GGGI

ASIA LOW CARBON BUILDINGS TRANSITION PROJECT

Life Cycle Assessment for Transitioning to a Low-Carbon Economy

Policy Review & Institutional Mapping of Building Energy Efficiency Programs in India

Asia Low Carbon Buildings Transition (ALCBT) Project

June 2025

ASEAN CENTRE FOR ENERGY ACE

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HEAT

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ASIA LOW CARBON BUILDINGS TRANSITION PROJECT

Life Cycle Assessment for Transitioning to a Low-Carbon Economy

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List of Abbreviations

ALCBT	Asia Low Carbon Buildings Transition
AHP	Affordable Housing in Partnership
BEAT	Building Emissions Assessment Tool
BEEP	Building Energy Efficiency Project
BIPV	Building-Integrated Photovoltaics
BIS	Bureau Of Indian Standards
BMPTC	Building Materials and Technology Promotion Council
BMS	Building Management System
BMWK	Federal Ministry for Economic Affairs and Climate Action of Germany
BOQ	Bill Of Quantities
BUR	Biennial Update Reports
CAGR	Compound Annual Growth Rate
CCUS	Carbon Capture, Utilization, And Storage
CDD	Cooling Degree Days
CFC	Chlorofluorocarbon
CII	Confederation Of Indian Industry
COP	Conference Of the Parties
CPWD	Central Public Works Department
DSIR	Department Of Scientific and Industrial Research
DST	Decision Support Toolkit
DX	Direct Expansion Cooling
ECBC	Energy Conservation Building Code
EDGE	Excellence In Design for Greater Efficiencies
EER	Embodied Energy Rates
EMS	Energy Management System
ENS	Eco Niwas Samhita
EPD	Environmental Product Declarations
EPI	Energy Performance Index
ESCO	Energy Service Company
EU-REI	European Union Resource Efficiency Initiative
GDP	Gross Domestic Product
GGGI	Global Green Growth Institute
GHG	Greenhouse Gas
GRIHA	Green Rating for Integrated Habitat Assessment
GWP	Global Warming Potential
HCFC	Hydrochlorofluorocarbons
HUDCO	Housing & Urban Development Corporation
HVAC	Heating, Ventilation, And Air Conditioning
IFC	International Finance Corporation
IGBC	Indian Green Building Council
IKI	International Climate Initiative
ISSR	In-Situ Slum Rehabilitation
LED	Light-Emitting Diode
LEED	Leadership In Energy and Environmental Design

MACC	Marginal Abatement Cost Curve
MNRE	Ministry Of New and Renewable Energy
MoEFCC	Ministry Of Environment, Forest and Climate Change
MoHUA	Ministry Of Housing and Urban Affairs
MoP	Ministry Of Power
MoRD	Ministry Of Rural Development
MSME	Ministry Of Micro, Small and Medium Enterprises
NAPCC	National Action Plan on Climate Change
NATCOM	National Communications
NDC	Nationally Determined Contribution
NGO	Non-Governmental Organization
NIUA	National Institute of Urban Affairs
NMCC	National Manufacturing Competitiveness Council
NZEB	Net Zero-Energy Building
PAT	Perform, Achieve and Trade
PAYS	Pay-As-You-Save
PCM	Phase Change Material
PMEGP	Prime Minister's Employment Generation Programme
PV	Photovoltaic
RGUMY	Rajiv Gandhi Udyami Mitra Yojna
SAT	Sustainability Assessment Tool
SDA	State Designated Agencies
SIDBI	Small Industries Development Bank of India
SSI	Small Scale Industries
TCP	Town & Country Planning
TERI	The Energy & Resource Institute
TWh	Terawatt Hour
UJALA	Unnat Jyoti By Affordable LED For All
ULB	Urban Local Bodies
UNFCC	United Nations Framework Convention on Climate Change
USGBC	U.S. Green Building Council
VRF	Variable Refrigerant Flow

Summary

India's building sector is one of the most energy-intensive sectors, accounting for 34% of the nation's electricity consumption. Given its significant contribution to global energy use and CO_2 emissions, the sector plays a critical role in achieving India's Nationally Determined Contributions (NDCs). Over the years, regulatory authorities have developed standards, regulations, policies, programs, and schemes to boost energy efficiency in buildings. Ensuring consistent implementation of these measures across the country is crucial for reducing carbon emissions and meeting NDC targets.

The growing energy demand is pivotal to India's economic development, necessitating innovative policies and regulations to manage and reduce consumption. This demand is projected to increase linearly, with the total constructed area expected to grow from 2,100 million square meters in 2005 to approximately 28,000 million square meters by 2050. This growth is driven by population expansion, economic activity, and an increasing concentration of residential and commercial construction in urban areas. Urbanization alone is expected to add 400 million people to cities by 2050, effectively doubling the urban population from 2014 levels. Currently, urban areas house 34% of India's population but are projected to contribute 75% of the total GDP by 2030. This urbanization trend is driving higher electricity demand, which is forecasted to rise from 414 TWh/year to 4,697 TWh/year by 2047. By then, buildings alone are estimated to account for 55% of total electricity consumption.

To address these urgent challenges, the Global Green Growth Institute (GGGI), with funding from Germany's Federal Ministry for Economic Affairs and Climate Action (BMWK) through the International Climate Initiative (IKI), has launched the "Asia Low-Carbon Buildings Transition (ALCBT)" project in India. The five-year project aims to significantly reduce GHG emissions by catalyzing nationwide transition toward low carbon buildings through technical and institutional tools, enhancing technical capacity of key industry stakeholders, creating financial pathways, and promoting knowledge replication and scaling up.

As part of the ALCBT project, this study was conducted to provide a comprehensive policy review and institutional mapping of building energy efficiency programs in India. The review focused on assessing the status, effectiveness, and strategic alignment of these initiatives, as captured in this report. It also identifies key barriers that hinder progress toward India's net-zero emissions pathway and climate policy goals.

International development agencies (IDAs), such as such as the United States Agency for International Development (USAID), United Nations Development Programme (UNDP), Swiss Agency for Development and Cooperation (SDC), Kreditanstalt für Wiederaufbau (KfW), Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), World Bank (WB), International Finance Corporation (IFC), United Nations Environment Programme (UNEP), Shakti Sustainable Energy Foundation, Collaborative Labeling and Appliance Standards Program (CLASP), Global Buildings Performance Network (GBPN), and International Energy Agency (IEA), along with national institutions like the Ministry of Power (MoP), Ministry of Housing and Urban Affairs (MoHUA), Ministry of New and Renewable Energy (MNRE), Bureau of Energy Efficiency (BEE), Building Materials and Technology Promotion Council (BMPTC), Energy Efficiency Services Limited (EESL), The Energy and Resources Institute (TERI), and Indian Green Building Council (IGBC), have made significant contributions towards enhancing sustainability and energy efficiency in India's building sector.

These efforts include publications, capacity-building initiatives, the establishment of standards, execution of demonstration projects, and the development of tools and software for both commercial and residential buildings, as well as green building materials. Government-led initiatives like the Energy

Conservation Building Code (ECBC) and Eco Niwas Samhita (ENS), along with various green building certification programs, aim to promote the construction of energy-efficient buildings and the adoption of renewable energy sources.

Beyond energy efficiency, the use of green building materials is crucial for minimizing resource consumption, reducing embodied energy, enhancing energy efficiency, and lowering carbon emissions. These materials are essential for the projected expansion of built-up areas in the country. Recognizing this, regulatory bodies and organizations such as MoHUA and GreenPro are actively promoting the use of green building materials. They also assess the sustainability and environmental impacts of construction materials to ensure a more sustainable and eco-friendly building industry.

The comprehensive policy review and institutional mapping have revealed several challenges impeding India's path to net-zero emissions and climate policy. These include the need for improved standards, the absence of net-zero energy building guidelines, low awareness of energy conservation measures, insufficient incentives, and a lack of knowledge exchange and capacity-building mechanisms. Specific barriers include low awareness of energy efficiency, uneven implementation of ECBC and ENS standards across states, high costs of cooling technologies and appliances, inadequate data acquisition systems, and weak policy enforcement.

Despite these challenges, 25 states have officially issued gazette notifications for ECBC 2017, and 17 states are making proactive strides toward notifying ENS 2021. This indicates a strong commitment to improving energy efficiency in buildings. However, there is a pressing need to enhance education and outreach efforts to raise awareness about the benefits of ECBC, ENS, and energy-efficient practices. Financial hurdles also remain a significant obstacle to the adoption of energy-efficient technologies and practices. Establishing a robust banking and financial ecosystem is essential to meet the capital requirements of Energy Service Companies (ESCOs) involved in energy efficiency projects.

In conclusion, India’s building sector faces substantial energy challenges due to rapid urbanization, economic growth, and increasing demand for amenities and technologies. Although the government has introduced various policy measures to manage this demand, stringent implementation and enforcement are critical for achieving meaningful energy efficiency gains and carbon emission reductions. This study presents actionable strategies to bridge the identified gaps in the Indian market, emphasizing the role of energy efficiency and green building materials in ensuring sustainable growth and development on the building sector.

1 The Indian Building Energy Landscape

1.1 The Rising Energy Demand

India is the world's second fastest-growing economy. Amid population growth, economic progress, and urbanization, energy consumption demand has surged significantly. This increase poses a significant threat due to the exponential growth in greenhouse gas emissions (GHGs) and the resulting impacts on climate change. The rise in energy consumption is attributed to various factors, such as the growth of building stock, rising demand for amenities and technologies, changes in lifestyle patterns and higher household incomes — all collectively influencing the energy consumption trends in the building sector.

Over the last two decades, the Indian government has developed various policy initiatives, memorandums of understanding, guidelines, codes, standards, and publications to address this rise in energy demand. However, if these policies and standards are not uniformly enforced and implemented at a scale across the nation, carbon emissions could multiply sevenfold by 2050[1].

The primary objective of this study is to comprehensively analyze and assess policy initiatives undertaken by various international development agencies, NGOs, ministry-level departments, ESCOs, and others. This study assesses the status of building energy efficiency programs and green building materials and proposes actionable strategies and opportunities to bridge existing gaps in the Indian market.

1.1.1 Quantitative Overview

India's rapidly rising energy demand is a crucial determinant of the country's economic growth. To address this, the development of new and innovative policies and regulations across various sectors is crucial for managing and reducing energy consumption.

The sector-wise electricity consumption in India for 2022-23 is presented below:[2]

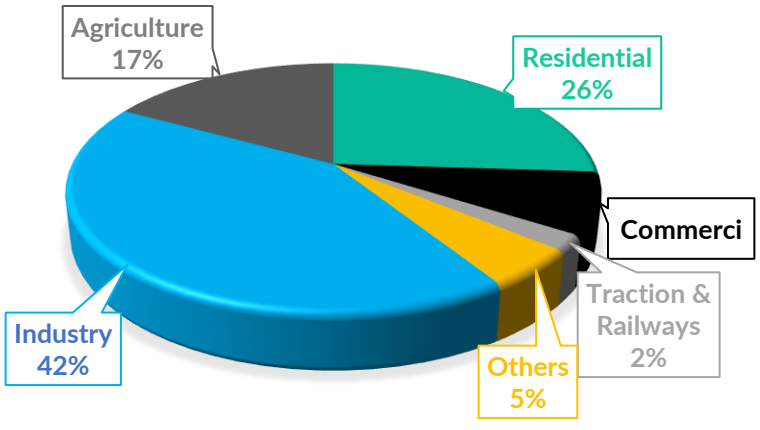


Figure 1: Sector-wise electricity consumption in India (2022-23)

[1] United Nations Framework Convention on Climate Change (UNFCCC). *The Evidence Is Clear: The Time for Action Is Now. We Can Halve Emissions by 2030*. April 4, 2022. https://unfccc.int/news/the-evidence-is-clear-the-time-for-action-is-now-we-can-halve-emissions-by-2030.

[2] Ministry of Statistics and Programme Implementation (MoSPI), *Energy Statistics India 2024: Chapter 6 – Consumption of Energy Resources* (New Delhi: Government of India, 2024), https://www.mospi.gov.in/sites/default/files/publication_reports/Energy_Statistics_2024/Chapter6-Consumption_of_Energy_Resources.pdf.

Electricity consumption increased from 411,887 GWh in 2010-11 to 1,380,900 GWh in 2022-23, showing a Compound Annual Growth Rate (CAGR) of 9.75%

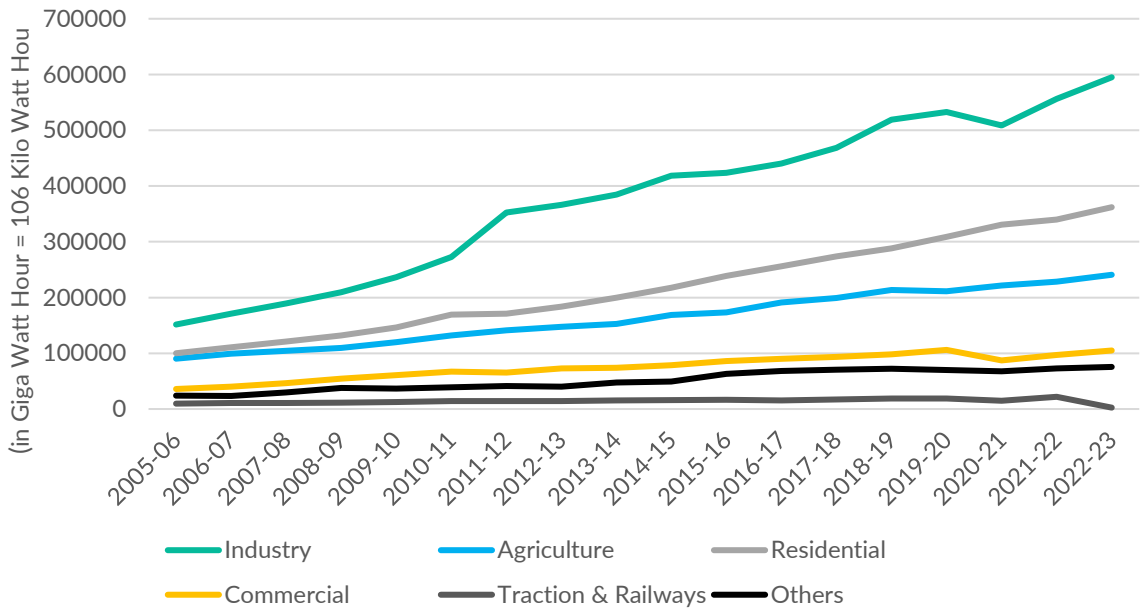


Figure 2: Trend of category-wise electricity consumption in India

In 2022-23, the industry sector accounted for the largest share of total electricity consumption (42%), followed by residential (26%), agriculture (17%), and commercial sectors (8%).[3] Since 2005, the residential and commercial sector have grown at a much faster pace, with CAGR of 10.3% and 8.5% respectively.

It is estimated that the total constructed area in 2005 was around 2,100 million square meters, projected to reach around 28,000 million square meters in 2050.[4] The main reason for this exponential growth is increasing population and greater economic activity.

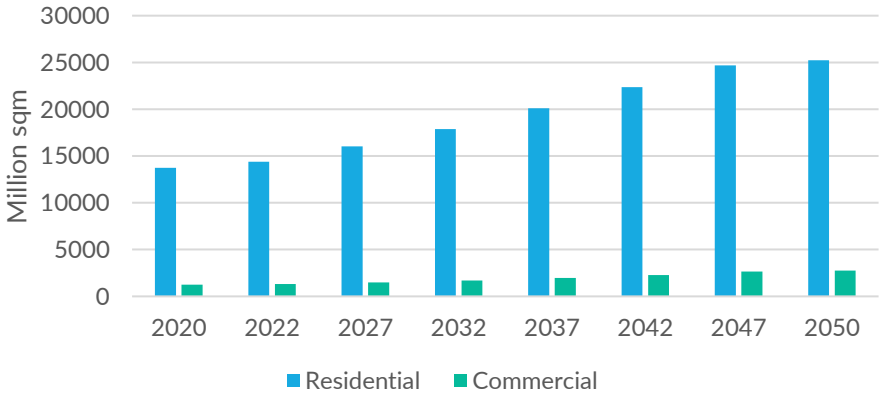


Figure 3: Residential and commercial floor area growth until 2050 [5]

[3] Ministry of Statistics and Programme Implementation (MoSPI), *Energy Statistics India 2024: Chapter 6 – Consumption of Energy Resources* (New Delhi: Government of India, 2024), https://www.mospi.gov.in/sites/default/files/publication_reports/Energy_Statistics_2024/Chapter6-Consumption_of_Energy_Resources.pdf.

[4] NITI Aayog, *India Energy Security Scenarios (IESS) 2047, Version 3.0: Determined Effort Scenario* (New Delhi: Government of India, 2023), https://iess2047.gov.in/.

[5] NITI Aayog, *India Energy Security Scenarios (IESS) 2047, Version 3.0: Determined Effort Scenario* (New Delhi: Government of India, 2023), https://iess2047.gov.in/.

India still needs to construct nearly two-thirds of its projected building stock by 2030, making the management of energy consumption and demand critical. The building sector plays a significant role in the country's total electricity consumption, with residential and commercial buildings together accounting for a substantial 34% share.

The existing institutional structure, such as the Bureau of Energy Efficiency, Ministry of Power, and IDAs, reinforce energy efficiency standards, yet rising energy demand varies significantly depending on various factors.

Regulatory

- Focuses on energy efficiency laws and regulations that enforce standards

Institutional capacity

- Focuses on adequate funding, skilled personnel, appropriate technological resources

Data monitoring

- Focuses on accurate and comprehensive data collection systems are essential for monitoring compliance

Interagency coordination

- Focuses on coordination between multiple stakeholders

Capacity building

- Focuses on campaigns and educational programs can encourage compliance and support for energy efficiency measures

The effectiveness of policies reveals a mixed impact on curbing the growing energy demand. While these policies have established a framework for energy conservation, uneven implementation across states has hindered their full potential. In states where policies are effectively enforced, there has been notable improvement in energy efficiency, leading to reduced energy consumption and lower operational costs for buildings.

1.1.2 Urbanization and Aspiration

By 2050, an additional 400 million people are projected to live in urban areas, double the population from 2014[6]. Urban India currently houses 34% of the country's population and is projected to contribute 75% of total GDP by 2030.[7] In this scenario, electricity demand is estimated to rise from 414 TWh/year to 4,697 TWh/year, with buildings projected to account for 55% of total electricity generated by 2047.

[6] United Nations Department of Economic and Social Affairs, World Urbanization Prospects, (New York, United Nations, July 2014, https://www.compassion.com/multimedia/world-urbanization-prospects.pdf

[7] McKinsey Global Institute, *India's Urban Awakening: Building Inclusive Cities, Sustaining Economic Growth*, Executive Summary (New York: McKinsey & Company, April 2010), https://www.mckinsey.com/~/media/McKinsey/Business%20Functions/Operations/Our%20Insights/Urban%20awakening%20in%20India/MGI_Indias_urban_awakening_executive_summary.pdf.

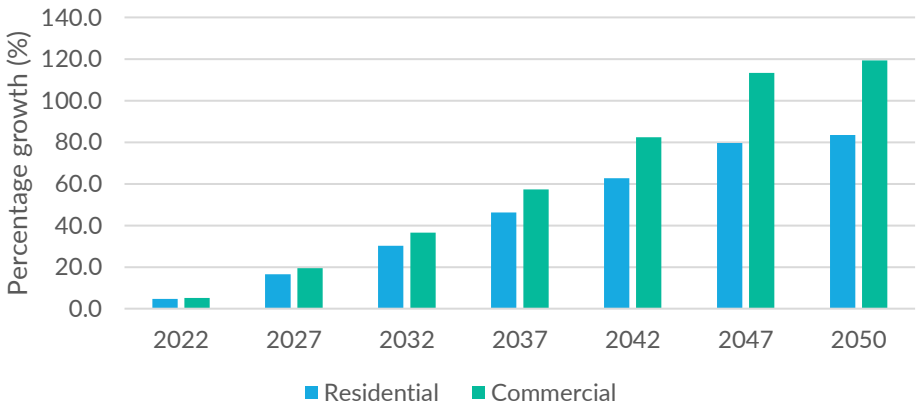


Figure 4: Residential and commercial sector percentage growth market [8]

Electricity consumption in the building sector is rapidly increasing, driven by factors such as the growing use of air conditioning, lighting, and various appliances in both residential and commercial buildings. Various policy initiatives, including the ECBC, ENS, and the India Cooling Action Plan, are designed to address energy efficiency challenges amid rising consumption trends. Collectively, these policies aim to create sustainable urban environments by integrating renewable energy, enforcing stringent standards, fostering public awareness, and promoting innovative technologies, thereby effectively managing the growing energy demand.

Residential sector

In the residential sector, major electricity contributors include fans, lighting, refrigerators, and air conditioning. Fans currently account for 34% of electricity consumption for their thermal comfort, but there is a transition toward increased air conditioning use.

India's air conditioning market is witnessing a remarkable growth due to climatic variations, thermal comfort demands, and rising household incomes. With increasing temperatures and urbanization, air conditioners (ACs) have become a necessity rather than a luxury. The demand for ACs is increasing significantly. From 30 million units in 2017, the stock of ACs is projected to rise rapidly from 30 million units in 2017 to about 240 million units by 2030 and 1,100 million units by 2050.[9]

Lighting remains one of the largest end uses of electricity across the country, accounting for 25-30 percent of total electricity consumption on average.

The increased ownership of appliances like fans, refrigerators, and televisions indicates a significantly enhanced quality of life, providing healthier and more comfortable living conditions for more Indians. In 2017-2018, the total fan market was around 55 million units, with ceiling fans accounting for 39 million units (72%) of the total. Refrigerator ownership is projected to grow from 0.18 per household in 2012 to 0.64 per household in 2030, while television ownership is expected to grow from 0.48 to 1.05 per household in the same period.[10]

[8] NITI Aayog, *India Energy Security Scenarios (IESS) 2047, Version 3.0: Determined Effort Scenario* (New Delhi: Government of India, 2023), https://iess2047.gov.in/.
[9] Shakti Sustainable Energy Foundation, "India's Cooling Demand Is Projected to Grow Eightfold by 2037 and Will Require 1,100 Million Units by 2050," accessed May 21, 2025, https://shaktifoundation.in/cooling-action-plan/#:~:text=India's%20cooling%20demand%20is%20projected,1%2C100%20million%20units%20by%202050.
[10] Sahil Ali, *The Future of Indian Electricity Demand: How Much, by Whom, and Under What Conditions?* (New Delhi: Brookings Institution India Center, October 2018), https://www.brookings.edu/wp-content/uploads/2018/10/The-future-of-Indian-electricity-demand.pdf.

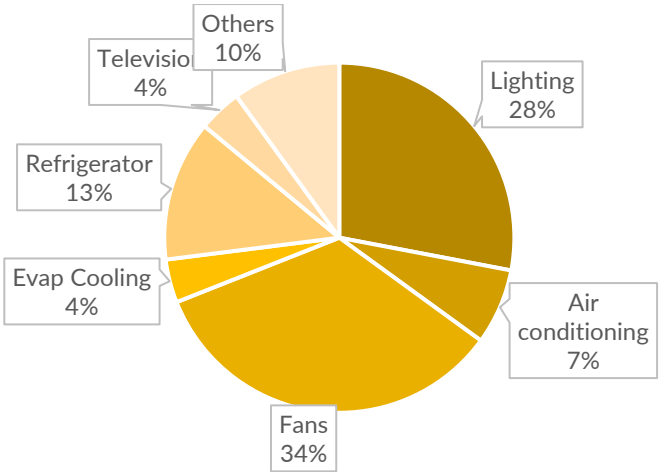


Figure 5: Residential building electricity consumption breakdown[11]

Commercial sector

Urbanization also fuels the growth of commercial real estate, including hospitals, hotels, restaurants, retail, office buildings, educational institutions, assembly places, transit buildings, and warehouses. As cities expand, the need for office spaces, retail outlets, and industrial facilities increases. The demand for flexible office spaces and co-working environments is on the rise, driven by the changing nature of work and the gig economy. Using 2017-2018 as the baseline, the commercial sector floor area is expected to grow around 1.5 to 2 times by 2020-2030, and by 2.5 - 3 times by 2037-38.[12]

The intensity of air conditioning demand and corresponding electricity consumption intensity in the commercial building sector is significantly higher as compared to the residential sector. Air coolers are an important cooling appliance for users, especially across medium size commercial buildings in hot and dry and composite climates.

Lighting in a commercial building account for 50 to 60 percent electricity consumption, depending on building typology and usage. The adoption of new lighting technologies can reduce energy use by 50 to 75 percent, offering significant monetary savings.

Fans are also widely utilized in small to mid-commercial segments. Due to their sheer volume, the total annual energy consumption of fans is currently only slightly lower than that of room air conditioners in India.

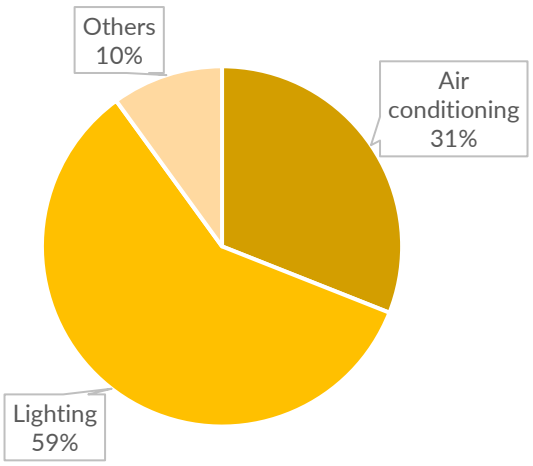


Figure 6: Commercial building electricity consumption breakdown[13]

[11] Manjeet Singh, Gurprasad Gurumurthy, and Shreya Shekhar, *Mapping the Refrigerant Trends in India: An Assessment of Room AC Sector* (New Delhi: The Energy and Resources Institute (TERI), March 2019), https://www.teriin.org/sites/default/files/2019-11/Mapping%20the%20Refrigerant%20Trends%20in%20India%20An%20Assessment%20of%20Room%20AC%20sector.pdf

[12] *India Cooling Action Plan*. New Delhi: Ministry of Environment, Forest and Climate Change, Government of India, March 2019. https://ozonecell.nic.in/wp-content/uploads/2019/03/INDIA-COOLING-ACTION-PLAN-e-circulation-version080319.pdf.

[13] Manjeet Singh, Gurprasad Gurumurthy, and Shreya Shekhar, *Mapping the Refrigerant Trends in India: An Assessment of Room AC Sector* (New Delhi: The Energy and Resources Institute (TERI), March 2019), https://www.teriin.org/sites/default/files/2019-11/Mapping%20the%20Refrigerant%20Trends%20in%20India%20An%20Assessment%20of%20Room%20AC%20sector.pdf

1.1.3 The Cooling Challenge

India is facing a critical challenge in providing cooling access to all its citizens without exacerbating global warming. Located in the hot tropical zone with over 3000 cooling degree days (CDD) per year, the country faces extreme heat conditions that affect public health and productivity, particularly as limited cooling options are available. In the building sector, heating, ventilating, and air conditioning (HVAC) systems are among the major contributors to electricity consumption across residential, commercial, and industrial applications. This leads to tremendous pressure on energy resources and ultimately impacts the climate. Currently, space-cooling requirements in India are predominantly met by fans and room Acs in residential buildings, and by chillers and variable refrigerant flow (VRF) in commercial buildings. The global energy use for space cooling is projected to jump from 2,020 terawatt-hours (TWh) in 2016 to 6,200 TWh in 2050, representing a 300 percent increase.[14] Cooling is not only enhancing the productivity, health, and well-being but has also become a necessity for survival. To cater to this growing cooling demand and necessity, several sectors and organizations have made significant contributions.

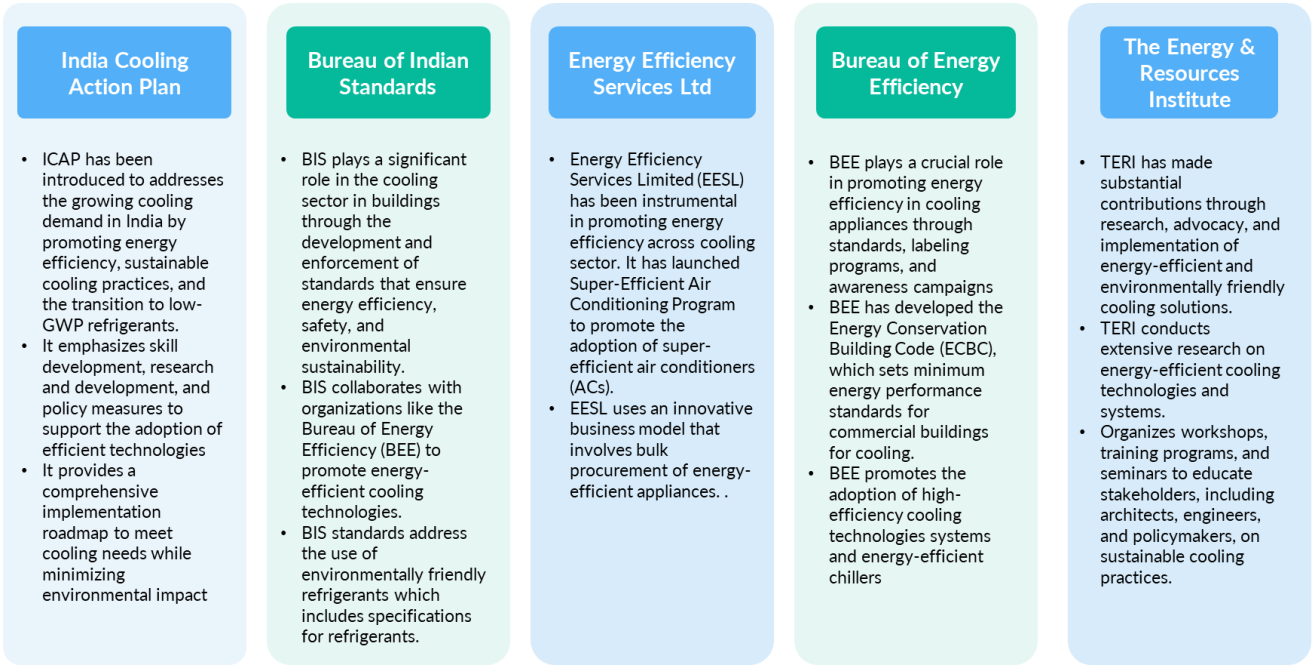


Figure 7: Cooling sector related contributions by various organizations

Organizations such as the Refrigeration and Air Conditioning Manufacturers Association (RAMA) and the Indian Society of Heating, Refrigerating, and Air Conditioning Engineers (ISHRAE) contribute to the development and dissemination of best practices in the cooling industry.

Residential Sector

Currently, only 9% of Indian households have air conditioning, yet this demand is projected to increase 20-fold by 2050. Under business-as-usual, this translates into a huge emissions and energy problem, as room air conditioners alone will account for one-quarter of India's emissions and 45% of nationwide peak electricity demand in 2050.[15]

[14] Ankit Kalanki et al., *Primer for Space Cooling* (Rocky Mountain Institute, 2020), https://rmi.org/insight/primer-for-space-cooling/.
[15] United Nations Environment Programme (UNEP), India – Cool Coalition, Cool Coalition, accessed May 20, 2025, https://coolcoalition.org/pilot-projects/india/

From the figure below, it is evident that India has the highest person cooling degree days but lowest AC ownership compared to other parts of the world.

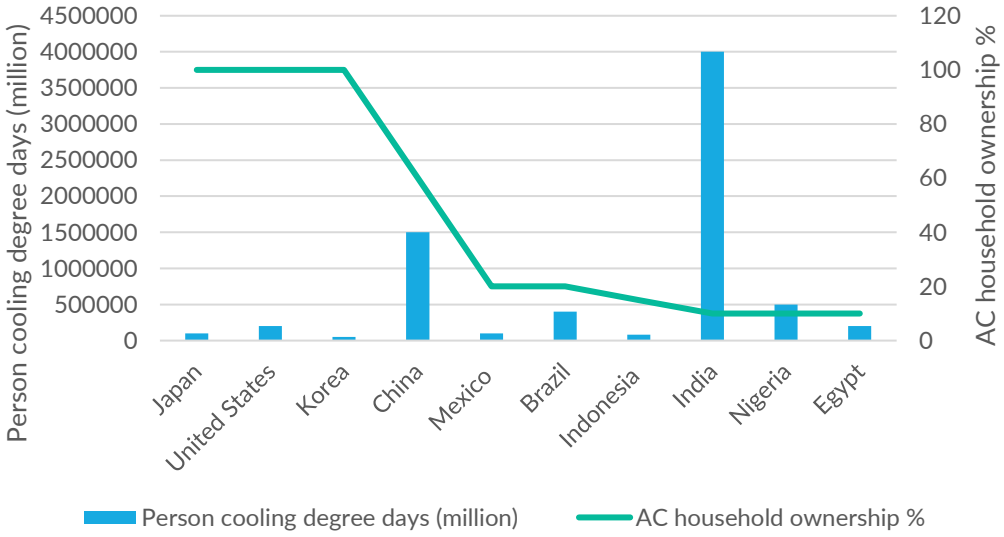


Figure 8: Cooling Demand Versus Current AC Ownership in Residential Sector

Note: The cooling demand, represented by "Person Cooling Degree Days," is calculated by multiplying a country's average annual cooling degree days by its population

Although India currently contributes only 5% of the global annual emissions from room ACs, in a business-as-usual scenario, the country is projected to account for over 25% of global annual emissions from this source by 2050. This is mainly due to the unprecedented rise in comfort cooling demand, particularly in the residential sector.[16]

With the growing demand for cooling and rising middle-class incomes in India, the number of Acs is expected to increase significantly as households seek better quality of life and thermal comfort. Typically, the cheapest Acs are purchased without consideration for operating costs or efficiency. These low-cost AC units are also the least efficient, adding to the already high energy demand during summers, especially in major cities where they contribute between 40% to 60% of total electricity consumption.

Commercial sector

In commercial buildings, air conditioning systems, excluding room air conditioner, can be classified into three major types: chiller systems, packaged direct expansion (DX) systems, and VRF systems.

Room Air Conditioner is a key appliance that is central to cooling in the country, but their role in commercial sector is very limited to small businesses. Chiller systems, particularly central chilled-water air conditioning systems, are the preferred choice for large commercial buildings. The future growth of the chiller industry is driven by growth in the retail, hospitality, and infrastructure sectors, and is projected to grow at a CAGR of 9-10% for centrifugal, 3-5% for scroll and 6-8% for screw chillers over the next ten years.

VRF systems are commonly used in medium-size commercial buildings that have varying exposure and cooling loads. HVAC industry experts suggest that the VRF market will grow at a CAGR of at least 15% in the next decade.[17] Packages DX systems, also known as unitary or light commercial systems, include

[16] Radhika Lalit and Ankit Kalanki, "How India is Solving Its Cooling Challenge," World Economic Forum, May 15, 2019, https://www.weforum.org/agenda/2019/05/india-heat-cooling-challenge-temperature-air-conditioning/
[17] *India Cooling Action Plan*. New Delhi: Ministry of Environment, Forest and Climate Change, Government of India, March 2019. https://ozonecell.nic.in/wp-content/uploads/2019/03/INDIA-COOLING-ACTION-PLAN-e-circulation-version080319.pdf.

ducted and packaged units typically used in small to medium-sized commercial buildings. These systems avoid complexity associated with chiller systems, and their market size is projected to grow at a CAGR of 5% by 2027-28.

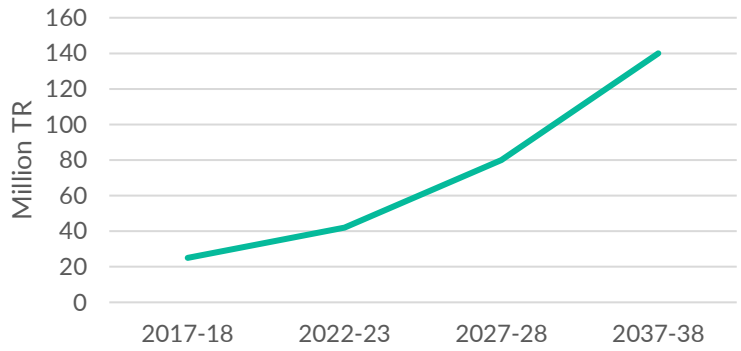


Figure 9: AC Demand in the Commercial Building Stock[18]

As the number of AC units increases, their impact on electricity consumption and the release of potential chlorofluorocarbons (CFCs) from refrigerants also rises. These refrigerants may leak during operation or be released into the atmosphere during maintenance, servicing, or replacement, contributing further global warming.

1.1.4 Renewable Energy Integration

India has been actively promoting solar rooftop programs to increase the adoption of renewable energy and reduce dependence on fossil fuels. The **Grid-Connected Rooftop Solar Programme**, initiated by the Government of India, aims to encourage the installation of rooftop solar photovoltaic (PV) systems that are connected to the electrical grid. The main objective is to significantly increase rooftop solar capacity, targeting an installation of 40 GW by 2022. As of November 2023, India's rooftop solar capacity has reached 10.4 GW, and the government has extended the deadline to achieve the 40 GW target to 2026. This program is part of India's broader efforts to increase the share of renewable energy in its energy mix and achieve its solar energy targets. Key programs and initiatives supporting this target include the following:

i. **Jawaharlal Nehru National Solar Mission (JNNSM)**:
   - Launched in 2010, the JNNSM aims to establish India as a global leader in solar energy.
   - The mission targets 100 GW of solar power by 2022, including 40 GW from rooftop solar installations.

ii. **Grid-Connected Rooftop Solar Program**:
   - Implemented by MNRE, this program encourages the installation of grid-connected rooftop solar systems.
   - It offers financial incentives, including subsidies of up to 40% for residential consumers and concessional loans.

iii. **Net Metering and Gross Metering**:
   - Net metering policies allow consumers to feed excess solar power back into the grid and receive credits, reducing their electricity bills.
   - Some states also offer gross metering, where consumers are paid a fixed tariff for all the solar power they generate.

iv. **Solar Energy Corporation of India (SECI)**:

[18] *India Cooling Action Plan*. New Delhi: Ministry of Environment, Forest and Climate Change, Government of India, March 2019. https://ozonecell.nic.in/wp-content/uploads/2019/03/INDIA-COOLING-ACTION-PLAN-e-circulation-version080319.pdf.

- SECI is responsible for implementing various schemes to promote solar power, including rooftop solar projects.
- It conducts tenders and auctions to allocate projects and ensure competitive pricing.

v. **Smart Cities Mission**:
- As part of the Smart Cities initiative, various cities are incorporating rooftop solar installations to enhance their sustainability.
- The mission promotes the integration of solar power in urban planning and infrastructure development.

vi. **Subsidies and Incentives**:
- The Indian government provides capital subsidies for residential rooftop solar installations.
- There are also tax benefits, such as accelerated depreciation for commercial and industrial installations.
- Mahabank Rooftop Solar Panel Loan Scheme supports installations under the Central Government Rooftop Solar Subsidy Programme and state-level subsidy programs for rooftop solar.
- Surya Shakti Solar Finance is a solar finance scheme offered by the State Bank of India (SBI).
- PM Surya Ghar Muft Bijli Yojana provides a subsidy of 60% of the system cost for units up to 2kW capacity and 40% of additional costs for systems between 2 to 3kW capacity.

1.2 Untapped Potential

With the growing energy demand and heavy reliance on fossil fuels, the untapped potential of energy efficiency in India is substantial. This potential is particularly significant in the areas of energy efficiency, innovative technology, market resilience, and economic benefits. Leveraging advanced technologies such as smart grids, IoT-based energy management systems, and high-efficiency appliances can drive significant improvements in energy use. Moreover, transforming markets through supportive policies and incentives can unlock greater adoption and scaling of these technologies. Economically, investing in energy efficiency reduces operational costs, mitigates energy-related risks, fosters job creation, and stimulates economic growth. Harnessing this potential is therefore crucial for meeting NDC goals while paving the way for a sustainable energy future.

1.2.1 Efficiency Frontier

India's building sector holds immense potential for energy efficiency improvements through various innovative strategies. The opportunities outlined below can collectively help achieve significant energy reductions, cost savings, and lower carbon emissions, driving the nation towards a more sustainable future.

i. **Deep energy retrofits for existing buildings**: A significant portion of India's building stock, constructed before the implementation of modern energy efficiency codes, presents a substantial opportunity for energy savings through deep energy retrofits. These retrofits involve comprehensive upgrades to building envelopes, systems, and appliances, resulting in significant energy reductions and cost savings.

Table 1: Untapped potential - Deep energy retrofits for existing buildings

Integration with existing policy framework	Barriers
• These comprehensive upgrades align with several existing policy frameworks aimed at promoting energy efficiency and sustainability in the built environment. • Retrofitting older buildings to meet or exceed ECBC standards enhances the energy performance of older building stock. • The National Mission for Enhanced Energy Efficiency (NMEEE) targets energy efficiency across sectors.	• High upfront costs for retrofitting can deter building owners from investing in energy-efficient upgrades. • Lack of awareness among building owners and occupants about the benefits of deep energy retrofits. • Technical expertise required for implementation. • Inconsistent enforcement of energy efficiency codes for existing buildings can hinder progress. • Older buildings may present unique technical challenges for retrofitting, including structural limitations and outdated systems.

ii. **Mainstreaming net-zero energy buildings (NZEBs)**: While some buildings in India have achieved net-zero energy status, this concept is not yet mainstream. Promoting and incentivizing the construction of NZEBs, where energy consumption is minimized and offset by renewable energy generation, could significantly reduce energy consumption in the building sector.

Table 2: Untapped potential - Mainstreaming net-zero energy buildings

Integration with existing policy framework	Barriers
• There is currently no standalone, comprehensive policy exclusively dedicated to NZEBs. • Initiatives and frameworks such as the Shunya Label for Net Zero and Net Positive Buildings directly support and promote the concept by emphasizing net zero building design in the Indian market	• The absence of a dedicated NZEB policy in India is the result of a combination of financial, technical, regulatory, and market barriers. • Addressing these challenges will require coordinated efforts from government agencies, industry, and the community. • Additional barriers include low awareness, limited technical capacity, and lack of market readiness.

iii. **District cooling**: District cooling is an emerging technology with the potential to cool multiple buildings efficiently from a central plant. Implementing district cooling systems in urban areas could lead to substantial energy savings compared to traditional air conditioning systems in individual buildings.

Table 3: Untapped potential - District cooling

Integration with existing policy framework	Barriers
• India currently lacks a comprehensive policy specifically for district cooling systems.	• Despite the high demand for cooling in India, the absence of a dedicated district

• This gap means there are no uniform regulations or incentives to promote the development and implementation of such systems across the country.	cooling policy can be attributed to several barriers. • High upfront infrastructure investment, including central plants, distribution networks, and advanced technology. • Technical complexity and the resource-intensive nature of developing district cooling systems.

iv. **Passive cooling in new buildings**: Passive cooling strategies, such as building design, orientation, shading, and natural ventilation, can significantly reduce the need for active cooling (e.g., air conditioning). Mandating or incentivizing passive cooling in new constructions could substantially decrease energy demand for cooling, leading to lower energy bills and reduced carbon emissions.

Table 4: Untapped potential - Passive cooling in new buildings

Integration with existing policy framework	Barriers
• Guidelines and recommendations for passive cooling, aimed at reducing energy consumption and enhancing thermal comfort without relying heavily on mechanical cooling systems, is available. These include the Passive–design Response in Increasing Thermal Comfort with Viable Solutions (PRiTHVi), National Building Code of India (NBC), Energy Conservation Building Code (ECBC), Eco-Niwas Samhita (ENS), and Climate-Responsive Design Guidelines.	• Low awareness of benefits and techniques among architects, builders, and developers. • Weak enforcement of existing guidelines and standards. • Lack of regulations mandating passive cooling strategies. • Developers often prioritize short-term gains over long-term sustainability. • Insufficient financial incentives or support programs targeting passive cooling implementation.

1.2.2 Technological Landscape

Advancements in building technologies in India offer transformative opportunities to enhance energy efficiency, optimization, and sustainability in the construction sector. These innovations play a critical role in reducing energy consumption, lowering operating costs, and enhancing occupant comfort and well-being.

Technological vendors in India are offering a range of solutions, including building automation systems supporting smart meters and controls (e.g., Honeywell International, Johnson Controls), energy storage solutions (e.g., Samsung SDI, AES Energy Storage, Panasonic), and phase change materials (PCMs) vendors such as PLUSS Advanced Technologies Pvt. Ltd. are pioneering PCM applications across sectors including HVAC&R, pharmaceutical transport, solar, medical devices, automobiles, buildings, cold chains, home appliances, retail and agribusinesses. These can be extended to the building sector due to their potential to reduce cooling and heating loads.

Currently, there are direct or indirect incentives to support the widespread adoption of such technologies in the Indian market. Government incentives through capital subsidies, viability gap funding, tax incentives, feed-in tariffs, performance-based incentives, pilot projects, regulatory support, participation in grid services markets, and state-level programs, could help mainstream these technologies.

The key technologies include:

i. **Smart Meters and Controls**: Provide real-time data collection and automated control of lighting, heating, cooling, and ventilation systems. Policies supporting smart metering in India include the National Smart Grid Mission (NSGM), Ujwal DISCOM Assurance Yojana (UDAY), ECBC, Smart Cities Mission, National Tariff Policy, and BEE initiatives. Additionally, state-level programs, Demand Side Management (DSM) initiatives, the Indian Smart Grid Forum (ISGF), and the Saubhagya scheme also support the deployment of smart metering infrastructure.

ii. **Building-Integrated Photovoltaics (BIPV)**: Integrates solar photovoltaic (PV) panels into building facades and roofs, offering a promising avenue for generating renewable energy on-site, reducing reliance on the grid, and lowering carbon emissions. BIPV is a relatively new concept in the Indian market and is gaining traction from various building owners and developers. However, its widespread implementation faces several challenges, including high initial costs, low technology efficiency, limited awareness, regulatory and policy gaps, technical and market-readiness issues, aesthetic concerns, financing challenges, performance uncertainties, and maintenance complexities.

iii. **Energy Storage Solutions**: Such as batteries and thermal storage, can enhance renewable energy integration in buildings, ensure reliable power supply, and enable load shifting. India's policy framework is evolving to support the deployment of energy storage solutions at national level, driven by the need to enhance grid stability, integrate renewable energy, and improve energy access. Key initiatives include the proposed National Energy Storage Mission (NESM), National Electricity Policy, Central Electricity Regulatory Commission regulations, renewable energy policies, NSGM, the draft National Energy Policy (NEP), MoP guidelines, and state-level initiatives.

iv. **Digital Platforms for Energy Management**: Facilitate data-driven decisions, optimize energy performance, and identify opportunities for further efficiency improvements. India has a growing policy framework that supports the development and deployment of digital platforms through initiatives such as the NSGM, ECBC, Smart Cities Mission, UDAY, the Perform, Achieve, and Trade (PAT) scheme, National Electricity Policy, BEE initiatives, Renewable Energy Management Centers (REMCs), NESM, and various state initiatives.

v. **Phase Change Materials (PCMs)**: Absorb and release heat as they change phase (e.g., solid to liquid), offering a way to store thermal energy and reduce the need for active cooling. Integrating PCMs into building materials can help regulate indoor temperatures and reduce energy consumption. Although India currently does not have a comprehensive national policy framework specifically addressing the use of PCMs, they are often included within broader energy efficiency and building material standards.

vi. **Advanced Insulation Materials**: Research into new insulation materials with higher thermal performance and lower environmental impact can significantly improve the energy efficiency of building envelopes, reducing the need for heating and cooling. While India lacks a dedicated policy for advanced insulation, various publications, including compendiums of available materials, provide guidance. Commonly used insulation materials include fiberglass, cellulose, natural fibers, cellulose, polystyrene, and polyurethane.

vii. **Cool Roofs**: Use of reflective coatings or materials can reflect sunlight and reduce heat absorption, lowering the cooling load of buildings and improving energy efficiency. India has been increasingly recognizing the benefits of cool roofs within its broader energy efficiency and urban heat management strategies. The ECBC and the National Building Code (NBC) recommend the use of reflective and high-emissivity roofing materials to reduce cooling loads. Various state-level initiatives, such as Telangana's Cool Roof Policy, further promote the adoption of cool roofs to mitigate urban heat islands and improve energy efficiency.

1.2.3 Market Transformation

Transforming the energy efficiency market requires addressing financial, technical, and educational barriers through the following strategies:

i. **Energy Service Companies (ESCOs)**: Play a crucial role by providing energy audits, implementating measures, and offering financing solutions to building owners. Promoting the growth and development of the ESCO market can accelerate the adoption of energy efficiency measures in buildings, as ESCOs help overcome key financial and technical barriers.

   The BEE grades ESCOs based on evaluation scores ranging from Grade A (highest) to Grade E (lowest). Several institutions support the scaling of energy services companies. **Energy Efficiency Services Limited (EESL)**, a "super ESCO," leads large-scale energy efficiency initiatives and public-private partnerships, often working with private ESCOs to expand programs and improve energy outcomes in India. Additionally, the **Small Industries Development Bank of India (SIDBI)** provides tailored financial products and services to help ESCOs enhance their market presence and operations.

   Apart from traditional ESCOs, **Renewable Energy Service Companies (RESCOs)** provide electricity to consumers from renewable energy sources such as solar, wind, or micro-hydro power.

   EESL's notable initiatives include the:

   - **Unnat Jyoti by Affordable LEDs for All (UJALA)** program aimed at replacing conventional incandescent bulbs with LED bulbs. As of 2020, over 360 million LED bulbs had been distributed, leading to annual energy savings of approximately 47 billion kWh and reduction in GHGs by approximately 38 million tonnes of CO_2 annually.
   - **Buildings Energy Efficiency Programme (BEEP)**, which retrofits commercial buildings in India into energy efficient complexes. So far, EESL has retrofitted over 12,710 various government buildings. Energy audits conducted in these buildings show energy saving potential of 30-50%, primarily through lighting and air-conditioning systems.
   - **Super-Efficient Air Conditioning Programme (ESEAP).** Under this first-of-its-kind initiative, EESL sold 50,000 high-efficiency air conditioners on a first come, first served basis in its first phase. These units are expected to save 145.5 million kWh annually and mitigate around 1,20,000 tonnes of CO_2 emissions.

ii. **Green Building Materials**: Promoting the use of sustainable and low-carbon building materials, such as recycled materials, locally sourced materials, and materials with low embodied energy, can significantly reduce the environmental impact of the construction industry and contribute to a more circular economy.

   The **Indian Green Building Council (IGBC)** promotes the adoption of green building materials through its certification programs and awareness initiatives. The **Energy and Resources Institute (TERI)** supports the use of sustainable materials via research, policy advocacy, and capacity-building programs. Additionally, the **Green Rating for Integrated Habitat Assessment (GRIHA)**, spearheaded by TERI and the MNRE, offers rating systems and incentives to encourage green building practices.

   International bodies such as the **U.S. Green Building Council (USGBC)'s LEED, EDGE certification** and others also play a role in advancing the use of green building materials in India.

Environmental Product Declarations (EPDs) are documents that quantify a product's environmental impact throughout its life cycle, based on Life-Cycle Assessment (LCA) methodology, from raw material extraction to end-of-life disposal. As of October 2023, the number of EPDs in India remains limited. Materials with available EPDs include cement and concrete, steel and metal, glass, ceramic and tiles, insulation materials, wood products, plastic and polymers, building finishes, and chemical additives.

iii. **Demand Aggregation for Emerging Technologies**: Aggregating demand for emerging energy-efficient technologies, such as smart meters, building automation systems, and advanced cooling solutions, can incentivize manufacturers to invest in research and development, leading to cost reductions and wider adoption. The Department of Science and Technology (DST), under the Ministry of Science and Technology, supports demand aggregation by funding pilot projects and innovation clusters for cutting-edge technologies. The government, through bulk procurement of energy-efficient appliances and materials, can create economies of scale, driving down costs and making these products more accessible to consumers and builders. EESL drives this transformation through various initiatives such as UJALA scheme for LED lighting and the ESEAP.

iv. **Public Procurement of Energy-Efficient Products**: Governments can leverage their purchasing power to stimulate the market for energy-efficient products and technologies. By setting procurement standards and preferences for energy-efficient building materials, appliances, and equipment, governments can create a demand for these products and encourage manufacturers to develop and offer more energy-efficient options. This standard integrated into the procurement policy through tender documents and mainstreaming the usage of energy efficient products in building sector. BEE sets standards and labelling programs that guide public procurement policies towards energy-efficient products.

v. **Financing Mechanisms**: Innovative financing mechanisms, such as green loans, Venture Capital Fund for Energy Efficiency (VCFEE), on-bill financing or Pay-As-You-Save (PAYS) models, can overcome the financial barriers to energy efficiency for new construction or retrofitting in existing buildings. These mechanisms allow building owners to pay for upgrades through energy savings, making retrofits more affordable and attractive. SIDBI offers tailored financial products for energy efficiency retrofits, including low-interest loans and credit guarantees, to support small and medium enterprises (SMEs).

vi. **Skills Development and Capacity Building**: Investing in training and certification programs for energy auditors, building professionals, and service technicians can create a skilled workforce capable of implementing and maintaining energy-efficient technologies, ensuring their effective operation and maximizing energy savings. The National Skill Development Corporation (NSDC) plays a crucial role in scaling up skill development and capacity building through various industry-aligned training programs. The Skill India Mission, spearheaded by the Ministry of Skill Development and Entrepreneurship, also offers extensive vocational training and certification to enhance workforce capacity.

1.2.4 Economic and Social Benefits

Energy efficiency in buildings offers wide-ranging economic and social benefits:

i. **Reduced energy costs**: Lowers operational costs for households and businesses. Savings from these can be reinvested in other productive areas of the economy.

ii. **Increased competitiveness**: Lowers production costs for commercial buildings, improving domestic and international market competitiveness.

iii. **Improved grid resilience**: Reduces peak demand pressure, easing the strain on the electricity grid and improving its reliability and resilience.

iv. **Lower greenhouse gas emissions**: Energy efficiency is a key strategy for reducing GHGs in the building sector, contributing to India's climate goals and mitigating the impacts of climate change. As per BEE's 2023 impact assessment report, savings from ECBC, ENS, BEE Star Rating, GRIHA, and UJALA programs amount to 125.497 MtCO2.

v. **Job creation**: Retrofits and technology deployment create jobs across skill levels, from engineers and architects to construction workers and technicians.

vi. **Improved public health**: Enhances indoor air quality and thermal comfort, leading to improved occupant health and well-being and improving productivity.

vii. **Energy poverty alleviation**: Lowers energy bills for low-income households, improving access to energy services and reducing the burden of energy poverty.

viii. **Enhanced energy security**: Reduces reliance on fossil fuel imports, enhances energy security, and contributes to a more stable and resilient energy system.

Note: Demonstration project details for economic and social benefits in building sector presented - Annexure 2.

2 Building Blocks: Policies, Programs, and Institutions

2.1 The Blueprint

Energy efficiency in India has emerged as a critical focus area in recent decades, driven by growing recognition of its pivotal role in sustainable development and economic growth. The country's journey towards improving energy efficiency can be traced back to the early 2000s, when policy frameworks began to emphasize conservation and optimization of energy resources. This marked a pivotal shift from a focus solely on energy generation toward a more holistic approach that prioritizes minimizing waste and environmental impact.

Figure 10 shows a consolidated timeline for major policy initiatives in India.

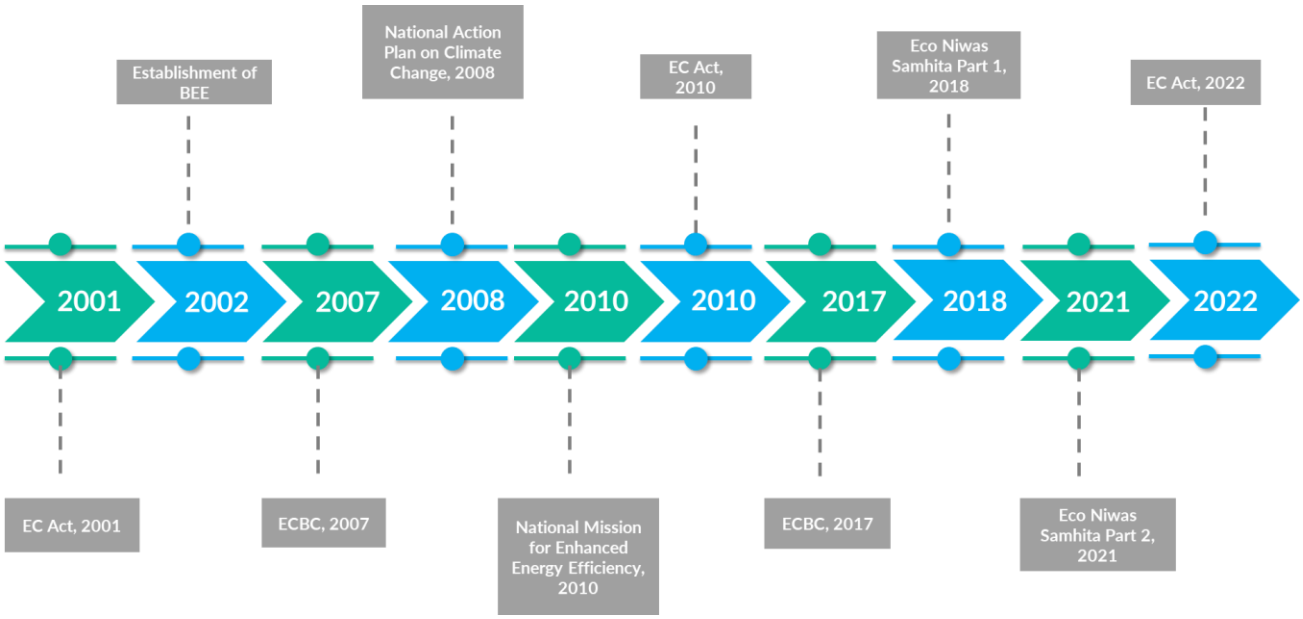


Figure 10: Consolidated timeline for policy initiatives

Early Efforts (2000-2007)

To promote energy conservation, the Indian government enacted the **Energy Conservation Act (EC Act)** in 2001, which came into effect on March 1, 2002. This legislation established the Bureau of Energy Efficiency (BEE) as a statutory body under the Ministry of Power, tasked with spearheading energy efficiency improvements through regulatory and promotional measures. The EC Act empowered both central and state governments to establish a legal and institutional framework for energy conservation, monitor progress towards energy-saving targets, and improve the overall energy intensity of the economy.

Recognizing the significant energy consumption and potential savings in the building sector, the ECO-II project was initiated to develop the ECBC. The ECBC aimed to address the lack of energy performance standards for commercial buildings and provide a benchmark for energy-efficient design and construction practices.

In 2007, the ECBC was officially released, setting minimum energy standards for commercial buildings. This marked a crucial step in promoting energy efficiency in the building sector and paved the way for further initiatives to reduce energy consumption and GHGs. As of 2024, out of 36 states and union territories (28 states and 8 UTs), 25 have notified the ECBC, and 11 have not yet done so.

To enhance understanding and implementation of the ECBC, the ECO-III project collaborated with BEE to develop an ECBC User Guide. This guide was designed to assist building designers, architects, and construction professionals in effectively applying the code. Additionally, ECBC Tip Sheets on various building systems like envelopes, HVAC, lighting, and energy simulation were developed and widely disseminated to raise awareness about the code's requirements and impact on different building aspects.

Consolidation and Expansion (2008-2014)

The period from 2008 to 2014 marked a significant consolidation and expansion of energy efficiency efforts in India's building sector. A key focus was on strengthening the implementation of the ECBC, with comprehensive training and capacity-building programs rolled out nationwide. To facilitate this, ECBC cells were established in relevant institutions, and 89 master trainers were empanelled to lead capacity-building initiatives. Additionally, a roadmap for the fast-track implementation of the code was developed, underscoring the commitment to widespread adoption.

During this period, under the leadership of BEE, the **Star Rating Program for Commercial Buildings** was launched, focusing on office buildings, BPOs, hospitals, and shopping malls. As of 2024, a total of 385 buildings have been awarded star ratings in the country. This period also witnessed a notable shift toward addressing energy efficiency in the residential sector, with the development of the **Resbuild tool**, which aimed at refinancing approximately 2,000 homes. The Resbuild Tool is an initiative designed to support the residential building sector in India by enhancing energy efficiency and promoting sustainable building practices. It was developed under various energy and building efficiency programs, with the support of government agencies, research institutions, and industry stakeholders.

Additionally, **National Cooling Action Plans (NCAPs)** were launched as an important tool to help countries integrate comprehensive actions to reduce energy-related emissions. These plans aimed to enhance access to cooling while also addressing other Sustainable Development Goals (SDGs), signalling a broader approach to energy conservation that encompassed both commercial and residential buildings within the national energy efficiency agenda.

Integration and Mainstreaming (2015-2019):

The period from 2015-2019 marked significant progress in integrating energy efficiency into mainstream policy and practice in India. Notably, the ECBC was updated in 2017, incorporating the latest advancements in energy-efficient technologies and practices to further enhance its effectiveness. In parallel, efforts were also made to promote sustainable materials in the construction sector through the development of the **India Construction Materials Database**, which provided information on the embodied energy and global warming potential of various materials. A sustainable public procurement framework, incorporating life cycle assessments of building materials, was also established to incentivize the use of environmentally friendly options.

In 2018, the first part of the Eco-Niwas Samhita (ENS) was launched, filling a crucial gap by establishing a comprehensive framework for energy efficiency in the residential sector, a major energy consumer in India. As of 2024, 17 out of 36 states have initiated steps to notify the ENS code. Complementing this, the **Star Labelling Program** for residential buildings was introduced, providing consumers with a clear indicator of energy performance and encouraging them to choose energy-efficient homes.

These initiatives collectively demonstrated a holistic approach to energy conservation, targeting both commercial and residential sectors while promoting sustainable practices across the construction industry.

Raising Ambitions (2020-2024):

The most recent phase, from 2020 to 2024, is marked by a significant shift in focus from mere compliance with minimum energy performance standards towards ambitious goals such as net-zero energy buildings and the integration of comprehensive sustainability metrics into building codes.

In 2021, BEE launched the **Shunya Labelling Program** for Net Zero and Net Positive Buildings. Two types of labels were proposed: the Shunya Label for NZEBs and the Shunya Plus Label. Buildings with 10 ≤ EPI ≤ 0 kWh/m2/year are awarded the Shunya Label, while those with EPI < 0 kWh/m2/year are awarded the Shunya Plus Label. As of 2024, a total of 76 buildings have been awarded these labels, with 41 Shunya Label and 36 the Shunya Plus Label. This shift is driven by a growing recognition of the urgency for climate action and the building sector's crucial role in mitigating GHGs.

This period also saw the ongoing evolution of energy codes, which now expand beyond energy efficiency to encompass broader sustainability considerations in building design and operations. Simultaneously, the development of passive and resilient thermal comfort standards for the affordable housing sector is prioritizing occupant well-being and equitable access to comfortable living environments. A directory of energy-efficient building materials such as the **Compendium of Emerging Construction Technologies**, developed under BMPTC, and sustainable material certified by GreenPro are now available to empower stakeholders with information to make informed decisions.

Efforts to translate policy into practice are evident in the expansion of integrated implementation cells operating across all states to support both the ENS and ECBC. A significant stride in advancing sustainable practices within the commercial and residential building sector is implemented through Energy Conservation and Sustainable Building Code (ECSBC). This code focuses on sustainability measures such as sustainable site and planning, indoor environmental quality, waste and water management etc. with respect to energy efficiency to improve the overall building and site performance. This concerted effort underscores a broader commitment to sustainable development and recognizes the building sector's critical role in achieving national climate goals.

Note: Detailed assessment of contributions by International Development Agencies (IDAs) to building sector sustainability and energy efficiency at central and state levels is presented in Annexure 1.

Status of ECBC & ENS Code Implementation

At the state level, most states have incorporated ECBC and ENS as mandatory requirements in building byelaws and regulations. Compliance is ensured at the local level by mandating an ECBC and ENS compliance certificate as part of the documentation submitted to Urban Local Bodies (ULBs) or Development Authorities for building approvals.

Significant progress has been made in implementing energy conservation codes in the building sector. As of this writing, 25 states and UTs (including Andaman & Nicobar, Andhra Pradesh, Arunachal Pradesh, Assam, Chandigarh, Chhattisgarh, Goa, Haryana, Himachal Pradesh, Jammu & Kashmir, Jharkhand, Karnataka, Kerala, Ladakh, Madhya Pradesh, Odisha, Puducherry, Punjab, Rajasthan, Sikkim, Tamil Nadu, Telangana, Tripura, Uttar Pradesh, and West Bengal) have officially issued gazette notifications for the ECBC 2017, demonstrating their commitment to enhancing energy efficiency in buildings.

Furthermore, 17 states have integrated the ECBC into their municipal building byelaws to ensure that new constructions adhere to these energy-saving guidelines. These states include Andaman & Nicobar,

Andhra Pradesh, Assam, Chandigarh, Haryana, Jammu & Kashmir, Jharkhand, Karnataka, Kerala, Ladakh, Odisha, Punjab, Rajasthan, Sikkim, Telangana, Uttar Pradesh, and Uttarakhand.

In addition to the ECBC, efforts are ongoing to adopt the ENS for residential buildings 2021. To date, 5 additional states have taken proactive steps toward the notification of ENS 2021, bringing the total number of states working on its implementation to 17. These include Andhra Pradesh, Arunachal Pradesh, Assam, Haryana, Jammu & Kashmir, Jharkhand, Karnataka, Kerala, Ladakh, Madhya Pradesh, Maharashtra, Nagaland, Pucuherry, Tamil Nadu, Telangana, Tripura, and Uttar Pradesh. This reflects a growing nationwide emphasis on sustainable building practices and energy conservation.

According to the State Energy Efficiency Index 2023, initiated by BEE, the top four performing states in India are Karnataka, Andhra Pradesh, Assam, and Chandigrah. These states have implemented significant measures in the buildings sector. The states have adopted the ECBC, and promoted energy-efficient appliances in commercial buildings, along with significant adoption of energy-efficient practices in new constructions and green building certification.

2.2 Government Policy Landscape

India's building energy efficiency sector has made significant progress, supported by a robust legal and policy framework. The Energy Conservation Act of 2001, along with its subsequent amendments, has laid the foundation for promoting energy efficiency in buildings through measures like the ECE, ENS, appliance labelling programs, star labelling program for buildings, and market-based mechanisms like the Perform, Achieve, and Trade (PAT) scheme.

Several national missions and programs contribute to the sector's development. Under the Ministry of Power, the National Mission on Enhanced Energy Efficiency (NMEEE) was initiated in 2011 to strengthen the market for energy efficiency by creating a conducive regulatory and policy environment. The mission aims to foster innovative and sustainable business models for the energy efficiency sector. The National Action Plan on Climate Change (NAPCC) further emphasizes the role of buildings in reducing emissions, particularly through the National Mission on Sustainable Habitat.

The schemes under NMEEE include the PAT, Market Transformation for Energy Efficiency (MTEE), Energy Efficiency Financing Platform (EEFP), and Framework for Energy Efficient Economic Development (FEEED). Despite the significant success of these initiatives, several challenges remain. Accurately forecasting program outcomes remains a practical challenge, leading to uncertainties in planning and implementation. Effective implementation requires continuous monitoring and adaptive decision-making processes, and robust feedback mechanisms. Additionally, longer payback periods for energy efficiency investments require the provision of incentives to encourage participation from individuals and businesses.

Under the Ministry of Environment, Forest and Climate Change, the **India Cooling Action Plan (ICAP)** was initiated in 2019 to reduce cooling demand in buildings through passive design strategies, energy-efficient technologies, and the promotion of district cooling systems. The **HCFC Phase-Out Management Plan** also targets the building sector's use of HCFCs in refrigeration and air-conditioning, facilitating a transition to environmentally friendly alternatives. Key government departments actively involved in various aspects of the ICAP have been the BEE, BIS, and ESSCI.

Major progress has been made on short-term recommendations for space cooling, particularly through the introduction of energy star labelling and energy conservation for buildings. However, a critical gap identified in the action plan is the absence of a clear implementation plan or enforcement mechanism. Critiques have also pointed out the lack of financial planning, concrete timelines and targets, as well as comprehensive monitoring, verification, and enforcement mechanisms within ICAP. Moreover,

several of the ICAP's recommendations have been noted to be ambiguous and largely qualitative in nature[19], making them difficult to track and measure effectively. Figure 11 shows various policy initiatives at the national level aimed at reducing energy consumption.

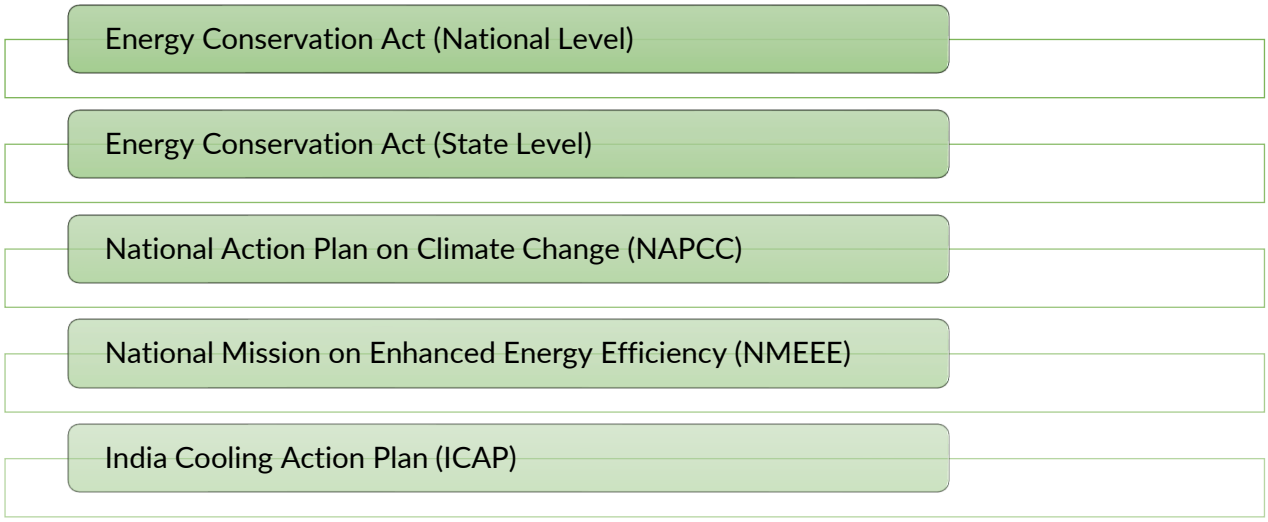


Figure 11: Policy initiatives at national Level

State governments and ULBs play a crucial role in implementing and enforcing building energy efficiency policies. Each state government is required to designate a State Designated Agency (SDA) responsible for implementing energy conservation programs within the state. SDAs are tasked with promoting energy efficiency, conducting energy audits, enforcing standards and labelling, and implementing demand-side management measures. They also coordinate with the BEE at the national level to achieve energy conservation targets. However, the effectiveness of energy conservation at the sub-national level varies across states due to differences in resources and institutional capacities.

India's renewable energy programs, while primarily focused on power generation, also play an important role in the building sector. The Rooftop Solar Program, particularly the PM Surya Ghar Muft Bijli Yojana, incentivizes the installation of solar panels on buildings, contributing to reduced grid dependence and promoting cleaner energy sources.

Overall, the programmatic landscape of India's building energy efficiency sector is both comprehensive and evolving. While challenges remain, the strong policy framework, coupled with a range of national and sub-national initiatives, provides a solid foundation for transitioning toward a more sustainable and energy-efficient building environment in India.

2.3 India's Energy Efficiency Timeline

Over the past two decades, India has embarked on a transformative journey toward enhancing energy efficiency across various building typologies. This progress has been underpinned by a series of robust policy initiatives, meticulously crafted strategic plans, and effective implementation frameworks.

[19] Shakti Sustainable Energy Foundation, Implementing the India Cooling Action Plan: Status Check and Way Forward (New Delhi: Shakti Sustainable Energy Foundation, June 2021), https://shaktifoundation.in/wp-content/uploads/2022/01/Policy-brief-ICAP.pdf

i. The timeline below highlights **significant policy initiatives and their contributions** to India's energy efficiency advancements over the past two decades.

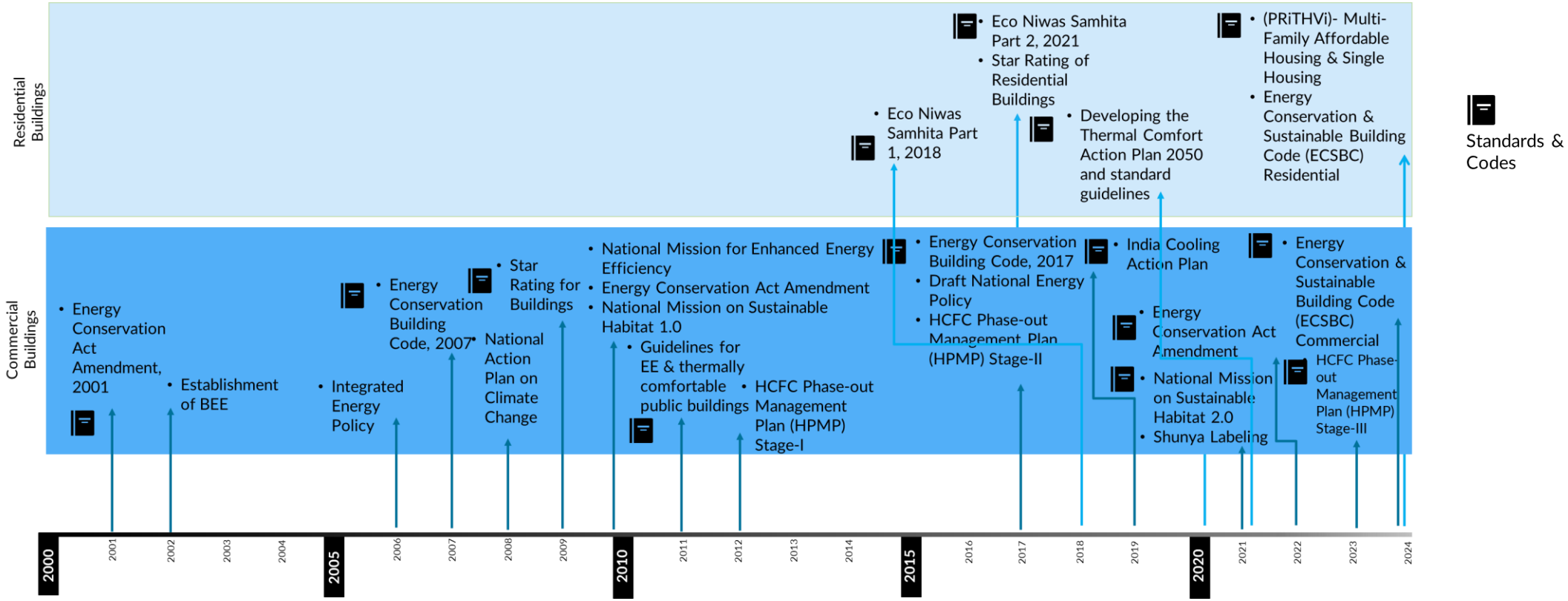


Figure 12: Timeline highlighting significant policy initiative

Inference: Multiple policy-level regulations have been implemented in India to enhance the sustainability and efficiency of both commercial and residential buildings. While the ECBC and ENS codes primarily focus on new construction, a significant portion of the building stock consists of existing buildings. Retrofitting these existing structures to meet energy efficiency standards poses unique challenges that are not fully addressed by the current codes. Notably, there has been considerable growth in the cooling sector, which has direct implications for the country's climate change commitments and NDC targets. This has led to the development of initiatives such as the ICAP, which promotes efficient cooling solutions using low GWP refrigerants or natural alternatives, while also raising awareness of other natural cooling options. Additionally, guidelines have also been established to address affordable housing for lower-income groups, with a focus on incorporating design elements that improve thermal comfort and overall liveability.

ii. The timeline below highlights **significant strategic planning and analysis efforts** that have contributed to India's energy efficiency advancements over the past two decades

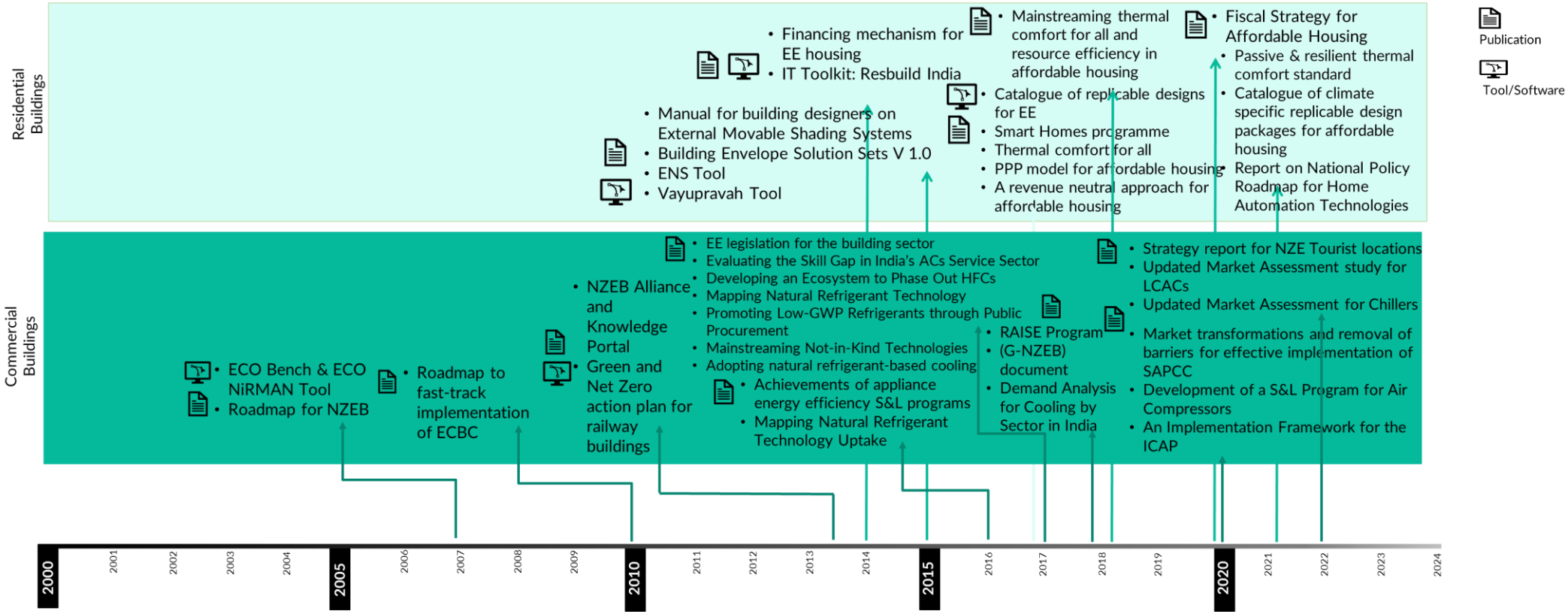


Figure 13: Timeline highlighting significant strategic planning

Inference: Specific studies within the cooling sector have explored the phase-out of high GWP hydrofluorocarbons (HFCs) and the adoption of energy-efficient refrigerants with lower GWP, while also identifying the barriers hindering their widespread implementation. Several reports have been published addressing these challenges, including analyses of banks' financing approaches, benefits, processes, methodologies, and their involvement in supporting the adoption of sustainable cooling solutions. Additionally, documents have been developed to establish public-private partnership frameworks, outlining mechanisms aimed at overcoming these barriers effectively. While NZEB strategies and roadmaps have been developed, India still lacks a comprehensive and dedicated policy framework specifically for NZEBs.

iii. The timeline below highlights **significant implementation framework and assessment milestones** that have supported India's energy efficiency advancements over the past two decades.

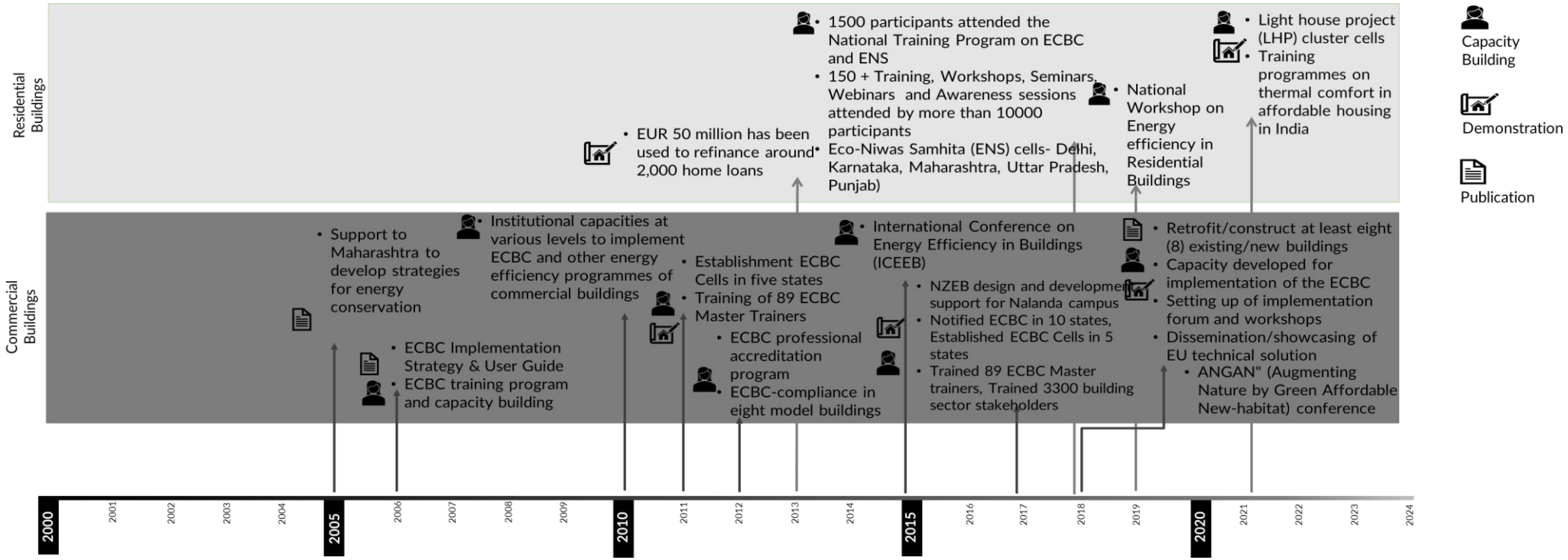


Figure 14: Timeline highlighting significant implementation framework

Inference: Over the past 17 years, the ECBC standard has undergone extensive awareness campaigns and market outreach efforts facilitated by various IDAs and BEE. As a result, 25 states have officially notified the ECBC, with 17 states adopting it into their bylaws. In contrast, the ENS code was introduced more recently, with its first part published in 2018 and an updated version in 2021. Over 150 training programs, workshops, seminars, and integrated design charrettes have been conducted nationwide, reaching more than 10,000 participants and supported by more than 89 master trainers across India. This concerted market outreach has significantly increased awareness of the ENS code, particularly in the residential sector and among the 17 states that have initiated steps towards its notification. Furthermore, various national and state-level bodies have allocated funding for ECBC demonstration projects, while technical assistance (TA) has been extended to ensure guaranteed compliance with the code.

2.4 Key Players

India's building energy efficiency landscape is shaped by a network of key stakeholders, including policy makers and regulators, financial enablers, research and development institutes, IDAs, state-level departments, and industry associations such as material manufacturers, suppliers, architects, engineers, and builders. Together, these entities collaborate to advance sustainable practices and innovations, ensuring a collective effort toward enhancing energy efficiency in the built environment and contributing to broader sustainability goals.

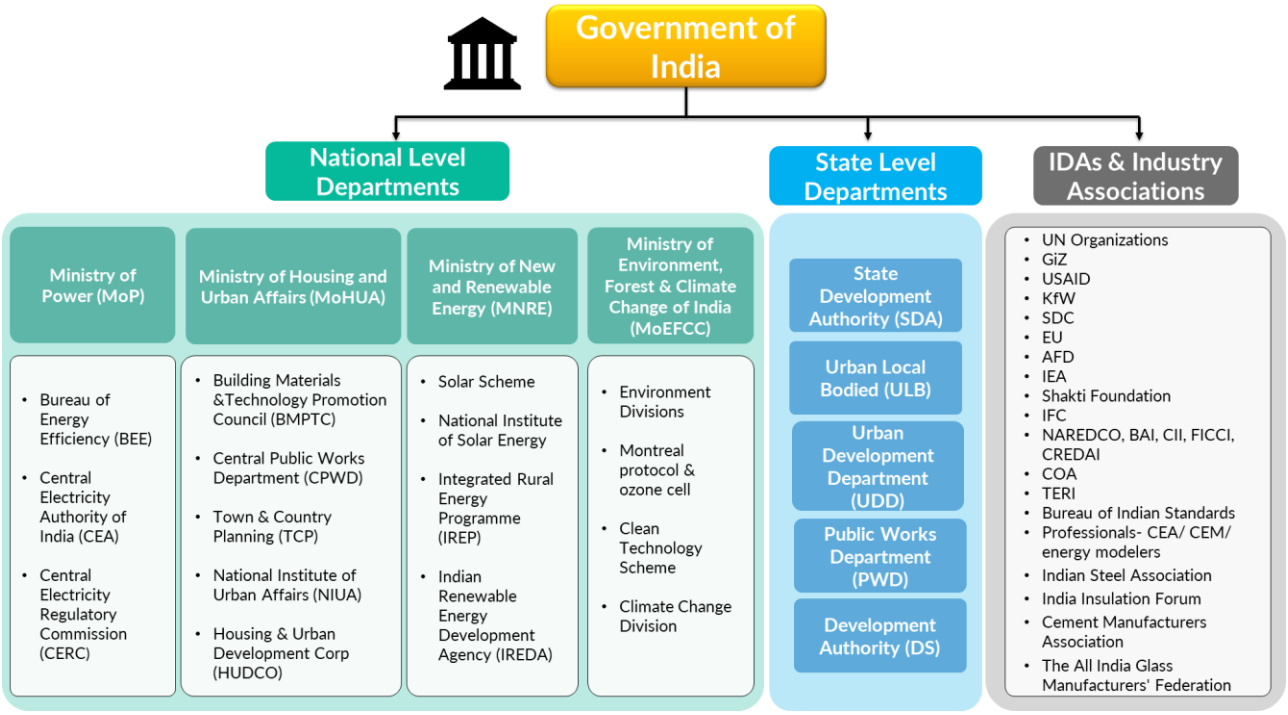


Figure 15: Key players at National and State level departments

Ministry of Power (MoP)

The Ministry of Power plays a crucial role in promoting and implementing energy efficiency initiatives in India. Under its jurisdiction, the Energy Conservation Act (EC Act) was enacted in 2001, aiming to reduce the country's energy intensity. BEE, a statutory body under MoP, was set up on 1 March 2002 to facilitate the implementation of the EC Act at the central level. Through BEE, the MoP has initiated several energy efficiency initiatives targeting household lighting, commercial buildings, appliance standards and labelling, among others.

At the state level, the EC Act 2021 empowers State Designated Agencies (SDAs) to coordinate, regulate, and enforce the provisions of the ECBC. State governments play a vital role in implementing energy efficiency codes in buildings, with SDAs mostly responsible for notifying and adopting the ECBC within their jurisdictions. This involves tailoring the code to suit regional and local conditions and officially publishing it in the state gazette. SDAs also oversee training programs and workshops for architects, engineers, builders, and other stakeholders to enhance their understanding and capacity to implement energy efficiency measures.

Major achievements from FY 2017-18 to FY 2022-23 include[20]:

[20] Bureau of Energy Efficiency (BEE), State Designated Agencies, New Delhi: Ministry of Power, Government of India, https://beeindia.gov.in/en/state-designated-agencies.

1. Replacement of conventional luminaries with LEDs and conventional fans with energy-efficient fans in over 5,000 government schools across the country. Additionally, Energy Clubs have been established in more than 12,500 schools, promoting awareness among students.
2. Awareness campaigns have impacted over 2 million students, teachers, and their families, positively influencing energy-saving understanding and behaviors across various states.
3. Twenty-eight SDAs have initiated the implementation of energy efficiency measures as pilot projects in about 220 government hospitals across the country. Out of these, implementation has been completed in 110 hospitals.
4. SDAs have also been engaged in activities such as innovation challenges and research projects. Ten states have collaborated with educational, technical, and research institutions to support these initiatives.
5. More than 2,500 physical and virtual workshops and capacity-building programs have been conducted, engaging energy managers, auditors, industries, designated consumers (DCs), ESCOs, distribution companies (DISCOMs), state electricity regulatory commissions (SERCs), building professionals, architects, engineers, developers, equipment and appliance manufacturers, ULBs, financial institutions (FIs), farmers, pump technicians, and government officials. More than 100,000 people have been trained and made aware of the latest developments in energy efficiency and their associated benefits.

Ministry of Housing and Urban Affairs (MoHUA)

The Ministry of Housing & Urban Affairs anchors India's commitments under international climate change agenda, SDGs, and the country's NDCs. The ministry leads flagship programs such as:

- **Smart Cities Mission**, which aims to promote sustainable and inclusive cities by providing core infrastructure, improving quality of life, and fostering clean, sustainable environments through the application of smart solutions in the building sector.
- **Pradhan Mantri Awas Yojana-Urban (PMAY-U)**, which aims to address the housing shortage in urban areas, especially for the Economically Weaker Sections (EWS), Lower Income Groups (LIG), and Middle Income Groups (MIG), by providing affordable housing.

MoHUA also has various administrative control, including:

1. **Building Materials and Technology Promotion Council (BMTPC)**: Established in 1990 to promote the development, manufacture, and use of innovative, sustainable building materials and technologies. Emphasis was laid on environmental protection using waste, energy conservation, and development of substitute materials for scarce materials.
2. **Central Public Works Department (CPWD)**: A comprehensive construction management agency providing services from project concept to completion and post-construction maintenance.
3. **Town and Country Planning Organisation (TCPO)**: A technical arm of MoHUA for town planning, regional planning, and urban development.
4. **National Institute of Urban Affairs (NIUA)**: Conducts research on urban local governance, management, financing, development programs, and capacity building.
5. **Housing & Urban Development Corporation (HUDCO)**: A techno-financial institution engaged in financing and promotion of housing and urban infrastructure projects across India.

Ministry of New and Renewable Energy (MNRE)

The Ministry of New and Renewable Energy primarily focuses on promoting renewable energy sources such as solar, wind, biomass, and small hydro power. While its core mandate is renewable energy, MNRE also contributes to energy efficiency in buildings through initiatives like:

- **Green Rating for Integrated Habitat Assessment (GRIHA)**: Encourages the adoption of renewable energy technologies such as solar power generation in buildings.
- **Solar Rooftop Program**: Promotes the installation of rooftop solar photovoltaic (PV) systems.
- **Collaboration with MoHUA and other stakeholders**: Supports the adoption of ECBC standards, particularly in integrating renewable energy into building designs, and provides

incentives, subsidies, and soft loans for buildings incorporating renewable technologies.

Ministry of Environment, Forest and Climate Change (MoEFCC)
The Ministry of Environment, Forest, and Climate Change serves as the nodal agency for overseeing India's environmental and forestry policies and programs. The Ministry's broad objective is to promote energy efficiency in the building sector through various policies, regulations, and initiatives aimed at reducing environmental impacts and promoting sustainable development. The Climate Change Division of MoEFCC coordinates all issues related to climate change, including international negotiations as well as domestic policies and actions. The Division is also responsible for submitting of National Communications (NATCOMs) and Biennial Update Reports (BURs) to the United Nations Framework Convention on Climate Change (UNFCCC).

2.5 Codes & Certifications Mechanisms

In India, several organizations offer green building certifications, awards and recognition for efforts and contributions to sustainable building practices. These certification programs emphasize reducing resource consumption through efficient design, use of renewable energy sources, and optimization of building systems such as lighting, heating, ventilation, and air conditioning. Sustainable water use and management, including rainwater harvesting, water-efficient fixtures, wastewater treatment, and reuse, are also key focus areas. These programs aim to minimize environmental impact during construction and operation, preserve natural habitats, and promote sustainable land use practices. Encouraging the use of sustainable, recycled, and locally sourced materials, ensuring good indoor air quality, adequate ventilation, natural lighting, and thermal comfort for building occupants are also essential components. The certifications prioritize the health and well-being of building occupants by ensuring access to natural light, views of nature, and promoting physical activity through design. The various codes and certifications in India can be classified in the following categories:

2.5.1 Building Codes

Building codes in India are established primarily by the BEE and set minimum energy efficiency standards for buildings, promoting energy conservation in both construction and operation. These codes cover various aspects of building design, construction, and systems to ensure that structures are more energy-efficient and environmentally sustainable. Currently, there is **no direct incentives mechanism available in the market to encourage building owners to adopt ECBC and ENS codes**. These incentives can be financial subsidies, tax benefits, expedited approvals, regulatory relaxations, recognition and certifications, access to preferential financing, capacity-building initiatives, and performance-based incentives.

1. **Energy Conservation Building Code (ECBC):** The Indian government issued the ECBC in 2007 to curb energy consumption in buildings. This code applies to commercial buildings with a connected load of 100 kW or 120kVA. The implementation of ECBC could help save 25-40% of energy, compared to reference buildings without such energy-efficiency measures. The code was updated in 2017 to include additional priorities of renewable energy integration, ease of compliance, inclusion of passive building design strategies, and flexibility for the designers.

2. **Eco Niwas Samhita (ENS) Part 1 & 2**: A residential energy conservation building code developed by BEE. It was launched in two parts:

    - **ENS 2018 (Part 1)**: Sets minimum standards for building envelope designs for energy-efficient residential buildings.

    - **ENS 2021 (Part 2)**: Focuses on code compliance and electromechanical systems. It also addresses other aspects such as energy efficiency in electro-mechanical equipment for building operation and renewable energy generation.

3. **Energy Conservation Sustainable Building Code (ECSBC):** The code provides norms and standards for energy efficiency and its conservation, use of renewable energy and other green building requirements for a building. This was launched in 2024 under Energy Conservation Act 2001**.** This code has two different methods of compliance, all the buildings typologies follow any one of the following methods in order to comply with the code, Integrative Compliance Method (ICM) (Simulation Approach) or Standardized Compliance Method (SCM) (Prescriptive approach).

2.5.2 Labeling Programs

Labeling programs help builders and building owners assess the energy efficiency of their buildings and encourage the adoption of energy-saving measures. Similar to building codes, there are currently no formal incentive mechanisms to promote building owners to adopt star rating of commercial building, energy efficiency label for residential building and shunya label. These incentives can be in the form of financial subsidies, tax benefits, expedited approvals, regulatory relaxations, recognition and certification, access to preferential financing, capacity-building initiatives, and performance-based incentives.

1. **Star Rating of Commercial Buildings**: Launched in 2018 by the MoP, this program rates buildings based on their annual energy usage per square meter (EPI). Presently, four typologies of the buildings are covered in the scope viz. Office buildings, BPO, Hospitals, and shopping malls. The buildings having connected loads 100kW and above are considered for the BEE star rating scheme. Recently, BEE has revised the EPI band for Star Rating for Office Buildings and BPOs. The revision of the scheme is effective from January 2022.

2. **Energy Efficiency Label for Residential Buildings:** This program initiated by the Bureau of Energy Efficiency (BEE), Government of India. The star-labelling program applies to all single and multiple dwelling residential units covering all the five different climatic zones of the country. There is no minimum requirement for the area or connected load (kW) for a building dwelling unit to be covered under this labelling program and it is applicable for both new and existing buildings. The label is based on the Energy Performance Index (EPI) of a building, which is its annual energy consumption in kilowatt hours per square meter of the building. currently.

3. **Shunya Labeling:** An important concept in the promotion of sustainable building practices, particularly in the context of Net-Zero Energy Buildings (NZEBs) and Net Positive Energy Buildings (NPEBs). Two types of labels are proposed under this initiative: (1) **Shunya Label** for NZEBs and (2) **Shunya+ (Shunya Plus)** for NPEBs. Under this program, buildings with an EPI between 10 and 0 kWh/m^2/year are eligible for the Shunya Label, indicating net-zero energy performance. Buildings with an EPI less than 0 kWh/m^2/year, meaning they produce more energy than they consume, are awarded with Shunya+ Label, recognizing their net-positive energy performance.

2.5.3 Green Building Certification Programs

Various certification bodies, including national and international private organizations, are available in India. The selection of a certification body depends on the specific requirements of the building owner. Among the available options, the Indian Green Building Council (IGBC) is currently the most widely adopted in the Indian market. As of 2024, a total of 11,436 projects across India are green-certified, covering approximately 223 million square meters of built-up area.

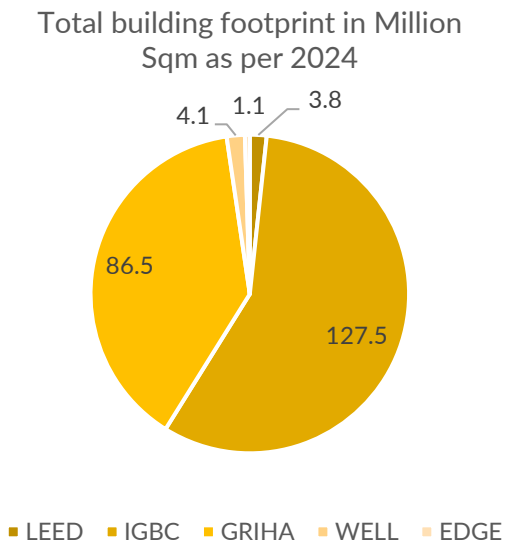


Figure 16: Green building footprint in India

To encourage more building owners to adopt IGBC, GRIHA, LEED, WELL and EDGE certifications, incentive mechanisms are provided by various government agencies and financial institutions. These include:

- Financial incentives: tax credits, grants, and reduced fees on loans
- Regulatory incentives: like expedited permitting processes and increased Floor Area Ratio (FAR) allowances
- Market incentives: including higher property values, premium rental income, and increased attractiveness to tenants, particularly among companies with sustainability goals.

i. **Indian Green Building Council (IGBC):** The IGBC, part of the Confederation of Indian Industry (CII), was formed in the year 2001 as India's first homegrown green building certification system. It aims to address the country's unique climatic challenges and evolving lifestyle needs. IGBC provides guidance and a structured certification process to convert conventional structures into green-certified buildings. As of 2024, over 5,820 buildings in India have received IGBC certification.[21]

ii. **Green Rating for Integrated Habitat Assessment (GRIHA):** GRIHA is a national rating tool that enables the assessment of a building's environmental performance against established benchmarks. It evaluates a building holistically over its entire life cycle, providing a clear standard for what qualifies as a "green building." The system is grounded in widely accepted energy and environmental principles and aims to balance traditional best practices with emerging national and international sustainability concepts. Awarded by TERI and MNRE, GRIHA follows a five-star rating structure based on various sustainability parameters. As of 2024, over 3,869 completed projects in India have received GRIHA certification.[22]

iii. **Leadership in Energy & Environmental Design (LEED):** Developed by USGBC, LEED is one of the most widely recognized global green certification systems. Applicable to a wide range of building types, including commercial offices, schools, hospitals, data centers, warehouses, hotels, and homes, LEED provides third-party verification of a building's performance across several sustainability metrics like energy efficiency, water use, materials selection, and indoor environmental quality. As of 2024, 1,605 buildings in India are LEED-certified.[23]

iv. **WELL Building Standard:** The WELL Building Standard focuses on integrating building design and construction with evidence-based strategies that enhance occupant health, well-being, and productivity. It addresses aspects such as nutrition, fitness, mood, sleep, air quality, and comfort.

[21] "Indian Green Building Council," Indian Green Building Council, https://igbc.in/.
[22] "Projects," Green Rating for Integrated Habitat Assessment (GRIHA), https://www.grihaindia.org/projects.
[23] https://www.usgbc.org/projects?Country=%5B%22India%22%5D

Certification is achieved by implementing programs and technologies designed to encourage healthy lifestyles while minimizing occupant exposure to harmful chemicals and pollutants. As of 2024, 111 buildings in India are WELL-certified.[24]

v. **Excellence in Design for Greater Efficiencies (EDGE) Certification**: The EDGE certification is a global framework developed by the International Finance Corporation (IFC) for assessing and improving the sustainability of buildings. It provides a standardized method to measure and validate a building's environmental performance, focusing on resource efficiency key areas: energy, water, and materials. The certification is designed to help builders, owners, and tenants achieve higher standards of sustainability while reducing the environmental impact of their buildings. IFC is committed to growing its climate-related investment portfolio between 2021 and 2025 and working with financial institutions to finance mitigation and adaptation projects. Through its Climate Finance Program, IFC assists clients in identifying climate-smart investment opportunities and offers business development support, including customized product training for loan officers. By earning EDGE certification, a building demonstrates its commitment to sustainable practices and enhanced resource efficiency. As of 2024, 30 buildings in India have been certied under the EDGE framework.[25]

Figure 17: Sample Existing Buildings identified for Retrofits under ALCBT project

[24] International WELL Building Institute, *Projects Directory*, https://account.wellcertified.com/directories/projects/.
[25] EDGE Buildings, "Project Studies," International Finance Corporation, https://edgebuildings.com/project-studies/.

3. Green Building Materials in Policy

In recent years, India has witnessed a significant shift towards sustainability and energy efficiency in the building sector, driven by growing awareness of the sector's contribution to carbon emissions. Green building materials, also referred to as eco-friendly materials, are construction materials that have a low environmental impact.[26] They are considered "green" because they aim to minimize the total energy consumed during extraction, processing, manufacturing, and transportation across their entire life cycle. This is achieved through various means, such as the use of recycled materials, locally sourced raw materials, energy-efficient manufacturing process, and reduced transportation-related emissions.

Embodied energy has become an important metric for evaluating building sustainability, especially as advancements continue to reduce operational energy use. In a typical building, embodied energy accounts for 10 to 25 percent of total lifetime energy consumption. However, in energy-efficient buildings, embodied energy can exceed 50 percent.[27] The share can reach up to 57 percent, or even up to 83 percent, when renewable energy sources are used for electricity production. In NZEBs, embodied energy may represent up to 100 percent of the life-cycle operational energy, although overall life-cycle energy consumption is significantly reduced.

The MoHUA in India plays a pivotal role in promoting the use of green building materials as part of its broader mandate to enhance urban development and housing. Green building materials are typically registered and certified through various certification bodies such as the GreenPro Product Certification and the Building Materials & Technology Promotion Council (BMTPC), which assess the sustainability and environmental impact of construction materials. Certification data is readily available on their websites, along with the annual compendiums and catalogues listing certified materials and technologies in the market.

India has made notable progress in promoting green procurement and sustainable construction practices, even though a single, unified green procurement policy for new or existing construction does not yet exist. Several initiatives contribute to the green building material usage such as the Green Rating for Integrated Habitat Assessment (GRIHA), Leadership in Energy and Environmental Design (LEED), Smart Cities Mission, Public Procurement Policy, National Action Plan on Climate Change (NAPCC) and state-level initiatives.

The adoption of green building materials plays a vital role in minimizing resource consumption, reducing embodied energy, enhancing energy efficiency, lowering carbon emissions. Recognizing these benefits, regulatory bodies and organizations in India have increasingly emphasized the importance of integrating green building materials into construction practices. While incentive mechanisms for using green materials in new construction remain limited, projects that adopt them may qualify for certifications like LEED, GRIHA, or IGBC, and may receive awards or public recognition, offering reputational and marketing advantages. Over the years, various programs and initiatives have supported the promotion of low-embodied-energy materials in India. A summary of key initiatives are listed below with a brief timeline of their contributions.

[26] Chris Jackson, "List of Building Material for Green Construction," *Construction21*, July 15, 2021, https://www.construction21.org/articles/h/list-of-building-material-for-green-construction.html.
[27] Jake Duncan, "Should I Stay or Should I Go: The Embodied Carbon of Buildings," *Institute for Market Transformation*, January 25, 2019, https://imt.org/should-i-stay-or-should-i-go-the-embodied-carbon-of-new-and-existing-buildings/.

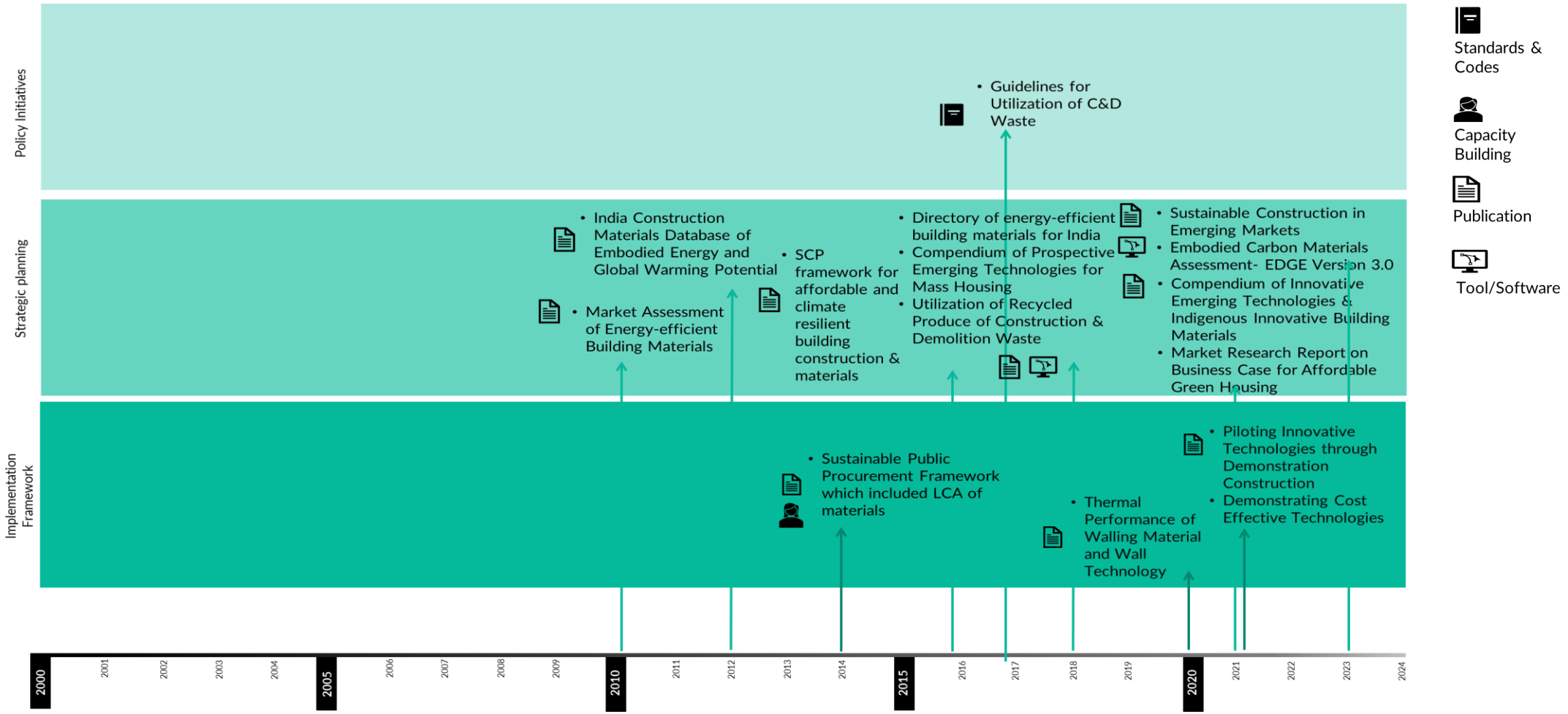


Figure 18: Green building materials timeline analysis

Inference: Over the past 10-15 years, the green building materials industry has gained significant prominence. Numerous organizations have concentrated their efforts on advancing this sector towards sustainability, resulting in the release of various strategic planning documents and implementation frameworks. However, despite these publications, the contribution of standards and codes remains limited. Addressing this gap at the national level is crucial to accelerating the industry's growth, which will benefit future developments in both the residential and commercial sectors. Additionally, there is a pressing need to focus on capacity building and the development of technological tools to support the implementation of standards and codes. Such initiatives are essential for enabling various stakeholders to effectively utilize green building materials.

3.1 Industry Sector Best Practices

Green building materials are integral to sustainable construction, aiming to reduce the environmental impact of buildings. Industry best practices for materials like steel, cement, glass, and brick emphasize reducing carbon footprints, enhancing energy efficiency, and utilizing recycled content. To decarbonize building materials production, comprehensive policies and plans are being implemented in the country. These include PAT cycle, compliance mechanisms, voluntary and involuntary mechanisms, carbon pricing, GHG emission regulations, and incentives for adopting green technologies. Collaborations across the supply chain aim to foster innovation and ensure the adoption of best practices, driving the transition towards a more sustainable construction industry.

i. Steel Industry

Steel remains one of the fundamental building blocks of modern life. Its importance is visible in many industries, from housing and construction to mechanical equipment. The steel supply chain involves multiple steps that transform raw materials into various steel products. These are mining and raw material extraction, steel production, steel manufacturing (continuous casting and rolling to main products) and logistics and transportation.

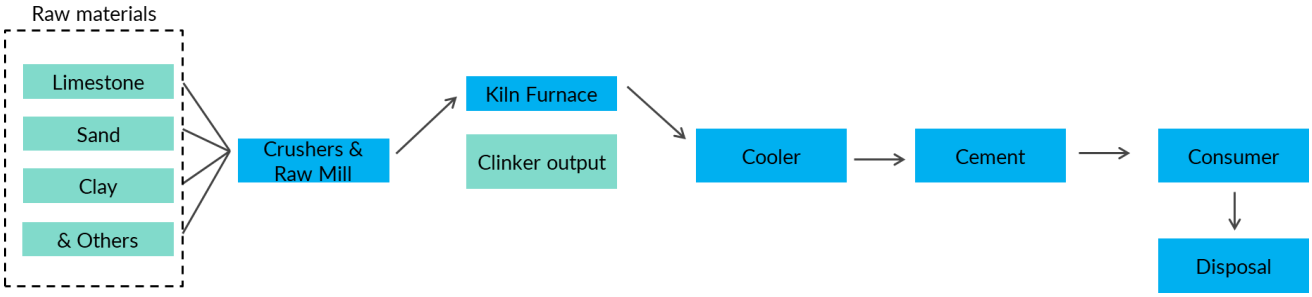


Figure 19: Schematic diagram of supply chain of steel industry

Over the last five years, crude steel production expanded from 109.25 million Tonne (MT) in 2018 to 124.72 MT (provisional) in 2022. Production in 2022 showed a year-on-year growth of 5.5% over 2021[28] and is projected to reach 230.03 million tons by 2030, growing at a CAGR of 9.18% during the forecast period (2025-2030).[29] India is currently the second-largest steel producer globally and has pledged to reduce the emissions intensity of its GDP by 45% from 2005 levels by 2030 (as declared at COP21).

The NDC goals for the steel industry focus on improving energy efficiency, reducing carbon intensity, and adopting cleaner technologies. This includes the implementation of advanced manufacturing processes, increasing the use of renewable energy sources, and promoting recycling and reuse of steel products. Additionally, the industry is encouraged to adopt the best practices in resource management and waste reduction to minimize its environmental footprint. As per NDCs submitted by the steel sector to MoEFCC, the average CO_2 emission intensity of the Indian steel industry was projected to decrease from 3.1 T/tcs in 2005 to 2.64 T/tcs by 2020, and 2.4 T/tcs by 2030, representing an approximate annual reduction rate of 1%.[30]

The steel industry has implemented various national-level measures and policies to reduce carbon emissions. These initiatives are primarily driven by the Perform Achieve & Trade (PAT) scheme, a market-based mechanism that certifies energy savings from steel plants, which can then be traded. Application of Marginal Abatement Cost Curve (MACC) for data-driven decision-making which uses AI

[28] Ministry of Steel, *Annual Report 2022–23* (New Delhi: Government of India, 2023), https://steel.gov.in/sites/default/files/MoS%20AR%202022-23.pdf.
[29] Mordor Intelligence, India Steel Market Size and Share Analysis- Growth Trends and Forecasts (2025-2030), https://www.mordorintelligence.com/industry-reports/india-steel-market
[30] Ministry of Steel, "Energy and Environment Management in Iron & Steel Sector," Government of India, https://steel.gov.in/en/energy-environment-management-steel-sector.

and other advanced technologies for monitoring and reporting emissions.

Under the National Green Hydrogen Mission, guidelines have been developed for pilot projects that aim to integrate green hydrogen into steel production. The Ministry of Steel has committed to achieving a Net-Zero target by 2070, with specific short-, medium- and long-term goals:

- Short-term (up to FY 2030): The focus is on reducing carbon emissions by promoting energy and resource efficiency and increasing the use of renewable energy.
- Medium-term goal (2030-2047): Emphasizes the adoption of green hydrogen and Carbon Capture, Utilization, and Storage (CCUS) technologies.
- Long term (2047-2070): The strategy includes embracing disruptive alternative technological innovations to transition to net-zero emissions, enhancing capacity building, and expanding market outreach on sustainability within the steel sector.

ii. Cement Industry

Cement is generally a mixture of limestone, sand, clay and iron. The most common type of hydraulic cement is the Portland cement. Cement production consists of two main steps: first, the production of clinkers from raw materials, and second, the grinding of clinker to produce cement. The process begins with the extraction of limestone and clay from quarries, followed by crushing the materials into smaller pieces. These materials are then ground into a fine powder and blended to create a uniform raw mix. The mix is preheated and partially calcined before being fed into a rotary kiln, where it is heated to around 1,400°C to form clinker nodules. The hot clinker is rapidly cooled to stabilize its mineral phases. The clinker is mixed with gypsum and other additives and then finely ground to produce cement. Finally, the cement is stored in silos and packaged for distribution.

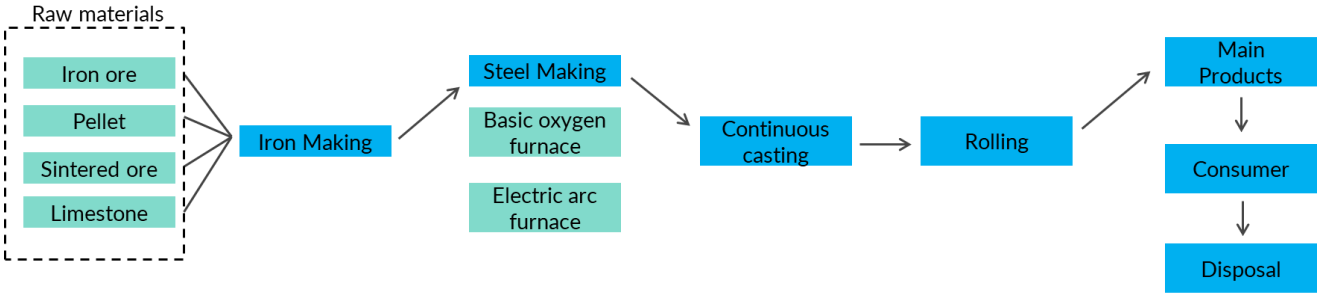


Figure 20: Schematic diagram of supply chain of cement industry

India is the second-largest producer of cement in the world. In 2022-23, India's total cement production reached 374 million tonnes, up from 273 million tonnes in 2015-16, reflecting an overall growth of 27th over the past eight years.

Aligned with India's NDCs, cement companies are focusing on enhancing energy efficiency, reducing carbon intensity, and adopting innovative technologies through three main levers:

a) **Energy efficiency**: Encouraging the use of cleaner production techniques and the increased use of blended cements, which have a lower carbon footprint
b) **Clinker substitution**: Improving clinker substitution rates
c) **Decarbonization of the grid**: Implementing waste heat recovery systems, to reduce CO_2 emissions.

The cement industry has categorized its decarbonization strategies across several priority areas.

- Improving thermal and electrical energy efficiency through measures that reduce energy consumption per unit output and enhance waste heat recovery at each manufacturing stage which is projected to cut carbon emissions by 9%.
- Integrating renewable energy sources such as alternative fuels and raw materials which can lower carbon emissions by 3.3%.
- Substituting fossil fuels with biomass and municipal solid waste is expected to further decrease emissions by 12%.

- Reducing the clinker factor by increasing the use of additives like steel slag and fly ash in cement production can lead to a 13.7% reduction in carbon emissions. The remaining emissions can only be addressed through advanced carbon management techniques, such as carbon capture, storage, and utilization, or through afforestation initiatives.

iii. Glass Industry

Glass is known for its unique dual characteristics: fragility and firmness, making it a typical example of a solid. The primary raw materials used in glass production include sand, soda, limestone, clarifying agents, coloring and glistening glass. Glass sand accounts for approximately three-fourths of the total glass composition. To manufacture glass, the process begins with batching the raw materials and then melting them. Temperature could reach up to 1600°C or above. This molten glass floated onto a bath of molten tin at a temperature of about 1000°C. On leaving the bath of molten tin, the glass - now at a temperature of 600°C - has cooled down sufficiently to pass to an annealing chamber called a lehr. After cooling, the glass undergoes rigorous quality checks. It is then cut into sheets of sizes varying.

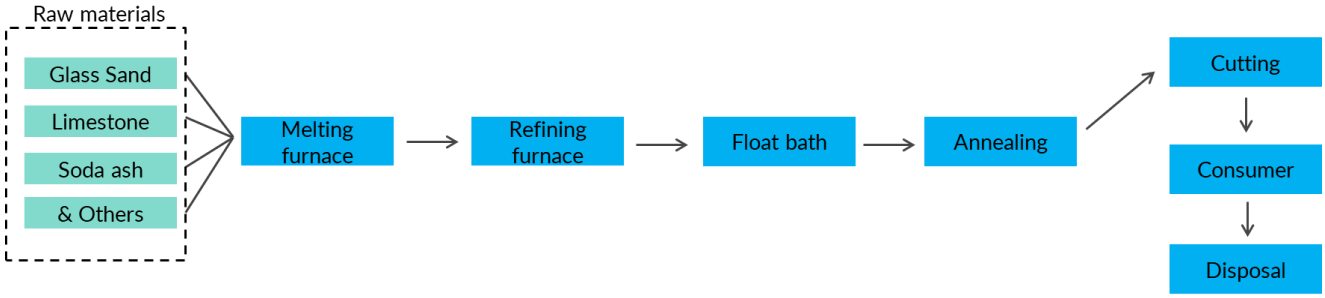


Figure 21: Schematic diagram of supply chain of glass industry

The India Glass Market is witnessing significant growth and transformation, driven by a myriad of factors such as rapid urbanization, rising disposable incomes, and increasing demand from the construction and automotive industries. India Glass Market has valued at USD 8.57 Billion in 2023 and is anticipated to project robust growth in the forecast period with a CAGR of 7.64% through 2029.[31] The NDC goals for the glass industry focuses on improving energy efficiency, reducing carbon emissions, and incorporating sustainable practices. This involves adopting advanced manufacturing technologies, optimizing furnace operations, and increasing the use of renewable energy sources. The industry is also encouraged to implement recycling programs and utilize waste materials to minimize environmental impact.

The glass industry has become more productive, energy-efficient, and sustainable over the past few decades in response to market conditions. Glass is a fully recyclable material that can be reprocessed and reused in a closed loop continuously, making it a prime candidate for participation in the circular economy. Energy-efficiency measures implemented by industry, including the increased use of cullet, have directly contributed to a reduction in greenhouse emissions over the last few decades.

iv. Brick industry

Brick manufacturing in India has remained largely unchanged over time. The manufacturing process has six general phases: (1) mining and storage of raw materials; (2) preparing raw materials such as break up of large clay lumps and stones; (3) size-reduction using crushing machines; (4) mixing and tempering to create a uniform clay mass, usually by adding water in a pug mill equipped with mixing changers and revolving shafts with blade extensions; (5) molding and drying, where wet bricks containing 7% to 30% moisture, depending upon the forming method, are dried in chambers at temperatures ranging from about 100 °F to 400 °F to remove most of the moisture; (6) firing, which takes between 10 and 40 hours depending on kiln type and other variables. Fuels used include natural gas, coal, sawdust, methane gas

[31] TechSci Research, *India Glass Market By Size, Share and Forecast 2030F*, https://www.techsciresearch.com/report/india-glass-market/22019.html.

from landfills, or a combination of these fuels.

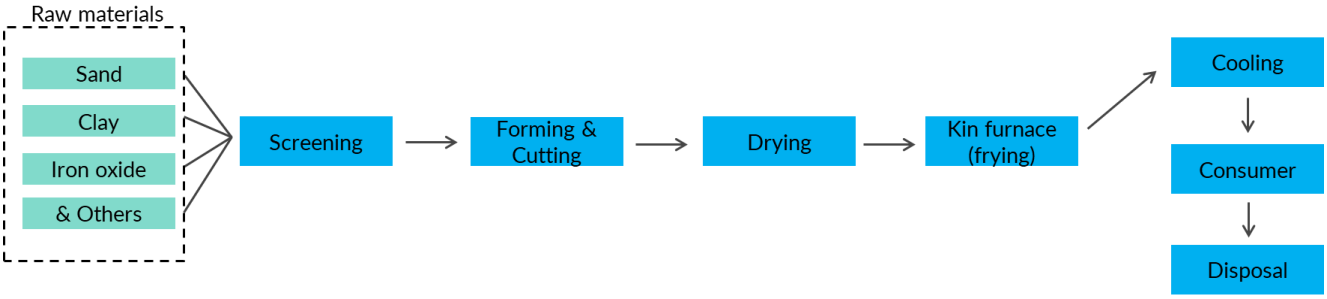


Figure 22: Schematic diagram of supply chain of brick industry

The brick sector is both resource-intensive and highly polluting. India is the world's second-largest producer of bricks, with an annual production of approximately 250 to 300 billion bricks. Given the projected growth in the country's building stock, the demand for bricks is expected to multiply by three to four times in the next 20 years, reaching 750 to 1000 billion bricks per year.[32] The NDC goals for the brick industry emphasize enhancing energy efficiency, reducing carbon emissions, and adopting environmentally friendly technologies. This includes shifting from traditional kiln technologies to modern, energy-efficient alternatives such as zigzag kilns and vertical shaft brick kilns. The industry is also encouraged to use cleaner fuels, improve kiln operations, and increase the use of fly ash and other industrial by-products in brick production. These measures are aimed at reducing the carbon footprint of brick manufacturing.

To produce 200 billion bricks, approximately 600 million tonnes of clay (topsoil) and 35 million tonnes of coal are required, resulting not only in bricks but also 60% of the total industrial emission of black carbon.[33] Given the considerable environmental and social impact of the brick industry, the UNFCCC and the Government of India proposed the **National Brick Mission.** The mission's objective is to reduce clay consumption and prepare a technology roadmap and emission roadmap. India's brick Industry is varied and complex, intersecting multiple policy domains. Various initiatives across various sectors directly or indirectly associated are mapped below. The main goal of all the different initiatives is to reduce the overall usage of clay, coal, reduction of CO2, PM10 and black carbon emissions.

Table 5: Various policy initiatives and contribution by various organizations in brick industry

Sector	Policy Initiatives	Contribution by various Organization
Industry	i. Improving productivity of enterprises in the unorganized sector ii. Technology and quality upgradation support to MSME's iii. Rajiv Gandhi Udyami Mitra Yojna (RGUMY) iv. Prime Minister's Employment Generation Programme (PMEGP) v. State Industrial Promotion Policies	i. National Manufacturing Competitiveness Council (NMCC) ii. RGUMY is a Part of the 11th FYPs objective is to support MSMEs iii. PMEGP is a credit linked subsidy programme for generation of employment opportunities

[32] Bureau of Energy Efficiency (BEE), *Market Transformation towards Energy Efficiency in Brick Sector: A Strategic Blueprint, from Vision to Mission* (New Delhi: BEE, December 2019), https://beeindia.gov.in/sites/default/files/Brick%20Sector%20Market%20Transformation%20Blueprint_BEE%281%29.pdf.
[33] Shakti Sustainable Energy Foundation, *National Brick Mission* (New Delhi: Shakti Sustainable Energy Foundation, 2014), https://shaktifoundation.in/wp-content/uploads/2014/02/National-Brick-Mission.pdf

Environmental	i. Climate Change Action Plan ii. Emission standards for various brick technologies iii. Criteria for setting up brick production iv. No Objection Certificate v. Use of fly ash for clay brick production	i. National Action Plan on Climate Change (NAPCC), ii. National Mission for Sustainable Habitat iii. National Mission on Energy Efficiency iv. Ministry of Environment, Forests and Climate Change (MoEFCC) v. Central/State Pollution Control Boards
Production	i. E-auction of coal through IT systems ii. Soil mining rules and guidelines	i. New Coal Distribution Policy by GoI ii. Ministry of Mines
Technology	i. Indian Standards for bricks, technologies, processes. ii. Performance Appraisal Certificate Scheme iii. Technology Upgradation Support by DSIR iv. Technology development support by DST	i. Bureau of Indian Standards (BIS) ii. Building Materials and Technology Promotion Council (BMPTC) iii. Ministry of Science and Technology
Finance	i. Credit Link Capital Subsidy Scheme for Technology Upgradation ii. Credit Guarantee Fund Scheme for Micro and Small Enterprises	i. Ministry of Small Scale Industries (SSI) ii. Ministry of Micro, Small & Medium Enterprises (MSME), Government of India and Small Industries Development Bank of India (SIDBI)
Market	i. National Housing Policy ii. National Building Code iii. Energy Conservation Building Code Policy Mapping Page 14 of 38 iv. Indian Green Building Council Green Homes v. Green Rating for Integrated Habitat Assessment vi. Public procurement guidelines for State and Central work vii. Indira Awas Yojana viii. Preferential procurement from MSME's	i. Ministry of Housing and Urban Affairs ii. Bureau of Indian Standards iii. Bureau of Energy Efficiency (BEE) iv. Confederation of Indian Industry (CII) v. The Energy & Resource Institute (TERI) vi. Public Works Department and Indian Railways vii. Ministry of Rural Development (MoRD) viii. Ministry of Mirco, Small & Medium Enterprises

3.2 Building Sector Best Practices

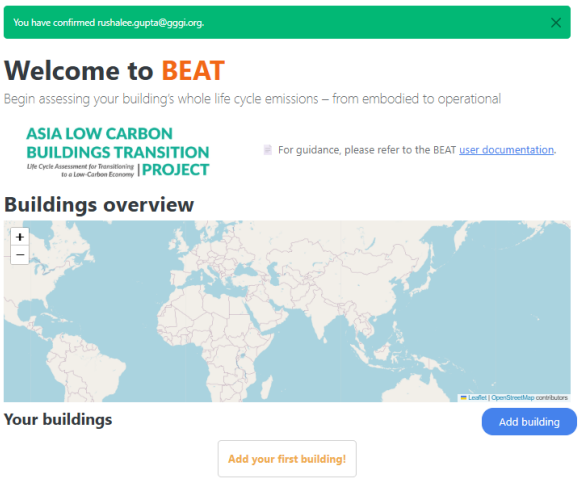
The building sector plays a pivotal role in advancing sustainable development through the adoption of green building materials and technologies. Best practices in this sector focus on minimizing environmental impacts, reducing energy consumption, and promoting the use of sustainable and recycled materials such as steel, cement, glass, brick, and other locally sourced alternatives. Incentives for adopting green technologies and cross-supply chain collaborations further drive innovation and the integration of sustainable practices. These concerted efforts are transforming the building industry, ensuring a more eco-friendly and resilient built environment.

i. Estimation of Embodied Energy for Low Carbon Building Construction

The Building Materials & Technology Promotion Council (BMTPC), in collaboration with IIT Roorkee, undertook a project titled *"Estimate of Embodied Energy for Low Carbon Building Construction."* The objective of this project was to:

- Study the Central Public Works Department (CPWD) Analysis of Rates for material breakups
- Compute revised Embodied Energy Rates (EER) for various items of work using Embodied Energy Value (EEV) of the individual building materials
- Upgrade of the existing data on the Schedule of Energy Rates to the Schedule of Embodied Energy Rates
- Apply the updated schedule to a range of case studies for validation
- Derive best-fit equations to serve as a tool for preliminary EEE estimate.

The ALCBT Project has developed the **Building Emissions Assessment Tool (BEAT)**[34], a standardized metric for assessing and managing carbon emissions in new and existing buildings. Environmental Product Declarations (EPDs) are a core component of the BEAT tool. They provide standardized and independently verified data on the environmental impacts of building materials throughout their life cycle. The tool was designed to estimate embodied carbon of a building construction using its Bill of Quantities (BOQ). It:



- Highlights key predictors of embodied energy in building construction
- Recommends suitable low carbon substitutes for high emission materials, tailored to regional conditions
- Estimates CO_2 emissions reductions and converts these into carbon credits equivalents

Governments can integrate it into building permit processes in order to monitor improvements over time and make better-informed decisions supporting national sustainability targets. So far, embodied energy values of more than 500 items have been calculated and compiled, and validation of the tool is under progress as of this writing.

[34] " Building Emissions Assessment Tool (BEAT)," Asia Low Carbon Buildings Transition (ALCBT) project website, https://alcbt.gggi.org/lca-tool/.

Figure 23: Snapshot of Building Emissions Assessment Tool (BEAT)

ii. India Construction Materials Database of Embodied Energy and Global Warming Potential

The India Construction Materials Database on Embodied Energy and Global Warming Potential (GWP) was developed by the International Finance Corporation (IFC) and was funded under the Eco-Cities Program. A report was published in 2017, providing a comprehensive database on the embodied energy and the GWP of building materials in India. The database contains embodied energy and GWP data of more than 100 building materials available in the Indian market. It was developed to help architects and engineers assess the environmental impact of commonly used building products and materials in construction.

The database has been integrated into the EDGE App, which has evolved through multiple versions over time. Within the EDGE rating system, the app enables users to analyze various combinations of preset construction materials and assemblies to reduce embodied energy in the design. It also provides real-time breakdown of embodied energy contributions from different building components, helping users make informed, performance-driven decisions related to material selection.

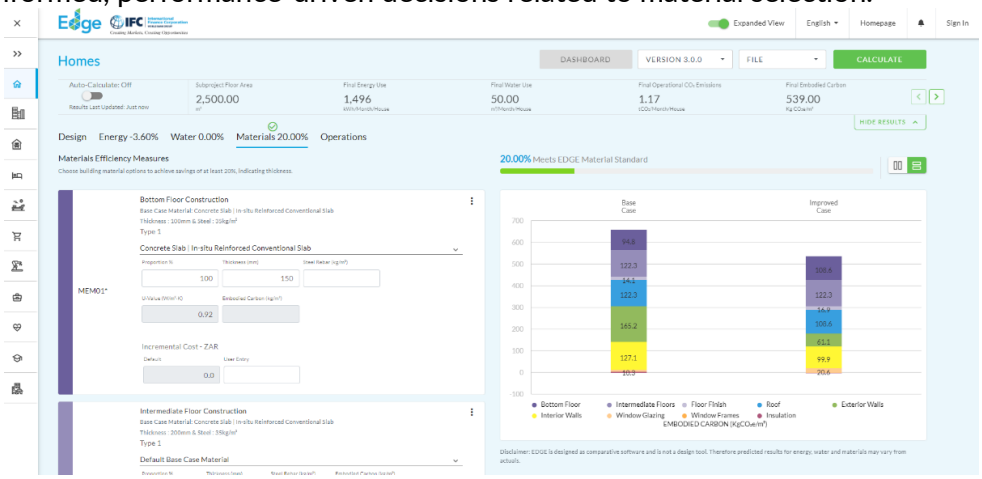


Figure 24: Snapshot of EDGE App

iii. Development of Decision Support Toolkit

The Decision Support Toolkit (DST) was developed under the UN-Habitat's 'Mainstreaming Sustainable Social Housing in India' project, funded by the United Nations Environment's 10 Year Framework Programme. The DST is aimed at enabling developers, practitioners, and policymakers to integrate sustainability concepts into the planning, design, and specification of social housing projects in India.

A Key feature of the DST is the Sustainability Assessment Tool (SAT), which addresses the absence of a comprehensive measurement framework for assessing sustainable materials. SAT fills missing data needed to quantify material performance and uses material mapping application to spatially identify the availability of sustainable building systems options across India. The tool has the capability to measure the relative performance of building materials and systems for social housing projects using a framework of 18 attributes categorized under four criteria: resource efficiency (which includes embodied energy and embodied carbon), operational performance, user acceptability, and economic aspects.

iv. GreenPro Certified Products, Materials, and Technologies Directory

The Confederation of Indian Industry (CII) launched the GreenPro product certification to facilitate

green product market transformation in India through credible product certification. Based on the life cycle approach, the certification assesses a product's environmental impact from raw material extraction through to the end of its useful life. GreenPro is intended to transform the existing linear, unsustainable process toward a sustainable circular process, thereby eliminating or reducing waste disposal in landfills and through incineration. The certification covers a wide range of construction products, including cement, blocks, construction chemicals, doors and window products, glass, insulation, paints and finishes, ready mix concrete, and tiles.

v. New and Emerging Construction Technologies Directory

Various research institutes across the country, including the BMTPC, have developed and used cost-effective, regionally available technologies over the years. These emerging technologies have generally been found suitable for high-rise structures and show strong potential for application under the Affordable Housing in Partnership (AHP), In-situ Slum Rehabilitation (ISSR) components of PMAY-U, as well as other high-rise housing projects in the country. Many of these materials and construction techniques have been successfully piloted in select projects and can be replicated and scaled up due to their demonstrated advantages. However, their adoption has largely remained limited to specific regions and has not expanded to other parts of the country. Some of the emerging construction technologies include:

- Industrialized 3-S System
- Pre-stressed precast prefab technology
- Monolithic Concrete Construction System using Plastic - Aluminum Formwork
- Waffle Crete Building System Disaster-Resistant Construction
- Insulated prefabricated structural
- Glass Fiber Reinforced Gypsum (GFRG) Panel Building System
- Light Gauge Steel Framed Structures
- Precast concrete panels
- Composite Engineered Steel Building Solution System etc.

vi. Energy Efficient Building Materials Directory

A dedicated directory has been developed to evaluate the thermal performance of opaque materials and map over 5,000 materials across India, including information on their manufacturers and suppliers. This also includes conducting market assessment and techno-economic analysis of the listed materials. Designed to eventually become a part of the ECO-NIWAS tool, the objective of the materials tool is to assist the building practitioners, developers, and policy makers, in taking informed decisions in selecting energy efficient materials. Although this initiative does not focus on embodied energy and embodied carbon, it is included here due to its comprehensive focus on the number and type of building materials and potential to focus on life-cycle performance.

vii. Studies on Fostering Resource Efficiency in the India Building and Construction Sector

Several studies conducted under the EU Resource Efficiency Initiative (EU-REI) have focused on assessing the consumption patterns of commonly used building materials in India and identifying pathways to increase resource efficiency in the building and construction sector. These studies highlighted practical and stakeholder-acceptable strategies that can have meaningful impact across the market. Key strategies identified include:

- Use of more sustainable raw materials, such as locally sourced components and reusable construction and demolition (C&D) waste
- Development of transparency tools to promote such materials through materials inventory and EPDs

- Development and promotion of indicator frameworks, green building rating systems, and inclusion of circularity concepts in existing indicator frameworks
- Establishment of a dedicated task force to support public authorities in implementing proposed strategies
- Pilot demonstrations of these strategies in collaboration with large private players to raise awareness and showcasing.

viii. Strategies for Resource Efficiency in Construction and Demolition (C&D) Sector

The Building Materials and Technology Promotion Council (BMPTC) developed guidelines for the management of C&D waste in 2017 to promote resource efficiency and sustainable waste management practices in the construction sector. These guidelines discuss the C&D waste generation and utilization scenario in both Indian and international contexts. The document provides detailed information on: the definition and scope of C&D waste, including materials considered within and outside its classification; C&D waste generation from different materials; and site-level C&D waste generation and appropriate management strategies. The guidelines also outline the duties of local bodies, including State Pollution Control Boards/ Committees, State Governments/UT Administrator, Central Pollution Control Board, BIS, Central Government, and C&D waste process. The guidelines discuss centralized common processing facilities, in-situ processing, and mobile plants. Furthermore, it provides information on the produce and downstream products usages of recycled C&D waste, thereby promoting a circular economy approach within the construction sector.

4. Gap Assessment

A comprehensive review related to energy efficiency in buildings, including the ECBC for commercial buildings, ENS for residential buildings, Shunya Labeling, and the Star Rating system has revealed several critical gaps. These gaps have been categorized into four main areas: **regulatory**, **technological**, **market**, and **fiscal transformation**. Addressing these barriers require a multi-faceted approach involving regulatory reforms, technological advancements, market development, and fiscal incentives to achieve the desired energy efficiency outcomes.

4.1 Regulatory Gaps

An assessment of the effectiveness of current regulations is presented below.

1. **Inconsistent Enforcement and Incentives:** Inconsistent enforcement of building codes and standards, such as ECBC and ENS, is due to slow adoption, lack of stringent regulations, low awareness and expertise, technical barriers, weak monitoring and verification, and limited financial incentives. This discourages developers and builders from prioritizing sustainable design solutions.

2. **Addressing Existing Building Stock**: Although ECBC and ENS prioritize new construction, expanding their scope to include the substantial stock of existing buildings can significantly promote comprehensive sustainability practices across the built environment. Retrofitting existing buildings to meet energy efficiency standards presents an opportunity to extend the impact of these codes beyond their current scope.

3. **Lack of Comprehensive NZEB Policy**: Despite the development of Net Zero Energy Building (NZEB) strategies and roadmaps, India lacks a comprehensive and specific policy framework to support the widespread adoption of NZEBs and India's target of net zero by 2070.

4. **Comprehensive Policy Framework for 2070 Target**: Developing a detailed policy framework that includes regulations, incentives, and strategic actions for both commercial and residential sectors is essential for achieving India's 2070 sustainability targets.

5. **Enhancing Building Materials Accountability**: Transparent and robust regulatory mechanisms in the building materials industry are necessary to increase the availability of Environmental Product Declarations and ensure accountability for the environmental footprints of material products.
6. **Sustainable Public Procurement Policy**: Implementing a sustainable public procurement policy that mandates the use of low-embodied energy and green building materials is crucial for promoting environmentally responsible practices.
7. **Standardized C&D Waste Regulations**: Implementing standardized regulations on construction and demolition (C&D) waste across the country can facilitate the widespread adoption of green building materials by reducing barriers and promoting sustainable practices.

4.2 Technological Gaps

An evaluation of the uptake of energy-efficient technologies and materials in the Indian market, highlighting barriers and opportunities for greater adoption, is highlighted below:

1. **Lack of Robust Building Performance Monitoring**: Establishing a comprehensive building performance monitoring mechanism is essential to assess the effectiveness of code provisions and identify areas for improvement, ensuring the continuous enhancement of energy efficiency standards.
2. **Energy-Intensive Material Processes**: Current methods of material extraction, manufacturing, and processing are highly energy-intensive. Implementing energy-efficient technologies and practices is crucial to reducing emissions and promoting sustainability in the building materials industry.
3. **Collaborative Research in Green Materials**: Research activities on green building materials in India are often limited and fragmented. There is a pressing need for more coordinated and collaborative research efforts to drive the development and adoption of sustainable building materials.
4. **Increased Testing Facilities for Green Materials**: India would benefit significantly from expanding the availability of testing facilities for green building materials. These facilities would support the validation, standardization, and widespread adoption of sustainable construction practices.
5. **Low Market Awareness of Smart Controls**: Awareness of the benefits of smart controls, such as energy savings through optimized usage and efficient appliances that reduce electricity consumption, remains relatively low in the market. Enhanced educational initiatives are needed to increase market awareness and adoption.
6. **Public Reluctance and High Upfront Costs**: Many individuals are reluctant to bear high upfront costs without a clear understanding of the return on investment or associated benefits. Demonstrating real-time data on energy savings and performance can help build public trust and encourage adoption.
7. **Inclusion of Embodied Energy in the Schedule of Rates (SoR)**: Incorporating embodied energy rates into the Schedule of Rates (SoR) is crucial for providing a comprehensive understanding of material choices in the construction industry and promoting more sustainable and informed decision-making.
8. **Awareness of Energy-Efficient Technologies in Residential Buildings**: Residential building owners are generally aware of the role and importance of star ratings and the level of energy savings associated with each star. According to BEE standards, a total 34 appliances are included in the S&L program, of which 11 are mandatory and 23 are voluntary labelling. Through this initiative, the majority of appliances used in the residential sector are covered under mandatory labelling. However, awareness remains low regarding other technologies such as smart controls and the use of low carbon building materials.

4.3 Market and Finance

An analysis of the impact of financial incentives and disincentives on energy efficiency investments, along with recommendations for optimizing their effectiveness, is presented below:

1. **High Upfront Costs**: The significant initial investment required for implementing NZEB technologies and design strategies acts as a major deterrent for developers and building owners.
2. **Need for Financial Incentives**: To make NZEBs economically viable, it is essential to introduce financial incentives, innovative financing models, and effective market mechanisms.
3. **Circular Economy Principles**: Integrating circular economy principles into the materials industry can substantially reduce waste generation and promote resource efficiency.
4. **Promoting Green Buildings**: Incentives aimed at promoting energy-efficient buildings are essential to create momentum and expand the adoption of green buildings across the country.
5. **Consumer-Level Incentives**: Providing consumer-level incentives is necessary to encourage the adoption of more energy-efficient technologies and to drive widespread behavioural change.
6. **Access to Financing and Risk Perception**: Limited access to financing and the perceived risks associated with innovative technologies hinder the progress of energy efficiency initiatives.
7. **Awareness and Education**: There is a pressing need to enhance awareness and education among stakeholders, including builders, architects, engineers, policymakers, and consumers, to effectively overcome barriers to the adoption of energy-efficient practices in India.

A pipeline for bankable low carbon buildings, a green finance network and an OSS platform for investor matchmaking will be developed under the ALCBT project.

5. Conclusion

5.1 Energy Efficiency as a Cornerstone of India's Future

Energy efficiency plays a vital role in addressing climate change and ensuring long-term sustainability in the building sector. India's energy demand is projected to grow significantly in the coming years, driven by post-pandemic economic recovery, increased urbanization, and greater penetration of residential end-use appliances. By 2030, the total electricity demand in the country, including captive demand (excluding transmission and distribution losses), is projected to be 2,060 – 2,699 TWh.[35]

Energy efficiency offers multiple benefits:

- **Environmental**: Reduces carbon emissions, conserves natural resources, and mitigates the impacts of climate change
- **Economic**: Promotes investments in sustainable and environmentally friendly spaces, enhances property values, and improves marketability.
- **Social and health**: Improves thermal comfort, indoor air quality, and ample natural lighting, contributing to higher productivity, comfort, and satisfaction among building occupants.

The Indian government has implemented several initiatives to enhance energy efficiency across different building typologies in an effort to mitigate rising electricity demand and achieve its NDCs. However, identifying and tracking building-related actions within the NDCs can be challenging, as buildings are not addressed as a stand-alone category. This reflects the complexity and cross-cutting nature of the sector, where several ministries or agencies have a stake in climate action, leading to fragmentation and difficulty in mapping existing climate measures.

One of the pivotal efforts taken is the launch of the ECBC for commercial buildings and the ENS codes for residential buildings. In addition, the government's UJALA scheme has promoted the widespread use of energy-efficient LED bulbs and appliances, significantly reducing electricity consumption in the residential sector. Through these efforts, India aims to achieve its NDCs targets by reducing carbon emissions and improving energy efficiency across building typologies. These initiatives collectively contribute to lowering energy consumption, cutting emissions, and enhancing sustainability in both commercial and residential buildings.

5.2 Building a Coalition and Unleashing Innovation for Energy Efficiency in Building Sector

As India continues to pursue its ambitious energy and climate objectives, the significance of state-level policies on energy efficiency and emission control becomes increasingly evident. These policies are not only integral to the nation's environmental stewardship but also serve as powerful catalysts for comprehensive progress. In this context, adopting a holistic, forward-thinking, and performance-based approach is essential. The primary objective of this initiative is to establish a robust coalition that harnesses collaborative efforts and innovative solutions to significantly enhance energy efficiency in India's building sector. The key components of this collaborative approach are outlined below:

1. **Policy and Regulatory Advocacy**: Advocate enabling policies and regulations at central and state levels, including building codes that mandate energy-efficient practices, incentives for

[35] Vasudha Foundation, *An Outlook of India's Electricity Demand: Analysis and Projections to the Next Decade* (New Delhi: Vasudha Foundation, 2024), http://www.indiaenvironmentportal.org.in/files/file/an%20outlook%20of%20india%20electricity%20demand.pdf.

green building certifications, and financial mechanisms such as subsidies and tax breaks for energy-efficient technologies.

2. **Technology Adoption**: Promote the adoption of energy-efficient technologies and building designs through capacity building initiatives. This could involve pilot projects, demonstrations of new technologies, and knowledge-sharing platforms that showcase best practices and success stories.

3. **Monitoring and Evaluation**: Establish mechanisms to monitor progress, evaluate effectiveness, and refine strategies for continuous improvement. This approach enhances speed, consistency, and transparency of energy efficiency projects, thereby significantly boosting the market.

4. **Stakeholder Engagement**: Engage key stakeholders, such as government agencies (MoHUA, MoP, MoEFCC, SDAs), industry associations, and community groups, to foster a unified approach to energy efficiency. This involves advocating for building code improvements, promoting incentives, encouraging adoption of energy-efficient practices and technologies, and facilitating joint research on building performance, energy modelling, and lifecycle assessments of sustainable materials.

5. **Financing Mechanisms:** Securing funding and resources from both public and private sectors to support initiatives aimed at improving energy efficiency in buildings. This can involve developing green financing products, facilitating access to funding for energy retrofits, and promoting investment in renewable energy technologies integrated into buildings.

6. **Market Outreach and Awareness:** Raise awareness among stakeholders and the public about the benefits of energy-efficient buildings and their role in advancing sustainability. By encouraging behavioral changes, such as optimizing energy use and adopting sustainable practices in daily operations, the coalition helps cultivate a culture of energy conservation. Through collaboration and collective action, it aims to significantly reduce energy consumption and carbon emissions in India's building sector.

5.3 International Best Practices

In response to the increasing complexity of construction and building operations, integrating global insights and innovations is essential to enhance **efficiency**, **sustainability**, and **resilience** in the Indian building sector. International best practices offer strategic models and exemplary case studies that can inform national approaches. Key practices relevant to the Indian context include carbon pricing, building taxonomy, mandatory adoption of codes, mandatory renewal of green building certification, and carbon credits markets.

1. **Carbon pricing** is a widely used mechanism globally, with nearly 25% of global GHG emissions currently covered by such policies. It internalizes the environmental cost of GHG emissions in goods and services. Two most common approaches are **carbon taxes** and **emission trading systems (ETS)**, also **called cap-and-trade systems**. Countries such as Germany, European Union, China, and Canada are well advanced in their implementation and execution of carbon pricing at various sectoral level, mobilizing finance toward climate-resilient investments.

2. **Buildings Taxonomy** features as a priority sector in the Government of India's draft Climate Finance Taxonomy (May 2025), presenting a timely opportunity to align a dedicated classification framework for buildings with the national taxonomy. A Building Taxonomy would serve as a convergence platform—harmonizing diverse national and sub-national policies, certifications, and regulations to create a unified, nationally endorsed definition of sustainable buildings. This alignment would enhance investor confidence, streamline regulatory approvals,

and support consistent tracking of buildings against national and global climate goals. Drawing from models like the EU Taxonomy, which defines criteria such as Primary Energy Demand (PED) thresholds for new construction, India can adopt a performance-based, locally adapted approach to ensure both credibility and coherence.

3. **Carbon credits** facilitate a market-based mechanism for reducing emissions by enabling the **buying, selling, and trading emission permits**. Each carbon credit allows the emission of one metric ton carbon dioxide (CO_2) or an equivalent amount of other GHGs. These credits are designed to incentivize investments in renewable energy, green building construction, and energy retrofits for existing infrastructure. Many countries, such as Uzbekistan, Australia, Japan, and Vietnam, have implemented carbon credit systems.

4. **Carbon taxes** are policy instruments designed to reduce GHGs by **increasing the prices of fossil fuels** that release emissions when burned. These taxes generally fall into two categories: **emissions taxes**, which are based on the quantity of GHGs emitted; and **product-based taxes**, which apply to goods or services that are GHG intensive. Countries such as Finland, Sweden, and Norway were among the first to introduce carbon taxes in 1900s.

5. **Cap-and-trade systems** are market-based approaches designed to reduce emissions cost-effectively by **placing a cap on total emissions and allowing the trading of emission allowances** among regulated entities. It works as a "command-and-control" approach where the government sets performance standards or dictates technology choices for individual facilities. Cap and trade allow the market to determine a price on carbon, and that price drives investment decisions and spurs market innovation. China has the world's largest carbon market, with a national carbon trading scheme that covers the power sector. In the United States, eleven states participate in the Regional Greenhouse Gas Initiative (RGGI), a cap-and-trade program focused on reducing CO_2 emissions from electricity generation.

6. The initiative to promote **R&D activities in building sector** aims to **improve the energy performance** of buildings and cities. It also seeks to **enhance knowledge and best practices** in the design, construction, and operation of human habitats. Key areas include energy demand reduction through improved building envelope design, low energy cooling & heating, and social practices of adaptive thermal comfort and post-occupancy evaluation. Special emphasis is placed on cooling technologies that require radically less energy, use of refrigerants with no ozone depletion potential, and low GWP, and are cost effective at scale.

5.4 Upcoming Program

Several international organizations, including the UNDP, UNEP, and GGGI, are actively supporting the promotion of building energy efficiency in India. These organizations collaborate with various stakeholders, including national and subnational governments, the private sector, and civil society, to implement programs aimed at reducing energy consumption, enhancing sustainability, and contributing to India's climate goals.

Ongoing and upcoming initiatives under the BEE Program in India include:

1. **Delivery of LCB Training Program** for Architects, developers, contractors, energy auditors and ESCOs as a part of ALCBT – GGGI Initiative.

2. **Delivery of Training Program** for government and financial institutions as a part of ALCBT – GGGI Initiative.

3. **Delivery of Training Program** for material manufacturers and technology providers as a part of ALCBT – GGGI Initiative.

4. The UNEP-convened **Climate and Clean Air Coalition (CCAC)** has deepened its role in aligning building energy efficiency with climate and air quality agendas, building momentum through its growing network of 90 partner countries.
5. **REC Ltd.**, under MoP, Government of India, issued USD 500 million in internationally verified Green Bonds with technical support from GGGI.
6. **Maharashtra Strengthening Institutional Capabilities in Districts for Enabling Growth Operation** supported by World Bank

Over the past 20 years, India has undertaken numerous projects and initiatives aimed at mainstreaming building energy efficiency. Despite these efforts, the impacts and transitions toward energy efficiency have been limited due to various local constraints, such as financial and regulatory challenges. To achieve the country's NDC targets and the goal of net-zero emissions by 2070, as well as to meet future urbanization demands, it is crucial to accelerate the execution of existing codes and initiate various programs tailored to the local context. By addressing these challenges through a more human-centered approach, India can realize a more sustainable, equitable, and energy-efficient built environment.

Figure 25: Launch of ALCBT project training program & Orientation for Master Trainers, January 21, 2025

Figure 26:" Low Carbon Buildings Training Program" for Master Trainers in Hyderabad, April 28 & 29, 2025

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Annexure 1

The timeline presented here chronicles the significant efforts of international development agencies (IDAs) in the building sector, starting from the year 2000. It highlights pivotal contributions aimed at enhancing sustainability and energy efficiency. Along the X-axis, you can observe a chronological progression of various key activities, including the release of publications, capacity-building initiatives, establishment of standards, execution of demonstration projects, and the development of tools and software. The Y-axis, on the other hand, categorizes these contributions into three main sectors: commercial buildings, residential buildings, and green building materials. This comprehensive timeline provides a holistic overview, showcasing the evolution and impact of IDA efforts in promoting sustainable practices and energy efficiency in the building industry over the past two decades

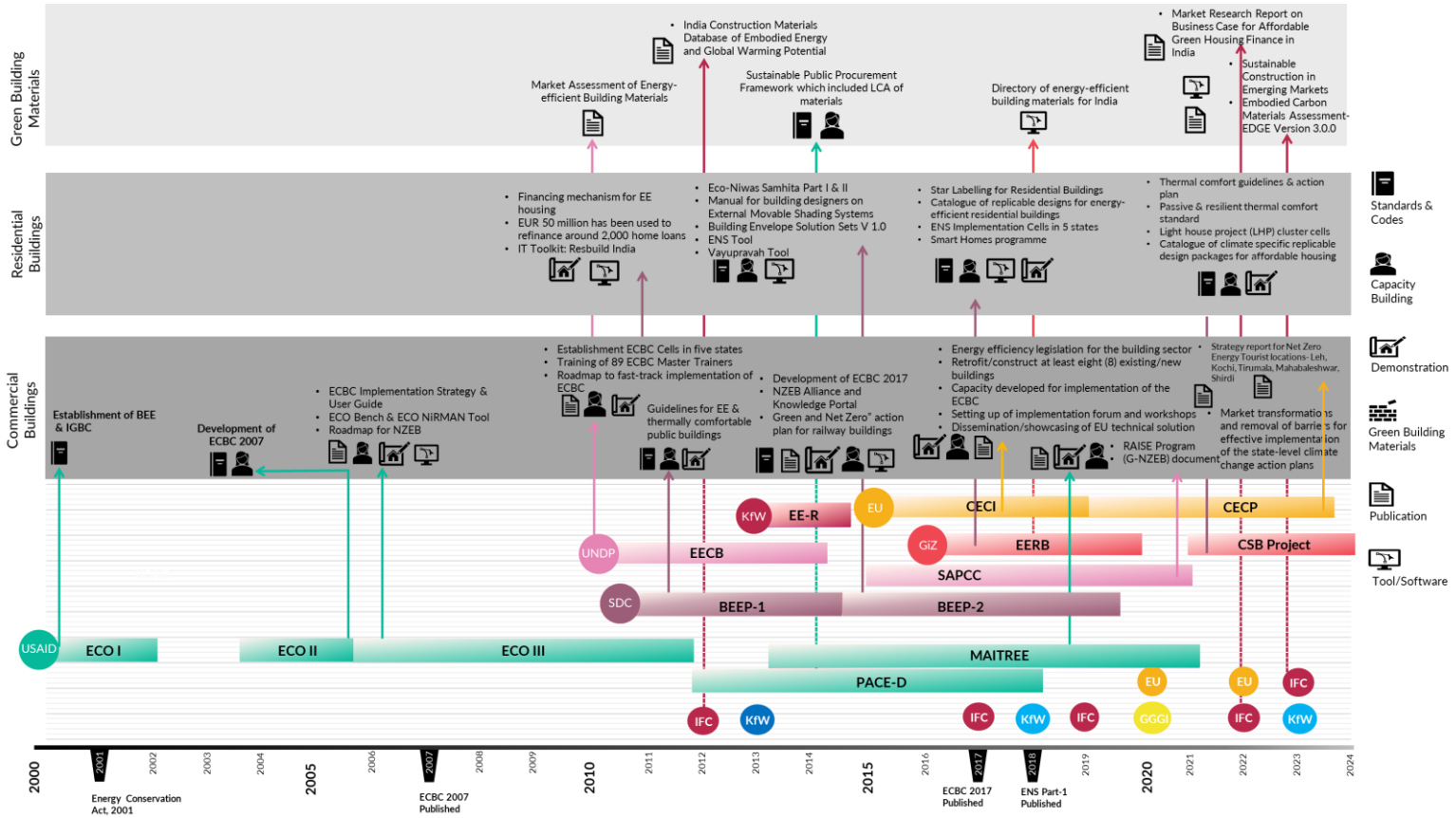

Figure 27: International Development Agencies contributions

Annexure 2

Indira Paryavaran Bhawan, India

Introduction
Indira Paryavaran Bhawan, the new office building for Ministry of Environment and Forest (MoEF) sets is a radical change from a conventional building design.

The project team put special emphasis on strategies for reducing energy demand by providing adequate natural light, shading, landscape to reduce ambient temperature, and energy efficient active building systems. Several energy conservation measures were adopted to reduce the energy loads of the building and the remaining demand was met by producing energy from on-site installed high efficiency solar panels to achieve net zero criteria. Indira Paryavaran Bhawan uses 70% less energy compared a conventional building. The project adopted green building concepts including conservation and optimization of water by recyclingwaste water from the site

Summary'	
Location	New Delhi
Occupancy Type	Office
Construction	New
Climatic zone	Composite
Project Area	9.5 m2
Grid Connectivity	Grid
EPI	44 kWh/m2/yr

Passive Strategies

- **Orientation**: Building is north south oriented, with separate blocks connected through corridors and a huge central court yard
- **Landscaping**: More than 50% area outside the building is covered with plantation
- **Daylighting**: 75% of building floor space is day lit
- **Ventilation**: Central courtyard helps in air movement as natural ventilation happens due to stack effect.
- **Optimized Building Envelope** – Window assembly (U-Value 0.049 W/m2K),VLT 0.59, SHGC 0.32
- **Cool roofs**: Use of high reflectance terrace tiles for heat ingress, high strength, hard wearing
- Rock wool insulation for building envelope

Active Strategies

Lighting Design- Energy efficient lighting system (LPD = 5 W/m2)
Optimized Energy Systems / HVAC system-
Chilled beam system/ VFD/ Screw Chillers
- 160 TR of air conditioning load of the building is met through Chilled beam system.
- HVAC load of the buildings is 40 m2/TR, about 50% more efficient than ECBC requirements
- Water cooled chillers, double skin air handling units with variable frequency drivers(VFD)
- Room temperature is maintained at 26 ±1 ° C

Geothermal heat exchange system
- There are 180 vertical bores to the depth of 80 meter all along the building premises
- One U-Loop has 0.9 TR heat rejection capacity. Combined together, 160 TR of heat rejection is obtained without using a cooling tower.

Renewable Energy

Solar PV System of 930 kW capacity
Total Area: 6,000 m2
Total Area of panels: 4,650 m2
No of panels: 2,844
Annual Energy Generation: 14.3 lakh unit

✓ Reduced energy cost ✓ Increased competitiveness ✓ Improved grid resilience ✓ Lower GHG emission ✓ Enhanced energy security ✓ Job creation ✓ Energy poverty alleviation ✓ Improved public health

Figure 28: Demonstration project details for economic and social benefits in India- 1

Jaquar Headquarters, India

Introduction

The Jaguar Headquarters located at Manesar is not only a beautiful building but a meticulously designed facility featuring cutting-edge technology solutions resulting in a net zero campus with a certified LEED Platinum (USGBC) rating. This project is reputed for being a visual treat with challenging organic design and space planning.

The design redefines a corporate space by making it a memorable experience though its iconic wing-shaped architecture. The horizontal glass building is topped by the sweeping wings of a metaphorical eagle, ready to take flight, symbolizing a company with global ambitions.

Summary	
Location	Haryana
Occupancy Type	Corporate and Manufacturing
Construction	New
Climatic zone	Composite
Project Area	48,000 m2
Grid Connectivity	Grid

Passive Strategies

- **Site layout & Planning:** The final design houses the corporate office on top and the factory below. The landscape is berm shaped and raises the drop off point by 8 meters, providing space for an elaborate, planned landscape with water features
- **Climate Responsive Design:** Minimal dependence on artificial lighting and air conditioning, natural light to the internal spaces while also providing shading and reduced the cooling load.
- **Form and Massing:** Staggered floor plates not only give an iconic appeal to the building but also help in channeling the surrounding air movement.
- **Facade and Envelope**: The façade of the building is covered in zinc panels. Zinc is a very resistant material averse to corrosion and dust.

Active Strategies

- **Cooling design:** The HVAC system comprises of a conventional cooling system, radiant cooling, heat pump, VRF indoor/outdoor, and ventilation mechanism.
- **Conventional Cooling Systems:** The high side comprises of one water cooled screw chiller of 232 TR capacity. For generating energy savings, secondary pumps are integrated with variable frequency drives which modulate them.
- **Radiant Cooling Systems:** It comprises of one water cooled screw chiller of 186 TR capacity. Secondary pumps are integrated with variable frequency drives which help in energy savings
- **Heat Pump System**: Depending upon the heat load and thermal comfort requirement, the facility can operate the heat pump.
- **Lighting Design:** All installed lighting are LEDs

Renewable Energy

The total installed solar plant capacity is 971.4 kWp. The project produces 122% of its electricity as on-site generated renewable electricity from solar photovoltaic panels. The panels are installed at the warehouse terrace and over the car parking space.

✓ Reduced energy cost ✓ Increased competitiveness ✓ Improved grid resilience ✓ Lower GHG emission ✓ Enhanced energy security ✓ Job creation ✓ Energy poverty alleviation ✓ Improved public health

Figure 29: Demonstration project details for economic and social benefits in India- 2

About the Asia Low Carbon Building Transition (ALCBT) Project:

The ALCBT Project is a five-year multi-stakeholder project that aims to facilitate the nationwide transition towards Low Carbon Buildings in five Asian countries namely, Cambodia, India, Indonesia, Thailand, and Vietnam. In India, ALCBT project will institutionalize the Building Carbon Assessment (BCA) tools and approaches, build the capacity of public and private sector entities, and link BCA to the implementation of building energy codes in three states. It will enhance building energy codes towards nationally determined ambitious standard using CO2eq/ m2/ year as a common performance metric. Successful implementation of the project will substantially reduce direct GHG emissions from the building sector by 2028. The ALCBT project is being implemented by the Global Green Growth Institute (GGGI) is partnership with Energy Efficiency Services Limited (EESL) from India, HEAT International from Germany, and ASEAN Centre for Energy (ACE) from Indonesia. It is supported by the Government of Germany through its Federal Ministry for Economic Affairs and Climate Action (BMWK) under the International Climate Initiative (IKI).

About Global Green Growth Institute (GGGI):

The Global Green Growth Institute (GGGI), headquartered in Seoul, Republic of Korea is a treaty-based international, inter-governmental organization dedicated to supporting and promoting strong, inclusive and sustainable economic growth in developing countries and emerging economies. GGGI spearheads the ALCBT project, driving national engagements and creating standardized tools for carbon management in the building sector. It also boosts regulator and practitioner expertise for low carbon building, facilitates financial avenues for such projects, and fosters the spread of best practices.

About ASEAN Centre for Energy (ACE):

The ASEAN Centre for Energy (ACE) is an intergovernmental organisation within the Association of Southeast Asian Nations' (ASEAN) structure that represents the 10 ASEAN Member States' (AMS) interests in the energy sector.

About Energy Efficiency Services Limited (EESL):

A joint venture of NTPC Limited, Power Finance Corporation, Rural Electrification Corporation and POWERGRID, Energy Efficiency Services Limited (EESL) was set up under the Ministry of Power to facilitate implementation of energy efficiency projects. EESL is a Super Energy Service Company (ESCO) that seeks to unlock energy efficiency market in India, estimated to at Rs. 74,000 crore that can potentially result in energy savings of up to 20 per cent of current consumption, by way of innovative business and implementation models. It also acts as the resource centre for capacity building of State DISCOMs, ERCs, SDAs, upcoming ESCOs, financial institutions, etc.

About HEAT International:

HEAT is an independently acting consulting firm with 30 years of experience in the field of climate, heating & cooling, and transport. HEAT's goal is to support countries in their effort to mitigate emissions and to implement transformative pathways towards zero GHG emission solutions. In this effort, HEAT consults national and international organisations, normative institutions as well as state and non-state actors on the implementation of relevant international frameworks such as the UNFCCC, the Paris Agreement (1992; 1997; 2015), the Montreal Protocol and the Kigali Amendment (1987; 2016) and respective national legislations.

GGGI

ASIA LOW CARBON BUILDINGS TRANSITION
Life Cycle Assessment for Transitioning to a Low-Carbon Economy | PROJECT

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