NITI Aayog

SCENARIOS TOWARDS VIKSIT BHARAT AND NET ZERO

SECTORAL INSIGHTS: BUILDINGS

(VOL. 5)

NITI Aayog
Government of India,
Sansad Marg, New Delhi–110001, India

Suggested Citation

NITI Aayog. (2026). Scenarios Towards Viksit Bharat and Net Zero - Sectoral Insights: Buildings (Vol. 5)

Available at: https://niti.gov.in/publications/division-reports

Disclaimer

1. This document is not a statement of policy by the National Institution for Transforming India (hereinafter referred to as NITI Aayog). It has been prepared by the Green Transition, Energy & Climate Change Division of NITI Aayog under various Inter-Ministerial Working Groups (IMWGs) constituted to develop Net Zero pathways for India.
2. Unless otherwise stated, NITI Aayog, in this regard, has not made any representation or warranty, express or implied, as to the completeness or reliability of the information, data, findings, or methodology presented in this document. While due care has been taken by the author(s) in the preparation of this publication, the content is based on independently procured information and analysis available at the time of writing and may not reflect the most current policy developments or datasets.
3. The assertions, interpretations, and conclusions expressed in this report are those of the author(s) and do not necessarily reflect the views of NITI Aayog or the Government of India, unless otherwise mentioned. As such, NITI Aayog does not endorse or validate any of the specific views or policy suggestions made herein by the author(s).
4. NITI Aayog shall not be liable under any circumstances, in law or equity, for any loss, damage, liability, or expense incurred or suffered as a result of the use of or reliance upon the contents of this document. Any reference to specific organisations, products, services, or data sources does not constitute or imply an endorsement by NITI Aayog. Readers are encouraged to independently verify the data and conduct their analysis before forming conclusions or taking any policy, academic, or commercial decisions.

सत्यमेव जयते

NITI Aayog

SCENARIOS TOWARDS
VIKSIT BHARAT AND NET ZERO

SECTORAL INSIGHTS: BUILDINGS

(VOL. 5)

डॉ. विनोद कुमार पॉल
सदस्य
Dr. Vinod K. Paul
MEMBER

सत्यमेव जयते

भारत सरकार
नीति आयोग
संसद मार्ग, नई दिल्ली – 110001
Government of India
NATIONAL INSTITUTION FOR TRANSFORMING INDIA
NITI Aayog
Sansad Marg, New Delhi – 110001
Tele.: 23096809, 23096820
E-mail: vinodk.paul@gov.in

February 4, 2026

Foreword

Under the visionary leadership of the Hon'ble Prime Minister, Shri Narendra Modi, India has placed sustainable and inclusive growth at the heart of its journey to a Viksit Bharat by 2047. Our G20 Presidency amplified India's voice as a trusted partner of the global community and reaffirmed our ancient conviction, Vasudhaiva Kutumbakam - that development and climate action must advance together.

This roadmap on decarbonising India's buildings reflects that conviction. Buildings touch every citizen's life - where we live, learn, heal, and work. As urbanisation accelerates, the choices we make today in planning, materials, design, construction, and operations will lock in comfort, affordability, and emissions outcomes for decades. An integrated, lifecycle approach that links efficiency, clean energy, resilient urban design, circularity in materials, performance disclosure monitoring, and skilled livelihoods is therefore essential.

Reforms are the enabling spine of this transformation. Clear, forward-looking codes and standards; competitive and predictable markets for low-carbon materials and efficient appliances; innovative finance and public procurement; and reliable data systems for measurement and verification will together de-risk investment and unleash entrepreneurship. Equally vital is coordination among the Centre, States, and cities, as well as strong partnerships across industry, academia, and civil society.

Mission LiFE translates our civilisational ethos into daily action. From architects adopting climate-appropriate design and masons installing efficient systems, to startups innovating in green materials and households choosing star-rated appliances, India's citizens are the true protagonists of this transition - Sabka Prayas turning ambition into impact. The co-benefits are compelling: reduced bills and peak loads, healthier indoor environments, competitive industries, high-quality jobs, and cooler, more liveable cities.

This report offers a pragmatic pathway, ambitious yet implementable, grounded in India's realities and opportunities. It is not a call for incrementalism, but for coordinated, time-bound action that marries growth with stewardship. Sustainability is not an external obligation for India; it is an expression of who we are as a people - trustees of nature, prudent with resources, and steadfast in ensuring that progress reaches the last mile.

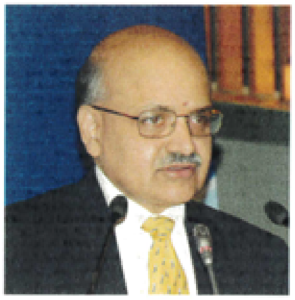
I commend the contributors to this report, especially the Alliance for an Energy Efficient Economy (AEEE) for providing inputs on modelling assumptions, supporting research and analysis, and compiling the roadmap. I invite all stakeholders to read this report and join in building a modern, green, and resilient Atmanirbhar, Viksit Bharat.

(Vinod Paul)

बी. वी. आर. सुब्रह्मण्यम
B.V.R. Subrahmanyam
मुख्य कार्यकारी अधिकारी
Chief Executive Officer

सत्यमेव जयते

भारत सरकार
नीति आयोग, संसद मार्ग
नई दिल्ली - 110 001
Government of India
National Institution for Transforming India
NITI Aayog, Parliament Street,
New Delhi - 110 001
Tel. : 23096576, 23096574
E-mail : ceo-niti@gov.in



FOREWORD

As we advance towards the vision of Viksit Bharat 2047, our ambition extends beyond accelerated economic growth to encompass sustainable, inclusive and resilient development. The Buildings sector is central to realising this vision. With the increase in income and urbanization expected in future, our built space is expected to more than double in the coming decades. As per our projections, most of the building stock that is expected to exist in 2070 is yet to be built. We are adding nearly one billion square metres of new floor area each year. This offers us an unprecedented opportunity to embed energy efficient systems, low-carbon materials and climate resilience from the outset. We can avoid far higher costs and locked-in inefficiencies of retrofitting.

With this objective, NITI Aayog undertook a detailed assessment of the Buildings sector as part of the overall study on developing India's pathways to Viksit Bharat and Net Zero. The working group has examined the future roadmap of both residential and commercial sectors. It has examined the role of present and emerging technologies in building materials and also appliances.

The comprehensive analysis suggests that the sector is expected to see new challenges. The rise in incomes coupled with increasing peak temperatures is likely to lead to a surge in cooling energy demand. Cooling is no longer a luxury, instead it is becoming a necessity. Therefore, building designs must incorporate thermal comfort. Air conditioners are among the fastest growing appliances and they will impact India's future electricity demand. Data Centres are also expected to be major drivers of future electricity demand.

This report outlines a pragmatic, phased pathway grounded in robust data, and detailed discussions with all stakeholders. It offers key interventions including stronger building codes and market incentives. The report highlights the choices that we should make today to shape prosperity for future generations.

I thank Dr. V. K. Paul, Member, NITI Aayog, for chairing the working group. I also thank all working group members for their keen involvement and devoting quality time. I thank the Alliance for Energy Efficient Economy (AEEE) as the lead knowledge partner supporting the working group. I congratulate the NITI Aayog team led by Dr. Anshu Bharadwaj, Shri Rajnath Ram, Shri Venugopal Mothkoor, Dr. Anjali Jain and Shri Nitin Bajpai, for their outstanding efforts. I am confident the findings of this report will guide policymakers across all related fields.

Dated: 4th February, 2026 **[B.V.R. Subrahmanyam]**

स्वच्छ भारत
एक कदम स्वच्छता की ओर

Authors and Acknowledgement

Chairperson

Dr. V.K. Paul

Member, NITI Aayog

Leadership

Sh. Suman Bery

Vice Chairman, NITI Aayog

Sh. B.V.R. Subrahmanyam

CEO, NITI Aayog

Dr. Anshu Bharadwaj

Programme Director, Green Transition, Energy & Climate Change Division, NITI Aayog

Sh. Rajnath Ram

Advisor, Energy, NITI Aayog

Core Modelling Team

Sh. Venugopal Mothkoor

Senior Specialist, NITI Aayog

Dr. Anjali Jain

Consultant Grade II, NITI Aayog

Sh. Nitin Bajpai

Consultant, NITI Aayog

Authors

NITI Aayog

Sh. Venugopal Mothkoor

Energy and Climate Modelling Specialist, NITI Aayog

Sh. Nitin Bajpai

Consultant, NITI Aayog

Dr. Anjali Jain

Consultant II, NITI Aayog

Lead Authors

Dr. Satish Kumar,

President & Executive Director, AEEE

Ms. Pratima Washan

Senior Expert, AEEE

Dr. Rana Veer Pratap Singh

Principal Research Associate, AEEE

Sh. Upendra Dwivedi

Manager, AEEE

Ms. Stuti Goyal

Research Associate, AEEE

Knowledge Partner

Sh. Prasun Pandey

Manager, CLASP

Peer Reviewers

Sh. Sharath Pallerla

Scientist G, MoEF&CC

Sh. Ajay Raghava

Scientist E, MoEF&CC

Ms. Neha Dhingra

Director, CLASP

Sh. Kishore Kumar
Senior Manager, CLASP

Ms. Ramya Natarajan
Research Scientist, CSTEP

Sh. Tarun Garg
Principal, RMI India

Sh. Sri Harsha
Manager, RMI India

Dr. Sunil Kumar Sansaniwal
Consultant, NITI Aayog

Dr. Sapna Bisht
Consultant, NITI Aayog

Technical Editors

Smt Aastha Manocha
Editor and Communication Consultant (Independent)

Ms. Rishu Nigam
Lead Editor and Communication Consultant (Independent)

Sanjay Chaurasia
Consultant – Graphics & DTP Designer, AEEE

Working Group Members

Ms. Anna Roy,
Principal Economic Adviser, NITI Aayog

Sh. Rajnath Ram
Member Secretary of Working Group-Adviser, Energy, NITI Aayog

Sh. Vishal K. Sinha
Young Professional, NITI Aayog (Working Group Coordinator)

Dr. Shailesh Kumar Agrawal
Executive Director, BMTPC, MoHUA

Sh. Gaya Prasad
Deputy Director General, MoRD

Sh. Ashish Shinde
Joint Director (RH), MoRD

Sh. R K Gautam
Deputy Director General, MoHUA

Sh. Divyanshu Jha
Deputy Secretary, MNRE

Sh. Ajay Raghava
Scientist E, MoEFCC

Sh. Deepak Shrivastav
Director, MoPNG

Sh. Ashok Kumar
Deputy Director General, BEE

Prof. Milind Kollegal
Member, Council of Architecture (COA)

Sh. R K Oberoi
Registrar, Council of Architecture

Dr. Sanjukkta Bahaduri
Director, School of Planning & Architecture

Ms. Debolina Kundu
Director, NIUA

Dr. Yash Shukla
Principal Research and Centre Head, CEPT

Sh. Soumen Maity
Assistant Vice President, Development Alternatives

Dr. Satish Kumar
President and Executive Director, AEEE

Sh. Tarun Garg
Principal, RMI India

Sh. Bishal Thapa
Senior Director, CLASP

Sh. Sanjay Seth
Senior Director, TERI

Sh. Yatin Choudhary
Fellow – Sustainable Buildings Division, TERI

Ms. Ramya Natarajan
Research Scientist, CSTEP

Sh. Aditya Chunekar
Fellow, Prayas

Collaborators/Expert Consultants

Sh. Hari Krishna
Director General, CREDAI

Smt Jaicy Paul,
Chief General Manager (ESG & CFU), State Bank of India

Sh. Aun Abdullah
Vice President, Lodha Group

Dr. Sameer Maithel
Independent consultant

Sh. O.P. Badlani
Technical expert-Owner, Prayag Clay, Varanasi

Sh. Sandeep Ahuja
Technical Expert- Zigzag Technology

Sh. Anand Damle
Director, Damle Clay Structurals Private Limited

Sh. Pritpal Singh
Executive Director, Department of Science, Technology & Environment, Government of Punjab

Dr. Nipun Batra
Associate Professor, CSE, IIT Gandhinagar

Sh. Nihar Shah
Presidential Director of the Global Cooling Program, Lawrence Berkeley National Laboratory (LBNL)

Sh. Pradeep K. Mukherjee
Technical Consultant, Climate, CLASP

Prof M V Rane
Department of Mechanical Engineering, IIT Bombay

Sh. Rajeev Ralhan
Partner and Leader, Clean Energy, PwC India

Ms. Shalu Agrawal
Director, Programmes Power Markets, CEEW

Communication and Research & Networking Division, NITI Aayog

Ms. Anna Roy
Programme Director, Research & Networking

Sh. Yugal Kishore Joshi
Lead, Communication

Ms. Keerti Tiwari
Director, Communication

Dr. Banusri Velpandian
Senior Specialist, Research and Networking

Ms. Sonia Sachdeva Sharma
Consultant, Communication

Sh. Sanchit Jindal
Assistant Section Officer, Research and Networking

Sh. Souvik Chongder
Young Professional, Communication

NITI Design Team

NITI Maps & Charts Team

Contents

List of Figures

List of Tables

Glossary

- **Building Lifecycle Carbon:** Lifecycle carbon in reference to buildings entails carbon emissions from all lifecycle phases, incorporating both embodied and operational carbon.
- **Carbon Emissions:** In this document, any reference to "carbon" or "carbon emissions" is to be interpreted as referring to emissions of all greenhouse gases (GHGs).
- **Cooling Degree Days (CDDs):** Cooling Degree Days (CDD) is the sum of the difference between daily average temperatures (calculated as the average of the daily minimum and maximum temperatures) and the base temperature, typically 65°F (18°C) for Indian climates, with the result being zero if the average temperature is below the base (ASHRAE Handbook Fundamentals 2021).
- **Current Policy Scenario (CPS):** The CPS refers to a trajectory where policies continue as they are today, and improvements in building design and appliance efficiency continue as per current trends. Technological advancements occur organically driven by normal innovation cycles and without any influence from aggressive policy interventions.
- **Energy Conservation and Sustainable Building Code (ECSBC):** The Bureau of Energy Efficiency (BEE) notified the Energy Conservation Building Code (ECBC) in 2007 to prescribe minimum energy performance standards for commercial buildings in India, which was subsequently revised and superseded by ECBC 2017. Building upon the ECBC 2017 framework, BEE notified the ECSBC in 2024, which expands the scope to include sustainability parameters in addition to energy efficiency, and similar to ECBC 2017 adopts a three-tier structure comprising ECSBC Compliant (mandatory), ECSBC Plus, and Super ECSBC (voluntary). The ECBC/ECSBC is applicable to commercial buildings or building complexes with a connected load of 100 kW or more or a contract demand of 120 kVA or more.
- **Eco-Niwas Samhita (ENS):** The Eco-Niwas Samhita 2024, also known as Energy Conservation and Sustainable Building Code (ECSBC) for Residential, is a consolidated energy conservation and sustainable building code that integrates the ENS Part I (Building Envelope) and, Part II (Electro-Mechanical and Renewable Energy Systems) and includes new provisions to improve the overall sustainability of residential buildings. The code applies to residential buildings or residential building complexes

which has a minimum connected load of 100 kilowatt (kW) or contract demand of 120 kilovolt ampere (kVA) or plot area of 3,000 m^2, whichever is more stringent. States and municipal bodies may change the plot area based on the prevalence in their respective areas of jurisdiction.

- **Environmental Product Declarations (EPDs):** EPD refers to a standardised method for presenting data regarding the environmental impacts of a product throughout its lifecycle.
- **Greenhouse gases (GHGs):** GHGs are gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of radiation emitted by the Earth's surface, by the atmosphere, and by clouds (IPCC 2021). This property causes the greenhouse effect. Water vapour (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and ozone (O_3) are the primary GHGs in the Earth's atmosphere. Human-made GHGs include sulphur hexafluoride (SF_6), hydrofluorocarbons (HFCs), chlorofluorocarbons (CFCs) and perfluorocarbons (PFCs); several of these are also O_3-depleting (and are regulated under the Montreal Protocol).
- **Lifecycle Assessment (LCA):** LCA refers to a methodical series of procedures for gathering and analysing the inputs and outputs of materials and energy, along with the related environmental impacts directly linked to a building, infrastructure, product, or material throughout its lifecycle. LCA can be used to assess a range of environmental impacts, including GHG emissions, acidification potential, eutrophication potential, abiotic depletion potential, etc. For this document, the term LCA is used in the context of assessing the GHG emissions associated with buildings or building materials/products over their lifecycle.
- **Lifecycle Embodied Carbon:** Lifecycle embodied carbon encompasses carbon emissions linked with materials and construction processes across the entire lifecycle of a building. This includes material extraction, transportation to the manufacturer, manufacturing, transportation to the site, construction, use phase, maintenance, repair, replacement, refurbishment, deconstruction, transportation to end-of-life facilities, processing, and disposal.
- **Minimum Energy Performance Standards (MEPS):** As per the Bureau of Energy Efficiency (BEE) in India, Minimum Energy Performance Standards (MEPS) are mandatory, government-set benchmarks for appliances and equipment, establishing the lowest acceptable energy efficiency level, below which products cannot be sold in the market, ensuring consumers get energy-saving choices and driving manufacturers to innovate for higher efficiency. The Standards and Labelling (S&L) program also establishes minimum energy performance standards that appliances must meet to be eligible for star ratings.

- **Net Positive Energy Buildings (NPEB):** As per BEE Shunya (Zero) Labelling Programme, a net-positive energy building is one that relies on renewable sources to produce as much energy as it uses and supplies excess generated electricity to grid, usually as measured over the course of a year.
- **Net Zero (NZ) Scenario:** The NZ scenario refers to a trajectory where significant improvements in building design and appliance efficiency are achieved through aggressive government policies that in turn stimulate rapid technological advancement.
- **Net Zero Energy Buildings (NZEB):** As per BEE Shunya (Zero) Labelling Programme definition, a Net Zero energy building is one that relies on renewable sources to produce as much energy as it uses, usually as measured over the course of a year.
- **Operational Carbon:** In this report operational carbon refers to carbon emissions from energy consumed during the use phase of buildings, and is associated with energy required for heating, cooling, lighting, powering appliances, and other functions necessary for day-to-day operation and comfort of the building's occupants.
- **Product Category Rules (PCRs):** PCRs are standardised guidelines used in environmental labelling and declarations, such as Environmental Product Declarations (EPDs). They detail the rules and requirements for Life Cycle Assessment (LCA) of a particular product category.
- **Standards and Labelling (S&L) program:** The Standards and Labelling programme by the Bureau of Energy Efficiency (BEE) aims to provide consumers with information about the energy efficiency of appliances, helping them make informed purchasing decisions. The program uses a star-rating system, where a higher number of stars (up to 5) indicates greater energy efficiency and potential cost savings. This helps consumers choose appliances that save energy and reduce electricity bills while also encouraging manufacturers to develop more energy-efficient products.

Executive Summary

The building sector is central to achieving India's Net Zero Emission goal while meeting Viksit Bharat 2047 development ambitions. The report lays down a strategic roadmap for low carbon growth of the sector, advocating comprehensive building codes and enabling mechanisms for market transformation including demand and supply-side interventions, research and development, and workforce skilling. To inform the policy recommendations, the energy demand projections to 2070 are structured around two scenarios: a Current Policy Scenario (CPS) reflecting business-as-usual, and a Net Zero Scenario (NZS) aligned with India's 2070 target.

Development Context and Outlook

Economic growth, increased urbanisation and the need for additional floor space: Rapid urbanisation and income growth is expanding built floor space, with total building stock projected to increase more than two times by 2070. Factoring in the demolition rate for existing buildings, 86% of the building stock that will exist in 2070 is yet to be built[i]. Much of the low-carbon transition and indeed 'infrastructure investment' need sits outside the buildings sector (e.g. power sector, as well as the industrial sector once embodied emissions from buildings are taken into account). In contrast, the Net Zero pathway pursues deep reductions through operational efficiencies, complemented by a near-zero-carbon grid by 2070 and switch to low-carbon building materials.

Better affordability & standard of living: India is currently amongst the countries with the lowest access to cooling despite the tropical climate. As economic growth spurs better standards of living and higher per capita wages, historical trends have shown that this will drive increase in appliance ownership and usage. Cooling is and will be the fastest-growing end-use. Residential Air Conditioning (RACs) ownership is projected to grow from 8% in 2022 to 65% in 2050 and 80% by 2070 in both scenarios highlighting the need for super-efficient appliances and equipment and passive building design elements to manage energy loads and peak demand at the source.

[i] Key macroeconomic assumptions informing building stock growth projections are provided in Chapter 4, Table 4.2

Increased heat stress due to climate change: India is extremely vulnerable to the negative impacts of climate change, in particular increased frequency and severity of heat waves, rainfall events, flooding, cyclones and other hazards. Severe heat waves in India are expected to increase 30 times by the end of the century even if global mean temperature rise is limited to 2 °C above pre-industrial levels[1]. Extreme heat waves will exacerbate the need for more cooling, putting further strain on energy resources and associated power infrastructure. Mitigating climate risks and heat stress is imperative for achieving India's long-term economic and development goals. This requires wider adoption of climate-responsive design, passive cooling strategies, and efficient active cooling technologies in homes and workplaces. Without these measures, rising heat will increasingly affect health, comfort, productivity, and overall economic performance. Building energy codes will inevitably need to evolve to enable this transition.

Current Policy and Technological Context

Key building-sector policies: India's policy and regulatory regime has been evolving over the past two decades to bring in an increased focus on energy efficiency, renewable energy generation and environmental issues. BEE's (Bureau of Energy Efficiency) Standards and labelling programme sets Minimum Energy Performance Standards (MEPS) and labels for appliances and equipment[2], and has facilitated a gradual shift to better efficiency alternatives. Operational energy code for new commercial building (ECBC 2007, 2017) with connected load greater than 100 kW have been adopted in 24 states & UTs. Operational energy codes for new residential buildings are yet to be adopted and remain voluntary with limited uptake to date (ENS 2018 superseded by ENS 2024). Currently, no specific policies exist to regulate embodied carbon in buildings, apart from the voluntary disclosures included in the recently launched (and yet to be adopted) building code (i.e. Energy Conservation and Sustainable Building Code (ECSBC)).

Governance structure and policy implementation: The building sector largely falls under state jurisdiction, with some aspects falling concurrently under both national and state jurisdiction. This split governance structure across ministries and state-level government bodies, and limited devolution of funds and functions to the local level, creates its own set of challenges. Both Energy Conservation and Sustainable Building Codes (ECSBC) and Eco-Niwas Samhita (ENS) are examples of well-designed policies facing implementation challenges due to fragmented governance and institutional structure, and limited devolution of funds and functions to the local level.

Technologies deployed and penetration of energy efficient alternatives: The market share of efficient technologies has been gradually increasing as cost differentials narrow down, and BEE's Standards and Labelling (S&L) programme drives market transformation.

However, there is significant scope to further drive energy efficiency improvements for certain categories of appliances based on current international practices and norms. Minimum Energy Performance Standards (MEPS) for air conditioners present the largest potential, with potential for 45% uplift to align with global best standards. MEPS for Brushless Direct Current (BLDC) motors and compressors have potential to be more stringent. The expanding market for efficient appliances can be met by domestic manufacturing, including manufacturing of key supply chain components, creates further economic opportunities. Targeted government support will be the key for commercialization.

Building materials and construction systems: Embodied emissions from key building materials, namely cement, steel, aluminium, bricks, and glass, make up 48% of the total lifecycle emissions associated with buildings in 2025[ii]. There is significant potential to reduce embodied carbon, which tends to be higher because of lower appliance penetration, by mainstreaming low-carbon alternatives to conventional materials. For example, low-carbon cements can reduce emissions by 50% compared to the ordinary Portland cement, depending on the application. Notably, red brick is a major contributor to embodied carbon in buildings but remains largely unaddressed within the existing industrial energy-efficiency policies. Prefabricated construction systems and components, though not yet mainstream, offer significant opportunities for resource and energy efficiency while enhancing build quality and structural integrity. In parallel, integrated design thinking must be embedded across disciplines to effectively manage trade-offs between operational and embodied carbon.

Modelling Approach, Scenario Outcomes, and Key Insights

Modelling Approach: The modelling results project India's building-sector energy trajectory from a baseline year of 2023 up to 2070. Energy demand is estimated for residential, commercial, and cooking uses, focusing on operational energy. Modelling method includes appliance stock and usage (residential buildings), building stock and Energy Performance Indicator (EPI) projections (commercial buildings), and fuel-mix transition (for cooking). This has been cross-checked with national planning tools (IESS, TIMES) to keep outputs policy-relevant and consistent with India's cross-sectoral Net Zero pathways.

Scenario Assumptions and Key Insights: The modelling results outline how India's building sector is likely to evolve under the Current Policy Scenario (CPS) and ambitious Net Zero Scenario (NZS) . While total built-up area expands at a similar pace across both scenarios, driven by economic growth, urbanisation, rising living standards, and the divergence emerges in how efficiently this space is built, occupied, and serviced. Electricity becomes the dominant energy carrier, and its demand profile is shaped largely by cooling needs, appliance ownership, and growth in emerging load centres such as data centres and cold chain facilities.

[ii] Refer section 3.1 for detailed narrative on analysis and assumptions.

Stronger building codes, higher compliance, low-carbon materials, and adopting best-in-class technologies play a decisive role in moderating demand growth. These measures, along with system-level interventions, help India move towards a lower-carbon, more resilient building stock aligned with long-term low-carbon transition goals. The following consolidated insights highlight the most critical shifts shaping India's building-sector energy trajectory.

- **Building stock growth and structural shifts:** Commercial and residential building stock expand 2.5 and 2 times respectively by 2070, with per-capita residential area rising from 12 m^2 to 23 m^2, reflecting urban densification and rising aspirations. This physical growth remains identical across both scenarios, making early adoption of energy-efficient envelopes and stronger building codes essential to avoid long-term lock-ins.
- **Electricity demand surge and deepening electrification:** Building-sector electricity demand rises roughly sevenfold under Current Policy Scenario (CPS) and fivefold under Net Zero Scenario (NZS) by 2070, with electricity share in building energy reaching 70%. Efficient and grid-interactive buildings can reduce peak demand and associated investment in power infrastructure.
- **Cooling and appliance loads as major demand drivers:** Cooling demand grows sharply as residential AC penetration rises toward universal adoption (65% by 2050 and 80% by 2070), with cooling electricity demand increasing from 129 TWh (2020) to 915 TWh under CPS and moderated to 604 TWh in NZS (2070) due to adoption of super efficient ACs aligned with global best bench marks. Other appliance-related consumption also grows substantially (112 TWh in 2020 to 302 TWh under CPS and 225 TWh in NZS).
- **Improving compliance with building energy codes:** Commercial code compliance (ECSBC and above) improves from today's low baseline to 35% under CPS and 60% under NZS by 2070. Residential compliance (ENS) progresses from 5% today to 15% by 2050 and 25% by 2070. Effective enforcement, capacity building at sub-national level, and green finance are pivotal to accelerate this shift and ensure consistent, high-quality implementation nationwide.
- **Emerging load centres reshaping demand profiles:** Data centres become a major baseload driver, with IT loads increasing from 16 GW (2030) to 105 GW by 2070, pushing overall data centre electricity demand toward 700 TWh. Cold-chain and logistics infrastructure also grow rapidly, while cooking energy transitions toward a more diversified mix (LPG share falling to 26% whereas PNG, electricity, and biogas rise). These sectors require targeted efficiency programs, renewable-powered hubs, and robust grid planning.

Key Structural Gaps and Priority Actions

Today's regulatory framework reaches only to a fraction of the building stock; coverage centres on operational energy and inadequately addresses lifecycle embodied carbon, heat stress, and resource circularity. Implementation varies widely across States/UTs; data and feedback loops are limited; and enabling market mechanisms for demand creation and supply-chain scaling is limited.

A clearer understanding of the underlying structural gaps helps define the priority actions and system enablers needed to accelerate progress.

Key Structural Gaps

i. **Absence of a national building data platform:** The absence of a unified, publicly accessible national platform to aggregate and track building-level energy and carbon data limits sector-wide monitoring, policy evaluation, and feedback loops. This undermines the ability to evaluate the effectiveness of building codes, retrofit programmes, and market interventions, and constrains evidence-based policy calibration and long-term planning.

ii. **Limited code coverage and narrow performance metrics:** Current mandatory codes apply to only a small portion of new construction and primarily target operational energy. Embodied carbon, climate resilience, and circularity are weakly integrated, constraining holistic low-carbon transition.

iii. **Uneven State/UT code implementation:** Enforcement capacity varies widely. Compliance mechanisms differ significantly while processes and transparency remain weak, with digital systems still emerging.

iv. **Underdeveloped markets for efficient and low-carbon products:** Market gaps exist on both the demand and supply sides for green products. Commercialisation pathways, including piloting, certification, and procurement linkages, remain limited, slowing scale-up and investment readiness.

v. **Data deficits in building and material performance:** The absence of standardised disclosures limits systematic benchmarking of operational performance, evaluation of retrofit potential and appliance efficiency outcomes, and availability of India-specific embodied carbon data, constraining the credible green-premium signalling, and incentive frameworks.

vi. **Skills and capacity gaps across the value chain:** Officials, designers, contractors, and workers often lack training on new materials, envelope practices, and energy/ resilience requirements, slowing adoption on the ground. Absence of dedicated training on operational energy management for asset management professionals and trades.

vii. **Dependence on broader industrial low-carbon transition:** Building-material emissions remain tied to wider industrial policy trajectories for cement, steel, metals, bricks, and glass.

viii. **Need for targeted support ecosystem for research and commercialisation of building products & technologies:** Current programs have a wide remit, with no dedicated focus on indigenous technologies. Limited feedback loop from field trails and limited visibility on enabling policies and incentives hamper commercialisation.

ix. **Persistent frictions in cooking transitions:** Affordability constraints, behavioural inertia, infrastructure gaps, and widespread use of biomass slow down the shift to cleaner fuels (PNG/electric/biogas).

Priority Actions and System Enablers

Suggestions on policy interventions are structured under 11 themes, with their ambition and scope progressively tightened over short (before 2030), medium- (before 2035), and long-term (post 2035). Clear visibility on forward policy pathway is key to helping businesses make more effective investment decisions, plan capex, and drive innovation.

i. **Strengthen national building energy data governance to** bridge critical gaps in granular end-use tracking and policy evaluation by establishing a standardized national demand-side energy data framework, beginning with a centralised data architecture anchored within BEE's Energy Demand Management Unit (EDMU) to formalise inter-ministerial coordination.

ii. **Tighten and broaden operational energy building codes for new commercial buildings**, including enhanced envelope and passive design requirements, quantitative thermal comfort criteria for naturally ventilated buildings, and progressively ambitious Energy Performance Index (EPI) targets. Expand coverage to small commercial buildings with a simplified code akin to Eco-Niwas Samhita (ENS) for residential buildings.

iii. **Expand code compliance for new residential buildings** for plot areas >500 sq.m, with progressive tightening of energy performance thresholds.

iv. **Close the compliance gap** via third-party assessors (TPAs) to address capacity crunch, digital state portals for verification and approvals, and consistent penalties; publish compliance data to enable accountability.

v. **Mainstream disclosures for operational energy and Star Labelling of existing commercial buildings** to unlock green premiums in asset and rental values. Underpin policy implementation by setting up procedures for notification of designated entities, reporting protocols and penalties.

vi. **Link (local/ state) government incentives to percentage improvement over mandatory codes,** with incentives targeted at both developer and buyers.

vii. **Target the cooling surge and increasing appliance use** through best-in-class appliance efficiency, stricter enforcement of Standards and Labelling (S&L) programme through third party accreditation, expanding remit of S&L programme to cover emissions from refrigerants, and progressive tightening of mandatory envelope performance requirements under building codes.

viii. **Initiate phased introduction of Environmental Product Declarations (EPD) requirements** for building materials and products, starting with the most emissions intensive materials/ product categories. Put in place enabling ecosystem i.e. standard Life Cycle Assessment (LCA) methodology and rules, approved independent verifiers, and a searchable public register of accredited EPDs. Draw on EPD data for periodic benchmarking and labelling of green products.

ix. **Coordinate with industry policy** (Carbon Credit Trading Scheme (CCTS), Extended Produced Responsibility(EPR)) to drive down embodied carbon across cement/steel/ bricks/ aluminium and allied products.

x. **Supercharge market transformation** for low-carbon materials and high-efficiency products through time-bound fiscal support and incentives for 'green' products, paired with public procurement pull.

xi. **Invest in people**, from frontline masons to design professionals, facility managers, and public sector officials through structured, industry-linked skilling programs that keeps pace with technology. Set up systems and processes to track and monitor skills and training gaps, and improve training programmes as needed. Use Mission LiFE to drive behavioural change and mainstream demand for efficient appliances (e.g., super-efficient cooling, lighting, fans) and better energy practices.

1

INTRODUCTION

1 Introduction

1.1 Background

The building sector plays a crucial role in India's economy, contributing to employment, infrastructure development, and overall economic growth. However, buildings also account for about 1/3rd of India's greenhouse gas (GHG) emissions, placing it among the highest-emitting sectors. Total building-sector emissions comprise those generated through operations (electricity and cooking fuels) and those embodied in building materials such as cement, steel, bricks, aluminium, and glass. Embodied carbon emissions account for about half of the total emissions in the buildings sector, commanding as much attention as the power consumption of the buildings does.

The sector has transitioned from traditional, climate-responsive designs to energy-intensive construction practices post-independence. Going forward, the sector's energy demand and emissions are projected to increase substantially due to a combination of economic growth, increased urbanisation, rising incomes and improved living standards. Climate change adds another critical dimension to the sector's challenges, intensifying vulnerabilities such as heat stress, flooding, and extreme weather events. The increasing intensity of heat waves will amplify the demand for cooling, thereby exacerbating energy consumption and stress on the power grid. Additionally, there are health and productivity imperatives.

Current challenges in India's building sector are multifaceted, ranging from high operational and embodied carbon emissions, inadequate penetration of energy-efficient technologies, fragmented governance structures, limited enforcement of building codes, and gaps in workforce skills. This highlights the need for a holistic approach that spans comprehensive building codes and enabling mechanisms for market transformation, research & development, and workforce skilling.

1.2 Tradition to Transition: India's Living Knowledge for a Sustainable Built Environment

India's pursuit of a Net Zero built environment is grounded in a deep civilisational legacy of climate-responsive design, rooted in the enduring concept of *Dharma*, which literally means "that which sustains". Long before modern global climate narratives, Indian building traditions reflected intrinsically sustainable and climate-responsive design practices. Classical architectural texts, such as *Vāstu Śāstra, Mānasāra, Mayamatam* and *Samarāṅgaṇa Sūtradhāra,* conceptualised buildings as organisms in dialogue with the sun, wind and water, guided by the axiom *deśa-kāla-paristhiti* (place, time, and context). This foundational approach aligns directly with today's fit-for-climate design and whole-life carbon thinking.

The Vernacular Wisdom

Across India's diverse climatic regions, traditional construction practices embedded climate-responsive and resource-efficient principles that remain relevant to contemporary low-carbon transition goals. Vernacular architecture across hot-dry, hot-humid, and cold-seismic zones employed passive strategies, such as courtyards, thermal mass, cross-ventilation, shading, and locally sourced materials, to deliver comfort, resilience, and durability with low embodied energy. From earthen and courtyard-based typologies in arid regions to permeable timber–laterite structures along the western coast and timber–stone systems in the Himalayas, these approaches reflect a long-standing tradition of building in harmony with climate and context. This ethos is succinctly captured in the *Samarangana Sutradhara*: "देशकालौ समीक्ष्यैव वास्तुनिर्माणमुच्यते।", emphasizing that construction should be guided by careful consideration of desha (place, region, and climate) and kaala (time and season).

However, the present context is shaped by rapid urbanisation, rising densities, and compressed construction timelines. The scale and speed of development required to meet India's growth aspirations limit the direct replication of traditional practices. The challenge, therefore, is not to replace this accumulated wisdom, but to reinterpret and integrate its underlying principles into modern building systems, materials, codes, and delivery models that can respond to current demands for speed, scale, affordability, and performance. Addressing this challenge by aligning traditional wisdom with modern 'green and resilient' materials and construction systems in a holistic manner, we can enable a more sustainable, low-carbon transition.

1.3 The Roadmap Development Process

Ensuring a resource-efficient, low-carbon and resilient buildings sector is critical to meeting India's development goals. Recognising this, the Indian government has taken significant policy actions aimed at achieving long-term sustainability and resilience.

In April 2024, NITI Aayog established Inter-Ministerial Working Groups (IMWGs) to develop pathways and policy actions for meeting India's 2070 Net Zero target, keeping in view India's commitments on climate change at the UNFCCC, its development needs, and the goal of becoming a developed nation by 2047. Specifically, a dedicated Inter-Ministerial Working Group (IMWG) was created to address the complexities and challenges within the building sector, chaired by Dr. V.K. Paul, Member, NITI Aayog. This illustrates the building sector's pivotal role in India's socio-economic and environmental future. The Alliance for an Energy-Efficient Economy (AEEE) was appointed as the Knowledge Partner to support the roadmap development.

The remit for this working group was to examine options for accelerating adoption of technologies to mitigate GHG emissions over the building lifecycle and recommend suitable policy interventions. In parallel, NITI Aayog has undertaken energy demand modelling to understand the impact of macro-economic drivers, technological transitions and climate change on future energy consumption.

Objective of Working Group: Develop an integrated roadmap for low-carbon transition of the building sector in line with India's 2070 Net Zero target. Examine options for accelerating the adoption of technologies to reduce GHG emissions over the building lifecycle and minimise climate-induced heat stress, including low-carbon & circular building materials, envelope design, & building services. Recommend suitable policy interventions based on cost-benefit analysis, covering building codes for residential and commercial buildings, performance data disclosures, financial incentives, behavioural nudges and market mechanisms needed to drive uptake of relevant technologies and standards.

Terms of Reference

1. Energy & carbon growth trajectories:
    - 1.1. Examine the growth in building sector energy demand and GHG emissions, considering GDP growth trajectories and urbanisation aligned to development aspirations.
    - 1.2. Examine the role of increase in the standard of living on appliance penetration and usage.
2. Climate change:
    - 2.1. Examine the impact of climate change on cooling demand and increased uptake of active cooling.
3. Technology, design, and cleaner fuels:
    - 3.1. Examine the role of efficient/ smart building design and low-carbon materials in bringing down the energy demand, improving thermal comfort and reducing embodied and operational carbon.

3.2. Examine the likely penetration and energy savings from super-efficient appliances and equipment for lighting, cooling, heating, cooking and water pumping.

3.3. Examine the role of the shift to cleaner/alternative fuels/demand electrification on energy consumption, emissions and energy security.

4. Behavioural, financial and macro-economic aspects

4.1. Examine the role of behavioural nudges (positive and negative) on energy consumption

4.2. Assess the potential of grid-interactive buildings in demand side management/demand flexibility.

4.3. Examine the role of energy and carbon data disclosures, benchmarking of energy consumption and performance standards.

4.4. Analyse financing instruments, market mechanisms and incentives to enable building sector low-carbon transition, including their role in facilitating higher penetration of building codes (ECBC, Eco-NIWAS).

Composition

1. **Representatives from Ministries/Departments:** Ministry of Housing and Urban Affairs, Bureau of Energy Efficiency (BEE), Ministry of Rural Development (PMAY), Ministry of Natural Resources and Environment, Ministry of Environment, Forest and Climate Change of India, Ministry of Petroleum and Natural Gas
2. **Lead Knowledge Partner:** Alliance for an Energy Efficient Economy (AEEE)
3. **Industry and Civil Society Organisations:** RMI India, CSTEP, CLASP, IISC, CEPT University, TERI, Development Alternatives, NIUA, SPA Delhi, CREDAI, Council of Architecture, Prayas

Three thematic sub-groups were created, as noted below, to enable better dialogue and coordination with working group members who bring expertise and experience on specific topics.

i. **SG-1 Integrated Building Design:** Examine barriers and related interventions for enabling integrated design thinking in building envelope design to reduce lifecycle GHG emissions and mitigate climate-induced heat stress.

ii. **SG-2 Building Materials:** Examine existing supply chains, skills gap, barriers and related interventions (including innovation) for mainstreaming low-carbon building materials and construction products.

iii. **SG-3 Energy Use in Buildings:** Examine barriers and related interventions for accelerating adoption of energy-efficient appliances, building energy systems & services, and clean/renewable energy generation technologies.

The terms of reference for the thematic sub-groups, as well as a list of organisations and/or individuals that were invited to be part of the working group, are included in Annexure A.

1.4 Scope of the Analysis and Suggestions

This analysis goes beyond a narrow view of buildings as energy users. It takes a whole-life perspective, covering the construction materials and supply chains, the design and operation of buildings, and the lived experience of comfort, resilience and productivity. This framing is essential to capture the full scale of opportunities and risks as India builds towards Viksit Bharat 2047 and its 2070 Net Zero goal. The gap analysis and the proposed policy interventions in this document cover the following aspects.

Operational and embodied[iii] emissions span the full building lifecycle that include the following:

- **Manufacturing** of building products and associated supply chains
- Building use stage covering emissions associated with **operational energy use** for heating, ventilation, air-conditioning, lighting, and equipment; emissions from refrigerants; and embodied emissions associated with maintenance, repair, refurbishment and replacement of building materials and components.
- **Building end of life**, i.e., emissions associated with demolition/ de-construction, transport, waste processing and disposal.

It is to be noted that while the roadmap addresses emissions across the whole building lifecycle, quantitative **energy demand modelling** carried out by NITI Aayog has been **limited to operational energy** use in residential and commercial buildings, including energy demand for cooking.

Mitigating heat stress and enhancing climate resilience: This roadmap considers climate resilience and adaptation aspects given the projected increase in frequency and severity of heat waves, flooding, cyclones and other climate-induced disasters. Both climate mitigation and resilience interventions need to be considered together to ensure a holistic approach to making the building sector 'future ready', and to minimise impact on occupant health, productivity and the economy.

Cross-sectoral measures: While this document focuses specifically on the building sector, there are overlaps and synergies with both the industrial and power sectors. The suggestions in the roadmap align with the low-carbon transition agenda for these sectors by reducing the future additional burden on electricity grid infrastructure through improved energy efficiency and integrated design, and nudging the manufacturing sector towards greener, low-carbon and energy-efficient options through product environmental disclosures and other interventions.

High-level Strategic Roadmap: This is intended to be a high-level strategic roadmap. The

[iii] Lifecycle embodied carbon encompasses carbon emissions linked with materials and construction processes across the entire lifecycle of a building. This includes: material extraction (A1), transportation to the manufacturer (A2), manufacturing (A3), transportation to the site (A4), construction (A5), use phase (B1), maintenance (B2), repair (B3), replacement (B4), refurbishment (B5), deconstruction (C1), transportation to end-of-life facilities (C2), processing (C3), and disposal (C4). The nomenclature in brackets used to refer to different lifecycle stages is as per the widely-accepted ISO standards 14040/14044 and European standard EN 15978, as illustrated in Figure 3.5

action plan will set out the mechanisms by which policy recommendations will be implemented, and the roles and responsibilities of the implementing agency/ agencies, along with more granular details on timelines and key milestones.

2

DEVELOPMENT IMPERATIVES AND DRIVER OF CHANGE: VIKSIT BHARAT AND THE NET ZERO FUTURE

2

Development Imperatives and Driver of Change: Viksit Bharat and the Net Zero Future

India's vision for "Viksit Bharat" (a developed nation) by 2047 emphasises inclusive, sustainable, and resilient growth, aligning economic development with environmental stewardship. The building sector is central to achieving this vision. Buildings are long-term assets, and therefore, what we are building today will be there in 2047, and a significant proportion of them will still be standing in 2070. Locking in inefficiencies today will be an economic burden for the future.

Within this context, following are the key factors affecting the building sector:

- **Economic growth, increased urbanisation and the need for additional floor space:** About 73% of the building stock that is expected to exist by 2050 is yet to be built. This presents both an opportunity and a challenge. There is an opportunity to get it right from the start by taking an integrated design approach and optimising the design to reduce peak loads (and in turn costs for additional grid infrastructure), as well as deliver better thermal comfort and whole-life carbon performance. The marginal cost of integrating energy efficiency and low-carbon interventions is typically much less for new build than retrofitting, plus there is potential to incorporate more comprehensive climate-responsive and passive design solutions. The rapid increase in total built stock will also drive significant demand for building materials and components, which are both energy and resource-intensive. This presents a huge opportunity to scale up low-carbon and resource-efficient alternative materials and construction systems.
- **Better affordability and standard of living:** As economic growth spurs better standards of living and higher per capita wages, historical trends have shown that this will drive an increase in appliance ownership and usage. Enabling the uptake of more efficient appliances through targeted policies will reduce energy consumption and peak loads. Ensuring that this expanding market for efficient appliances can be met by domestic manufacturing, including the manufacturing of key supply chain components, creates further economic opportunities.

- **Increased heat stress due to climate change:** India is extremely vulnerable to the negative impacts of climate change, in particular, increased frequency and severity of heat waves, rainfall events, flooding, cyclones and other hazards. Extreme heat waves will exacerbate the need for more cooling, putting further strain on energy resources and associated infrastructure. Ensuring buildings are designed to be resilient to heat stress and other climate risks will also help mitigate the negative impacts on occupant health and productivity, and the economy.

The cumulative impact of the above factors means energy demand and emissions in the building sector will increase significantly under business-as-usual growth projections for the sector. This will result in significant upstream environmental impacts from increased demand for construction materials and products, as well as require increased investment in energy generation, transmission and distribution infrastructure. Relying solely on low-carbon transition of the power grid is unrealistic given the costs and technical limitations, and also because transport and industrial sectors are expected to add to this growing power demand as energy systems in those sectors gradually shift away from fossil fuels. Ensuring a resource-efficient and low-carbon building sector is important to mitigate these negative impacts and to meet our developmental as well as climate goals.

The following subsections go deeper into the quantitative data related to the drivers discussed.

2.1 Economic Growth, Urbanisation and Need for Additional Floor Space

Rapid economic growth and urbanisation will necessitate the construction of vast amounts of new residential and commercial space. India's building stock is projected to grow 2 times by 2050, and 2.5 times by 2070 relative to 2020 (refer to Figure 2.1 and Table 2.1 below). It is worth highlighting that factoring in the high demolition rate of existing building stock owing to suboptimal quality, coupled with consistent economic growth, 86% of the building stock that will exist in 2070 is yet to be built.

Majority of this growth is expected to be in urban centres and will be driven by the need for housing. The urbanisation rate assumes a continued shift in population from rural to urban, increasing from 35% urban population in 2020 to 51% in 2047. This translates into circa 814 million people living in cities in 2047 compared with 471 million in 2020. In addition, improving economic status and living conditions will also drive aspiration for bigger homes, with per capita floor space expected to double from 12m^2 per person in 2020 to 23m^2 in 2070.

Expansion in the commercial building segment is equally significant, driven by India's accelerating economic growth and the expansion of its services sector. Commercial building stock is projected to more than triple, increasing from approximately 1.3 billion m^2 in 2020 to around 4.4 billion m² by 2070. The proportion of commercial building stock in the total building stock is projected to marginally increase, from 7% in 2020 to around 10% in 2070. This trend is consistent with rising service sector dominance, increasing commercial activities, and the growing demand for office spaces, retail centres, and hospitality facilities. Additionally, policies promoting industrial corridors and digital economy expansion are expected to further accelerate the demand for commercial real estate.

Data Centres, in particular, are emerging as major consumers of energy within commercial buildings. India is witnessing significant growth in its data centre market, with power capacities projected to rise sharply, making them substantial contributors to energy demand in the coming decades. While these data centres represent substantial energy-intensive infrastructures, there are notable opportunities for adopting energy-efficient and renewable-powered solutions. Several data centres in India are already implementing advanced cooling solutions and AI-driven energy management, lowering their energy use and environmental impact.

Assumptions on a range of macro-economic indicators have been used to inform the projections, which are included in Annexure B.

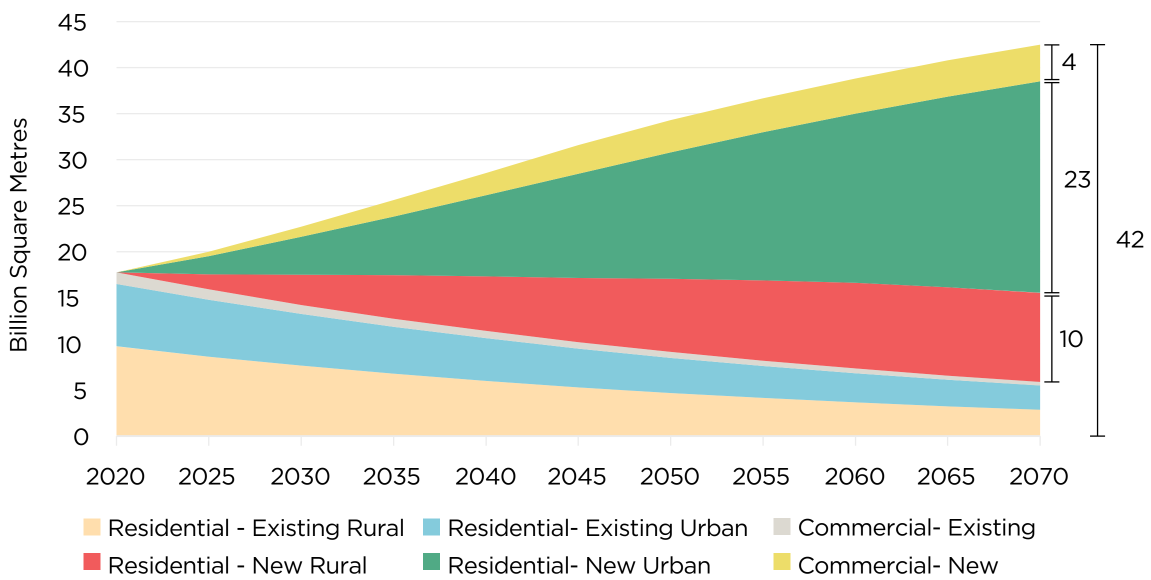


Figure 2.1: Building Floor space Projections 2020-2070[iv]

Table 2.1: Building stock projections for 2050 and 2070

Sub-sector	2020 estimate (billion m²)	2025 estimate (billion m²)	2050 projections (billion m²)	2070 projections (billion m²)
Residential	16.5	18.4	30.2	38.1
Commercial	1.3	1.6	4.1	4.4
Total floor space	17.8	20.0	34.3	42.5

[iv] NITI Aayog, 2025

While NITI Aayog's projections offer one perspective, alternative estimates by some of the research organisations suggest a more aggressive trajectory. Analysis by NIUA and RMI indicates that about 1.25 billion sq.m of new floor space is being added annually. This could rise to 1.91 billion sq.m per year by 2050, resulting in a 2.5-fold increase in total floor space between 2020 and 2050[3]. The Alliance for an Energy Efficient Economy (AEEE), in its work for the India Cooling Action Plan, estimates that total floor space will rise from 16.5 billion sq.m in 2017 to 31.53 billion sq.m in 2037[4]. Similarly, the Global Alliance for Buildings and Construction projects an increase from 15.8 billion sq.m in 2015 to about 57.6 billion sq.m in 2050, over 3.5 times growth[5]. The Center for Study of Science, Technology and Policy (CSTEP) also presents higher estimates, projecting over 80 billion m^2 by 2070 under a business-as-usual scenario[6].

In comparison to some of these alternative estimates, **NITI Aayog's projections assume a relatively modest increase in residential floor space per capita** in the coming decades. Given India's rising population density, land constraints, and rapid urbanisation, it is reasonable to expect that per capita floor space increases may not match those of the developed and, less populous, countries. Instead, the trend could be akin to land-constrained developed economies such as Singapore, or urban centres like Mumbai.

Comparing India's building stock growth pathways

As one of the world's most densely populated countries (8,177 people/km^2)[7], Singapore has a per capita living space of 25–30 m^2 per person[8,9]. Given a shortage of land, this has led to high-rise development that optimise density and liveability. In contrast, less land-constrained developed economies, such as the USA, have undergone horizontal growth. The average home size in the US increased from 97m^2 in 1920 to about 214 m^2 in the early 2000s, or more than 60 m^2 per person in many homes[10]. Lower population density and abundant land enabled suburban development and spacious residential units, driving per capita floor area significantly above that of dense Asian cities. Countries like China, which do not have significant land constraints, also experienced a dramatic rise in per capita residential living space, from under 5 m^2 in the 1980s to over 40 m^2 on average by 2020, with urban households providing a space of around 36.5 m^2 per person[11,12].

India faces unique constraints of rising density, limited land, and rapid urbanisation. Its future growth in per capita residential area will likely rely on vertical housing and efficient urban planning, echoing aspects of Singapore's experience . With projected urban per capita floor area reaching 24 m^2 by 2070, India may still remain below China's (36 m^2) and USA's average levels (60 m^2), but closer to Singapore's range.

While building stock projections may vary based on underlying assumptions, the projected figures present a reasonably good picture of trends and challenges ahead. The new building stock to be constructed in the coming decades will increase demand for energy- and resource-intensive building materials.

Table 2.2 presents the current and projected growth in national production of key construction materials, cement, steel, bricks, aluminium, and glass. At present, buildings consume a dominant share of several materials, accounting for about 75% of cement production in India[13], and approximately 40% of steel production[14], both of which are highly energy-intensive industries. Cement production releases significant amounts of CO_2 emissions during calcination, a chemical reaction during clinker production. Calcination process alone accounts for 50-60% of total cement emissions. Moreover, burnt clay bricks dominate masonry construction in both urban and rural areas. Local manufacturing in inefficient kilns causes agricultural topsoil loss and land degradation. Around 30 million tonnes of coal and approximately 10 million tonnes of biomass are used annually for firing of burnt clay bricks making this one of the largest energy consuming industries in the country[15].

In absolute terms, national production of cement and steel is projected to grow sharply, increasing by about four times by 2050, driven by combined demand from buildings, infrastructure, and industrial sectors. Expert consultations further indicate that brick production is likely to increase by about two times, reaching approximately 1.5-1.6 billion tonnes annually by 2050.

Table 2.2: Projected national production in million tonnes (Mt) of key materials

Material	2020 reported production in Mt	2025 estimated production in Mt	2050 projected in Mt	2070 projected in Mt
Steel[v]	110	160	624	820
Cement[v]	335	450	1,600	1,990
Bricks	700-750[16]	750-800[17,18,vi]	1,500-1,600[17,18,vi]	1,300-1,500[17,18,vi]
Aluminium[v]	5	6	28	38
Glass	2-4[19,20]	3-5[19,20]	14-17[vii]	22-28[vii]

Source: *Based on data from the Working Group Report on Industry Sector (Vol. 4) and analysis conducted under Buildings Working Group, informed by multiple secondary data sources and expert consultations*

Out of total demand as shown in Table 2.2, the Table 2.3 shows building sector's demand for steel, cement, aluminium, and glass. Annual additions to built floor area are currently at historical highs of around 0.9-1.0 billion m^2, but are expected to moderate post-2030, consistent with the floor area projections shown in Figure 2.1.

[v] Based on data received from the Industry Sector Working Group (Vol. 4)

[vi] Analysis conducted under working group on buildings based on data from multiple sources and expert consultations[21,22,23,24,25]

[vii] Assumes a conservative compound annual growth rate (CAGR) of 5–6% during 2020–2050 and 1.5–2% during 2050–2070, consistent with projected floor-area expansion and growth trends in key building materials (e.g., steel and cement)..

Table 2.3: Estimated demand of key materials for the building sector

Material	2020 Estimated demand (million tonnes)	2025 Estimated demand (million tonnes)	2050 Estimated demand (million tonnes)	2070 Estimated demand (million tonnes)
Steel	45-50	50-65	90-100	100-110
Cement	230-260	300-350	500-550	450-500
Bricks	550-600	600-650	550-600	500-600
Aluminium	0.5-1	0.8-1.5	3-4	4-5
Glass	1.5-2	2-3	4-5	5-6

Source: *Analysis conducted under working group on buildings sectors based on data from multiple sources and expert consultations*[21,22,23,24,25]

Rapid urbanisation, coupled with a transition towards mid-rise and high-rise construction prioritising structural integrity, increases steel and cement use per unit floor area while reducing brick intensity (kg/m^2) in modern buildings. Evidence from global literature[11,12,26,27,28] indicates similar trajectories, with material demand rising rapidly in early stages of urbanisation before plateauing as saturation in built-up area is reached. Consistent with these patterns, India's building material intensity is projected to stabilise by the late 2040s, with only marginal year-on-year increases thereafter. National production trends for key materials, as projected by NITI Aayog, are closely linked to GDP growth across buildings, infrastructure, and industrial segments, as well as policies promoting exports and import substitution. As a result, an increasing share of national output, particularly for cement, steel, aluminium, and glass, is absorbed by infrastructure projects and export markets over time.

These projections underscore the importance of strategic material efficiency measures in the building sector, not only to mitigate environmental impacts but also to ensure supply security in the context of competing national demands.

Policies and market mechanisms are crucial for India to meet its long-term economic and development goals. These must improve manufacturing energy efficiency, scale up low-carbon alternatives, optimize building-level material use, and enhance durability and circularity.

2.2 Better Affordability and Improved Standards of Living

Income growth and improved living standards will drive greater appliance ownership and prolonged usage, particularly for cooling.

India has among the lowest access to cooling despite its tropical climate. Room air conditioners (RACs) have low penetration rates of 13% in urban and 4% in rural areas, averaging approximately 7% at national level in 2020[viii]. Figure 2.2 shows that air-conditioners ownership is disproportionately low in India given the high cooling demand, even compared to other developing economies such as China. This indicates significant latent demand, while

[viii] NITI Aayog estimates, 2025

highlighting the need to make affordable cooling a national priority. Affordable cooling requires both passive building design measures to improve thermal comfort and reduce cooling demand, and efficient air-conditioning equipment.

Figure 2.2 shows latent cooling demand for India, expressed in person cooling degree days[ix]. This indicates that cooling demand in India is well over two times that of China and nearly 10 times that of the United States, while current AC household ownership is less than 10%.

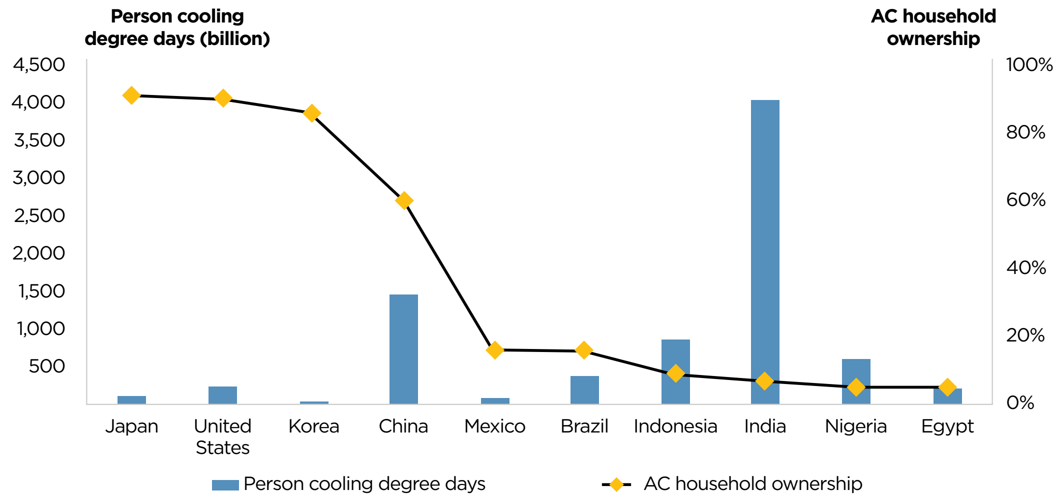


Figure 2.2: Cooling Demand (Cooling Degree Days) Versus Current AC Ownership in Different Countries[29]

The India Cooling Action Plan estimates that room air conditioner (RAC) ownership could reach around 40% by 2037–38. This is further projected to reach 80% in urban areas and around 50% in rural areas by 2047, and 80% by 2070.[30] Rising disposable income, particularly among medium-income urban households, will drive substantial growth in air conditioner penetration. This is expected to reach 80% in urban areas and 50% in rural areas by 2047. India is projected to have over 20% of the global installed stock of RACs, at nearly 1.2 billion units, by 2050[3].

Other appliances have varying penetration rates in urban and rural areas, but the projected trend is also upwards. NITI Aayog estimates that refrigerator ownership is projected to increase from 63% in urban and 25% in rural households in 2020, to 90% and 80% respectively by 2047, and reach 100% by 2070. Ceiling fans are expected to reach 100% penetration by 2030, compared to 96% in urban and 85% in rural households in 2020[x].

The projected increase in appliance ownership presents substantial economic opportunities.

[ix] Person cooling degree days is the country's average annual cooling degree days (CDD) multiplied by its population. CDD is the difference between the mean daily temperature (average of the daily high and daily low) and a reference or base temperature (18 °C in this instance)

[x] NITI Projections, 2020 values based on multiple surveys (NFHS-5, CEEW's IRS)

These include investment in scaling up domestic production and advancing research and commercialisation of low-carbon, high-efficiency technologies, including both active and passive cooling solutions. This approach will ensure equitable access to affordable cooling while delivering significant economic benefits through job creation, enhanced productivity, and reduced costs for new electricity infrastructure.

2.3 Climate Change and Heat Stress

India is highly susceptible to heat waves due to its location and geography, population density, and increasing urbanisation rates,[31]. In recent years, this trend is increasing in both frequency and intensity.

Severe heat waves in India are expected to increase 30 times by the end of the century, even if the global mean temperature rise is limited to 2°C above pre-industrial levels[1]. According to IPCC (2023) there is more than a 50% chance that the global temperature rise will reach or surpass 1.5°C between 2021 and 2040. Recent observations indicate that 2024 was the warmest year on record and likely exceeded 1.5 °C, signalling an increasing risk of a sustained breach of this threshold[32,33]. This reinforces the urgency of accelerating mitigation while strengthening adaptation measures to address escalating heat stress, particularly in highly climate-vulnerable regions. The India Meteorological Department's review of heat wave studies indicates heat wave duration will increase by 12-18 days during the pre-monsoon season (April-June) over 2020-2064.This will extend further to southern and coastal parts of India[34]. Alternative projections of heat stress in South Asia region indicate potential widespread increases in wet bulb globe temperature (WBGT) of 6.50°C.These increases could exceed theoretical human tolerance limits by the mid-21st century (refer to Figure 2.3 below).

Heat stress affects human health by increasing the heat-related illnesses incidences and exacerbating chronic conditions. In extreme cases it can cause permanent disability or death[35]. Beyond health and mortality impacts, heat stress reduces productivity and results in economic losses through reduced labour efficiency and increased healthcare costs. According to 2019 International Labour Organisation data for India, heat stress caused a 4.3% loss of working hours in 1995 with projections showing an increase to 5.8% by 2030. This could result in productivity losses equivalent to approximately 34 million full-time jobs[36].

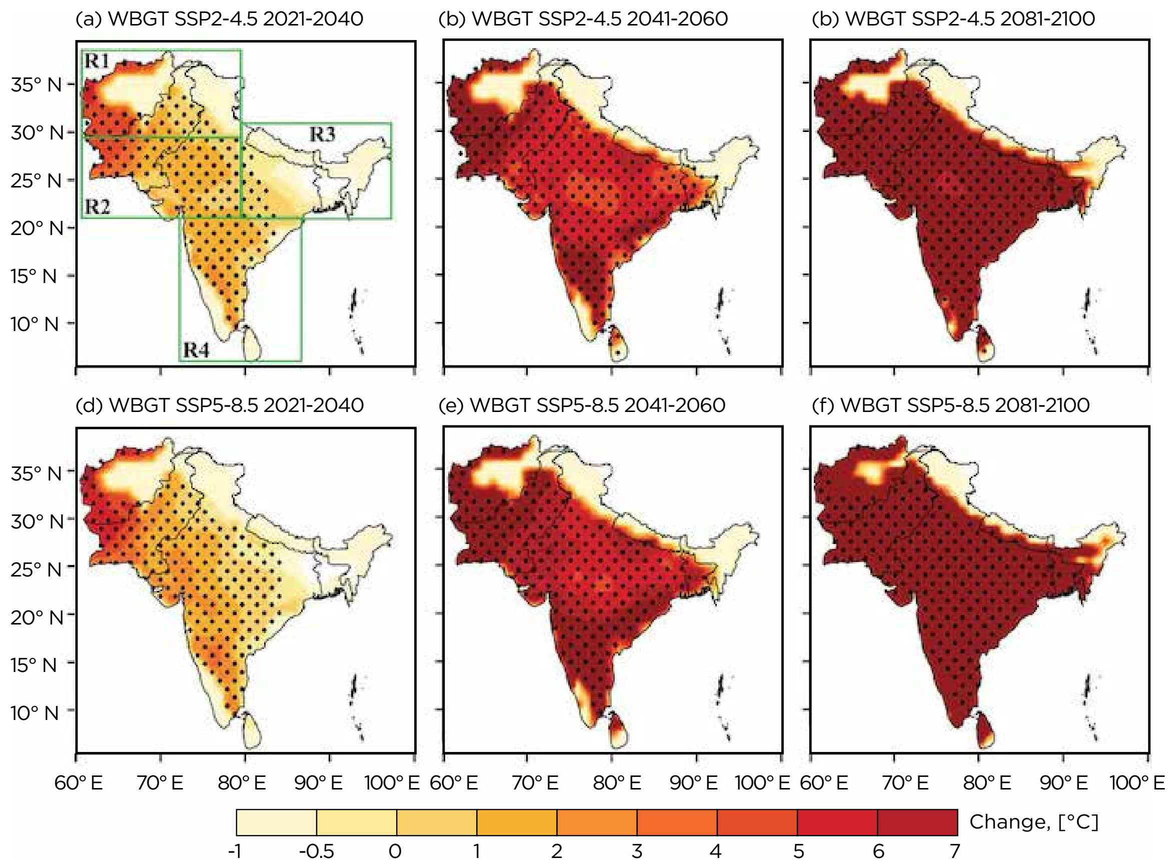


Figure 2.3: Projected changes in wet bulb global temperatures for south asia under two alternative socio-economic pathways and over 2040, 2060, 2100[31*]

***Note:** Country boundaries corrected*

Mitigating heat stress and providing affordable cooling is imperative to meeting India's long-term economic and development goals. This requires adoption of climate-responsive design, passive cooling measures, and efficient active technologies in homes and workplaces. Building energy codes will need to evolve to enable this. This aligns with the Indian government's vision and commitment to reduce heat wave-related deaths to zero by strengthening disaster risk governance and investing in prevention, preparedness and resilience[37]. Designing and scaling heat-resilient shelters will also require focus in the coming years. These shelters represent a potentially new class of buildings to provide relief to commuters and outdoor workers.

3

CURRENT BUILDING SECTOR LANDSCAPE

Current Building Sector Landscape

3

3.1 Energy Use and Emissions

The building sector's GHG emissions include emissions from energy use during operation, and emissions related to the manufacturing, maintenance, repair, replacement and end of life disposal of building materials or products used for construction (referred to as lifecycle embodied emissions or embodied carbon).

Table 3.1 shows estimates of building sector emissions using multiple data sources, including NITI Aayog's analysis on operational energy use, the 4th Biennial Update Report to UNFCCC[38] (BUR 2024), and supplementary analysis. The national GHG inventory does not include building sector data separately, making it challenging to build a comprehensive picture. Assumptions and data used for the estimates are provided in Table 3.1.

Table 3.1: Estimated building sector GHG emissions (2025)

Category	Sub-category	GHG emissions (million tCO2e)	Remarks
(a) Operational emissions from existing building stock and cooking			
Electricity-related emissions (million tCO_{2e})	Residential	297	Operational emissions are calculated based on the energy projections obtained from the NITI Aayog's building sector energy models, and emission factors from CEA for electricity use and IPCC 6 for cooking fuels.
	Commercial	102	
Cooking (million tCO_{2e})		83	
Annual operational emissions*		482	

Category	Sub-category		GHG emissions (million tCO2e)	Remarks
	Annual production (million tonnes)	% attributable to building sector	GHG emissions (million tCO2e)	Remarks
(b) Embodied emissions for key building materials (Million tCO2e)				
Cement	451	73	214	Embodied emissions have been estimated using the data sources cited in Tables 2.2 and 2.3. Emission factors for 2025 are primarily sourced from the Working Group on Industry Sector constituted by NITI Aayog, along with other sources listed in the same tables
Steel	162	43	143	
Bricks	800	75	72	
Aluminium	6	15	21	
Glass	4	70	3	
Annual embodied emissions (Million tCO2e)			453	
Total annual building-sector GHG emissions (Million tCO_{2e})			935	

** Excludes fossil fuel-based captive generation on-site and Scope-3 related GHG emissions from material production. Estimates for GHG emissions from refrigerants used in heating and cooling are also not included. These are estimated to be circa 15 MtCO2e (excluding cold chain and mobile air conditioning) based on research published by Alex Hillbrand et al, 2022 Environ. Res. Lett. 17 074019.*

The building sector, encompassing both embodied and operational emissions, accounts for an estimated 30% of national GHG emissions including cooking and 25% excluding cooking. These estimates include emissions associated with the manufacturing of cement, steel, aluminium, bricks, and glass. These key materials make up 70-85% of a conventional building's lifecycle embodied emissions[39]. Including emissions from these materials, operational and embodied emissions for the building sector account for 52% and 48%, respectively, of the total emissions when cooking energy emissions are included. These shares are 47% and 53%, respectively, when cooking energy emissions are excluded (refer to Figure 3.1 below). While case studies assessing the embodied emissions of individual buildings have been published, there is no comprehensive data on the embodied emissions of new typologies of buildings being constructed across the country. This is a critical data gap and limits the potential for targeted policies to address building sector embodied emissions.

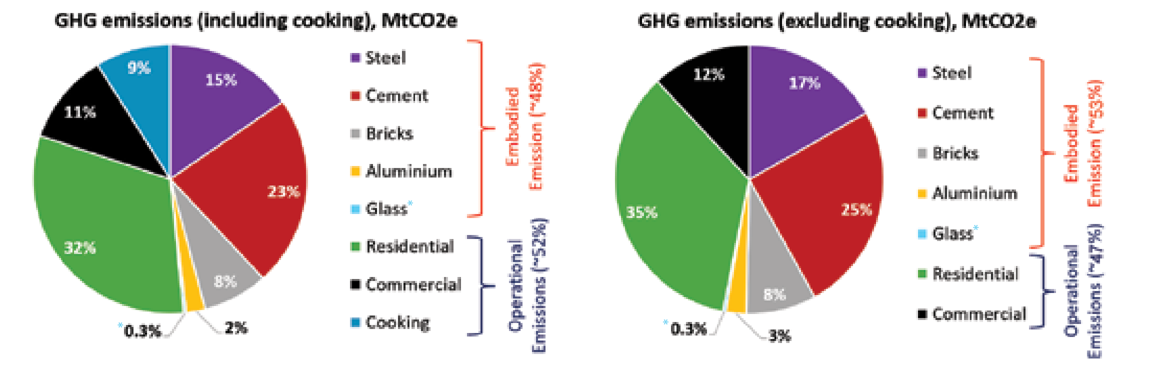


Figure 3.1: Breakdown of Current GHG Emissions from the Building Sector in 2025, With and Without Cooking-Related Emissions[xi]

3.2 Technologies Deployed and Penetration of Energy-Efficient Alternatives

3.2.1 Appliances

Energy use by appliances is the highest contributor to building sector emissions. The appliances that currently contribute the most to operational energy use in buildings are listed in Table 3.2.

Table 3.2: Energy Consumption for Key Appliances Used in Residential Buildings

Key Appliances	Energy consumption (TWh)	
	Year 2020	Year 2025
Fan and Cooler	94	106
Room AC	29	71
Refrigerator	55	57
Lighting Fixtures	40	42
Heating (Space heaters, geyser, immersion rods)	27	43
Others (TV, Washing Machine, Pumps, etc.)	60	66
Total energy consumption (TWh)	**305**	**385**

The market share of efficient technologies has been gradually increasing as cost differences narrow, and Bureau of Energy Efficiency's (BEE's) Standards and Labelling (S&L) programme drives market transformation through minimum performance standards and better consumer awareness (refer to Figure 3.2 below). The apparent shifts in star-wise market shares shown in Figure 3.2 should be interpreted in the context of periodic Minimum Energy Performance

[xi] Analysis conducted under NITI Aayog Working Group on buildings sector

Standards (MEPS) revisions, which raise the efficiency baseline and reclassify products across star categories. For instance, following the 2019 MEPS revision for ceiling fans, models that were rated 5-star in FY2019 were reclassified as 1-star from FY2020 onwards. As a result, the observed increase in the market share of 1-star fans and the corresponding decline in 5-star fans after 2019 reflect an improvement in underlying efficiency rather than a market regression. A similar pattern is evident for variable-speed Room Air Conditioners (RACs), where the share of 5-star ACs has continued to rise from FY2020 onwards despite MEPS upgrades, indicating sustained adoption of more efficient technologies even as efficiency thresholds become more stringent. The section 3.3 outlines the S&L program's success in increasing the adoption of energy-efficient alternatives in recent years.

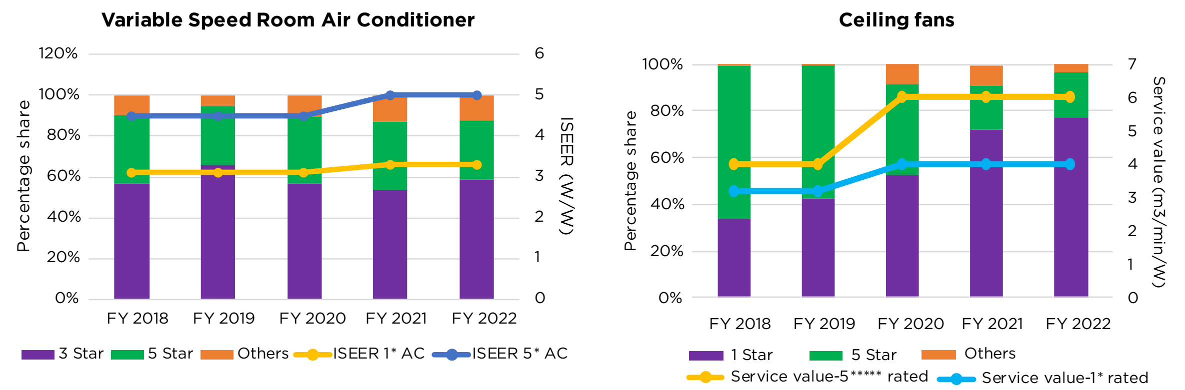
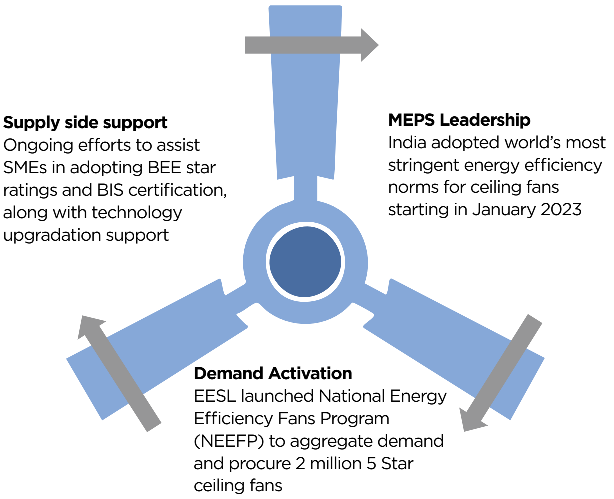


Figure 3.2: Market Share of Ceiling Fans and Variable Speed ACs by Star Rating

Source: *CLASP*

There is still scope to further improve energy efficiency for certain categories of appliances in line with international practices and norms. Figure 3.3 shows how India's Minimum Energy Performance Standards (MEPS) for specific appliance categories, compare with global energy efficiency norms and Best Available Technologies (BAT). A larger gap (numbers shown in blue) implies a greater scope for improving appliance energy efficiency performance standards. The world's best MEPS shown in the Figure 3.3 are already being implemented in a number of countries or are in the process of being enforced[40].

How India's Minimum Energy Performance Standards (MEPS) for ceiling fans foster market transformation



Combination of Policy, Demand and Supply side interventions are impacting the market:

- Pricing and communication: A 25% reduction in retail prices of 5 Star rated fans. Greater focus on BLDC technology, cost efficiency, energy savings, and BEE star labels.
- Over two years, 5-star fan production increased by 63%, with manufacturers rising from 36 in 2023 to 105 in 2024. Registered 5-star fan models also tripled.

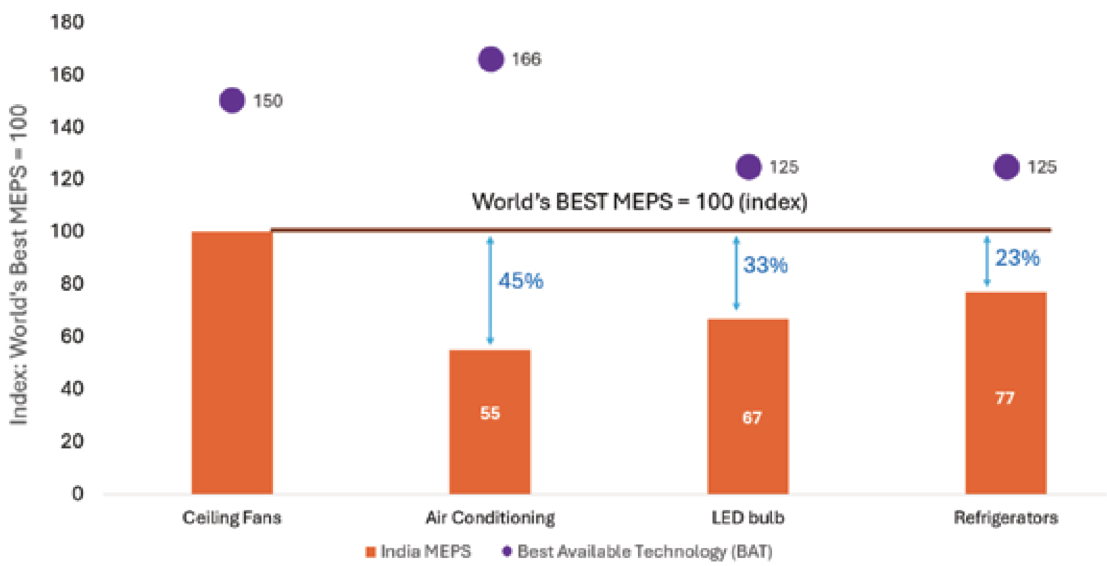


Figure 3.3: Comparison of India's Appliance Minimum Energy Performance Standard (MEPS) with Global Best Available Technology (BAT)

Figure 3.3 shows that India's current MEPS for ceiling fans is in line with international norms. India's lighting MEPS at 90 lm/watt for LED lamps is also on par with the global best standards in force. As the USA and South Africa have committed to ratcheting up MEPS in the near future, there is potential to raise lighting Minimum Energy Performance Standards (MEPS) by 33% from present values. MEPS for air conditioners present the largest potential, for 45% improvement to align with global best standards. This would still be significantly lower than the best available technology currently.

Other than consumer appliances, electric motors and motor based systems are pervasive in residential, commercial, and industrial buildings. Low-efficiency motors represent an estimated two-thirds of the motors stock in India and the world. India's IE2 MEPS for motors can be made more stringent, aiming for IE4 standards and progressively moving towards IE5 for industrial electric motors. There is also scope to expand current policies to cover larger motor systems (pumps, compressed air systems, etc.).

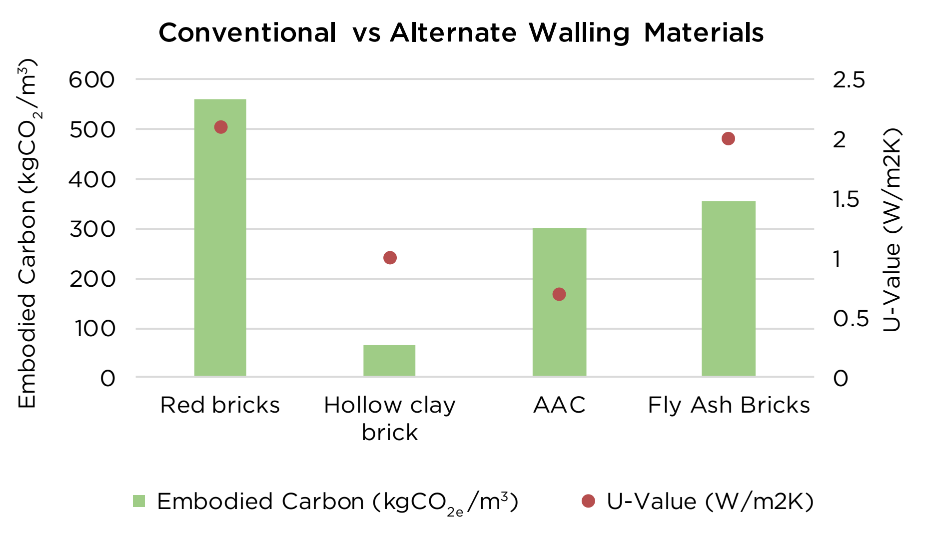
3.2.2 Building Materials and Construction Systems

New buildings in urban and peri-urban areas largely comprise load-bearing red brick walls with RCC slab (in low-rise buildings), or RCC frame construction with brick or other infill walling material (in medium to high rise buildings). In areas prone to earthquakes or other disasters, framed RCC construction has been adopted for low-rise construction as well. Alternate walling materials include AAC (Autoclave Aerated Concrete) blocks, cement blocks, fly ash bricks, and hollow clay bricks. These make up a small proportion of the total production volume relative to red bricks. In recent years, there is increasing preference for monolithic RCC construction[xii], particularly in Tier 1 cities as they help speed up construction and require less labour. However, the embodied carbon impact of monolithic construction can be several times higher than vernacular and contemporary construction technologies.

Building material thermal characteristics affect operational GHG emissions. Their 'green' credentials—carbon intensity, structural strength, durability, recycled content, and circularity potential—affect lifecycle embodied emission. Figure 3.4 below shows the thermal characteristics and embodied carbon intensity of red brick and other alternatives, along with comparative costs and estimates of current production volumes. Low-carbon cements, such as Portland Pozzolana Cement (PPC) and Limestone Calcined Clay Cement (LC3), also have significantly lower emissions intensity than Ordinary Portland Cement (OPC) (see box below). This is not an exhaustive list. Alternative materials may not provide a like-for-like replacement for conventional materials when all thermo-physical properties are considered. However, depending on the specific circumstances and local supply chains, alternative materials may offer a significant reductions in embodied carbon.

Almost 2000 tonnes of LC3 has been produced in India and worldwide under pilot scale[41]. Sustainability impact assessment has demonstrated a reduction of nearly 40% of CO_2 emissions, and about 20% lower energy for production of LC3 as compared to OPC[42,43].

[xii] Construction method where building structural elements such as walls, roof and floor slab are cast-in-situ using reinforced concrete forming a single structure without distinct joints. Prefabricated (typically aluminium) formwork is used for the purpose.



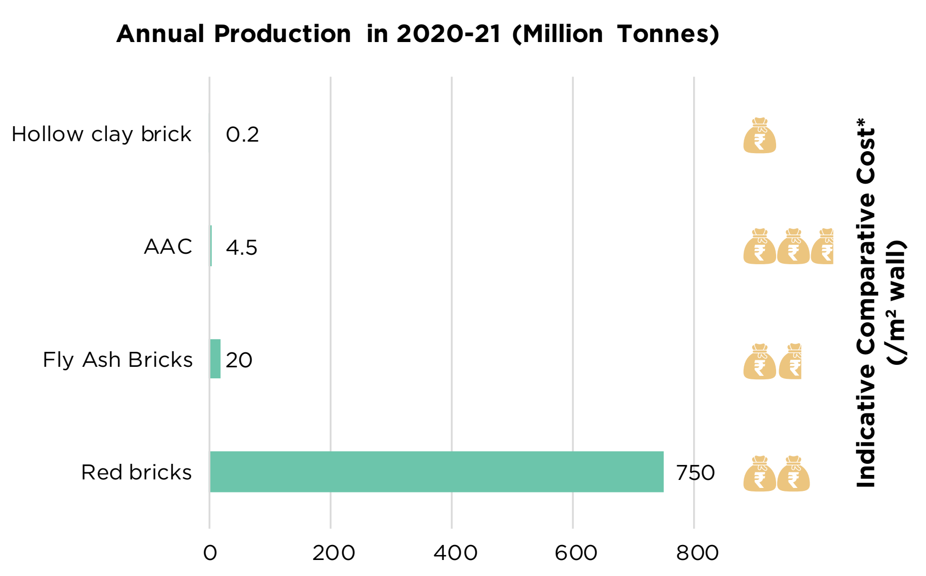
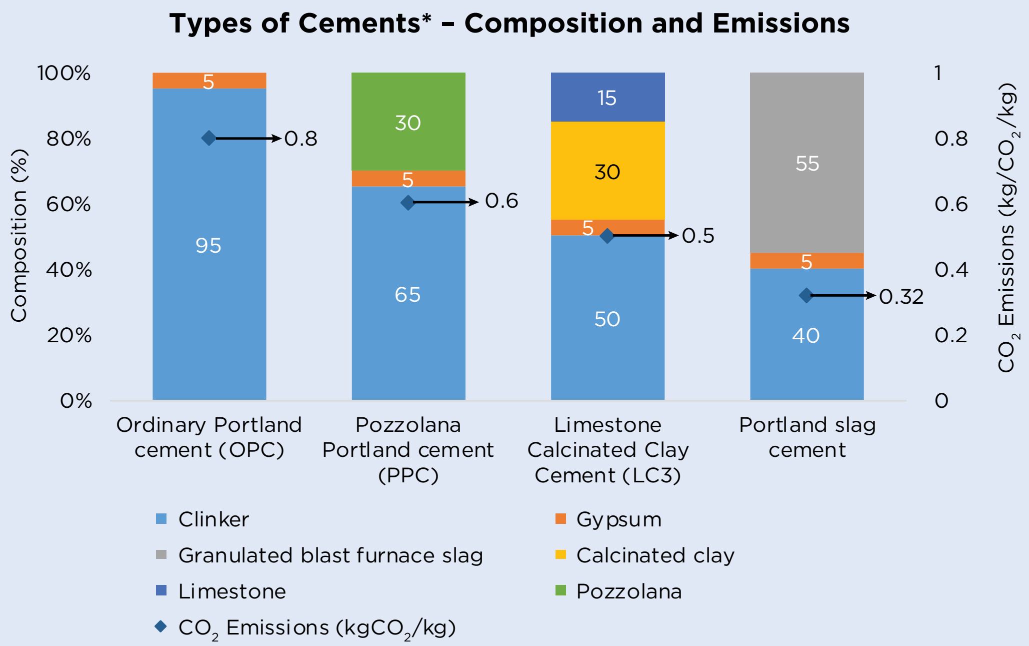


Figure 3.4: Thermal Performance, Embodied Carbon and Market Maturity of Conventional Materials and Low-Carbon Alternatives[44,45,46]

****Note:** Comparative costs may vary across the country depending on the local supply chain constraints*

Different types of low-carbon cements and reduction potential relative to Ordinary Portland Cement (OPC)

The figure below shows the differences in composition of different types of cements and their emissions intensity per kg. Ordinary Portland Cement (OPC) comprises 95% clinker. By partially replacing clinker with Supplementary Cementitious Materials (SCMs) such as fly ash, blast furnace slag, limestone powder, etc., substantial reductions in CO_2 emissions can be achieved. Depending on the type of application (structural or non-structural), these can help reduce the emissions intensity of OPC by up to half.



** **Sources:** i. for the composition of OPC, PPC, LC3: https://lc3.ch/wp-content/uploads/2023/03/2016.02.06EconomyLC3.pdf; ii. for CO_2 emissions of OPC, PPC, LC3: https://civil.iitm.ac.in/admin/civilcont/sanoop%20prakasan.pdf; iii. for composition and emissions from PSC: https://api.environdec.com/api/v1/EPDLibrary/Files/d20934da-2b0c-40e3-b029-4da5f1ad4d6e/Data*

Table 3.3 provides comparative data on the embodied carbon of case study buildings constructed in India, along with some international examples. This suggests that the lifecycle embodied carbon of buildings in India may be much higher than in other geographies, where supply chains are relatively decarbonised and design considerations to reduce material use are more common place.

However, comparing published data across case study buildings is challenging. Variations include lifecycle analysis boundaries (i.e., what is included/ excluded from the calculations), different emission factor databases, and inconsistent methodologies. These methodological differences encompass standard floor area definitions, on-site renewables accounting, and material end-of-life circularity benefits. Such inconsistencies make cross-project and regional comparisons difficult, highlighting the need for a national standardised approach supported by product-level environmental performance disclosures.

Table 3.3: Embodied Carbon Of Buildings: Indian and International Case Studies[47, 48]

	Residence A	Residence B	Residence C	NZEB* at CEPT University	Infosys	Canal Reach	Harris Academy, Sutton	81-103 Kings Road
Type	High-rise residential complex	Low-rise residential complex	Residential – 4-storey Builder floors	Office	Office	Office	Education	Office/ Retail
Location	Bengaluru	Bengaluru	Bengaluru	Ahmedabad, India	Kolkata, India	UK	UK	UK
Area (m^2)	-	-		515	26,557	54,921	10,625	17,177
Construction Type	Monolithic concrete	RCC frame with bricks, CSEB & concrete blocks	RCC frame with solid concrete blocks	Brick masonry	Concrete masonry			
Assessment boundary	Structure, foundation, all walls, plaster, shading	Structure, foundation, all walls, plaster, shading	Structure, foundation, all walls, plaster, shading	Structure, envelope, finishes, HVAC, PV, electrical	Structure, envelope, finishes, HVAC, PV, site, interior layout, foundation	-	-	-
A1-A5# ($kgCO_2/m^2$)	338	419	374	3292	952	705	563	623
C1-C4 ($kgCO_2/m^2$)	-	-	-	350	324	50	305	95
Total ($kgCO_2/m^2$)	338	419	374	3643	1276	755	868	718

** Net Zero Energy Building (NZEB)*
 # A1- A5, C1-C4 Explained in next page

Building lifecycle assessment (LCA) boundary and terminology

Lifecycle embodied carbon includes carbon emissions related to materials and construction processes across the entire lifecycle of a building. This includes: material extraction (A1), transportation to the manufacturer (A2), manufacturing (A3), transportation to the site (A4), construction (A5), use phase (B1), maintenance (B2), repair (B3), replacement (B4), refurbishment (B5), deconstruction (C1), transportation to end-of-life facilities (C2), processing (C3), and disposal (C4). The nomenclature in brackets above is used to refer to different building lifecycle stages as per the widely-accepted ISO standards 14040/14044 and European standard EN 15978, and as illustrated in Figure 3.5 below.

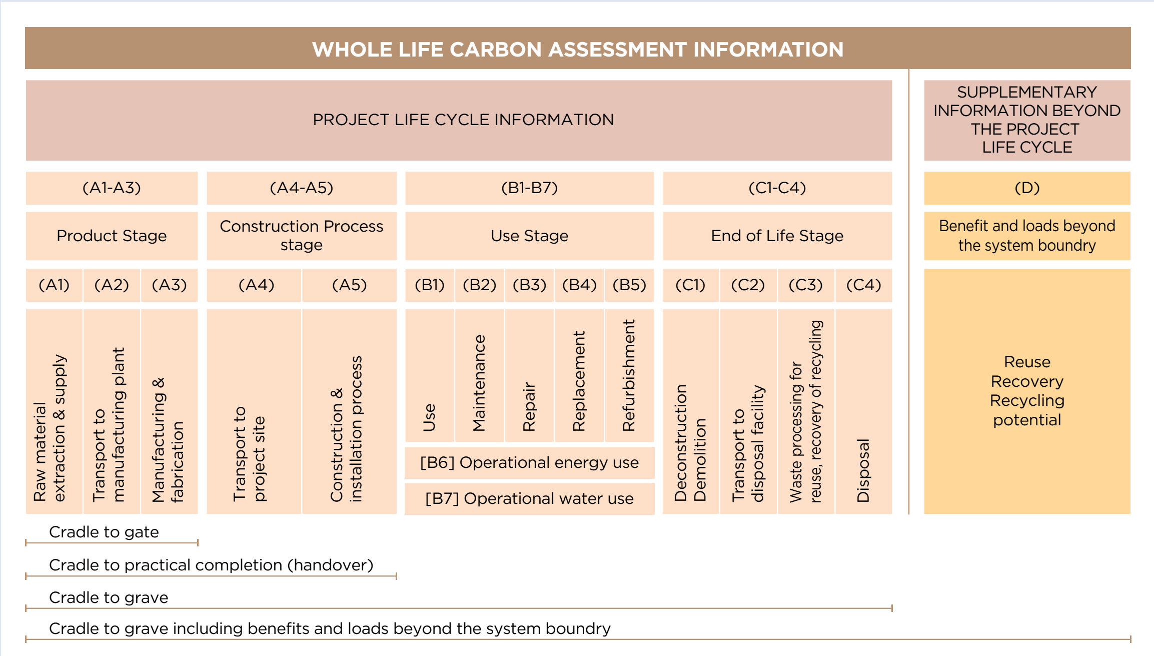


Figure 3.5: Building lifecycle assessment stages and nomenclature as per ISO standards

Source: *Based on BS EN 15978, RICS 2017*

3.3 Policy Baseline: Codes, Labels and Disclosure Gaps

Key building sector policies: India's policy and regulatory regime has evolved over the last two decades to increase its focus on energy efficiency, renewable energy generation and environmental protection. The key building-sector policies are summarised in Table 3.4. Table 3.5 shows the indicative average annual emissions avoided as a result of some of the policies.

Table 3.4: Current Building-sector Policy Framework Across Asset Lifecycle

Asset lifecycle	Type of policy instrument	Name	Mandatory/ voluntary*	Jurisdiction	Applicability (building type / size, etc.)	Attributes				
						OE	RE	TC	EC	CL
Supply chain (building materials, components and HVAC equipment)	Energy labelling	Standards and labelling (S&L) program for appliances and equipment	Part mandatory	National	Invoked for 28 categories of equipment, including air-conditioners, refrigerators, fans, pumps, washing machines, gas stoves, LED lamps, microwave ovens, chillers, packaged boilers, and air compressors, among others.	✓				
	Cap and trade scheme	Perform, Achieve and Trade (PAT)	Mandatory	National	Caps energy intensity for select industrial sectors over a 3-year cycle. Covers cement, iron & steel, and aluminium.	✓				✓
	Financing instrument	Unnat Jyoti by Affordable LED for All (UJALA)	Voluntary for beneficiaries	National	LEDs in residential buildings. Beneficiaries benefit from the cost efficiencies of bulk procurement and the ability to pay upfront costs in instalments through 'On Bill Financing'.	✓				
New buildings (design and construction)	Building code	Energy Conservation Building Code (ECBC 2007 & 2017)	Part mandatory	ECBC 2017 adopted in 18 states & UTs, ECBC 2007 in 5, yet to be adopted in 13.	Varies by state. Typically, commercial buildings >100kW connected load or >120kVa contract demand. Adopted with amendments in some states with thresholds for plot, built-up or conditioned area.	✓	✓	✓		
	Building code	Eco-Niwas Samhita (ENS 2018 (Part 1) and 2021 (Part 2))	Voluntary	Not adopted by states to date	Residential buildings on plot area >500m². Focus on the thermal performance of the building envelope.	✓	✓	✓		
	Building code	Energy Conservation & Sustainability Building Code (ECSBC 2024 & ECSBC-R 2024)	Voluntary	Not adopted by states to date	Commercial and residential buildings >100kW connected load or >120kVa contract demand	✓	✓	✓	✓	

Asset lifecycle	Type of policy instrument	Name	Mandatory/ voluntary*	Jurisdiction	Applicability (building type / size, etc.)	Attributes				
						OE	RE	TC	EC	CL
	Financial incentive	Financial incentives for green building ratings	Voluntary	Select states	Applies to buildings with GRIHA 3-star and above, LEED and IGBC ratings. Incentives vary by state (between 3-15% increase in FAR, part reimbursement of certification fee, or one-time rebate on stamp duty or property taxes).	✓	✓		✓	
Existing buildings (in-use phase)	Cap and trade scheme	Perform, Achieve and Trade (PAT)	Mandatory	National	Covers hotels and airports as designated entities. Sets a cap for energy intensity over a 3-year cycle.	✓				
	Energy labelling	BEE star rating scheme	Voluntary	National	Covers four typologies of commercial buildings with connected load >100kW: office buildings, BPO, hospitals, and shopping malls	✓				
	Energy labelling	BEE Shunya Labeling for Net Zero Energy Buildings (NZEB) and Net Positive Energy Buildings	Voluntary	National	Open to all building types having an EPI of less than 10 kWh/m^2/year based on actual energy consumption data.	✓				
	Public sector market transformation initiative	Building Energy Efficiency Programme (BEEP)	Voluntary	National	Covers retrofitting of existing public, institutional, and industrial buildings with energy-efficient appliances and systems. Focus on building energy use for cooling and lighting.	✓				
End of life (demolition)	Environmental legislation	Construction & Demolition (C&D) Waste Management Rules (2016)	Voluntary (recycling req.)	National	Promote recycling and reuse of C&D waste from all building sites.					✓

****Note this reflects the current status quo OC = Operational carbon RE = Renewable Energy TC = Thermal comfort EC = Embodied carbon CL = Circularity***

The Bureau of Energy Efficiency's (BEE) standards and labelling program defines Minimum Energy Performance Standards (MEPS) and labels for appliances and equipment. Launched in 2006 as a voluntary initiative, it is now mandatory for 16 categories of equipment and appliances[49]. Thirty-nine types of appliances were registered under the program as of March 2025.

Success of India's Standards and Labelling (S&L) program

India has witnessed a remarkable transformation in appliance energy performance driven by BEE's S&L program.

For instance, in the room air conditioner (RAC) market, the initiative has significantly increased the adoption of energy-efficient inverter ACs, replacing the less efficient fixed speed ACs. In 2015, the market share of inverter ACs was less than 1% in a total RAC market of 4.7 million units. In 2018, BEE took a technology-neutral approach by unifying the rating for fixed speed and inverter ACs. This meant fixed speed ACs could only achieve up to a 3-star rating, while more efficient inverter technology could go as high as 5 stars. By 2024 the market share of inverter ACs in a total RAC market of 11 million units had increased dramatically from 1% to 86%.

Overall the S&L program has led to reduction of 58.2 $MtCO_{2e}$ in 2022-23 due to interventions carried out over the previous 5 years across all categories of appliances. Direct cool refrigerator, colour television, and frost-free refrigerator combined contributed to nearly 60% of the total energy savings given their significant market demand and high household penetration rates currently compared to ACs.

The Energy Conservation Building Code, applicable to newly built commercial buildings with a connected load greater than 100kW (ECBC 2007 & 2017), and Eco-Niwas Samhita (ENS 2018) for new residential buildings, were also launched as '*voluntary*' initiatives at the national level. Since then, ECBC has been notified in 23 states and Union Territories. Both ECBC and ENS have focused mainly on operational energy performance. The latest amendment to the ECBC, India's Energy Conservation and Sustainability Building Code (ECSBC 2024) has enhanced performance standards for operational energy and additionally includes voluntary disclosures for embodied carbon of building materials. In 2024, ENS 2018 was superseded by ENS 2024 and now applies to large residential buildings in line with the threshold criteria for ECSBC. Both ECSBC 2024 and ENS 2024 are yet to be adopted by states.

There are limited policies addressing operational energy and/or carbon performance in existing buildings. BEE's Star Rating scheme[50] (2009) for commercial buildings and the relatively recent Shunya Labeling[51] for Net Zero Energy Buildings (NZEB) and Net Positive Energy Buildings (NPEB) are voluntary labelling schemes. While these schemes provide valuable frameworks for rating operational energy performance, they do not comprehensively address embodied carbon, lifecycle impacts, or mandatory performance data disclosures. This limits their ability to holistically reduce emissions in the building sector. Adoption has also been low; only about 500 buildings have been rated under the schemes.

Other than voluntary disclosures included in the recently launched ECSBC, there are no policies that specifically regulate embodied carbon in buildings. There is also currently no prescribed national methodology or mandated requirement for GHG disclosures of building materials and products. The Perform, Achieve and Trade (PAT), which was introduced as a cap and trade scheme in 2012, does set specific energy consumption targets for designated industrial sectors over a three-year cycle. Designated industries relevant to the building sector include cement, iron and steel, and aluminium manufacturing. Hotels and airports were also brought into the remit in 2017 and 2020, respectively. Other key building materials, such as bricks and glass, are not covered. The PAT scheme notably excludes non-fuel-related GHG emissions, which constitute a significant proportion of emissions from some construction materials. For instance, emissions released during calcination, a chemical reaction during clinker production, represent 50-60% of total emissions associated with cement production. Recognising the limitations of PAT, India is now preparing to transition to the Carbon Credit Trading Scheme (CCTS), which aims to cover a broader range of emissions and sectors, including energy and process-related emissions.

The above discussed policies for the building sector have achived progressively increasing GHG emissions savings, with the scale of impact varying across measures. The impact assessment report 2022-23 by Bureau of Energy Efficiency (BEE) shows that schemes like Standards and Labelling (S&L) and Unnat Jyoti by Affordable LEDs for All (UJALA) have played substantial role in reducing GHG emissions in the building sector (59.7 Mt CO_2e avioded). However, the emissions reduction through various other policy instruments targeting building designs (such as ECBC, BEE star rating, Green Building Rating Program, (GRIHA), Eco-Niwas Samhita (ENS), Building Energy Efficiency Programme (BEEP)) have been modest due to their limited adoption, as shown in Table 3.5.

Table 3.5: Annual Avoided Emissions for Key Building Sector Policies[52]

Policy instrument	Avoided energy consumption (MTOE)	Average annual avoided GHG emissions (Mt CO_2e)
Standards and Labelling (S&L) program for appliances	7.04	58
Unnat Jyoti by Affordable LEDs for All (UJALA)	0.207	1.7
Others (ECBC, BEE star rating, Green Building Rating Program, (GRIHA), Eco-Niwas Samhita (ENS) and Building Energy Efficiency Programme (BEEP))	0.350	2.9

Governance structure and policy implementation: Under India's federal governance structure, the building sector largely falls under the legislative domain of the state; some aspects are under the concurrent domain of both the central government and the state. This means building codes need to be formally notified by states before they can be implemented. Some enforcement and regulatory functions (e.g. local building by-laws) are further delegated to Urban Local Bodies (ULBs). States also have the flexibility to modify the codes and put in place the enforcement regime and processes. At the national level, several ministries and government bodies regulate different aspects affecting the building sector. The fragmented governance and institutional structures, and limited devolution of funds to the local level, affect the implementation of otherwise well-designed policies like the ECBC and ENS. Policy implementation challenges are further discussed in Chapter 5.

Enabling legislative and strategic framework: The core building-sector policies are enabled by legislations like the Electricity Act 2003 and the Energy Conservation Act 2001. Regulations, schemes and programs related to energy efficiency (e.g. State Energy Efficiency Action Plans developed by several states since 2023), renewable energy generation (e.g. Pradhan Mantri Surya Ghar Yojana, 2024) and environmental protection (Environmental Protection Act 1986) further affect the sector.

Policies and interventions in the building sector are also guided by high-level strategic vision documents and action plans such as:

i. *National Action Plan for Climate Change* (2008), which outlines the national strategy for mitigating and adapting to climate change. Under this, are eight 'National Missions' including the National Solar Mission, National Mission for Enhanced Energy Efficiency, and National Mission on Sustainable Habitat.

ii. *India Cooling Action Plan* (2019), an action plan for reducing cooling demand through better thermal performance of the building envelope and efficient equipment, with a view to ensuring thermal comfort for all.

iii. *National Disaster Management Plan (2019)*, which provides a framework to government agencies on all aspects of disaster management, and covers thematic areas for disaster risk reduction including understanding risk, inter-agency coordination, structural measures, non-structural measures, capacity development, and climate change risk management.

iv. *Long-term Low-emission Development Strategy* (LT-LEDS 2022), India's long-term strategy to transition to a low-carbon economy, which was created as per the Paris Agreement. It also covers the building sector.

4

SECTORAL ENERGY DEMAND MODELLING AND RESULTS

Sectoral Energy Demand Modelling and Results

4

This chapter presents the methodology and the results of a comprehensive, rigorous modelling exercise focused on two components:

i. **Built-up floor space** projections for residential and commercial buildings, based on factors like population, household size, income groups, urbanisation, and service sector employment. Commercial energy projections are linked to floor space and its energy intensity. Estimates of floor space also provide insights into future material and infrastructure requirements of urban India.

ii. **Energy demand** modelling focuses exclusively on operational energy use, i.e., energy consumed during the use phase of buildings in lighting, cooling, appliances, and cooking. The modeling excludes embodied emissions and end-of-life energy impact estimations in this exercise, while the emissions from associated material demand has been captured by Inter-Ministerial Working Group on Industry sector pathways to Net Zero. Demand from residential, commercial, and cooking uses are estimated using sector-specific methodologies as described below:

   a. The residential segment is modelled using a bottom-up appliance stock and usage framework;

   b. The commercial segment is driven by floor area growth, Energy Performance Index (EPI), and green code adoption. Crucially the model includes high-load categories such as cold chain infrastructure and data centres, given their growing prominence in energy demand.

   c. Cooking energy demand is modeled using per-capita energy consumption baselines for urban and rural houeseholds, adjusted for fuel mix transitions (e.g., LPG, PNG, biogas, electricity) and efficiency gains from advanced cooking technologies (e.g., induction stoves).

The modelling methodologies capture relationships between economic growth, urbanisation, climate variability, technological shifts, and evolving household behaviour. This modelling approach draws on a review of methods used by leading national institutions and expert organisations to ensure analytical robustness and sectoral alignment (Table 4.1).

Table 4.1: Overview of Building Energy Demand Modelling Approaches in India

Modelling Approach	Purpose / Focus	Methodology Overview	Institutions Using This Approach
System Dynamics (e.g., SAFARI)	Captures long-term feedbacks between socio-economic drivers and energy use	Simulates policy, technology, and behavioural interactions over time to assess demand and emissions trajectories	CSTEP
Appliance Stock and Usage (Bottom-Up)	Models residential energy demand based on ownership and usage patterns	Tracks penetration of appliances by income group, usage hours, and efficiency improvements	AEEE, TERI, adopted in multiple household energy studies
Floor Space and Energy Performance Index (EPI)	Projects commercial sector demand based on floor area and energy intensity	Applies building-type specific EPIs and efficiency improvements; includes emerging loads (data centres, cold chains)	NIUA, RMI, AEEE and others working on commercial sector studies
Energy System Optimization (TIMES/ GCAM)	Identifies least-cost energy pathways across sectors including buildings	Techno-economic optimization of energy technologies to meet service demand under constraints	NITI Aayog, CEEW, PNNL
Scenario Framework (India Energy Security Scenarios–IESS)	Provides policy-aligned demand trajectories	Uses macro drivers (GDP, population) and sectoral modules to project demand under policy scenarios	NITI Aayog

The final estimation of operational energy demand in residential, commercial, and cooking segments was undertaken using the India Energy Security Scenarios (IESS) and the TIMES models. These tools align with India's national energy planning frameworks and integrate with cross-sectoral Net Zero pathways. The scenario design and parameterization used inputs from diverse modelling approaches and feedback from consultations with expert institutions specialized in system dynamics, appliance-based modelling, and commercial energy analysis. This approach ensures methodological robustness and policy relevance.

4.1 Key Macroeconomic Assumptions

Floor space expansion and energy demand growth projections are shaped by macroeconomic, demographic, and urbanisation trends, that influence consumption patterns across residential, commercial, and cooking sectors. Key assumptions defining floor space and energy demand evolution from 2020 to 2070 are shown below (Table 4.2).

Table 4.2: Key macroeconomic assumptions for deriving building stock and energy demand projections

Category	2020	2025	2050	2070	Assumption & Key Trend
Population (Million)	1347	1411	1608	1621	Peaks at 1,631 million (2062) and then declines slightly based on MoHFW projections till 2036 and extended using UN DESA World Population Prospects (2022).
Urbanisation (%)	35%	37%	53%	65%	Doubling of urban population aligned with Viksit Bharat vision and the urbanisation experience in upper-middle income countries (e.g., China and Brazil).
Urban Household Size	4.2	4.1	3.41	3.41	Reduction based on past Census/NSSO data that mirrors trends in rapidly urbanising Asian and Latin American economies.
Rural Household Size	4.5	4.4	3.81	3.81	Gradual decline consistent with historical rural demographics and aligns with the experience in Indonesia, Vietnam, and China.

4.2 Estimation of Building Stock

4.2.1 Residential Building Stock

Residential floor space projections (refer to Figure 2.1) are critical for understanding India's future built stock and its implications on construction material demand, urban infrastructure planning, and lifecycle emissions. While these projections do not directly inform operational energy demand estimates in this study, they provide the basis for estimating upstream impacts including cement, steel, and brick consumption, for developing low-carbon construction policy strategies.

The estimation uses a structured framework combining demographic growth, urban transition, income-based housing segmentation, and typology-based dwelling size considering the following steps.

1. **Population and Urbanisation:** India's total household count is projected based on historical data from Ministry of Statistics and Programme Implementation (MOSPI) and National Sample Survey Office (NSSO). From a base of 215 million energy-using households in 2012, the number is estimated to grow to over 444 million by 2047, with the urban share increasing from 37% in 2023 to 51% in 2047 and further to 65% by 2070. The average household size is also assumed to decrease from 4.2 and 4.5 in urban and rural areas to 3.4 and 3.8, respectively.

2. **Economic Segmentation of Households:** Households are categorized into income groups using NSSO consumption expenditure data. Urban segments include EWS, LIG, MIG (≤2 bedrooms), and HIG (≥3 bedrooms). Rural households are classified into EWS, LIG, and MIG+ categories. The share of households in higher income brackets increases over time, reflecting economic development, and aligns with Viksit Bharat aspirations (Table 4.3).

Table 4.3: Economic Segmentation of Households for the Urban and Rural Sectors

	Urban			Rural	
	2020	2070		2020	2070
EWS	9%	0%	EWS	60%	0%
LIG	70%	52%	LIG	36%	80%
MIG<=2BR	16%	34%	MIG+	4%	20%
MIG>=3BR	5%	14%			

3. **Average Built-up Area:** Average built-up area per household is assumed based on housing surveys and literature benchmarks, and held constant within each economic group across years (Table 4.4).

Table 4.4: Built up Area per Household Based on Income Group

Urban	Built up area (in square meters)	Rural	Built up area (in square meters)
EWS	16.1	EWS	30.4
LIG	48.7	LIG	75.5
MIG<=2BR	97.5	MIG+	115.6
MIG>=3BR	176.5		

The estimation accounts for building stock turnover using a demolition rate derived from RMI's "Decarbonizing from the Ground Up" study. This serves as a proxy for building retirement given the lack of granular data on building service life in India. While necessary given data constraints, this approach has limitations. A more robust method would combine satellite-based spatial analysis of built-up areas with cadastral or municipal-level occupancy records.

In this context, emerging geospatial tools offer a timely opportunity to address these data gaps and strengthen future stock estimation efforts. Recently, AEEE launched the Geospatial Open Building Stack (GOBS)[xiii], a satellite- and machine-learning–driven platform that generates high-resolution insights into India's building stock. A future rerun of the GOBS analysis, potentially in 2027, when Google updates its datasets, can yield a definitive net rate of stock addition (new construction minus demolition). This would significantly enhance the precision of estimating sectoral growth and building churn. Integrating these updated geospatial outputs with municipal-level records will allow future model iterations to reflect real-world stock dynamics more reliably.

[xiii] https://gobs.aeee.in/

4.2.2 Commercial Building Stock

Commercial floor space estimation serves as the primary driver for modelling of operational energy demand in India's commercial building sector. Commercial energy consumption is derived from floor space and Energy Performance Index (EPI) values assigned to building types. Therefore, robust estimation of total commercial built-up area is central to projecting long-term energy use.

The study adopts top-down approach to estimate total commercial building stock using macroeconomic and demographic indicators rather than building-level inventories. This method, developed and refined by RMI and NIUA in earlier studies, is structured as follows:

Commercial Building Stock = Number of Service Sector Employees* × *Average Floor Area per Employee

Where:

- Service sector employment is calculated as:

  Population* × *Share of Economically Active Population* × *Share of Employment in Services

  Share of Economically Active Population: India's economically active population, defined as those engaged or willing to engage in productive work, is assumed to increase from approximately 40% in 2020 to around 61% by 2047, stabilising at 62% by 2070. This is similar to the current figures for the United States (62.3%), Germany (61.1%), and China (61.4%) and reflects demographic stabilisation, urbanisation with increased workforce participation.

  Share of Employment in Services Sector: From 31% of total employment at present, the share of service sector employment is assumed to rise to 35% by 2047 and stabilise at 47% by 2070, as the economy continues its transition from agrarian and informal sectors to formalised, service-oriented growth. This is in line with global trends, China's share of service sector employment increased from 33% in 2005 to nearly 48% by 2021, following increase in domestic consumption, logistics, and urban service infrastructure.

- Average floor space per employee is assumed to be constant at 10.7 m^2/person across the modelling horizon. This assumption figure is in line with other studies and is based on inputs provided during stakeholder consultations, reflecting perceived impacts of rising land prices and the adoption of space-efficient designs like open-plan offices and flexible workspaces.

Building Type-wise Segregation

India's commercial floor space is projected to expand more than threefold from 1,314 million square meters (sq m) in 2023 to 4,582 million sq m by 2070 driven by rising incomes, sectoral shifts in employment, and improved access to health, education, and logistics infrastructure (See Table 4.5 for building type wise breakup).

Table 4.5: Projection of Commercial Buildings by Type, Showing Absolute Floor Area (in Million sq m) and Share of Total Floor Area (in %)

Building Type	2023	2050	2070	Assumption
Hospitals	79	383	412	Increased hospital beds from 0.6 to 3 per 1,000 population in line with WHO recommendations and achieved under Ayushman Bharat and state missions.
Hotels	122	468	504	Rising domestic tourism, business travel, and cultural circuits, Infrastructure and National Tourism Policy push will raise India's current hotel rooms per 1,000 people from 0.2 to emerging market benchmarks (e.g., Thailand's 1.2).
Retail	287	723	780	Absolute area increases but share declines due to consolidation into malls and e-commerce growth mirroring global retail densification.
Office Space	307	851	916	Sustained growth due to rising formal employment (projected to reach 45% by 2047).
Educational	237	766	824	Stable share of floor space aligned with National Education Policy 2020 goals of raising enrolment. Floor area expansion to accommodate rising demand for secondary and vocational education.
Assembly Spaces	192	340	366	Absolute area grows modestly, but share declines as civic needs shift toward essential infrastructure.
Transit Infrastructure	12	85	92	Seven-fold growth in area driven by increased passenger and freight movement (4-5 times by 2070) driven by PM Gati Shakti, National Infrastructure Pipeline, and metro rail expansion and in line with China's infrastructure expansion experience.
Warehouses / Logistics	78	638	687	India's per capita warehousing space (0.03 m^2) to rise to that of China (0.15 m^2) and the US (4 m^2) through National Logistics Policy, GST-enabled hubs, cold chain expansion, and e-commerce.

4.3 Estimating Operational Energy Demand

Operational energy demand of India's building sector is modelled using bottom-up approaches that reflect different end-use patterns across residential, commercial, and cooking applications. The models are based on national data sources, expert consultations, and international best practices. Projections are made under the Current Policy Scenario (CPS) and the Net Zero Scenario (NZS).

4.3.1 Residential Sector

Residential energy demand is modeled using appliance-based approaches, as opposed to floor space and Energy Performance Index (EPI)-based methods used for commercial buildings. Unlike in commercial buildings, energy intensity in Indian residential buildings does not correlate with space because of differences in appliance ownership and their efficiency levels. An appliance-driven approach, thus, provides better estimates of energy demand, and helps account for technology improvements, efficiency gains, and behavioural shifts. Additionally, residential energy demand depends on demographic trends, technological transitions, appliance penetration, and consumer behaviour. Figure 4.1 illustrates the modelling approach and parameters used to predict residential energy demand, focusing on household-level electricity demand from appliances and other energy-using systems.

The energy services included in the framework are lighting (CFLs, LEDs, tube lights), television, refrigerators, cooling (air conditioners and fans), water heating, water pumping, washing machines, and space heating. While electric vehicles (EVs) also draw power from residential sources, in the modelling framework they are associated with the transport sector. Other minor contributors such as computers, Wi-Fi routers, grinders, and purifiers (water and air) are excluded due to data limitations and their relatively small impact on overall demand.

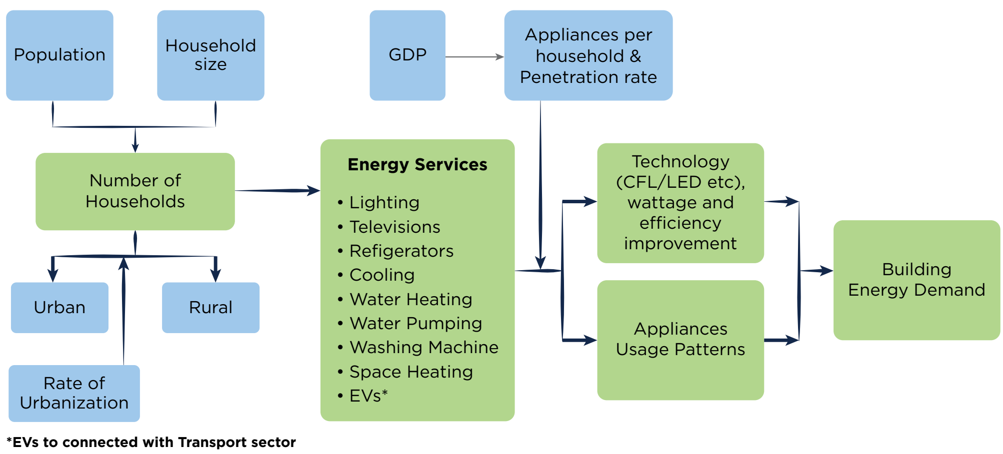


Figure 4.1: Parameters Considered for Modelling Energy Demand in Residential Buildings

Energy demand is calculated at the level of appliances or energy service units and then aggregated to obtain total residential energy use. First, for each energy service category, the penetration rate or the percentage of households that own the specific energy service units, is derived from national surveys, income projections (linked to GDP), and consumer trends. Then the average number of energy service units per household is determined. For example, a household may own more than one fan or television and only one refrigerator and washing machine. A diversity factor is also incorporated to account for limited usage of the units (For example, a household owning three fans may only operate two).

These two parameters, penetration rate and appliances per household, combined with the total number of households, are used to derive the total appliance stock.

$$\textit{Appliance Stock} = \textit{Households} \times \textit{Penetration} \times \textit{Units per Household}$$

For each appliance, demand is estimated based on three technical variables: rated power or capacity, average hours of use per year, and the efficiency of the technology used. Efficiency is technology-specific, for example, lighting may use CFLs, LEDs, or tube lights, each with differing power consumption and efficacy. Air conditioners may be classified by tonnage (e.g., 1-ton or 2-ton) and energy efficiency ratio (EER). To reflect this, appliances are disaggregated by technology type, and weighted for the share of households using each technology.

Building Design and Climate Change Considerations

Beyond appliance usage, building energy demand is also influenced by architectural design and climatic conditions. Building orientation, shading, reflective roofs, natural ventilation, and generous daylighting lower residential energy demand from air-conditioners and electric lights. The model assigns lower runtimes for cooling and lighting in homes where such architectural features are in place.

Further, to incorporate the rise in cooling-degree days due to climate change, the model considers higher hours of air conditioner use. Despite these considerations, a more detailed and spatially detailed study in the near future would be necessary to comprehensively assess these impacts.

4.3.2 Commercial Sector

Commercial sector energy demand is estimated using a bottom-up approach based on projected floor space, end-use energy intensities i.e., Energy Performance Index (EPI) and building efficiency standards. As economies develop, the demand for formal workspaces, services, and institutional buildings expands proportionally. As outlined previously in section 4.2.2, commercial building stock projections are derived from employment trends in the service sector and per-employee workspace assumptions. Commercial energy demand is then calculated by combining building stock with energy intensity values specific to different building typologies and usage categories (AC and Non-AC).

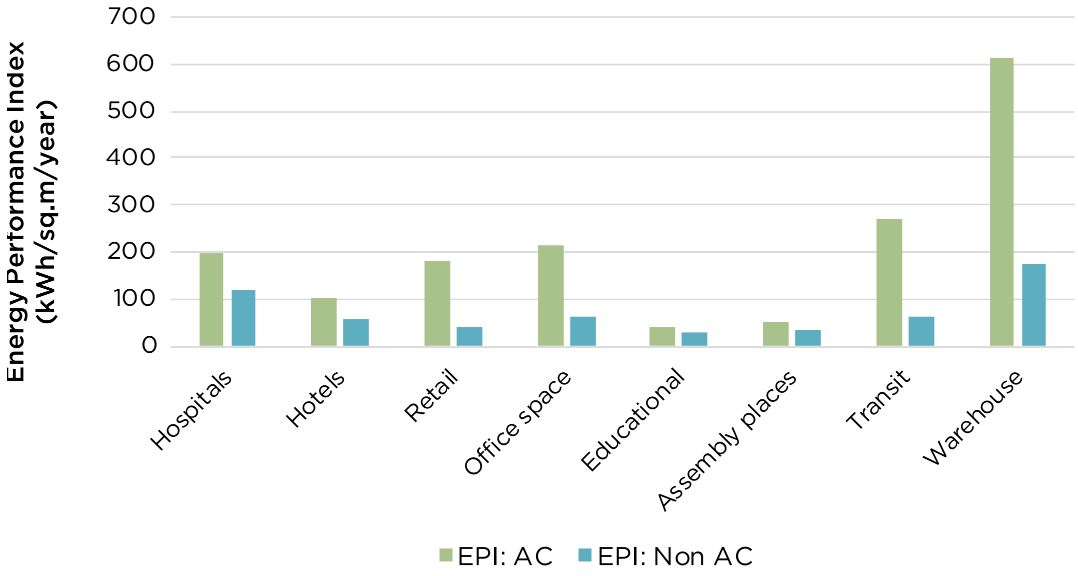


Figure 4.2: Benchmark Energy Performance Index considered for different building types in commercial buildings (AEEE, BEE)

Building types like hospitals, hotels, retail outlets, office spaces, educational institutions, warehouses, transit hubs, and assembly areas, each have unique energy performance profiles (Figure 4.2 above). Figure 4.3 below illustrates the parameters considered for the energy modelling for the commercial sector.

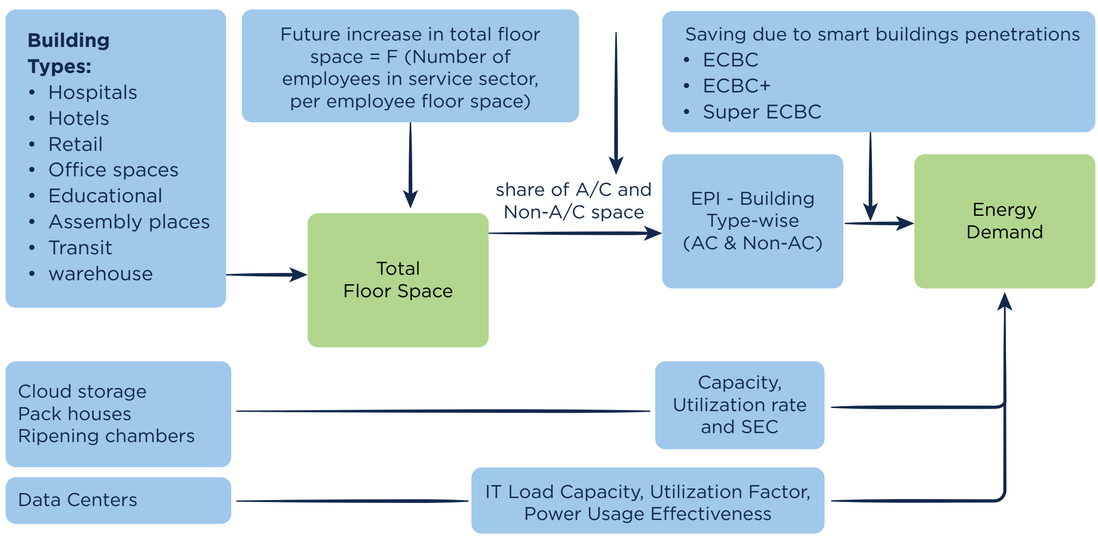


Figure 4.3: Parameters Considered for Modelling Energy Demand in Commercial Buildings

The baseline energy demand is calculated as:

$$E = \sum_{\text{building type}} \left(\text{Total Floor Space} \times (\text{Share of AC} \times \text{EPI}_{\text{AC}} + \text{Share of Non-AC} \times \text{EPI}_{\text{Non-AC}})\right)$$

The model includes savings associated with the proliferation of smart buildings, such as those which adhere to ECSBC, ECSBC+ and Super ECSBC standards. The additional savings for these building types are highlighted in Table 4.6 (*Source: BEE*).

Table 4.6: Energy Savings from ECSBC-compliant Buildings

ECSBC and its superior variants	Additional savings
Energy Conservation and Sustainable Building Code (ECSBC)	25%
ECSBC+	35%
Super-ECSBC	50%

Emerging Load Centres

Cold chains and data centres are expected to emerge as significant electricity consumers. Cold storage energy use is modelled based on growth in refrigerated storage capacity and its associated specific energy consumption, while data centre demand is projected using IT load growth and power usage effectiveness (PUE) over time.

Data Centre Facilities

High energy intensity and continuous operation mean that data centers are a distinct and increasingly relevant end-use category within the commercial sector. Their energy demand is estimated using:

$$\textit{Electricity Demand} = \textit{IT Load Capacity} \times \textit{Utilization Factor (UF)} \times \textit{Power Usage Effectiveness (PUE)}$$

India's IT load capacity is projected to reach 16 GW by 2030, largely driven by data localisation policies and digital service expansion. At a typical utilization rate of 40% and a Power Usage Effectiveness (PUE) of 1.6, this translates to an estimated electricity demand of around 10 GW in 2030.

In the medium-term (2030–2050), IT load is expected to grow at 12% per annum due to AI integration. By 2050 IT load is projected to reach 64 GW, Utilization Factor to 50% and Power Usage Effectiveness dropping to 1.4, resulting in a total electricity demand of approximately 45 GW.

In the long-term (2047–2070), the integration of quantum computing and further digitalisation is expected to sustain growth at 6% per annum. By 2070, IT demand could reach 105 GW, with further operational improvements (Utilization Factor at 60% and Power Usage Effectiveness at 1.3) resulting in an estimated electricity demand of about 80 GW.

These projections underscore the increasing importance of data centres in national energy planning. While their energy footprint expands, efficiency improvements through optimized cooling systems, renewable energy integration, and advanced power management can help moderate their energy demand.

Cold Storage

Cold storages, pack-houses, and ripening chambers are another critical component of India's commercial energy use based on rising demand for perishable goods, processed food, and pharmaceuticals. Energy demand from cold chain infrastructure is estimated for different types of facilities based on their installed capacity, utilization rates, and specific energy consumption (SEC) per tonne or per unit volume of stored material.

Energy Demand Cold Chain =Capacity × Utilization Rate × Specific Energy Consumption

Table 4.7: India's Cold Storage Facility Type-wise Growth Projection

Facility Type	Unit Type	Capacity (2017)	Capacity (2070)	Utilisation Rate	Specific Energy Consumption (SEC) (kWh/ tonne)
Cold Storage	Million Tonnes	35	70	75%	90
Packhouses	Number of Units	500	1,80,750	55%	950
Ripening Chambers	Number of Units	1,000	30,750	65%	4,275

India's cold storage systems currently exhibit high SEC values, often significantly above global benchmarks, due to outdated technologies, poor insulation, and inefficient refrigeration systems. Over the modelling horizon, the SEC for cold chain infrastructure is expected to improve with the adoption of best practices and energy-efficient technologies (Table 4.7). The modelling framework does not include energy demand from reefer vehicles (refrigerated transport), which is addressed under commercial transport.

4.3.3 Cooking

Cooking energy demand is estimated using per capita useful energy requirement of 2 MJ per capita per day, a benchmark widely used in energy access studies. This requirement is in line with estimates in other studies like IEA Energy Access Outlook (1.9–2.5 MJ/capita/day), Global LPG Partnership (2–2.2 MJ/capita/day), TERI's India Cooking Energy Study (1.8–2.3 MJ/capita/day), Prayas (2.2–2.4 MJ/capita/day), and NIUA-RMI studies (1.9–2.1 MJ/capita/day). The model does not differentiate between residential and commercial cooking energy demand, reflecting real-world overlaps in food preparation and supply chains.

Figure 4.4 illustrates the parameters considered in modelling cooking energy use. Total useful energy demand is calculated from population projections and household size, with urban and rural segmentation reflecting variations in cooking fuel access and efficiency. Final energy demand applies fuel-specific efficiencies across LPG, PNG, biomass, and electric cooking technologies. Fuel mix transitions are projected using historical adoption trends, urbanisation rates, policy incentives, and expected technology improvements. The assumptions on these parameters are presented in Annexure B.

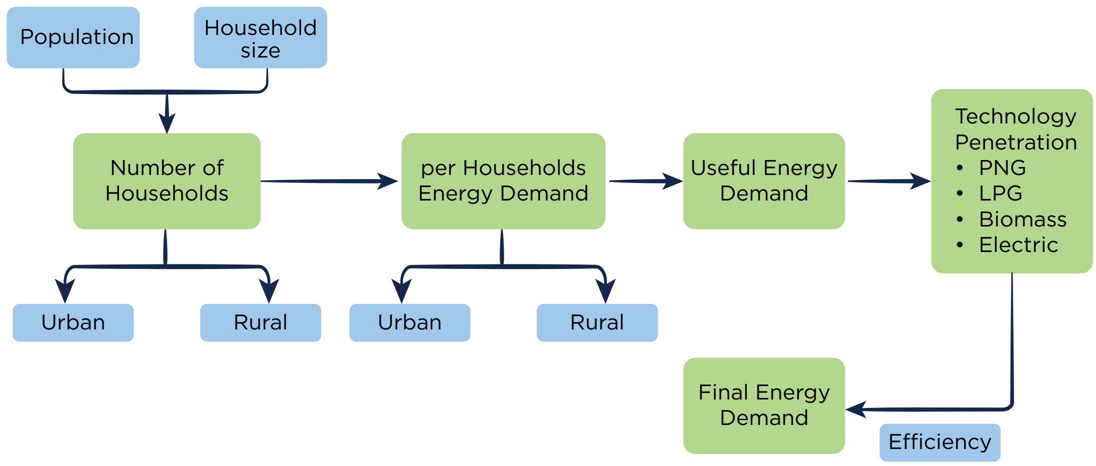


Figure 4.4: Parameters Considered for Modelling Energy Demand for Cooking

4.4 Scenarios For Energy Modelling

The modelling framework assesses energy demand trajectories under two contrasting scenarios. The Current Policy Scenario (CPS) reflects business-as-usual developments based on currently implemented or officially announced policies. The Net Zero Scenario (NZS) explores an ambitious yet plausible pathway aligned with India's 2070 Net Zero target. Assumptions differentiating these pathways consider technological and behavioural changes, as well as policy and implementation capacity.

4.4.1 Residential Sector

Residential energy demand is shaped by appliance efficiency, building envelope performance, cooling needs, and user behaviour. The scenarios diverge on how these factors evolve in response to policies and market transformation.

Appliance Efficiency

Under the Current Policy Scenario (CPS), efficiency improvements are assumed to follow a steady trajectory consistent with the evolution of India's Standards & Labelling (S&L) programme. Major residential appliances, such as fans, refrigerators, lighting, and air conditioners, are assumed to converge toward the best-performing options currently available in the Indian market. This transition is modelled as gradual and progressive, aligning with typical appliance replacement cycles and current adoption patterns across income groups.

Under the Net Zero Scenario (NZS), appliance efficiency reaches levels aligned with current (2024) best-in-class global benchmarks. This assumption assumes no future breakthroughs in appliance technology ensuring the scenario remains grounded in today's technical feasibility. Adoption progresses over time, reflecting likely policy support through expanded labelling, market transformation programmes, and efficiency improvement.

Thermal Performance and Cooling Demand

In both scenarios, air-conditioners (ACs) penetration in the residential sector is projected to rise from approximately 8% in 2022 to 65% by 2047 and 80% by 2070. This growth is primarily driven by rising incomes, urbanisation, and thermal comfort aspirations. Growth is assumed similar in both scenarios.

Cooling-related electricity demand in the residential sector is influenced by appliance efficiency and building envelope thermal quality. In the Current Policy Scenario (CPS), adoption of thermal performance standards such as the Eco-Niwas Samhita (ENS) remains limited to only 5% of new residential buildings by 2070. As a result, despite increased access to cooling, poor building design leads to high space cooling loads per household.

In the Net Zero Scenario (NZS), new housing thermal performance improves through wider application of ENS-compliant construction. This includes insulation, shading, reflective roofing, and ventilation. By 2047, 15% of new residential buildings are assumed to adopt these features, and rising to 25% by 2070. These enhancements significantly reduce effective cooling energy demand. Air-conditioned floor area remains similar in both scenarios due to rising incomes and thermal comfort aspirations.

User Behaviour

User behaviour, particularly in appliance usage patterns and thermostat settings, plays an important role in shaping residential electricity demand. However, behaviour is also difficult to influence through policy alone, as it depends on habits, social norms, and perceptions of comfort.

While Mission LiFE promotes energy-conscious habits like higher AC temperature setpoints and reduced usage, these are offset by rising cooling demand due to climate change and evolving comfort expectations. Globally, such trends are well-documented. In China, longer AC usage hours increased average residential cooling intensity fivefold from 0.8 kWh/m^2 in 2000 to 4 kWh/m^2 by 2017[53]. In the U.S., nearly 95% of locations have seen an increase in cooling degree days since 1970[54], with AC ownership now above 90% and usage hours steadily rising. Reflecting this, the Net Zero Scenario (NZS) assumes lower AC usage hours than the baseline, guided by Mission LiFE principles, while still accounting for upward pressure from rising temperatures and first-time users.

4.4.2 Commercial Sector

In commercial buildings, the scenarios are differentiated mainly through changes in energy performance index (EPI), adoption of low-carbon building standards, and the extent of air-conditioned floor space. The share of air-conditioned floor space is assumed to grow similarly in both scenarios. This is because cooling demand in commercial buildings is largely driven by aspiration and services (See Annexure B). The Net Zero Scenario does not limit access to thermal comfort, but focuses instead on delivering energy services more efficiently, through improved design and performance standards. The key points of divergence across the two scenarios are detailed below.

Energy Performance Index (EPI)

Effective EPI (energy use per square metre of total commercial floor space) is expected to increase over time due to the growing share of air-conditioned floor area and higher energy intensity associated with air-conditioned spaces. However, despite this increase in service intensity, the energy intensity of buildings (measured per square metre of conditioned space) is assumed to gradually decline due to ongoing technology upgrades and system-level improvements.

In the Current Policy Scenario (CPS), these improvements are modest, and yield a 10% reduction in intensity by 2070, largely due to the natural upgrade cycle of commercial equipment. However, these improvements are limited in scope as older commercial stock-such as small offices, retail outlets, and private institutions- continue to operate with suboptimal systems, and there is no widespread mandate for retrofits.

In the Net Zero Scenario (NZS), improvements of 15% by 2070 are assumed, enabled by wider uptake of building energy management systems (BEMS), occupancy-based lighting and cooling controls, and better zoning of HVAC systems. These assumptions recognise that retrofitting older commercial stock at scale will require significant institutional and financial support.

Low-Carbon Buildings Standards

The Current Policy Scenario (CPS) and Net Zero Scenario (NZS) differ in their adoption of low-carbon building codes and standards, including the Energy Conservation and Sustainable Building Code (ECSBC) and its enhanced variants (ECSBC+ and Super ECSBC). The scenarios also differ in their institutional capacity and penetration in Tier-II and III cities.

Under the CPS, the implementation of building codes is limited. Although ECSBC is notified in many states, its enforcement is weak and complied mostly in premium urban developments. Under the NZS, there is greater enforcement of the codes in public buildings, improved institutional capacity, and growing market interest in green-certified spaces (Table 4.8).

Table 4.8: Penetration Growth Assumed for Energy Conservation and Sustainable Building Code (ECSBC) and its Superior Variants in the Building Sector

	Current Policy Scenario		Net Zero Scenario	
	2050	2070	2050	2070
ECSBC	12%	20%	18%	30%
ECSBC+	6%	10%	12%	20%
Super ECSBC	3%	5%	6%	10%

4.4.3 Cooking Sector

Cooking energy demand has been modelled based on household fuel share evolution across urban and rural segments. The model considers long-term trends in fuel stacking, affordability, and infrastructure access. The two scenarios reflect different transition rates from traditional fuels to cleaner alternatives (Annexure B).

While this shift is more ambitious than in Current Policy Scenario (CPS), the Net Zero Scenario (NZS) remains realistically conservative. It accounts for continued affordability challenges, grid reliability issues, and cultural inertia that sustains traditional cooking methods, particularly in remote and low-income households. Infrastructure constraints in expanding PNG and electric induction networks beyond urban cores also moderate the pace of change.

These assumptions are informed by historical NSSO data, the ACCESS survey, and recent trends under schemes like PM Ujjwala Yojana. They do not presume complete electrification or universal fuel switch, even under NZS.

While the Net Zero Scenario (NZS) represents a high-ambition, realistic pathway for low-carbon transition of the building energy demand, it does not capture the full range of decarbonisation opportunities. Structural and behavioural constraints, such as slow shifts in cooking fuel mix and partial adherence to energy codes, limit the potential reductions. Greater reductions could result from behavioural change, large-scale retrofits, and future technological breakthroughs.

4.5 Building Sector Energy Demand Outlook: Results and Trends

4.5.1 Residential Energy Demand: Urbanisation, Appliances, and Comfort

Figure 4.5 depicts current and projected energy demand from key appliances in residential buildings. India's residential energy demand is rising because urbanisation, economic growth, and improved access to electricity are enabling households to broaden their use of energy services. From basic lighting and cooking to space cooling, water heating, and household appliances, the shift reflects rising living standards, changing aspirations, and an emphasis on comfort and convenience.

Unlike the Current Policy Scenario (CPS) and Net Zero Scenario (NZS) envisions demand growth will be combined with aggressive interventions, such as accelerated uptake of efficient appliances, cleaner mode of heating and cooling technologies, and behaviour-led demand management.

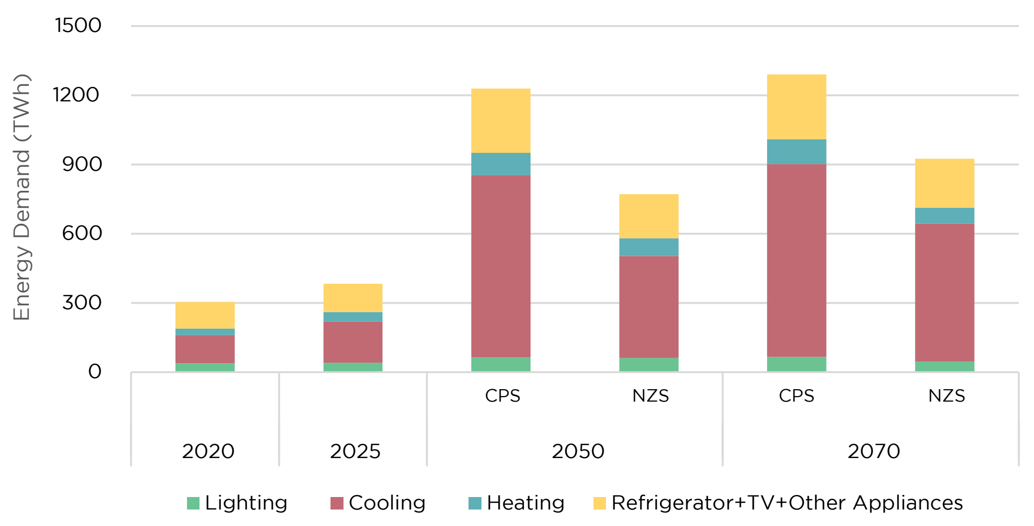


Figure 4.5: Energy Demand Projection from Appliances in Residential Buildings under Current Policy Scenario (CPS) and Net Zero Scenario (NZS)

Lighting, once a dominant source of residential electricity use, has seen a significant efficiency improvement due to the widespread adoption of LED technologies. In 2020, residential lighting demand stood at 40 TWh. Under the Current Policy Scenario (CPS), it is expected to increase to 66 TWh by 2050 and 69 TWh by 2070. However, in the Net Zero Scenario (NZS) , greater efficiency programs result in lower lighting demand, 62 TWh in 2050 and 48 TWh by 2070, because efficient technologies will moderate energy use despite growing demand.

Cooling is the fastest-growing demand in Indian homes, driven by rising heat stress, urban aspirations, and affordability. Fewer than 10% of households currently own air conditioners, which is set to surge in future. Under the CPS, electricity consumption for cooling is projected to rise significantly from 123 TWh in 2020 to 834 TWh by 2070. Under the NZS, early adoption of efficient cooling systems and behaviour-led interventions are projected to raise demand to a lower level to 596 TWh in 2070, underscoring the importance and effectiveness of energy efficient appliances, and climate-aligned interventions.

The Cooling Surge: Rising Demand in a Warming Climate

Cooling is the most rapidly escalating component of building energy demand in India, driven by rising temperatures, more frequent heatwaves, and economic growth enabling wider adoption of cooling devices. This "cooling surge" is evident in booming air-conditioner sales, expanded use of evaporative coolers and fans, and a rising number of Cooling Degree Days (CDD) across much of the country. More CDDs translate to longer hours of fan and AC operation, and without intervention, climate-linked load growth could push cooling energy needs to unprecedented levels as extreme heat becomes the new normal.

The **impact on peak electricity demand** is a major concern. During heatwaves, simultaneous AC use creates sharp evening peaks, straining grids and triggering brownouts. As ownership grows, peak loads will intensify, risking a "peak load crisis" on the hottest days. IEA projects a 60% rise in peak electricity demand by 2030, with cooling driving nearly half the increase.

The surge is also self-reinforcing: waste heat expelled from AC units contributes to urban heat islands, making cities even warmer and driving further cooling demand. Recognizing these risks, the **India Cooling Action Plan (ICAP)** outlines strategies to deliver "cooling for all" while restraining energy use. Key measures include improving thermal envelopes, adopting passive cooling techniques (shading, green roofs, ventilation), tightening efficiency standards for appliances, and exploring alternatives like district or evaporative cooling. Traditional Indian designs—courtyards, jaali screens, thick walls—combined with modern materials (reflective paints, insulation) can significantly reduce indoor temperatures and avoid mechanical cooling needs. IPCC studies highlight that in warm climates, bioclimatic design alone can avoid a large share of cooling demand.

International experience underscores the urgency. China's rapid increase in air-conditioner penetration, exceeding 60% of urban households within two decades, led to a sharp surge in cooling-related electricity demand. India could mirror or even surpass this trajectory in the absence of timely policy, regulatory, and market-based interventions to improve efficiency, manage demand, and expand alternative cooling solutions. The U.S. reached near-total AC saturation long ago, leading to very high per-capita cooling demand and summer grid peaks. U.S. utilities responded with demand-response programs and time-of-use tariffs, which India may need to adopt. In contrast, Europe historically cooling-light now faces rising AC sales after recent heatwaves but focuses heavily on retrofits, shading, and ventilation to limit demand. Its "Renovation Wave" upgrades old buildings with insulation and heat pumps, reducing both heating and emerging cooling needs.

Cooling is both a major challenge and an opportunity. Left unmanaged, it could dominate future energy demand and emissions, while well-designed interventions—urban planning, passive architecture, efficient appliances, and smart operation can provide comfort sustainably. A Net Zero pathway shows that even with expanded cooling access, overall demand can be contained through these measures, avoiding a massive drain on power systems. India can also learn from global examples: district cooling in the Middle East, natural ventilation in Southeast Asia, and advanced building codes elsewhere. Targeting cooling efficiency is thus critical to shaping a low-carbon building sector.

Heating, which includes both space and water heating, is gaining significance with the affordability of electric and solar geysers and space heating needs in colder regions. Under the Current Policy Scenario (CPS), electricity demand from this sector is expected to grow from 27 TWh in 2020 to 96 TWh in 2050 and 106 TWh in 2070. Under the Net Zero Scenario (NZS), with more efficient technologies, demand would reach 76 TWh in 2050 and moderate to 70 TWh in 2070. This too illustrates how clean technology adoption can facilitate greater access with lower emissions.

Other appliances, covering refrigerators, televisions, washing machines, and other household devices, reflect India's improving living standards. Under the CPS, electricity use for other appliances is expected to grow from 115 TWh in 2025 to 277 TWh in 2050 and 281 TWh in 2070. Under the NZS demand is projected to reach 192 TWh in 2050 and to 210 TWh in 2070.

Summary: The residential sector's energy profile is shifting from one dominated by basic lighting and cooking towards a more diversified mix including space cooling and appliance use, with growth strongly correlated to income and urban lifestyles. Higher-income urban residents consume significantly more energy for comfort and convenience – for example, running multiple fans, refrigerators, and entertainment devices – whereas poorer or rural households still consume only a fraction of that, sometimes limited by affordability or access. This divergence underlines the dual challenge: expanding energy access for underserved populations while curbing excessive or inefficient consumption among the rapidly growing middle class. Encouragingly, wealthier households often purchase more efficient appliances (thanks in part to standards and labeling programs), but any efficiency gains can be offset by the greater number and size of appliances in use. Thus, managing residential energy demand will require not just efficient technology but also attention to consumer behavior and "sufficiency" – avoiding wasteful energy use even as living standards improve.

4.5.2 Commercial Buildings: Floor Space Growth and New Demands

Energy use is increasing in India's commercial and institutional buildings. Economic growth, and development and a shift towards service sector are increasing the number of offices, malls, hospitals, hotels, and other commercial buildings. Total commercial floor space is increasing even as floor area per employee is low, a reflection of high urban land costs and evolving workspace designs. More floor space and longer operating hours mean greater requirements for lighting, air-conditioning, ventilation, and equipment. Globally, non-residential (i.e., commercial) buildings energy use has climbed faster than residential buildings, a pattern India is poised to follow.

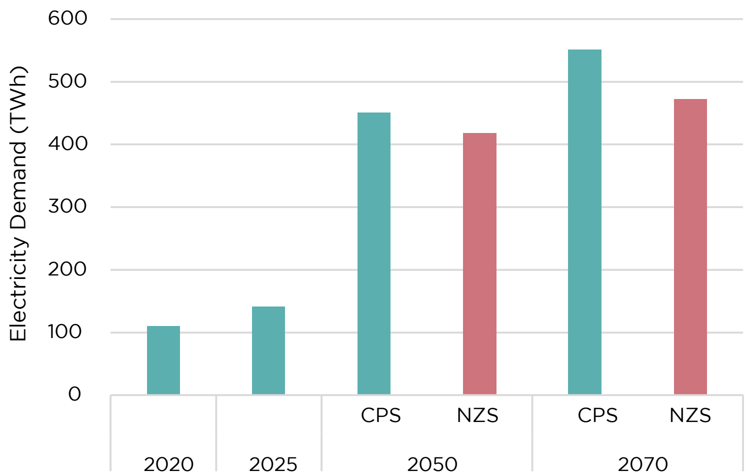


Figure 4.6: Electricity Demand (Excluding Data Center) Projection for the Commercial Building Sector under Current Policy Scenario (CPS) and Net Zero Scenario (NZS)

Figure 4.6 indicates that in 2020 electricity demand from commercial buildings stood at 106 TWh. Under the Current Policy Scenario (CPS), this is expected to rise sharply to 417 TWh in 2050 and 504 TWh in 2070. Under the Net Zero Scenario (NZS), with higher adoption of low carbon buildings, electricity demand grows relatively moderately to 476 TWh in 2070.

A shift in the share of different floor-space segments will also determine future commercial energy use.

For instance, offices and retail currently constitute nearly half of the commercial floor space. However, by 2050, other segments such as warehouse, cold-chains, or data centres – as discussed in the previous section–will have grown rapidly. The share of air-conditioned spaces will also go up from the present 25% to 60% in 2050.

Changing Energy Use

End-use patterns within commercial buildings are changing rapidly. Space cooling and ventilation have become dominant loads especially in large, glass-clad buildings relying on centralized air conditioning in India's hot and humid climate. Plug loads from office equipment, servers, elevators, and retail signage are growing across building types. Fortunately, lighting in commercial spaces is moving swiftly toward LEDs and smart controls like motion sensors and daylight harvesting, helping to moderate lighting demand despite extended operating hours.

Summary: The commercial buildings sector in India is on a steep upward trajectory in energy demand, propelled by floor space growth and new types of loads. Without intervention, this trajectory could mirror the experience of other rapidly growing economies where commercial energy use surged by double digits, outpacing other sectors. However, it also presents an opportunity since much of India's future commercial building stock is yet to be built, there is significant scope to shape it via efficient design (daylighting, insulation, efficient HVAC systems) and smart energy management, thus avoiding being locked into inefficient energy use. Policies like mandatory Energy Conservation Building Codes for large commercial buildings are crucial in this context, as are efforts to promote energy management systems and high-performance technologies in commercial operations. The rise of data centers particularly calls for strategic planning including integration of renewable energy to ensure these new loads are met sustainably.

4.5.3 Transition in Cooking Energy: Clean Fuels and Changing Habits

Cooking remains a foundational energy service in Indian homes, and its evolution marks one of the most significant shifts in the building energy landscape. Historically, rural and low-income households relied on solid biomass (firewood, crop residues, dung) using simple stoves or open fires, resulting in severe impacts on health and air quality. Over the past decade, India's clean-cooking push anchored by the Ujjwala scheme and Liquid Petroleum Gas (LPG) subsidies has brought LPG connections to tens of millions of households, especially in rural areas. Urban families have already moved predominantly to LPG and, more recently, to piped natural gas (PNG) and electric cooking options such as induction stoves and microwaves. Yet, in many rural households, fuel-stacking persists, where LPG is blended with biomass for reasons of affordability and accessibility.

In 2020, traditional biomass supplied more than three-quarters of India's cooking energy but delivered only around 40% of useful cooking service, reflecting the low efficiency of rudimentary stoves relative to LPG, PNG, and electric cooking. LPG accounted for roughly 22% of energy use while meeting about 57% of cooking demand; PNG contributed a small share concentrated in urban areas, and electricity and Traditional Biomass were negligible (See Figure 4.7)

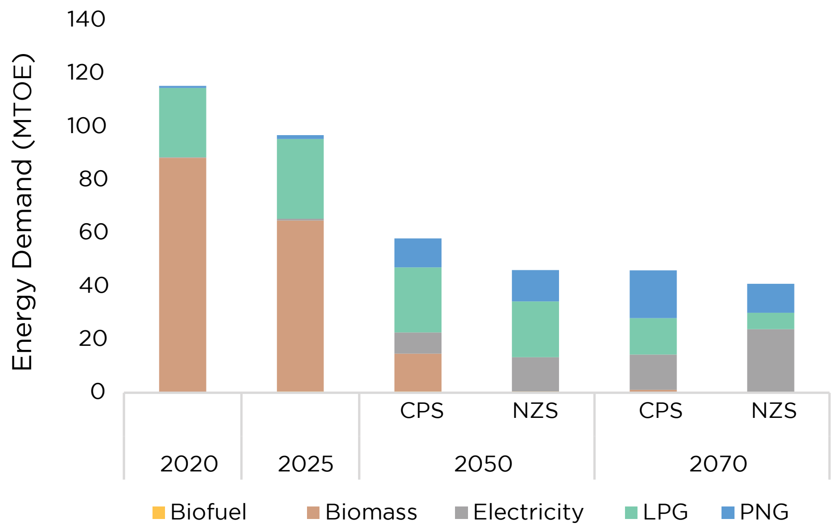


Figure 4.7: Energy Demand Projections for Cooking under Current Policy Scenario (CPS) and Net Zero Scenario (NZS)

Under the Current Policy Scenario (CPS), biomass is eliminated in cooking fuel mix by 2050, but LPG remains the dominant fuel. As shown in Figure 4.8, by 2050, LPG supplies about 42% of total cooking energy demand, followed by PNG (19%), electricity (13%), modern biomass (25%). By 2070, LPG provides 30% of the total, with PNG at 40%, electricity at 39%, and biogas at 1%. This reflects households' reliance on LPG's well-established distribution, cultural familiarity, and relative affordability, while shifts to electricity and biogas remain gradual.

In contrast, the Net Zero Scenario (NZS) achieves a much more diversified and efficient transition. By 2050, LPG would account 45% of total demand, followed by electricity at 28%, PNG at 26%, and biogas contribution of 1%. By 2070, LPG's share would decline to 15% of total, followed by PNG expanding to 26%, electricity growing to 57%, and biogas to 2%. This shift would be enabled by stronger electrification, wider PNG networks, and greater adoption of biogas, coupled with more efficient cooking technologies that reduce overall energy demand.

From the above, it is clear that CPS locks households into LPG dependence for decades, whereas NZS achieves diversification, efficiency, and resilience, critical for both climate and energy security goals. The implications of the cooking energy transition are profound. In the near term, it is primarily an issue of energy access and health moving households to cleaner fuels yields immediate benefits by reducing indoor air pollution with huge health gains, especially for women and children.

Summary: The cooking sector's results show a transition from traditional to modern energy that is well underway and set to continue. The exact pathway will depend on policy support, technology (for example, affordable induction stoves and reliable power in villages could be a game-changer), and cultural preferences. Urban and rural differences will need to be addressed by tailored approaches, urban areas might focus on electrification and gas grids, while rural areas might emphasize LPG distribution and perhaps decentralized biogas. Importantly, both scenarios underscore that by mid-century India can virtually eliminate the historical reliance on solid fuels for cooking, marking a pivotal shift in the building energy landscape.

4.5.4 Overall Energy Demand

In 2020, building energy demand in India was dominated by cooking, which contributed to four times the combined demand from residential and commercial buildings (Figure 4.8). However, this mix is expected to shift over time. Cooking demand would decline steadily, reflecting the widespread transition to cleaner and more efficient fuels and the near-elimination of traditional biomass use.

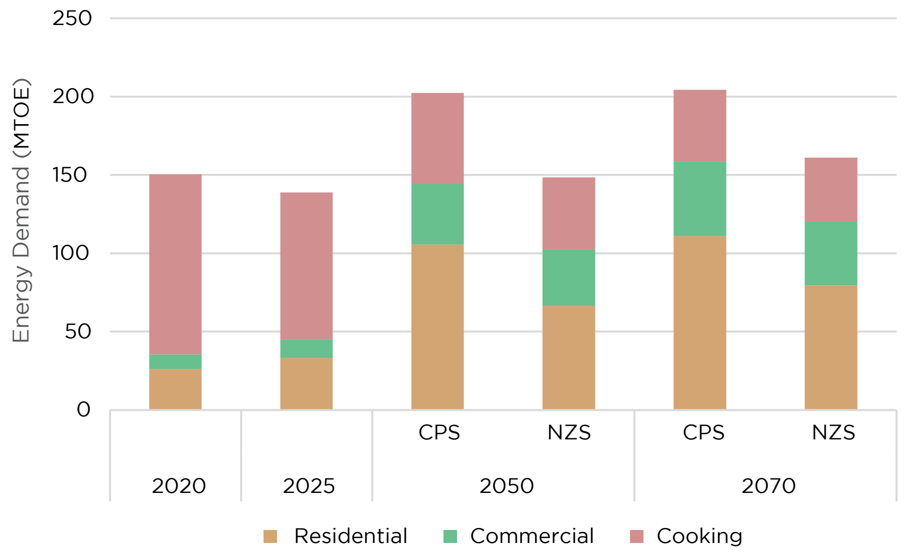


Figure 4.8: Overall Energy Demand from Building Sector under Current Policy Scenario (CPS) and Net Zero Scenario (NZS)

These projections signal a structural transformation in India's building sector energy use. While current energy demand is dominated by cooking, by 2070 residential and commercial electricity services, particularly cooling and appliances, would dominate. Policy ambition would significantly shape this trajectory. Under the Current Policy Scenario (CPS), demand would escalate with economic growth, while under the Net Zero Scenario (NZS), efficiency improvements, passive design, and clean technology adoption could contain energy use despite improved comfort.

Summary: Several forecasts point to a electrification of India's building sector over the next three decades. In 2020, electricity accounted for roughly one-fifth of total building energy demand—20 percent according to Bloomberg and 24 percent per NITI Aayog. By 2050, both project a marked shift towards electrification, reaching 70% validating the modeled trajectory of electricity becoming the dominant energy carrier in buildings. IEA expects India's air-conditioner stock to grow tenfold by mid-century, consistent with the modeled surge in cooling demand as a key driver of future electricity use.

When comparing absolute demand growth in 2050, there is strong convergence across studies despite methodological differences. NITI Aayog's estimates show commercial building demand increasing 3.7 times, while residential demand grows more than 3 times. RMI projects a similar magnitude, with commercial demand up 4.2 times and residential demand up 2.6 times. The close agreement across these independent sources validates the directional trends—rapid electrification, cooling as a dominant load, and significant growth in both residential and commercial energy use

Electricity Demand

Under the Current Policy Scenario (CPS), electricity demand in India's buildings would increase more than fourfold from 412 TWh in 2020 to about 1997 TWh in 2070. Under the Net Zero Scenario (NZS), enhanced appliance efficiency, particularly improvements in air-conditioning performance and passive building design, would reduce demand by about 16% to around 1671 TWh by 2070. (See Figure 4.9). Notably, air-conditioning efficiency improvement alone would save nearly 700 TWh by 2070 corresponding to approximately **500 MtCO_2 lower emissions** (at current grid emission factor). This further highlights the role cooling and appliances will play in future building electricity demand, and the critical need for efficiency improvements to moderating energy demand growth.

The data centers would place an additional 700 TWh of demand by 2070. Given the unpredictable and rapidly evolving nature of digital infrastructure, this demand is analysed separately. When included, it would raise total building-related electricity consumption in 2070 to five times the 2025 levels under the NZS and by seven times under CPS.

Additional Digital Infrastructure Load

By 2070, data centers alone could exceed the commercial sector electricity demand.

Baseload Nature: Unlike cooling, which drives seasonal and diurnal peaks, data centers create a continuous 24/7 baseload, shifting grid load profiles.

Location Concentration: Clusters in urban and digital hubs will require localized grid reinforcements and renewable integration.

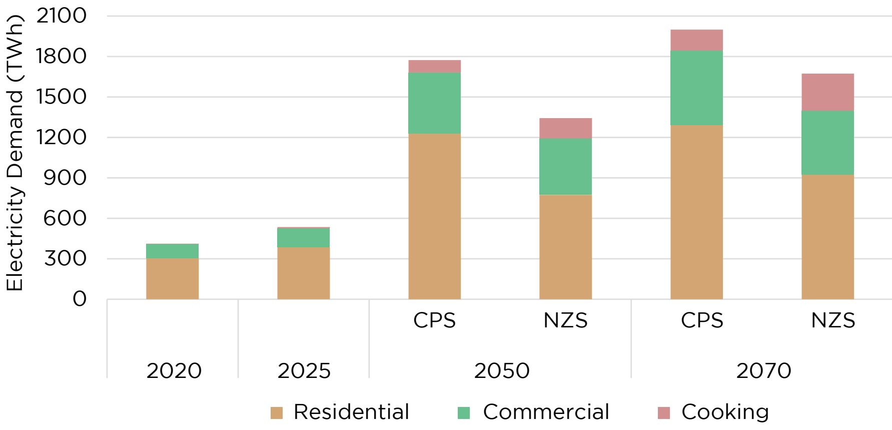


Figure 4.9: Electricity Demand for Building Sector under Current Policy Scenario (CPS) and Net Zero Scenario (NZS)

1. Electricity's share in total building energy demand would rise from 24% at present to 70% by 2050. The increased electrification would present two key challenges: Managing peak loads, especially during cooling-driven demand spikes in extreme heat events, and
2. Carbon emissions associated with higher electricity generation, depending on the future share of non-renewables in the grid.

Dedicated Working Groups were convened to examine low-carbon transition options in the power and industry sectors. Further details are available in the sectoral reports, Volume 4 (Industry Sector) and Volume 7 (Power Sector).

5

CHALLENGES, BARRIERS AND POLICY GAPS FOR NET ZERO TRANSITION

5

Challenges, Barriers and Policy Gaps for Net Zero Transition

The preceding sections discussed the India's building sector and its future emission trends. Building sector emissions are projected to increase manifold, driven by additional floor space, socio-economic factors, and the effects of climate change itself. Policies such as BEE's Standards & Labelling (S&L) program and Unnat Jyoti by Affordable LEDs for All (UJALA) succeeded in improving energy efficiency of appliances. Although building energy codes have been developed and strengthened but persistently low compliance has constrained their effectiveness, resulting in slower-than-expected progress. However, with nearly 1 billion m^2 new floor space being built every year, more aggressive efforts are required to ensure that the newly constructed buildings are more energy efficient. Addressing rising embodied emissions, enhancing the efficiency of the existing building stock, and improving trends in grid emissions factors will be important to support broader efforts to manage climate-related risks affecting the built environment. This section provides an overview of the current challenges, barriers and policy gaps for building sector low-carbon transition, focusing on policy sufficiency, market ecosystems, data availability, skills and supply chain.

Table 5.1: Summary of Building-sector-Specific Challenges, Barriers and Policy Gaps

Building energy codes & standards | Market development | Workforce and skills

Building sector energy and emissions data/ models	• Absence of credible national-level consolidated data and trends on building sector growth and projections to inform infrastructure decisions • Need of data to understand market trends and inform policy design • Incomplete evaluation of policy effectiveness due to lack of on-the-ground performance data
Building energy codes: Coverage and performance metrics	• Mandatory codes apply to a small subset of new buildings. Existing building are excluded • Focus on 'design stage' operational energy. Whole life energy/ carbon performance and climate resilience metrics not included • Absence of minimum envelope thermal performance requirements in commercial building codes

		• Absence of quantifiable performance requirements for mitigating heat stress in naturally ventilated buildings • No mandatory commissioning protocols and guidelines • Need for performance data and benchmarks to inform future code development
Building energy codes: Implementation and enforcement		• Disparities across states and UTs in maturity of enforcement systems, with weak institutionalization of compliance workflows. • Manual and resource intensive compliance procedures • Limited capacity of ULBs for compliance checks • Inadequate qualified third-party professionals for compliance checks • No penalty provisions for non-compliance with codes
Market development	**Demand-side interventions**	**Buildings:** • No information to prospective buyers and tenants on building performance to drive market demand • Need for 'real-world' energy performance validation and benchmarking • Incentive structures not tailored to different stakeholder groups **Appliances:** • Scope to strengthen BEE's S&L to cover broader range of technologies • Weak enforcement of testing and verification protocols erodes consumer confidence • Need for targeted policies to nudge consumer behaviour **Materials:** • Need for Environmental Product Declarations (EPDs) • Underdeveloped public sector green procurement policies to help drive demand and economies of scale
	Supply-side interventions	**Appliances:** • Minimum Energy Performance Standards (MEPS) below international trends and best practices • High dependence on imported components and lack of comprehensive policy support ecosystem to address supply chain constraints **Materials:** • Absence of long-term low-carbon transition policy visibility for carbon intensive construction materials and products. • Absence of policies to tackle unsubstantiated green claims • Need for targeted polices to mainstream secondary materials and those using industrial waste streams.

	Research & innovation	• Need for targeted support ecosystem for research and commercialization of building products and technologies. Wide remit for current programs • No quantitative criteria to appraise, benchmark, and certify low carbon products and technologies • Limited feedback loop from field trails and demonstration projects • Need for visibility on the forward trajectory of low-carbon transition policies which inhibits investment in low carbon alternatives
Workforce capacity & skills ecosystem		• Need for comprehensive view of construction skills and gaps • Need for explicit focus in training programs on low carbon materials, components and technologies • Absence of dedicated training on operational energy management for asset management professionals and trades • Insufficient emphasis on informal sector • Fragmented training ecosystem

5.1 Building sector energy and emissions data/ models

At present, there is no official data source to establish baseline values or to systematically track policy implementation and impacts on an annual or biannual basis. The challenges pertaining to sector are:

i. **Absence of credible national-level consolidated data and trends on building sector growth and projections:** The lack of a nationally consolidated and regularly updated dataset on building stock, floor area growth, typologies, and future demand limits the ability to develop robust projections. This constrains informed planning of energy, cooling, and urban infrastructure investments and weakens alignment between building-sector growth and broader development pathways.

ii. **Limited data to understand market trends and inform policy design:** Inadequate and fragmented data on technology adoption, cost trajectories, financing models, and consumer behaviour restricts understanding of evolving market dynamics. This limits the ability to design targeted, evidence-based policies and to anticipate market responses to regulatory and fiscal interventions.

iii. **Incomplete evaluation of policy effectiveness due to lack of granular on-the-ground performance data:** In the absence of systematic, real-world performance data on building energy use, comfort outcomes, and compliance constrains the assessment of the effectiveness of building codes, standards, and incentive programmes. As a result, policy impacts cannot be consistently evaluated, limiting feedback for course correction and iterative policy refinement.

5.2 Building Energy Codes: Coverage and Performance Metrics

i. **Coverage of mandatory codes:** Mandatory building energy codes currently cover a very small proportion of the projected building stock to 2070, estimated to be less than 1%. This, coupled with the lag in adoption of codes by states and UTs as well as enforcement gaps (refer section 6.2), is one of the key impediments for low-carbon transition of the building sector.

   ECBC[xiv] and its latest version, ECSBC only cover new commercial buildings >100kW, or depending on the state regulations those >120kVa. It is yet to be adopted in 10 states and 3 UTs. Eco-Niwas Samhita (ENS) is a voluntary code for new residential buildings with a plot area >500 m^2, and anecdotally adoption has been minimal[xv]. The recently launched ECSBC-R 2024 for residential buildings is yet to be adopted by states and UTs. No specific codes exist for existing buildings.

ii. **Lack of whole life carbon and climate resilience metrics:** The codes focus on 'design stage' operational energy, and to a limited degree on thermal comfort in air-conditioned buildings. Key gaps and limitations are:

   - Absence of minimum required envelope thermal performance requirements in commercial building codes and lack of emphasis on passive design strategies. ECBC provides option to trade off envelope thermal performance requirements with improvements in equipment performance in certain circumstances, resulting in high cooling demand and high marginal cost of retrofitting the building fabric in the future to meet low-carbon transition targets.
   - Absence of quantifiable performance requirements for mitigating heat stress and improving thermal comfort in naturally ventilated buildings
   - No disclosures and/or targets related to building embodied carbon[xvi], which can be as much as 50% of the total whole life carbon of a building.[55,56]
   - Lack of mandatory commissioning procedures and guidelines at whole building level or component level, which can deliver substantial operational savings at minimal extra cost. Published literature suggests that proper commissioning can deliver energy savings of 10-20% with similar reduction in operating costs.[57,58]

Addressing these gaps will be key to ensuring we meet our long-term low-carbon transition targets, while enhancing resource efficiency, energy security, ensuring resilience to climate change and minimising the associated negative impacts on health and productivity.

[xiv] Note that the Energy Conservation and Sustainable Building Code (ECSBC) 2024 is not currently adopted by any of the states or UTs.

[xv] No comprehensive data on ENS adoption is available, and based on inputs from working group members, level of awareness among developers is low.

[xvi] ECSBC has an optional requirement to report embodied carbon related to stages A1-A3 (extraction and manufacturing of materials and building components)

iii. **Lack of performance data and benchmarks for code evolution:** Currently, there is limited 'real-world' performance data to comprehensively assess the lifecycle costs and benefits of compliance with existing building codes across India's diverse climatic zones and regions. This evidence gap weakens policy feedback loops by limiting insights into the on-ground performance of deployed technologies and the implementation challenges faced by design and project teams. It also limits the ability of design professionals to setting realistic and up-to-date design stage KPIs (Key Performance Indicators) and for asset managers to understand potential for improvements. It also limits the ability of design professionals to setting realistic and up-to-date design stage KPIs (Key Performance Indicators) and for asset managers to understand potential for improvements.

Current initiatives, such as BEE's voluntary 'star rating' scheme, are a step in the right direction. The scheme could however benefit from a more extensive and comprehensive set of data across building typologies and regions, as well as frequent review of typical, good and best practice benchmarks considering technological advancements and changing technology costs. Table 5.2 below provides a comparison of Energy Performance Index (EPI) values and target values for 5-star rating under the 'star rating' scheme for select office buildings. The comparison indicates that buildings are achieving EPI values 40-50% better than those for 5-star rated buildings, suggesting there is significant scope to raise the bar.

Table 5.2: Comparison of EPI Reference Values Under the BEE 'Star Rating' Program with Good Practice Case Studies

	Atal Akshay Urja Bhawan	SIERRA'S eFACiLiTY®	Unnati Office
Building type	Office, Delhi	Office, Chennai	Office, Noida
Climate	Composite	Warm-humid	Composite
EPI for BEE 5- star rating (kWh/m^2.y)	76	118	109
Declared EPI (kWh/m^2.y)	47	56.2	60
% improvement	38%	52%	45%

Environmental declarations for construction products

Requirement to disclose environmental performance as part of wider disclosures for all construction materials/ products (e.g., Construction Products Regulation in Europe to be implemented mid-2026)

Energy benchmarking laws: Mandate disclosure of energy/ carbon performance to enable better benchmarking (e.g., mandated disclosure of embodied carbon data for new buildings by Greater London Authority, energy transparency ordinances in the US)

Data and benchmarks: LETI (Low Energy Transformation Initiative)* in the UK has set out good and typical practice benchmark values for upfront embodied carbon (A1-A5) to help design teams set realistic yet ambitious targets at the design stage, along with guidance and toolkits to help achieve those targets. The benchmark values are to be reviewed over time to reflect changes in technologies and associated costs.

Band	Office	Resindential (6+ storeys)	Education	Retail
Upfront Embodied Carbon, A1-A5 ($kgCO_{2e}/m^2$)				
A++	<100	<100	<100	<100
A+	<225	<200	<200	<200
A	<350	<300	<300	<300
B	<475	<400	<400	<425
C	<600	<500	<500	<550
D	<775	<675	<625	<700
E	<950	<850	<750	<850
F	<1100	<1000	<875	<1000
G	<1300	<1200	<1100	<1200

Figure 5.1: International Example of Benchmarking Initiatives and Policies Mandating Data Disclosures

** LETI. (2020). LETI Embodied Carbon Primer.*
(i) https://www.leti.uk/_files/ugd/252d09_8ceffcbcafdb43cf8a19ab9af5073b92.pdf
(ii) https://www.leti.uk/_files/ugd/252d09_25fc266f7fe44a24b55cce95a92a3878.pdf

5.3 Building Energy Codes: Implementation and Enforcement

There is a significant lag in the adoption of building codes across States and Union Territories (UTs). Not all states and UTs have adopted Energy Conservation and Building Codes (ECBC) as a mandatory code since it was introduced in 2007, and different versions exist in the jurisdictions where they have been adopted. As shown in Figure 5.2, 13 States/UTs are yet to notify the ECBC. Among those that have adopted the code, 18 States/UTs have notified the ECBC 2017/2020 version, while 5 States/UTs continue to implement the 2007/2008 version, often with varying scope and applicability. Maharashtra most recently notified the ECBC in May 2025, indicating incremental progress amid persistent implementation gaps.

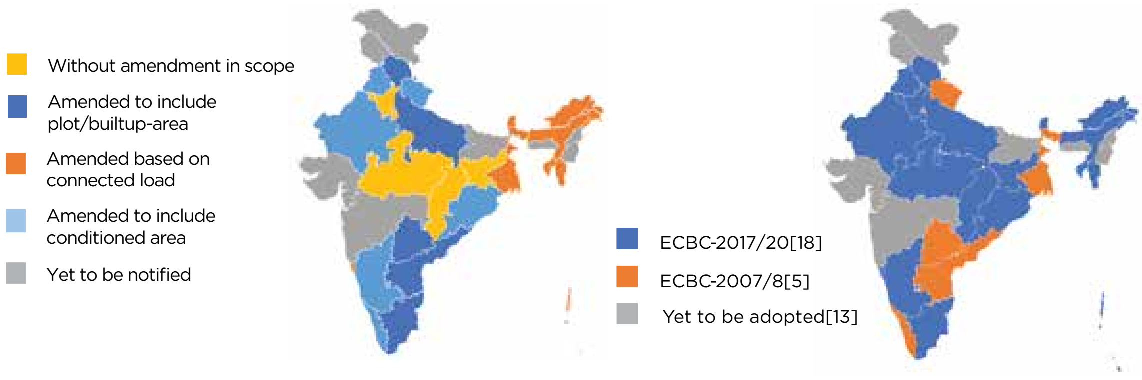


Figure 5.2: Status of ECBC Adoption in India

*(**Source:** https://beeindia.gov.in/en/programmes/buildings-0 and AEEE analysis*

The enforcement related challenges vary by jurisdiction, though broadly can be summarised as below:

i. **Disparities across states and UTs in maturity of enforcement systems, with weak institutionalization of compliance workflows:** There are significant variations in level of maturity by states/ UTs, with often insufficient processes and systems for rigorous compliance checks. Some use in-house officials (e.g. Punjab), while others use external auditors (e.g. BEE certified energy auditors in Kerela, approved third-party assessors in Telangana). In other jurisdictions officials rely on self-declaration by the architect (such as in case of Haryana).

ii. **Incomplete evaluation of code effectiveness due to lack of granular end-use data:** In the absence of a national demand-side data framework, enforcement agencies cannot validate whether design-stage code compliance translates into actual energy savings, as current national statistics track aggregate sectoral energy flows rather than socket-level end-use granularity (e.g., cooling, lighting, etc.) and the building performance for code-compliant and non-code compliant buildings.

iii. **Manual and resource intensive compliance procedures:** While some states have or are in the process of introducing online portals, the use of manual compliance procedures in most jurisdictions provide limited ability to monitor, track and provide comprehensive regional data.

iv. **Limited capacity of ULBs for compliance checks:** Most municipal bodies lack the capacity, both in terms of skills and resources, for enforcement, verification and compliance checks.

v. **Insufficient qualified third-party professionals for compliance checks:** Some of the states have faced challenges with non-availability of sufficient pool of certified third-party assessors (TPAs). The reasons for this are not entirely clear.

vi. **No penalty provisions for non-compliance with codes:** While state/ local bodies have powers to introduce financial penalties, none have been levied so far except for holding up the completion certificates. This further dilutes the compliance rigour.

Some states such as Telangana have been working towards addressing some of these implementation gaps and can provide useful steer and learning for other states/ UTs to enhance code implementation. Figure 5.3 below provides an overview of the ECBC approval process for Telangana. The state introduced an online portal for submission and approval process to facilitate consistency of data submissions and transparency. Empanelled TPAs carry out compliance check both at design-stage and during construction. Additional random post-occupancy inspections may be conducted by municipal authorities during construction stage and post-occupancy. The issuance of Building Operations Certificates (BOCs) by municipal bodies has been linked to ECBC approval. States such as Madhya Pradesh, have made permanent electricity connection contingent on ECBC compliance, thereby discouraging buildings to be occupied in the absence of a valid BOC.

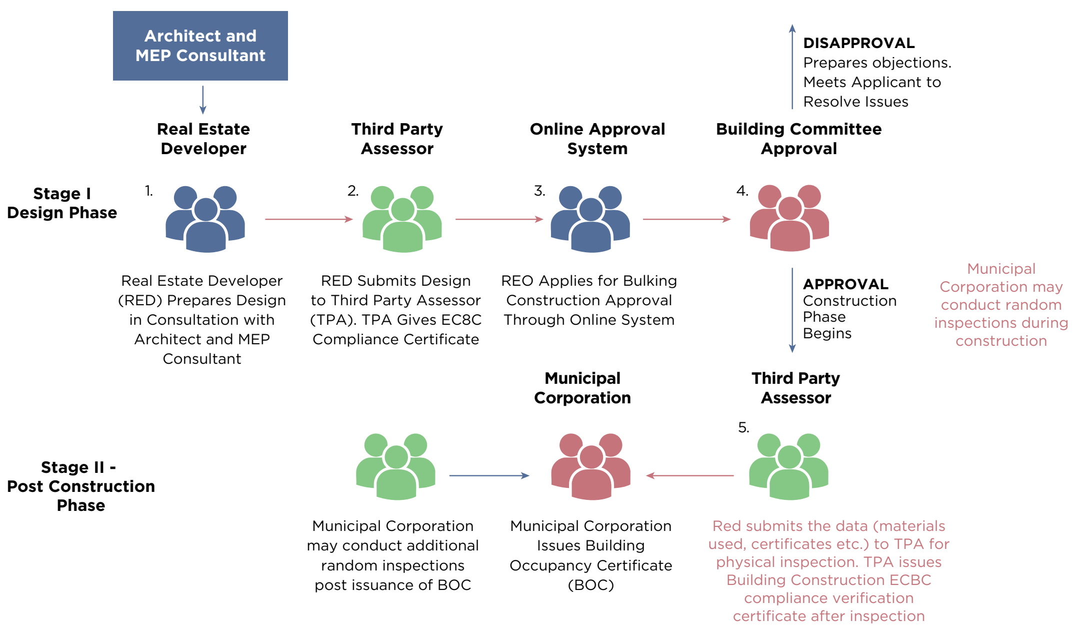


Figure 5.3: ECBC Approval Process for Telangana[59]

5.4 Market development

Developing a mature market for low-carbon, green, energy-efficient and resilient buildings require a three-pronged approach, namely

i. Driving consumer demand for such buildings and associated components, materials and products (demand-side interventions)

ii. Facilitating the supply of materials, products and associated supply chains that enable such buildings to be constructed (supply-side interventions)

iii. Creating the enabling ecosystem for research and commercialisation of construction techniques, materials and products that will drive future innovation in the sector.

5.4.1 Demand-side Interventions

i. **Provide information to prospective buyers and tenants on building performance:** This is one of the first steps in creating awareness and providing more transparency to end consumer, akin to what Standards and Labelling (S&L) program has been doing in case of appliances. Where this information is benchmarked relative to typical and good practice performance levels, it can help users make informed decisions. International examples, such as the provision of energy labels (or ratings) at the point of sale and rental under the EU Energy Performance of Buildings Directive (EPBD) and the NABERS energy rating scheme for commercial buildings in Australia[xvii], have shown positive outcomes in nudging the market in the right direction.

ii. **Develop framework for 'real-world' energy performance validation and benchmarking:** Currently, there are no standardized national methodologies or frameworks to appraise, benchmark and validate energy and/or carbon performance on a like-for-like basis. Even when reviewing published data from case studies, comparisons are often challenging due to different boundary conditions, inclusions and exclusions. Validated 'real-world' energy performance can form the basis for green premiums for low-carbon and efficient buildings (or alternatively brown discounts for inefficient buildings) and help build the business case for action. They also create a feedback loop to understand on-the-ground challenges & performance of innovative and/or new technologies.

iii. **Build dedicated national building data platform:** Currently, India lacks a dedicated national public platform to systematically capture and harmonise demand-side building energy data. Operational performance, appliance and retrofit outcomes, and India-specific embodied carbon data are therefore collected inconsistently,

[xvii] A NABERS Energy rating is compulsory whenever an office building larger than 1,000 square meters is being sold or leased. It has helped create a culture of "building for performance" rather than "building for compliance". Since it's mandatory introduction in 2010/11 it has improved the average energy intensity of Australian rated offices by 42% (data published 2022, source: https://www.nabers.gov.au/sites/default/files/energy_efficiency_in_commercial_buildings_summary.pdf)

using non-standard formats and boundary conditions, limiting robust benchmarking and policy evaluation. Fragmented disclosures constrain like-for-like comparisons across buildings, technologies, and materials. A unified building energy data platform with standardised, third-party-validated disclosures would enable credible national benchmarking, support green-premium and brown-discount market signals, inform green finance decisions, and establish a continuous evidence loop to strengthen building codes, standards, and incentive frameworks over time.

iv. **Incentive structures tailored to different stakeholder groups:** No specific incentives exist to encourage adoption of low-energy and/or low-carbon buildings. However, incentives for compliance with green building ratings are being offered in some states (e.g. increased Floor Area Ratio (FAR), or rebate on stamp duty or property taxes). The green building ratings differ in their ambition and therefore may not always work as proxy for good energy performance of buildings. It is also worth highlighting that incentives alone will not necessarily drive market demand at scale. The low uptake of reduced-interest credit lines, such as KfW's credit line for high-performance envelopes in residential buildings[xviii], suggests that there are wider systemic barriers at play e.g. limited skills & supply chains, consumer awareness, etc. The role of non-financial incentives such as expedited permitting, technical assistance, as well as recognition and rewards needs to be further explored.

v. **Strengthen BEE's Standards & Labelling (S&L) program to cover broader range of technologies:** BEE's S&L program has helped drive energy efficiency improvements for building appliances and HVAC equipment, and is a good example of how disclosure can nudge market transformation. Gaps that need addressing to further enhance the scheme are:

- Exclusion of certain technologies from the current scheme, such as heat pumps and evaporative coolers, that could be a vital part of the future mix of cost-effective technology solutions for cooling and thermal comfort[xix].
- Weak enforcement of testing and verification protocols that may erode consumer confidence in labelled appliances.
- Exclusion of GHG emissions associated with refrigerants in the labels, which can be significant depending on the type of refrigerant used.

vi. **Targeted policies to nudge consumer behaviour:** Current programmes insufficiently address behavioural economics, i.e. nudges, information design, or demand aggregation, to promote energy-efficient appliance choices. Study conducted by AEEE[60] to evaluate the impact of dynamic-displays on household behaviour yielded valuable insights into room air conditioner (RAC) usage, how socioeconomic factors

[xviii] AEEE experience as one of the project implementation partner

[xix] VRF systems, packaged DX and solar PVs are in the pipeline for inclusion in the program.

influence responses, and the effectiveness of awareness-based nudges. Notably, displaying real-time energy consumption and sending periodic and timely awareness messages encouraged households to change usage patterns, achieving 3-4% energy savings. The study evidenced Mission LiFE's behavioural transformation strategy in action, and demonstrates that low cost, scalable behaviour change tools can yield measurable energy savings.

vii. **Disclosure framework on environmental performance of building materials/ products:** This includes data relating to their thermal characteristics, embodied carbon, reuse/recycled content, and circularity potential. Environmental Product Declarations (EPDs) are certificates that are used to disclose information based on a defined methodology. While international frameworks exist, there is a need for a national methodology and associated rules for each category and sub-category of building materials and products. EPDs are needed to enable benchmarking of product carbon intensities and performance, and drive the market for low carbon alternatives.

viii. **Develop public sector green procurement policies to help drive demand and economies of scale:** Inclusion of low-carbon, energy efficiency and climate resilience criteria in public procurement can significantly boost demand for associated products and materials. The demand certainty provided can drive innovation and investment in manufacturing facilities, as well as realise economies of scale to bring costs down. On the contrary, national and state level schedule of rates rarely include low-carbon materials and products, or typically have a long time-lag for inclusion.

5.4.2 Supply-side Interventions

i. **MEPS thresholds can be raised to international trends and best practices:** Minimum Energy Performance Standards (MEPS) for appliances are not keeping up to reflect market evolution or international best practices, weakening their market transformation potential to drive low-carbon transition. The gap for some of the key building sector appliances has been discussed earlier in Section 3.

ii. **Develop a comprehensive policy support ecosystem to address supply chain constraints:** A significant proportion of the critical components for high-efficiency air-conditioners and fans are imported, including compressors (more than 85%), PCBs and controllers (more than 80%), Brushless Direct Current (BLDC) and non-Brushless Direct Current (Non-BLDC) motors (80%, fans and blowers (20%), and grooved copper tubes (nearly 100%)[61]. Dependence on imports creates supply chain risks and increases costs for end consumers. It, however, presents a huge opportunity for creating economic value through domestic production by combining targeted policies with a support ecosystem for research and commercialisation. The Production Linked Incentive Scheme for White Goods (PLIWG), launched in 2021 and subsequently revised in 2023, is a step in this direction. It provides financial incentives to boost domestic manufacturing of white goods and components. It has shown some value addition for specific categories of products, i.e., compressors, motors and LED drivers. It could, however, benefit from further simplification, expanding the scope to a wider set of technologies and components (e.g. heat pumps and control electronics), as well as enabling better MSME participation.

iii. **Set up targets and long-term low-carbon transition policy visibility for manufacturers:** For construction materials covered under the PAT scheme i.e. cement, iron & steel, and aluminium, specific energy consumption targets are set over a 3-year cycle, though these targets do not cover GHG emissions associated with manufacturing processes or the extraction of raw materials. Impact analysis of the scheme to date has highlighted the level of ambition in terms of the strictness of targets as a constraint[62]. Apart from materials covered under PAT, there are currently no targets to reduce material or product carbon (or energy) intensity including from brick manufacturing, which accounts for the majority of masonry construction in the country[xx]. Lack of long-term goals and uncertainty about future benchmarks hinder effectiveness and investment decisions.

iv. **Formulate policies to tackle unsubstantiated green claims:** The lack of disclosures, along with the absence of a green taxonomy for key building products (i.e., threshold values to claim a product is green/ low carbon), means there is no way to tackle misinformation on green claims and ensure fair competition. It is noted that the taxonomy for green steel was introduced in December 2024, and a similar taxonomy is needed for other key building products.

v. **Targeted polices to mainstream secondary materials and those using industrial waste streams:** India's Long-term Low-carbon Development Strategy (2022) acknowledges the need for industry-specific solutions to address waste and for budgets to be allocated to pursue R&D. Construction and Demolition (C&D) Waste Management Rules by MoEFCC also promote recycling and reuse. Also, certain financial incentives already exist in the value chain, e.g., excise duty exemption for waste-based building materials; equity and term loan support for manufacturing building materials/ components using agricultural and industrial wastes by Housing and Urban Development Corporation (HUDCO). However, creating a financial incentive or disincentive at the point where such waste streams are being diverted (e.g., landfill tax in certain countries) to landfill is needed to assign a monetary value to such waste streams, and thereby encourage further innovation and investment.

[xx] MoEFCC regulates air emission standards for the brick manufacturing sector, but not GHG emissions associated with the manufacturing process.

5.4.3 Research and Innovation

The current R&D support ecosystem broadly consists of the following organisations and initiatives:

i. Building Materials & Technology Promotion Council (BMTPC) has been mandated to promote innovative, resource-efficient, climate-resilient, disaster-resistant construction practices. As the technology partner for MoHUA's Technology Sub Mission (TSM), BMTPC facilitates the adoption of modern and innovative technologies for faster & quality construction of houses. It also evaluates and certifies materials and construction systems under the Performance Appraisal Certification Scheme (PACS).

ii. Incubation Centers (with grant support from MoHUA) have been set up under ASHA-India in four IlTs (Bombay, Kharagpur, Madras, Roorkee CBRI-CSIR) and at North-East Institute of Science and Technologies (NEIST), Jorhat.

iii. Technology Innovation Grant (TIG) promotes innovative technologies under lighthouse projects.

The key barriers and gaps in the enabling ecosystem to facilitate the transition from lab to commercialisation include:

i. **Need for targeted support ecosystem for research and commercialization of building products and technologies:** Wide remit for current programs, with no dedicated focus on technologies that are critical to India's development and low-carbon transition needs (e.g., low-energy and low-cost cooling systems, alternatives to clay bricks that result in loss of agricultural topsoil and land degradation, prefabricated modular construction, etc.)

ii. **Need for quantitative criteria to appraise, benchmark, and certify low-carbon products and technologies**, which could then form the basis for further technological and financial support.

iii. **Need for feedback loop from field trials and demonstration projects** to understand performance. Lessons from field trials and pilot projects are not systematically captured or used to update codes, tools, or incentive schemes.

iv. **Need for visibility on the forward trajectory of low-carbon transition policies** that can help with demand certainty and therefore underpin the business case for investment in manufacturing facilities or other assets.

Case Study: Global Cooling Prize Challenge

Launched in 2018 by RMI, India's Department of Science and Technology, Mission Innovation, CEPT University, AEEE, RMI, and Conservation X Labs, the **Global Cooling Prize** challenged innovators globally to design residential air conditioners with at least **5 times lower climate impact** than standard units. Over 2,100 teams from 96 countries registered; eight finalists received funding to build prototypes that were rigorously tested in CEPT University's climate-simulation laboratory and in real-world apartment settings in India.

This initiative significantly enhanced institutional capacity: CEPT University designed testing protocols and built testing infrastructure, elevating India's technical laboratory capabilities in appliance evaluation. Meanwhile, cross-sector participation, from universities, startups, and established manufacturers like Daikin and Gree, fostered research collaboration, knowledge exchange, and innovation networks across countries and disciplines. The initiative also led to the formation of the **Global Cooling Efficiency Accelerator**, which continues to support commercialization, develop revised test methods, and engage policymakers and manufacturers to scale up breakthrough cooling technologies globally.

By combining clear performance targets, global collaboration, lab based validation, and downstream scaling mechanisms, the Global Cooling Prize exemplifies a successful model of strengthening R&D systems and institutional capacity in the building sector.

5.5 Workforce Capacity and Skills Development

A skilled workforce is required to design, construct, operate, maintain and retrofit buildings over their lifecycle. This includes design professionals (architects, engineers, specialist consultants), construction trades (masons, carpenters, electricians, plumbers, etc.), HVAC installers, commissioning engineers, plant operatives, and energy auditors, among others. There is currently limited information on the current status and gaps in skills. The key challenges facing the sector are:

Need for comprehensive view of construction skills and gaps. There is no comprehensive assessment of workforce skill levels and training needs specific to low-carbon construction across the value chain. Stakeholder consultations indicate that skills gaps exist across the board, particularly in the areas of low-carbon materials and technologies (e.g., handling & installing insulation products, handling & curing alternative low carbon cements, etc.).

i. **Need for explicit focus in training programs on low-carbon materials, components and technologies.** There is currently a wide mandate for agencies involved.

ii. **Absence of dedicated training for operational energy management.** Training for facilities managers and O&M professionals neglects critical aspects of energy management, demand response, and performance tracking.

iii. **Insufficient emphasis on informal sector.** Most training and awareness initiatives target organised sector stakeholders, overlooking the vast informal workforce responsible for on-ground construction.

iv. **Fragmented training ecosystem.** Existing training and awareness efforts are scattered across institutions, and no central feedback mechanism to assess outcomes or course-correct. There is no specific focus on building materials & technologies in national skill development initiatives, such as PMKVY, AMBER, PM Vishwakarma, etc. This is no information on the success of existing training and awareness programs imparted through National Building Centres & what (if any) linkage exists with efforts underway by BMTPC.

A more forward-looking set of targeted upskilling programs is required to train the workforce for design, construction and operation of low-carbon buildings and technologies, which will be the norm in the future.

Case Study 1: Solar Decathlon India (SDI)

Solar Decathlon India, initiated in 2020 by IIHS and AEEE under IUSSTF/DST, replicates the U.S. DOE Solar Decathlon model within Indian academia and industry. Students from over 150 institutions collaborate on real-world netzero projects across six building typologies, supported by industry partners, mentors, and simulation tools. By providing access to **performance-based modeling, multidisciplinary curriculum modules, and live project engagement**, SDI enhances institutional research capacity and establishes a pipeline for green building expertise within universities and the corporate sector. It cultivates sustainable design R&D through prototype-building and industry linkages, while alumni transition into climatetech roles, supporting workforce capacity and policy, awareness in India's formal building sector

Case Study 2: European Union: BUILD UP Skills Initiative

The **BUILD UP Skills initiative**, launched by the European Commission, aims to strengthen the skills of building professionals across Europe to support the transition toward high-energy performance renovations and nearly zero-energy buildings (nZEBs). The initiative focuses on addressing skill gaps across the construction value chain, from onsite workers and installers to engineers and architects, by developing national skills roadmaps, designing innovative training and qualification schemes, and fostering mechanisms that enhance the uptake of such training. BUILD UP Skills aims to expand Europe's skilled building workforce to deliver high-performance renovations and nearly zero-energy buildings (nZEBs). It focuses on: **skills intelligence** (mapping green-transition skill gaps), **skills development** (training in deep renovation, nZEB, heat pumps, BIM, and circular construction), and **skills uptake** (awareness campaigns, skills passports, professional registers, and procurement frameworks). The initiative supports the EU Pact for Skills, targeting upskilling/reskilling of 25% of the construction workforce (3 million workers) in five years. By aligning training schemes, national roadmaps, and capacity-building with this goal, it helps prepare the construction sector to meet green transition demands and EU climate objectives.

6

POLICY SUGGESTIONS

Policy Suggestions

6

This section builds on India's architectural legacy and contemporary lessons to frame actionable policy, emphasising a whole-life carbon perspective. The suggestions also call for strengthening of building codes and their compliance, and indigenisation across materials, skills, and innovation. They are presented not as distant targets but as a pragmatic and prioritised roadmap for the next two decades, recognising that strategies must remain adaptive to evolving technologies, economic transitions, and climate realities.

The suggestions are grounded in evidence and shaped through extensive consultations with working group members and industry stakeholders. They are sub-categorised to mirror the structure of the preceding analysis of key challenges, barriers, and policy gaps, ensuring a clear line of sight from diagnosis to action.

There are near-term operational savings, medium-term embodied-emission reduction, and the system enablers, forming a credible pathway to Net Zero buildings by 2070. The interventions have been organised and prioritised across short-term (i.e. those before 2030), medium-term (before 2035) and long-term interventions (beyond 2035). The suggestions are intended to drive the following outcomes:

i. **Provide visibility of forward policy trajectory:** Clear visibility on the forward trajectory of standards and targets is critical to enabling businesses and manufacturers to make informed investment and strategic planning decisions. It will also drive investment in research and innovation to deliver both economic and environmental benefits. Specifics of each of the policy interventions will be further detailed as part of the action plan, including implementation mechanism, roles and responsibilities, and indicative threshold values or targets over short, medium and long-term[xxi].

ii. **Incrementally expand the proportion of new and existing building stock falling within the remit of building codes:** It is imperative to progressively expand the share

[xxi] Threshold values or targets, where relevant, will be developed as part of the detailed design of the policy instrument considering both a top-down approach (i.e. trajectory needed to meet long-term targets) and bottom-up approach (that is, the lifecycle cost and benefits of current technological solutions to meet target values).

of the building stock covered under building energy codes, while also broadening the scope of performance metrics to include resilience to heat stress and lifecycle embodied carbon. For smaller buildings/ developments (that currently do not fall within the remit of ECSBC and ENS), more simplified versions of the codes are to be developed to ensure the regulatory burden is not disproportionate. Given the long design life of building envelopes and the high cost of retrofitting in the future relative to the marginal cost of integrating energy-efficient fabric measures at the construction stage, building codes to have minimum thresholds for thermal performance of the building fabric (minimum values for ETTV[xxii] or RETV[xxiii]). EETV values are to be tailored to the climatic zone with a view to mitigating heat stress, reducing cooling loads, and the resultant grid infrastructure.

iii. **Drive market transformation through demand-side interventions, including disclosures, awareness and incentives:** Disclosure of operational and embodied carbon data was acknowledged as a critical first step to driving demand for low-carbon buildings, building components and products. Such disclosures aim to provide insights into the 'real-world' performance of buildings and the associated supply chain. This, in turn, informs benchmarking and green labelling, as well as provides valuable data and insights for future policies and targets. Standardised methodologies (e.g., for Environmental Product Declarations (EPDs) or operational energy ratings) enable consistent and comparable disclosures. Secondly, learnings from international policy implementation indicate that provision of (energy or carbon) performance data to end users at the point of sale or rental helps drive green premiums for more efficient and/or low carbon buildings and products. Tailored incentives, both financial or non-financial, for different industry stakeholders can further help to create demand for efficient, low-carbon buildings and products.

iv. **Use public procurement policies to drive demand for low-carbon materials and products:** This helps create demand at scale to nudge the market in the right direction. The public sector is seen as leading by example. The demand certainty drives innovation and investment in new solutions and products.

v. **Nudge market transformation through supply-side interventions:** Having the right policies to boost energy and resource-efficient manufacturing, addressing any supply-side constraints in terms of availability of raw materials and skills (including over-dependence on imports of critical components), plus incentivising use of agricultural and industrial waste streams, can all deliver downstream benefits for the building sector. Consideration should also be given to tiered/ preferential incentives under the PLI scheme for components and technologies that are critical

[xxii] Envelope Thermal Transmittance Value

[xxiii] Residential Envelope Transmittance Value

for the manufacturing of high-efficiency white goods and appliances. It is, however, recognised that these interventions are the remit of the industrial working group, and it is recommended that these are considered as part of the overall industrial sector low-carbon transition roadmap.

vi. **Enable market transformation through research and innovation:** Dedicated programmes and targeted grants are needed to support research and development in green and low-carbon materials and products, alongside commercialisation support to enable their transition from laboratory research to demonstration and early market deployment. Forward visibility on policies that drive demand for such green products will help underpin the business case for investment in manufacturing facilities and developing associated supply chains.

vii. **Ensure construction skills and trades keep pace with changing technological landscape:** There is a clear need for dedicated programmes to build skills and capacity across the workforce and trades involved throughout the building lifecycle. Systems and processes are also needed to track and monitor skills and training gaps, which will inform the future focus of such programs.

viii. **Enable data-driven approach to future policy design:** To model and track the impact of building sector policies on GHG emissions now and in the future, it is recommended that a comprehensive national building sector energy model and framework be developed. The model should have functionality to enable bottom-up and top-down scenario analysis and assess the impact of moderate to aggressive policy interventions on future low-carbon transition trajectories for the building sector. The model can be enhanced with satellite-based monitoring, coupled with land-use data to reliably capture current building stock, annual growth and future projections. The model's functionality should be expanded to include embodied carbon of materials as well as the impact of future climate change on energy use, thermal comfort and cooling demand.

Over time, as 'real-world' energy consumption data starts to become available from surveys and disclosures recommended in this chapter (e.g., number of code-compliant buildings, energy use in existing buildings, embodied carbon data, etc.), the model inputs and attributes can be continually refined to aid future policy design. Such a model will be an important policy design tool for public sector agencies, in particular, given the complex and disaggregated nature of the building sector. In effect, primary building data, real-world energy consumption data, and modelling of future trends all need to work in tandem. The national model and underpinning data collection can be institutionalised to inform the policy pivot that will inevitably need to happen in the medium to long term.

Figure 6.1 presents a high-level overview of the policy interventions further detailed in Table 6.1, highlighting the key themes and focus areas of the recommended policy measures. The figure serves as a visual summary of the phased and coordinated measures proposed to enable a Net Zero transition in the building sector.

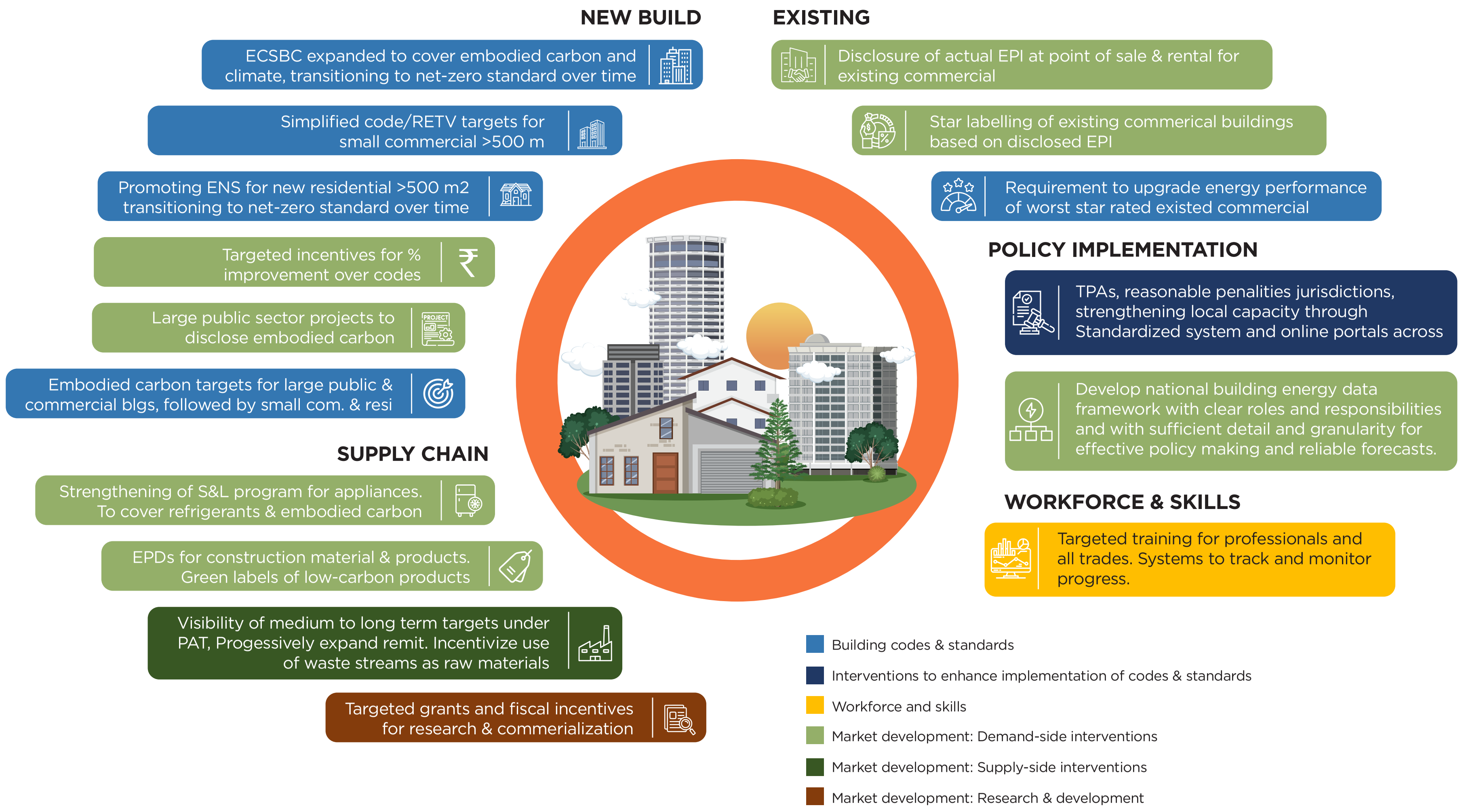


Figure 6.1: Overview of Building Sector Suggestions for Net Zero Transition

Table 6.1 summarises the proposed policy interventions for enabling a Net Zero transition in India's building sector, structured across the building lifecycle and aligned with short-, medium-, and long-term timelines. The table consolidates suggestions spanning building energy codes, compliance and enforcement, market development, data and disclosure, financing mechanisms, materials and construction practices, and workforce skilling. Together, these interventions provide a phased and coordinated policy framework to address current implementation gaps, avoid long-term carbon lock-in, and support the development of a more energy-efficient, low-carbon, and climate-resilient building stock.

Table 6.1: Summary Matrix of Proposed Policy Interventions

Building energy codes & standards	Market development
Workforce and skills	Data & models to inform policy and reliable forecasts

1. National building energy stock model & framework	
Short term (before 2030)	National Data Architecture & Governance: Establish a centralised building energy data platform within BEE Efficiency Energy Data Management Unit (EDMU). Formalize data-sharing coordination with MoSPI, NITI Aayog, and MoEFCC. Strengthen State Designated Agencies (SDAs) to enable sub-national disaggregation of energy consumption and building stock data.
	Integrated Data Inventory: Release a national building energy and stock inventory by synthesizing measured data (e.g., anonymized utility billing, smart meter, etc.), surveys (appliance penetration, usage hours, technology adoption), and modeling (operational and embodied carbon projections)
Medium term (before 2035)	Carbon Benchmarking at Scale: Integrate satellite-based building stock monitoring and urbanisation trends with smart-metering data from CEA and DISCOMs.
	Dynamic Policy Review: Conduct comprehensive reviews of Energy Conservation and Sustainable Building Code (ECSBC) and S&L programs by combining utility electricity data with national surveys on household consumption, appliance penetration, and urbanisation trends.
	Sub-national Performance Tracking: Empower State Designated Agencies (SDAs): Empower SDAs to capture city-level measured data on retrofit outcomes and fuel-transition indicators. Utilize these benchmarks to target local operational and embodied carbon reduction interventions.
Long term (beyond 2035)	National building sector dashboard: Validated data from model available to relevant ministries, public sector organisations and researchers for informed decision-making and as inputs to Biennial Transparency Reporting.
	Satellite-Based Stock Monitoring: Integrate geospatial tracking with measured energy data to definitively calculate the net rate of stock addition (new construction vs. demolition) and its impact on 2070 Net Zero targets.
2. Tighter code standards for new commercial buildings	
Short term (before 2030)	Required Mandatory minimum envelope performance thresholds under Energy Conservation and Sustainable Building Code (ECSBC).

	Simplified code / Envelope Thermal Transmittance Value (ETTV) targets for small commercial >500m² plot area.
	Procedures stipulated for commissioning & handover of HVAC equipment.
Medium term (before 2035)	Tighter targets (20-40% improvement) under ECSBC plus quantitative thermal comfort criteria for naturally ventilated buildings
	Tighter ETTV (20-40% improvement) target for >500m² plot area.
Long term (beyond 2035)	Net Zero ECSBC for plot area >500m².
	ETTV targets for all other commercial premises to ensure resilience to heat stress.
3. Eco-Niwas Samhita (ENS) and performance disclosures for new residential	
Short term (before 2030)	Promote ENS for plot area >500m². States encouraged to adopt ENS in their jurisdictions.
Medium term (before 2035)	Tighter ENS targets (20-40% improvement) for plot area >500m²
Long term (beyond 2035)	Net Zero ENS for plot area >500m²
	'Design based' disclosure of performance at point of sale and rent for residential units in plots >500m²
4. Disclosures and targets for existing commercial	
Short term (before 2030)	Disclosure of actual EPI at point of sale & rental for buildings falling under ECSBC as market signal for green premiums[xxiv]. Procedures for notification of designated entities, reporting protocols and penalties to be defined. Online portal to be set up for reporting and data collection that enables data to be used for benchmarking and future target setting.
	Rules for Star labelling based on disclosed EPI to be redefined (validity period, disclosure requirements, etc.) building on BEEs existing star labelling program
Medium term (before 2035)	Requirement to upgrade energy performance of worst rated existing commercial based on benchmarking of disclosed EPI
	Use accumulated empirical data to inform design of government or Discom incentive schemes.
5. Incentives for improved EPI	
Short term (before 2030)	Financial incentives for green buildings linked to % improvement over ECSBC and ENS. Incentives to be provided both for developer and end customer (e.g., stepped increase in FAR depending on modelled EPI for developer and rebate on property taxes for buyer).
	Guidance to be developed for states/ UTs to operationalize the incentives, including accreditation protocols and penalties in case of non-compliance post-construction.
6. Green labelling of equipment and appliances	

[xxiv] Green buildings give whole building rating but not ratings specific to energy consumption and emission

Short term (before 2030)	Third party accreditation for green labelling of equipment & appliances under BEE S&L program.
	Labelling to cover GHG emissions for refrigerants.
Medium term (before 2035)	Thresholds for labels to be revised to raise the bar in line with international benchmarks.
	Green labels for appliances & equipment to cover both embodied carbon & refrigerants.
Long term (beyond 2035)	Thresholds for labels to be reviewed and revised in line with international benchmarks.
	Phasing out of worst rated equipment
7. Embodied carbon disclosures, benchmarks and targets	
Short term (before 2030)	Standard Life Cycle Assessment (LCA) methodology & rules for construction materials/ products and building-level LCA
	Phased introduction of Environmental Product Declaration (EPD) requirements for building materials & products. Product category rules (PCRs) developed by experts to enable like-for-like comparisons across specific product categories (e.g., steel, brick, admixtures, etc.).
	Approved independent accreditation bodies or individual verifiers for accrediting EPDs
	Online public register of accredited EPDs, readily searchable. National database of generic material / product embodied carbon values made available, which are to be used in absence of product specific EPDs.
	EPD data used for benchmarking and assigning green labels for low-carbon products.
	Green-labelled products are included in the public sector schedule of rates (national. state, UT) on an ongoing basis.
	Public sector (> defined threshold) & commercial buildings falling under ECSBC disclose embodied carbon. Online portal for reporting and data collection that enables data to be benchmarked and used for future target setting.
Medium term (before 2035)	Embodied carbon reduction targets for large public sector (> defined threshold) & commercial buildings under ECSBC.
Long term (beyond 2035)	Tighter embodied carbon reduction targets for all public sector & commercial projects falling under ECSBC
	Embodied carbon reduction targets for small commercial & residential buildings.
8. Facilitating better enforcement of building codes and standards	
Short term (before 2030)	Establish a standardized pool of Third-Party Assessors (TPAs). Develop and enforce a unified set of criteria and guidelines for TPAs across states and Union Territories.

	All states and UTs to establish a dedicated web portal to streamline the application, verification, and approval processes for ECBC code compliance. Data and systems to be aligned to provide comprehensive national level data.
	Introduce enforceable and reasonably moderate penalties for non-compliance with codes, including withholding occupancy approval and essential services like electricity, water, telecom, etc., connections until compliance is met. Transparency to be ensured by recording non-compliance issues on the web portal.
9. Complementary industrial sector policies	
Short term (before 2030)	Visibility of medium to long term GHG emission reduction targets under Carbon Credit Trading Scheme (CCTS) for key building materials (cement, steel, metals, bricks, glass) to drive investment and innovation
	Policies to improve supply of waste streams as raw materials, such as penalties and/or incentives to divert agricultural and industrial waste from being burned or going to landfill.
Medium term (before 2035)	Perform, Achieve and Trade (PAT) remit progressively expanded to cover other key building materials & products
Long term (beyond 2035)	Perform, Achieve and Trade (PAT) remit further expanded to cover additional building materials & products
10. Commercialization support for green materials and energy efficient products	
Short term (before 2030)	Targeted grants and other financial incentives for R&D, commercialization as well as domestic manufacturing of green materials, energy efficient equipment and critical supply chain components (e.g. tax incentives for 'green labelled' products[xxv]). This includes specific policies to encourage academic and research institutions to proactively collaborate with industry for product development and commercialisation.
	Provide support for commercialisation through RESCO/ESCO models targeting low energy and low-cost cooling, low-carbon masonry, prefabricated systems, high-performance envelopes
Medium term (before 2035)	Track market progress, review and refine policies to support commercialization.
Long term (beyond 2035)	Track market progress, review and refine policies to support commercialization.
11. Targeted training for professionals and all trades	
Short term (before 2030)	Mason and construction worker training specifically for new construction techniques and materials (e.g., handling of low carbon cements, use of agrocrete blocks, etc.).
	Real estate companies and developers to be encouraged to spend CSR funding on such training.

[xxv] Refer suggestions on green-labelled products under row 6 'embodied carbon disclosures, benchmarks and targets'.

	Certificate courses on energy management for industry trades (installers, plant operatives repair and maintenance staff).
	Mandatory sustainability modules in professional courses (architects, engineers, asset managers).
	Enhance ongoing training & capacity-building of officials involved in ECBC approvals to include latest technologies, systems & best practices.
Medium term (before 2035)	Set up systems and processes to track and monitor skills and training gaps, and refine training programs as needed.

7

CONCLUSION AND NEXT STEPS

Conclusion and Next Steps

7

India's Net Zero goals are well aligned with its long-term economic and development goals. Ensuring resource-efficient, low-carbon, and climate-resilient growth in the building sector is critical to realising India's vision of a Viksit Bharat. This can be leveraged to position India a global leader in these technologies.

There are currently significant barriers and policy gaps to mainstreaming low-carbon and climate-resilient buildings. Mandatory codes cover a small fraction of the building stock, and focus mainly on operational energy performance. They do not currently address aspects related to lifecycle embodied carbon, climate-related heat stress, and resource efficiency. Challenges exist in code implementation with significant variations across states and UTs. There is limited data and a feedback loop to understand on-the-ground challenges, technologies being deployed, and 'real-world' performance, as well as a lack of enabling market mechanisms to drive demand and scale up supply chains for low-carbon buildings

The importance of comprehensive building sector data cannot be undermined. Comprehensive sectoral data is needed to inform policy development, appraise the impact of those policies, and track progress against national targets. The data needs to be granular enough to capture regional variations in building sector attributes, market dynamics and stakeholder behaviour. This sectoral data needs to be underpinned by data disclosures related to product environmental attributes and asset performance, which are validated, consistent and comparable. Such validated disclosures create awareness and form the basis of green premiums needed to spur investment and innovation in low-carbon alternatives. Current policies, such as BEE's S&L programme, have demonstrated the market shift that such data discourses can facilitate.

Low-carbon transition of the building sector requires a holistic approach. This includes gradually expanding the remit and coverage of building codes and standards, tightening of minimum performance standards over the medium and long term, enabling policies and market mechanisms to drive demand for high-efficiency and low-carbon buildings, supply-side interventions to decarbonise the supply chain and enhance transparency, while creating an ecosystem that encourages more research and innovation. Comprehensive skills and capacity building are needed for professionals and tradespeople across the building cycle.

Next Steps: Preparation of Action Plan

A key next step to operationalising this strategic roadmap is the preparation of an action plan. The action plan will help translate India's long-term targets into actionable items, enable periodic reviews to assess where we stand and recast our path to Net Zero where needed. This action plan will detail the following:

i. **Implementation mechanism:** Establish the mechanism by which the proposed interventions will be implemented and operationalised, whether under an existing legislation that assigns powers to specific government agency/ agencies or through new legislation.

ii. **Roles and responsibilities:** Define the roles and responsibilities of the implementing agency, other relevant public sector departments, industry bodies and stakeholders. Establish reporting lines and protocols to ensure accountability. States play a pivotal role in implementing national policies, with MoHUA/MoP, NITI Aayog providing essential technical and financial support to drive compliance and capacity-building. Urban development authorities and ULBs will also play an integral role.

iii. **Design of policy instruments:** Set out the key principles and high-level low-carbon transition goals that will inform the detailed design of the proposed intervention, including, for instance, indicative threshold performance values over short, medium and long-term. The key principles and goals will need to be established, considering both a top-down approach (i.e. trajectory needed to meet long-term targets) and a bottom-up approach (that is, the lifecycle cost and benefits of current technological solutions to meet target values).

iv. **Timeline and key milestones:** Establish a clear timeline for design and implementation of the proposed interventions, along with specific milestones to track progress. This timeline will need to align with national climate goals and relevant policy cycles.

v. **Resource Allocation:** Estimate the financial and human resources required to implement the proposed interventions and identify funding sources, where relevant. Explore innovative financing mechanisms, such as public-private partnerships, to mobilise resources.

vi. **Stakeholder Engagement:** Develop a comprehensive stakeholder engagement strategy to ensure broad-based support and input to the action plan. This includes consultations with industry associations, professional organisations, civil society groups, and building occupants. Strengthening global collaboration will also help position India as a leader in sustainable buildings across the Global South, fostering knowledge exchange and innovation.

vii. **Monitoring and Evaluation Framework:** Establish a robust monitoring and evaluation framework to track the effectiveness of the action plan and make necessary adjustments. This framework should include clear indicators, data collection mechanisms, and periodic reviews.

By developing a comprehensive action plan to transition to a Net Zero building sector, India can create a more sustainable, resilient, and prosperous future while unlocking significant economic value. A concerted and collaborative effort will be key to fulfilling this vision.

ANNEXURES

Annexure A: Terms of Reference for Working Group

Sub-group - 1: Integrated Building Design

Sub-objective

Examine barriers and related interventions for accelerating adoption of low carbon and energy efficient construction technologies to mitigate climate induced heat stress and reduce GHG emissions over the building lifecycle. The focus of this sub-group is on approaches for enabling integrated design thinking to reduce lifecycle GHG emissions taking into consideration building envelope thermal performance, as well as carbon intensity, durability and circularity of building materials and construction systems. The outputs from this sub-group will from part of the overall roadmap for building sector low-carbon transition.

Scope:

i. Examine (or provide input to relevant building sector models on) the business-as-usual (BAU) growth in building sector GHG emissions considering GDP growth trajectories and urbanisation aligned to development aspirations.

ii. Examine (or provide input to relevant building sector models on) the impact of climate change on cooling demand.

iii. Examine the role of building envelope performance and related technologies in bringing down the energy demand, improving thermal comfort and reducing operational carbon.

iv. Examine the role of low-carbon materials and optimised design in reducing lifecycle embodied carbon.

v. Examine the role of embodied / building lifecycle carbon disclosures, benchmarking and related performance standards in low-carbon transition of the sector.

vi. Make recommendations on potential market mechanisms and financial incentives to address whole building lifecycle emissions.

Sub-group - 2: Building materials

Sub-objective: Examine existing supply chains, skills gap, barriers and related interventions (including innovation) for mainstreaming low carbon building materials and construction products. The sub-groups work encompasses macro-level questions relating to scaling up low carbon and sustainable building materials, and may also interface with the work of the industrial working group focussing on hard to abate sectors such as cement and steel. The outputs from this sub-group will from part of the overall roadmap for building sector low-carbon transition.

Scope:

i. Examine (or provide input to relevant building sector models on) the BAU growth in building sector GHG emissions considering GDP growth trajectories and urbanisation aligned to development aspirations.

ii. Appraise the current landscape for low carbon and circular building materials / products (both conventional and alterative), including supply, demand and skills gaps.

iii. Examine options to scale up demand and address barriers identified above.

iv. Examine the role of mandating material / product embodied carbon disclosures (or EPDs) and other interventions (e.g., circularity specifications) in low-carbon transition of the sector.

v. Examine the role of wider policies (e.g., C&D waste management, industrial sector policies and incentives) on encouraging circular building materials, as recommendations for consideration by the relevant working groups.

vi. Make recommendations to encourage innovation (and related investment) in low carbon materials/ products for further consideration.

Sub-group-3: Energy use in buildings

Sub-objective: Examine barriers and related interventions for accelerating adoption of energy-efficient appliances, building energy systems & services, and clean/renewable energy generation technologies. The outputs from this sub-group will from part of the overall roadmap for building sector low-carbon transition.

Scope:

i. Examine (or provide input to relevant building sector models on) the BAU growth in building sector energy demand and GHG emissions considering GDP growth trajectories and urbanisation aligned to development aspirations.

ii. Examine (or provide input to relevant building sector models on) the role of increase in standard of living on appliance penetration and usage.

iii. Examine (or provide input to relevant building sector models on) the impact of climate change on cooling demand and increased uptake of active cooling.

iv. Examine the likely penetration and energy savings from super-efficient appliances and equipment for lighting, cooling, heating, cooking and water pumping.

v. Examine the role of the shift to cleaner/alternative fuels/demand electrification on energy consumption, emissions and energy security.

vi. Examine the role of behavioural nudges (positive and negative) on energy consumption.

vii. Examine the role of operational energy/ carbon disclosures, benchmarking of energy consumption and performance standards.

viii. Make recommendations on market mechanisms and incentives to enable building sector low-carbon transition, including their role in facilitating higher penetration of building codes (ECBC, Eco-NIWAS).

Annexure B: Assumptions for Energy Modelling

1. Residential Sector Energy Modelling

Appliance Penetration (%)

	Urban			Rural		
	2020	2050	2070	2020	2050	2070
Lights	100%	100%	100%	100%	100%	100%
Ceiling Fans	96%	100%	100%	86%	100%	100%
Table Fans	14%	14%	14%	14%	14%	14%
Air Coolers	28%	50%	50%	13%	30%	45%
Space Heating Equipment	5%	8%	10%	6%	8%	10%
Television	88%	100%	100%	61%	100%	100%
Refrigerator	65%	90%	100%	29%	80%	100%
ACs	17%	80%	90%	7%	50%	70%
Geyser	23%	60%	80%	9%	50%	70%
Washing Machine	39%	80%	90%	11%	30%	50%
Water Pump	24%	50%	60%	18%	30%	50%

Appliance Per Household

	Urban			Rural		
	2020	2050	2070	2020	2050	2070
Ceiling Fans	2.1	2.5	3.0	1.8	2.1	2.5
Table Fans	1.1	1.2	0.2	1.1	1.1	1.2
Air Coolers	1.2	1.5	1.5	1.1	1.2	1.5
ACs	1.2	1.6	2.0	1.2	1.2	1.5
Incandescent Bulb	0.4	0.0	0.0	0.6	0.0	0.0
CFL	0.8	0.0	0.0	0.6	0.0	0.0
LED	3.3	7.0	8.0	2.8	5.0	7.0
LED Tubelight	0.7	2.0	3.0	0.3	1.3	2.0

	Urban			Rural		
	2020	2050	2070	2020	2050	2070
CFL Tubelight	0.4	0.0	0.0	0.1	0.0	0.0
Electric Heater	1.0	1.3	1.4	1.0	1.0	1.0
Geyser	1.0	1.3	1.4	1.0	1.0	1.0
Immersion Rod	1.0	1.3	1.4	1.0	1.3	1.4
TV	1.1	1.1	1.1	1.0	1.0	1.1
Refrigerator	1.0	1.1	1.1	1.0	1.0	1.0
Washng Machine	1.0	1.1	1.1	1.0	1.0	1.0
Water pump	1.0	1.0	1.0	1.0	1.0	1.0

Usage Hours (Urban/ Rural)

	Usage Hours- Urban						Usage Hours- Rural					
	CPS			NZS			CPS			NZS		
	2020	2050	2070	2020	2050	2070	2020	2050	2070	2020	2050	2070
Ceiling Fans	1950	2200	2450	1900	2200	2400	1950	2200	2450	1900	2200	2400
Table Fans	800	900	1000	900	100	1100	800	900	1000	900	100	1100
Air Coolers	900	1200	1500	825	1200	1500	900	1050	1200	825	1200	1500
ACs	1000	1800	1800	800	1400	1800	1000	1400	1600	800	1200	1500
Lighting	2250	1800	1500	1650	1500	1200	2250	1800	1500	1650	1500	1200
Incandescent Bulb	2250	1800	1500	1650	1500	1200	2250	1800	1500	1650	1500	1200
CFL	2250	1800	1500	1650	1500	1200	2250	1800	1500	1650	1500	1200
LED	2250	1800	1500	1650	1500	1200	2250	1800	1500	1650	1500	1200
LED Tubelight	2250	1800	1500	1650	1500	1200	2250	1800	1500	1650	1500	1200
CFL Tubelight	2250	1800	1500	1650	1500	1200	2250	1800	1500	1650	1500	1200
Electric Heater	450	500	500	550	550	550	450	500	500	550	550	550
Geyser	180	180	180	180	180	180	180	180	180	180	180	180
Immersion Rod	180	180	180	180	180	180	180	180	180	180	180	180
TV	1850	1850	1850	1600	1600	1600	1850	1850	1850	1600	1600	1600
Refrigerator	7200	8000	8000	8000	8000	8000	7200	8000	8000	7200	8000	8000
Washing Machine	150	200	200	130	130	130	150	200	200	130	130	130
Water pump	280	300	350	250	250	250	280	300	350	250	250	250

Appliance Wattage (considering improvement in efficiency)

	Baseline Year	CPS		NZS	
	2020	2050	2070	2050	2070
Fans	70	50	35	35	20
Coolers	225	175	125	125	75
AC - 1S	1750	1450	1175	1175	900
ACs - 2S	1500	1250	1000	1000	775
ACs - 3S	1250	1075	875	875	675
ACs - 4S	1100	925	750	750	575
ACs - 5S	950	800	650	650	500
Incandescent bulb	60	60	60	60	60
CFL	20	15	12	12	8
LED	10	8	6	6	4
LED Tubelight	40	32	24	24	16
CFL Tubelight	60	45	36	36	24
Electric Heater	2000	1500	1200	1200	800
Geyser	2000	1600	1200	1200	1000
Immersion Rod	1500	1250	1100	1100	900
Water Heater Solar	400	350	300	300	240
TV & Other Electronic Display Devices	80	65	50	50	35
Refrigerator	80	65	50	50	40
Washing Machine	750	600	500	500	400
Water pump	1150	1000	800	800	650

2. Commercial Sector Energy Modelling

Share of AC floor space (building type-wise)

Share of AC floor space (%)	2020	2050	2070
Hospitals	34%	75%	90%
Hotels	50%	75%	95%
Retail	19%	60%	90%
Office space	35%	75%	90%
Educational	14%	50%	70%
Assembly places	7%	30%	50%
Transit	42%	50%	70%
Warehouse	23%	40%	60%

Penetration of Low carbon buildings by 2070

	CPS	NZS
Share of ECBC	30%	20%
Share of ECBC+	20%	10%
Share of Super- ECBC	10%	5%

3. Cooking Sector Energy Modelling

Fuel Mix in Cooking Sector

			CPS		NZS	
		2020	2050	2070	2050	2070
Rural	Biogas	0%	2%	2%	2%	2%
	Biomass	57%	22%	2%	0%	0%
	Electric	1%	9%	21%	35%	50%
	LPG	42%	50%	45%	47%	19%
	PNG	0%	17%	30%	17%	29%
Urban	Biogas	0%	0%	0%	0%	0%
	Biomass	9%	0%	0%	0%	0%
	Electric	1%	24%	50%	32%	70%
	LPG	85%	51%	10%	38%	10%
	PNG	5%	25%	40%	30%	20%

REFERENCES

1 Mishra, V., Mukherjee, S., Kumar, R., & Stone, D. (2017). Heat wave exposure in India in current, 1.5 °C, and 2.0 °C worlds. Environmental Research Letters, 12(12).

2 Bureau of Energy Efficiency. (n.d.). Standards and labeling programme. https://beeindia.gov.in/en/programmes/standards-labeling

3 National Institute of Urban Affairs, & Rocky Mountain Institute. (2022). From the ground up: A whole-system approach to decarbonising India's buildings sector. New Delhi.

4 Ministry of Environment, Forest and Climate Change. (2019). India cooling action plan. Government of India.

5 Global Alliance for Buildings and Construction. (2016). Global status report 2016: Towards zero-emission efficient and resilient buildings. UNEP.

6 Centre for Study of Science, Technology and Policy. (2024). Pathways to steer India's buildings sector towards a Net Zero future. Bengaluru.

7 World Population Review. (2025). Countries by population density 2025. https://worldpopulationreview.com/country-rankings/countries-by-density

8 Singapore Property News. (2025, March 7). Are home sizes in Singapore shrinking? https://www.edgeprop.sg/property-news/are-home-sizes-singapore-shrinking

9 CEIC Data. (2025). Singapore: Built-up area per capita. https://www.ceicdata.com

10 U.S. Census Bureau. (n.d.). Construction characteristics: Current data. U.S. Department of Commerce. https://www.census.gov/construction/chars/current.html

11 Huang, T., Shi, F., Tanikawa, H., Fei, J., & Han, J. (2013). Materials demand and environmental impact of buildings construction and demolition in China based on dynamic material flow analysis. Resources, Conservation and Recycling, 72, 91–101.

12 Van Vliet, J., Yang, H., Bakker, V., & Li, M. (2024). Global inequality in built-up land per capita and its change trajectories between 1985 and 2020. Geography and Sustainability, 5(4), 541–547.

13 The Energy and Resources Institute. (2017). Cement industry trends report. TERI.

14 Ministry of Steel. (2017). National Steel Policy. Government of India.

15 Greentech Knowledge Solutions. (2017). Roadmap for promoting resource-efficient bricks in India: A 2032 strategy. New Delhi.

16 Tibrewal, K., Venkataraman, C., Phuleria, H., Joshi, V., Maithel, S., Damle, A., Gupta, A., & Sinha, B. (2023). Reconciliation of energy use disparities in brick production in India. Nature Sustainability, 6, 1248–1257. https://doi.org/10.1038/s41893-023-01165-x

17 Greentech Knowledge Solutions. (2017). Roadmap for promoting resource-efficient bricks in India: A 2032 strategy.

18 Bureau of Energy Efficiency, & GIZ. (2019). Market transformation towards energy efficiency in the brick sector: A strategic blueprint.

19 PR Newswire. (2025). Global construction glass market poised to exceed US$190.3 billion.

20 Bureau of Energy Efficiency, Nandi, N., Mohan, R. V., Kumar, S., Sharma, Y., Patnaik, B. R., & Sunder, P. S. (2021). Achieving energy and resource efficiency in glass and refractory industries: A sectoral roadmap for MSMEs. https://beeindia.gov.in/sites/default/files/Glass_&_Refractory_sector-Energy_mapping.pdf

21 Fishman, T., Mastrucci, A., Peled, Y., Saxe, S., & van Ruijven, B. (2024). RASMI: Global ranges of building material intensities differentiated by region, structure, and function. Scientific Data, 11(1), 418.

22 Hong, L., Zhou, N., Feng, W., Khanna, N., Fridley, D., Zhao, Y., & Sandholt, K. (2016). Building stock dynamics and its impacts on materials and energy demand in China. Energy Policy, 94, 47–55.

23 Hong, L., Zhou, N., Fridley, D., Feng, W., & Khanna, N. (2014). Modeling China's building floor-area growth and the implications for building materials and energy demand. In Proceedings of the ACEEE Summer Study on Energy Efficiency in Buildings.

24 World Business Council for Sustainable Development. (2018). Low carbon technology roadmap for the Indian cement sector: Status review. WBCSD.

25 Saint-Gobain Research Institute. (2025). Expert consultation. Chennai.

26 Alliance for Energy Efficient Economy. (2023). Analysis based on India Net Zero steel demand outlook 2023, National Steel Policy 2017, and Greening the steel sector in India: Roadmap and action plan, Government of India 2024.

27 Sharma, P., Gupta, A., & Moudgil, P. (2025). Green power procurement by aluminium sector in India.

28 Sripathy, P., Nitturu, K., Yadav, D., & Mallya, H. (2024). Evaluating Net Zero trajectories for the Indian aluminium industries. Council on Energy, Environment and Water.

29 World Economic Forum. (2019). India's heat and cooling challenge. https://www.weforum.org

30 Singhal, A., Sharma, S., & Garg, T. (2021). Transitioning to super energy-efficient room air conditioners: Fostering ICAP implementation.

31 Ullah, I., et al. (2022). Projected changes in socioeconomic exposure to heatwaves in South Asia under changing climate. Earth's Future, 10, e2022EF002240.

32 United Nations Environment Programme. (2024). Emissions gap report 2024: No more hot air… please! https://www.unep.org/resources/emissions-gap-report-2024.

33 Bevacqua, E., Schleussner, C.-F., & Zscheischler, J. (2025). A year above 1.5 °C signals that Earth is most probably within the 20-year period that will reach the Paris Agreement limit. Nature Climate Change, 15(3), 262–265. https://doi.org/10.1038/s41558-025-02246-9.

34 India Meteorological Department. (2023). Heat and cold waves in India: Processes and predictability. Ministry of Earth Sciences.

35 World Health Organisation. (n.d.). Climate change, heat and health. https://www.who.int/news-room/fact-sheets/detail/climate-change-heat-and-health

36 International Labour Organisation. (2019). Working on a warmer planet: The impact of heat stress on labour productivity and decent work.

37 National Disaster Management Authority. (n.d.). Heat wave management guidelines. Government of India.

38 Ministry of Environment, Forest and Climate Change. (2024). Fourth biennial update report to the UNFCCC. Government of India.

39 United Nations Environment Programme. (2023). Building materials and the climate: Constructing a new future. UNEP.

40 Mavandad, S., & Malinowski, M. (2022). World's best MEPS: Assessing top energy efficiency standards for priority appliances. CLASP.

41 LC3 Consortium. (n.d.). A viable and sustainable alternative to existing cement varieties.

42 Indian Institute of Technology Madras. (2022). New cement with the potential to realize low carbon goals in the construction industry.

43 Lodha Group. (2025). Creating and sustaining market for limestone calcined clay cement (LC3) in India.

44 Development Alternatives. (2019). Low carbon and resource-efficient technology: Scaling up of fly ash brick technology in India.

45 World Business Council for Sustainable Development. (2018). Low carbon technology roadmap for the Indian cement sector: Status review. WBCSD.

46 PR Newswire. (2025). Wienerberger India achieves lowest carbon footprint with Porotherm smart bricks.

47 Jain, M. (2023). Life cycle assessment: Infosys campus, Kolkata. Monk Spaces.

48 Chetia, S., Mital, N., Phogat, S. K., Bhanware, P., Jain, M., Maithel, S., & Patel, H. (2024). Whole-life carbon analysis of residential buildings in India. Greentech Knowledge Solutions.

49 Bureau of Energy Efficiency. (n.d.). Standards and labeling programme. https://beeindia.gov.in/en/programmes/standards-labeling

50 Bureau of Energy Efficiency. (n.d.). Star rating programme for buildings. https://beeindia.gov.in

51 Bureau of Energy Efficiency. (n.d.). Shunya labelling programme. https://beeindia.gov.in

52 Bureau of Energy Efficiency, & Ministry of Environment, Forest and Climate Change. (2024). Impact assessment reports and fourth biennial update report. Government of India.

53 International Energy Agency. (2023). The future of cooling in China.

54 Climate Central. (n.d.). Cooling degree days. https://www.climatecentral.org

55 World Green Building Council. (2019). Bringing embodied carbon upfront. https://worldgbc.org

56 World Business Council for Sustainable Development. (2021). Net Zero buildings: Where do we stand? https://www.wbcsd.org

57 Mills, E. (2011). Building commissioning: A golden opportunity for reducing energy costs and greenhouse gas emissions in the United States.

58 Therma. (2024). Benefiting from building commissioning. https://www.therma.com

59 Natural Resources Defense Council. (n.d.). Building a better future: Implementing the energy-saving building code in Hyderabad.

60 Alliance for Energy Efficient Economy. (2024). Dynamic display of power in room air conditioners for nudging user behaviour.

61 Dixit, H., & Bhasin, S. (2022). Technology gaps in India's air-conditioning supply chain. Council on Energy, Environment and Water.

62 Bhandari, D., & Shrimali, G. (2018). The Perform, Achieve and Trade scheme in India: An effectiveness analysis. Renewable and Sustainable Energy Reviews, 81, 1286–1295

63 Tibrewal, K., Venkataraman, C., Phuleria, H., Joshi, V., Maithel, S., Damle, A., Gupta, A., & Sinha, B. (2023). Reconciliation of energy use disparities in brick production in India. Nature Sustainability, 6, 1248–1257. https://doi.org/10.1038/s41893-023-01165-x

64 Greentech Knowledge Solutions. (2017). Roadmap for promoting resource-efficient bricks in India: A 2032 strategy.

65 Bureau of Energy Efficiency, & GIZ. (2019). Market transformation towards energy efficiency in the brick sector: A strategic blueprint.

66 PR Newswire. (2025). Global construction glass market poised to exceed US$190.3 billion.

67 Bureau of Energy Efficiency, Nandi, N., Mohan, R. V., Kumar, S., Sharma, Y., Patnaik, B. R., & Sunder, P. S. (2021). Achieving energy and resource efficiency in glass and refractory industries: A sectoral roadmap for MSMEs. https://beeindia.gov.in/sites/default/files/Glass_&_Refractory_sector-Energy_mapping.pdf

सत्यमेव जयते

NITI Aayog