Efficient Grid-Interactive Buildings in India

Status and opportunities

International Energy Agency

INTERNATIONAL ENERGY AGENCY

The IEA examines the full spectrum of energy issues including oil, gas and coal supply and demand, renewable energy technologies, electricity markets, energy efficiency, access to energy, demand side management and much more. Through its work, the IEA advocates policies that will enhance the reliability, affordability and sustainability of energy in its 32 Member countries, 13 Association countries and beyond.

IEA Member countries:

Australia
Austria
Belgium
Canada
Czech Republic
Denmark
Estonia
Finland
France
Germany
Greece
Hungary
Ireland
Italy
Japan
Korea
Latvia
Lithuania
Luxembourg
Mexico
Netherlands
New Zealand
Norway
Poland
Portugal
Slovak Republic
Spain
Sweden
Switzerland
Republic of Türkiye
United Kingdom
United States

The European Commission also participates in the work of the IEA

IEA Association countries:

Argentina
China
Egypt
India
Indonesia
Kenya
Morocco
Senegal
Singapore
South Africa
Thailand
Ukraine
Viet Nam

Source: IEA.
International Energy Agency
Website: www.iea.org

Abstract

This report assesses the opportunities for efficient grid-interactive buildings (EGIBs) to support India's clean energy transition. EGIBs unite energy efficiency, smart digital technologies and demand-side flexibility, allowing them to optimise energy use, shift or reduce peak demand and better align consumption with renewable energy generation.

The buildings sector is central to clean energy transitions in a context where rapidly increasing electricity demand is driven by cooling and appliance use, and the share of variable renewable energy in electricity generation is continuously growing. Without targeted action, unmanaged peak loads and variable supply could jeopardise grid stability and increase system costs. EGIBs offer an important solution for optimising electricity use, reducing peak demand and enhancing system flexibility.

Applying a structured framework, this report assesses India's policy landscape and opportunities across efficiency, decarbonisation, smartness, resilience, materials and building-to-grid interaction. It concludes with recommendations for a comprehensive policy package that encompasses regulations, incentives and information. Scaling up the adoption of efficient grid-interactive buildings would enable India to align its fast-growing building stock with national climate goals and international commitments while lowering system costs and enhancing energy security.

Acknowledgements, contributors and credits

This report was prepared by the International Energy Agency (IEA) Office of Energy Efficiency and Inclusive Transitions in the Directorate of Energy Markets and Security. It was authored by Ksenia Petrichenko and Simrat Kaur. Melanie Slade, Senior Programme Manager of the Energy Efficiency in Emerging Economies (E4) Programme, provided overall guidance. Keisuke Sadamori, Director of Energy Markets and Security, and Brian Motherway, Head of the Office of Energy Efficiency and Inclusive Transitions, provided strategic direction.

The authors would like to extend their gratitude to Ian Hamilton for his invaluable review and feedback on the analytical framework, methodology and policy recommendations.

Several IEA colleagues provided valuable inputs, comments and feedback (in alphabetical order): Chiara Delmastro, Sangitha Harmsen, Lucien Hua, Roland Gladushenko, Axel Nordin Furdos and Anthony Vautrin.

The work was carried out in close collaboration with India's Bureau of Energy Efficiency, the continued engagement and expertise of which were essential to this report.

The authors also wish to thank the members of the Technical Working Group that was established to support this work for their active participation in consultations, data sharing and insights on related developments in India, and for their review of preliminary drafts. Their contributions were instrumental in shaping the assessment and tailoring policy recommendations to the national context. Members of the Technical Working Group were (in alphabetical order):

Pratik Agarwal	Electric Power Transmission Association
Sumedh Agarwal	Alliance for an Energy Efficient Economy
Dhruvak Agarwal	Council on Energy, Environment, and Water
Kanagaraj Ganesan	Integrative Design Solutions
Tarun Garg	Rocky Mountain Institute India
Gerry George	Natural Resources Defense Council India
Akash Goenka	Natural Resources Defense Council India

Abhishek Gupta	Energy Efficiency Services Limited
Arjun Gupta	Smart Joules
Shweta Kulkarni	Prayas Energy Group
Mahesh Patankar	MP Ensystems
Sabyasachi Pattanaik	Oracle Utilities - OPower
Chandana Sasidharan	World Resources Institute India
Pramod Singh	Alliance for an Energy Efficient Economy
Reena Suri	India Smart Grid Forum
Gyan Prakash Upadhyaya	Electric Power Transmission Association
Reshmi Vasudevan	MP Ensystems
Rohit Vijay	Centre for Social and Economic Progress

The authors would also like to thank colleagues from the IEA Communications and Digital Office (CDO) for their assistance in producing this publication, in particular Astrid Dumond and Liv Gaunt for communication support for the report, as well as Philip Swanson for editing the report.

Table of contents

Executive summary

Efficiency, electrification and flexibility are at the heart of India’s clean energy transitions

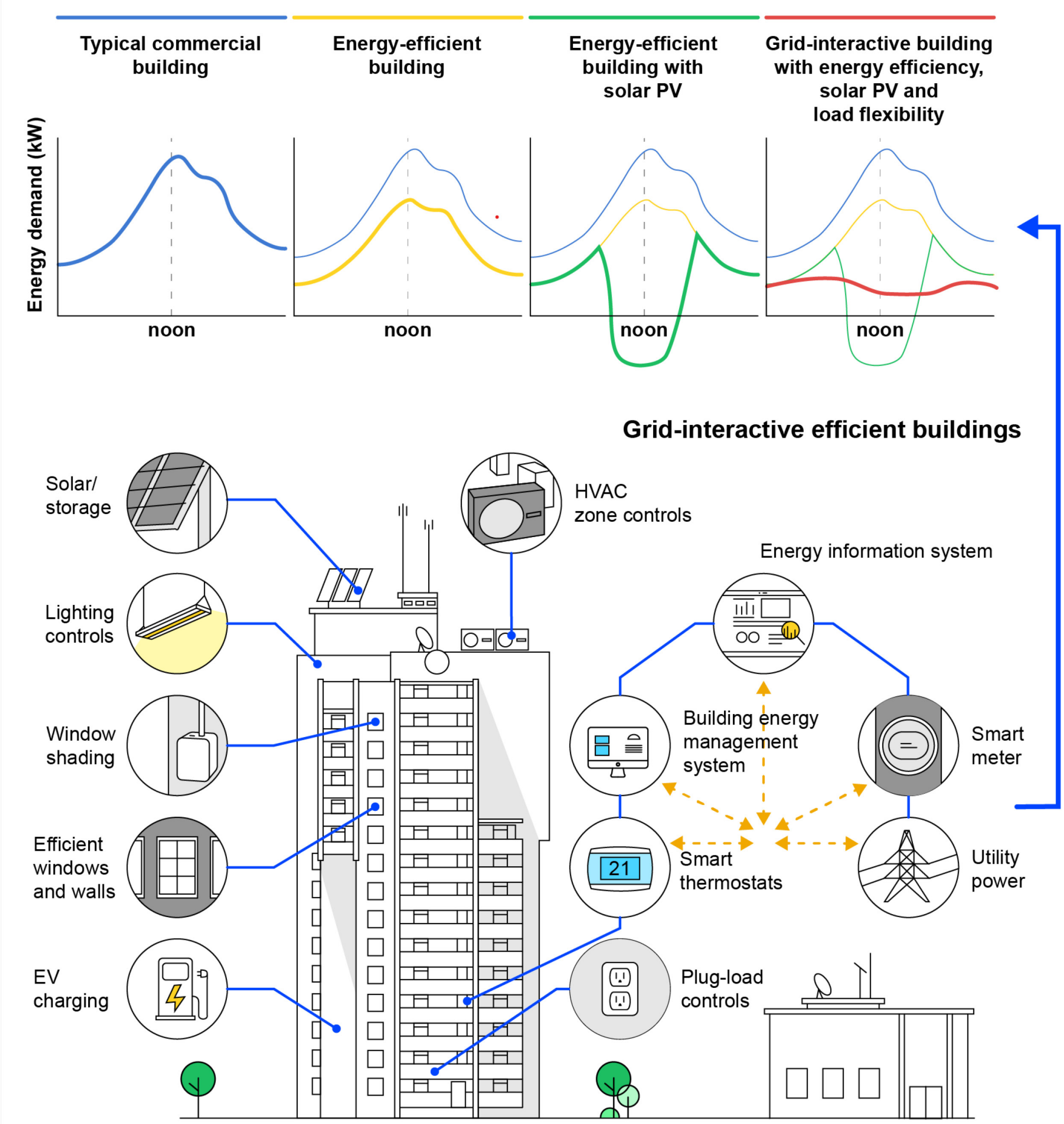
Evolving trends in India’s energy system put buildings at the crossroads of two critical priorities: optimising growing energy demand and managing variable supply. As India urbanises and incomes rise, energy use in buildings has been increasing at nearly 2% per year since 2010, exceeding 8 EJ in 2023. This growth has been driven by expanding floor space, increasing appliance ownership and growing demand for thermal comfort. Energy use in buildings accounts for over one-third of the country’s total final energy demand and is expected to rise steadily in the coming decades. At the same time, the power system is undergoing a major transformation, with variable renewable generation (particularly solar and wind) expanding at an unprecedented pace. It is estimated that India could add close to 345 GW of renewable electricity capacity between 2025 and 2030 (under the Accelerated case), more than tripling its 2022 level. These trends make buildings both a critical source of demand growth and a key potential provider of flexibility within the energy system.

Flexibility in buildings helps integrate renewables and manage peak electricity demand. India’s peak demand is already reaching new record highs and is likely to continue growing steadily in the coming decades. Buildings are estimated to account for more than half of this future growth, putting significant pressure on the power grid. Within the buildings sector, space cooling is the largest and fastest-growing driver of peak electricity demand as rising temperatures and more frequent heatwaves accelerate the need for air conditioning. Meeting this growing demand through increasing energy supply would require building additional generation and network capacity that would be used for only a few hours each day. Such investments would be expensive, lock in higher emissions and increase overall system costs. Managing peak demand through realising flexibility potential in buildings – by shifting or reducing their consumption during high-demand hours – offers a cost-effective alternative that enhances system efficiency and reliability.

Efficient grid-interactive buildings could deliver benefits to both the system and consumers

Efficient Grid-Interactive Buildings provide a strategic pathway to ensure that the growth of India’s buildings sector supports rather than strains the power system. EGIBs combine high levels of energy efficiency with smart digital controls and the ability to interact dynamically with the electricity grid. EGIBs are energy-efficient, connected, smart and flexible. Efficiency involves the use of high-performance building envelopes, as well as appliances and systems that optimise energy consumption in an efficient manner. Smartness refers to the deployment of sensors, controls and analytics to monitor and optimise building operations. Connectivity enables buildings to exchange signals with the grid and respond to changes in supply and demand. Flexibility means that it is possible to adjust energy use in buildings in real time by shifting loads, storing energy or supplying excess electricity back to the grid. This transforms buildings from passive consumers into flexible assets that support system stability and the integration of renewables. At the same time, these features of EGIBs can enhance comfort, reduce consumer bills, and improve resilience to outages and extreme weather, achieving the best results for both occupants and the grid.

Efficient grid-interactive buildings: Technologies and demand flexibility benefits

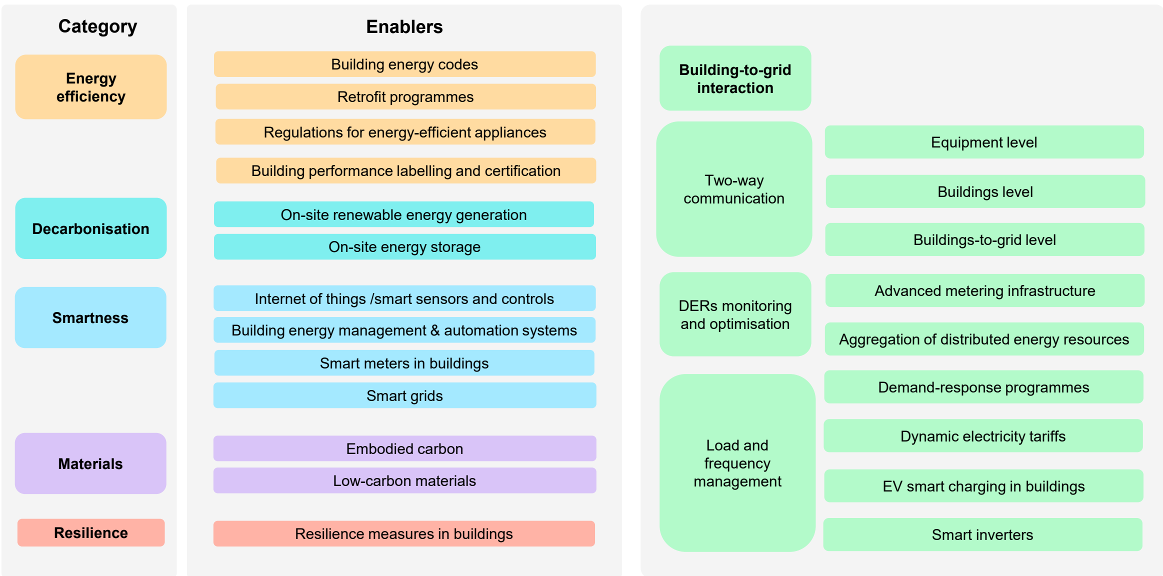


Notes: kW = kilowatts; HVAC = heating, ventilation and air conditioning.
Source: IEA (2022), Unlocking the Potential of Distributed Energy Resources.

Comprehensive actions are required throughout a building's lifecycle

The transformation of buildings into efficient, grid-interactive assets depends on a policy and regulatory ecosystem that enables technological adoption and market readiness. This report applies a structured framework to assess the maturity of the ecosystem through a set of defined enablers – essential attributes that collectively determine a country's potential and readiness to advance efficient and grid-interactive buildings. The methodology evaluates the presence, strength, and level of implementation of these enablers, offering a benchmark for assessing the current policy landscape. The enablers are organised into six overarching categories: (1) energy efficiency, (2) decarbonisation, (3) smartness, (4) materials, (5) resilience, and (6) building-to-grid interaction.

Enablers for efficient grid-interactive buildings

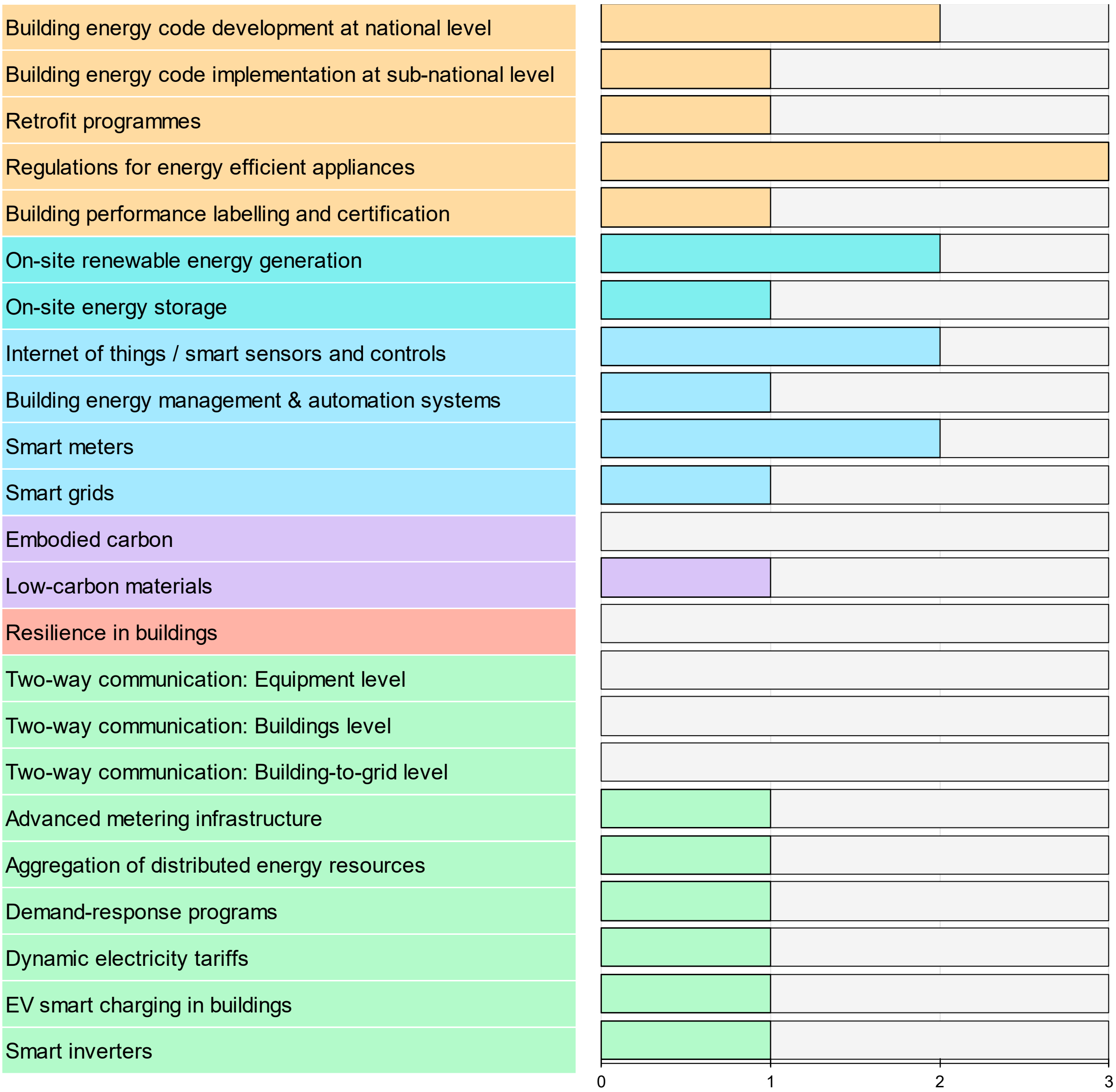


Note: DER = distributed energy resource.

The report evaluates each enabler in order to determine the current level of progress, identify priorities and inform the development of policy recommendations. The lowest level means that *policies are not yet in place* for that enabler, highlighting an opportunity to develop governance or institutional readiness. This is followed by an *initial development stage*, where early initiatives demonstrate emerging policy intent through voluntary policies and/or pilot programmes. The next stage, *consistent developments*, indicates the presence of mandatory policies or programmes with partial or limited coverage. The highest level, *developments at scale*, denotes a mature policy environment with comprehensive, mandatory frameworks that are effectively implemented at scale. This graduated assessment enables cross-country comparison of policy progress and highlights priority areas for strengthening institutional capacity, regulatory coherence and market readiness to accelerate the adoption of efficient and grid-interactive buildings.

India's policy framework demonstrates an enabling foundation and emerging opportunities to scale up efficient grid-interactive buildings

Assessment of current policy framework by enablers



Notes: Scoring scale: 0 = Policies not yet in place, 1 = Initial developments, 2 = consistent developments, 3 = developments at scale.

As in many countries, India, in some areas, is only starting to explore the opportunities for efficient grid-interactive buildings. Many smart and digital solutions are still relatively new, requiring time and sustained effort for scaled implementation. The fact that India is actively developing policy frameworks and implementing pilot projects related to efficient grid-interactive buildings is a clear sign that the country has already laid a strong foundation and is following a deliberate, phased approach - prioritising core efficiency measures, appliance standards, and digital infrastructure first, while progressively preparing the market and institutions for more advanced building-to-grid interactions.

This staged progression reflects the natural evolution of complex energy system transformations, where early investments in energy efficiency, smart metering, and digitalisation create the necessary enabling conditions for scaling advanced demand response, aggregation, and two-way communication solutions over time.

India's strong policy base in energy efficiency, on-site renewables and smart systems, combined with emerging action across building-to-grid interaction, supports the country's pathway toward efficient grid-interactive buildings.

Energy efficiency

India has established a robust policy framework for promoting energy efficiency in buildings through its Energy Conservation and Sustainable Building Codes and Standards and Labelling programme for appliances. The national building energy codes are relatively comprehensive, incorporating requirements for energy efficiency and on-site renewables, and are regularly updated. Currently, however, the codes only apply to larger buildings, covering less than 10% of the total building stock. Implementation also remains uneven due to challenges in state-level adoption, including limited institutional capacity. India's Standards and Labelling programme is among the most comprehensive globally, covering all major appliances and driving significant efficiency gains. With cooling being one of the strongest drivers of the growing electricity demand, strengthening minimum energy performance standards for air conditioners is a key priority area. Expanding the policy to existing buildings through retrofit programmes that promote upgrades in insulation, glazing, HVAC systems and other efficiency measures would deliver further large-scale benefits. Voluntary labelling and green certification schemes, such as the Indian Green Building Council certification, continue to expand, particularly in the commercial sector. This highlights strong market engagement and the opportunity to scale these initiatives across residential and public buildings as well.

Decarbonisation

India's strong progress in renewable energy deployment and distributed solar adoption provides a solid foundation for decarbonising its buildings sector. The National commitment to triple renewable capacity and ongoing policy support for rooftop solar under schemes such as Surya Ghar are helping integrate on-site generation into the built environment. However, uptake of distributed energy storage remains limited, constraining the ability of buildings to manage variability and provide flexibility to the grid. Strengthening regulatory incentives for building-level renewables and storage, improving grid interconnection standards, and promoting business models that enable consumers to monetise flexibility will be essential for accelerating decarbonisation and advancing toward zero-carbon-ready buildings.

Smartness

India's digital infrastructure and smart grid initiatives are rapidly evolving, creating the basis for smarter, more responsive buildings. The nationwide rollout of smart meters under the Revamped Distribution Sector Scheme is an important step toward enabling real-time energy optimisation and demand response. Early pilot projects under the National Smart Grid Mission mark the start of smart grid expansion. In addition, the gradually expanding use of smart sensors and controls and advanced building energy management and automation systems, particularly within the corporate and commercial sectors, are supporting more efficient, data-driven operations. This limited yet emerging expansion mainly reflects market-led momentum, underscoring both strong private-sector leadership and the potential for policy instruments to catalyse wider uptake.

Materials

India is in the early stages of integrating embodied carbon considerations into building policy, largely due to limited material-level data and the absence of an India-specific life-cycle assessment methodology. Progress is emerging through voluntary rating systems and targeted programmes. These include IGBC's Net Zero Rating System and ash-utilisation guidelines to support fly-ash-based materials, alongside selected state and city initiatives to promote low-carbon construction. However, the lack of mandatory national requirements and standardised benchmarks constrains widespread adoption of low-carbon materials.

Resilience

Resilience-aligned measures are incorporated across several national and state-level initiatives but not yet unified under a comprehensive national mandate. Building codes now include passive design measures that support thermal resilience, and cooling strategies such as cool roofs are gaining traction through the India Cooling Action Plan and state-level Heat Action Plans. A number of States, including Telangana, Delhi, and Gujarat, have introduced cool-roof policies. However, resilience provisions remain distributed across multiple instruments, and the absence of an integrated national framework limits systematic and scalable climate-resilient building practices.

Building-to-grid interaction

Opportunities to strengthen the enabling ecosystem for building-to-grid interaction are emerging through pilot projects and regulatory sandboxes. However, relevant policy and regulatory frameworks are at early stages of development. Communication between smart devices, equipment, building energy systems and grids remains nascent, hindered by the absence of comprehensive interoperability standards, limited automation in buildings and low consumer participation. Strengthening data governance, interoperability frameworks and incentives for smart building technologies will be key to unlocking the full benefits of digitalisation and grid interactivity.

At the grid level, India is making early progress through pilot projects in automated demand response, aggregation of distributed energy resources, peer-to-peer trading and vehicle-to-grid solutions. The rollout of smart meters and the push for time-of-day tariffs under the amendments to Electricity (Rights of Consumers) Rules 2020 mark foundational steps toward price-driven load flexibility, though automated demand response and real-time dynamic pricing are still at an early stage. States have started issuing guidelines for DER aggregation, such as through Green Open Access Rules and demand flexibility. Early vehicle-to-grid pilots show potential, though regulation, market incentives and technical systems are still developing. Overall, pilots and standards are emerging, and clear national frameworks for interoperability, building automation, smart inverters and bi-directional EV charging can help achieve scalable building-to-grid integration.

India is well-placed to scale efficient grid-interactive buildings with an integrated policy package

Implementing energy efficiency measures, smart technologies and solutions for building-to-grid interactions requires a well-designed and integrated policy framework. An effective policy package that combines regulatory instruments, financial incentives and information-based tools would be key for driving improvements in building energy performance and enhancing the flexibility of the broader energy system. Such a framework should be grounded in clear and ambitious – yet achievable – targets, which should then be effectively communicated to all relevant stakeholders. Grounded in global best practices and informed by national expert consultations, resulting policy recommendations outline priority policy actions to accelerate EGIB deployment and position EGIBs as a central pillar of a secure and flexible low-carbon energy future for India.

Policy package recommendations by enabler category

	Regulation	Information	Incentives
Energy Efficiency	Expand mandatory building energy codes to all building types, enforce post-construction verification, mandate disclosure of energy performance during sale/lease, expand appliance minimum energy performance requirements for key equipment and appliances.	Expand building energy performance certification programmes to different building types, conduct public campaigns on energy-efficient homes, build capacity at all governance levels for building energy code implementation, and promote R&D for passive cooling strategies	Link tax breaks and capital subsidies to building energy performance certifications, offer increased floor area bonuses and permitting benefits to buildings with higher performance, support retrofits through public and private finance, and provide performance-based incentives for load flexibility and carbon reduction
Decarbonisation	Mandate rooftop solar during new construction and major renovation of large buildings, require solar-plus-storage readiness (conduits, wiring, safety), align building codes with national energy storage obligations, and streamline battery system permitting.	Raise awareness about benefits of rooftop solar and battery storage, disseminate tools for system sizing and integration, build capacity of architects and installers to design and carry out construction and renovation of buildings that achieve net zero energy performance	Scale up existing incentive programmes to include higher-capacity systems and storage, offer retrofit incentives for solar-plus-storage including low-interest loans, and enable peer-to-peer trading and differential feed-in tariffs for energy exported from storage
Smartness	Amend building energy codes to require smart readiness (e.g. use of smart devices and Building Energy Management Systems), smart meters in large/public buildings, sub-metering for tenants, and mandate EV smart chargers in large new buildings.	Create a Smart Building Toolkit that presents different smart building solutions and their benefits, supported by information campaigns, train distribution companies and building professionals in deployment and use of smart building systems	Provide subsidies or government sales tax relief for building energy management systems and other smart building systems, incentivise distribution companies to expand smart metering and building energy management systems through performance-linked funding
Materials	Introduce embodied carbon reporting for large buildings, require life cycle analysis use in public projects, and mandate use of certified low-carbon materials in public procurement.	Encourage use of the India Construction Materials Database in compliance with building energy code, train professionals on embodied carbon and global warming potential calculations, run campaigns on low-carbon materials options	Award bonus points in building performance certifications for the use of low-carbon material use and verified embodied carbon reductions, support startups and small businesses in manufacturing bio-based and circular construction products
Resilience	Publish voluntary climate-resilient design guidelines (e.g. for passive cooling, flood resistance), integrate resilience recommendations into building codes (thermal comfort during outages, air quality).	Develop state-level toolkits on building resilience risks and needs, provide region-specific climate risk maps, and train local professionals and planners on climate-resilient building practices	Offer floor area ratio bonuses, faster approvals and tax relief for projects with verified climate-resilient design, prioritise resilience retrofits in low-income housing, and award additional points in building performance certification for heat- and flood-adaptive elements
Buildings-to-Grid Interaction	Mandate grid-ready infrastructure in large new buildings (e.g. smart inverters, smart EV chargers), enforce demand-response-ready appliances or devices, enable participation of distributed energy resources and their aggregators in energy markets, and expand use of time of use tariffs for all smart-metered consumers.	Publish national building-to-grid toolkit covering integration of distributed energy resources, grid interaction and control systems; create a public tracking system for demand response events and building-to-grid interaction pilots; engage consumers via information campaigns and digital applications, and build capacity via national training programmes	Provide financial rewards to buildings participating in demand response, create a national certification and labelling for buildings based on their capabilities to interact with the grid, or integrate it into existing building certification schemes, offer subsidies for smart inverters and automation solutions, and fund pilots for aggregation of distributed energy resources and virtual power plants

Policy priorities for Efficient Grid-Interactive Buildings in India

Scaling up efficient grid-interactive buildings could align India's fast-growing building stock with national climate goals, lower system costs, improve energy security and people's wellbeing, while fostering digital, flexible, and resilient buildings as integral parts of sustainable energy systems.

1. **Make EGIBs a cornerstone of India's clean-energy transition**

Efficient grid-interactive buildings combine energy efficiency, renewable integration, and digitalisation to mitigate energy demand growth from buildings operations, cut emissions, reduce peak demand, enhance grid reliability, and strengthen India's pathway to net-zero.

2. **Act now: most of India's 2040 building stock is yet to be built**

Embedding EGIB principles in new construction and retrofit programmes could realise benefits of energy savings, flexibility, and reduced fossil-fuel capacity needs, avoiding locking-in inefficiencies for decades to come.

3. **Develop a comprehensive national policy package**

Integrate regulations, incentives, and information tools across the building lifecycle to accelerate adoption of energy efficiency, smart technologies, and building-to-grid (B2G) functionality.

4. **Strengthen and expand building energy codes**

Scale up state-level adoption and enforcement of the Energy Conservation and Sustainable Building Code for residential and commercial buildings; introduce retrofit mandates for public and commercial buildings; and embed flexibility- and electric-ready provisions in updates of buildings regulations and supporting policy instruments.

5. **Tighten and extend appliance efficiency standards**

Enhance minimum energy performance standards for high-load appliances, especially space cooling equipment, and promote demand-response-ready and smart appliances and devices through labelling and incentives.

6. **Scale up distributed renewables and on-site storage**

Expand rooftop solar and battery storage with smart inverters, standardised interoperability, and financial incentives for two-way communication and participation in grid services.

7. **Accelerate digital infrastructure and data-enabled management**

Achieve nationwide smart-meter rollout by 2028, extend advanced metering infrastructure, require use of building energy management systems in large buildings, encourage use of smart sensors and controllers in buildings.

8. Unlock demand flexibility through dynamic pricing and aggregation

Implement time-of-use tariffs, strengthen demand-response programmes, and enable participation of building owners and aggregators in virtual power plants (VPPs) and other flexibility markets.

9. Invest in innovation, interoperability, and skills

Support: R&D, pilot projects, and capacity-building in DER aggregation; AI-driven energy management; vehicle-to-grid (V2G) integration; and adopt open communication protocols to ensure seamless interoperability.

10. Embed resilience and low-carbon materials in policy development

Integrate climate-resilient design requirements, embodied-carbon reduction targets, and sustainable materials into building regulations, standards, and public procurement to support energy security and job creation.

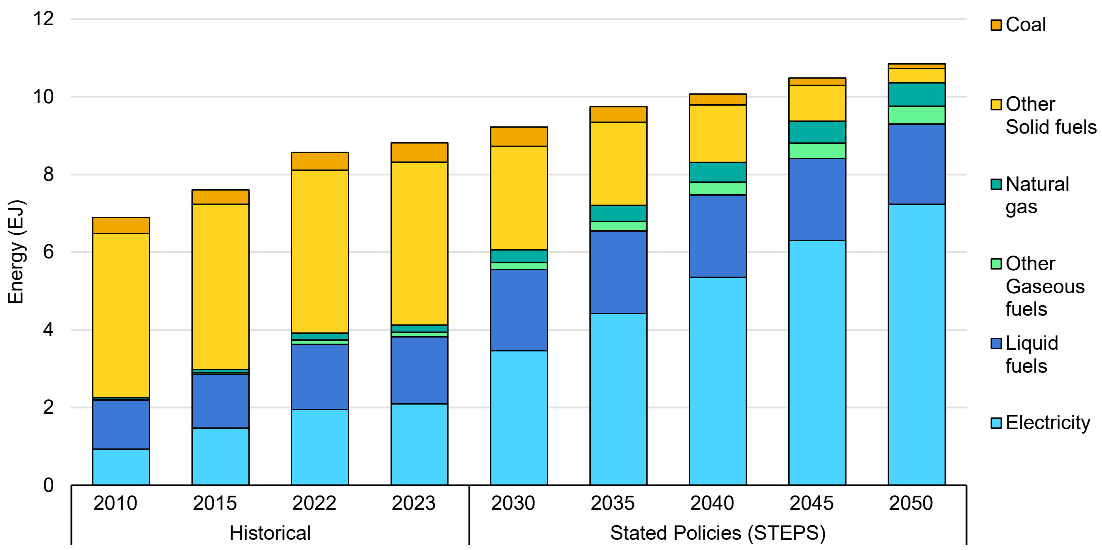
Chapter 1. Buildings-to-grid ecosystem for the clean energy transition

Status of energy efficiency and electrification in buildings

Energy demand in buildings in India continues to grow

Buildings account for over a third of total energy consumption in India. Almost 90% of this is used in residential buildings. Energy demand in India was over 8 EJ in 2023, after increasing at nearly 2% per year since 2010. Under current policy settings in the Stated Policies Scenario (STEPS), building energy demand grows to nearly 11 EJ in 2050.

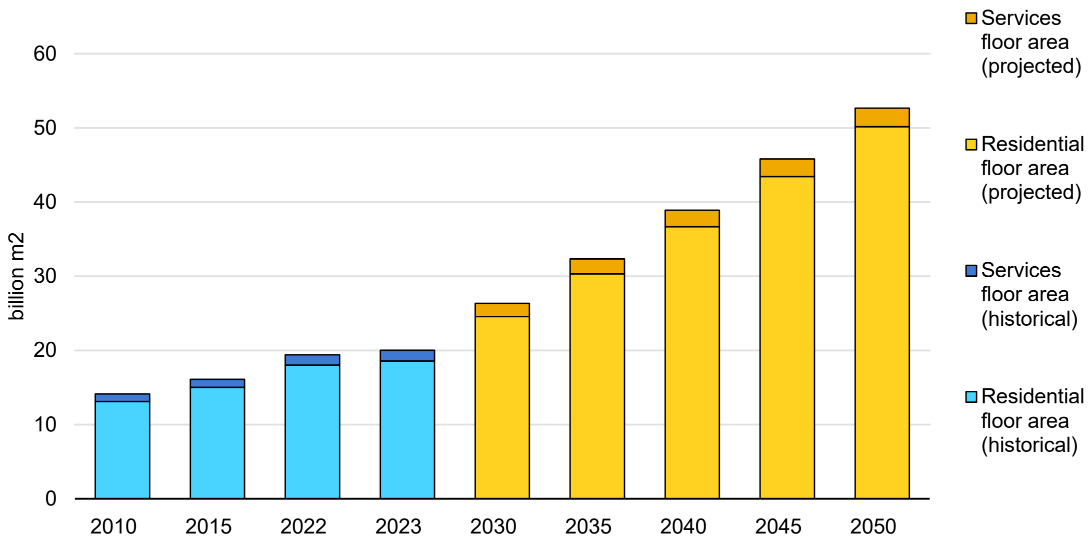
Total final energy consumption in buildings in India



Notes: STEPS = Stated Policies Scenario, which reflects energy-related policies that are currently in place;

Floor area is one of the key drivers of increasing energy demand in India. From 2010 to 2023, the total floor area of buildings in India grew at an average rate of 2.7% per year. The built space in India is set to increase by over 1 billion square metres annually over the next decade, roughly equal to the total existing built space in Punjab. This growth reinforces the importance of improving energy efficiency as early as possible: to mitigate energy demand growth and avoid locking in inefficiencies in buildings for decades to come, thereby lowering future operational energy costs and reducing the need for expensive new system-level energy infrastructure.

Building floor area in India, 2010-2023, and 2030-2050 estimated in STEPS



Until the late 2010s, most cooking in India employed traditional solid fuels, which are inherently low in efficiency and pose significant risks to health and quality of life. Since 2016, the Pradhan Mantri Ujjwala Yojana programme has provided subsidies and incentives for liquefied petroleum gas (LPG) connections to more than 103 million households, helping make LPG the country's primary cooking fuel. The Go Electric campaign and the National Efficient Cooking programme have provided a similar push toward electric cooking.

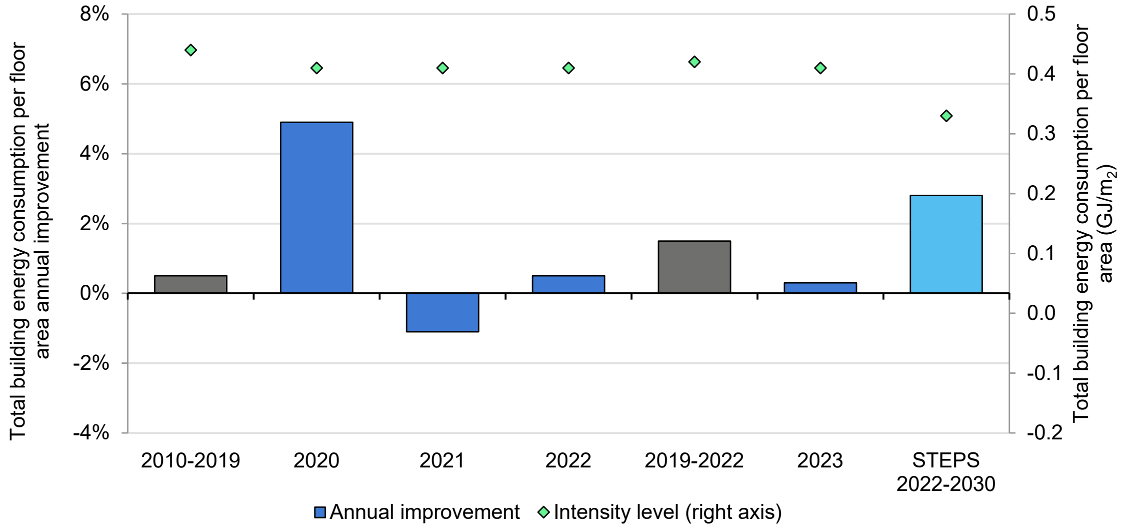
The increased penetration of space cooling will exert an upward pressure on electricity demand in buildings. Household ownership of air conditioners (ACs) in India is still modest compared to advanced economies: Nearly 20% of Indian households currently possess ACs, compared to 90% in the United States and Japan. However, cooling demand in India is projected to grow significantly in the coming years as incomes rise and temperatures increase. In 2024 alone, nearly 14 million ACs were sold in the country, and it is expected that a further 130-150 million units is estimated to be added between 2025 and 2030.

Existing policies pave the way for achieving India's carbon neutrality goals

India's climate and development agenda has long prioritised energy efficiency, beginning with the launch of the National Action Plan on Climate Change (NAPCC) in 2008, followed by the National Mission for Enhanced Energy Efficiency (NMEEE) in 2011. In its 2022 update to the Nationally Determined Contribution (NDC), India set a target to cut the emissions intensity of GDP by 45% by 2030 from 2005 levels, with energy conservation noted as a key measure to achieve this. In 2023, India published a Voluntary Action Plan on Doubling the Global Rate of Energy Efficiency Improvement by 2030. The Government of India has implemented a range of energy efficiency policies in the buildings sector in order to help achieve the aims of these plans.

Supported by policies and programmes, energy efficiency in India's building sector has been improving. The energy intensity of building energy use per square metre decreased by 1.5% annually between 2019 and 2022, from just 0.5% per year during 2010–2019. The Stated Policies Scenario (STEPS) sees India maintain a steady 2.8% annual rate between 2022 and 2030.

Annual improvement in energy consumption per floor area in India, 2010-2023, and 2030 under different scenarios



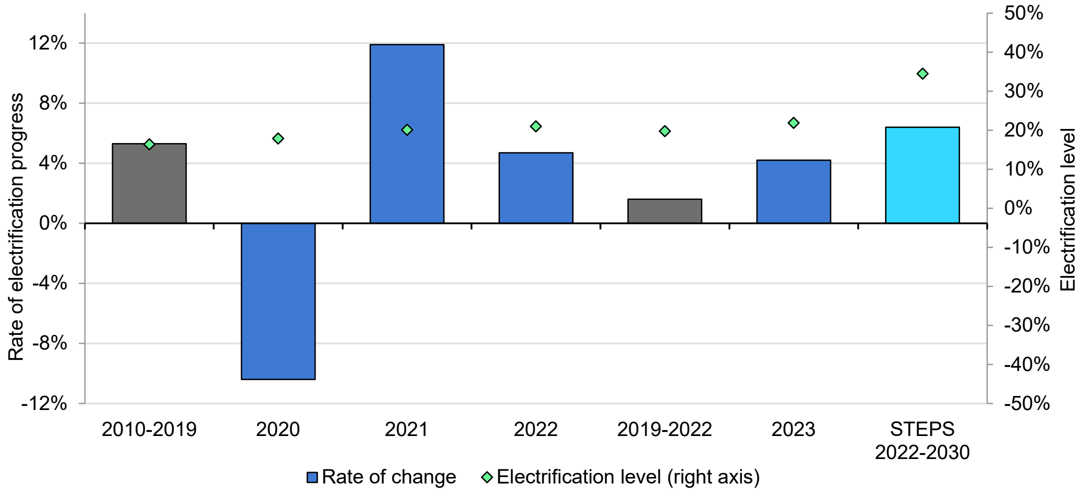
Notes: STEPS = Stated Policies Scenario; Light grey denotes the compound average growth rate (CAGR) for timeframes. Dark blue is for single years, and light blue denotes the CAGR of IEA scenarios.

Increasing electrification is putting pressure on power systems

Expanding floor space coupled with a rapid uptake of appliances – especially air conditioners – has driven an increase in electricity demand across residential and commercial spaces. Electricity accounts for nearly 30% of the sector's total final energy consumption. With incomes increasing and access to reliable electricity expanding, electricity's share of building energy use is expected to grow in the coming decades.

In 2023, building electrification grew by 4%, double the average during 2019-2022. The Stated Policies Scenario (STEPS) assumes annual building electrification rates of more than 5% between 2022 and 2030. While this shift supports efficiency and decarbonisation goals, it also presents challenges for the power system. These include higher peak demand, greater variability, and the need for expanded generation, transmission and distribution capacity.

Rate of change and level of electrification in buildings in India, 2010-2023, and by scenario, 2022-2030

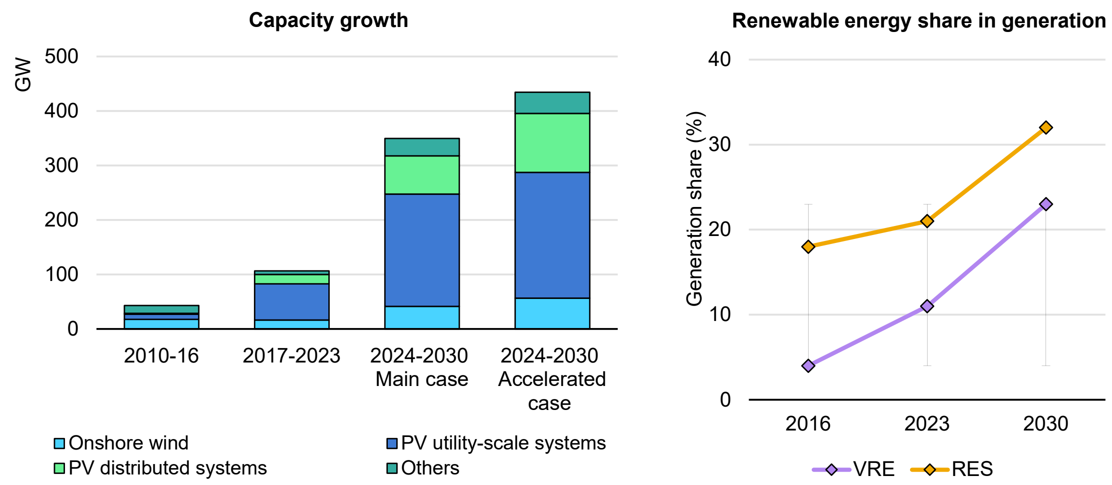


Notes: STEPS = Stated Policies Scenario Electrification level is defined as the share of electricity in total final energy demand. Rate of electrification progress is the annual percentage change in the electrification level. Light grey denotes the compound average growth rate (CAGR) for timeframes. Dark blue is for single years, and light blue denotes the CAGR of IEA scenarios.

Increasing uptake of distributed variable renewable energy poses challenges for the grid

India is ramping up its use of renewable energy. As part of its Nationally Determined Contribution under the Paris Agreement, it committed to having half of installed electricity capacity based on non-fossil sources by 2030, a milestone it already surpassed in 2025. During 2024-2030, India's renewable energy capacity is expected to increase by 350 GW to reach over 550 GW – almost triple the 2022 level and in line with the COP28 global tripling pledge. Variable Renewable Energy (VRE), primarily solar and wind, drives this momentum, making up nearly 90% of India's renewable capacity. VRE accounted for 11% of total power generation in 2023, and its share is projected to rise to over 20% by 2030. VRE introduces supply variability depending on the weather. This variability will require increasing the flexibility of the entire power system, for example, by leveraging dispatchable generation, enhancing the grid, and increasing storage and demand response capabilities.

Capacity growth by generation technology and renewable energy share in generation, India



Notes: The Main case is based on current policy and market conditions, while the Accelerated case assumes changes in the policy or market to address current challenges. Others include bioenergy, hydro, and renewables dedicated to H2 production. VRE = variable renewable energy, including solar PV and wind. RES = renewable energy sources, including all renewable technologies.

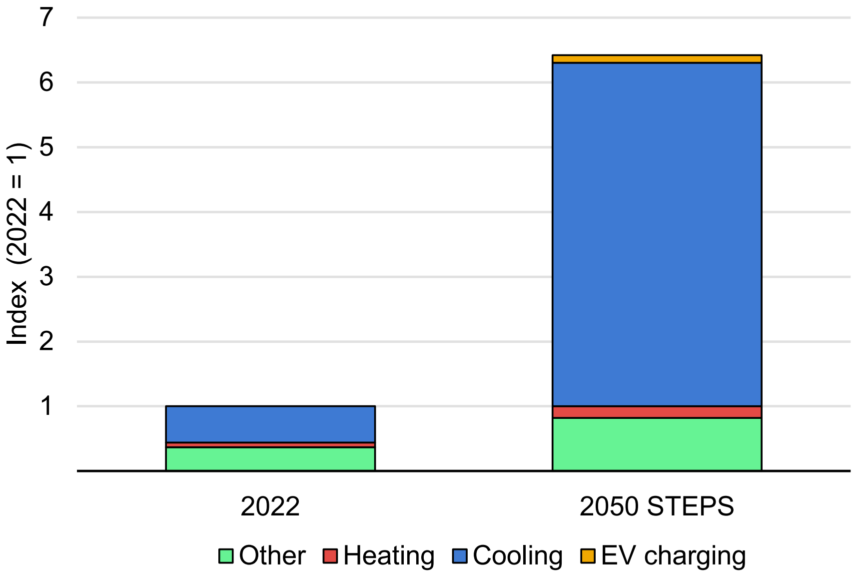
Source: IEA analysis based on Renewables 2024 and Renewables Energy Progress Tracker (accessed 2 September 2025).

Unmanaged peak demand in buildings creates stress for the power system

Rising incomes, expanding economic activity, and growing heat stress are expected to drive a sharp increase in India's peak electricity demand in the coming decades. Over half of this growth is driven by end uses in the building sector, with space cooling accounting for the largest share. Residential electricity demand for space cooling is expected to increase fivefold by 2050, despite the expanded use of energy-efficient air conditioners and improved insulation for buildings.

The increase in peak demand in buildings is largely driven by expanding needs for space cooling and EV charging. The Stated Policies Scenario (STEPS) estimates a sixfold growth in peak electricity demand in buildings by 2050. This increase could be cut in half with widespread adoption of more efficient building designs, other passive cooling strategies and stricter minimum energy performance standards for appliances.

Peak electricity demand in buildings in India and contributions by end-use, 2022-2050



Notes: Peak demand here is the average of demand for the 500 highest load hours of the year, before activation of demand response. Heating includes space and water heating. Other includes lighting, cooking and appliances. STEPS = Stated Policies Scenario.
Source: IEA (2024) More efficient and flexible buildings are key to clean energy transitions.

Relevance of efficient grid-interactive buildings for India

Efficient grid-interactive buildings can transform India's buildings sector into a flexible, low-carbon pillar of the energy system

India's buildings sector is undergoing a profound transformation. Energy demand is rising steadily, driven by expanding floor space, increasing appliance ownership and a growing shift towards electrification. This trend is compounded by the rapid uptake of space cooling, the electrification of end-uses such as cooking and transport, and the scaling up of variable renewable energy (VRE) sources. These developments are placing mounting pressure on the power system, particularly during periods of peak demand.

Without targeted interventions, unmanaged peak loads and supply variability risk undermining grid stability and increasing system costs. But buildings can play a pivotal role in addressing these challenges. Efficient grid-interactive buildings (EGIBs) offer a pathway to optimise electricity use, reduce peak demand and enhance system flexibility. They represent a new paradigm in building design and operation, combining high levels of energy efficiency with the ability to interact dynamically with the grid.

EGIBs are defined by four key attributes: they are efficient, smart, connected and flexible. Efficiency involves the use of high-performance building envelopes, appliances and systems that minimise energy consumption. Smartness refers to the deployment of sensors, controls and analytics to monitor and optimise building operations. Connectivity enables buildings to exchange signals with the grid regarding changes in supply and demand. Flexibility allows buildings to adjust their energy use in real time by shifting loads, storing energy or supplying power back to the grid.

These capabilities deliver benefits at both the system and consumer levels. From a system perspective, EGIBs help reduce peak electricity demand, which is typically the most expensive and carbon-intensive part of the load to serve. By shifting energy use to off-peak periods or times of high renewable generation, EGIBs can reduce the need for fossil-based peaking plants and alleviate grid congestion. This improves grid reliability and lowers overall system costs. For consumers, EGIBs can lower energy bills through more efficient operation and participation in demand response programmes. They can also enhance indoor comfort and resilience to extreme weather. IEA analysis shows that such measures can lower household electricity bills by 7–12% in advanced economies by 2050, and by nearly 20% in emerging markets and developing economies.

Documented data from several programmes in the United States (presented in A National Roadmap for Grid-Interactive Efficient Buildings) also demonstrate promising results. For example, an automated precooling and demand-limiting strategy for the Philadelphia Customs House reduced peak demand by around 20% and lowered annual electricity bills by 14%, equivalent to about USD 100 000 per year. At the portfolio level, analysis for the US General Services Administration (GSA) found that integrating EGIB measures could reduce annual energy costs by more than 20% while delivering 180 GWh of energy savings and 165 MW of peak-demand reduction across its office buildings. Similarly, an assessment of a large US retail portfolio showed that an optimised package of efficiency, distributed energy resources and flexibility measures could lead to energy cost reductions of up to 37% while lowering electricity demand by 17%.

EGIBs are particularly helpful for integrating VRE. As solar and wind power scale up, their variability poses challenges for grid management. EGIBs, especially when equipped with energy storage, can help align demand with supply by adjusting consumption patterns to match periods of high renewable generation. Under the IEA Net Zero Emissions by 2050 Scenario by 2030 buildings are estimated to provide about half of the increase in demand response availability required by the energy system - a tenfold increase from 2020 levels.

Digitalisation is a key enabler of EGIBs. Smart meters, sensors, controls and data analytics allow real-time monitoring and optimisation of energy use. These technologies also facilitate automated responses to grid signals, enabling buildings to participate in time-varying pricing schemes and grid services without compromising occupant comfort. As digital infrastructure becomes more widespread, the potential for EGIBs to contribute to system flexibility and decarbonisation will continue to grow.

The relevance of EGIBs is particularly pronounced in India. With over 1 billion square metres of new building space being added annually, the choices made today will shape the country's energy system for decades. EGIBs offer a strategic opportunity to ensure that this growth is aligned with India's climate goals, grid reliability needs and consumer affordability.

The adoption of EGIB principles in both new construction and retrofits can significantly reduce stress on India's electricity grid, particularly during periods of peak demand. By enabling buildings to adjust their energy use in response to grid conditions, EGIBs contribute to a more resilient and efficient power system.

EGIBs also enhance the ability of buildings to maintain comfort and functionality during grid disruptions or extreme weather events, supporting broader goals of energy security and climate adaptation. Their role in improving system flexibility also reduces the need for fossil-based peaking power, lowering overall system costs and emissions.

As India pursues its net zero ambitions and continues to expand access to modern energy services, EGIBs can help ensure that the buildings sector evolves from a source of growing energy demand to one of flexibility, efficiency and sustainability.

Background to this report

At COP28, governments agreed to double the global average annual rate of energy efficiency improvements by 2030. India helped shape and drive this agenda. During India's G20 Presidency in 2023, its Bureau of Energy Efficiency, with support from the IEA, presented a detailed Strategic Plan for Advancing Energy Efficiency Across Demand Sectors by 2030. Guided by this plan, the G20 Energy Transition Working Group (ETWG) and the G20 New Delhi Leaders' Declaration supported a voluntary action plan to double the rate of energy efficiency improvement by 2030, paving the way for the COP28 agreement.

India is set to play a crucial role in achieving global energy efficiency targets. With India's growing electricity demand and peak demand, along with its national targets for energy efficiency and renewable energy, grid-interactive buildings could help India achieve its ambitious energy efficiency goals.

This report builds on the analytical framework developed in the IEA publication, Efficient Grid-Interactive Buildings: Future of buildings in ASEAN (2023), which introduced a structured approach for assessing the readiness and potential of buildings to become efficient and grid-interactive. That framework identified key enablers across multiple dimensions – energy efficiency, decarbonisation, smartness, building-to-grid interaction – for unlocking the benefits of demand-side flexibility and digitalisation in the buildings sector.

This report updates that framework to incorporate additional policy angles, including considerations of embodied carbon, low-carbon materials and resilience measures in buildings. It also incorporates feedback from a working group of local experts formed specifically to support this study. Two stakeholder consultations were held: one on 11 February 2025 (online) and another on 20 February 2025 (in person in New Delhi).

Data on the current policy landscape and ongoing projects related to each enabler were collected through desktop research and expert consultations to identify existing trends and practices.

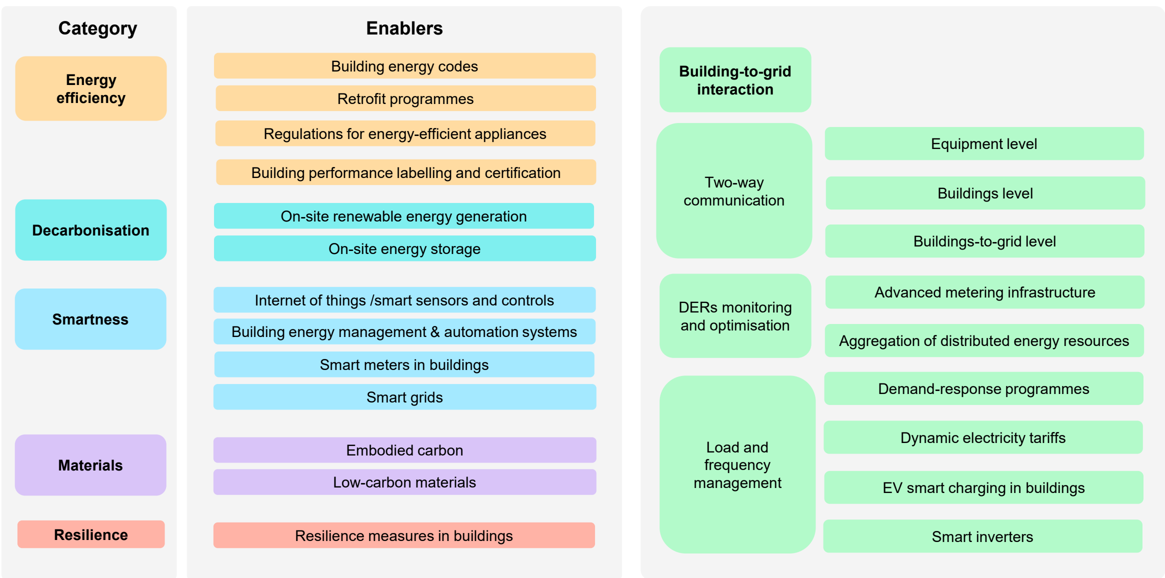
The updates to the methodology are discussed in detail in the next chapter, which outlines the revised enablers and their relevance to the Indian context. The updated framework is then applied to assess the current status and opportunities for EGIBs in India and to develop targeted policy recommendations. The report aims to support India's efforts to accelerate the adoption of EGIBs and transform its buildings sector into a flexible, low-carbon pillar of its energy system.

Chapter 2. Enablers for efficient grid-interactive buildings

This chapter examines the essential attributes – "enablers" – that facilitate the transformation of buildings into efficient, grid-interactive entities. Successful implementation of these enablers requires supportive policies and the adoption of certain advanced technological solutions. The degree to which these enablers are present can serve as a benchmark for evaluating the readiness of any country for efficient grid-interactive buildings (EGIBs).

The methodology of this report follows the analytical framework presented in the International Energy Agency's report, Efficient Grid-Interactive Buildings: Future of buildings in ASEAN, with important updates to reflect certain aspects of buildings' operation over their lifetime. The enablers fall into six primary categories: (1) energy efficiency, (2) decarbonisation, (3) smartness, (4) materials, (5) resilience, and (6) building-to-grid interaction. Since the previous version of the methodology, the Energy efficiency category has been expanded from two to four enablers, and two new categories have been added – materials and resilience – to expand the scope of the assessment beyond operations.

Enablers for efficient grid-interactive buildings



Note: DER = distributed energy resource.

Evaluation criteria for enablers of efficient grid-interactive buildings

	Enabler	Brief explanation	Evaluation criteria
Energy efficiency	Building energy codes	Status of development and implementation of the building energy code (BEC) and its energy efficiency requirements (regulations/standards for building efficiency).	0: No codes; 1: Voluntary codes; 2: Mandatory codes for some buildings; 3: Mandatory codes for all buildings (new + retrofits).
	Energy-efficient appliances & equipment	Minimum energy performance standards (MEPS) and labels for HVAC, lighting, water heating, and appliances.	0: No MEPS; 1: For a few appliances; 2: For most appliances; 3: For all major appliances.
	Retrofit programmes	Policies requiring energy-efficient retrofits of existing buildings.	0: No retrofit policies; 1: Voluntary schemes; 2: Mandatory for some buildings; 3: Mandatory for all buildings.
	Building performance labelling & certification	Labels and certifications for new and existing buildings.	0: No schemes; 1: Voluntary labels/certifications; 2: Mandatory for some buildings; 3: Mandatory for all buildings.
Decarbonisation	On-site renewable energy generation	Solar PV/wind installed at building sites to reduce reliance on fossil fuels.	0: No policies; 1: Voluntary schemes; 2: Mandatory for some buildings; 3: Mandatory for all buildings.
	On-site energy storage	Battery/thermal storage to balance demand, enable self-consumption and grid services.	0: No policies; 1: Voluntary schemes; 2: Mandatory for some buildings; 3: Mandatory for all buildings.
Smartness	Internet of things (IoT), smart sensors & controls	Connected devices for real-time monitoring and automated adjustments.	0: No policies; 1: Voluntary schemes; 2: Mandatory for some buildings; 3: Mandatory for all buildings.
	Building energy management & automation systems	Integrated systems that optimise building operations and enable demand response.	0: No policies; 1: Voluntary schemes; 2: Mandatory for some buildings; 3: Mandatory for all buildings.
	Smart meters	Digital meters for granular energy use, dynamic tariffs, and grid integration.	0: No policies; 1: Voluntary installation; 2: Mandatory for some buildings; 3: Mandatory for all buildings.
	Smart grids	Digitalised electricity networks that integrate renewables and optimise supply/demand.	0: No plans; 1: High-level plans without targets; 2: Plans with targets but weak implementation; 3: Comprehensive plans with clear targets + implementation.
Materials	Embodied carbon	Policies addressing lifecycle emissions of construction materials.	0: No policies; 1: Voluntary schemes; 2: Mandatory for some buildings; 3: Mandatory for all buildings.
	Low-carbon materials	Use of sustainable and recycled materials (cross-laminated timber/CLT, low-carbon concrete, etc.).	0: No policies; 1: Voluntary schemes; 2: Mandatory for some buildings; 3: Mandatory for all buildings.
Resilience	Resilience measures in buildings	Climate adaptation measures (floodproofing, seismic requirements, passive cooling, power backup systems, etc.).	0: No policies; 1: Voluntary measures; 2: Mandatory for some buildings; 3: Mandatory for all buildings.

Enabler		Brief explanation	Evaluation criteria
Building-to-grid interaction	Two-way communication – equipment level	Appliance interfaces (e.g. CTA-2045) for grid-ready demand response.	0: No policies; 1: Voluntary standards; 2: Mandatory for some appliances; 3: Mandatory for all appliances.
	Two-way communication – building level	Grid-ready buildings with open protocols (BACnet, Modbus, KNX, etc.).	0: No policies; 1: Voluntary standards; 2: Mandatory for some building types; 3: Mandatory for all buildings.
	Two-way communication – building-to-grid level	Standards (OpenADR, IEEE 2030.5) for automated building–grid interoperability.	0: No policies; 1: Voluntary standards; 2: Mandatory for some buildings; 3: Mandatory for all buildings.
	Advanced metering infrastructure (AMI)	Networks and data systems enabling two-way communication, monitoring, and DR.	0: No policies; 1: Voluntary rollout; 2: Mandatory for some buildings; 3: Mandatory for all buildings.
	Aggregation of distributed energy resources (DERs)	Grouping of DERs (solar, storage, EVs) into virtual power plants (VPPs) or other aggregation schemes to provide grid services.	0: No policies; 1: Voluntary schemes; 2: Mandatory for some areas/users; 3: Mandatory for all.
	Demand response (DR) programmes	Mechanisms for load management in response to price or grid signals.	0: No DR; 1: Voluntary/manual DR; 2: Mandatory automated DR for some users; 3: Mandatory automated DR for all users.
	Dynamic electricity tariffs	Time-varying tariffs (Time-of-use, real-time pricing) to encourage load shifting, reduce peak demand, and integrate renewables.	0: No tariffs; 1: Voluntary for some users; 2: Mandatory for some users; 3: Mandatory for all users.
	EV smart charging	Intelligent, often bi-directional EV charging optimised with grid conditions.	0: No programmes; 1: Voluntary schemes; 2: Mandatory for some building types; 3: Mandatory for all.
	Smart inverters	Advanced inverters for PV/storage providing voltage/frequency support.	0: No programmes; 1: Voluntary schemes; 2: Mandatory for some building types; 3: Mandatory for all.

Energy efficiency

Energy efficiency is a fundamental pillar of the transition towards net-zero emissions. Strengthening energy efficiency measures beyond current policies has the potential to eliminate approximately one-quarter of new energy demand by 2030 and more than half of new demand by 2050. However, achieving net-zero emissions in the global buildings sector by mid-century (in order to limit global warming in line with the Paris Agreement) will require a combination of deep efficiency improvements, electrification of end uses, and decarbonisation of the electricity supply.

Recognising the critical role of energy efficiency, world leaders at COP28 in 2023 committed to doubling the global annual rate of energy efficiency improvement to 4% per year by 2030.

Within the buildings sector, transitioning to highly energy-efficient designs and technologies will be key. Behavioural changes and increased digitalisation for optimised energy management can help reduce energy demand from buildings further without compromising the quality of energy services – particularly for high-impact end-uses such as space heating, space cooling and water heating.

A comprehensive approach is required to enhance the energy efficiency of the entire building stock. This report focuses on four critical enablers in the energy efficiency category: high-performance building envelopes, building retrofit programmes, energy-efficient appliances, and building energy performance certification. These areas are typically addressed through distinct policy frameworks, and their combined impact is important for achieving energy savings and enabling the broader transition toward efficient grid-interactive buildings.

Building energy codes

The building envelope – walls, roofs, windows, and floors – directly impacts energy demand, occupant comfort, and emissions. Strengthening the performance of the building envelope is key to reducing heating and cooling loads, enhancing the use of daylighting, improving indoor air quality, and lowering both operational and embodied carbon emissions.

Building energy codes can set minimum efficiency standards for the overall energy performance of a building as well as for individual components of the building envelope, such as insulation, windows and glazing, airtightness, daylighting, and the thermal transmittance of roofs, walls and floors.

As of 2024, 85 residential and 88 non-residential building energy codes were in place globally. However, over 100 countries still lack mandatory energy efficiency requirements, and only 50 countries have such requirements for existing buildings. In 2022, 2.4 billion m² of floor space was built worldwide without efficiency mandates, and over 2.5 billion m² in 2023. Constructing new buildings without efficiency measures risks locking in inefficiencies for decades, delaying progress toward a zero-carbon-ready building stock.

The IEA's Building Energy Code Content Assessment methodology facilitates the assessment of country's building regulations based on how comprehensively they support the transition towards more efficient and low-carbon buildings. Ideally, such regulations will be mandatory, cover both new and existing buildings, enforce high-efficiency standards, include requirements for renewable energy, ensure thermal comfort, integrate smart features and energy management, be regularly updated, and become progressively stricter over time.

Retrofit programmes

In all countries, existing buildings account for a significant share of energy consumption and emissions. This makes retrofitting a crucial strategy for improving efficiency and reducing carbon footprints. Energy-efficient retrofits can enhance thermal performance, reduce heating and cooling demand, and integrate smart and renewable energy technologies, extending the lifespan of buildings while lowering operational costs.

Retrofit programmes can provide structured policy frameworks, financial incentives and technical support to encourage building owners to upgrade insulation, windows and HVAC systems, and to take other efficiency measures. Such programmes can be implemented through regulatory mandates, voluntary initiatives, or public-private partnerships.

As of 2024, only around 50 countries had mandatory energy efficiency requirements for existing buildings, leaving a large share of the global building stock uncovered. In countries where such requirements do exist, they usually aim to ensure that notable energy savings are attained when major renovations take place. Without stronger policies for deep renovation, many inefficient buildings could remain in operation for decades, delaying the shift toward zero-carbon-ready buildings and increasing long-term energy demand.

Energy-efficient appliances

Minimum energy performance standards (MEPS) are among the most effective policy tools for improving the energy efficiency of appliances and equipment and for limiting the presence of inefficient models on the market. By setting mandatory efficiency thresholds, MEPS help phase out inefficient products, drive technological improvements, and encourage manufacturers to develop higher-performance appliances. As of 2024, over 100 countries had adopted MEPS and/or energy labelling for key appliances, though coverage remains uneven across product categories and regions. For example, while MEPS for refrigeration and freezers exist in approximately 80 countries, fewer than 50 countries regulate washing machines, televisions, or monitors, despite the growing energy demand from these products.

To complement MEPS, energy labels provide efficiency ratings, enabling consumers to make informed choices when purchasing appliances. Additional measures, such as financial incentives (rebates, tax credits and low-interest loans), consumer awareness campaigns, and support for R&D, can further accelerate the shift toward energy-efficient technologies.

International cooperation is important for harmonising efficiency standards, facilitating trade, and ensuring consistency across markets. Continuous monitoring and policy updates need to keep pace with technological advancements to ensure that efficiency gains continue to drive market transformation.

Building performance labelling and certification

Building performance labelling and certification help drive energy efficiency, transparency, and market transformation by providing standardised assessments of a building's energy consumption, emissions, and sustainability performance. These tools help homeowners, businesses, and policymakers make informed decisions, encourage higher efficiency standards, and create market incentives for energy-saving investments.

Energy performance certificates (EPCs) and green building certifications set benchmarks for energy efficiency, indoor environmental quality and carbon footprint. Many certification schemes, such as LEED (Leadership in Energy and Environmental Design), BREEAM (Building Research Establishment Environmental Assessment Method), and EDGE (Excellence in Design for Greater Efficiencies), have gained global recognition, influencing building design and operation. Additionally, the World Green Building Council has established more than 75 Green Building Councils in different countries that actively promote energy performance certification and labelling systems. While these schemes largely remain voluntary, some countries have established mandatory national building certification schemes linked to regulatory instruments, incentives and capacity building (e.g. NABERS in Australia, and GreenMark in Singapore), which have demonstrated a much greater improvement of energy performance than voluntary schemes.

Decarbonisation

The transition to low-carbon energy sources, such as renewables, coupled with electrification and energy efficiency improvements, can dramatically reduce emissions from the buildings sector, while enhancing energy security and lowering energy bills. Decarbonisation also supports healthier indoor environments and aligns with broader sustainability goals, making it a cornerstone of any credible net-zero strategy.

Variable renewable energy (VRE) technologies, such as solar photovoltaics (PV) and wind turbines, have a significant role to play in decarbonising energy consumption. The share of renewables in the electricity sector worldwide is projected to rise from 30% in 2023 to 46% by 2030. Nearly all of the increase is expected to come from solar and wind. As the share of VRE grows, however, many markets are experiencing a corresponding increase in curtailed (unused) wind and solar PV generation. Curtailment is especially common in regions where

VRE deployment has outpaced investments in grid infrastructure or the evolution of market design and regulatory frameworks. Buildings can support the effective integration of VRE into the energy system by providing opportunities for on-site distributed electricity generation and storage, thereby helping align energy supply with demand.

On-site renewable energy generation

At the 2023 UN Climate Change Conference (COP28) in Dubai, governments agreed to work together to triple the world's installed renewable energy capacity by 2030. Global renewable capacity additions are set to accelerate sharply, rising from 666 GW in 2024 to nearly 935 GW by 2030, with solar PV emerging as the dominant driver of this growth. The share of variable renewables in total electricity generation in the Stated Policies Scenario is estimated to increase from slightly more than 10% in 2023 close to 45% in 2035.

Rapid, unmanaged adoption of distributed VRE technologies can strain electricity grids, leading to instability and even blackouts caused by reverse power flows. To prevent such problems, grid operators must plan proactively and implement tools for real-time monitoring and control of distributed energy resources.

Some countries are incorporating these considerations into policy developments. For example, the Net-Zero Energy Buildings Code in British Columbia, Canada, encourages (and in later steps requires) new buildings to be net-zero ready, with optional pathways that include on-site PV generation. The Solar Homes Programme in the Australian state of Victoria offers rebates of up to AUD 1 400 and interest-free loans for rooftop PV installations in homes. Some local governments in Japan, such as Tokyo and Osaka, offer direct subsidies for rooftop solar and batteries. And the Green Building Index (GBI) in Malaysia offers points for renewable energy integration in buildings. While voluntary, it has been widely adopted by developers of commercial and residential properties.

On-site energy storage

Distributed energy storage is rapidly emerging as an important component of successful VRE integration. Battery storage in buildings allows households and businesses to store excess generation and shift consumption to lower-cost or "cleaner" periods. This helps stabilise the grid, reduce peak demand, and increase self-consumption – leading to greater energy independence. The most common solution for distributed storage involves lithium-ion batteries, though other technologies, such as sodium-ion batteries, are also gaining ground.

In buildings with significant cooling demand, thermal energy storage (TES), such as chilled-water or ice storage tanks, can shift electricity use for cooling production to off-peak or high-renewable periods, providing demand flexibility similar to behind-the-meter batteries. While often deployed at the district or commercial level, building-integrated TES can help reduce peaks where cooling loads are large.

In 2023, global battery storage installations more than doubled, adding over 42 GW. More than a third of this growth (35%) came from behind-the-meter systems. Policies that provide incentives for private storage are helping overcome the upfront investment barrier. For example, the Bring your own device (BYOD) programme in Hawaii allows building owners to monetise stored energy by participating in grid services markets.

The development of more cost-effective technologies (such as, potentially, sodium-ion batteries), along with the wider utilisation of digital platforms for managing and monetising distributed energy resources, can help distributed storage play an important role in grid modernisation, resilience and climate action. In India, enabling policy measures, such as net metering and virtual net metering, along with emerging regulatory frameworks for distributed energy resource aggregation and peer-to-peer energy trading, can support the scale-up of distributed storage by improving economic returns for prosumers and community energy projects.

Smartness

Incorporating smart interactive technologies alongside conventional energy efficiency measures introduces a time-sensitive, dynamic layer to building energy performance. These technologies enable buildings to reduce energy use as well as optimise it in real time, based on grid conditions or user needs. Common examples include smart meters, building automation systems, energy and load management platforms, and smart sensors and controls for equipment and appliances. These systems facilitate two-way communication between buildings and utilities or grid operators, enabling greater flexibility and responsiveness.

Internet of things

The Internet of Things (IoT) in buildings refers to a network of connected sensors, devices and equipment that communicate with each other and analyse data to optimise energy performance and enhance operational efficiency. These systems monitor key building components, such as HVAC and lighting, and automatically trigger actions to improve functionality. Such devices facilitate real-time monitoring and management of energy consumption, contributing to sustainability goals and cost savings.

Combining IoT with artificial intelligence (AI) and machine learning offers promising opportunities for more sophisticated data analysis and enhanced building performance. Predictive maintenance that incorporates IoT and AI solutions has led to a reduction in maintenance costs of 10–40% across various industries. However, scaling these solutions requires strong data privacy standards and robust cyber security measures to protect connected building systems from potential vulnerabilities.

Building energy management and automation

Building energy management systems (BEMS) and building automation systems (BAS) integrate sensors, software and communication technologies to collect real-time data on HVAC, lighting, occupancy and energy use, enabling optimisation of both comfort and efficiency. These systems can automatically adjust conditions based on pre-defined and pre-programmed 'rules' or AI-driven algorithms, improving thermal comfort for occupants, optimising energy consumption, and reducing equipment faults and operating costs. When connected to smart meters, solar PV or battery storage, BEMS can forecast and balance energy demand and on-site generation.

Global markets reflect this momentum: the BEMS sector was valued at about USD 35 billion in 2024 and is expected to more than double by 2030, while the market for BAS is projected to reach over USD 176 billion by 2034. Growth is driven by the integration of IoT, AI and machine learning, the rise of cloud-based solutions that scale across building types, and advances in interoperability standards (such as Matter 1.4) that simplify device compatibility. This expanding ecosystem provides growing opportunities for private-sector participation, including aggregators and solution providers that can deliver integrated services, optimise multi-building portfolios, and facilitate demand response markets.

Smart meters in buildings

Smart meters are digital devices that track electricity use in near real time and enable two-way communication between utilities and consumers. They improve visibility of behind-the-meter demand, support time-of-use pricing and enable automated billing. At the same time, they give grid operators tools for faster outage detection, peak load management and renewables integration. Although smart meters are critical for demand flexibility and system efficiency, concerns over data privacy and the slow roll-out of advanced metering infrastructure (AMI) have so far limited their full potential for building-to-grid interaction.

Globally, the adoption of smart meters is growing rapidly. It is estimated that their number worldwide will double between 2023 and 2033, reaching 3.4 billion installed units and generating around USD 40 billion in market revenue. The Asia-Pacific region is leading this growth, accounting for nearly 60% of global installations and reaching a penetration rate of 49%, mainly due to large-scale rollouts in China and Japan. Continued deployments in India, Indonesia, Singapore and Australia are expected to push the regional penetration of smart meters to 67% by 2030.

Over 186 million smart meters had been deployed by 2023 in Europe, where the penetration rate is expected to reach 78% by 2028. North America had an installed base of nearly 146 million smart meters in 2023, with projections of up to 94% coverage in the United States and 96% in Canada by 2029. Latin America is also expanding smart grid infrastructure. As of 2023, there were about 14 million installed smart meters across the region, a number expected to climb to nearly 43 million by 2029, raising market penetration from 6.5% to more than 18%.

Smart grids

Smart grids use digital technologies to balance power flows from diverse sources with real-time demand. Employing two-way communication among generators, operators, consumers and markets, smart grids improve efficiency, reliability, and the integration of clean energy sources. SCADA (supervisory control and data acquisition) systems underpin this activity by remotely monitoring and controlling grid assets. The integration of advanced metering, distributed energy resources and demand response creates a flexible, intelligent grid. In order to stay aligned with net-zero pathways, global investments in smart grids will need to more than double by 2030, including in emerging economies.

Effective policy is needed to drive these investments and accelerate smart grid deployment. Some governments and utilities are already developing comprehensive grid modernisation plans. These typically include digital infrastructure, advanced control systems, policy frameworks and customer engagement strategies aimed at boosting resilience, energy efficiency and carbon reduction. For example. the EU's Digitalising the Energy System action plan targets interoperability and cybersecurity, while the US Department of Energy's Grid Modernization Initiative aims to increase the resilience and integration of distributed energy resources.

Materials

Building materials play an important role in driving both energy efficiency improvements and the broader clean energy transition in the buildings sector. Embodied carbon refers to emissions generated during the production, transportation and installation of building materials, as well as their maintenance and eventual disposal. It accounted for 18% of total emissions related to buildings and construction in 2023, with cement and steel production contributing the most.

Modular construction and reuse of materials not only reduce embodied carbon emissions, but support emerging circular economy practices and resilience in global building supply chains.

Embodied carbon

Embodied carbon is emerging as a defining metric in the global pursuit of zero-carbon buildings. Recent global analyses show that it might account for nearly half of the building sector's carbon footprint by mid-century if left unaddressed. The World Green Building Council has called for a 40% reduction in embodied carbon in all new projects by 2030 and mandatory whole-life carbon targets by 2050.

National building codes and procurement policies are increasingly incorporating requirements for whole-life carbon assessment, life cycle analysis (LCA) and mandatory disclosure. Recent examples include the revised EU Energy Performance of Buildings Directive and Viet Nam's GHG inventory mandates for large projects. Cities and regions with the most ambitious climate targets – such as London, New York and Oslo – are setting embodied carbon benchmarks and enacting policies that require the calculation and reduction of emissions at the design stage.

Yet, the lack of harmonised global benchmarks, supply chain transparency and digital measurement tools remain persistent barriers to scaling these efforts. This underscores the importance of closing data gaps and building capacity for standardised assessment. The sector's ability to monitor, report and drive down embodied carbon will be crucial for aligning the world's building stock with Paris Agreement pathways.

Low-carbon materials

Use of low-carbon materials can reduce emissions across a building's lifecycle, catalysing both environmental and economic gains.

Concrete and steel — the two most widely used construction materials — account for around 18% of the global carbon emissions from the buildings and construction sector. Decarbonising their production, or replacing them with low-carbon alternatives, should therefore be a global priority.

Green steel is produced by replacing coal with hydrogen in the direct reduced iron (DRI) process, which is then powered by renewable electricity. The production of green steel cuts emissions from steelmaking by up to 90%. Another promising solution is mass timber products, such as cross-laminated timber (CLT). Mass timber products sequester carbon during tree growth and are increasingly used as low-carbon substitutes for concrete and steel in mid-rise buildings.

Concrete is another major focus for decarbonisation. It is the world's most widely used building material and the most consumed resource after water. Concrete's climate impact is largely tied to cement, which makes up only about 10% of concrete's mass but accounts for around 96% of its embodied carbon and 85% of its embodied energy. Emerging low-carbon solutions, including supplementary cementitious materials and carbon-mineralisation technologies, are already cutting emissions by roughly 5–15% per unit in commercial mixes, with even greater reductions possible in advanced applications. New materials demonstrate the potential for deep emission reductions beyond traditional cement-based solutions. This includes Agrocrete, a carbon-negative bio-concrete made in India from agricultural residues.

Policy is driving adoption. For example, the European Union, United States and China are ramping up incentives for circular, recycled and renewable materials as part of broader climate strategies. The EU's Circular Economy Action Plan and the US Inflation Reduction Act are incentivising producers and developers to invest in supply chain transformation, while platforms such as Madaster are digitising material passports for reuse and recycling, creating new markets for reclaimed wood, recycled steel and other low-carbon materials.

As carbon pricing mechanisms and ESG-linked financing mature, these products are becoming economically competitive, fuelling rapid scale-up. The global market for low-carbon construction materials is projected to expand by about 12% annually through 2034. Whole-life carbon approaches, supported by procurement standards and greater digitalisation, can help ensure that material choices deliver both climate and resilience benefits for buildings worldwide.

Resilience

Resilience in the context of the built environment can be defined as a "building's ability to anticipate, prepare for, respond to, and recover from adverse climate-related events". In a world where the frequency and severity of extreme weather events caused by climate change is increasing, resilience is becoming more important. According to the IEA, "zero-carbon-ready" buildings must not only be energy-efficient but also resilient, to ensure that critical functions are maintained under stress, including during interruptions in energy supply. Resiliency can reduce economic losses, safeguard occupants, and support recovery through design strategies such as improved drainage, elevated foundations and robust materials. These features can dramatically reduce damage in the first place and ensure habitability after a shock.

Resilience measures in buildings

Resilience strategies can take different forms, depending on local climate hazards and risks related to natural phenomena. Building design strategies can include impact-rated windows, doors and roofing; sealed/anchored roof decks; and structural hardening for high winds and debris loads, such as hazard-specific wind retrofit and roofing measures to reduce water intrusion and impacts from hurricanes.

Measures for flood-risk areas include elevating finished floors and critical services, deploying barriers and using flood-tolerant or sacrificial finishes. These are often complemented by site measures such as permeable surfaces, rainwater harvesting, green roofs, and detention ponds.

Improving buildings' heat resilience requires a combination of cooling resilience strategies, such as high-performance insulation, solar-control glazing and external shading with reflective (cool) roofs and walls. Such measures keep interiors safe during heatwaves while lowering loads. Where poor outdoor air quality is the hazard, authorities may advise filtration, controlled ventilation and "clean-room" strategies to protect occupants.

Power resilience may be enhanced through the use of on-site solar plus batteries and other distributed energy resources, managed through smart controls so buildings can operate in island mode, shed non-critical loads, and support the grid during disturbances.

For multi-hazard contexts, designing for de-/re-construction and modularity can speed post-event repairs, while "floodable" or sacrificial ground-floor zones are used in some geographies to limit losses and enable faster reoccupation. Taken together, these strategies can reduce downtime and safeguard occupants, though their effective implementation usually requires policy support.

Japan has some of the world's strictest seismic building codes. These are continuously updated, especially following major earthquakes such as those in 1981 and 2000. Buildings must meet rigorous structural integrity and base isolation requirements to withstand earthquakes. Japan also has (mandatory) certification and labelling schemes that show the level of a building's resistance to earthquakes.

The Green Building Council of Australia includes resilience in its Green Star certification, encouraging designs against climate risks such as heatwaves and flooding. The Bushfire Attack Level (BAL) standard defines construction requirements to improve resilience of homes in areas prone to wildfires.

The FORTIFIED program in the United States is a voluntary, tiered certification programme for homes and commercial buildings that adopt measures to improve resilience. It offers a market-recognised pathway to resilience and has even reduced insurance premiums in some jurisdictions. Relevant measures include reinforced roof decks, stronger connections between building elements (e.g. roof-to-foundation, roof-to-wall, etc.) and improved water protection. Canada is piloting the Climate-Resilient Building Codes initiative, which provides voluntary guidelines to supplement mandatory codes, focusing on resistance to flooding, extreme heat and wildfires.

Building-to-grid interactivity

Improving energy efficiency in buildings can involve integrating digital technologies that unlock demand flexibility. Demand flexibility allows buildings to adjust their energy use in response to grid signals, enabled by technologies that automate and shape consumption patterns. Technologies that enable demand flexibility help deliver equal or better energy services at lower costs for both consumers and the energy system.

India's first efficient grid-interactive, net-zero building

The Government of Telangana and the Telangana Renewable Energy Development Corporation (TGREDCO) developed the first grid-interactive office building in Hyderabad. Completed in 2024, the six-storey structure houses TGREDCO and Telangana State Southern Power Distribution Company Limited (TSSPDCL). The building integrates passive design, high-efficiency systems, thermal-mass cooling and on-site solar generation.

As a facility compliant with the Super-Energy Conservation Building Code, the building uses highly efficient systems and equipment and is designed to achieve a high energy performance for the building envelope. A 100-kWp solar PV system generates roughly 175 000 kWh annually, meeting part of the building's electricity needs and ensuring net-zero energy performance within a year. The building features an advanced Building Management System (BMS) that coordinates load-flexibility measures, such as shifting cooling demand by using the structure's thermal mass and optimising equipment operation during off-peak hours. Its metering infrastructure enables two-way communication with the utility, providing real-time data on demand and power quality to support automated load adjustments. An automated demand-response programme modulates peak load by adjusting lighting, cooling and ventilation in response to signals from the utility.

Two-way communication

Interoperability is the capacity of different systems, devices and applications to communicate and exchange information seamlessly, enabling more efficient operations and improved service delivery. By allowing devices from different manufacturers to interact, exchange data and respond to signals from the grid, it forms the backbone of smart, responsive and flexible energy systems. In the context of efficient grid-interactive buildings, interoperability should take place on several levels: equipment level, building level, and between buildings and the grid.

Equipment level: communication-ready hardware

At the most granular level, interoperability requires appliances and equipment such as HVAC systems, water heaters and EV chargers to be physically capable of receiving and acting in response to digital signals. This requires built-in or add-on communication interfaces or control modules that allow such devices to respond automatically to price or load-shifting signals from the grid.

Examples include:

- Smart communication interfaces, such as CTA-2045 in the United States and energy smart appliances in the United Kingdom.
- Demand response enabling devices, such as those in Australia, New Zealand that allow grid operators to control or cycle loads.
- Smart inverters that comply with standards such as IEEE 1547-2018 for the interconnection of distributed energy resources (DER) and support grid stability through voltage/frequency services

Building level: internal communication across devices

At the building level, the goal is the coordination of various devices, sensors and DERs through interoperable platforms such as building energy management systems (BEMS), home energy management systems (HEMS) or building automation systems (BAS).

Examples of related technologies and protocols:

- Open communication protocols such as BACnet, KNX, Modbus, Zigbee, Z-Wave, and the Matter standard.
- Thread, a low-power, secure, wireless mesh networking protocol designed for the Internet of Things (IoT) and smart building environments. Thread offers a reliable, self-healing network that ensures devices stay connected without relying on a central hub. Thread enables more efficient and scalable device communication than Wi-Fi or Bluetooth and is supported by Matter.
- Cloud computing, AI, and machine learning for real-time optimisation, predictive maintenance and load forecasting.

What's Matter?

Matter is an open-source, royalty-free standard that provides a unified IP-based communication protocol for smart home and building devices. Launched in 2022 by the Connectivity Standards Alliance (CSA), Matter is backed by major industry players including Apple, Google, Amazon, Samsung and IKEA. Its key promise is interoperability across brands and platforms, with robust security and local control.

Matter runs on Thread, which operates similarly to existing smart home protocols such as Zigbee and Z-Wave, but with a key advantage: it doesn't require a central hub or bridge. Instead, Thread-enabled devices communicate directly with one another, creating a self-healing mesh network, enabling a faster, more resilient performance, especially in larger setups.

Matter and Thread simplify the integration of smart appliances, sensors, and energy devices (such as thermostats, EV chargers or smart plugs) into BEMS or HEMS. This reduces vendor lock-in and makes it easier to scale energy management solutions across device types and brands. Matter ensures semantic and syntactic interoperability, meaning devices "speak the same language". It also ensures technical and network reliability, making it a good choice for resilient, smart home networks. Devices such as smart thermostats, light switches and EV chargers can easily be added to the home/building energy ecosystem or can communicate directly with the grid without protocol compatibility issues.

Building-to-Grid Level: communication with the grid

Interoperability at the grid level ensures that buildings can interact with the grid to provide flexibility services such as demand response, ancillary support and DER coordination.

Examples of open standards for building-to-grid communication

Standard / Protocol	Purpose / Application
OpenADR	Automated demand response: communicates price and event signals from utilities to end-use systems and smart appliances; supports Zigbee.
IEEE 2030.5/ SEP 2.0	Integration of DERs: enables smart inverter control, metering, load management and grid interaction.
IEC 61850	Communication across substations and grid equipment, and increasingly used for DER coordination.
IEEE 1547-2018	Defines interconnection and interoperability requirements for DERs, including voltage/frequency support.
IEC 61968 / IEC 61970 (CIM)	Data exchange between utility systems and DER assets using a common information model (CIM).

Standard / Protocol	Purpose / Application
OSGP (Open Smart Grid Protocol)	Utility-to-device communication (e.g. smart meters, thermostats, lighting) for smart grid operations.
IEC 62325	Market communication protocol for buildings participating in electricity trading or aggregated energy services.
MQTT (Message Queuing Telemetry Transport)	Lightweight messaging protocol for IoT communication in smart buildings, used in platforms that aggregate data from DERs such as solar panels, batteries and EV chargers, virtual power plants and DERMS.
CoAP (Constrained Application Protocol)	RESTful protocol for low-power devices in IoT: complements Matter/Thread in BEMS and grid communication.

An example of an open communication standard in India is the Beckn protocol. This provides an open digital interoperability layer allowing distributed energy consumers and producers to easily interact with each other and transact on a common digital network, supporting scalable aggregation and market participation (see IEA and FIDE 2025).

Monitoring and optimisation of distributed energy resources

As DERs such as rooftop solar, battery storage and electric vehicles become more prevalent across the building stock, ensuring their effective integration into the energy system become increasingly important. Monitoring and optimisation tools allow these assets to support not only individual building performance but wider grid reliability and flexibility.

Advanced metering infrastructure (AMI) enables real-time energy monitoring, data analysis and demand response at the building level. Distributed energy resource management systems (DERMS) operate at the grid level to coordinate and optimise DERs across multiple locations. When aggregated into virtual power plants (VPPs), DERs can be dispatched to provide grid services and optimise energy flows in real time, transforming buildings from passive consumers into active participants in the energy transition.

Advanced metering infrastructure

Advanced Metering Infrastructure (AMI) is a system of smart meters, communication networks and data management tools that enables two-way communication between buildings and utilities. Unlike traditional metering, AMI provides detailed, real-time data on electricity consumption, enabling dynamic pricing, demand response, remote monitoring and outage detection.

AMI is a foundational enabler of efficient grid-interactive buildings. It increases visibility of behind-the-meter energy use at the meter level and provides the data required for more granular analytics. When combined with BEMS/HEMS, sub-metering or device-level control hardware, AMI data can inform real-time response to grid signals. By supporting time-based tariffs, automated load adjustments and the integration of distributed energy resources, AMI helps buildings become active, flexible grid participants, while supporting load management, peak shaving and a greater use of renewables.

Aggregation of distributed energy resources

As the number of distributed energy resources and smart appliances increases across the building sector, managing these assets individually becomes increasingly complex for both building operators and grid managers. Aggregation enables coordination, control and optimisation of multiple DERs as a single, flexible resource.

Aggregation refers to the process of combining several DERs – often across different locations or buildings – into a unified portfolio that can be monitored and dispatched collectively. Aggregated DERs can function as part of a virtual power plant (VPP) or be integrated into a distributed energy resource management system (DERMS). These platforms optimise energy use, manage grid constraints and enable participation in electricity markets.

For efficient grid-interactive buildings (EGIBs), aggregation offers a variety of benefits:

- Enhanced flexibility: Aggregated assets can respond to grid signals by collectively reducing or shifting demand, or injecting stored energy back into the grid.
- Scalable grid services: While a single building may not have enough flexibility to support the grid on its own, aggregated DERs can provide services such as frequency regulation, voltage support and peak shaving.
- Market access: Depending on regulations, aggregation can allow smaller DER owners to access wholesale electricity or ancillary service markets, monetising their flexibility.
- Load predictability and optimisation: Aggregated data enable better forecasting and coordinated energy optimisation across a wider network of buildings.
- Support for resilience and decarbonisation: improving visibility and dispatchability of behind-the-meter resources allows for more effective VRE integration, increasing their share of electricity generation without the need for curtailment.

- Planning and design using building simulation: simulation and digital twin models can be used to assess flexibility potential, evaluate control strategies and optimise aggregation portfolios before deployment.

By enabling demand-side flexibility at scale, DER aggregation is a foundational element of the transition toward smarter, more responsive and lower-carbon buildings.

Demand response programmes

Demand response (DR) is the practice of balancing supply and demand on the grid by incentivising consumers to shift consumption to periods of lower demand or higher supply, usually through time-varying prices or financial rewards. DR adds flexibility to wholesale and ancillary power markets, balancing the grid and lowering costs by moving consumption to periods when electricity generation is cheaper and potentially "cleaner" (i.e. with a higher share of VRE). Modern data-driven demand response (or automated DR) programmes typically use real-time validation of available demand response through two-way communication with connected, electricity-consuming appliances and equipment. A user can often overwrite the demand response settings when needed.

There are two main DR mechanisms: (1) implicit, or price-based programmes, which use price signals to encourage consumers to shift consumption and adapt their behaviour to save energy; and (2) explicit, or incentive-based programmes, which monetise demand response through direct payments to consumers.

Dynamic electricity tariffs

Dynamic electricity tariffs, such as time-of-use pricing, charge more during peak hours and less when demand is low, encouraging consumers to shift usage to off-peak periods. This helps reduce peak demand, ease grid stress, integrate variable renewables and lower costs – while also potentially promoting cleaner electricity consumption. Dynamic pricing is intended to encourage consumers to shift electricity use to hours when it may be cheaper to produce or come from cleaner sources, or when the power grid is less stressed.

Time-of-use tariffs are also important for promoting the adoption of EVs. With EV uptake increasing, there is a growing need for charging infrastructure that can accommodate the increased demand for electricity for vehicles. Time-of-use tariffs can incentivise consumers to charge their EVs during off-peak hours. A study in the United Kingdom showed that customers using hourly dynamic pricing through smart meters shifted 28% of their demand from peak periods and on average saved around GBP 180 on their annual energy bills.

EV smart charging in buildings

The global electric vehicle (EV) market is experiencing rapid expansion: in 2024, global EV sales exceeded 17 million units, pushing their share to just over 20 % of new vehicle sales.

The increasing adoption of EVs in the world is also driving the demand for related charging infrastructure. Since most charging takes place in buildings, EV charging is becoming an additional energy-consuming end use in the buildings sector.

Smart charging uses advanced controls and communication to optimise electricity use for EV charging, taking into account grid capacity, electricity demand and user needs. By shifting charging to off-peak hours or periods of high renewable output, it reduces grid stress, lowers related carbon emissions, cuts costs for consumers and avoids costly infrastructure upgrades for utilities to meet peak demand.

A typical EV battery can hold enough energy to power a US home for more than three days. Employing bi-directional vehicle-to-grid capability, EVs can act as distributed storage, supporting demand response, backing up buildings during outages, and helping integrate renewables.

Smart inverters

The interface point between the grid and energy generating and storing resources is the inverter, which converts direct-current (DC) from renewable energy and storage systems into usable, grid-quality alternating current (AC). Smart inverters are an emerging technology that help integrate solar energy and other DERs into the electric grid.

Modern inverters also support grid functions such as voltage regulation, frequency support, and active/reactive power control, capabilities that are now codified by standards such as IEEE 1547-2018 and UL 1741 SB.

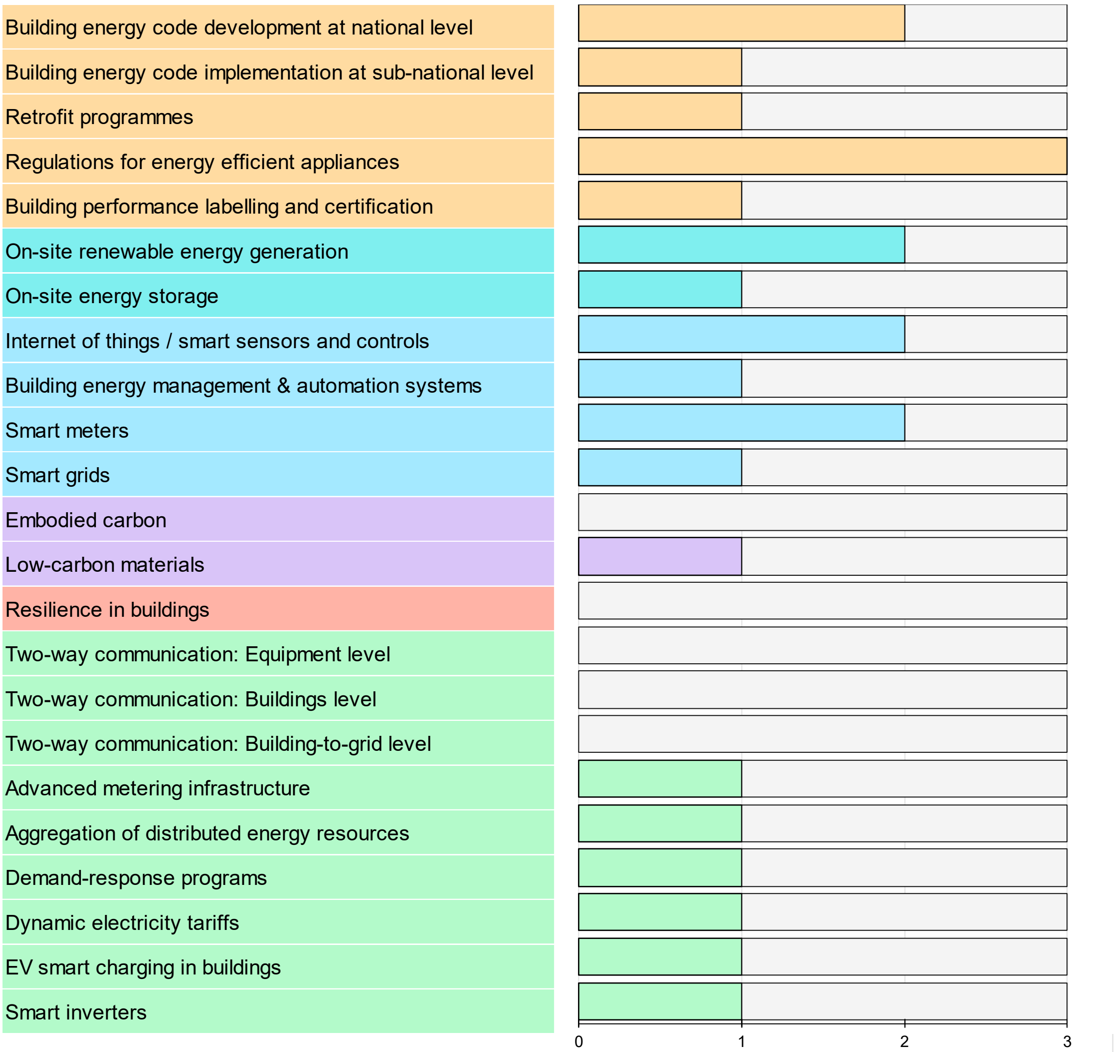
Features such as Volt-Watt functions dynamically reduce output when local voltage spikes. This helps support grid stability, though sometimes at the cost of curtailing local generation. Several US states, including California, Maryland and Oregon, have mandated adoption of IEEE 1547-compliant inverters for new DER interconnections.

While certification delays and interoperability challenges remain, smart inverters are becoming an essential link between DER growth and grid stability.

Chapter 3. Assessment of opportunities for efficient grid-interactive buildings in India

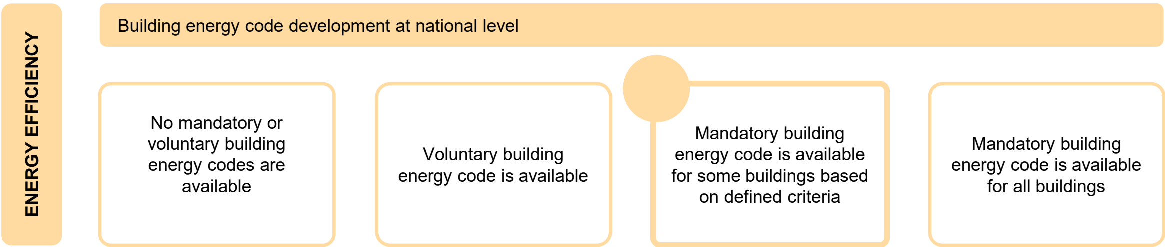
The previous chapter introduced a framework to assess the degree to which different enablers of building-to-grid interactivity are present in a country or power system. This chapter applies this framework to assess the current status of these enablers in India. Based on a review of the current policy landscape, each enabler is scored from 0 to 3, according to its current ability to enable the uptake of EGIBs.

Assessment of current policy framework by enabler in India



Notes: Scoring scale: 0 = Policies not yet in place, 1 = Initial developments, 2 = consistent developments, 3 = developments at scale.

Building energy codes provide a strong policy framework, but coverage is limited



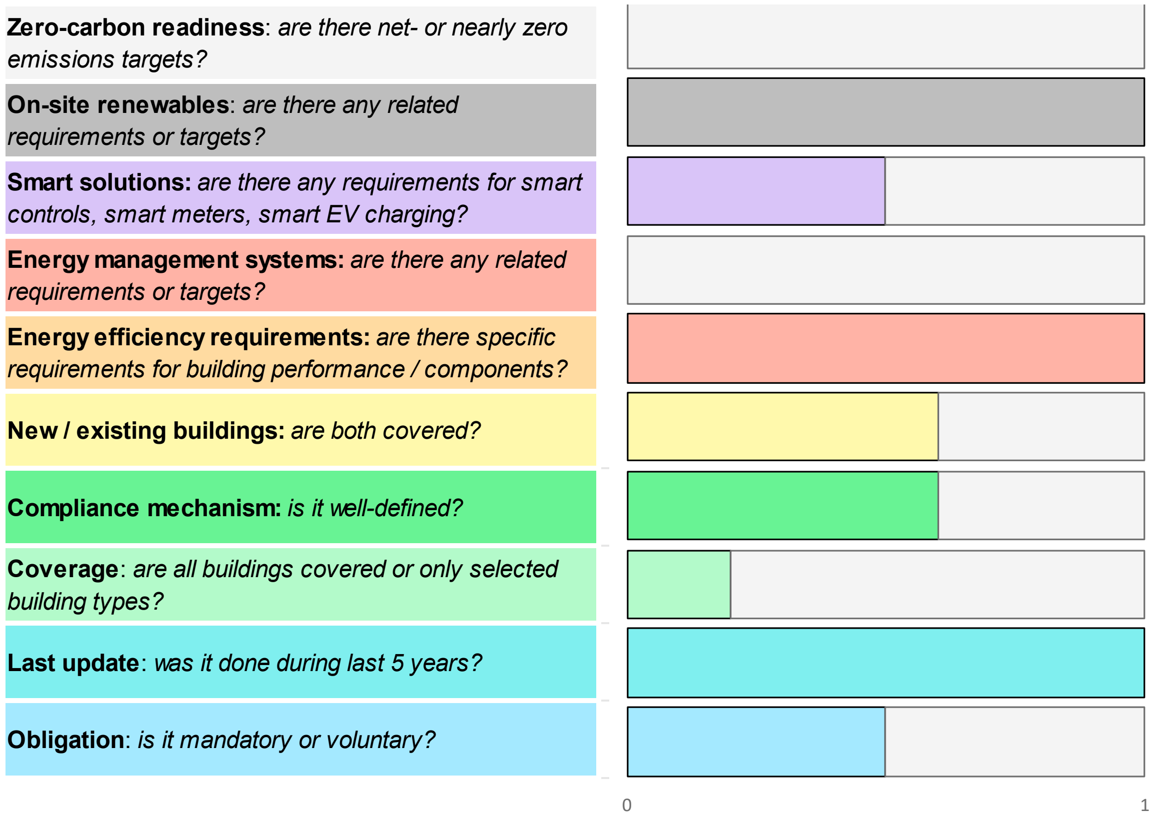
India's Energy Conservation and Sustainable Building Codes for commercial and residential buildings provide minimum energy performance, energy efficiency and sustainability requirements for new buildings. They set requirements for the building envelope, mechanical systems and equipment, including heating, ventilating and air conditioning, service water heating, lighting, and renewable energy systems.

Building energy codes set at a national level in India need to be implemented at the state level before they are mandatory, since buildings are a state-governed subject. National codes serve as a basis that states can adopt with amendments, based on local conditions. The national-level codes establish norms and standards for buildings with a connected load of more than 100 kW or a contracted demand of more than 120 kVA, applicable to both residential and commercial buildings. For residential buildings, the code also applies if the floor area is more than 3 000 square metres.

The IEA's building energy code content assessment (BECCA) tool contains ten elements that the IEA considers important in a comprehensive building energy code for the transition to zero-carbon-ready buildings. The tool analyses the extent to which national building energy codes include these elements and provides insights for further policy development, particularly for the next building energy code update or revision cycle. While analysis based on the BECCA tool evaluates the content of building energy codes, it does not consider the degree to which they have been implemented or enforced.

An evaluation of India's building energy codes indicates that the national-level code is relatively comprehensive, with strengths such as requirements for energy efficiency and on-site renewables. The building energy codes have also been periodically revised, including as recently as 2024. However, only a limited proportion of the country's building stock is covered under the code requirements. There are also opportunities to make the code more comprehensive with requirements on zero-carbon readiness, integration of building energy management systems and smart solutions.

Building energy code content analysis for India



Notes: Scoring scale: 0 = Not covered, 0.5 = Partially covered, 1 = Well covered.
Source: IEA, Energy Efficiency 2024.

India's building energy codes prescribe quantifiable energy efficiency requirements by setting U-values for the thermal transmittance of roofs and walls. This measures the rate of heat transfer through these building components. The required U-values vary according to the climate zone (hot and dry, warm and humid, temperate, composite, and cold).

U-values (W/m²·K) for roof and walls for different climate zones in India

Climate zone	Commercial buildings		Residential buildings
	Roof	Walls	Roof
Composite	0.26	0.40	1.2
Hot and dry	0.26	0.40	1.2
Warm and humid	0.26	0.40	1.2
Temperate	0.26	0.55	1.2
Cold	0.20	0.34	1.2

Notes: The U-values apply to most building types; some exceptions for commercial buildings exist. For residential buildings, compliance is assessed through the residential envelope transmittance value (RETV) for walls, which measures heat gains through the building envelope.
Source: Bureau of Energy Efficiency.

Sub-national implementation of building energy codes remains uneven

ENERGY EFFICIENCY

Building energy code implementation at sub-national level

No implementation of the BEC at the sub-national or local level, meaning there is no enforcement beyond national-level intent	Some jurisdictions are implementing the BEC, but it is not effectively enforced or remains largely aspirational	Certain jurisdictions are actively implementing the BEC with moderate enforcement, but adoption is not widespread across all jurisdictions	The BEC is widely enforced across most sub-national/local jurisdictions, with clear compliance monitoring and enforcement mechanisms in place

In India, 25 of the 36 states and union territories have adopted the national code for commercial buildings. Twelve of these have further adopted the code in municipal building bylaws. Most state-level ECBCs align with the national standards, but Chhattisgarh, Tripura and Chandigarh have stricter requirements, as their code applies to buildings with a connected load of more than 50 kW or a contract demand of more than 60 kVA. In Sikkim, the code even applies to buildings with a connected load of more than 40 kW or a contract demand of more than 50 kVA. The U-values for walls and roofs in the state-level codes generally align with the national code's specifications for each climate zone.

Adopting the residential code was made mandatory for states under the 2022 Energy Conservation Act. While several states and union territories, including Telangana, Andhra Pradesh, Arunachal Pradesh and Chandigarh, are preparing to roll out the residential code, no state has yet fully implemented it.

While national building energy codes provide a strong policy framework for states, certain challenges limit their widespread implementation in India. The number of commercial code-compliant buildings in India was estimated to be around 1 326 in 2024. Most of these were in Punjab, Andhra Pradesh, Uttar Pradesh and Telangana. However, the estimated energy savings from code compliance contributed less than 1% of the total energy saved nationwide through energy efficiency measures. Two key factors inhibiting the efficiency gains were code coverage and compliance. Based on stakeholder consultations, it is estimated that less than 8% of India's building stock is covered by the code requirements.

The institutional framework for building energy codes in India involves multiple stakeholders at the central, state and local levels. Capacity at the state level for code adoption and implementation remains underdeveloped in most cases, leading to considerable delays in integrating the code into building bylaws. The limited budgetary support for capacity building and recruitment of sufficient staff also poses challenges to the implementation of building energy codes.

Lack of mandatory policies slows retrofit momentum in India

ENERGY EFFICIENCY

Retrofit programs

No policies or programmes for retrofit with energy efficiency requirements are available	Voluntary policies or programmes for energy efficient building retrofits	Mandatory policies for energy efficient building retrofits available for some buildings based on defined criteria	Mandatory policies for energy efficient building retrofits available for all buildings

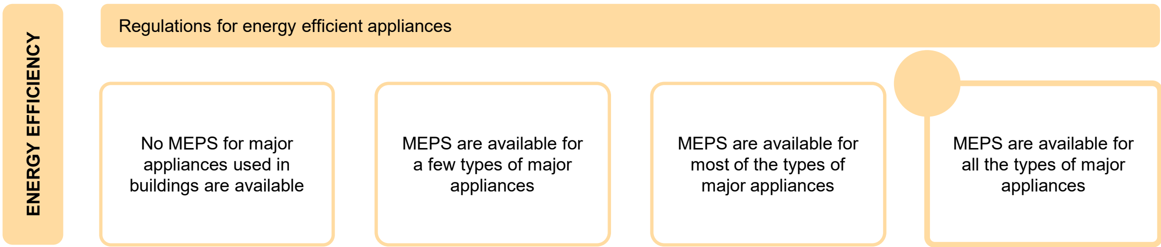
For the large portion of India's vast and ageing building stock that was constructed without energy efficiency considerations, retrofitting offers a pathway for reducing energy consumption and greenhouse gas emissions – while improving occupant comfort and lowering utility costs. The regulatory status for retrofitting in India is still evolving, with no national regulation mandating energy retrofits in existing buildings. However, several government policies, notifications and programmes provide enabling frameworks, particularly for public-sector buildings, while encouraging voluntary uptake in the private sector.

The Bureau of Energy Efficiency has developed Energy-Efficient Retrofit Manuals to guide the systematic assessment, planning and implementation of retrofits in both commercial and residential buildings. These manuals provide detailed technical recommendations across a range of passive and active measures that cover building envelopes, lighting, HVAC systems and electrical equipment.

Energy Efficiency Services Limited (EESL), a joint-venture company under the Ministry of Power, has been implementing the Buildings Energy Efficiency Programme (BEEP) to transform public and commercial buildings into energy-efficient complexes. Following a 2017 government directive that mandates all ministries and departments to adopt energy efficiency measures, EESL has completed retrofit projects in over 12 700 buildings, including railway stations, airports and government offices.

Energy audits indicate an energy savings potential of 30–50%, primarily through improvements in lighting and cooling systems. Successful examples include the Paryavaran Bhawan in Chandigarh, which now operates as a Net Zero Energy building with a 5-Star label awarded by India's Bureau of Energy Efficiency. The Paryavaran Parisar and Udyog Bhawan in Madhya Pradesh saw energy savings of 40% through upgrades to lighting (LCD), HVAC and insulation, with a payback period of 5–7 years. These case studies underscore the transformative impact of retrofitting. Broader market adoption will depend on strengthened regulatory frameworks, innovative financing models and greater awareness among stakeholders.

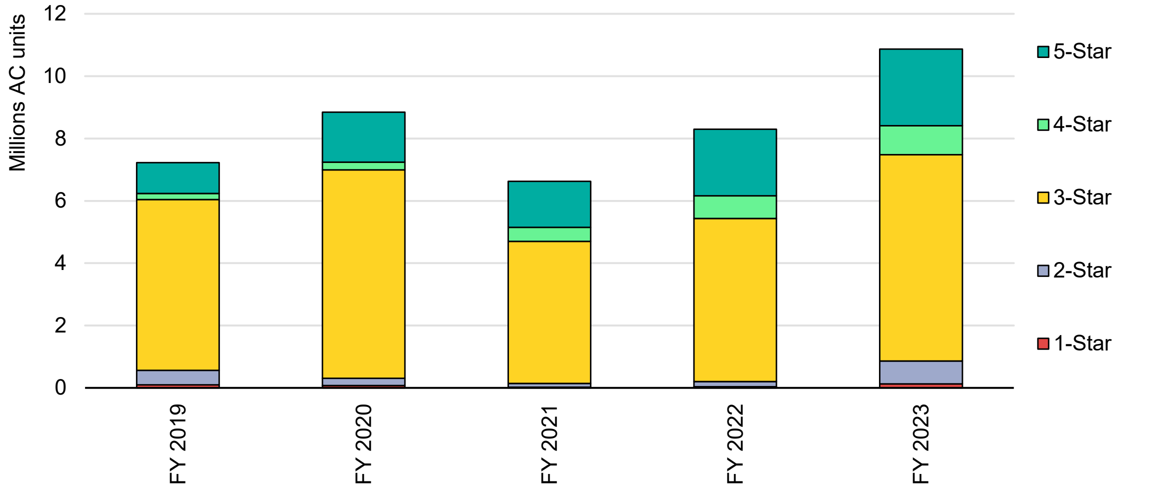
Appliance efficiency has led to major gains, with further opportunities to strengthen regulations for air conditioners



India's standards and labelling program defines minimum energy performance requirements for products and issues labels from 1-star to 5-stars, based on a model's performance. The programme currently covers 40 appliances, 16 for which labelling is mandatory and 24 for which it is voluntary. The labelling programme aims to create awareness and increase efficiency by periodically revising the energy efficiency standards corresponding to the labels. In 2023, the programme led to total energy savings of 7 Mtoe, and consumer savings of about USD 6 billion, thanks to reduced electricity bills.

Air conditioners are the main driver of India's rising electricity demand, with annual sales of this appliance reaching nearly 15 million. Some 130-150 million air-conditioners are expected to be added between 2025 and 2030. Market trends indicate that sales in India are dominated by models with lower efficiency ratings.

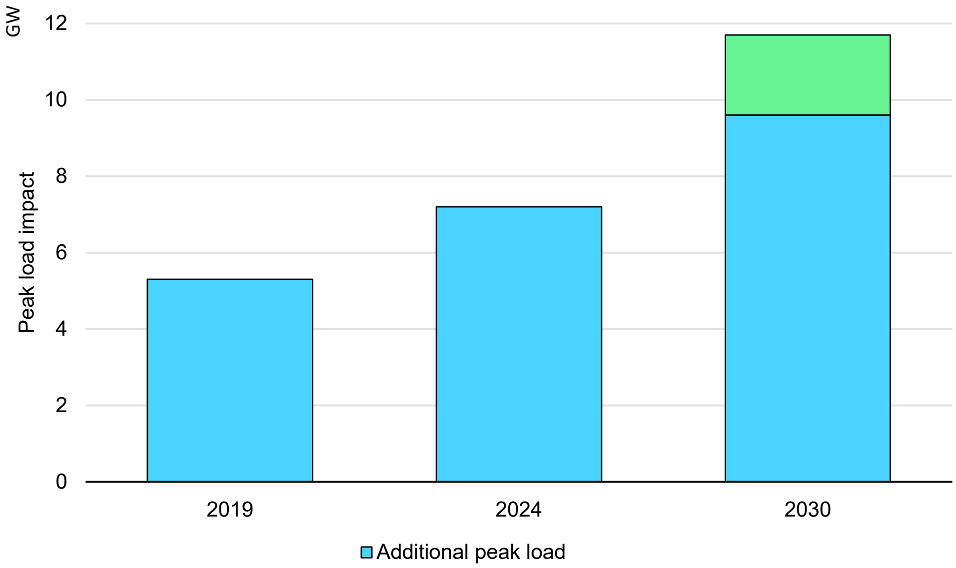
Annual air conditioner production volumes by efficiency rating in India, fiscal years 2019-2023



Notes: Energy efficiency standards were tightened just prior to FY 2023, leading to an increase of models classified as 2-Star. Produced units are used as a proxy for sales by the Indian Bureau of Energy Efficiency.
Source: IEA (2024) Energy Efficiency.

Strengthening minimum energy performance standards avoids locking in inefficient technologies. Rising temperatures and the consequent growth in the use of air conditioning are already straining India's electricity system. In 2019, each 1°C increase in outdoor temperature added around 5 GW to peak demand. By 2024, this had risen to 7 GW, and without stronger efficiency measures could reach 12 GW by 2030. If India were to experience additional heatwaves similar to those of recent years, with temperature anomalies exceeding 4°C, peak demand could surge by an additional 47 GW. If all new air conditioners met high efficiency standards, however, the resulting peak load during heatwaves could be cut by almost 9 GW (around 20%).

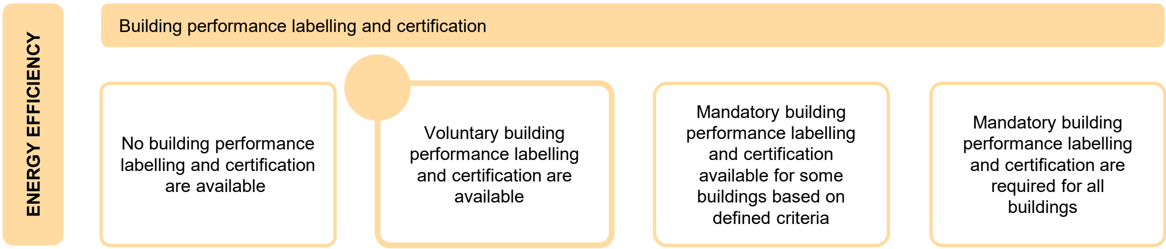
Additional peak load caused by an outdoor temperature increase of 1 °C and avoided peak load due to the sale of higher-efficiency air conditioners in India, 2019-2030



Notes: High efficiency scenario assumes replaced and new equipment from 2024 to 2030 is in line with the IEA Net Zero emissions guidance for space cooling (SEER 5.0 – 6.5).

Source: IEA (2025), Energy Security.

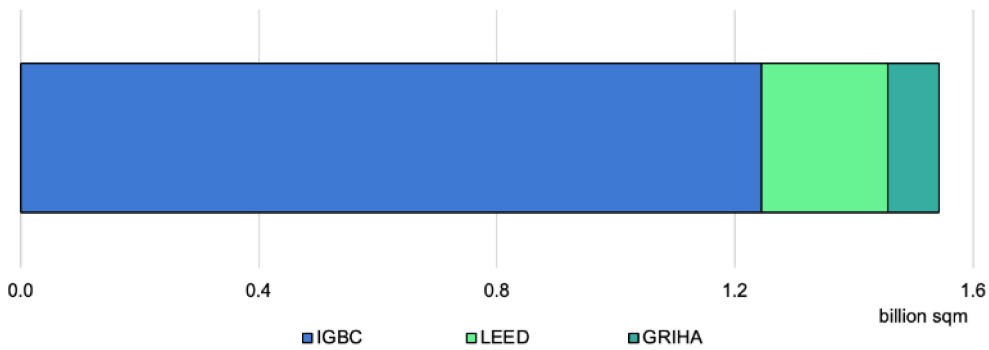
Voluntary green building certifications are growing in the commercial sector



India has a voluntary rating programme for residential and commercial buildings, including office buildings, hospitals, and shopping malls. Energy performance is assessed using the Energy Performance Index (annual energy consumption in kilowatt hours per square metre) benchmarked to climatic zones, with ratings from 1 to 5 stars. Over 400 commercial buildings have been certified, with office buildings comprising approximately 70% of the total. The Bureau of Energy Efficiency also runs the voluntary "Shunya" Labelling Programme for Net Zero Energy Buildings (NZEB) and Net Positive Energy Buildings (NPEB), with over 100 buildings certified to date. Other voluntary green building rating systems include the Green Rating for Integrated Habitat Assessment (GRIHA), Excellence in Design for Greater Efficiencies (EDGE), and schemes run by the Indian Green Building Council (IGBC) and the Leadership in Energy and Environmental Design (LEED).

As of 2024, the country's green building footprint exceeds 1.5 billion square metres, with over 90% certified by IGBC. Although still less than 5% of new construction, India's green building footprint is growing, led by the commercial sector. Green-certified office stock in India grew at a compound annual growth rate (CAGR) of 9% from 2015 to 2023, doubling from 178 million square feet to about 342 million square feet. The major urban centres of Bangalore, Delhi and Mumbai together account for more than 68% of India's certified green office space.

Green certified building footprint in India



Notes: Data on EDGE-certified buildings in India were not found at the time of publishing this report and is not included.
Source: IEA analysis based on data from IGBC, GRIHA, and GBCI .

Rising adoption of residential rooftop solar presents an opportunity for decarbonisation in the building sector

DECARBONISATION

On-site renewable energy generation

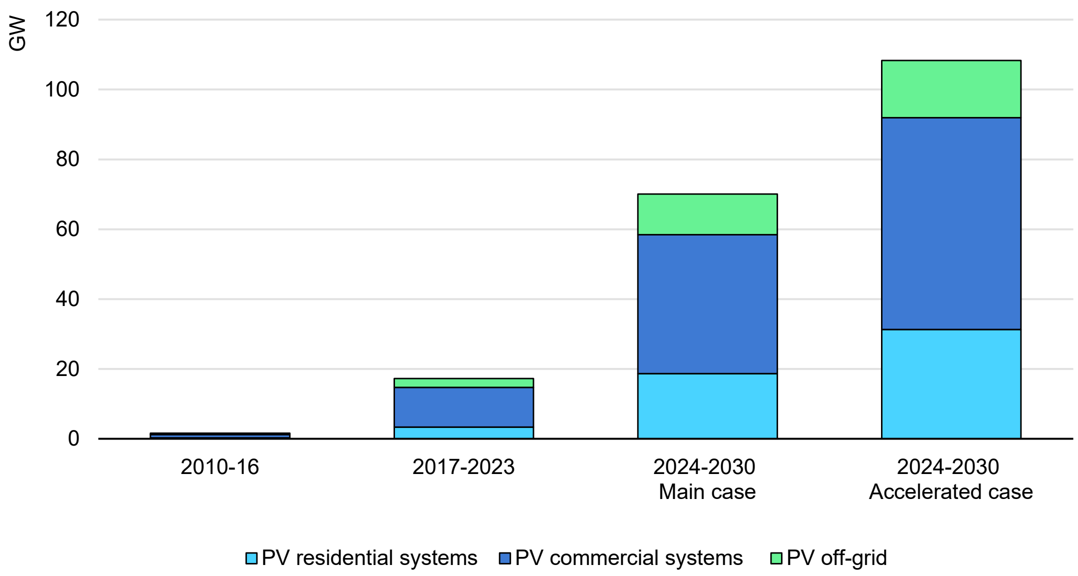
No policies or programmes for on-site RE generation in buildings are available	Voluntary policies or programmes for on-site RE generation are available	Mandatory policies for onsite RE generation for some building types are available	Mandatory policies for onsite RE generation for all building types are available

India has a target to install 500 GW of generating capacity from non-fossil fuel sources by 2030, including 30 GW of solar rooftop capacity by 2027. To promote the widespread adoption of rooftop solar for Indian households, the government introduced the Grid-Connected Rooftop Solar Programme in 2024 to achieve a cumulative installed capacity of 40 000 MW.

An additional programme, PM Surya Ghar: Muft Bijli Yojana, was introduced in 2024 to install rooftop solar PV on 10 million homes by 2027. The scheme offers subsidies and accessible financing options, with subsidy amounts varying according to average monthly electricity consumption and solar capacity required. Households can receive a subsidy of up to 60% for solar systems up to 2 kW, and a 40% subsidy for systems between 2 and 3 kW. The scheme also provides an opportunity for households to sell surplus power to the grid. The scheme has already completed more than 1 million rooftop solar installations, with the highest number of installations in Rajasthan, Maharashtra, Gujarat and Tamil Nadu. India's rooftop solar installations represent 16% of total installed solar PV capacity. Distributed PV installations are expected to increase nearly fivefold between 2023 and 2030.

State-level policies also play an important role in accelerating the adoption of rooftop solar in India. These often complement national schemes by offering direct or indirect incentives. For instance, Jharkhand provides subsidies based on household income, limiting eligibility to those consumers in lower electricity consumption tiers. Uttarakhand and Andhra Pradesh offer tax exemptions such as waivers on electricity duty and other local levies.

Forecast capacity growth in distributed PV systems in India, 2010–2030

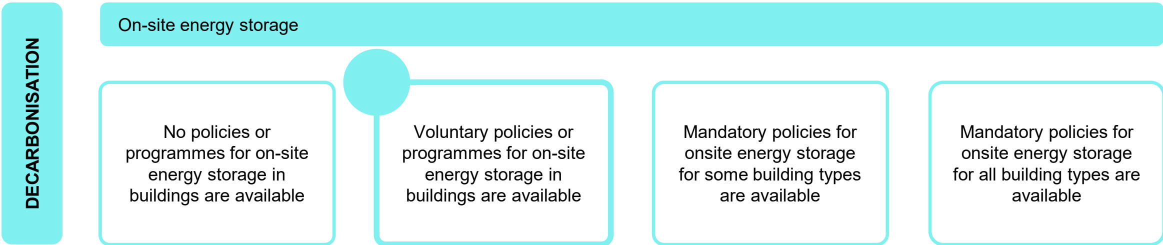


Source: IEA (2024) Renewable Energy Progress Tracker (accessed 2 September 2025).

States also define the metering frameworks under which rooftop solar operates, including net metering, gross metering and net billing. Several states, including Madhya Pradesh, Odisha and Maharashtra, recently introduced group net metering and virtual net metering, enabling energy sharing across multiple consumers or locations, such as housing societies and government buildings.

The building energy codes also call for code-compliant buildings to have onsite renewable energy systems. For commercial buildings, compliance can be met by installing onsite renewable energy capacity equivalent to at least 4% of the building's maximum electrical load or by covering at least 50% of the available roof area. For residential buildings, the codes require onsite renewable systems covering at least 10% of the plot area (defined as the gross land area within the site's property boundaries, inclusive of built structures, landscaped zones, and unbuilt open areas).

Limited deployment of energy storage weakens grid reliability during peak demand



As India integrates an increasing share of renewable energy into its power mix, there is growing availability of solar generation around midday, when the sun shines brightest. However, electricity demand in India typically peaks in the evening, which is when solar-powered generation is relatively low, leading to a mismatch between solar generation and electricity demand. The need to manage the intermittent nature of renewable energy sources is therefore driving up the need for flexibility in the power system. Deploying on-site, building-level energy storage systems alongside on-site renewable generation can address this issue by storing surplus power during periods of high generation and supplying it when demand rises but generation is low. Energy storage not only enhances the reliability of renewable energy but helps stabilise the grid.

Energy storage deployment so far has been mostly limited to a few grid-scale projects. For example, a 20 MW utility-scale battery energy storage project was launched in 2025 in Delhi.

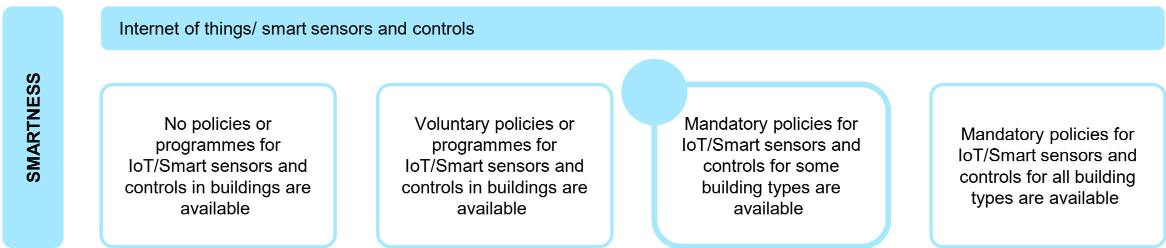
Energy storage integration in buildings usually occurs close to the point of generation and consumption. States such as Goa and Uttarakhand offer subsidies to promote the adoption of battery storage with rooftop solar, though the deployment of on-site energy storage in India is still nascent. Without sufficient energy storage at the building level, the country risks underutilising its growing renewable energy capacity and facing grid stability challenges during peak hours.

Thermal energy storage (TES) can be integrated into both new and existing cooling systems and can support India’s adoption of efficient grid-interactive buildings by enabling cooling load shifting – producing cooling during off-peak hours and using stored chilled water or ice during the daytime peak. This reduces stress on distribution networks, lowers operating costs for buildings, and complements India’s wider grid-modernisation and demand-response agenda.

India already has early examples of TES-driven demand flexibility. The Thermal Energy Storage Programme in Mumbai, pioneered by Tata Power for large commercial buildings, included central air-conditioning plants operated at night to freeze water in ice tanks, allowing buildings to use the stored ice for cooling during the day. The programme delivered a flatter system load curve, improved load and power factors, and reduced operating costs for consumers, who benefited from time-of-day(ToD) tariff incentives and an additional rebate for nighttime consumption. By January 2014, Tata Power had enabled 3.6 million units of load shifting, meaning that 3.6 GWh of electricity consumption for cooling was shifted from daytime peak hours to off-peak periods. In parallel, it deployed 15 000 tonnes of refrigeration (TR) of TES, where one tonne of refrigeration represents the cooling power required to freeze one tonne of water over 24 hours (approximately 3.5 kW of cooling). This TES capacity allowed buildings to store cooling energy during low-demand hours and use it later to meet cooling needs during peak periods, reducing stress on the electricity network and lowering operating costs for consumers.

Several other large infrastructure projects also demonstrate TES integration. For example, GIFT City in Gujarat uses an efficient district cooling system (consuming 30% less energy than typical AC systems) with a thermal storage tank, system of chillers and a pipe networks to produce, store and distribute cool water through buildings, with monitoring and metering enabled through SCADA systems. Results show lower operational and maintenance costs for end users and flatter peak electricity demand for the grid.

IoT is gaining ground in corporations, though policy gaps hinder wider deployment

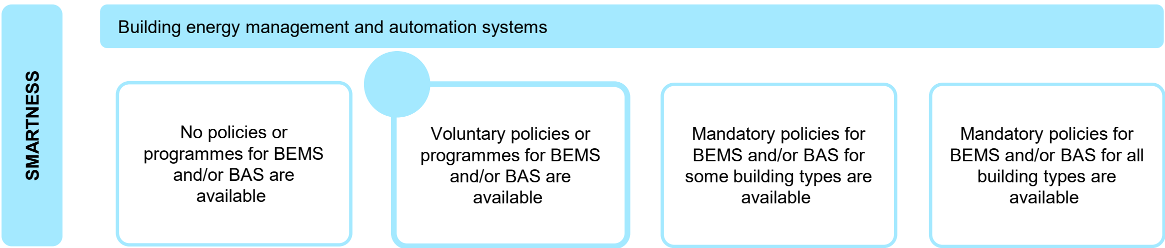


The Energy Conservation and Sustainable Building Codes integrate provisions for advanced controls and sensors, including occupancy-based lighting, automatic shut-off mechanisms and demand-controlled ventilation. However, the absence of complementary policies and enforcement frameworks has resulted in relatively low adoption in practice. Nevertheless, voluntary adoption is gradually expanding, primarily in non-residential buildings, driven by energy cost and productivity considerations. For example, Infosys, a leading Indian IT company that achieved carbon neutrality in 2020, has integrated over 19 500 sensors across its office campuses. These sensors feed into advanced building energy management systems, enabling real-time demand management that has contributed to a 44% reduction in per-capita electricity consumption over a decade. Similarly, the Godrej Group has leveraged AI and data analytics to optimise energy use to achieve a 57% reduction in consumption while improving productivity through real-time energy monitoring, digital alerts and process automation.

Energy efficiency service companies are also advancing the market. Smart Joules, for instance, provides energy efficiency solutions for large buildings such as hospitals and commercial facilities through its DeJoule platform. DeJoule uses IoT sensors and AI-driven algorithms to monitor and optimise energy systems in real time, collecting minute-by-minute data and adjusting operations based on occupancy, weather and behaviour patterns. The platform supports remote control and automated alerts and delivers guaranteed energy savings, typically between 15% and 60%.

The smart homes market in India is also expected to grow significantly, with projections estimating it will reach USD 9.2 billion by 2028, representing a CAGR of approximately 9% between 2024 and 2028.

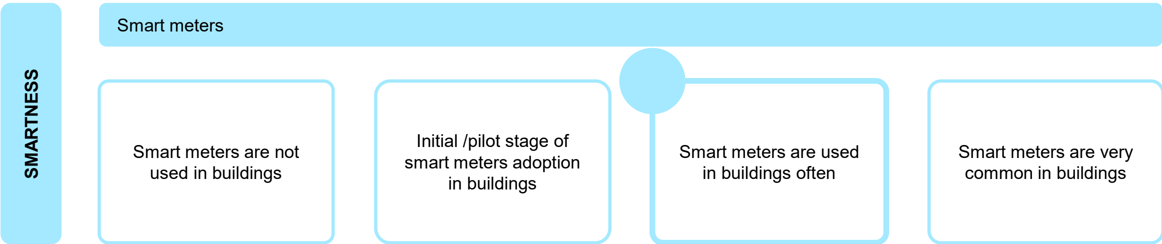
Building energy management and automation systems are mostly used in high-end commercial buildings



The adoption of building energy management systems and automation technologies in India is limited. However, it is gaining momentum, particularly in commercial buildings, public infrastructure and green-certified developments. While not yet mandated at the national level, key policy instruments, such as building energy codes and certification and labelling programmes, are encouraging the integration of energy management and control systems. For example, the Energy Conservation and Sustainable Building Codes for commercial and residential buildings recommends the use of automation controls for lighting, HVAC and ventilation systems, and recognises building energy management systems as a compliance pathway to meet performance-based targets.

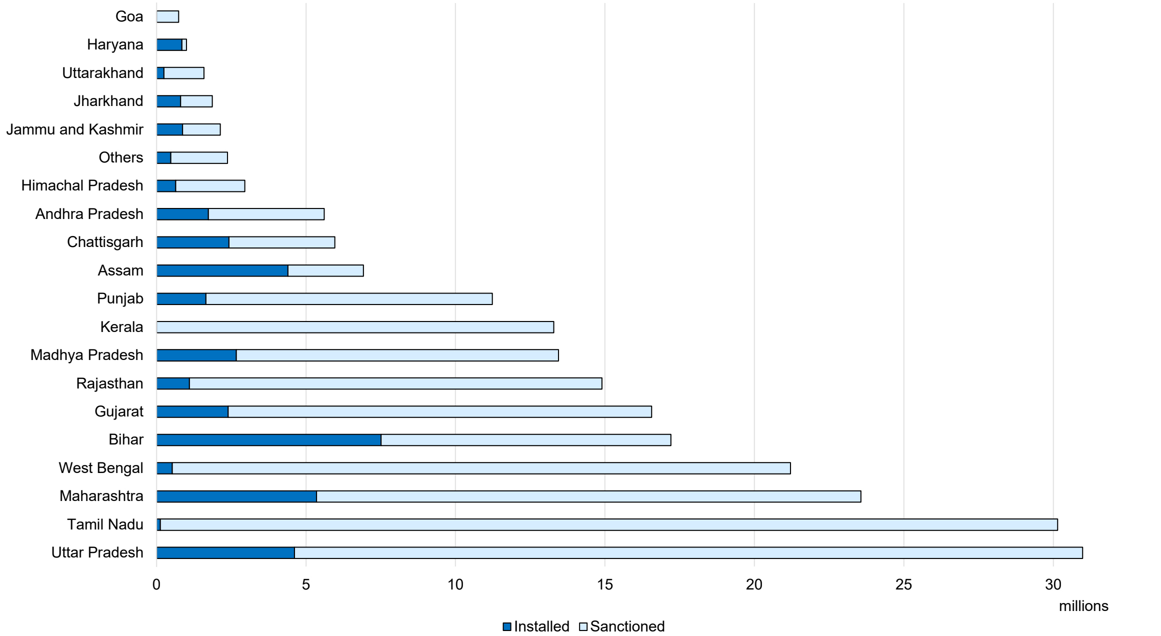
The initial adoption of building energy management and automation systems in India has been most prominent in the commercial sector, where large corporate and hospitality players are leading the way. For example, the smart building automation systems that Infosys has implemented across its campuses are enabling predictive maintenance, real-time energy analytics and centralised control of lighting and HVAC systems, thereby contributing to substantial reductions in energy consumption and operational costs. Similarly, ITC Hotels has deployed automated building management systems across its properties to optimise HVAC operations, manage lighting and monitor energy performance through detailed dashboards. However, the lack of mandatory requirements, high upfront costs, and limited awareness among smaller developers continue to be barriers to wider adoption.

Ambitious smart meter deployment targets are in place, but adoption is still limited



To improve the operational efficiency and financial sustainability of distribution companies, India introduced the Revamped Distribution Sector Scheme (RDSS) in 2021. The scheme, which has an estimated total outlay of USD 33 billion (~INR 3 trillion) over five years, aims to replace 250 million conventional electricity meters with smart meters. The original 2026 deadline has now been extended to 2028. As of September 2025, over 220 million smart meters had been approved ("sanctioned") for funding, though only 40 million installed. More than two-thirds of these are in four states – Bihar (33%), Assam (16%), Uttar Pradesh (9%) and Madhya Pradesh (8%).

Allocation of sanctioned and installed smart meters by state in India, as of September 2025



Notes: "Others" includes Manipur, Meghalaya, Tripura, Nagaland, Mizoram, Arunachal Pradesh, Delhi, Sikkim, Telangana and Odisha.
Source: National Smart Grid Mission (accessed 2 September 2025).

The Central Electricity Authority’s (CEA) mandatory technical specifications for smart meters include bi-directional communication for remote meter reading and control, integrated load-limiting switches for managing or disconnecting supply, and capability for over-the-air firmware upgrades. Smart meters are also required to support net metering (recording both imported and exported electricity) and include time-of-day tariff functionality (to enable dynamic pricing and demand response), as well as tamper detection, event logging, minimum data storage capacity, and compliance with relevant Indian standards such as IS 16444 and IS 15959.

The Revamped Distribution Sector Scheme (RDSS) operates on the Design-Build-Finance-Own-Operate-Transfer (DBFOOT) model. This means that advanced metering infrastructure service providers are responsible for financing, supplying, installing and operating smart meters, along with the required communication and IT infrastructure. Service providers receive a partial payment for capital expenditure upfront, while the remaining cost is recovered over a 7–10-year operation & maintenance period through a monthly service charge per meter that is linked to performance indicators. Smart meter contracts are awarded through a competitive bidding process, with the monthly service charge per meter serving as the primary evaluation criterion. This model allows distribution companies to roll out smart meters without significant upfront capital investments, while gaining full ownership of the infrastructure at the end of the contract period at no additional cost.

Smart meters enable the grid integration of distributed energy resources (DERs) such as rooftop solar, battery energy storage systems and electric vehicles. They also provide the enabling infrastructure for demand-side management (DSM) initiatives, including dynamic pricing and demand response programmes.

Challenges that continue to hinder the pace of smart meter deployment in India include a lack of standardised protocols and interfaces. This has led to compatibility issues between smart meters, network cards and communication networks. It has also reportedly caused some users to signal problems related to billing transparency, digital access and the payment function. Such issues may require more attention from distribution companies, since a lack of consumer trust and engagement can pose significant barriers to widespread adoption.

Early pilot projects mark the start of smart grid expansion

SMARTNESS

Smart grids

Smart grid plans are not available	High-level smart grid plans are available, but the targets and implementation are not well defined	Smart grid plans are available and set targets, but their implementation is not well defined	Comprehensive smart grid plans are available, with well-defined targets and implementation

In 2015, India established the National Smart Grid Mission (NSGM) to accelerate the deployment of smart grids in India. Smart grids enable grid automation, real-time exchange of electricity and information, and the integration of renewable energy. The NSGM aims to modernise the country's electricity grid, making it more efficient, reliable and resilient.

Under the NSGM, smart grid pilot projects have been launched in several states, including Assam, Gujarat, Himachal Pradesh, Haryana, Karnataka, Rajasthan, Telangana, Tripura, Puducherry, Uttar Pradesh and West Bengal. The pilot projects aim to test and demonstrate smart grid technologies and build utility capacity and experience for scaling them up. Piloted technologies include advanced metering infrastructure (AMI), time-of-day tariffs, peak load management, net metering, outage management systems (OMS) and rooftop solar integration. With a total investment of USD 30 million (INR 2.5 billion), these projects have installed approximately 156 000 smart meters, resulting in notable reductions in aggregate technical and commercial (AT&C) losses.

Pilot projects under the NSGM have highlighted numerous challenges in scaling up smart grids. For example, the lack of standards for smart grid technologies has created problems related to interoperability and efficiency. Utilities' experience with pilot projects also underlined the importance of gaining consumer trust and acceptance for new technologies. Addressing challenges such as cybersecurity risks, effective data management and the stability of energy storage systems will also be important for scaling up smart grid solutions.

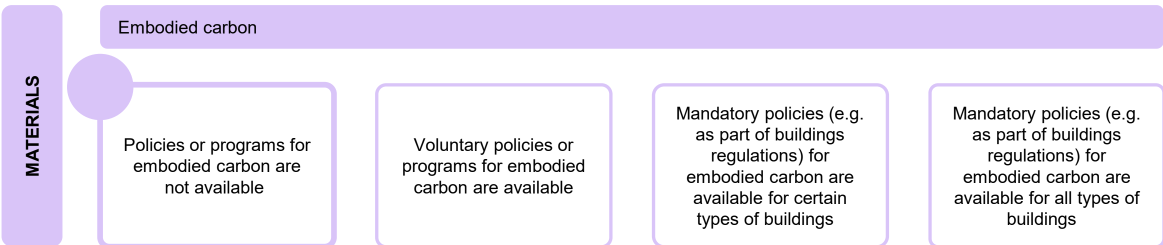
Pilot programmes implemented under the National Smart Grid Mission programme

Utility and state	Consumer base	Main functionalities implemented	Reduction in AT&C losses
Ajmer Vidyut Vitran Nigam Limited, Rajasthan	1 000	AMI	20% to 13.5%
Assam Power Distribution Company Limited (APDCL), Assam	15 000	AMI, PLM	23% to 14%

Utility and state	Consumer base	Main functionalities implemented	Reduction in AT&C losses
Chamundeshwari Electricity Supply Corporation Limited (CESC), Mysore	24 000	AMI, PLM, OMS, DG	10% to 4%.
Himachal Pradesh State Electricity Board Limited (HPSEB), Himachal Pradesh	1 500	AMI, PLM, OMS	3% to 1%
Electricity Department-Puducherry (PED), Puducherry	30 000	AMI	22% to 16%
Tripura State Electricity Corporation Ltd (TSECL), Tripura	45 000	AMI, PLM	35% to 7%
Telangana State Southern Power Distribution Company Limited (TSSPDCL), Telangana	11 000	AMI, PLM, OMS	9% to 4%
Uttar Haryana Bijli Vitran Nigam Limited (UHBVN), Haryana	11 000	AMI, PLM, OMS	23% to 18%
Uttar Gujarat Vij Company Limited (UGVCL), Gujarat	23 000	AMI, PLM, OMS, PQM	12% to 5%
West Bengal State Electricity Distribution Company Limited (WBSEDCL), West Bengal	5 700	AMI, PLM	20% to 8%.

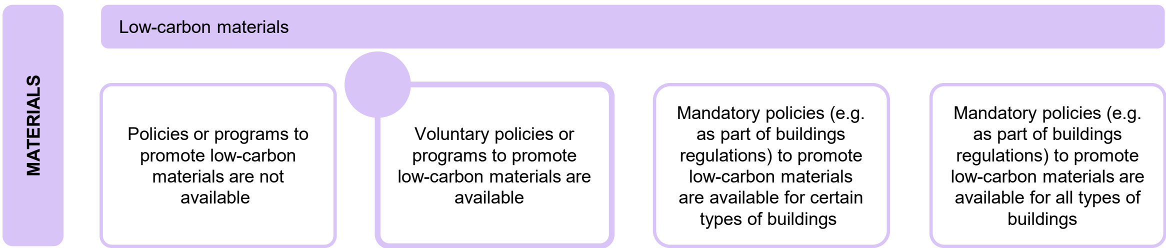
Notes: AMI = advanced metering infrastructure, DG = distributed generation, OMS = outage management system, PLM = peak load management, PQM = power quality management.

Consideration of embodied carbon is still at a nascent stage in both policy and practice



India currently lacks a mandatory national framework for measuring, reporting and regulating embodied carbon. Building codes, energy regulations and building rating systems remain focused on operational energy efficiency. A key challenge is the absence of reliable embodied energy data for construction materials, which constrains the use of life cycle assessment in accurately quantifying environmental impacts. Moreover, the absence of a standardised life cycle assessment framework tailored to the Indian context further hampers its systematic adoption within the building sector. Nevertheless, there has been some progress through voluntary approaches. For example, the Indian Green Building Council's Net Zero Rating System encourages the use of low-embodied carbon materials. (The rating system has proposed a benchmark that embodied carbon should not exceed 700 kg CO_2equivalent per m² of built-up area.)

Early progress on low-carbon materials is emerging at the sub-national level



India's policy landscape for low-carbon construction materials is still at an early stage of development, with no binding national mandate requiring their use. However, several enabling programmes are beginning to create pathways for their adoption. The 2024 Ministry of Power guidelines on ash utilisation support low-carbon construction in India by mandating full utilisation of fly ash from thermal power plants and promoting its use in bricks, blocks and cement in order to reduce reliance on carbon-intensive materials such as clinker and fired clay bricks. In affordable housing, the Pradhan Mantri Awas Yojana programme encourages resource-efficient and affordable materials such as fly ash bricks and aerated autoclaved concrete (AAC) blocks.

At the state level, Karnataka is drafting a circular economy policy that would require a minimum share of sustainable or recycled materials in commercial construction. City-level climate action plans, such as those of Nagpur and Thiruvananthapuram, are promoting low-carbon construction materials as part of their net-zero roadmaps. Together, these programmes provide early momentum, but their impact remains limited in the absence of national-level mandatory requirements.

The policy landscape for climate resilience in buildings remains fragmented

RESILIENCE

Resilience in buildings

Policies or programs for resilience in buildings are not available	Voluntary policies or programs for resilience in buildings are available	Mandatory policies (e.g. as part of buildings regulations) resilience in buildings are available for certain types of buildings	Mandatory policies (e.g. as part of buildings regulations) resilience in buildings are available for all types of buildings

India does not yet have a mandatory national policy for integrating climate resilience and adaptation into building-related regulations. However, several national frameworks and codes have begun to embed resilience considerations in different forms.

The Energy Conservation and Sustainable Building Codes for commercial and residential buildings include passive design measures such as shading, natural ventilation and reflective roofing that also strengthen thermal resilience. The India Cooling Action Plan promotes cool roofs and passive cooling techniques, with recommendations to mainstream these into building codes.

More than 23 states and 120 districts have implemented Heat Action Plans, which increasingly recommend passive design features in buildings. States such as Telangana, Delhi and Gujarat have adopted dedicated cool roof policies or incorporated cool roof measures within their Heat Action Plans.

Despite these developments, the policy landscape for climate resilience in buildings remains fragmented, with resilience measures scattered across various codes and initiatives.

Lack of interoperability standards is a major challenge for grid-interactivity

Equipment level

BUILDING-TO-GRID INTERACTION

Two-way communication: Equipment level

No policies on open communication standards for appliances are available	Voluntary policies on open communication standards for appliances are available	Mandatory policies on open communication standards for some major appliances are available	Mandatory policies on open communication standards for all major appliances are available

Adoption of smart home devices and connected appliances in India is growing. However, interoperability is needed to enable these devices to actively coordinate energy use with the broader electricity system in real time. Communication between devices, platforms and energy management systems can unlock new capabilities, such as time-of-use optimisation and demand response.

India currently lacks mandated policies, projects or programmes to enable communication and information flow at the equipment level. There are no nationally adopted standards or requirements to ensure that everyday appliances such as air conditioners, refrigerators or washing machines can automatically connect and communicate with energy management systems or the electricity grid. This makes it difficult to integrate and remotely control appliances based on real-time signals such as electricity prices or grid load. However, in early 2025 the Central Electricity Authority issued guidelines to help ensure standardisation and interoperability in India's advanced metering infrastructure systems.

Most smart meters in India follow the Device Language Message Specification (DLMS)/Companion Specification Model (COSEM) protocol (IS 15959), which allows meters and utility systems to communicate seamlessly across different vendors. For the transfer of data between Head-End Systems (HES), which collect meter data, and Meter Data Management Systems (MDMS), which process and analyse it, the guidelines mandate the use of IEC 61968-9. Looking ahead, the Central Electricity Authority is promoting a modular design where communication modules can be plugged into meters, allowing easy upgrades and reducing the likelihood of vendor lock-in.

Building level

BUILDING-TO-GRID INTERACTION

Two-way communication: Buildings level

No policies on open communication standards for buildings automation (BA)	Voluntary policies on open communication standards for BA are available	Mandatory policies on open communication standards for BA are available for some building types	Mandatory policies on open communication standards for BA are available for all buildings

There are no policies that mandate the installation of building automation and communication protocols. Nevertheless, there are some examples of large commercial buildings using such protocols. For example, Indira Gandhi International Airport uses the KNX protocol to seamlessly integrate multiple building systems, including its Building Management System, HVAC systems and Energy Management System. The BACnet protocol has been implemented in several facilities across India, including at a British Petroleum facility in Pune, the New Plasser railway equipment manufacturing plant in Gujarat, and the Hubli Court Complex in Karnataka.

Building-to-grid level

BUILDING-TO-GRID INTERACTION

Two-way communication: Building-to-grid level

No policies on B2G interoperability are available	Voluntary policies on B2G interoperability are available	Mandatory policies on B2G interoperability are available for some building types	Mandatory policies on B2G interoperability are available for all building types

Standardised protocols for interoperability between buildings and the grid are still in early phases of adoption, primarily confined to pilot projects. One of the most notable examples is the automated demand response pilot conducted in 2015 by Tata Power Delhi Distribution Limited and Honeywell, marking India's first large-scale deployment of OpenADR 2.0. The pilot connected 160 commercial and institutional buildings using smart meters and enabled real-time, automated load curtailment in response to grid stress events. This initiative demonstrated that buildings could respond within minutes to utility signals, achieving peak load reductions of up to 11 MW and demand drops of approximately 10% during critical events. The success of this pilot established a foundation for broader consideration of ADR in India's demand-side management strategies. However, large-scale replication has been slow, constrained by the lack of mandatory interoperability standards, limited regulatory incentives and insufficient readiness of building automation infrastructure.

Guidelines are supporting the rollout of advanced metering infrastructure

BUILDING-TO-GRID INTERACTION

Advanced metering infrastructure

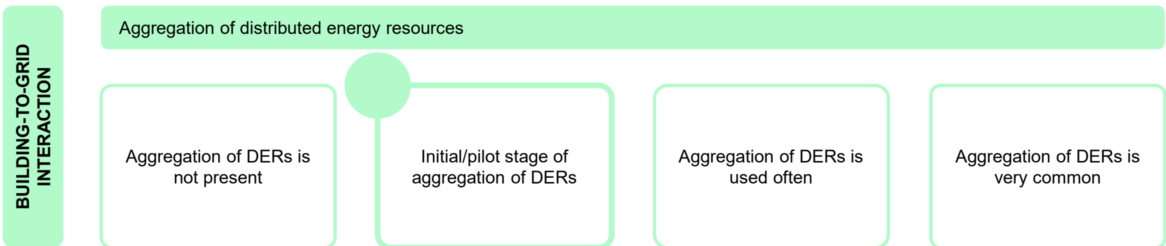
AMI is not used	Initial/pilot stage of AMI adoption	AMI is used often	AMI is very common

The Revamped Distribution Sector Scheme forms the backbone of India's advanced metering infrastructure rollout. The Central Electricity Authority guidelines require the Advanced Metering Infrastructure Implementing Agency to ensure seamless interoperability and data exchange among key components, including smart meters, communication infrastructure, Head End Systems (HES), Meter Data Management Systems (MDM) and Web Application Interfaces with real-time consumer data. This policy is designed to establish a fully integrated and functional AMI ecosystem that supports automated metering, data-driven billing, remote operations, and demand-side management features.

The guidelines cover the nationwide deployment of smart meters with various communication technologies and site-specific requirements. Smart meters across all consumer categories are to be installed using either Radio Frequency (RF) mesh networks (allows meters to relay information wirelessly to one another), Power Line Communication (PLC) (uses existing electricity distribution lines for data transfer) or cellular technologies such as GPRS, 3G, or 4G (enables meters to send information over mobile networks), or a combination of these. For RF mesh and PLC systems, meter data must first be collected through local hubs known as Data Concentrator Units (DCUs) before being transferred to a central platform called the Head End System (HES). Cellular meters, by contrast, can send data directly to the HES without the need for DCUs. Allowing utilities to choose gives them the flexibility to select the most cost-effective and reliable technology mix based on local infrastructure, while still ensuring that data from all consumers flow into a unified system for billing, monitoring and energy management.

The India Energy Stack is an emerging digital public infrastructure intended to create a standardised and interoperable data exchange framework across smart meters, buildings, DERs and utilities. It is enabled by unique IDs and verifiable digital transactions. This platform could be useful for scaling the use of mechanisms such as dynamic pricing and green tariffs.

DER aggregation is gaining regulatory momentum



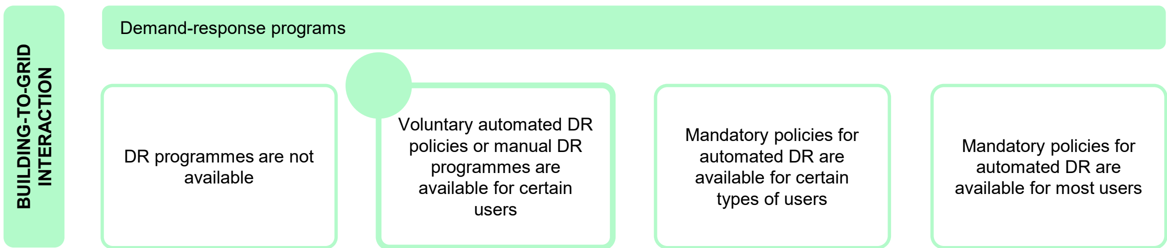
While deployment of distributed energy resources is accelerating, policies for aggregating them are still at an early stage. The Green Open Access Rules enable consumers with a minimum connected load of 100 kW to procure energy directly from renewable energy generators or the open market. By increasing competition in the electricity market, these rules facilitate the aggregation of DERs, allowing multiple small-scale renewable energy producers to participate in energy trading. This helps optimise resource utilisation, contributing to a more decentralised and efficient power system.

Peer-to-peer (P2P) trading using blockchain technology is still nascent in India, but early successes and recent policy developments signal growing momentum. For example, in April 2023, the Uttar Pradesh Power Corporation Limited released guidelines for P2P trading of rooftop solar energy using blockchain platforms. In June 2024, the Delhi Electricity Regulatory Commission issued the P2P Energy Transaction Guidelines, 2024, and in August 2024, the Karnataka Electricity Regulatory Commission announced the Implementation of the P2P Solar Transaction Regulations, 2024.

Peer-to-peer pilot projects in India

Utility	State/UT	Year	Description
Tata Power-DDL	Delhi	2021	The pilot used Power Ledger's blockchain platform to enable P2P trading of over 2MW of solar power in North Delhi, with nearly 150 sites selling excess energy under dynamic pricing.
Uttar Pradesh Power Corporation Limited	Uttar Pradesh	2021	The pilot with nine prosumers and three consumers tested blockchain-based electricity trading between households with and without rooftop solar.
Calcutta Electricity Supply Corporation Limited	West Bengal	2022	The 6-month pilot with 1 000 participants tested Power Ledger's P2P trading platform across fixed, preferential, and dynamic pricing scenarios.

Automated demand response is developing through pilots



Demand response programmes help manage energy consumption during peak hours and stabilise the grid. Historically, demand response in India has focused on commercial and industrial consumers, whose high energy usage allows for substantial load reductions with relatively few participants. Since cooling has become a key driver of peak demand growth, focus on residential buildings is increasing,.

In 2024, an automated demand response pilot program with over 900 participants tested Wi-Fi-enabled smart switches, which could be connected to appliances, such as air conditioners. The smart switches allowed users to monitor energy use in real time via a smartphone application, while utilities could monitor usage through the POWBAL web platform. Utilities triggered 30-minute automated switch-off events, with incentives provided to consumers. The pilot programme demonstrated household energy demand reductions of 8% to 15%.

In 2023, Schneider Electric and BSES Yamuna Power Limited conducted an automated demand response pilot programme with 48 households from four residential societies in Delhi. Using long-range communication technology, the pilot achieved a 9% to 35 % reduction in peak demand during demand response events. Another pilot in Uttar Pradesh engaged 30 residential participants and showed a 17% reduction in peak load during peak hours (17:00 to 23:00).

Until recently, demand response programmes in India were operated without formal regulatory backing. This has begun to change. For example, the Demand Flexibility and Demand Side Management Regulations issued by the Maharashtra Electricity Regulatory Commission (MERC) in 2024 include a Demand Flexibility Portfolio Obligation that requires distribution licensees to achieve flexibility equivalent to 1.5% of their peak demand in the first year and 3.5% by the fifth year.

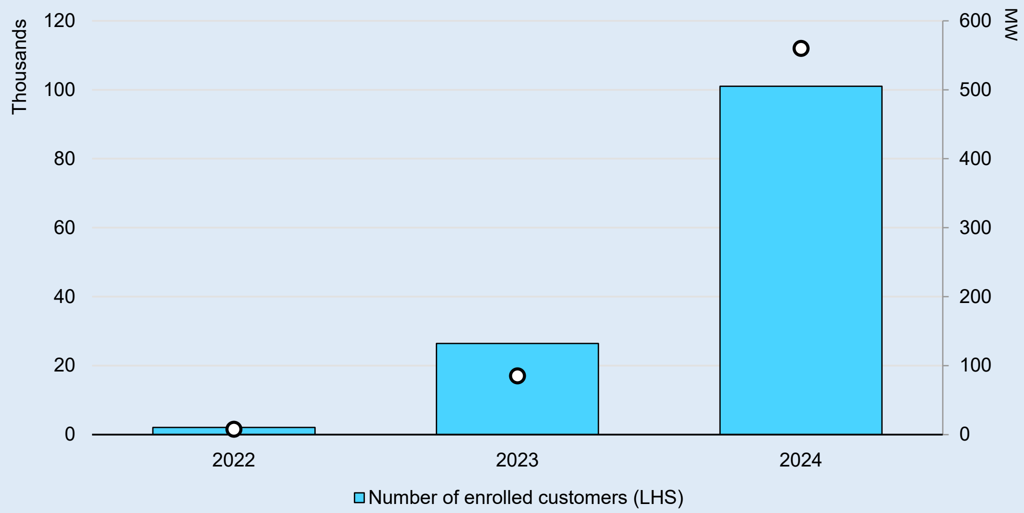
Historically, demand response programmes in India have relied on manual or behavioural demand response, due to their simplicity and lower operational costs. The introduction of automated demand response allows for faster and more precise two-way communication. Despite this progress, several barriers remain in scaling up demand response programmes. The lack of accurate, granular data hampers the identification of flexibility potential by consumer segment, making it difficult to design cost-effective and targeted programmes. Another challenge is the absence of effective price signals. With relatively low electricity tariffs, the price differential between peak and off-peak demand may be insufficient to motivate consumers to adjust their usage. Limited adoption of advanced metering technologies also restricts the ability to implement programmes across a large number of consumers.

Tata Power Delhi Distribution Limited’s Demand Response Programme

In 2021, Tata Power Delhi Distribution Limited conducted an 11-week pilot project in New Delhi, engaging over 2 000 households through calls and brochures. Focusing on reducing load during the afternoon and nighttime peaks (14:30 to 17:30 and 21:30 to 00:30), the pilot programme achieved an average load reduction of 470 kW per demand response event and a cumulative load shed of 7.7 MW. The programme expanded to over 100 000 customers by 2024 and delivered a cumulative load reduction of 1 052 MW over four years. Tata Power also partnered with Auto-Grid to roll-out an AI-enabled smart energy management system in

Mumbai, involving 55 000 residential consumers and 6 000 large commercial and industrial customers to achieve up to 200 MW of peak capacity reduction by 2025.

Tata Power demand response programme progress, 2022-2024



Source: Tata Power DDL .

Time-of-Day tariffs gain ground, but dynamic pricing holds the key to demand flexibility

BUILDING-TO-GRID INTERACTION

Dynamic electricity tariffs

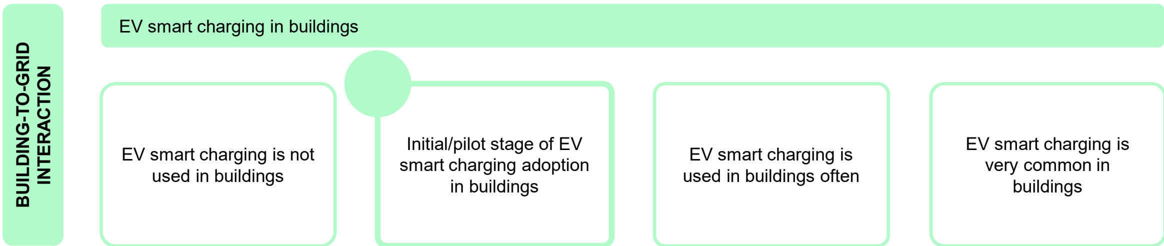
Dynamic electricity tariffs are not available	Voluntary dynamic electricity tariffs are available for certain types of users	Mandatory dynamic electricity tariffs are available for certain types of users	Mandatory dynamic electricity tariffs are available for all types of users

The 2023 amendments to the 2020 Electricity (Rights of Consumers) Rules, mark a key policy development towards the implementation of time-of-day tariffs in India. The revised rules require state electricity regulators to set tariffs 10–20% lower during hours of solar activity and 10–20% higher during peak demand hours, while maintaining standard rates during other periods. The provisions will initially apply from April 2024 for commercial and industrial consumers whose demand is greater than 10 kW, and will be extended to all other consumers (excluding agriculture) by April 2025, after the installation of smart meters.

Several states in India have implemented time-of-day tariffs, primarily targeting industrial and commercial customers, though in some cases including residential consumers. For example, Uttarakhand has implemented time-of-day tariffs with three time slots. Kerala offers time-of-day tariffs for residential consumers whose monthly electricity consumption exceeds 250 kWh. Electricity charges are reduced by 10% during non-peak hours (6:00 to 18:00) and are subject to a 25% surcharge during peak hours (18:00 to 22:00). Andhra Pradesh allows residential consumers whose monthly consumption is at least 500 kWh to opt for smart meters and a time-of-day tariff rebate between 10:00 and 12:00 noon. Gujarat offers a concession to consumers with smart meters between 11:00 and 15:00. Several states, including Assam, Jharkhand, Kerala, Madhya Pradesh, Maharashtra, Rajasthan, Tamil Nadu, and West Bengal, have implemented time-of-day tariffs for electric vehicle charging stations.

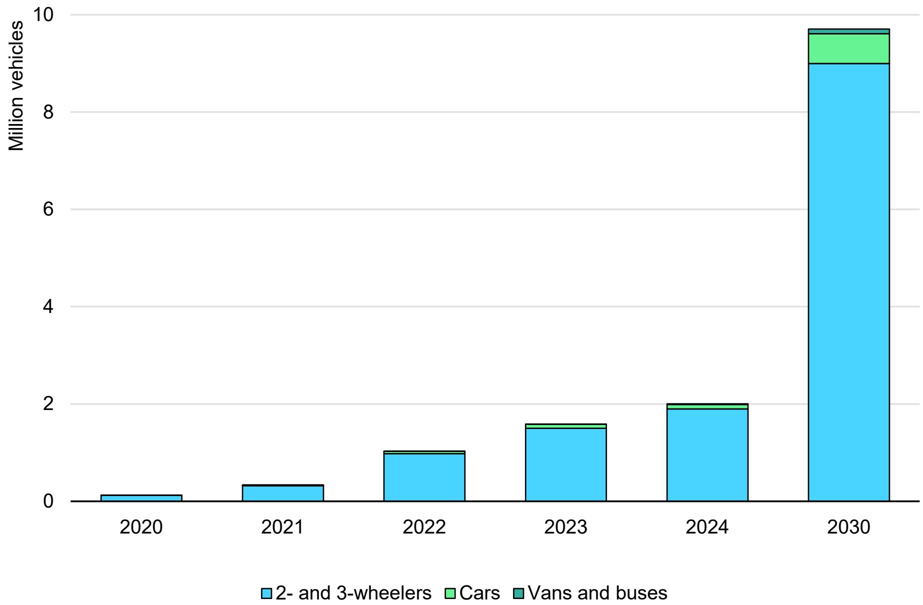
Existing time-of-day tariffs in India are static and predetermined. They typically offer lower rates around midday (solar hours) and higher rates during evening peak demand. Time-of-use tariffs offer a more advanced, dynamic pricing model, reflecting fluctuations in wholesale electricity markets and grid load. Instead of being restricted to static time slots, dynamic time-of-use rates can vary day to day or even hour to hour, depending on actual demand and supply conditions.

Pilots signal growing interest in vehicle-to-grid technology



Thanks to government policies, the use of electric vehicles has gained momentum. This notably includes the FAME scheme, which subsidises the purchase price of electric buses, as well as two-, three- and four-wheelers. Policy support has continued with the PM Electric Drive Revolution in Innovative Vehicle Enhancement (PM E-DRIVE) programme, launched in September 2024 for implementation through March 2026. This initiative aims to support the deployment of 2.4 million electric two-wheelers, 316 000 electric three-wheelers and over 14 000 electric buses. It will also support the installation of public charging infrastructure. The policy has significantly helped support the deployment of EVs, particularly two- and three-wheelers, which constitute more than 80% of total EV sales in India. (India is the world's largest market for electric three-wheelers and second-largest for electric two-wheelers.)

Electric vehicle sales by category, India, 2020-2024, and 2030 in the Stated Policies Scenario



Source: IEA (2024), Global EV Outlook.

As in many other countries, home charging is emerging as the dominant mode of electric vehicle charging. Tata Power has installed over 100 000 EV chargers in homes across the country under its EZ Home charging program.

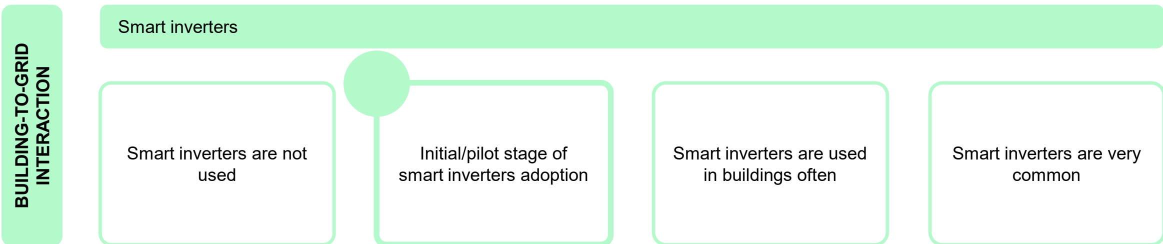
Policy support for EV charging provisions in residential associations is also growing. For instance, the Delhi Development Authority's amended Unified Building Bylaws (2016) require 20% of all parking capacity in buildings to be provided with charging infrastructure for EVs. In March 2021, the Delhi Government also directed all commercial and residential institutions with a parking capacity of 100 or more vehicles to reserve 5% of parking space for electric vehicles and to provide suitable chargers. Uttar Pradesh mandates all new housing complexes above 5 000 square metres to have at least one EV charging unit.

The growing adoption of EVs in India presents an opportunity to support grid balancing and reduce emissions through vehicle-to-grid (V2G) integration. V2G technology enables bi-directional energy flow, allowing EVs not only to draw power from the grid but to discharge stored energy back into it. As EV adoption increases, unlocking this potential will depend on supportive policies, investment in smart charging infrastructure, and integration with demand response and energy management platforms.

V2G technology is currently in the early stages of exploration, with limited but growing momentum driven by pilot projects and initial regulatory interest. For instance, Tata Power Delhi Distribution Limited has partnered with the India Smart Grid Forum and the University of Delaware to launch a V2G pilot in Delhi. This initiative aims to explore the potential of electric vehicles to support the grid through frequency regulation, voltage control and backup power during outages, while enabling two-way power flows. Similarly, Sheru, a startup focused on energy storage software, has collaborated with BSES Rajdhani to develop NetBat, India's first V2G-enabled battery swapping system. Additional demonstrations include those led by IIT Bombay and the Kerala State Electricity Board, which are testing use cases for V2G, Vehicle-to-Home (V2H), and Vehicle-to-Vehicle (V2V) energy sharing.

Despite these promising developments, the absence of a dedicated regulatory framework, lack of market incentives for consumers, and concerns over battery degradation remain key challenges for V2G implementation in India. Furthermore, the availability of V2G-compatible charging infrastructure is limited, and the cost of such chargers remains significantly higher than that for standard EV chargers. On the grid side, only a small fraction of distribution companies have deployed smart grid technologies needed to support V2G functionality. The Central Electricity Authority has formed a committee to draft guidelines on bi-directional power flow.

A policy framework for smart inverters is emerging



India's policy framework for smart inverters is still in its formative stages. As yet there are no mandatory national regulations requiring smart inverter functionalities such as reactive power control, frequency response or remote curtailment. Nevertheless, India took an important enabling step in 2024 by introducing the Standards & Labelling programme for grid-connected solar inverters up to 100 kW, establishing minimum efficiency thresholds for voluntary adoption.

Under India's residential rooftop solar scheme, PM Surya Ghar: Muft Bijli Yojana, hybrid inverters have been explicitly permitted. From mid-2025 onwards, all eligible inverter models must incorporate secure machine-to-machine (M2M) SIM-based connectivity, a provision that allows real-time remote monitoring and lays the foundation for future smart grid integration. Related to this, the Ministry of New and Renewable Energy is finalising guidelines for a vendor-neutral communication protocol and national software platform for data exchange. Once operational, this could facilitate the rollout of smart inverter functionalities.

Centre of Excellence on the Grid-Interactive Built Environment

An important step in accelerating work on efficient grid-interactive buildings was taken in 2025 when the Electric Power Transmission Association (EPTA), the Indian Institute of Technology (IIT) Delhi and Integrative Design Solutions jointly established the Centre of Excellence on the Grid-Interactive Built Environment (GIBE) at IIT Delhi. The Centre is intended to serve as India's institutional anchor for advancing grid-interactive buildings through research, regulatory support, training and demonstration projects. It will provide technical inputs for national and state-level policy design, develop testing and validation protocols for smart building technologies, and build analytical capabilities such as digital twins and demand-side data observatories. In alignment with India's commitments on energy efficiency, renewable energy integration and deep decarbonisation, the Centre will facilitate collaboration among government agencies, regulators, utilities, industry and academia

.

Chapter 4. The way forward

Recommendations to support the uptake of efficient grid-interactive buildings

Unlocking the potential of efficient grid-interactive buildings (EGIBs) will be important for advancing India's clean energy transition. By combining energy efficiency, renewable integration, digitalisation and smarter interaction with the grid, EGIBs can play a key role in reducing peak demand, lowering system costs and enhancing grid reliability. As electricity demand in India continues to rise – particularly from the buildings sector – enabling policies and market mechanisms will be needed to scale up EGIB deployment. Beyond system-level benefits, EGIBs can improve energy security, reduce GHG emissions, lower operating costs, enhance comfort and productivity for occupants, and help manage peak load.

Governments, industry and consumers all stand to benefit from EGIB adoption. Realising these benefits will require greater investment in research and development, as well as promoting the value of interactivity within buildings and with the electricity system at large. This can be done by engaging users to increase awareness of potential benefits and cost savings, and by supporting the development and implementation of policies, programmes and projects.

India's progress in advancing energy efficiency, expanding renewable energy and strengthening digitalisation provides a strong foundation for scaling up the adoption of EGIBs through additional supportive policies and programmes. Drawing on relevant international trends and best practices, as well as perspectives gathered from national-level expert consultations, the following recommendations outline priority actions for consideration by government, industry and consumers to accelerate EGIB adoption and maximise their contribution to India's power system and broader development goals.

Develop a comprehensive policy package

Implementing energy efficiency measures, smart technologies and solutions for building-to-grid interactions will require a well-designed and integrated policy framework. An effective policy package combines regulatory instruments, financial incentives and information-based tools to drive improvements in building energy performance and enhance the flexibility of the broader energy system. This framework should be grounded in clear and ambitious-yet-achievable targets, such as improving energy efficiency, decarbonising energy used in the buildings sector, and enabling active grid interaction. Moreover, these priorities need to be effectively communicated to all relevant stakeholders.

Energy efficiency policy package for buildings

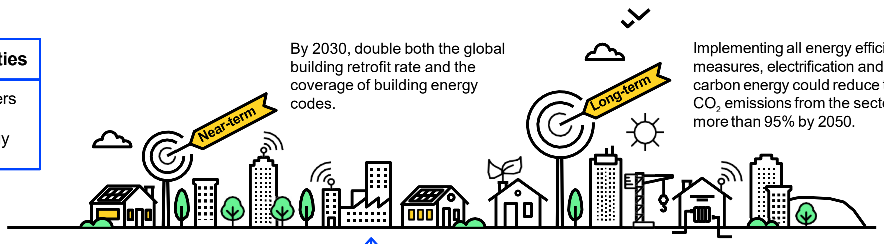
Policy Package – Buildings Energy Efficiency

Immediate opportunities

Replacing fossil fuel boilers with high efficiency heat pumps can reduce energy use by up to 75%.

By 2030, double both the global building retrofit rate and the coverage of building energy codes.

Implementing all energy efficient measures, electrification and low-carbon energy could reduce total CO_2 emissions from the sector by more than 95% by 2050.



REGULATION

- **Targets for energy efficiency** in buildings, including for renovation rates, fosters market growth and facilitates long-term investment decisions.
- **Building energy codes** for new and existing buildings can cost-effectively accelerate the transition to zero-carbon-ready buildings. It is important that they are regularly updated to increase coverage and stringency.
- **Minimum energy efficiency requirements** for existing buildings help guarantee performance and accelerate the process of renovation through instruments such as the standardisation of processes.
- **Regulations** can ensure that buildings are equipped with smart interactive technologies and can become demand response ready.

INFORMATION

- **Information on building performance** allows consumers to identify the most efficient options when buying or renovating buildings. Examples include energy performance certificates, disclosure programmes, one-stop shops for upgrades and renovation passports.
- **Smart interactive technologies** can show real-time energy performance, help adjust occupants' behaviour and optimise energy use based on signals from the grid.
- **Training and education programmes** for building sector workers are important to ensure a suitably skilled work force.
- **Public awareness campaigns** designed to include behavioural insights encourage low-cost actions, such as thermostat adjustment and use of smart technologies.

INCENTIVES

- **Financial incentives** such as green mortgages, energy performance-based preferential loans and tax rebates and grants can motivate consumers and developers to increase investment in energy efficient solutions.
- **Expedited administrative procedures**, including accelerated permitting, targeted at high performing new build or retrofit projects, encourage the implementation of energy efficient measures.
- **Award** and recognition programmes encourage the development of highly energy efficient buildings.

Source: IEA (2024), Energy Efficiency Policy Toolkit.

Regulatory policies as foundational tools

Regulations establish minimum benchmarks and targets to drive retrofitting – or in some cases replacement – of the worst-performing buildings. They can help phase out inefficient products and materials while guiding investments toward efficient, low-carbon, smart and flexible alternatives.

Building energy codes are among the most scalable and effective regulatory instruments for improving building performance and are already in place in over 80 countries. Their successful implementation requires tools for verifying compliance before and after construction. These tools, increasingly enabled by digital technologies and smart controls, not only ensure adherence to standards but also provide valuable feedback for improving construction practices and real-world performance.

Mandatory minimum energy performance standards (MEPS) and appliance labelling programmes are also important regulatory tools. Implemented in over 120 countries, they significantly improve efficiency, cutting energy consumption of major appliances by more than half in countries with long-standing programmes.

Supporting instruments: information, incentives and capacity building

Regulatory policies are most effective when supported by complementary tools. Information and targeted incentives can reinforce implementation, drive compliance and promote actions that exceed minimum requirements.

- **Building certification and labelling schemes** offer clear, credible indicators of a building's energy and carbon performance, enabling consumers and industry to make better-informed decisions. Labelling can also indicate demand-response readiness and integration with smart technologies.
- **Public awareness and education campaigns** guide developers, owners and occupants toward low-carbon choices for construction, renovation, leasing and purchasing.
- **Capacity-building programmes** ensure a strong base of local expertise to support the rollout of policies. Training and accreditation for professionals – such as energy managers or smart building specialists – are essential for implementing grid-interactive, efficient solutions.
- **Financial and non-financial incentives** can ease early adoption of regulations, especially where there are market barriers such as upfront costs or limited access to capital. These incentives can be tied to certification or performance, further encouraging the uptake of advanced, flexible, low-carbon technologies.

Strengthening stakeholder engagement is key for mainstreaming adoption of EGIB enablers

Transitioning to efficient grid-interactive buildings (EGIBs) requires a whole-of-system approach, engaging actors across both the buildings and electricity sectors. Technological enablers such as high-performance envelopes, distributed energy resources (DERs), smart devices and communication protocols form the technical backbone of EGIBs. However, their successful adoption depends on the coordinated roles, actions and investments of multiple stakeholders. International evidence shows that early, structured stakeholder engagement leads to more cost-effective implementation, faster market uptake, and improved system-level outcomes for flexibility and reliability.

Adoption of EGIBs depend on integrated planning and coordination across domains that historically have operated in silos. For example:

- Requirements and provisions in building energy codes and appliance standard are usually set without considering grid constraints or flexibility potential.
- Utility planning rarely considers demand flexibility from buildings as a resource.
- Consumers and technology suppliers often lack awareness or incentives to adopt interactive technologies.

Effective engagement aligns technical, regulatory, financial and behavioural elements that allow EGIB enablers to be mainstreamed across markets. It also ensures that the value of flexibility – often invisible to individual consumers – is recognised and integrated into planning frameworks, utility incentives and building-sector policies.

In this report, the following stakeholder groups are considered key for the adoption of EGIB enablers – while acknowledging that there are some actors that might not fall directly into these categories:

1. Government and regulators

Examples of stakeholders: Ministry of Power, Ministry of Urban Development, Bureau of Energy Efficiency, Central Electricity Authority, state electricity regulatory commissions, municipal governmental bodies.

Roles:

- Set national and subnational vision for EGIBs.
- Update building codes to include smart-ready, resilient and low-carbon material requirements.
- Establish standards for the interconnection of distributed energy resources (DERs), smart meters, smart inverters and interoperability.
- Define tariff frameworks for demand response, time-of-day pricing and smart EV charging.
- Set data governance rules (access, privacy, interoperability, cybersecurity).
- Support digitalisation, capacity building and market transformation.

2. Utilities and system operators

Examples of stakeholders: distribution companies, state load dispatch centres, state transmission utilities, system operators.

Roles:

- Integrate demand flexibility into planning and procurement.
- Deploy and operate advanced metering infrastructure (AMI) and enable consumer-centric demand response.

- Implement and enforce grid codes for DERs, smart inverters, and EV charging.
- Operate distributed energy resource management systems (DERMS), virtual power plants (VPPs), and advanced grid-management systems.
- Monitor and optimise DER output and manage two-way communication with buildings.
- Provide consumption and grid-capacity data to inform policy and building-sector decisions.

3. Building sector actors

Examples of stakeholders: developers, architects, engineers, energy service companies (ESCOs), manufacturers, material suppliers, smart-tech vendors.

Roles:

- Integrate EGIB enablers into design, construction and retrofits.
- Specify and install low-carbon materials and ensure embodied-carbon compliance.
- Supply interoperable smart devices (OpenADR, CTA-2045, IEEE 2030.5, KNX, BACnet).
- Install controllable DER technologies (PV, storage, heat pumps, smart EV chargers).
- Provide and commission BEMS/HEMS and ensure compatibility with AMI and DERMS.
- Ensure user-friendly installation, maintenance, and performance.

4. Consumers and end-users

Examples of stakeholders: households, tenants, commercial operators, public institutions, Resident Welfare Associations (RWAs).

Roles:

- Adopt efficient appliances, rooftop PV, storage, smart thermostats, and smart charging.
- Participate in demand response, ToU tariffs, and other flexibility programmes.
- Consent to data sharing through AMI, building/home energy management systems (BEMS/HEMS), or utility platforms.
- Adjust behaviours (precooling, set-points, EV charging times, load shifting).
- Enable automation and respond to grid signals to provide flexible demand.

The roles and impact of different stakeholder groups for each enabler can vary greatly, depending on the nature of the enabler, governance structure and interlinkages between stakeholders.

Mapping of stakeholders and their importance for the adoption of different EGIB enablers

Enabler category	Government and regulators	Utilities and system operators	Building sector actors and solution providers	Consumers / end users
Energy efficiency (building energy codes, retrofits, MEPS, labels & certification)	Set standards and enforce compliance	Provide data on electricity consumption, grid constraints, etc.	Implement policies through building design and retrofits	Choose efficient products and practices
Decarbonisation (on-site RE, storage)	Define incentives and interconnection rules	Manage integration and grid impacts	Install / commission technologies	Invest in technologies
Smartness (IoT, BEMS/BAS, smart meters, smart grids)	Set mandates and targets for installations; develop data and cyber security policies	Deploy smart meters and digital grid tools	Install and commission smart technologies	Invest in and use systems; share data
Materials (embodied carbon, low-carbon materials)	Set requirements for embodied carbon	(Not involved)	Select and procure low-carbon materials	Favour low-carbon options
Resilience (building resilience measures)	Set climate-resilient building requirements	Strengthen grid resilience	Comply with climate-resilient requirements in construction	Invest in resilience upgrades
Buildings-to-grid interaction	**Government and regulators**	**Utilities and system operators**	**Building sector actors and solution providers**	**Consumers / end users**
Two-way communication	Set interoperability standards	Operate communication infrastructure	Provide compatible equipment	Invest in compatible equipment; participate in data sharing
Advanced metering infrastructure	Set mandates, technical standards, data privacy and sharing rules	Deploy, operate and maintain AMI systems; manage data & analytics	Ensure compatibility of building systems with AMI; assist commissioning	Provide meter access; use real-time data; consent to data sharing
Aggregation of DERs	Create enabling regulations	Monitor and optimise DER flows; manage aggregators	Install DER-related technologies in buildings	Invest in DER techologies; participate in programmes
Demand-response programmes	Approve DR frameworks and incentives	Operate DR events and platforms	Provide and install DR-ready equipment	Invest in DR-ready equipment; participate in DR programmes

Enabler category	Government and regulators	Utilities and system operators	Building sector actors and solution providers	Consumers / end users
Dynamic electricity tariffs	Set tariff structures and rules	Implement billing and metering	(Not involved)	Shift energy use according to tariffs
EV smart charging in buildings	Set EV-ready codes and tariff incentives	Manage charging load on grid	Install smart charging infrastructure	Schedule charging flexibly
Smart inverters	Set grid code requirements	Configure and validate inverter settings	Install compliant equipment	Enable smart-mode operation

Importance of a stakeholder group for the enabler:
Very high High Medium Low

Implementation plan to define policy priorities and steps for achieving them

Once the policy package has been developed and a broad set of actions identified, the next step is to determine which measures should be implemented first, which require medium-term preparation, and which depend on longer-term market or institutional readiness. Prioritisation is the starting point of the implementation process. Prioritisation allows governments to sequence actions in a realistic and strategic manner, balancing what is urgently needed with what is feasible in the near term – while ensuring that early steps create enabling conditions for more complex measures that follow.

To identify near-term, medium-term and long-term priorities, countries may assess each proposed action against several guiding criteria:

The level of effort required – including administrative complexity, potential barriers and available enablers – helps identify measures that can be deployed quickly versus those that require foundational work.

The expected impact of each action – in terms of energy savings, emissions reductions, socio-economic benefits and alignment with national and international commitments – helps ensure that high-impact measures are prioritised.

The resource requirements – financial, human, technical and institutional – should be compared with current capacities and funding, in order to flag actions that may face delays or require targeted support. Consideration of lifetime costs and savings, rather than only upfront investment costs, is crucial for a balanced assessment.

Once priority measures and implementation timelines have been established, they should be consolidated into a coherent implementation plan. This plan should clearly assign institutional roles and responsibilities for each action, ensuring alignment with the country's governance structures, local context and existing policy frameworks. It should also include a strategy for tracking progress through detailed, action-specific indicators that enable data collection, monitoring and evaluation. Such a framework supports transparency, allows mid-course corrections, and ensures that policy implementation stays on track toward a more efficient, flexible and sustainable buildings sector.

Key components of a comprehensive policy package may include:

- **Zero-carbon-ready building mandates** for new construction and major retrofits, covering both operational and embodied emissions, along with requirements for (ideally smart) EV charging, demand-side flexibility, and integration with variable renewable energy (VRE) sources.
- **Minimum energy and demand-response performance standards** for appliances and equipment, ensuring efficiency and grid-readiness.
- **Certification and labelling schemes** that identify energy-efficient, demand-flexible, and smart-enabled technologies, to build market confidence and transparency.
- **Targeted incentives** (financial or otherwise) that reward improvements in energy performance, carbon intensity and demand-side flexibility.
- **Monitoring and evaluation frameworks** to track policy implementation and building performance across regions, using indicators to inform future decision-making.
- **Robust data collection systems** – such as Building Passports – that track energy use, renewable generation and retrofit activity, to support progress measurement, policy refinement and investment planning.
- **Improved financing conditions** through harmonised standards and quality assurance systems, to reduce investor risk and attract funding for sustainable building projects.
- **Government and industry capacity-building** through training, accreditation, and knowledge-sharing platforms, to strengthen implementation at national, subnational and local levels.
- **Stakeholder engagement** in the policy development process, to build consensus, align objectives across governance levels, and maintain momentum for a just, inclusive transition to low-carbon buildings.
- A sequenced **implementation plan** that prioritises actions across the near-, medium- and long-term based on level of effort, expected impact and resource requirements, ensuring that the policy package is delivered in a feasible and strategic order.

The policy package below summarises the priority areas for designing and implementing effective measures for EGIBs enablers. It combines policies across three core pillars: regulation, information and incentives. A detailed description of the policy recommendations for each enabler is provided in the following sections.

Policy package recommendations by enabler category

	Regulation	Information	Incentives
Energy Efficiency	Expand mandatory building energy codes to all building types, enforce post-construction verification, mandate disclosure of energy performance during sale/lease, expand appliance minimum energy performance requirements for key equipment and appliances.	Expand building energy performance certification programmes to different building types, conduct public campaigns on energy-efficient homes, build capacity at all governance levels for building energy code implementation, and promote R&D for passive cooling strategies	Link tax breaks and capital subsidies to building energy performance certifications, offer increased floor area bonuses and permitting benefits to buildings with higher performance, support retrofits through public and private finance, and provide performance-based incentives for load flexibility and carbon reduction
Decarbonis ation	Mandate rooftop solar during new construction and major renovation of large buildings, require solar-plus-storage readiness (conduits, wiring, safety), align building codes with national energy storage obligations, and streamline battery system permitting.	Raise awareness about benefits of rooftop solar and battery storage, disseminate tools for system sizing and integration, build capacity of architects and installers to design and carry out construction and renovation of buildings that achieve net zero energy performance	Scale up existing incentive programmes to include higher-capacity systems and storage, offer retrofit incentives for solar-plus-storage including low-interest loans, and enable peer-to-peer trading and differential feed-in tariffs for energy exported from storage
Smartness	Amend building energy codes to require smart readiness (e.g. use of smart devices and Building Energy Management Systems), smart meters in large/public buildings, sub-metering for tenants, and mandate EV smart chargers in large new buildings.	Create a Smart Building Toolkit that presents different smart building solutions and their benefits, supported by information campaigns, train distribution companies and building professionals in deployment and use of smart building systems	Provide subsidies or government sales tax relief for building energy management systems and other smart building systems, incentivise distribution companies to expand smart metering and building energy management systems through performance-linked funding
Materials	Introduce embodied carbon reporting for large buildings, require life cycle analysis use in public projects, and mandate use of certified low-carbon materials in public procurement.	Encourage use of the India Construction Materials Database in compliance with building energy code, train professionals on embodied carbon and global warming potential calculations, run campaigns on low-carbon materials options	Award bonus points in building performance certifications for the use of low-carbon material use and verified embodied carbon reductions, support startups and small businesses in manufacturing bio-based and circular construction products
Resilience	Publish voluntary climate-resilient design guidelines (e.g. for passive cooling, flood resistance), integrate resilience recommendations into building codes (thermal comfort during outages, air quality).	Develop state-level toolkits on building resilience risks and needs, provide region-specific climate risk maps, and train local professionals and planners on climate-resilient building practices	Offer floor area ratio bonuses, faster approvals and tax relief for projects with verified climate-resilient design, prioritise resilience retrofits in low-income housing, and award additional points in building performance certification for heat- and flood-adaptive elements
Buildings-to-Grid Interaction	Mandate grid-ready infrastructure in large new buildings (e.g. smart inverters, smart EV chargers), enforce demand-response-ready appliances or devices, enable participation of distributed energy resources and their aggregators in energy markets, and expand use of time of use tariffs for all smart-metered consumers.	Publish national building-to-grid toolkit covering integration of distributed energy resources, grid interaction and control systems; create a public tracking system for demand response events and building-to-grid interaction pilots; engage consumers via information campaigns and digital applications, and build capacity via national training programmes	Provide financial rewards to buildings participating in demand response, create a national certification and labelling for buildings based on their capabilities to interact with the grid, or integrate it into existing building certification schemes, offer subsidies for smart inverters and automation solutions, and fund pilots for aggregation of distributed energy resources and virtual power plants

Strengthen the coverage and implementation of energy efficiency regulations at the subnational level

Regulation

Strengthen and expand mandatory building energy codes

- Accelerate state-level adoption and enforcement of the updated 2024 Energy Conservation and Sustainable Building Codes (ECSBC) for both commercial and residential buildings, and work towards uniform implementation across all climate zones.
- Expand and update building regulations to mandate energy code compliance for a larger share of India's building stock, prioritising high-growth segments and integrating requirements into state and municipal bylaws for effective enforcement.
- Promote adoption of the Energy Conservation and Sustainable Building Code for all residential projects beyond the defined threshold (i.e. built-up area > 1 000 m²) across all states by maintaining sustained engagement with sub-national stakeholders, integrating ENS compliance into online building permission systems, and establishing a pool of certified third-party assessors.
- Develop simplified state-level implementation guidelines that include model forms, compliance checklists, prototype designs (with prescriptive packages by climate zone), and a concise handbook to support consistent enforcement.
- Integrate zero-carbon readiness requirements and provisions for EV charging infrastructure, smart metering and building energy management systems into the national and state building energy codes.

Enforce minimum standards for renovations

- Introduce mandatory energy efficiency requirements for major renovations, particularly those involving building envelope upgrades, HVAC replacement or lighting systems.
- Require that such retrofits meet minimum performance thresholds aligned with current building energy codes, ensuring that the energy performance of existing buildings progressively improves.

Mandate disclosure at the point of sale or lease

- Require the disclosure of building energy performance (e.g. Star Rating, Energy Performance Index) at the point of sale or lease for both residential and non-residential buildings.
- Use standardised digital tools and labels to ensure transparency for buyers and tenants and to drive market demand for efficient buildings.

Mandate post-occupancy performance verification

- Create a dedicated institution – and build institutional capacity – to carry out building design assessments based on the building energy codes, issue building and occupancy permits, and carry out on-site inspections to verify compliance with the building regulations.
- Require post-construction energy audits or benchmarking at the local level to verify compliance with energy codes and enable corrective actions (e.g. post-audit adjustments and repairs).
- Develop digital building logbooks or "building passports" to store key performance data, including information on building retrofits.

Strengthen appliance standards

- Expand the coverage of mandatory minimum energy performance standards (MEPS) to include additional high-impact appliances such as fans, water heaters, EV chargers and building automation systems, as well as smaller consumer electronics that contribute to standby power consumption.
- Place particular focus on energy efficiency requirements for cooling appliances by setting higher minimum efficiency standards for fans, ACs and ventilation systems, and regularly (every 3–5 years) increasing their stringency, with clear advance communication on such updates to manufacturers.
- Align appliance testing procedures with India's climate and usage patterns, moving beyond reliance on international benchmarks. Incorporate robust measurement, verification and enforcement protocols, such as field performance monitoring and periodic re-testing, to ensure that labelled efficiency levels are maintained under typical operating conditions.
- Incorporate functional requirements for demand response-ready capabilities through MEPS for key appliances such as air-conditioners, water heaters, refrigerators and EV chargers, including features such as automated load shifting, remote control interfaces and interoperability with standard communication protocols.

Scale up energy performance certification and labelling

- Expand the Star Rating programme to cover a wider range of building types, including mixed-use, educational and mid-size residential complexes.
- Strengthen implementation of the "Shunya" Net Zero and Net Positive Energy Building labelling system by aligning it with international best practices such as Passive House and LEED Zero.

Build capacity across governance levels

- Develop a nationwide capacity-building programme for municipal authorities, architects, engineers and contractors that is focused on:
    - ECSBC implementation

    - Energy modelling and compliance tools
    - Smart building design and energy management systems.
- Establish a network of certified professionals – such as energy managers and Energy Conservation Building Code (ECBC) masters – for on-the-ground implementation and verification.
- Support R&D for affordable passive cooling solutions, with particular encouragement of local innovation, in order to improve adoption.

Expand public awareness campaigns

- Launch a mass public awareness campaign targeting homebuyers, real estate developers and tenants on the benefits of energy-efficient homes, such as lower utility bills and improved comfort.
- Promote digital tools and mobile apps to simulate energy savings from energy-efficient buildings and retrofits.

Incentives

Link financial incentives to performance and certification

- Provide tax incentives, interest subvention, or capital subsidies for buildings that achieve high Star Ratings, Shunya certification, or other approved labels.
- Offer additional FAR (Floor Area Ratio) or faster permitting for certified green or energy-efficient buildings.
- Link energy efficiency support to state performance. States that demonstrate strong implementation of energy efficiency programmes should receive additional funding from the national government and/or international donors.

Support retrofit market development

- Scale up public-sector programmes such as EESL's Buildings Energy Efficiency Programme to include private-sector buildings, especially in Tier II/III cities.
- Launch a national retrofit fund for residential and commercial buildings, prioritising envelope upgrades, smart controls and efficient HVAC systems.

De-risk private-sector investment in building efficiency

- Create a national green guarantee facility or risk-sharing mechanism to reduce perceived risk for private banks and developers investing in efficient buildings.
- Promote on-bill financing or "green lease" models to allow investors to recover retrofit costs via energy savings.

Incentivise demand-side flexibility

- Offer dynamic, time-of-use tariff-based incentives and rebates for buildings equipped with demand-response-ready appliances and control systems.
- Introduce performance-based incentives for buildings that demonstrate measurable reductions in peak load or carbon emissions.
- Incorporate avoided grid investment and capacity costs into incentive design, for example by allowing regulators and distribution companies to share savings from deferred infrastructure upgrades or reduced capacity procurement with participating consumers or aggregators through bonus payments, rebates or tariff credits.
- Ensure that regulatory frameworks explicitly value capex deferral and the long-term system benefits of flexibility when determining programme funding and tariff structures.

Enable flexible decarbonisation by promoting on-site renewable energy generation and energy storage solutions

Regulation

Mandate on-site renewable energy integration in new and retrofit projects

- Require all new buildings and major renovations (residential and commercial) above a certain threshold (such as. 500 m² roof area or 50 kW connected load) to install rooftop solar systems covering either:
    - at least 50% of usable roof area, or
    - a minimum share of annual electricity demand (such as 20–30%), with differentiated targets by climate zone and building type.

  Make this a formal compliance pathway under the Energy Conservation and Sustainable Building Code (ECSBC) and Eco-Niwas Samhita, linked with post-occupancy verification.

Establish minimum on-site storage readiness requirements

- Require solar-plus-storage readiness in all new commercial buildings and large multi-dwelling residential projects. This could include
    - dedicated electrical conduit and wiring pathways
    - solar-ready electrical panels with reserved slots for solar and storage circuits
    - inverter compatibility configurations
    - adequate indoor or shaded space for battery storage with ventilation and fire safety clearances.

- For buildings with diesel generator sets, enforce the transition to clean backup systems (renewables with storage) within the five-year limit as per the Electricity (Rights of Consumers) Amendment Rules, 2022.

Align building energy codes with national energy storage framework

- Integrate energy storage obligations (ESOs) into building energy codes by requiring new large commercial buildings to install or connect to on-site/off-site storage systems that are aligned with state-specific ESO targets.
- Formally recognise battery energy storage systems (BESS) as a core, permissible component of building infrastructure in building energy codes and other regulations – similar to the case for electrical wiring, plumbing or elevators – with a streamlined permitting and approval process.

Information

Promote awareness of building-integrated solar and storage

- Launch targeted information campaigns to promote awareness of:
  - the benefits of rooftop solar and energy storage for cost savings, reliability, and grid resilience
  - case studies of buildings using solar-plus-storage successfully across India and internationally.

Expand technical guidelines and design tools

- Disseminate simplified solar system sizing tools and storage calculators tailored to residential users and mid-size commercial buildings.
- Provide updated technical handbooks and digital templates for integrating rooftop PV, battery storage and energy management systems into both new designs and retrofits.

Build market and institutional capacity

- Train local government officials, architects and installers in solar PV design, battery safety standards, net metering processes and grid integration.
- Establish accredited training for “net-zero building consultants” and expand the capabilities and certification of existing ECBC Master Trainers to cover decarbonisation technologies.

Incentives

Strengthen and scale up the PM Surya Ghar Yojana programme

- Expand subsidy ceilings beyond 3 kW for large households and group housing societies (such as cooperative housing societies), while maintaining high subsidy rates for small systems.
    - Include a battery storage incentive add-on for solar users opting to include storage with their rooftop systems.

Support solar and storage in building retrofits

- Create a dedicated green retrofit fund offering:
    - capital subsidies or tax rebates for adding rooftop solar and battery storage during building renovation
    - low-interest loans through public-sector banks and housing finance companies.
- Introduce a performance-linked incentive (PLI) for commercial buildings that reduce grid reliance through on-site solar and storage by >50%.

Enable grid interaction and monetisation

- Promote participation of residential and commercial solar-plus-storage systems in peer-to-peer energy trading, virtual net metering and the High-Price Day-Ahead Market (HP-DAM).
- Provide differentiated feed-in tariffs or buy-back rates for energy exported from storage, with higher rates for peak-time export.

Synergies with other categories

- Bundle rooftop solar and storage solutions with energy efficiency retrofits (such as LED upgrades and HVAC improvements) in incentive schemes to maximise demand reduction and peak load management.
- Use building performance labelling and digital building passports to track energy use, on-site generation, and storage capacity, enabling future financing and policy targeting.

Integrate intelligent systems and advanced controls to optimise building performance and occupant comfort

Regulation

Establish smart-readiness requirements for new buildings

- Amend the Energy Conservation and Sustainable Building Code (ECSBC) and Eco-Niwas Samhita to include:
    - smart-readiness indicators for new large buildings, including readiness for building energy management systems (BEMS), smart meters, demand-response integration and IoT-based monitoring
    - minimum provisions for smart-sensor infrastructure (temperature, occupancy, lighting, air quality) to be installed or pre-wired at the construction stage.

Mandate smart metering in large and public buildings

- Require installation of smart meters in all new buildings with connected loads above 50 kW and in all public buildings (new and retrofit) over 500 m².
- Integrate smart sub-metering requirements in large commercial and multi-tenant residential buildings to enable resident-level or tenant-level energy management.

Include requirements for building energy management systems (BEMS) in building energy codes

- Include BEMS as essential infrastructure within national and state-level building bylaws.
- Define technical standards for BEMS interoperability, cybersecurity and integration with rooftop solar, battery storage and EV charging.

Link smart buildings to smart grids

- Mandate grid-interactive capabilities in buildings participating in demand response programmes, allowing utilities to send signals for load shifting.
- Establish technical standards for real-time communication between buildings and distribution companies via smart meters and IoT platforms.

Information

Develop a national smart building toolkit

- Create a comprehensive "smart building toolkit" for architects, engineers and developers, covering:

  - IoT system integration
  - BEMS design and commissioning
  - data security, privacy and communication protocols
  - case studies from Indian pilots such as Mysuru, Puducherry and Bihar.

Launch consumer and industry awareness campaigns

- Conduct targeted campaigns to increase trust in and adoption of smart meters, IoT-enabled devices and building automation systems.
- Educate users on how smart systems can lead to bill savings, increased comfort, and energy reliability, particularly in tier II/III cities and housing societies.

Build capacity in BEMS and smart grid integration

- Develop training programmes for building professionals and distribution company staff in:
  - smart meter deployment and analytics
  - BEMS installation and troubleshooting
  - interfaces for buildings with smart grid and demand response infrastructure.
- Expand the scope of ECBC Master Trainers and introduce a new cadre of "smart building readiness professionals".

Incentives

Provide capital subsidies or GST relief for smart building technologies

- Offer financial incentives for:
  - smart sensors, smart controls, smart home systems, BEMS and other IoT kits
  - automated lighting and HVAC systems.
- Provide value-added tax relief or accelerated depreciation benefits for certified smart building technologies.

Link utility incentives to smart system performance

- Allow buildings with BEMS and smart meters to access:
  - time-of-day (ToD) tariffs
  - peak reduction incentives
  - dynamic pricing schemes.
- Offer rebates for buildings participating in automated demand response (Auto-DR) or flexible load programmes.

De-risk smart metering projects in distribution companies

- Expand performance-based incentives under the Revamped Distribution Sector Scheme (RDSS) to encourage distribution companies to:
    - reach installation and activation milestones for smart meters.
    - pilot and evaluate advanced-use cases for smart meters integrated with BEMS and smart analytics, in order to enhance demand management, billing accuracy and service reliability.
    - support public documentation and evaluation of pilot outcomes in order to inform future large-scale rollouts and to quantify benefits, such as reduced losses, improved load forecasting and better consumer engagement.
    - provide grants or concessional loans for BEMS retrofits in existing commercial buildings, especially in urban local government properties, schools and healthcare facilities.

Synergies with other categories

- BEMS and smart meters can track energy performance, facilitating code compliance, certification and access to performance-based incentives.
- Smart grids enable better integration of rooftop solar, battery storage and EV charging, reducing peak loads and enhancing system resilience.
- IoT systems enhance occupant comfort, improve equipment lifespan, and help distribution companies and building operators to monitor and optimise demand in real time.

Adopt policies to mainstream embodied carbon reduction in construction

Regulation

Introduce voluntary guidelines on embodied carbon assessment

- Develop and publish national voluntary guidelines on embodied carbon accounting in buildings that are aligned with international standards such as ISO 14067 and EN 15978.
- Encourage the use of life cycle analysis (LCA) tools during project design, particularly for large public and commercial buildings.

Expand scope of building energy codes

- Update the Energy Conservation Building Code (ECBC) and Eco-Niwas Samhita to include requirements for embodied carbon, starting with a reporting requirement for new projects above a certain size (such as 5000 m²), as well as a requirement to limit embodied carbon to a certain level.

Mandate GreenPro or equivalent certifications in public procurement

- Require the use of GreenPro-certified or equivalent low-carbon materials in government-funded construction projects, including schools, hospitals and housing.

Information

Promote the use of the India Construction Materials Database

- Integrate the India Construction Materials Database into government-approved design and compliance tools, such as those for building codes and energy simulations.
- Offer training for architects and engineers on how to evaluate material choices based on embodied energy and global warming potential (GWP).

Raise awareness of low-carbon material alternatives

- Conduct outreach campaigns to target developers and local builders, showcasing cost-effective and regionally available alternatives such as:
    - fly ash bricks
    - AAC blocks
    - bamboo composites
    - recycled aggregates and construction and demolition (C&D) waste products

Incentives

Provide bonus points in green certification schemes

- Offer additional points in building certification systems such as IGBC, GRIHA and EDGE for:
    - projects using low-carbon or recycled materials
    - buildings with embodied carbon reductions verified through life cycle analysis.

Support innovation and local production

- Introduce support schemes for startups and micro, small and medium-sized enterprises, in order to encourage local manufacturing of low-carbon materials, especially in rural areas and Tier II/III cities.
- Provide recognition and grants for companies developing bio-based or circular construction products, such as crop-waste-based panels and earth blocks.

Synergies with other categories

- Materials policy can complement energy efficiency by reducing the life cycle emissions of net-zero-energy buildings.
- Digital building passports and labelling systems could include embodied carbon data and the origin of materials.
- Support from smart meters and IoT can extend to tracking material-related performance during use, including thermal mass and impact on indoor air quality.

Encourage adoption of climate-resilient design in buildings

Regulation

Introduce resilience guidelines for new construction projects

- Develop and issue voluntary guidelines on climate-resilient building design, covering:
  - heat resilience, including passive cooling, shading and reflective roofs
  - flood and cyclone resilience, including elevated plinths and water-resistant materials
  - earthquake safety (based on Bureau of Indian Standards BIS standards)
- Encourage states to integrate resilience criteria into local building bylaws, prioritising vulnerable regions such as coastal areas, flood plains and seismic zones.

Link resilience to energy codes and green building codes

- Add a resilience section to both the ECBC and Eco-Niwas Samhita to recommend (but not mandate) features such as:
  - thermal comfort without active cooling during power outages
  - water harvesting and backup systems
  - ventilation and air quality measures for public health events such as COVID-like situations.

Information

Develop regional climate risk maps and guidance

- Publish state-level building resilience toolkits using data from the National Disaster Management Authority (NDMA), the India Meteorological Department (IMD) and local climate models to guide site-specific risk assessment and design responses.

Build awareness of resilience among professionals

- Conduct short-term capacity-building modules for architects, engineers and local authorities on integrating resilience in building design and urban planning.
- Promote resilience through existing platforms such as Smart Cities Mission and the Urban Learning Internship Programme (TULIP).

Incentives

Offer design incentives for resilience in affordable housing

- Provide extra Floor Area Ratio (FAR), faster permitting, or tax rebates for projects incorporating certified resilience features such as disaster-resistant construction, passive survivability, or flood resilience.
- Prioritise low-income housing schemes for resilience retrofits and design upgrades in climate-vulnerable zones.

Link resilience to green certification bonus

- Award additional points for resilience-related design measures (such as heat-adaptive facades, stormwater buffering or blackout-readiness) in green certification schemes such as the Indian Green Building Council (IGBC), the Green Rating for Integrated Habitat Assessment (GRIHA), or Excellence in Design for Greater Efficiencies (EDGE).

Synergies with other categories

- Resilient buildings are naturally aligned with energy efficiency, since passive cooling and ventilation reduce dependence on energy.
- Resilience strategies, such as solar-plus-storage and smart energy management, enhance performance during climate-induced outages.
- Using low-carbon, durable, local materials contributes to both resilience and embodied carbon reduction.

Promote interoperable technologies and standards for buildings-to-grid (B2G) interaction

Regulation

Establish B2G-readiness standards for new buildings

- Mandate that large new residential and commercial buildings include basic infrastructure, such as smart meters, BEMS compatibility and smart inverters, to support grid interaction.

- Encourage the use of open communication protocols to allow buildings and appliances to efficiently interact with the power grid.
- Include B2G-readiness standards in updates to the Energy Conservation Building Code (ECBC) and Eco-Niwas Samhita, to ensure that buildings constructed today can host distributed energy resources, participate in demand response, and enable energy exports or curtailment in the future.

Mandate demand-response-readiness for appliances

- Introduce demand-response capability in appliances. Regulations should require that large electricity-consuming appliances (such as air conditioners and water heaters) be demand-response ready and equipped with hardware and software that enable them to participate in demand-response schemes.

Mandate smart EV charging infrastructure in new buildings

- Require that new buildings above certain thresholds (such as housing societies with more than 50 units or commercial buildings >1000 m²) be equipped with smart chargers that can delay, stagger or shift charging based on grid signals, in order to facilitate EVs become grid assets rather than liabilities.

Enable aggregation of distributed energy resources (DERs)

- Create a regulatory framework that allows third-party aggregators to pool small-scale DERs from homes and buildings into virtual power plants (VPPs).
- Update current electricity regulations to enable aggregators to participate in energy markets (day-ahead, ancillary services) or to offer grid-balancing services. This unlocks greater value for DER owners while increasing grid reliability and flexibility.

Enforce dynamic tariffs for all smart-metered consumers

- Enforce time-of-use (ToU) tariffs for all consumers with smart meters, as per the updated Electricity Rules.
- Require distribution companies to publish clear schedules and to integrate dynamic tariffs into their billing software and apps, in order to reward consumers for using energy when it is cheapest and cleanest, and to help manage peak demand.

Include B2G contributions in grid planning and operations

- Update the Indian Grid Code and Distribution System Operator (DSO) frameworks to allow buildings to provide services such as:

    - fast frequency response through rapid injection or withdrawal of power from a resource, to stabilise the grid frequency after a sudden imbalance between electricity supply and demand
    - reactive power support, which is the ability of a system (such as a building or inverter) to supply or absorb reactive power, thereby helping maintain voltage levels on the grid
    - peak load reduction, which is the lowering of electricity consumption during peak demand hours (typically in the evening or during extreme weather), either by reducing usage or shifting it to off-peak times.

  Provision of these grid services ensures that grid operators can rely on buildings as part of the energy system and not just as passive consumers.

Information

Develop a national B2G design guide and assessment toolkit

- Develop a practical toolkit with model building layouts, cost–benefit calculators, DER integration guides, and examples of control system architecture.
- Include guidance for integrating rooftop solar, battery storage, smart meters, EV chargers and building energy management systems (BEMS) at the building design or retrofit stage.

Launch a centralised B2G monitoring platform

- Create a public platform for policy monitoring, benchmarking and programme design that is able to track:
    - B2G-enabled buildings by type and location
    - peak load shaved through demand response
    - performance of DER aggregation pilots.

Strengthen consumer engagement via distribution company channels

- Distribution companies could use their mobile apps and SMS systems to:
    - alert consumers to high-price periods
    - share performance feedback (for example: “You saved X rupees this month by shifting your load”).
- Offer easy opt-in/out for demand response (DR) programmes.

Build capacity of distribution companies and energy professionals

- Train distribution company and municipal staff on:
    - designing DR programmes and evaluating B2G offers

    - monitoring DER interconnection and performance
    - enabling communication between BEMS and distribution systems.
- Develop a B2G professional certification under national programmes such as ECBC Trainer networks.

Incentives

Offer financial rewards for demand response participation

- Provide bill credits or direct payments to consumers (residential or commercial) who:
    - reduce load during peak hours
    - participate in distribution company or aggregator demand response programmes.
- Develop a billing and reward scheme under which consumers are paid based on how much electricity they reduce during a peak event.

Introduce a B2G certification linked to green building labels

- Create a "B2G-Ready Building" label, either as a standalone programme or an add-on to IGBC, GRIHA or EDGE. Such a label should certify:
    - demand response capability
    - DER integration
    - smart EV charging.

  Link this label to extra FAR, fast-tracked permitting, or green tax benefits to encourage uptake.

Provide capital subsidies and GST relief for smart grid-ready equipment

- Offer subsidies (such as those under PM Surya Ghar) for:
    - smart inverters
    - plug load control solutions
    - building automation systems.
- Reduce GST for approved B2G-enabling technologies.

Support aggregator startups and innovation pilots

- Fund pilot projects for distributed energy resource (DER) aggregation, peer-to-peer trading, or Virtual Power Plants (VPPs) under the National Smart Grid Mission (NSGM) or the Revamped Distribution Sector Scheme (RDSS) innovation tracks.

- Offer grants, soft loans, or performance-linked incentives to early-stage aggregators and platform developers.
- Use these pilots to develop scalable models for residential and SME participation in grid services.

Synergies with other categories

- Smart controls reduce load and enable precise demand-side participation, contributing to energy efficiency.
- B2G enables smoother integration of variable renewables such as rooftop solar, promoting decarbonisation.
- Smart meters, building automation and IoT are important B2G enablers.
- Grid-interactive buildings can self-manage during outages or grid stress events, increasing resilience.

Conclusion

India's buildings sector is at a turning point. Expanding floor space and the need for cooling are increasing electricity demand while the share of variable renewable energy is rapidly growing on the supply side. Efficient grid-interactive buildings (EGIBs) offer an important pathway for the energy transition by optimising consumption, supporting the integration of renewables and enhancing grid stability.

One of the key advantages of EGIBs lies in their flexibility and benefits they provide to the electricity grid. By dynamically adjusting their energy consumption and generation in response to grid signals, EGIBs help improve stability of electricity supply. This flexibility is particularly valuable for smoothing peaks in energy demand as well as for reducing grid congestion and mitigating the risk of blackouts and voltage fluctuations. By actively engaging with the electricity grid, EGIBs offer numerous benefits to the environment, the grid and consumers. This makes EGIBs an important component of the transition towards a sustainable and resilient energy future.

This report provides a comprehensive assessment of the EGIB landscape in India, based on an analysis of the key enablers for EGIB adoption. These enablers consist of technologies and policies across several categories: energy efficiency, decarbonisation, smartness, materials, resilience, and building-to-grid interaction. The analytical framework facilitates evaluation of the current situation under each enabler, based on a four-point evaluation scale.

The results of the assessment show promising progress by India in areas such as building energy codes, minimum energy performance standards for appliances, on-site renewable energy generation, and smart meter deployment. Further opportunities to strengthen the enabling ecosystem for EGIBs are emerging through pilot projects and regulatory sandboxes that demonstrate benefits and potential of smart grids, advanced metering infrastructure, distributed energy resource (DER) aggregation, demand response programmes, and dynamic tariffs.

As many countries, India in some areas is only starting to explore the opportunities for efficient grid-interactive buildings. Many smart and digital solutions are still relatively new, requiring time and sustained effort for scaled implementation. The fact that India is actively developing policy frameworks and implementing pilot projects related to efficient grid-interactive buildings is a clear sign that the country has already laid a strong foundation and is following a deliberate, phased approach - prioritising core efficiency measures, appliance standards, and digital infrastructure first, while progressively preparing the market and institutions for more advanced building-to-grid interactions.

This staged progression reflects the natural evolution of complex energy system transformations, where early investments in energy efficiency, smart metering, and digitalisation create the necessary enabling conditions for scaling advanced demand response, aggregation, and two-way communication solutions over time.

To move from pilots to scale, it will be essential to ensure that the full set of policy instruments is in place to support the wide-scale adoption of EGIBs. Interoperability standards are crucial for establishing two-way communication between building systems and the grid, though their use in India is nascent. Policy provisions to support integration of smart sensors and controls into building systems and energy management at the building level are also important. Moreover, India could benefit from introducing requirements to reduce embodied carbon in construction and encouraging the adoption of climate-resilient design in buildings.

Policy recommendations offered in this report outline the priority actions for India to embark on a transformative journey towards EGIB adoption. Development of a comprehensive policy package that combines regulations, information instruments and incentives is key – especially for new buildings, as a lot of the buildings that will be consuming energy in India in the decades to comes are yet to be built. Incorporating energy efficiency requirements, flexibility considerations and demand-response-readiness features for interaction with the grid into regulations for buildings and appliances can help the buildings sector leapfrog towards higher levels of energy performance, flexibility and decarbonisation, while at the same time supporting the modernisation of the electricity system.

India is on the cusp of a transformative energy transition through the adoption of EGIBs. By leading the way to an energy efficient, grid-interactive built environment, India can contribute to a cleaner and more sustainable energy landscape for generations to come.

Abbreviations and acronyms

AAC	Aerated autoclaved concrete
AC	Air conditioners
AI	Artificial intelligence
AMI	Advanced metering infrastructure
APDCL	Assam Power Distribution Company Limited
AT&C	Aggregate technical and commercial
BAL	Bushfire Attack Level
BAS	Building automation systems
BEC	Building energy code
BECCA	Building energy code content assessment
BEEP	Buildings Energy Efficiency Programme
BEMS	Building energy management systems
BESS	Battery energy storage systems
BMS	Building management system
BYOD	Bring your own device
C&D	Construction and demolition
CAGR	Compound average growth rate
CDO	Communications and Digital Office
CEA	Central Electricity Authority
CESC	Chamundeshwari Electricity Supply Corporation
CIM	Common information model
CLT	Cross-laminated timber
COSEM	Companion Specification Model
CSA	Connectivity Standards Alliance
DBFOOT	Design-Build-Finance-Own-Operate-Transfer
DCU	Data Concentrator Units
DER	Distributed energy resource
DERMS	Distributed energy resource management system
DR	Demand response
DRI	Direct reduced iron
DSM	Demand-side management
DSO	Distribution System Operator
ECBC	Energy Conservation Building Code
ECSBC	Energy Conservation and Sustainable Building Code
EDGE	Excellence in Design for Greater Efficiencies
EESL	Energy Efficiency Services Limited
EGIB	Efficient grid-interactive buildings
EPC	Energy performance certificates
EPTA	Electric Power Transmission Association
ESCO	Energy service companies
ESO	Energy storage obligations
ETWG	Energy Transition Working Group
EV	Electric vehicle
FAR	Floor Area Ratio
GBI	Green Building Index
GIBE	Grid-Interactive Built Environment
GRIHA	Green Rating for Integrated Habitat Assessment
GSA	General Services Administration
GWP	Global warming potential

HEMS	Home energy management systems
HES	Head-End Systems
HPSEB	Himachal Pradesh State Electricity Board
IGBC	Indian Green Building Council
IIT	Indian Institute of Technology
IMD	India Meteorological Department
IoT	Internet of things
LCA	Life cycle analysis
LEED	Leadership in Energy and Environmental Design
LPG	Liquefied petroleum gas
MDM	Meter Data Management
MDMS	Meter Data Management Systems
MEPS	Minimum energy performance standards
MERC	Maharashtra Electricity Regulatory Commission
NAPCC	National Action Plan on Climate Change
NDC	Nationally Determined Contribution
NDMA	National Disaster Management Authority
NMEEE	National Mission for Enhanced Energy Efficiency
NPEB	Net Positive Energy Buildings
NSGM	National Smart Grid Mission
NZEB	Net Zero Energy Buildings
OMS	Outage management systems
PLC	Power Line Communication
PLI	Performance-linked incentive
RDSS	Revamped Distribution Sector Scheme
RETV	Residential envelope transmittance value
RF	Radio Frequency
RWA	Resident Welfare Associations
SCADA	Supervisory control and data acquisition
STEPS	Settings in the Stated Policies Scenario
TES	Thermal energy storage
TGREDCO	Telangana and the Telangana Renewable Energy Development Corporation
ToD	Time-of-day
ToU	Time-of-use
TR	Tonnes of refrigeration
TSECL	Tripura State Electricity Corporation Ltd
TSSPDCL	Telangana State Southern Power Distribution Company Limited
TULIP	The Urban Learning Internship Programme
UGVCL	Uttar Gujarat Vij Company Limited
UHBVN	Uttar Haryana Bijli Vitran Nigam
VPP	Virtual power plant
VRE	Variable Renewable Energy
WBSEDCL	West Bengal State Electricity Distribution Company Limited

See the IEA glossary for a further explanation of many of the terms used in this report.

IEA Publications
International Energy Agency
Website: www.iea.org
Contact information: www.iea.org/contact

Typeset in France by IEA - March 2026
Cover design: IEA
Photo credits: © ShutterStock