants and animals to live there. People can meet each other in these spaces and that is good for the community. The open spaces are all linked together. That helps the environment too.

The open spaces are spread out so that people can walk to them from their homes. This is important because it means people can get to the spaces easily. The United Nations said in 2020 that having spaces that people can get to makes cities better places to live.

The open space system is also good at keeping cities cool. It does this by reducing the amount of heat that gets trapped in the city. The open space system is like a helper that makes the city

a better place to live. The open space system is really good, at doing its job. That is why it is so important.

8.3 Climate Design Interventions

8.3.1 Solar- Responsive Planning

Solar-responsive planning formed one of the major climatic interventions within the proposed design. The planning structure minimizes excessive east-west exposure through:

- North-south Street orientation
- Controlled block placement
- Vegetation-based shading
- Reduced exposed hardscape surfaces
- Shaded public corridors

Solar heat gain significantly affects operational cooling demand within hot-climate cities (Givoni, 1998). Therefore, the proposal emphasizes passive solar control through urban morphology and landscape integration. Built forms were arranged to optimize daylight access while minimizing direct heat exposure during peak summer periods (Givoni, 1998).

8.3.2 Ventilation- Oriented Urban Form

The new city plan includes paths to help the air move better around the homes. These paths are like open spaces that let the wind blow through and make the area feel cooler. When buildings are too close together they block the breeze and make people feel hotter. This is what happened in the past, as Oke (1987) explained. The proposal therefore includes the following (Oke, 1987):

- Leaving space, between buildings
- Creating open areas with plants and trees
- Making public spaces that let the air through
- Designing streets that work with the wind

These things will make it more comfortable to be outside and people will not have to use air conditioners as much.

8.3.3 Heat Reduction Strategies

Urban Heat Island reduction formed a major environmental objective within the design proposal. The proposed strategies include (Bowler et al., 2010; EPA, 2021):

• Continuous tree canopy systems
• Green roofs
• Permeable landscapes
• Reduced asphalt exposure
• Shaded public spaces
• Vegetation buffers
• Water-sensitive landscapes

According to Bowler et al. (2010), urban vegetation systems significantly reduce localized temperatures and improve thermal comfort. Similarly, the Environmental Protection Agency (2021) states that shaded urban surfaces may remain 11°C to 25°C cooler than exposed surfaces. The proposal therefore prioritizes landscape integration as a thermal infrastructure system rather than decorative open space (Bowler et al., 2010; EPA, 2021).

8.4 Public Realm Development

8.4.1 Pedestrian- Oriented Public Spaces

The public area is made to be a place where people can interact with each other. It also responds to the weather. Pedestrian spaces include:

- Shaded walkways
- Community plazas
- Courtyard systems
- Interactive public spaces

- Green mobility corridors
- streets

The design is made so that cars do not take over the areas where people live and it helps people walk around and interact with each other in public spaces. Public spaces are connected through paths that have plants and places where people can do things. According to (Gehl, 2010) said that when the public spaces are nice and easy to walk it helps people interact with each other and it makes the public life, in cities better.

8.4.2 Street Design Strategy

The neighborhood is designed to be easy to get around on foot. This is because the neighborhood has a structure and a planning system that is made for people who walk (ITDP, 2017). Key things that will be done include:

• Making places where people can live and work in the area so they can walk to these places
• Creating paths that people can walk on that are not broken up
• Making sure everyone can get around easily
• Creating paths with shade so people can walk in the shade
• Making sure it is safe for people to cross the street
• Reducing the areas where cars and people can crash into each other

People can get to the places they need to go every day by walking a short distance. This means they do not have to use their cars as much. According to ITDP (2017), neighborhoods that are designed for people to walk and use transportation use less energy for transportation and are better for the environment. Neighborhoods like this are good for the neighborhood and the people who live there. Walkable neighborhoods are really important for reducing the energy that is used for transportation and improving the sustainability of cities. Walkable neighborhoods help make the neighborhood a better place to live (ITDP, 2017).

8.5 Sustainable Mobility Systems

8.5.1 Walkability Framework

The neighborhood is designed to be easy to get around on foot. This is because the neighborhood has a structure and a planning system that is made for people who walk. Key things that will be done include (ITDP, 2017):

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8.5.2 Cycling and Transit Integration

They built roads for bicycles all over the neighborhood to help people get around without cars. The bike paths connect a lot of places, like:

- Residential clusters
- Public spaces
- Community facilities
- Transit corridors
- Commercial activity zones

This makes it easier for people to get where they need to go. They also planned the neighborhood so that people can easily use transportation and do not have to commute very far. The neighborhood has areas that combine homes and businesses near the main roads to help people use public transportation more and rely less on cars. The cycling. Public transportation work together to make the neighborhood a better place to live.

8.6 Ecological Infrastructure Systems

8.6.1 Green Infrastructure Integration

Green infrastructure systems are all throughout the neighborhood forming a network to help the environment.

The proposal includes:

- Urban forests
- Community parks
- Ecological corridors
- Native landscape systems
- Green buffers
- Green roofs
- Tree-lined streets

We use vegetation systems to make the air cooler, cleaner and fuller of different plants and animals and to make the environment stronger. The (EPA, 2021) more plants in cities can really help with managing rainwater and keeping the air cool. We chose vegetation species because they need less maintenance and can adapt better to the climate. Green infrastructure systems help a lot. Vegetation systems are very helpful, for the environment. Green infrastructure systems are a thing.

8.6.2 Water- Sensitive Landscape Systems

Water-sensitive planning systems were integrated to reduce runoff and improve groundwater recharge Water-sensitive planning systems were set up to cut down on runoff and boost groundwater recharge.

The proposal is as follows:

- Bioswales
- Rainwater harvesting systems
- Permeable paving
- Retention landscapes
- Ecological drainage channels
- Decentralized water reuse systems

Water-sensitive systems make the environment more resilient and reduce the strain on city infrastructure. These water-sensitive systems also help surface heat buildup from hard surfaces like roads and buildings. They reduce the pressure, on urban systems. Water-sensitive planning helps to manage water It makes cities cooler and more eco-friendly.

8.7 Infrastructure Integration

8.7.1 Renewable Energy Infrastructure

We are talking about energy systems that work at the neighborhood level. These systems include things like

• Rooftop solar panels
• Street lights that use power
• Community projects that use solar energy
• Building roofs that are designed to get the most from the sun

The plan is to reduce the amount of energy we use first before we start using renewable energy sources. According to (MNRE ,2021) cities in the middle of India get a lot of sunlight,

which makes them great for using energy. This is perfect, for energy systems that are not controlled by a central power plant.

8.7.2 Waste and Resource Management

The proposed neighborhood integrates decentralized environmental infrastructure systems including:

- Waste segregation systems
- Organic waste composting
- Greywater reuse
- Localized wastewater treatment
- Community recycling infrastructure

Such systems improve resource efficiency and reduce dependency on centralized municipal infrastructure systems.

8.8 Site Analysis and Proposal

8.8.1 Site Area Calculations

20 Acres = 82300.0 m²

Ground Coverage = 30%

FAR = 1.3

EWS proportion in coverage = 15%

Table 3: Site Area Calculations

S.No	Particulars	Area (sq.m)	Percentage
1	Area for Plottable Development	82,300	100%
2	Plottable Area (EWS + LIG + MIG)	38,733.62	47%
3	Open & Services	26,914.30	32.6%
4	Roads	16,861.10	20.4%
	Total	**82,300**	**100%**

Table 4: Dwelling Unit Size

Category	Unit Size (m^2)
EWS	30 to 40
LIG	60 to 90
MIG	120 to 150

Table 5: Percentage Dwelling Unit Distribution

E.W.S. & LIG IS 15 % OF THE TOTAL PLOTS NOS. TOTAL PLOTS NOS. =291 NOS. =291 X15 %=43.65 NOS. (SAY 44)		
A.	E.W.S. UNITS (60 % OF THE 15%)	= 44.00 X 60%
	NUMBER OF UNIT REQUIRED	= 26.40 NOS. (SAY 26)
	AREA REQUIRED FOR ONE UNIT	= 30 TO 40 SQ.MT.
B	L.I.G. UNITS (40 % OF THE 15%)	= 44.00 X 40%
	NUMBER OF UNIT REQUIRED	= 17.60 NOS. (SAY 18)
	AREA REQUIRED FOR ONE UNIT	= 41 TO 96 SQ.MT.
C	M.I.G. UNITS	
	NUMBER OF UNIT REQUIRED	= 247 NOS. (SAY 18)
	AREA REQUIRED FOR ONE UNIT	= 120 TO 150 SQ.MT.

Table 6: Population and Area Distribution Under each Category

Category	**No. of Units**	**Size of HH**	**Total Population**	**Avg. Plot Area (sq.m)**	**Total Area (sq.m)**
EWS	26	4	104	35	910
LIG	18	4	72	70	1260
MIG	247	5	1235	135	33345
Total	**291**		**1411**		**35515 sq.m**

Assumptions used

EWS household size = 4 persons

LIG household size = 4 persons

MIG household size = 5 persons

Table 7: Plot distribution (Row House)

Category	**No. of Units**	**Plot Size Range (sq.m)**	**Avg Plot Size (sq.m)**	**Total Plot Area (sq.m)**
EWS	26	30 – 40	35	910
LIG	18	41 – 96	70	1260
MIG	247	120 – 150	135	33345
Total	**291**			**35515 sq.m**

8.8.2 Demand Calculations

Total Population = 5600 persons

Table 8: Water Demand

Parameter	Population	LPCD	Water Demand
Water Requirement	5600	35	756 KL/day
Hot Water Requirement	5600	25	140 KL/day
STP Capacity	5600	108	605 KL/day
Flushing Demand	5600	50	280 KL/day

Fire Demand (25%)

756 × 0.25 = 189 KL

Total Water Requirement 756 + 189 = 945 KL/day

8.8.3 GRIHA-Based Assessment Framework for Net Zero Energy Residential Neighbourhoods

The research uses the GRIHA framework to assess how sustainable a neighbourhood is. This framework looks at how a neighbourhood uses energy, water and other resources. It also checks how the neighbourhood is designed to work with the environment. The GRIHA framework is used of special computer programs that create 3D models. This is because GRIHA is a tool for evaluating neighbourhoods in India.

Here are the things that the GRIHA framework looks at:

1. Site Planning and Climate Responsiveness

- The GRIHA framework checks how well the neighbourhood is planned. It looks at the layout of the neighbourhood the direction the buildings face and the streets. It also checks if the neighbourhood is designed to work with the climate (GRIHA Council, 2019/2023).
- The framework wants to make sure that the neighbourhood has lots of spaces and is easy to walk around. It also wants to protect the environment.

2. Green Infrastructure Assessment

- The GRIHA framework evaluates how green space the neighbourhood has. It checks if there are parks, gardens and trees. It also looks at how the neighbourhood protects the local plants and animals.
- The framework wants to make sure that people can walk in areas and that there are green spaces for people to enjoy (GRIHA Council, 2019/2023).

3. Water Resource Management

- The GRIHA framework checks how well the neighbourhood collects and uses rainwater. It also evaluates how well the neighbourhood manages stormwater and wastewater.
- The framework wants to make sure that the neighbourhood uses water efficiently and promotes water conservation.

4. Energy Efficiency Assessment

- The GRIHA framework looks at how the neighbourhood is designed to use less energy. It checks if the buildings are oriented correctly and if they use ventilation and daylight.
- The framework wants to reduce the need for air conditioning and other mechanical cooling systems.

5. Energy Integration

- The GRIHA framework evaluates how well the neighbourhood uses renewable energy sources like solar power. It checks if the neighbourhood has panels on the roofs of the buildings.
- The framework wants to increase the use of energy in the neighbourhood.

6. Sustainable Mobility

- The GRIHA framework checks how well the neighbourhood is designed for walking and cycling. It evaluates how well the public transport system works.
- The framework wants to reduce the number of vehicles in the neighbourhood and promote low-carbon transportation.

7. Solid Waste and Resource Management

- The GRIHA framework looks at how the neighbourhood manages waste. It checks if the neighbourhood has a system for recycling and composting.
- The framework wants to promote use of resources and reduce waste.

8. Outdoor Environmental Quality

- The GRIHA framework evaluates how comfortable the outdoor spaces are. It checks if the neighbourhood has plenty of shaded areas and green spaces.
- The framework wants to improve the microclimate of the neighbourhood and make it a pleasant place to live.

9. Comparative GRIHA Evaluation

- The neighbourhood is first evaluated using the GRIHA framework to see how sustainable it is. Then the researchers propose some changes to the neighbourhood to make it more sustainable (GRIHA Council, 2019/2023).
- The neighbourhood is evaluated again using the GRIHA framework to see how much it has improved.
- The GRIHA framework is used for things in this research including:
- Assessing how sustainable the neighbourhood is.

- Identifying areas where the neighbourhood can improve.
- Evaluating the use of design and green infrastructure.
- Assessing the potential for energy.
- Developing guidelines for Net Zero Energy Residential Neighbourhoods.
- Validating the proposed planning framework.
- The GRIHA framework is a tool, for evaluating neighbourhoods and proposing changes to make them more sustainable. It helps to create an environment for people to live in.

8.8.4 Renewable Energy Integration Strategies

A photovoltaic (PV) system is installed to generate electricity, reducing reliance on conventional grid power. The building is strategically oriented to maximize solar exposure, optimizing renewable energy capture. The unobstructed terrace is ideal for solar panel installation, ensuring maximum energy efficiency throughout the year. For detailed technical specifications of each measure, refer to Table 2. Solar Panel Design Specifications: Orientation: Panels will be installed facing south, which is the optimal direction for solar gain in the Northern Hemisphere. Refer to (Table 9) for Details on Solar Panel Specifications.

Table 9: Details of Solar Panels

S. No.	Details	Case Study
1	The panels' inclination angle	19°
2	Type of panels	Polycrystalline solar panel (cost-effective)
3	Power generation per panel	330 Watts/hour
4	Generation time	6 am to 6 pm
5	Peak generation time	9 am to 4 pm
6	The daily average energy requirement of a building	4 kWh
7	The maximum energy requirement of the building	5 kWh

8	Number of solar panels needed to satisfy the maximum energy demand	16 solar

Table 10: Details Showing the Total Capacity of PV Panels

S. No.	Details	Value
1	Annual energy needed	25,228.43 kWh
2	Average Solar Irradiance (Bhopal)	5.5 kWh/m²/day
3	Solar generation per kW/year	1,800–2,000 kWh
4	Total capacity required	8–9 kW
5	Panel capacity used	330 W
6	Total panels needed	24 panels

8.8.5 Sequential Integration of Design Parameter

The design parameters evaluated included enhancements to the building envelope, improved glazing and window-to wall ratios (WWR), the application of external shading devices, a reduction in lighting power density (LPD), the implementation of advanced lighting controls, and finally, the integration of a rooftop photovoltaic (PV) system. (Table 11) summarizes the progressive reduction in energy consumption with each intervention.

Table 11: Design Parameters

Parameters	Building Description	Design Parameters	Suggested Material (Low Cost + High Performance)	Energy Performance
P1	Row Housing	Base Case	Burnt brick wall + single glass window + RCC roof	High energy consumption

P2	Row Housing	Building Envelope (Roof + Wall)	**Fly-ash brick / AAC block wall + plaster**	Reduces heat transfer
P3	Row Housing	Envelope + Glass	**AAC block + double glazed / tinted glass window**	Better insulation
P4	Row Housing	Envelope + Glass + WWR (20%)	**AAC wall + WWR 20% + aluminium/UPVC frame**	Lower solar gain
P5	Row Housing	Envelope + Glass + WWR + External Shading	**0.6 m chajja + light reflective paint**	Passive cooling
P6	Row Housing	Envelope + Glass + WWR + Shading + Lighting Control	**LED lighting + natural daylight design**	Lower electricity use
P7	Row Housing	Envelope + Glass + WWR + Shading + Lighting + LPD	**Energy-efficient appliances + insulation roof tiles**	Reduced energy demand
P8	Row Housing	Envelope + Glass + WWR + Shading + Lighting + LPD + PV Roof	**Polycrystalline Solar PV roof system**	Net-zero energy

Parameters	**Building Description**	**Design Parameters**	**Suggested Material (Low Cost + High Performance)**	**Energy Consumption (kWh)**	**Energy Performance**

P1	Row Housing	Base Case	Burnt brick wall + single glass window + RCC roof	62.00	High energy consumption
P2	Row Housing	Building Envelope (Roof + Wall)	**Fly-ash brick / AAC block wall + plaster**	58.30	Reduces heat transfer
P3	Row Housing	Envelope + Glass	**AAC block + double glazed / tinted glass window**	54.10	Better insulation
P4	Row Housing	Envelope + Glass + WWR (20%)	**AAC wall + WWR 20% + aluminium/UPVC frame**	51.20	Lower solar gain
P5	Row Housing	Envelope + Glass + WWR + External Shading	**0.6 m chajja + light reflective paint**	48.70	Passive cooling
P6	Row Housing	Envelope + Glass + WWR + Shading + Lighting Control	**LED lighting + natural daylight design**	42.90	Lower electricity use
P7	Row Housing	Envelope + Glass + WWR + Shading +	**Energy-efficient appliances + insulation roof tiles**	38.60	Reduced energy demand

		Lighting + LPD			
P8	Row Housing	Envelope + Glass + WWR + Shading + Lighting + LPD + PV Roof	**Polycrystalline Solar PV roof system**	0	Net-zero energy

8.8.6 Energy Conservation Measures

Table 12: Material Description for Base Case with U-values

S. No.	**Base Case Materials**	**Row Housing**	**U Value W/m²K**
1	Building Envelope External Walls	Paint + 15 mm External Cement Plaster + Fire burnt bricks + 15 mm Internal Cement Plaster + paint	2.00
2	Windows	Single-glazed (0.006) clear glass with Aluminium frame	5.778
3	WWR	27%	-
4	Roof Slab	Finishing Tiles + Concrete laid to slope (min. 50 mm) + waterproofing (bitumen) + 125 mm R.C.C slab + 15 mm cement plaster + paint	2.534

Table 13: Material Description for the Proposed case with U- values (Cost- Effective)

S. No.	**Proposed Materials**	**Row Housing**	**U Value W/m²K**
1	Building Envelope: External Walls	External reflective paint + 15 mm gypsum plaster + 200 mm AAC block + 12 mm internal gypsum plaster + interior paint	0.45

2	Fenestrations / Windows	Tinted double-glazed glass with UPVC / aluminium frame	2.60
3	Window-to-wall ratio	20%	-
4	Roof Slab	Cool roof tiles / China mosaic + 50 mm screed + waterproofing + 125 mm R.C.C slab + 12 mm gypsum plaster	0.38
5	Shading	0.5 m overhang	-

8.9 Spatial Outcomes of the Proposed Design

The proposed spatial planning interventions are expected to generate multiple environmental and social benefits including:

- Reduced operational cooling demand
- Improved outdoor thermal comfort
- Reduced Urban Heat Island intensity
- Improved walkability
- Reduced transportation emissions
- Enhanced public realm quality
- Increased ecological resilience
- Improved groundwater recharge
- Enhanced social interaction
- Improved neighborhood livability

The proposal demonstrates how integrated planning systems can significantly improve environmental performance at neighborhood scale.



Figure 8: Site Plan (Source: Author)



Figure 9: Road Layout (Source: Author)

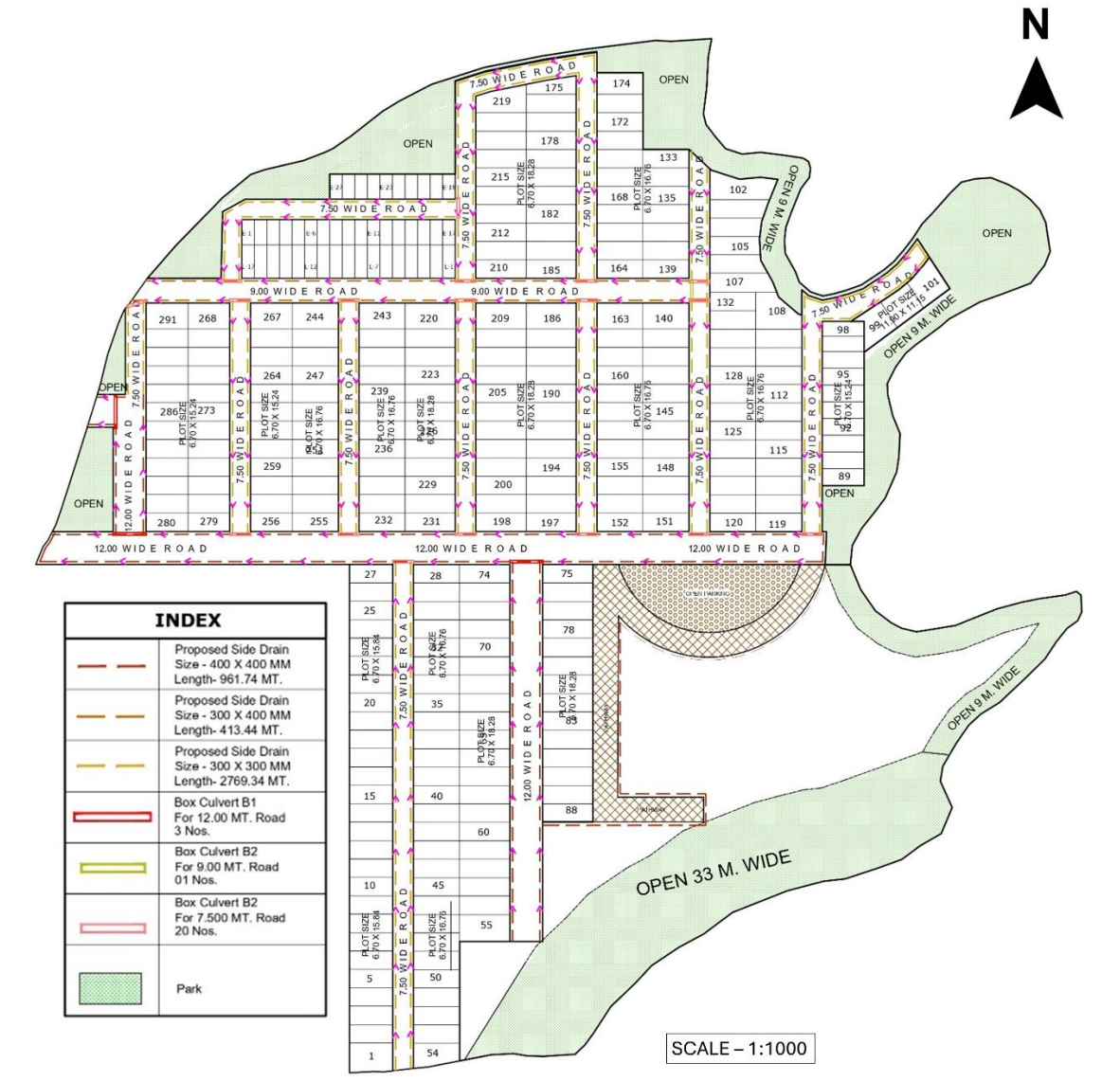


Figure 10: Drainage Layout (Source: Author)



Figure 11: Sewer layout (Source: Author)

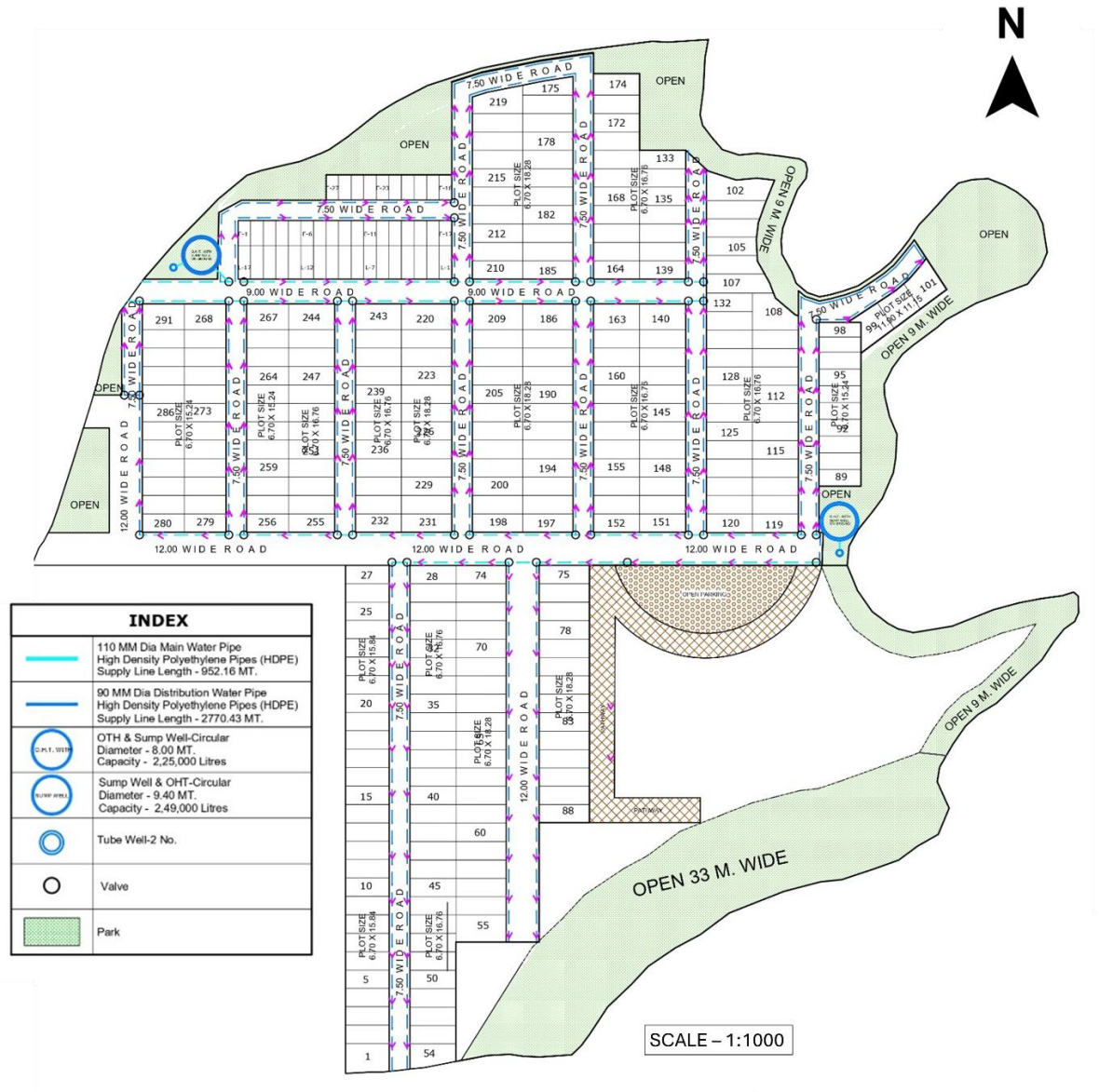


Figure 12: Water Supply Layout (Source: Author)



Figure 13: Rain water Harvesting (Source: Author)

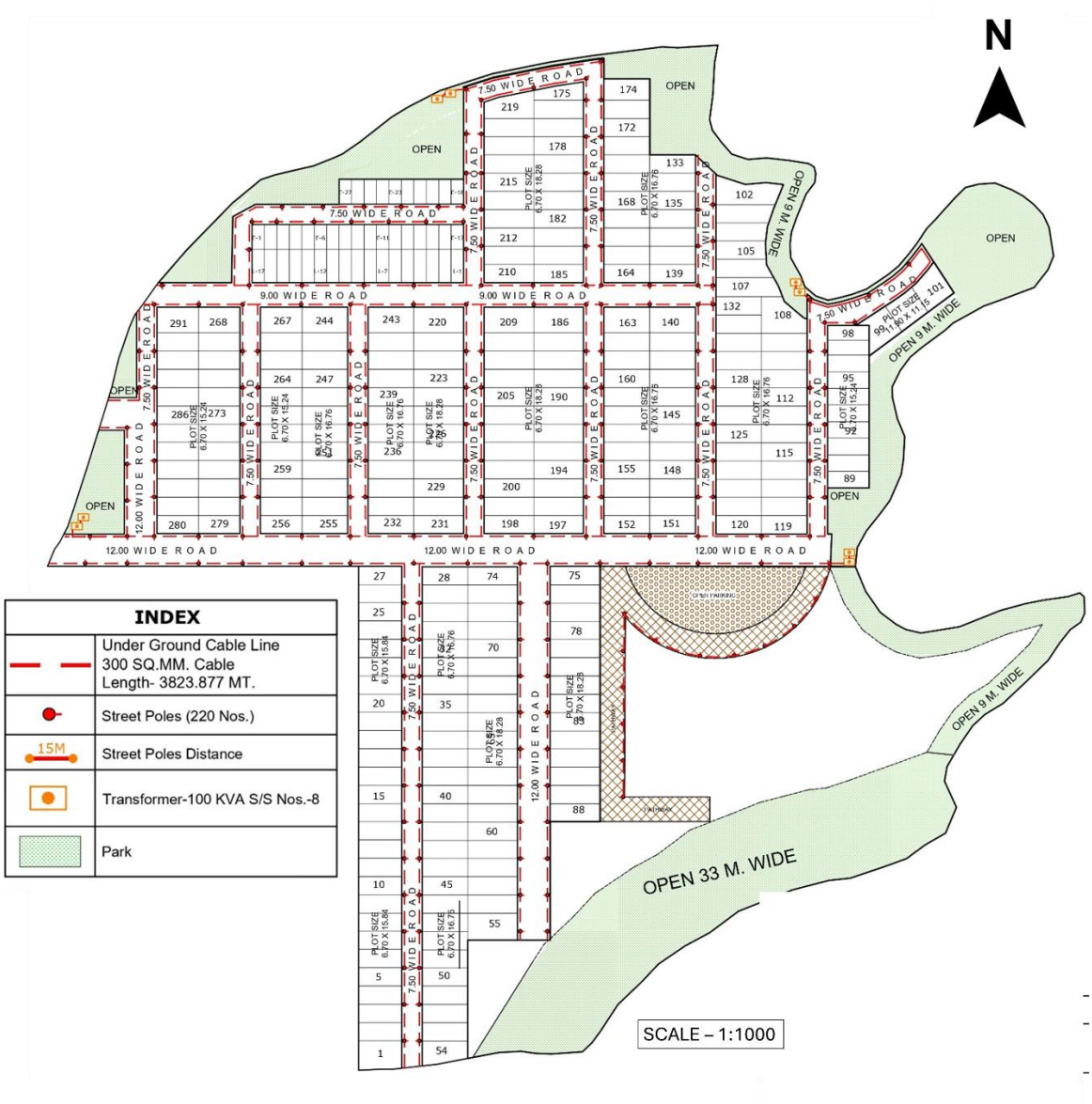


Figure 14: Electrical Layout (Source: Author)



Figure 15: Waste Management Layout (Source: Author)

CHAPTER 9
CONCLUSION AND RECOMMENDATIONS

9.1 Conclusion

The research on "Passive Design Strategies for Net Zero Energy Residential Neighborhoods in Hot Climate Cities" shows that we cannot make residential areas sustainable by using technology in individual buildings. We need to plan the neighborhood in a way that everything works together.

In cities with hot climates things are getting worse because of rapid urbanization the need for more cooling, rising temperatures, ecological degradation and relying too much on transportation. This creates a lot of problems so we need planning systems that can respond to the climate and make cities sustainable in the long run.

The usual way of planning areas, which is mainly about dividing land and providing basic infrastructure is not enough to deal with the new environmental challenges we are facing.

So the research looked at sustainability in a way by focusing on how cities are designed to respond to the climate including things like green spaces, sustainable transportation and systems for managing the environment in a decentralized way as well as how to put these plans into action through good governance. The research on "Passive Design Strategies for Net Zero Energy Residential Neighborhoods in Hot Climate Cities" is very important, for this.

Through a review of literature assessing climate analyzing case studies and evaluating plans the research found that the way a city is laid out greatly affects how well neighborhoods perform in terms of the environment. Things like the direction buildings face how densely populated an area is, the hierarchy of streets corridors for ventilation the structure of spaces and transportation systems all directly impact how comfortable an area is in terms of temperature how much energy is needed for cooling and how much energy is used for transportation. The study showed that planning neighborhoods to be compact with a mix of

uses and incorporating strategies for the environment can greatly reduce the need for mechanical cooling and private cars while also making neighborhoods more livable and accessible. The findings also suggest that these passive planning strategies work better when applied at the neighborhood level because all the environmental systems like corridors shaded walkways, landscapes that make good use of water and planning that is oriented around public transit work together to help regulate temperature and improve environmental efficiency.

The research identified that urban form significantly influences neighborhood-scale performance. Parameters such as orientation, density distribution, street hierarchy, ventilation corridors, public realm structure and mobility systems directly affect comfort, operational cooling demand and transportation energy consumption. The study established that mixed-use planning integrated with passive environmental strategies can substantially reduce dependency on mechanical cooling systems and private automobile usage while simultaneously improving neighborhood livability and accessibility. The findings further indicate that passive planning interventions become more effective when implemented at neighborhood scale because interconnected environmental systems such, as corridors, shaded pedestrian infrastructure, water-sensitive landscapes and transit-oriented planning collectively strengthen thermal regulation and environmental efficiency.

The study also finds that blue infrastructure systems should be considered as main environmental infrastructure, not just for decoration. These systems, which include vegetation, ecological corridors, bioswales, permeable landscapes and water-sensitive planning help in ways. They make the environment cooler reduce the Urban Heat Island effect support biodiversity help recharge groundwater and make the environment more resilient. Sustainable mobility planning is also crucial for developing Net Zero neighborhoods. This is because transportation systems use a lot of energy and harm the environment. To solve this we need mixed-use development, cycling infrastructure shaded walkways and good public transport. These together reduce emissions from transportation.

Improve social interaction and public spaces. A key part of the research is that it addresses concerns about implementation.

The study notes that sustainable neighborhood plans often fail due to governance, weak planning regulations and lack of economic feasibility. To overcome these the research suggests recommendations. These include climate- development rules, incentives for planning approvals and decentralized infrastructure. The research also emphasizes the need for coordination among government agencies. By combining planning regulations and policy mechanisms with strategies the research makes sustainable neighborhood development more practical in Indian cities. The study provides recommendations that can be implemented such as climate- Development Control Regulations and interdisciplinary governance coordination. These recommendations aim to strengthen the applicability of sustainable neighborhood development, within Indian urban contexts.

The plan for neighborhoods and the way we design spaces show how we can use the environment to help us in a way. We can make our neighborhoods better by planning at a scale to use less energy and make people feel more comfortable when they are outside. This can also help our neighborhoods be stronger and more livable in cities that're very hot. The research shows that to make neighborhoods that use no energy we need to work together on many things like the environment how people move around the way cities look how we plan for nature and how we make decisions. We cannot just focus on buildings.

This study is important because it shows how planning can help shape what our cities will be like in the future when it comes to dealing with climate change. It also adds a lot to the field of city planning especially when it comes to housing. The study helps us think differently about sustainability moving away from thinking about individual buildings and, towards thinking about whole neighborhoods.

9.2 Recommendations

The study suggests that cities in India that are growing fast should include planning ideas that consider the climate in their rules and regulations for building and development. Now the rules mainly focus on how land is used how far buildings should be from the road and how much open space is needed. They do not pay attention to keeping buildings cool being kind to the environment connecting with nature or making it easy to get around without hurting the planet. In the future the rules should make it necessary to include things like: Planning for the direction buildings face, Having green spaces, using surfaces that let water soak through, building walkways that are shaded, creating paths for air to flow, Using energy, Planning for water use. This way being sustainable is not just an extra thing to think about but a key part of planning. The goal is to make sustainability a main consideration in planning than just an optional environmental measure. Cities should make sustainability a priority by including these ideas in their planning rules. This will help create an environment, for the people living in these cities (UN-Habitat, 2020; IPCC, 2022).

The study says that when we build homes we should think about making neighbourhoods that are close together and have everything people need like stores and parks and that are easy to get around without a car. Neighbourhoods that are easy to walk and have a mix of homes and stores use less energy for transportation and people do not have to rely so much on cars, which makes it easier for everyone to get around and makes the community a nicer place to be. We should make sure that our neighbourhoods have sidewalks and bike paths and that people can easily get to transportation and that there are trees and other things to make walking more comfortable. We should plan our cities so that they are good for people, not cars (ITDP, 2017; Calthorpe, 1993).

The research also says that we should make sure our cities have plenty of spaces, like parks and gardens that are all connected. These green spaces help keep our cities cool and make them more able to handle storms and they also help keep our air and water clean. We should plant trees and other plants that're good for hot weather and do not need a lot of water so that

our cities are sustainable and easy to take care of. This way our cities will be places to live and we will be kinder, to the environment (EPA, 2021; UN-Habitat, 2020).

To improve implementation feasibility, the study recommends the introduction of incentive-based planning mechanisms capable of encouraging private-sector participation within sustainable residential development. Planning authorities and governments should provide FAR incentives, fast-track development approvals, tax rebates, infrastructure subsidies, and regulatory flexibility for projects integrating climate-responsive planning systems and decentralized environmental infrastructure. Such mechanisms would address concerns regarding reduced commercially saleable area and improve the economic viability of sustainable neighborhood development.

The study further recommends stronger interdisciplinary coordination between planning authorities, environmental agencies, housing boards, infrastructure departments, transportation agencies, and private developers during planning and implementation stages. Fragmented governance systems often lead to inefficient infrastructure planning and environmental conflicts. Therefore, integrated planning coordination is necessary to ensure successful implementation of climate-responsive neighborhood systems.

Finally, the research recommends further investigation into quantitative environmental performance assessment, GIS-based climatic analysis, neighborhood energy simulation, smart infrastructure integration, and climate-responsive affordable housing systems. Future research should also examine the applicability of the proposed framework across different climatic regions and urban contexts within India. Such studies would further strengthen the implementation potential of climate-responsive Net Zero residential neighborhood planning and contribute toward sustainable urban development practices in the future.

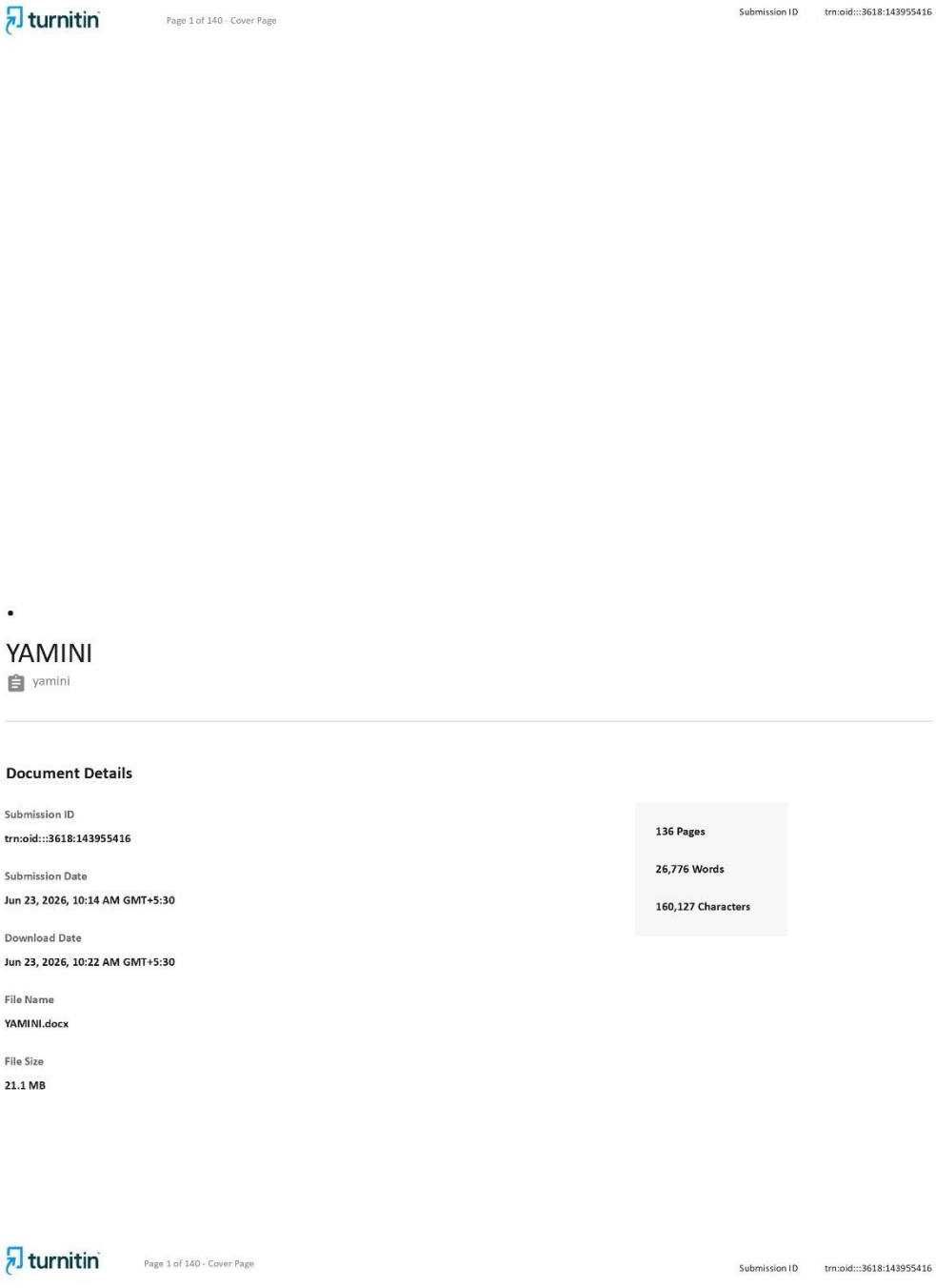
REFERENCES

- Banister, D. (2011). The sustainable mobility paradigm. Transport Policy, 15(2), 73–80.
- Bioregional. (2009). BedZED seven years on. Bioregional Development Group.
- BMTPC. (2021). Green building materials and technologies for affordable housing. Building Materials and Technology Promotion Council.
- Lombardi, D. R., et al. (2011). BedZED eco-village: A case study of sustainable living. Journal of Urban Design, 16(1), 1-17.
- Masdar. (2022). Sustainability and ESG report. Masdar City.
- Ratti, C., Baker, N., & Steemers, K. (2005). Energy consumption and urban texture. Energy and Buildings, 37(7), 762-776.
- Reiche, D. (2010). Renewable energy policies in the Gulf countries: A case study of the carbon-neutral "Masdar City" in Abu Dhabi. Energy Policy, 38(1), 378–382.
- Salat, S., & Nowacki, C. (2011). Cities and forms: On sustainable urbanism. Hermès Science Publishing.
- Santamouris, M. (2015). Regulating the damaged thermostat of the cities—Status, impacts and mitigation challenges. Energy and Buildings, 91, 43–56.
- Scheurer, J., & Newman, P. (2009). Vauban: A sustainable model district. European Planning Studies, 17(1), 61-81.
- Basu, R., & Nagendra, H. (2021). Perceptions of urban park users in Hyderabad, India. Urban Forestry & Urban Greening, 59, 126985.
- Chang, Y., Chen, C., & Abe, T. (2024). Evaluating balcony green curtains for thermal comfort and air quality in Taiwan. Building and Environment, 236, 110315.
- Galagoda, R., Jayasinghe, G., & Kariyawasam, S. (2018). Living walls and thermal regulation in Colombo, Sri Lanka. Urban Climate, 25, 1-15.
- Gupta, P., & De, S. (2024). Blue-green infrastructures for South Asian cities: A systematic review. Sustainable Cities and Society, 103, 104573.

- Priya, U. K., & Senthil, R. (2024). Analysis of urban residential greening in tropical climates using quantitative methods. Environmental Science and Pollution Research, 31, 44096-44119.
- Yungstein, L., & Helman, A. (2023). Performance of vertical wall greening systems in urban housing. Energy and Buildings, 293, 113295.
- Anand, S., & Bhattacharya, R. (2024). Residents' perceptions of urban greening ecosystem services in Delhi, India. Environmental Science and Pollution Research.
- Galagoda, R., et al. (2018). Performance of green infrastructures in Colombo: thermal regulation and air quality. Urban Climate.
- Gupta, R., & De, A. (2024). Review of blue-green infrastructures in South Asia. Environmental Research.
- Imam, R., & Banerjee, S. (2016). Residential gardens and microclimate cooling in dense neighbourhoods. Urban Forestry & Urban Greening.
- Jim, C. Y. (2015). Green infrastructure and urban heat island mitigation. Urban Forestry.
- MoHUA. (2021). Pradhan Mantri Awas Yojana - Housing for All Mission Guidelines. Government of India.
- Priya, U. K., & Senthil, R. (2024). Analysis of urban residential greening in tropical climates using quantitative methods. Environmental Science and Pollution Research
- Safikhani, T., et al. (2014). Impact of green walls on energy consumption in buildings. Energy and Buildings.
- UN DESA. (2018). World Urbanization Prospects: The 2018 Revision. United Nations Department of Economic and Social Affairs.
- Wardeh, S., et al. (2022). Urban densification and its climate impacts. Journal of Environmental Management.
- Bureau of Energy Efficiency (BEE). (2017). Energy Conservation Building Code 2017. Ministry of Power, Government of India.
- Jim, C. Y. (2015). Green roofs and urban biodiversity. Urban Forestry & Urban Greening, 14(2), 292-301.

- Lemoine-Rodríguez, R., et al. (2022). Urban greenery and thermal comfort. Urban Climate, 41, 101052.
- Priya, U. K., & Senthil, R. (2024). Analysis of urban residential greening in tropical climates using quantitative methods. Environmental Science and Pollution Research, 31(44096–44119). Wardeh, R., et al. (2022). Climate change, urban heat islands and housing. Sustainable Cities and Society, 87, 104195.
- Auroville Earth Institute. (2018). Vernacular Architecture and Passive Design in Auroville. Tamil Nadu: Auroville Foundation.
- BioRegional & Peabody Trust. (2002). BedZED - Beddington Zero Energy Development Report. Housing Corporation, London.
- Coates, G. J. (2013). Vauban District, Freiburg: A sustainable urban development case study. Design and Nature & Ecodynamics, 8(4), 389-400.
- Infosys Limited. (2021). Sustainability Report 2020-2021. Bengaluru: Infosys Foundation.
- Masdar City. (2024). Masdar City ESG Report 2024. Abu Dhabi: Masdar.

ANNEXURE



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