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Transforming Urban Energy: Dynamics, Policies and Innovations in Suburban Energy Efficiency and Building Sustainability in India

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Abstract: This review article provides a thorough examination of the factors affecting energy consumption in India and around the world, focussing on suburban areas and their role in the broader context of building construction and energy efficiency. The study examines the switch from conventional energy sources to more diversified energy portfolios, including electricity, natural gas, oil, biomass, and waste. Moving deeper into the subject, the review delves into the realm of carbon emissions resulting from building and construction. It spotlights the critical contribution of residential energy consumption to the overall carbon footprint and discusses the dual significance of operational and embodied emissions in the construction sector. This research underscores the necessity for integrated strategies to mitigate carbon emissions in building practices. Furthermore, the paper critically evaluates the evolution of energy regulations, with a special focus on the shift from prescriptive to performance-based Building Energy Codes (BECs). It assesses the capacity of current energy policies to curtail global warming and provides an in-depth analysis of energy usage patterns, policies, and CO_2 emissions in the Indian suburban context. The study highlights India's efforts to modernise building codes and improve energy efficiency while promoting multifaceted strategies that include building code improvements, the use of energy-efficient technologies, and sustainable urban design, and ends with a plea for sustainable development and major reductions in carbon emissions, thereby highlighting the critical role that both local and global initiatives can play. This study provides a thorough understanding of sustainable building practices and energy efficiency, especially in suburban development.

Keywords: CO_2 emissions; Suburban energy consumption; Renewable energy integration; Energy efficiency policies; Net zero energy buildings; Environmental impact of construction.

Introduction

The issue of rising energy demand is attributed to factors such as; world population growth and growing affluence. This trend is more apparent in developing countries like India where population increase, increased urbanisation and overall growth puts immense strain on energy (Agrawal et al., 2020). India's residential

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sector is also a key player in this energy mix, which accounts for a huge chunk of the total energy requirement (Kirikkaleli & Adebayo, 2021). India on the development front has made improvements in terms of extension of electricity coverage to access nearly universal level inclusive of rural areas by 2019 but this is done at some cost (Amado & Poggi, 2022). Statistics show that energy consumption has doubled since the year 2000 and forecasting clearly suggests that the energy demands of India will increase at least through the year 2040 due to a heady pace of industrialisation and urbanisation (EI Kenawy et al., 2023). This situation presents a critical challenge: emphasising the need for appropriately addressing India's developmental needs and wants on one hand and the requirement for sustainable energy solutions on the other hand. As much as the process of urbanisation contributes to the growth of the economy, it comes with various environmental problems, especially in the use of energy and emissions of greenhouse gases. Through current estimates, cities consume over 60% of the total energy consumption globally making them responsible for a chunk of the total carbon emissions (Hanif, 2018). This trend is expected to increase in the future with global emission of Green House Gases (GHG) estimated to increase significantly by 2050 mainly due to energy demand (Bansal, Saini, & Khatod, 2013). India for instance even as it has attempted to diversify its energy mix, one that relies on traditional fuels such as coal and biomass is unsustainable environmentally. This clearly shows why sustainable building solutions should be sought at this certain time given the increasing global temperatures as well as changing climatic conditions (Omer, 2009). Net Zero Energy Buildings appear as a fit solution that can help in realising a potential for reduction of energy consumption and avoidance of carbon emissions relevant to the Intergovernmental Panel on Climate Change for sustainable low-energy building forms (Farzaneh et al., 2021). Another problem in implementing sustainable building design highlighted in the document presented by the IPCC is concerning the rates of increase in the global average surface temperature (Salvia et al., 2021). On the same score, heating requirements will decline as global warming proceeds whereas cooling requirements will rise and be compounded by increased humidity (Mohajan, 2011). This shift has pointed to the need to have correct climate data in assessing building performance as Holmes along with Hacker (2007) pointed to. To the existing challenge, global energy demand in buildings is already massive, accounting for about 40 percent of global energy consumption and is predicted to rise tremendously by the middle of this century. Hence, the rate of energy demand by buildings in developing countries is projected to rise rapidly and increase by more than 4400 Mtoe by 2050. This energy demand has been projected to continue rising in the future, making it important that sustainable practices in the building be practiced to reduce the negative impact on the environment.

The world is therefore tied to unprecedented demand for energy in the current world and the future due to high population growth, rising income levels and urbanisation (Bansal et al., 2013). Such a trend, however, is more discernible in suburban regions which have described themselves as some of the biggest energy consumers thus pointing to the increasing energy demand for residential sectors (Singh, Henriques, & Martins, 2018). This phenomenon is well evident in the global world today and especially in countries like India where the economy is rapidly growing and the population of the country is continually increasing. China's total energy consumption has more than doubled since 2000, driven by industrialisation, urbanisation, and a rise in the standards of living (Li, Mao, Wang, & Wu, 2023). But this is a progress which has several crucial issues. India has heavily relied on conventional energy resources and energy consumption projection in the future will grow, especially in its growing suburban areas, measuring the need for green solutions (Ghosh, 2023). This research focusses on this important concern by examining the aspects that explain energy consumption in India and stressing optimal energy usage as a key to attaining a secure energy regime. Although urbanisation is a key factor for economic development, this is one of the most influential factors threatening the environment including the use of energy and greenhouse gas emissions (Stephan & Stephan, 2020). Metropolitan areas today consume over two-thirds of the total energy today and this is expected to rise and this will significantly contribute to global GHG emissions increase by 2050 (Arıoglu Akan, Dhavale, & Sarkis, 2017). The challenge to India however, of shifting from traditional sources of energy such as coal and biomass seriously hampers efforts to reduce the impact on the environment. This climate agrees with the IPCC urging the need to include sustainable, low-energy building designs as emphasised due to the challenges of making buildings comfortable as evidenced by the increasing global temperatures (EI Kenawy et al., 2023). Global temperatures are expected to rise further as indicated by the IPCC, and this is a challenge to sustainable building design especially in the area of energy control for comfort. Heating demand may reduce as observed because of global warming which may increase the cooling demand in addition to raising humidity levels. This movement stresses the global energy demand projection indicating that the energy consumption by buildings will increase to over 4400 Mtoe in the year 2050 owing mainly to the developing countries (EI Kenawy et al., 2023).

Enhanced insulation, energy-efficient appliances, smart home technologies, and renewable energy integration are crucial for reducing energy use and GHG emissions in buildings (Stephan & Stephan, 2020). The building sector accounts for over one-third of global energy-related emissions, with energy consumption ranging from 20% in devloped countries to 35% in developing nations. Figure 1 shows the Global construction energy appetite of residential as well as commercial unit of different countries. Net Zero Energy Buildings (NZEB) aims to match energy consumption with on-site renewable energy production (Magrini et al., 2020). This review examines the complex relationship between urbanisation, energy use, and sustainable building practices, leveraging comprehensive studies to identify current trends and future pathways for energy-efficient residential designs and methodologies.

Materials and Methods

This study used a systematic review process to assess published research on Net Zero Energy Buildings accessing the effect of interaction with ecosystem services. The review process involved:

1. **Search and Selection of Literature:**
   - Search Strategy: Web of Science, Google Scholar, Scopus, PUBMED.
   - Keywords: "CO_2 production by structures", "impact of environmental factors on energy consumption in buildings","governmental efforts to reduce energy use","CO_2 emissions in residential buildings", "Net Zero Energy Building", and "ecosystem services".
   - Timeframe: 1994-2022.
   - Selection: 903 papers, with 600 unique studies after removing duplicates.
   - Final selection: 103 articles (pre-screened, abundance and citation frequency), (rated based on relevance or aligned with research themes).
2. **Research Themes:**
   - NZEB Evaluation Theoretical Framework.
   - Environmental impact factors.

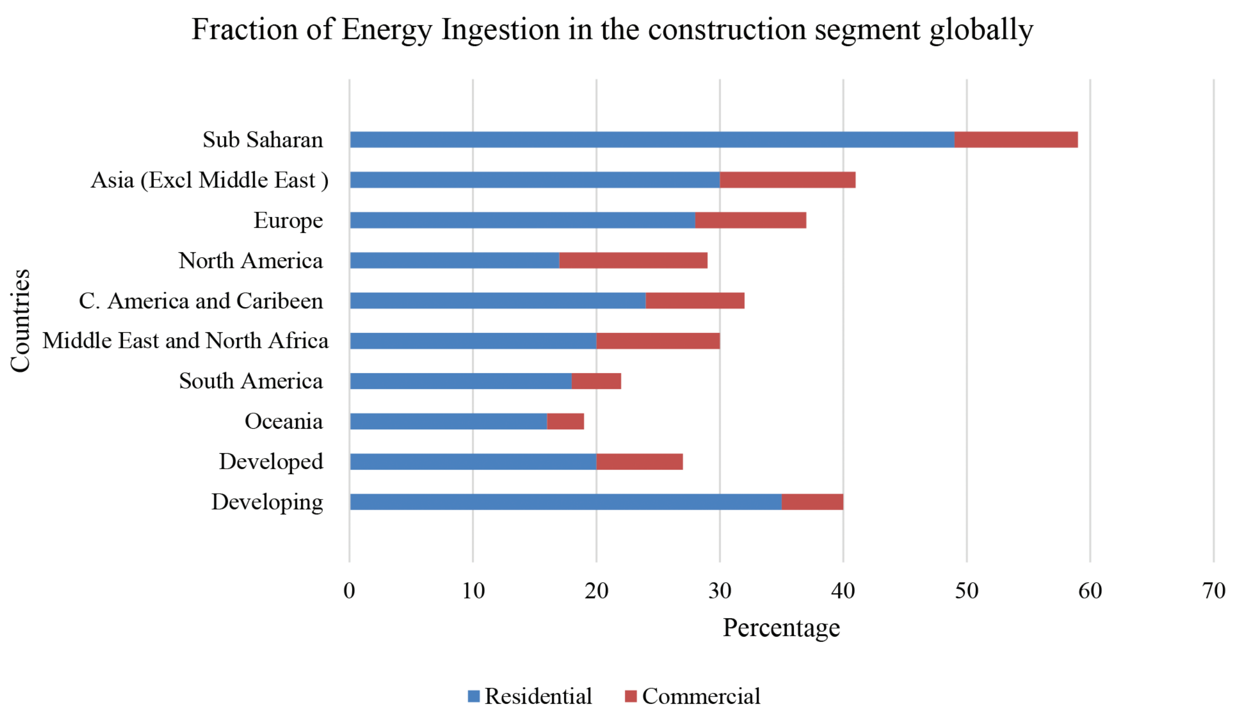

Figure 1: Global construction energy appetite: A bar graph unveiling the fractional feast of energy ingestion in the building sector.

- Methodological considerations and assessment methods.
- Implications for natural sciences and socio-economic frameworks.

3. **Scope and Objectives:**
   - Explore the Gaps and Current Strategies in NZEB Research.
   - Examine the wide variety of methods implemented in ecosystem services assessments by concentrating on how they apply to the building sector.
   - Assessment of NZEB to energy saving, environment Protection and CO_2 reduction solution.
   - NZEB, climate change and the Sustainable Development Goals.

4. **Further Analysis:**
   - Energy Dynamics: Globally and in India.
   - Energy Consuming Tendencies and Manner of the Sub-Urban Areas.
   - How energy use behaviours affect carbon output — especially in our buildings.
   - How energy regulations have changed.
   - Energy Efficiency and Building Codes in India.

This review systematically interprets (Figure 2a) the linkages between urban development, energy consumption, and environmental impacts due to the likely influence of NZEBs and policy measures in creating a sustainable urban landscape. A comprehensive literature review was conducted, presenting a significant methodological challenge. The research was organised into four primary themes (Figure 2b) theoretical frameworks for NZEB evaluation, environmental impact factors, methodological considerations, and assessment methods, as well as implications for natural sciences and socio-economic frameworks. Following this in-depth process 103 articles were identified that aligned with the defined themes (Figure 2c).The subsequent sections of this paper will delve into energy dynamics both globally and in India, covering current trends and patterns in energy use in suburban areas, the impact of these patterns on carbon emissions (especially from buildings and construction), and the evolving nature of energy regulations. Additionally, the paper will explore India's recent advancements in energy efficiency and building codes.

Energy Dynamics in Suburban Areas: Global and Indian Perspectives

This section assesses the critical aspects of energy and CO_2 emissions in suburban areas, providing a

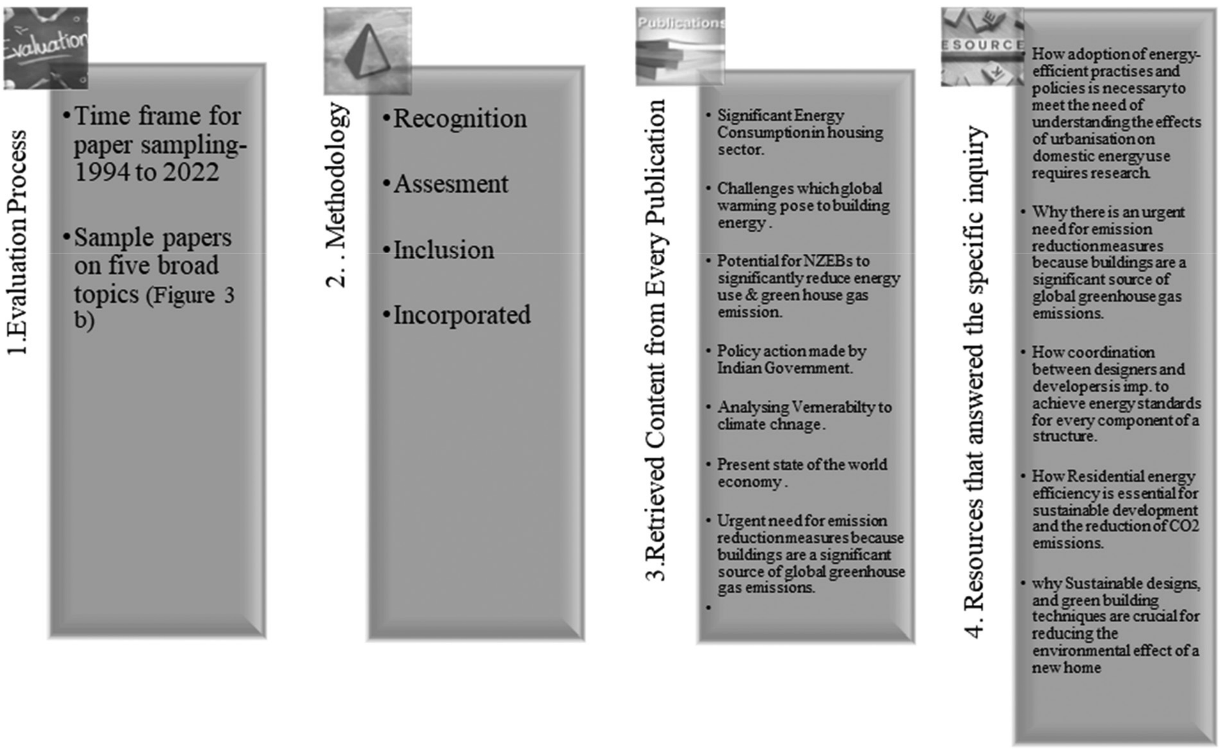

Figure 2a: Visual roadmap for a comprehensive literature review, mapping out foundational parameters and queries.

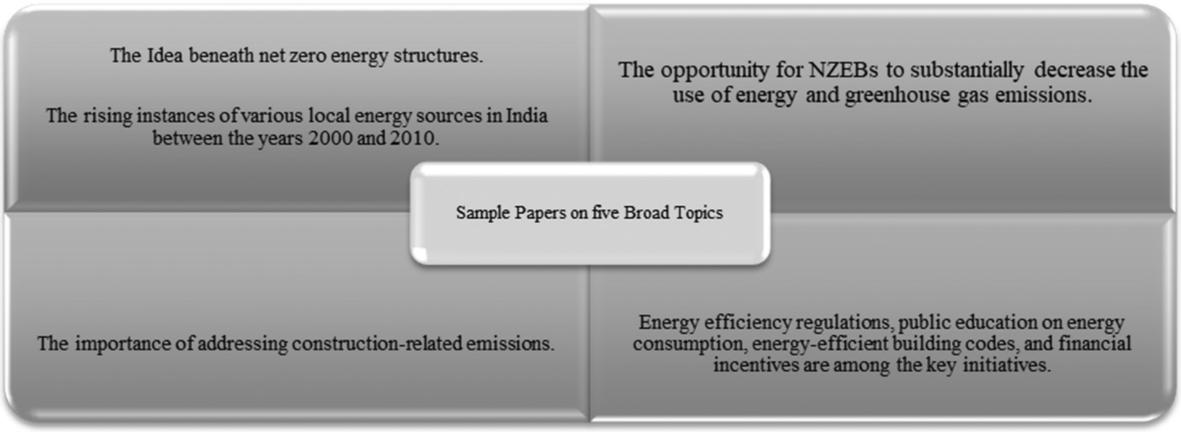

Figure 2b: Systematic review journey.

Figure 2c: Visual representation highlighting the 103 articles aligning with the specified review themes.

comparative analysis of global trends and specific case studies from India. It also highlights the patterns, sources, and impacts of energy use in residential sectors across diverse geographic and economic contexts by examining global standards and the unique challenges faced by a rapidly developing nation like India (Ohene, Chan & Darko, 2022).

Worldwide Energy Usage in the Suburban Areas

Dependence of the residential sector central district utilities varies by country, contributing approximately 20–40% of global CO_2 emissions from the suburban areas (Bandyopadhyay & Thukral, 2010). These areas consume a large amount of electricity for lighting and other energy for heating & cooling with the major energy sources being electricity, Natural Gas, Oil, & Solid Fuels. These CO_2 emissions are a result of the use of fossil-based fuels and inefficient appliances in suburban residential buildings Mac Kinnon, Brouwer, & Samuelsen, 2018). Measures taken towards lowering emissions include energy standards, building code amendments, and, subsidies to renewable energy systems. One disadvantage, though, which exists in the delivery of energy efficiency practices or products to the consumers, is that there are high chances of low-income earners being unable to adopt high-level energy efficient practices (Azimi, Hon, Tyvimaa & Skitmore, 2023).

Energy Ingestion in India's Suburban Areas

Among the sectors that take up the daily energy consumption in India's suburbs are lighting, cooling, and appliances as well as traditional fuels such as biomass, kerosene, and LPG for cooking. Improper use of stoves and low-quality biomass enhance CO_2 emissions and IAQ (Hasanbeigi, Price & Lin, 2012). This is in addition to the emissions that come from the suburban areas from the dependency on the grid electricity which is primarily generated from fossil fuels in the urban areas. Government drives like the Pradhan Mantri Ujjwala Yojana not only improve the living standards through the supply of cleaner energy, energy-efficient products also find people's attention through programs like energy labelling by BEE and Energy Conservation Building Code (ECBC) (Swain & Mishra, 2020). Nevertheless, constraints such as cost, availability and infrastructural constraints hamper the use of clean energy in the suburbs.

Results

Carbon Emissions and Energy Dynamics in Building and Construction

Here, we explore the critical aspects of carbon emissions and energy dynamics within the building and construction sector. This comprehensive analysis begins by examining CO_2 emissions from building operations, exploring both direct and indirect contributions to global GHG levels (Berwal & Yadav, 2021). The focus then shifts to the intricate nexus between residential energy usage and emissions, highlighting the interplay between household energy use and climate change. Finally, the section culminates with an in-depth exploration of the carbon footprint associated with new house construction, emphasizing emissions and the potential for sustainable practices (Chau, Leung & Ng, 2015).

CO_2 Emissions from Building Operations

In 2022, CO_2 emissions from building operations shifted, with direct emissions decreasing to 3 gigatons (Gt) (Figure 3) but indirect emissions, primarily from the power and heat transformation sector, rising to 6.8 Gt. This 1.4% rise in indirect emissions reflects increased electricity use in building operations. The U.S. saw a rise in building emissions due to extreme weather and increasing heating and cooling demands (Magrini, Lentini, Cuman, et al., 2020). To meet Net Zero Energy Building (NZEB) targets, emissions must drop by 9% annually until 2030 (Pham, Huynh, & Nasir, 2020). Additionally, 2.5 Gt of CO2 emissions were linked to building construction, mainly from energy-intensive materials like steel, aluminum, and cement, underscoring the need for sustainable materials, energy efficiency, and low-carbon technologies.

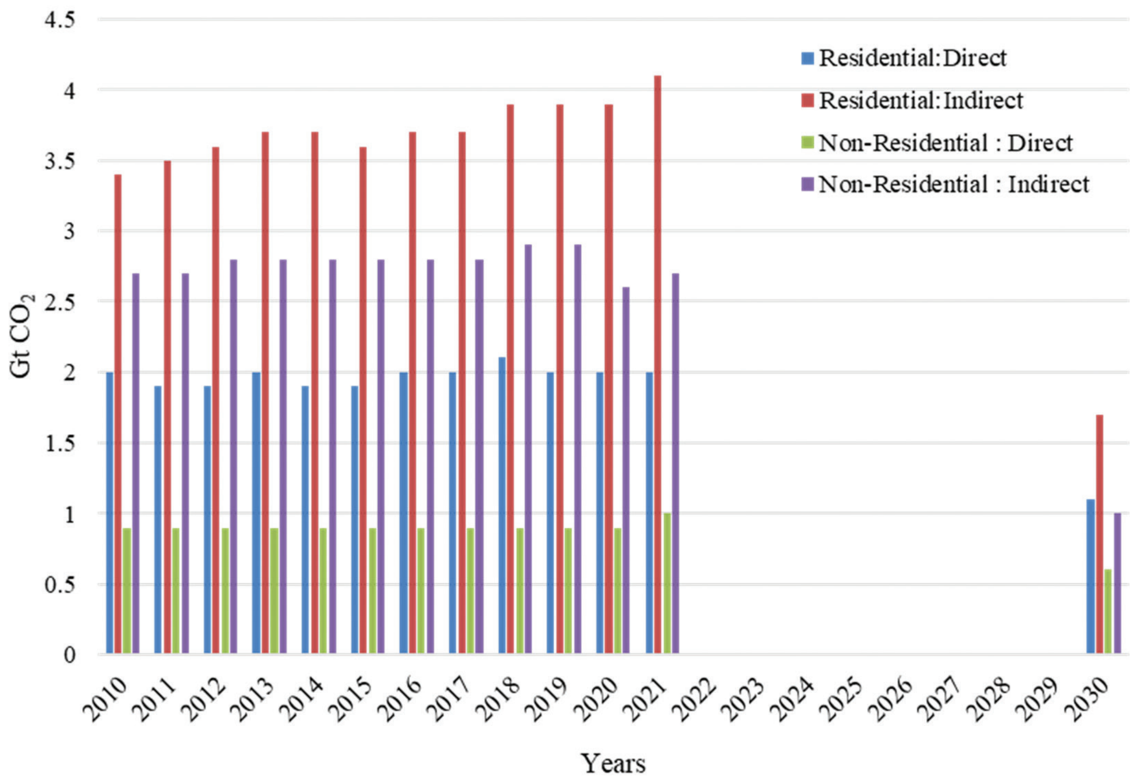

Figure 3: Trajectory of global CO_2 emissions from building operations under the Net Zero Scenario, spanning from 2010 to 2030.

Relationship Between Residential Energy Usage and Emissions

Fossil energy sources constitute 80% of global energy and are a source of GHG emissions, ozone depletion, and climate change among others (Brown, Soni, Lapsa, et al., 2020). Therefore, an attempt to unravel the acceptable emission reduction measures reveals that the world continues to pump twice the level of emissions it did 40 years ago, with CO_2 emissions standing at 32 billion tons in 2011 and expected to produce 36 billion tons of emissions by 2020 (Ibn-Mohammed, Greenough, Taylor, et al., 2013). Power generation, the fourth highest emitter of CO_2, is elongating global warming through elevated cooling demands as well as indoor humidity levels (Kabeyi & Olanrewaju, 2022) and calls for proper energy procedures in constructing and utilizing residences.

Understanding the Carbon Footprint of New House Construction

The carbon footprint of new house construction varies based on size, materials, and energy sources. An average house generates 80-100 metric tons of embodied emissions (from material production) and 2-5 metric tons of annual operational emissions (from heating, cooling, and electricity) (Bouramdane, 2023). Lifecycle emissions can range from tens to hundreds of metric tons. Using energy-efficient systems and renewable energy, along with integrating low-carbon materials like timber, can reduce a house's environmental impact (Chau, Leung, & Ng, 2015). The paper highlights the importance of sustainable building practices and policies to address the significant emissions from the building sector, especially in suburban areas.

Energy Regulations for the Suburban Areas

Suburban green energy strategies started due to the 1973 oil crisis were primarily aimed at reducing energy demands – cutting down greenhouse gases, exhaustion of fossil energy sources, and developments in renewable energies (Dunham-Jones & Williamson, 2011). These attempts have gradually been extended over the last 40 years to tackle greenhouse gases, fossil fuel depletion, and renewable energy progress by 2010, slightly over 118 countries have had policies on energy efficiency through BECs, appliance standards, and consumer information Building (Ghosh, 2023)..

Transitioning from Prescriptive to Performance-Based BECs

BECs are subdivided into prescriptive and performance-based, and the latter is considered more efficient, as it establishes certain energy level requirements for building constructions. Today there is performance-based BECs in Denmark, France and Tunisia (Gottdiener, Hohle, & King, 2019). These standards themselves have to be constantly changing with the goals that are set for energy and its relevance. More recently, there has been a growing interest in the next-generation BECs for near-zero energy buildings that optimise energy supply and demand with renewable energy generation within the buildings (Graham & Rawal, 2018). The shift I will be discussing is a progressive achievement towards establishing and maintaining energy conservation, cutting down greenhouse emissions, and increasing the green and resilience of buildings.

Assessing the Recent Energy Policies in Mitigating Global Warming

The 2009 Copenhagen Climate Summit aimed to limit global temperature rise to 2°C to prevent severe impacts on weather, sea levels, and ecosystems (Griffiths, Sovacool, Furszyfer Del Rio, et al., 2023). Achieving this target requires substantial reductions in energy use and GHG emissions across all sectors. Suburban areas play a crucial role in this, contributing significantly to global GHG emissions through household energy use. By 2030, efforts in these areas could save 7.3 gigatons of CO_2 annually, with suburbs contributing about 25% of this reduction (Jain, Siva, Hoppe, & Bressers, 2020). Implementing rigorous energy efficiency standards and reducing installation costs are essential for achieving significant global reductions in building energy demand and fostering a sustainable built environment (Li, Li, Xia, et al., 2023).

Energy Consumption, Policies, and CO_2 Emissions in India's Suburban Areas

With 36% of total final consumption (TFC) coming from suburban areas, the world's energy consumption is dominated by this sector (Figure 4). In 2012, India was the fourth largest consumer of natural gas and crude oil but imports about 80% of its crude oil and 22% of its natural gas (Omer, 2018). Economic growth has led to increased energy use, especially in suburban areas, which consume over 36% of the country's energy. Biomass remains the primary energy source for over 0.8 billion households, particularly in rural regions. Projected increases in electricity demand in metropolitan areas are expected to rise eight-fold by 2050 as traditional biomass is replaced by efficient technologies (Mac Kinnon, Brouwer & Samuelsen,

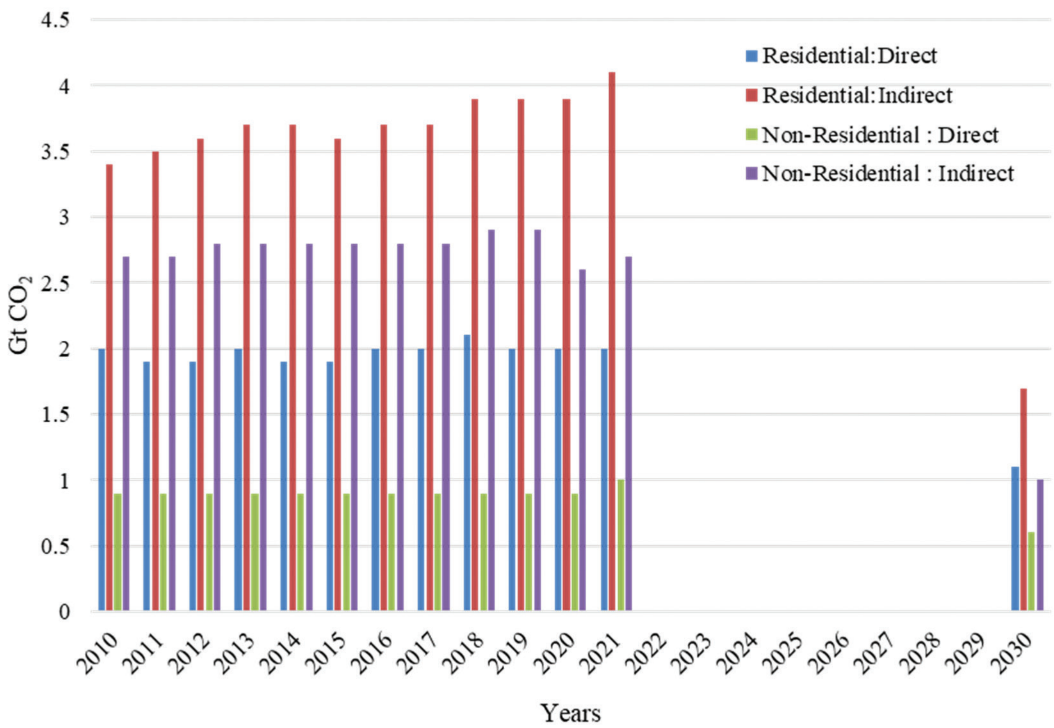

Figure 4: Suburban areas constitute a significant 36% of the total final consumption (TFC), emerging as the leading sector in global energy consumption.

2018). Despite India's voluntary BECs from 2007 and 2008, only two out of fifteen states mandate their implementation. Strengthening these codes and transitioning to green energy are crucial for reducing GHG emissions and meeting climate goals (Mikhail, Mather, Parker & Kapsis, 2023).

Indian BECs: Paving the Way for Sustainable Construction

India is on the vanguard of a considerable commercial expansion, and by 2030, over one billion square meters of new commercial floor space are expected. At present, residential sectors are first in terms of carbon footprint (Figure 5). Indian buildings are the second-largest energy guzzlers and are projected to become the largest by 2030. Beginning in 2007, BECs were adopted to target immediate improvements in energy efficiency during construction (Jain, Siva, Hoppe, & Bressers, 2020; Mikhail, Mather, Parker & Kapsis, 2023).

These codes have significant energy-saving opportunities necessary for India to comply with its Paris Climate Agreement commitments. Although the energy-saving benefits of these standards have been partially realised, more can be done to ensure that a fixture maximises its capacity (Hanif, 2018). Tips: It is important to meet the target of India's ECBC has

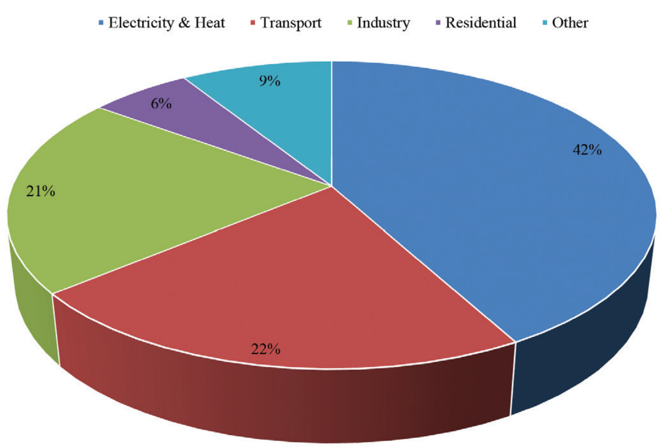

Figure 5: Carbon Footprint - Sector-specific CO_2 emissions worldwide, offering a snapshot of the global environmental landscape.

been described above. Now abbreviation is enough. Same has been done to BEC. Thanks ECBC in order to achieve energy savings and emissions reductions. The construction of commercial buildings was happening at a lightning pace (Li, Mao, Wang & Wu, 2023).

Introducing Fresh Initiatives for Energy Efficiency

In June last year, as part of the "Azadi Ka Amrut Mahotsav" celebrations, India launched the "Towards

Sustainable Habitat: Business activity description: The start of the “2021 New Building Energy Efficiency Initiatives” program. Some of the measures included under this scheme executed by the Bureau of Energy Efficiency (BEE) are the online building materials directory, training and development of new employees, and recognition of national-level awards for innovative designs in energy efficient buildings (Mikhail, Mather, Parker & Kapsis, 2023).. The energy code for the year 2021 known as the “Eco Niwas Samitha 2021” extended only to the building envelope before, but all the building systems are now included in it. They help to promote energy saving and promises and efforts to achieve net zero emissions in India The implemented measures are part of Indian sustainable development and contributions made by India to the framework of climate and the Paris Agreement.

Discussion and Summary

The discussion integrates global and Indian perspectives on energy dynamics, carbon emissions, and advancements in building codes. Rapid urbanisation and population growth, especially in developing countries like India, drive increasing energy demand and emissions, highlighting the need for comprehensive energy strategies. The construction sector plays a critical role in global carbon emissions, emphasizing the importance of sustainable building designs and materials. Transitioning from prescriptive to performance-based BECs reflects global trends toward flexible energy policies (Mazur, Bac,Vaverkova et al., 2022). India’s efforts to update building codes and adopt energy-efficient practices offer insights into policy-driven change. The growing population, urbanisation, and appliance ownership in developing countries further increase energy consumption. The analysis stresses the need for integrated approaches combining building codes, energy-efficient technologies, and sustainable urban planning to achieve significant reductions in carbon emissions and ensure energy sustainability. Global and local actions are essential to steering development toward sustainable and energy-efficient practices.

Conclusions

This paper synthesises global energy dynamics, particularly in suburban areas, with a focus on rising energy consumption, carbon emissions from construction, and evolving energy regulations. It highlights the intricate relationship between urbanisation, economic development, and energy demand, emphasising the need for sustainable building practices and materials to reduce carbon footprints (Allioui & Mourdi, 2023).. The transition from prescriptive to performance-based BECs and India’s advancements in energy efficiency offer valuable insights for global sustainable urban development. Addressing operational and embodied emissions is crucial for carbon reduction, and policy-driven initiatives play a key role. The paper underscores the need for integrated, multi-faceted approaches, involving policymakers and communities, to tackle energy consumption, climate change, and urbanisation (Bhardwaj, Tewari, & Natarajan, 2023). The insights provide a roadmap for future research, policy-making, and practical solutions aimed at achieving energy-efficient, low-carbon, and sustainable development globally.

Conflicts of Interest

The authors declare no conflicts of interest.

Author Contributions

Conceptualization, S.S; methodology, G.M; software, S.S; validation, S.K.G and M.M; formal analysis, S.S; investigation, S.K; resources, S.S; data curation, S.S and M.M; writing—original draft preparation, S.S; writing—review and editing, S.S and S.K.S; visualization, S.K.G; supervision, S.K.S; project administration, S.K.S. All authors have read and agreed to the published version of the manuscript.

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References

Agrawal, S., Mani, S., Aggarwal, D., Hareesh, C., Kumar, K.G. and Jain, A., 2020. Awareness and adoption of energy efficiency in Indian homes. Council on Energy, Environment and Water, New Delhi.

Alabid, J., Bennadji, A. and Seddiki, M., 2022. A review on the energy retrofit policies and improvements of the UK existing buildings, challenges and benefits. *Renewable and Sustainable Energy Reviews*, **159:** 112161. https://doi.org/10.1016/j.rser.2022.112161

Allioui, H. and Mourdi, Y., 2023. Exploring the full potentials of iot for better financial growth and stability:

A comprehensive survey. *Sensors*, **23:** 8015. https://doi.org/10.3390/s23198015

Amado, M. and Poggi, F., 2022. Sustainable Energy Transition for Cities. Elsevier.

Arehart, J.H., Hart, J., Pomponi, F. and D'Amico, B., 2021. Carbon sequestration and storage in the built environment. *Sustainable Production and Consumption*, **27:** 1047-1063. https://doi.org/10.1016/j.spc.2021.02.028

Arıoğlu Akan, M.Ö., Dhavale, D.G. and Sarkis, J., 2017. Greenhouse gas emissions in the construction industry: An analysis and evaluation of a concrete supply chain. *Journal of Cleaner Production*, **167:** 1195-1207. https://doi.org/10.1016/j.jclepro.2017.07.225

Azimi, S., Hon, C.K.H., Tyvimaa, T. and Skitmore, M., 2023. Barriers to energy efficiency: Low-income households in Australia. *Buildings*, **13:** 954. https://doi.org/10.3390/buildings13040954

Bandyopadhyay, K. and Thukral, K.L., 2010. Passenger road transport in India: Major challenges in reducing energy consumption and CO_2 emissions and ways ahead. MPRA Paper No. 25764

Bansal, M., Saini, R.P. and Khatod, D.K., 2013. Development of cooking sector in rural areas in India—A review. *Renewable and Sustainable Energy Reviews*, **17:** 44-53. https://doi.org/10.1016/j.rser.2012.09.014

Bauner, C. and Crago, C.L., 2015. Adoption of residential solar power under uncertainty: Implications for renewable energy incentives. *Energy Policy*, **86:** 27-35. https://doi.org/10.1016/j.enpol.2015.06.009

Belussi, L., Barozzi, B., Bellazzi, A., et al., 2019. A review of performance of zero energy buildings and energy efficiency solutions. *Journal of Building Engineering*, **25:** 100772. https://doi.org/10.1016/j.jobe.2019.100772

Berwal, A.K. and Yadav, M., 2021. Retrofit strategy in existing building for implementing energy conservation building code in India. *European Journal of Engineering and Technology Research*, **6:** 134-140. https://doi.org/10.24018/ejers.2021.6.5.2535

Bhardwaj, S., Tewari, D. and Natarajan, B., 2023. Energy Efficiency (EE) for Climate Action: Evolution of India's EE Policies and Way Forward. *In:* The Handbook of Energy Policy, pp. 645-681. Singapore: Springer Nature Singapore.

Bouramdane, A.-A., 2023. Optimal water management strategies: Paving the way for sustainability in smart cities. *Smart Cities*, **6:** 2849-2882. https://doi.org/10.3390/smartcities6050128

Brown, M.A., Soni, A., Lapsa, M.V., et al., 2020. High energy burden and low-income energy affordability: conclusions from a literature review. *Progress in Energy*, **2:** 042003. https://doi.org/10.1088/2516-1083/abb954

Cao, X., Dai, X. and Liu, J., 2016. Building energy-consumption status worldwide and the state-of-the-art technologies for zero-energy buildings during the past decade. *Energy and Buildings*, **128:** 198-213. https://doi.org/10.1016/j.enbuild.2016.06.089

Carley, M. and Christie, I., 2017. Managing Sustainable Development. Routledge

Casini, M., 2016. Smart Buildings. Woodhead Publishing.

Chau, C.K., Leung, T.M. and Ng, W.Y., 2015. A review on life cycle assessment, life cycle energy assessment and life cycle carbon emissions assessment on buildings. *Applied Energy*, **143:** 395-413. https://doi.org/10.1016/j.apenergy.2015.01.023

Chel, A. and Kaushik, G., 2018. Renewable energy technologies for sustainable development of energy efficient building. *Alexandria Engineering Journal,* **57:** 655-669. https://doi.org/10.1016/j.aej.2017.02.027

Churkina, G., Organschi, A., Reyer, C.P.O., et al., 2020. Buildings as a global carbon sink. *Nature Sustainability*, **3:** 269-276. https://doi.org/10.1038/s41893-019-0462-4

Clarke, S., Kersey, J., Trevorrow, E., Wilby, R., Shackley, S., Turnpenny, J., Wright, A., Hunt, A. and Crichton, D., 2002. London's Warming: The Impacts of Climate Change on London. London Climate Change Partnership .

Clay, Jr. L., 2021. Integrative Ecosystem Management: Designing Cities and Co-creating the Flourishing Ecosystem. Case Western Reserve University. OECD Working Paper.

Corfee-Morlot J, Marchal V, Kauffmann C, Kennedy C, Stewart F, Kaminker C, Ang G (2012) Towards a green investment policy framework: The case of low-carbon, climate-resilient infrastructure.

Dafnomilis, I., den Elzen, M. and van Vuuren, D.P., 2023. Achieving net-zero emissions targets: An analysis of long-term scenarios using an integrated assessment model. *Annals of the New York Academy of Sciences*, **1522:** 98-108. https://doi.org/10.1111/nyas.14970

De Genaro Chiroli, D.M., Menezes, M.G., Zola, F.C., et al., 2023. Integrating resilience and sustainability: A systematic analysis of resilient cities using ISO 37123. *International Journal of Disaster Risk Reduction*, **96:** 103960. https://doi.org/10.1016/j.ijdrr.2023.103960

Du, Y., Zhao, D., Jiang, M., et al., 2022. Local and non-local drivers of consumption-based water use in China during 2007–2015: Perspective of metacoupling. *Journal of Environmental Management*, **312:** 114940. https://doi.org/10.1016/j.jenvman.2022.114940

Dunham-Jones, E. and Williamson J., 2011. Retrofitting Suburbia, Updated Edition. John Wiley & Sons

EI Kenawy, A.M., Al-Awadhi, T., Abdullah, M., et al., 2023. A preliminary assessment of global CO_2: Spatial patterns, temporal trends, and policy implications. *Global Challenges*, **7:** 2300184. https://doi.org/10.1002/gch2.202300184

Farzaneh, H., Malehmirchegini, L., Bejan, A., et al., 2021. Artificial intelligence evolution in smart buildings for energy efficiency. *Applied Sciences*, **11:** 763. https://doi.org/10.3390/app11020763

Fekete, H., Kuramochi, T., Roelfsema, M., et al., 2021. A review of successful climate change mitigation policies in major emitting economies and the potential of global replication. *Renewable and Sustainable Energy Reviews*, **137:** 110602. https://doi.org/10.1016/j.rser.2020.110602

Fernandes, J., Santos, M.C. and Castro, R., 2021. Introductory review of energy efficiency in buildings retrofits. *Energies*, **14:** 8100. https://doi.org/10.3390/en14238100

Ghosh, A., 2023. Can India become a green superpower? The stakes of the world's most important energy transition. *Foreign Affairs*, **102:** 144.

Gielen, D., Boshell, F., Saygin, D., et al., 2019. The role of renewable energy in the global energy transformation. *Energy Strategy Reviews*, **24:** 38-50. https://doi.org/10.1016/j.esr.2019.01.006

González-Torres, M., Pérez-Lombard, L., Coronel, J.F., et al., 2022. A review on buildings energy information: Trends, end-uses, fuels and drivers. *Energy Reports*, **8:** 626-637. https://doi.org/10.1016/j.egyr.2021.11.280

Gottdiener, M., Hohle, R. and King, C., 2019. The New Urban Sociology. Routledge

Graham, P. and Rawal, R., 2018. Achieving the 2°C goal: The potential of India's building sector. *Building Research & Information*, **47:** 108-122. https://doi.org/10.1080/09613218.2018.1495803

Griffiths, S., Sovacool, B.K., Furszyfer Del Rio, D.D., et al., 2023. Decarbonizing the cement and concrete industry: A systematic review of socio-technical systems, technological innovations, and policy options. *Renewable and Sustainable Energy Reviews*, **180:** 113291. https://doi.org/10.1016/j.rser.2023.113291

Guo, Q., Zeng, D. and Lee, C.-C., 2023. Impact of smart city pilot on energy and environmental performance: China-based empirical evidence. *Sustainable Cities and Society*, **97:** 104731. https://doi.org/10.1016/j.scs.2023.104731

Hanif, I., 2018. Impact of fossil fuels energy consumption, energy policies, and urban sprawl on carbon emissions in East Asia and the Pacific: A panel investigation. *Energy Strategy Reviews*, **21:** 16-24. https://doi.org/10.1016/j.esr.2018.04.006

Hasanbeigi, A., Price, L. and Lin, E., 2012. Emerging energy-efficiency and CO_2 emission-reduction technologies for cement and concrete production: A technical review. *Renewable and Sustainable Energy Reviews*, **16:** 6220-6238. https://doi.org/10.1016/j.rser.2012.07.019

Hoegh-Guldberg, O., Jacob, D., Taylor, M., et al., 2019. The human imperative of stabilizing global climate change at 1.5°C. *Science*, **365:** 6974. https://doi.org/10.1126/science.aaw6974

Holmes, M.J. and Hacker, J.N., 2007. Climate change, thermal comfort and energy: Meeting the design challenges of the 21st century. *Energy and Buildings*, **39:** 802-814. https://doi.org/10.1016/j.enbuild.2007.02.009

Ibn-Mohammed, T., Greenough, R., Taylor, S., et al., 2013. Operational vs. embodied emissions in buildings—A review of current trends. *Energy and Buildings*, **66:** 232-245. https://doi.org/10.1016/j.enbuild.2013.07.026

Jain, M., Siva, V., Hoppe, T. and Bressers, H., 2020. Assessing governance of low energy green building innovation in the building sector: Insights from Singapore and Delhi. *Energy Policy*, **145:** 111752. https://doi.org/10.1016/j.enpol.2020.111752

Jing, R., Wang, M., Zhang, R., et al., 2017. A study on energy performance of 30 commercial office buildings in Hong Kong. *Energy and Buildings*, **144:** 117-128. https://doi.org/10.1016/j.enbuild.2017.03.042

Joensuu, T., Edelman, H. and Saari, A., 2020. Circular economy practices in the built environment. *Journal of Cleaner Production*, **276:** 124215. https://doi.org/10.1016/j.jclepro.2020.124215

Kabeyi, M.J.B. and Olanrewaju, O.A., 2022. Sustainable energy transition for renewable and low carbon grid electricity generation and supply. *Frontiers in Energy Research*, **9:** 743114. https://doi.org/10.3389/fenrg.2021.743114

Kirikkaleli, D. and Adebayo, T.S., 2021. Do public-private partnerships in energy and renewable energy consumption matter for consumption-based carbon dioxide emissions in India? *Environmental Science and Pollution Research*, **28:** 30139-30152. https://doi.org/10.1007/s11356-021-12692-5

Lawn, P., 2016. Resolving the Climate Change Crisis. Springer, 628 p.

Li, B., You, L., Zheng, M., et al., 2020. Energy consumption pattern and indoor thermal environment of residential building in rural China. *Energy and Built Environment*, **1:** 327-336. https://doi.org/10.1016/j.enbenv.2020.04.004

Li, Y., Li, S., Xia, S., et al., 2023a. A review on the policy, technology and evaluation method of low-carbon buildings and communities. *Energies*, **16:** 1773. https://doi.org/10.3390/en16041773

Li, Y., Mao, Y., Wang, W. and Wu, N., 2023b. Net-zero energy consumption building in China: An overview of building-integrated photovoltaic case and initiative toward sustainable future development. *Buildings*, **13:** 2024. https://doi.org/10.3390/buildings13082024

Lorincz, J., Capone, A. and Wu, J., 2019. Greener, Energy-efficient and sustainable networks: state-of-the-art and new trends. *Sensors*, **19:** 4864. https://doi.org/10.3390/s19224864

Mac Kinnon, M.A., Brouwer, J. and Samuelsen, S., 2018. The role of natural gas and its infrastructure in mitigating greenhouse gas emissions, improving regional air quality, and renewable resource integration. *Progress in Energy and Combustion Science*, **64:** 62-92. https://doi.org/10.1016/j.pecs.2017.10.002

Magrini, A., Lentini, G., Cuman, S., et al., 2020. From nearly zero energy buildings (NZEB) to positive energy buildings (PEB): The next challenge - The most recent European trends with some notes on the energy analysis of a forerunner PEB example. *Developments in the Built Environment*, **3:** 100019. https://doi.org/10.1016/j.dibe.2020.100019

Mazur, Ł., Bać, A., Vaverková, M.D., et al., 2022. Evaluation of the quality of the housing environment using multi-criteria analysis that includes energy efficiency: A review. *Energies*, **15:** 7750. https://doi.org/10.3390/en15207750

Meleshko, V.P., Pavlova, T., Bobylev, L.P. and Golubkin, P., 2020. Current and Projected Sea Ice in the Arctic in the Twenty-First Century. *In:* Johannessen, O., Bobylev, L., Shalina, E., Sandven, S. (eds) Sea Ice in the Arctic. Springer Polar Sciences. Springer, Cham.

Mikhail, M., Mather, D., Parker, P. and Kapsis, K., 2023. Net-positive office commissioning and performance gap assessment: Empirical insights. *Energy and Buildings*, **279:** 112717. https://doi.org/10.*1016/j.enbuild.2022.*11**2717**

Min, J., Yan, G., Abed, A.M., et al., 2022. The effect of carbon dioxide emissions on the building energy efficiency. *Fuel*, **326:** 124842. https://doi.org/10.1016/j.fuel.2022.124842

Omer, M.A., 2018. Sustainable development in green energies and the environment. *Trends in Green Chemistry*, **04:** 009. https://doi.org/10.21767/2471-9889-c1-009