Climate Centre for Cities

From the Ground Up

A whole-system approach to decarbonising India's buildings sector

Report / November 2022

About NIUA

Established in 1976, the National Institute of Urban Affairs (NIUA) is India's leading national think tank on urban planning and development. As a hub for the generation and dissemination of cutting-edge research in the urban sector, NIUA seeks to provide innovative solutions to address the challenges of a fast-urbanizing India, and pave the way for more inclusive and sustainable cities of the future.

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RMI is an independent nonprofit founded in 1982 that transforms global energy systems through market-driven solutions to align with a 1.5°C future and secure a clean, prosperous, zero-carbon future for all. We work in the world's most critical geographies and engage businesses, policymakers, communities, and NGOs to identify and scale energy system interventions that will cut greenhouse gas emissions at least 50 percent by 2030. RMI has offices in Basalt and Boulder, Colorado; New York City; Oakland, California; Washington, D.C.; and Beijing.

Authors & Acknowledgments

Authors

National Institute of Urban Affairs (NIUA)
RMI

Contacts

For more information, contact indiainfo@rmi.org

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List of acronyms and abbreviations

ADR	Automated Demand Response
AEEE	Alliance for Energy Efficient Economy
ANSI/CTA	American National Standards Institute/Consumer Technology Association
API	Application Programming Interface
BBP	Better Buildings Partnership
BEE	Bureau of Energy Efficiency
BEEP	Building Energy Efficiency Program
BLDC	Brushless direct current
BRPL	BSES Rajdhani Power Limited
CEEW	Council on Energy Environment and Water
CGD	City Gas Distribution
COP26	UN Climate Change 26th Conference of Parties
Cx	Commissioning
DER	Distributed energy resources
DF	Demand flexibility
Discom	Distribution company
DR	Demand response
DSM	Demand side management
DST	Department of Science and Technology
EaaS	Efficiency as a service
EC	Embodied carbon
ECBC	Energy Conservation Building Code
EDGE	Enhancing Development and Growth through Energy
EE	Energy efficiency
EESL	Energy Efficiency Services Limited
EMI	Equated monthly instalment
ENS	Eco Niwas Samhita
EPD	Environmental Product Declaration
ESCO	Energy service company
ESPC	Energy service performance contracts
EUI	Energy use intensity
EV	Electric velhicle
GCP	Global Cooling Prize
GDP	Gross domestic product
GEB	Grid-interactive buildings
GHG	Greenhouse gas
GoI	Government of India
GRIHA	Green Rating for Integrated Habitat Assessment
Gt	Gigatonnes
GTAM	Green Term Ahead Market
GW	Gigawatt
HCFC	Hydrochlorofluorocarbons
HER	Home Energy Report
HFC	Housing Finance Companies
HFC	Hydro Fluoro Carbons
HVAC	Heating Ventillation and Air Conditioning
I-PHEE	Initiative to Promote Habitat Energy Efficiency
ICAP	India Cooling Action Plan
IEEE	The Institute of Electrical and Electronics Engineers
IESP	Integrated energy services provider
IGBC	Indian Green Building Council
IRP	Integrated resource plan
IT	Information technology

List of acronyms and abbreviations

LaaS	Lighting as a service
LBNL	Lawrence Berkeley National Lab
LEED	Leadership in Energy and Environmental Design
LPG	Liquified petroleum gas
MAITREE	Market Integration and Transformation for Energy Efficiency
MEPS	Minimum Energy Performance Standards
MoEFCC	Ministry of Environment, Forest, and Climate Change
MoHUA	Ministry of Housing and Urban Affairs
MoPNG	Ministry of Petroleum and Natural Gas
MT	Million tonnes
MW	Megawatt
NBFC	Non-banking finance companies
NGO	Non-governmental organisations
NZEB	Net-zero energy building
PAYS	Pay As You Save
PMAY	Pradhan Mantri Awas Yojana
PMUY	Pradhan Mantri Ujjwala Yojana
PNG	Piped natural gas
PPA	Power purchase aggrement
PSU	Public-sector undertaking
PV	Photovoltaic
R&D	Research & development
RAC	Room air conditioners
RBI	Reserve Bank of India
RCx	Retro-commissioning
REC	Renewable energy certificate
RESCO	Renewable Energy Service Company
RIBA	The Royal Institute of British Architects
RPO	Renewable purchase obligation
RTS	Rooftop solar
S&L	Standards and labelling
SBTi	Science Based Targets Initiative
SCM	Supplementary cementitious materials
SEAD	Superefficient Equipment and Appliance Deployment
SEEI	State Energy Efficiency Index
SERC	State Electricity Regulatory Commission
TES	Thermal energy storage
TV	Television
TWh	TeraWatt hour
UJALA	Unnat Jyoti by Affordable LEDs for All
USAID	United States Agency for International Development
WGBC	World Green Building Council

Foreword

Transforming the built environment is critical to achieving India's ambitious 2030 climate targets announced by our Honourable Prime Minister at COP26. In India's fight against climate change, there is now real momentum and ambition to pursue transformative decarbonisation. When India's building stock is set to double in the next two decades, the buildings sector has significant responsibility and opportunity to reduce greenhouse gas emissions.

This immense opportunity to decarbonise India's buildings sector has the potential to deliver vast benefits even beyond climate change mitigation. We can reduce energy consumption while improving our thermal comfort and productivity, increasing resilience, and reducing investments in energy supply infrastructure. We can do this in a manner that is cost-effective and accessible to all.

Recognizing this, the National Institute of Urban Affairs (NIUA) has partnered with RMI to develop a first-of-its-kind report – "*From the Ground Up: A whole-system approach to decarbonising India's buildings sector*". This report provides a structured perspective to transforming India's building sector and includes a broad range of integrated solutions and innovative financing mechanisms around minimising embodied carbon through cost-effective low-embodied-carbon design decisions and material selection; reducing energy demand through passive measures, super-efficient equipment; and further serving the reduced energy demand efficiently through demand flexibility and clean energy.

This effort will assist the numerous programmes and policy initiatives underway at the ministry. The decisions we take today will influence India's emissions impact, economic growth, and energy savings for decades to come. Therefore, we must proactively choose to evolve the way we design, construct, and operate buildings so that our buildings can contribute to a net-zero future.

I would like to commend and congratulate the team members from NIUA and RMI for carrying out such a comprehensive study. For the transition towards net zero building, I have full faith and trust that the study will serve as an important reference for policymakers, industry, associations, financial institutions and other stakeholders. NIUA will keep the momentum towards net zero buildings and will support efforts and interventions to achieve the transition.

Shri Kunal Kumar, IAS
Joint Secretary (Smart City Mission)
Ministry of Housing and Urban Affairs (MoHUA), Government of India

Executive Summary

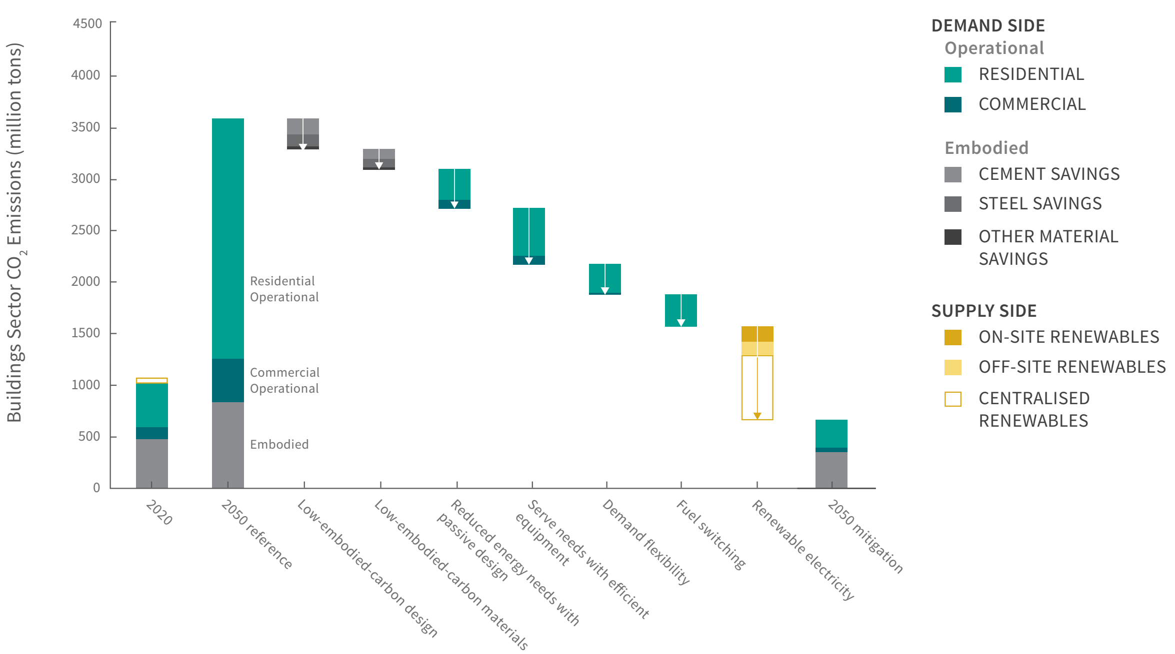
Building operations in India account for about a third of its energy use. Approximately another 10% of the country's energy is used in the production of building material and construction of new buildings. In the absence of peremptory energy-efficiency improvements and policy measures, the buildings sector is estimated to consume over three times more energy by 2050 compared with that utilised today, and carbon emissions are expected to nearly quadruple (see Exhibits 1, 5A and 7A, pages 16 and 18). Notably, there is no energy transformation without a buildings sector transformation.

The recommendations in this report — which are additive to and integrate with ongoing interventions — can maximise the buildings sector's role in helping India achieve its ambitious Nationally Determined Contribution (NDC) 2030 climate goals (see Exhibit 1). India's buildings sector must adopt an integrative whole-system approach to cost-effectively address embodied and operational emissions across the demand side and supply sides collectively — first by reducing the building-energy needs, then serving the needs as efficiently as possible, and finally optimising the demand and providing a clean energy supply.

Exhibit 1

Buildings Sector Energy Transformation Potential

Buildings Sector Waterfall Diagram



Source: Lawrence Berkeley National Laboratory, RMI Analysis

The whole-system approach is a holistic and integrated sequence of actions within the buildings sector, with cascading benefits that unlock a significant outcome. Each step entails high-priority, near-term technical solutions (see Exhibit 2). Integrative approaches to building-energy technology and policy can leapfrog narrow, incremental approaches and help overcome key challenges such as invisibility of benefits, financial barriers, limited capacities, complexity of the sector and solutions, and a fragmented approach to transformation.

The timing of India's urban migration and development presents an unprecedented opportunity to transform how buildings are designed, constructed, and operated, slashing energy consumption and energy-supply infrastructure investments while improving cooling access, health and productivity, and resilience. India's buildings sector leaders have made great strides in crucial areas such as energy codes, building ratings, and product standards and labelling. Adding to the momentum, this set of high-impact technical solutions and implementation accelerators can inform and support the roadmap efforts undertaken by policy and business leaders towards India's net-zero goal and NDC commitments.

Exhibit 2 **The "what": Whole-system, high-impact technical solutions**

MINIMISE EMBODIED ENERGY AND EMISSIONS		
1	Low-Embodied-Carbon Design and Construction	• The current embodied-carbon emissions from construction are approximately of the same magnitude as building operational carbon emissions. The buildings sector has a crucial demand-side role in driving embodied-carbon savings. • Integrative design thinking during the programming, design, and construction processes represents an enormous, cost-effective opportunity to reduce embodied carbon while delivering the same or better building services.
2	Low-Carbon-Material Production and Selection	• Low-carbon options exist for key material types such as concrete, steel, insulation, brick, and other wall constructions. • The buildings sector must drive demand through embodied-carbon accounting and low-carbon-material specification.
MINIMISE ENERGY AND EMISSIONS FROM BUILDING OPERATIONS		
Reduce energy needs in buildings		
3	Urban-Scale Passive Solutions	• Incorporate heat-minimising and heat-resilience requirements into urban planning and building requirements, reducing urban temperatures while improving resilience, cooling equity, and energy costs. • Where feasible, aggregate new cooling demand through district cooling systems.

4	Integrative, Passive Building Design	• Use passive building strategies to reduce or eliminate the need for mechanical cooling, while increasing resilience and reducing energy-supply strains. • Integrative design of high-performance buildings can reduce first costs. • Indigenous techniques and materials provide a pathway for beneficiary-led and informal housing sectors.
Serve energy needs as efficiently as possible		
5	Super-Efficient Cooling Equipment	• The Global Cooling Prize demonstrated technologies with five times (5X) less climate impact than traditional room air conditioners (RACs). These can reduce India's peak electricity by 400 gigawatts (GW) in 2050. • Fans remain the first cooling access for much of India, particularly low-income and weak-grid communities, and will remain the largest contributor to residential energy demand. Efforts are required to create and sustain the market for super-efficient ceiling fans by combining technology with financing solutions.
6	Other Appliances, Equipment, and Control Systems	• Residential: With a wide variety of residential energy end uses, visibility and automation can drive behavioural change and identify high-priority efficiency opportunities for homeowners and programme designers. Market-transformation programmes can be coordinated with minimum efficiency performance standards that incorporate next-generation, leapfrog technologies in priority end uses such as cooling and water heating. • Commercial: Building controls, automation, and commissioning/retro-commissioning are low-cost, high-impact opportunities for efficiency improvements via ratings, programmes, codes, and standards.
Optimise Clean Energy Supply		
7	Demand Flexibility and Energy Storage	• Demand flexibility (DF) offers customer-focused value propositions, complementary to demand response (DR) programmes bringing flexible demand to traditional generation services. • Demand flexibility in residential and commercial buildings can drive clean energy by shifting energy demand when renewable energy (RE) is higher in the generation mix. This can help reduce power purchase cost of discoms at peak hours, electricity costs for consumers, and RE curtailment risks for generators. • The reliability of DR services is greatly enhanced by smart appliances and other controllable devices. They not only make DR participation effortless for consumers but also increase the certainty of response for Discoms reliant on DR.

8	Fuel Switching	• Combustion for cooking and water heating make up about a quarter of urban residential energy consumption and most of rural residential energy consumption. • New clean cooking and water heating technologies are available for the India market. • Cooking fuel infrastructure strategy should be co-optimised for resilience, health, financial risk mitigation, and environmental considerations.
9	Clean Energy Procurement	• The buildings sector can play a key demand-side role in advancing India's national RE goals. • Buildings can integrate clean energy from a wide range of RE procurement models and benefit from significant savings owing to the cost-competitiveness of RE-based generation.

The sector-wide transition can move quickly and comprehensively with the help of whole-system accelerators to jump-start, accelerate, and scale the adoption of low-carbon solutions. This requires extensive collaboration with a range of buildings sector actors, but government policymakers and task forces at the national, state, and local levels can play crucial leadership roles to catalyse the transition, conducting the symphony and initiating high-impact market accelerators. Sector leaders can structure, calibrate, and track the whole-system components, with discrete sub-elements that are measurable and accountable by a matrix of initiatives (see Exhibit 3, next page). While some of these initiatives are targeted at advancing specific technical solutions, others have a crosscutting impact across technical end uses. Some are leadership collaboratives at the leading edge to "raise the ceiling," while others are statutory mechanisms to "raise the floor" for all through codes and standards.

Exhibit 3 "The How": Buildings sector whole-system transition accelerators and targets

	WHAT? Technical Solutions	TECHNOLOGY SUB TARGETS	HOW? Targeted Accelerators	IMPACT TARGETS	HOW? Cross Cutting Impact Accelerators	
EMBODIED energy and carbon	Low-embodied-carbon design & construction	Market penetrations of low-embodied-carbon design strategies	→ Embodied carbon design force accelerator	Embodied carbon intensity	→ Corporate commitments → Government agency commitments → Embodied carbon codes	**BUILDINGS SECTOR REDUCTION** in energy and carbon, in direct support of national goals
	Low-carbon-material production and selection	Carbon intensity, by material	→ Embodied carbon design force accelerator → Supply chain disclosure/targets			
OPERATIONAL energy and carbon	REDUCE ENERGY NEEDS: Urban scale passive solutions; Passive buildings	Market penetrations of passive strategies	→ City cooling plans → Integrative passive design hub → Indigenous design challenge	Design energy use intensity	→ Zero code roadmap	
	SERVE NEEDS EFFICIENTLY: Ultra-efficient equipment and smart systems	Appliance and equipment efficiency, by type	→ Demand aggregation programs → Appliance/equipment roadmap	Operational energy use intensity	→ Corporate commitments → Finance focus → Government agency commitments → Integrated resource plans → Building performance standards	
	SUPPLY WITH CLEAN ENERGY: Demand flexibility	Demand flexibility capacity, by type	→ Demand Reduction and flexibility commission			
	SUPPLY WITH CLEAN ENERGY: Fuel switching	Clean cooking market share	→ Clean cooking access plan	Peak demand	→ Integrated resource plans	
	SUPPLY WITH CLEAN ENERGY: Clean energy procurement	Renewable procurement capacity, on- and off-site	→ Buildings renewables coalition → Buildings renewables requirements			

KEY → Leadership collaboratives → Statutory mechanisms

I. A Convergent Moment to Achieve India's NDCs

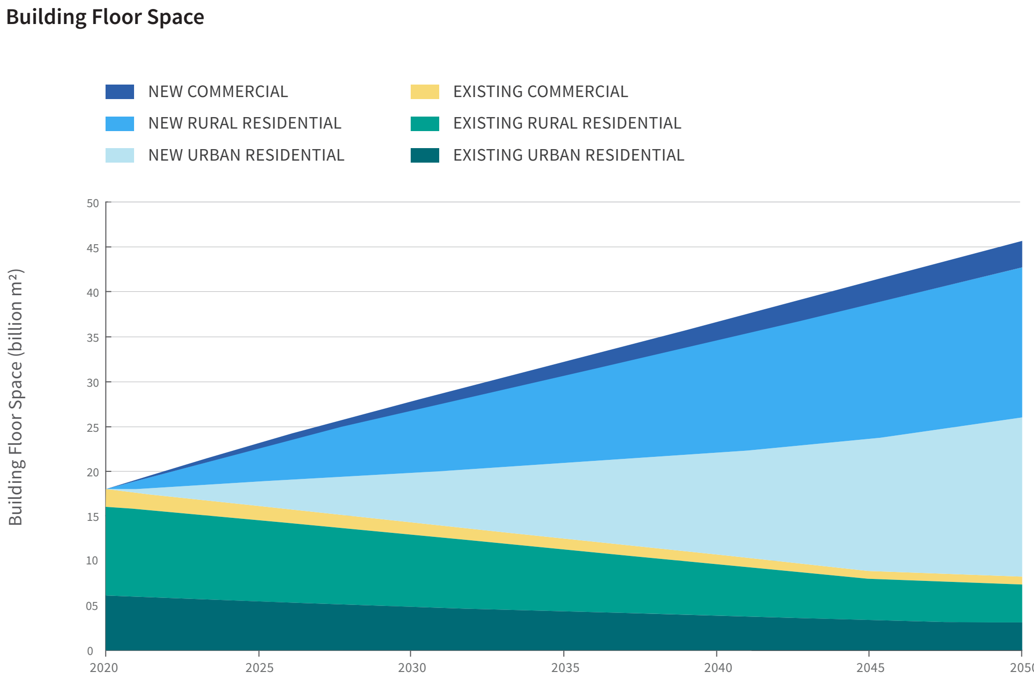
The timing of India's urban migration and development presents an unprecedented opportunity to transform how buildings are designed, constructed, and operated. Integrative, whole-system approaches to building-energy technology and policy can break through technical, cost, and implementation barriers and leapfrog narrow, incremental approaches. They can slash building-energy consumption and energy-supply infrastructure investments while improving cooling access, health and productivity, and resilience.

Integrative solutions can also make India a leader in responding to the global climate crisis. The built environment is both the cause of and solution for energy challenges today and in the coming decades. A buildings-sector transformation can be a cornerstone of plans to realise the ambitious carbon goals announced at COP26 — reducing carbon intensity by 45% by 2030 (compared with 2005), slashing 1 billion tonnes of emissions by 2030, and ultimately achieving net zero.

Today, building operations in India account for about a third of its energy use, with the residential sector alone consuming one-fourth of the total national demand. Approximately another 10% of the country's energy is used in the production of building material and construction of new buildings. Notably, there is no energy transformation without a buildings sector transformation.

Furthermore, India's floor area is projected to more than double by 2040 (see Exhibit 4, page 15). This growth, along with the projected end of life of much of today's building stock, implies the vast majority of building stock that will exist in 2050 is yet to be built. In this convergent moment of development and urbanisation, India can build right the first time — avoiding the energy and carbon lock-in effects associated with inefficient construction — and operate optimally to unlock a powerful compounding effect that minimises the energy and carbon intensity of the buildings sector. The largest share of the new building stock will be residential construction to meet the demands of urban housing and a growing economy and buildings sector innovation can improve lives by ensuring energy and environmental prosperity.

Exhibit 4 Buildings stock projection



Source: Lawrence Berkeley National Laboratory, RMI Analysis

In the absence of peremptory energy-efficiency improvements and policy measures, the buildings sector is estimated to consume over three times more energy by 2050 compared with that utilised today, and carbon emissions are expected to quadruple (see Exhibits 5A and 7A, pages 16 and 18). It is widely acknowledged that space cooling will dominate energy consumption and contribute massively to electric grid peak demand. However, building-energy consumption is, perhaps surprisingly, evenly spread across end uses, including appliances, water heating, and cooking. Moreover, as India's buildings sector transformation is a story about new construction, the energy and carbon from the manufacture of material and components and construction of buildings will majorly drive sector emissions between now and 2050. This embodied energy is within the crucial influence of buildings-sector stakeholders to mitigate.

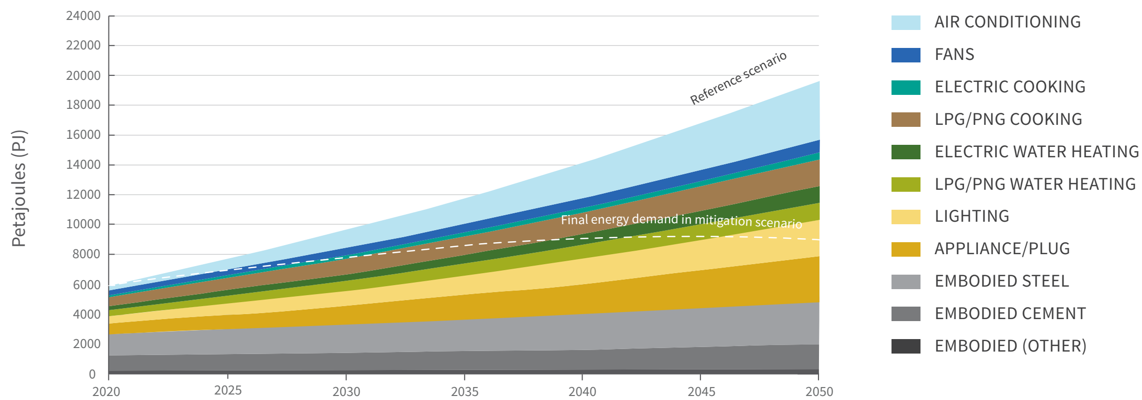
Integrative applications of today's technologies can bend the energy growth curve across end uses, trimming final energy consumption by approximately half by 2050 compared with the current trajectory (see Exhibit 5, page 16). The electricity required to meet the shrinking energy needs must also be decarbonised, with buildings playing a crucial role in driving and enabling the transition to a renewable grid. The whole-system approach of building solutions could significantly contribute to the ambitious 2030 carbon intensity reduction target announced at COP26 and reduce carbon emissions from the sector by more than half by 2050 compared with a baseline scenario. This is in line with India's ultimate net-zero goal (see Exhibits 7 and 8, pages 18 and 19). Discom-led, electricity-supply decarbonisation efforts would lead the remaining path to net zero and ensure massive supply-side investment savings in light of the buildings sector demand for renewable generation reducing to half.

Exhibit 5

Buildings sector final energy consumption through 2050

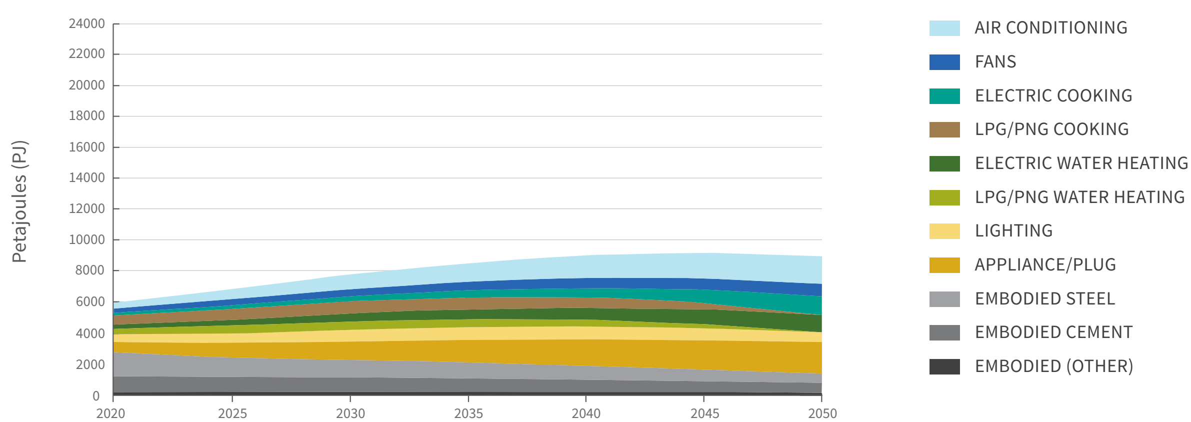
A. Unmitigated reference scenario

Final Energy Demand in Reference Scenario



B. Mitigated, aligned with COP26-announced goals

Final Energy Demand in Mitigation Scenario (Demand Side Efficiency)



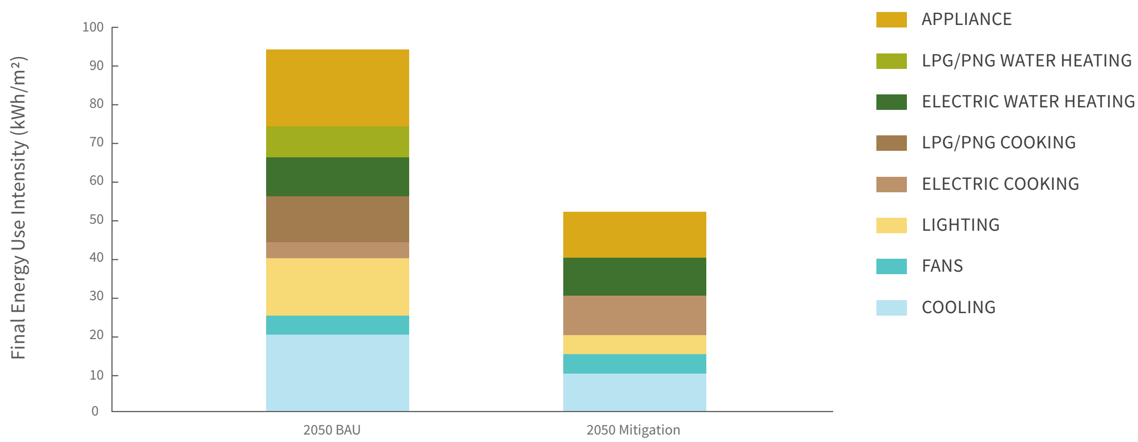
Source: Lawrence Berkeley National Laboratory, RMI Analysis

Exhibit 6

Buildings sector energy use intensity in 2050

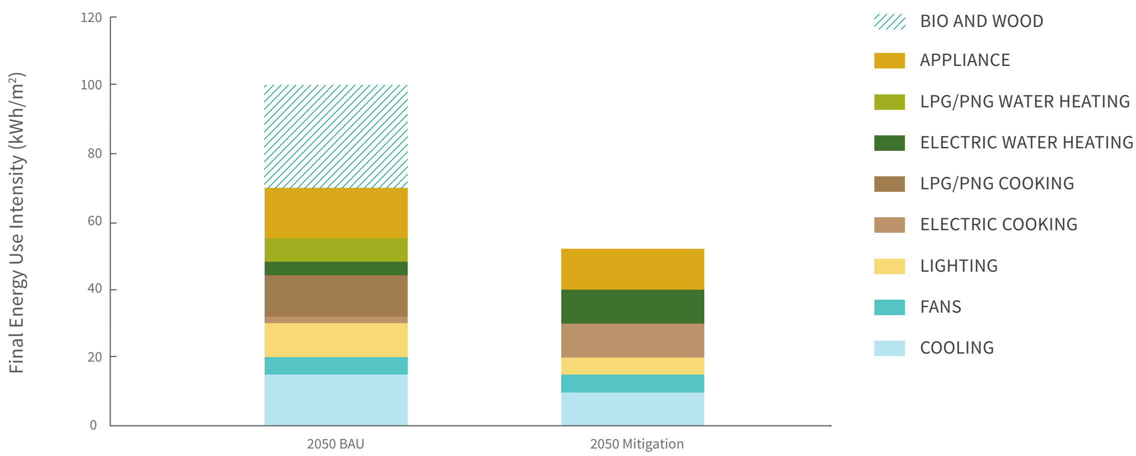
A. Urban Residential

Urban Residential Building Final Energy Use Intensity



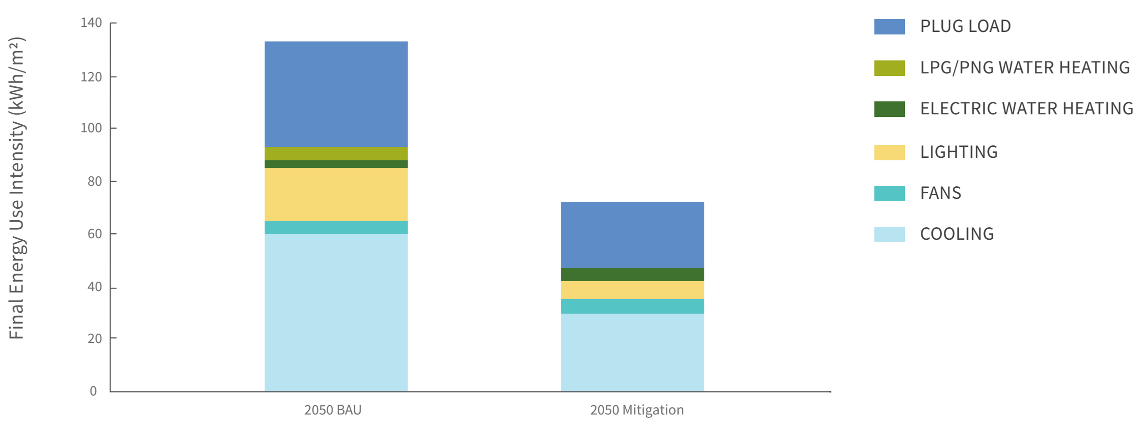
B. Rural Residential

Rural Residential Final Energy Use Intensity



C. Commercial

Commercial Building Final Energy Use Intensity



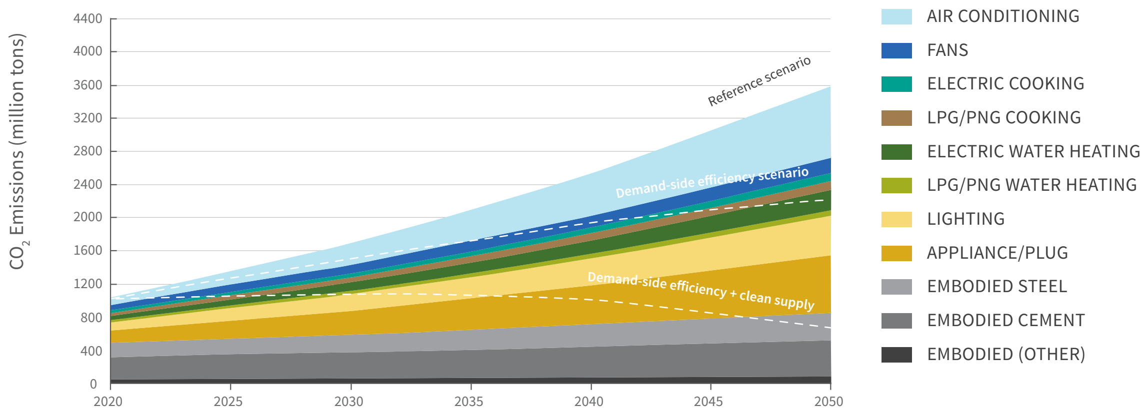
Source: Lawrence Berkeley National Laboratory, RMI Analysis

Exhibit 7

Buildings sector carbon emissions through 2050

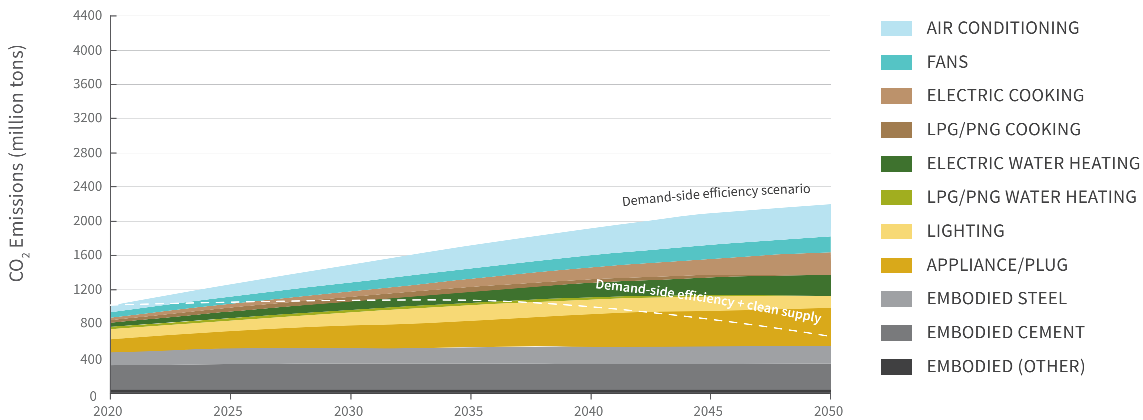
A. Unmitigated reference scenario

CO_2 Emissions in Reference Scenario



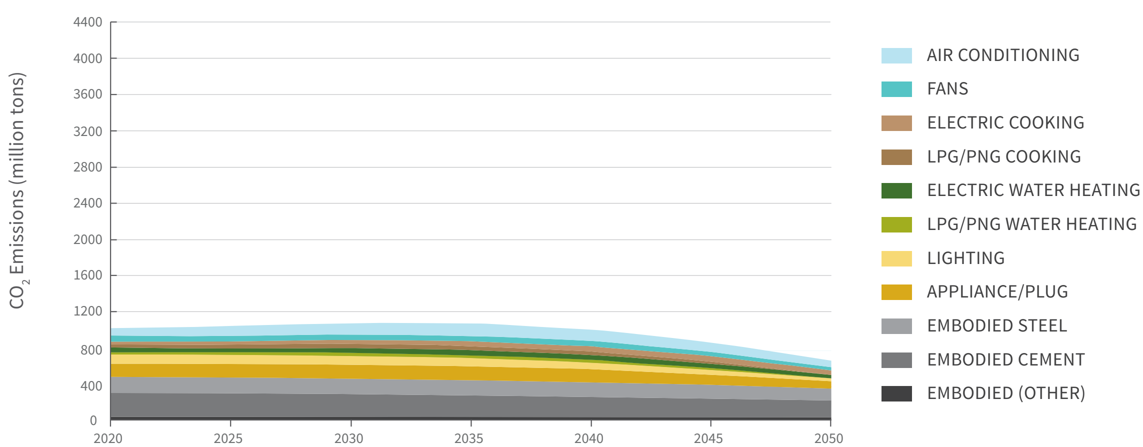
B. Mitigated, aligned with COP26-announced goals

CO_2 Emissions in Mitigation Scenario (Demand-side efficiency)



C. Mitigated, Scenario (Demand-side efficiency + clean supply)

CO_2 Emissions in Mitigation Scenario



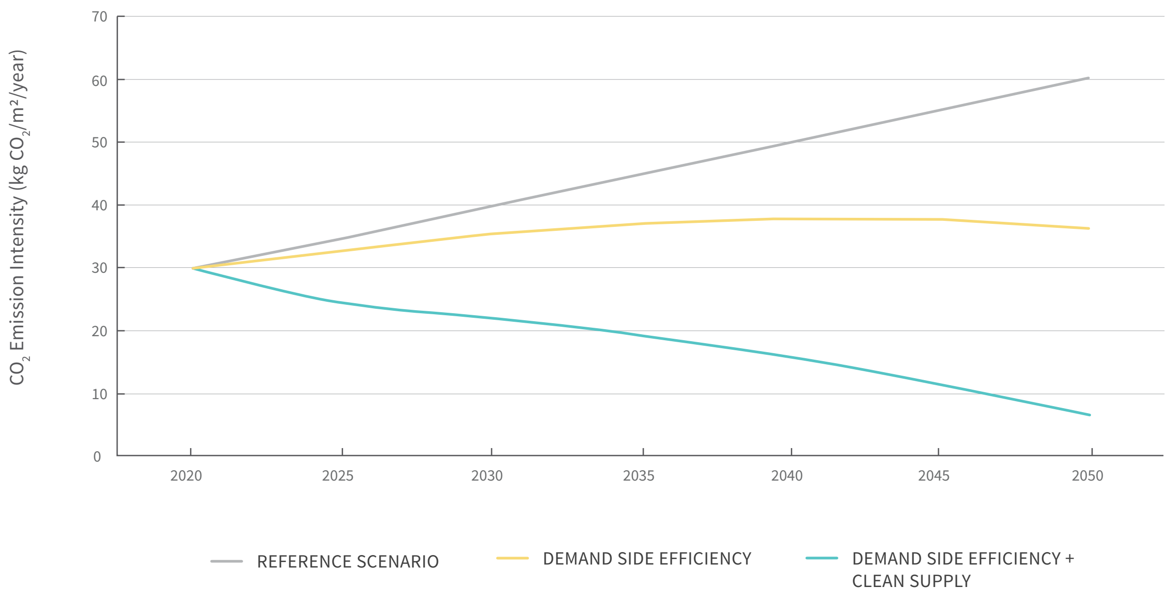
Source: Lawrence Berkeley National Laboratory, RMI Analysis

Exhibit 8

Buildings sector carbon intensity

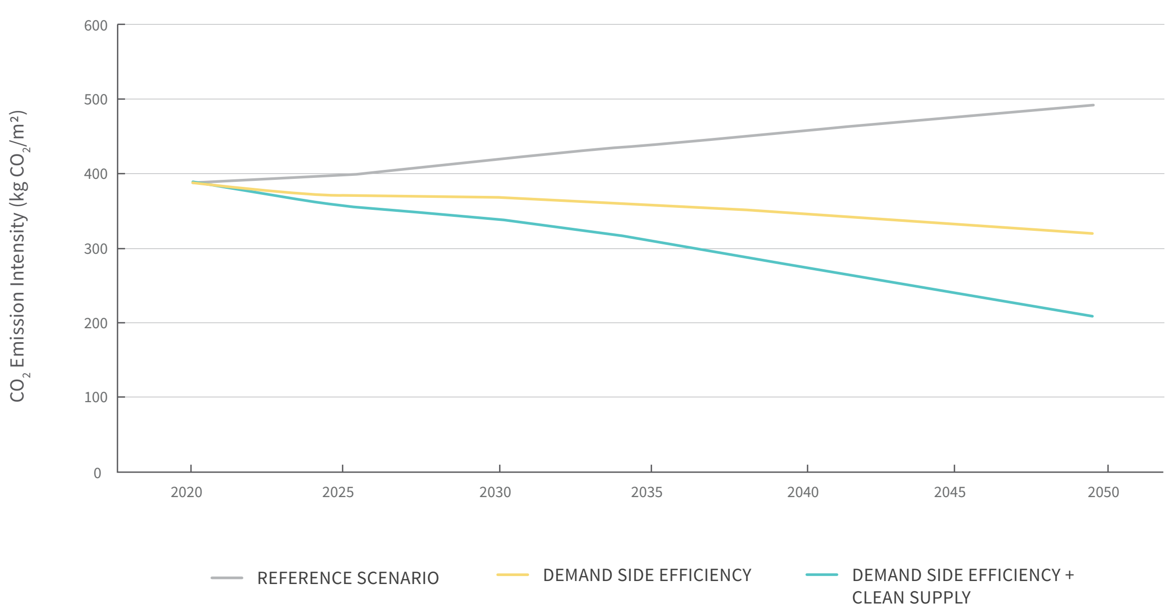
A. Operational Energy

Buildings Sector Operational Energy Carbon Emission Intensity



B. Embodied Energy

Buildings Sector Embodied Energy Carbon Emission Intensity



Source: Lawrence Berkeley National Laboratory, RMI Analysis

Enabling Conditions

Several converging factors make this a unique moment of opportunity for India's leaders to set the country on a path towards a net-zero buildings sector:

- **Building growth moment:** As described above, India is expected to more than double its floor area in the next two decades. This represents a critical window of opportunity to lock intrinsic prosperity and resilience in the most important elements of the nation's energy-system infrastructure — its homes, businesses, schools, hospitals, government facilities, and places of worship. The most comprehensive and cost-effective energy efficiency and resilience solutions are obtained during new construction, when broad-brush decisions have an enormous energy impact and integrative design can realise virtuous cost-saving feedback loops. India can "build right the first time," leapfrogging decades of energy waste and risk, and avoiding the intractable costs of afterthought retrofits or overbuilt energy supply.

- **Growing middle class:** As India emerges from the challenges of COVID-19, sustained growth in its middle class would mean expansion of energy services. Many millions of households will expect to gain access to cooling equipment — RACs, air coolers, fans — and resilient electricity service in general. Even an equipment life of 10 years would span India's expected period of energy transformation to achieve the goals announced at COP26. It is, thus, imperative to get it right the first time, ensuring new equipment stock has leading-edge efficiency and grid interactivity and eliminates the use of dangerously climate-damaging refrigerants. It is also an opportunity to include passive building efficiency first, providing myriad whole-system cost, comfort, and resilience benefits better than the mechanical equipment alone.

- **Energy-system investment:** The expansion of building stock, middle-class population, and access to energy services will be reflected in the increase in electricity generation capacity. Coupled with the announced goal of 50% renewables by 2030 and ultimately a net-zero economy, this means massive supply-side investment. Disregarding demand-side resources in planning a new energy sector would imply drastic overbuild, wasting capital and operational resources. The saved supply infrastructure costs change the calculus of energy efficiency and load flexibility, which is then limited only by technological and policy ingenuity to align the whole-system value. The new energy system resource would be the first of its kind in the world.

- **Technology and solution maturity:** Even if this transition had begun five years ago, many of the demand-side solutions for India would have still included emergent technologies, design concepts, or regulatory constructs by innovators from around the globe. Today, the solutions are proved, plentiful, and founded in India, making the challenge about achieving scale through markets, policies, and public awareness. For example, the Global Cooling Prize, launched in India with government support, yielded two technologies that are 5X more climate-friendly and 2X more energy-efficient than today's standard RACs.

- **Burgeoning policy and programme landscape:** India has a solid policy foundation in place to catalyse action towards building-sector energy transition, and the momentum is building. Exhibit 9, page 21, highlights some recent game-changing government commitments and regulatory and policy drivers, and some related ongoing programmes and initiatives. Integrating the value and execution of these initiatives will be key to an accelerated transition to net zero in the buildings sector.

Exhibit 9

Sample of ongoing government commitments and initiatives interrelating with building-sector energy and emissions

These exhibits are not meant to be exhaustive but indicative of the breadth of initiatives in place. In addition, several knowledge-creation and on-the-ground implementation efforts are in motion, with active involvement from the private sector and a growing number of civil society organisations, academic institutions, and industry associations, highlighting a dynamic and evolving ecosystem of actors in this space.

INITIATIVE	SHORT DESCRIPTION

India's updated Nationally Determined Contribution (NDC)	• By 2030:
	  • 50% of cumulative installed capacity from non-fossil fuel based energy sources
	  • Reduce emission intensity of GDP by 45% from 2005 levels
	• By 2070:
	  • Net-zero emissions

Energy Conservation Amendment Bill – Ministry of Power	The amendment bill was introduced to promote energy efficiency and conservation across equipment, buildings, appliances, and industries. The bill highlights actions on the following key proposals: (i) obligation to use nonfossil sources of energy, (ii) carbon trading, (iii) energy conservation code for buildings, (iv) applicability to residential buildings, (v) standards for vehicles and vessels, (vi) regulatory powers of SERCs, and (vii) composition of the governing council of BEE.
Clean Energy Open Access Rules – Ministry of Power	To ensure access to affordable, reliable, sustainable, and green energy for consumers, the limit of open access transaction was reduced from 1 MW (megawatt) to 100 kW for green energy. The rules will help streamline the overall approval process, provide certainty on open access charges, and incentivise consumers to go green.
Commitments to the Montreal Protocol and its Kigali Amendment	• In September 2021, India officially ratified the Kigali Amendment of the Montreal Protocol, joining the fight to phase out hydrofluorocarbons (HFCs). • The country's phaseout management plan for hydrochlorofluorocarbons (HCFC) is on track as per the Montreal Protocol schedule.
India Cooling Action Plan (ICAP) — Ministry of Environment, Forest, and Climate Change (MoEFCC)	In 2019, India became the first major economy to launch a national action plan on cooling. A first-of-its-kind integrative policy roadmap developed through collaboration among multiple ministries, industry partners, and civil society organisations, ICAP provides a comprehensive 20-year perspective on India's cooling growth and a cross-sectoral policy roadmap to address this growth sustainably.

INITIATIVE	SHORT DESCRIPTION
National building-energy codes for commercial and residential buildings — Bureau of Energy Efficiency (BEE), under the Ministry of Power	• The Energy Conservation Building Code (ECBC) — launched in 2007 and updated in 2017 and 2021 — aims to optimise energy savings, keeping in mind occupant comfort and life-cycle cost-effectiveness, to achieve energy neutrality in commercial buildings. • Eco-Niwas Samhita (ENS), i.e., the Energy Conservation Building Code for Residential Buildings, was launched in 2018 and encourages the adoption of passive design principles and strategies, and careful material selection to enhance thermal comfort and energy efficiency.
Smart Cities Mission — Ministry of Housing and Urban Affairs (MoHUA), jointly with state governments	Launched in 2015, this national mission is aimed at driving economic growth and improving the quality of life of people in cities by enabling sustainable development and harnessing technology.
Standards and Labelling Programme — Bureau of Energy Efficiency (BEE), under the Ministry of Power	The scheme targets the display of energy performance labels on various end-use equipment and appliances, and lays down minimum energy performance standards (MEPS).
Climate Smart Cities Assessment Framework (CSCAF) — Ministry of Housing and Urban Affairs (MoHUA)	Developed under the Smart Cities Mission by NIUA, the CSCAF intends to provide a climate-sensitive approach to urban planning and development in India. The framework has 28 indicators across five categories: (i) energy and green buildings, (ii) urban planning, green cover, and biodiversity; (iii) mobility and air quality; (iv) water management; and (v) waste management.
Pradhan Mantri Awas Yojana (PMAY) — Ministry of Housing and Urban Affairs (MoHUA), supported by state-level nodal agencies, urban local bodies/implementing agencies, central nodal agencies, and primary lending institutions	PMAY is a government initiative that addresses the urban housing shortage — among the economically weak segment, including slum dwellers and the middle-income group — and the rural housing shortage by ensuring *pucca* (permanent) houses for all eligible households by 2022.
Market Integration and Transformation for Energy Efficiency (MAITREE) — Ministry of Power, US Agency for International Development (USAID), BEE, Energy Efficiency Services Limited (EESL), state and local government stakeholders, private-sector entities, and multiple international agencies	MAITREE is a bilateral programme between USAID and the Ministry of Power, Government of India, under the US government's Asia Enhancing Development and Growth through Energy (EDGE) Initiative. Focused on promoting energy efficiency across the buildings sector in partnership with public and private entities, the programme includes support for the uptake of building-energy codes and net-zero energy buildings, capacity building and technical assistance, and market enablement and transformation strategies.

Barriers and Challenges

While government initiatives and policies provide a solid foundation for an ecosystem to advance buildings sector efficiency, implementation is a challenge largely due to the following key barriers:

Invisibility of benefits: The full-value proposition for high efficiency is still unfamiliar or undefined for many stakeholders such as owners, builders, investors, and policymakers. In the absence of convincing cost and performance data, the sector defaults to past practices.

The benefits of energy-efficient practices and solutions can be difficult to attribute and not easily evident. For instance, lack of appropriate valuation of a building's energy or thermal performance is common, because awareness and institutional and data frameworks may be immature. Therefore, the market does not recognise, and is not primed to pay a premium for, a high-performance building, contributing to lack of demand. Unavailability of reliable normalised data to validate cost savings and other benefits reinforces the broad indifference to efficient solutions in general — in building construction, operations, or appliances — contributing to a systemic lack of demand for efficient buildings. Consistent and robust data and information channels to reach different stakeholders remain weak. As a result, growth in the buildings sector is notoriously slow.

Financial barriers: Financial barriers manifest in several ways. It is often assumed that efficient new buildings and equipment come at a cost premium, although integrative design and systems thinking can tunnel through would-be additional costs. Legitimate cost premiums warrant quantified scrutiny to further understand and explore solutions through cost compression. However, in the simplest sense, efficiency retrofits, equipment replacement, and renewable energy investments generally require capital outlay. Although some segments of the population have access to cash or low-cost financing, low-income populations have extremely limited buying or borrowing power, regardless of the potential cost payback from energy savings or non-energy ancillary benefits.

Limited financial means skew decisions away from efficient options that typically have a higher first cost but lower life-cycle cost due to contraction in operating costs. This indicates an underlying market characteristic — first-cost bias — where the decisions made by those specifying and procuring infrastructure, buildings, materials, and appliances are typically made with a focus on the first cost. This bias is reinforced by insufficient awareness or transparency of the broad benefits of efficient solutions, no clarity or understanding of their low life-cycle costs, or general lack of awareness of the available options and their applicability.

In other cases, a split incentive may exist between a landlord who develops and/or owns the assets and a tenant who would benefit from energy improvements. Capital access and split incentive barriers also exist in the societal energy system with regard to financial interest of discoms, or lack thereof, in demand-side investments. Moreover, mechanisms fail to appropriately align costs with the ultimate beneficiaries across many applications and scales.

Dearth of financial resources also poses a challenge for government initiatives towards buildings sector efficiency, where transformative policies may not manifest full benefits due to lack of access to funding for appropriate administration. Additionally, the absence of fit-for-purpose financing can hinder developers, facility owners, and consumers from opting for the usually higher first-cost energy-efficient buildings or efficient equipment (reinforcing the first-cost bias).

Limited capacities: Even when robust policies exist, they may face implementation and enforcement challenges due to inadequate institutional capacities and skills. The effectiveness of policies — concerning mandatory actions and requirements in particular — depends on the capacity and ability of authorities to enforce them (e.g., enforcement of building codes). It is essential to expand training and capacity-building for state and municipal authorities and critical institutions and to supplement them with effective frameworks for monitoring and evaluation.

Market actors also struggle with lack of capacities. Parallel measures to encourage technical capacity within trade institutions, such as the construction industry, heating, ventilation, and air conditioning (HVAC) service sector, and informal building sector, are important for the appropriate delivery and adoption of efficient solutions.

Complexity of the sector and the solutions: The buildings sector is innately complex, comprising countless small, medium, and large enterprises. The diverse range of solutions to address buildings sector efficiency (e.g., urban planning strategies, passive building design and construction, simple appliances, complex cooling systems, and building automation and controls) and their interplay add significant complexity to selecting the best-fit solutions. Moreover, these solutions apply at different scales — from an individual room or building to a district or city — and their implementation can range from individual decisions to municipal models. The decisions that determine the energy footprint of a building are typically influenced by, or involve the collaboration of, a range of tradespeople; suppliers; manufacturers; professionals in real estate, finance, design, and construction; and end-users. Creating shared prerogatives among sector stakeholders is challenging; they may lack knowledge of the appropriate applicability of the available solutions. As a result, their decision-making (limited to what they know) often defaults to the lowest first cost.

Fragmented approach: Policies and programmes have made great strides but must continue to evolve to help India realise its ambitious goals announced at COP26. Commendable programmes and regulations have been implemented across national ministries and state and local jurisdictions with the support of various nongovernmental entities and foreign aid sources. While discrete initiatives and measures have proved beneficial in the past, going forward, accelerating the pace and ambition of the energy transition will require overarching coordination and synergistic action towards a shared goal such that the whole is much greater than the sum of parts.

A key challenge is coordination. Just as the buildings sector has diverse components, so does its governance — involving multiple ministries and state and local government entities. These, along with multiple stakeholders such as discoms, buildings sector professionals, technology providers, financial institutions, and market actors, must collaborate, leverage synergies, and act cohesively to meet the ambitious goals ahead. An underlying challenge is public support, which can be particularly difficult to gain when the solutions are diverse and complex, with benefits that are real but nuanced, delayed, or even invisible to the layperson.

II. The Whole-System Vision

Pathway to address the barriers

Effectively countering these barriers requires a multipronged approach that: combines regulatory and market instruments to spur demand as well as supply; addresses embodied energy and operational energy across the building life cycle; and synergises action across multiple stakeholder groups to the fullest extent possible. To facilitate this, India's building sector must adopt an integrative whole-system approach to energy transition. This approach calls for the following core steps that should be applied collectively:

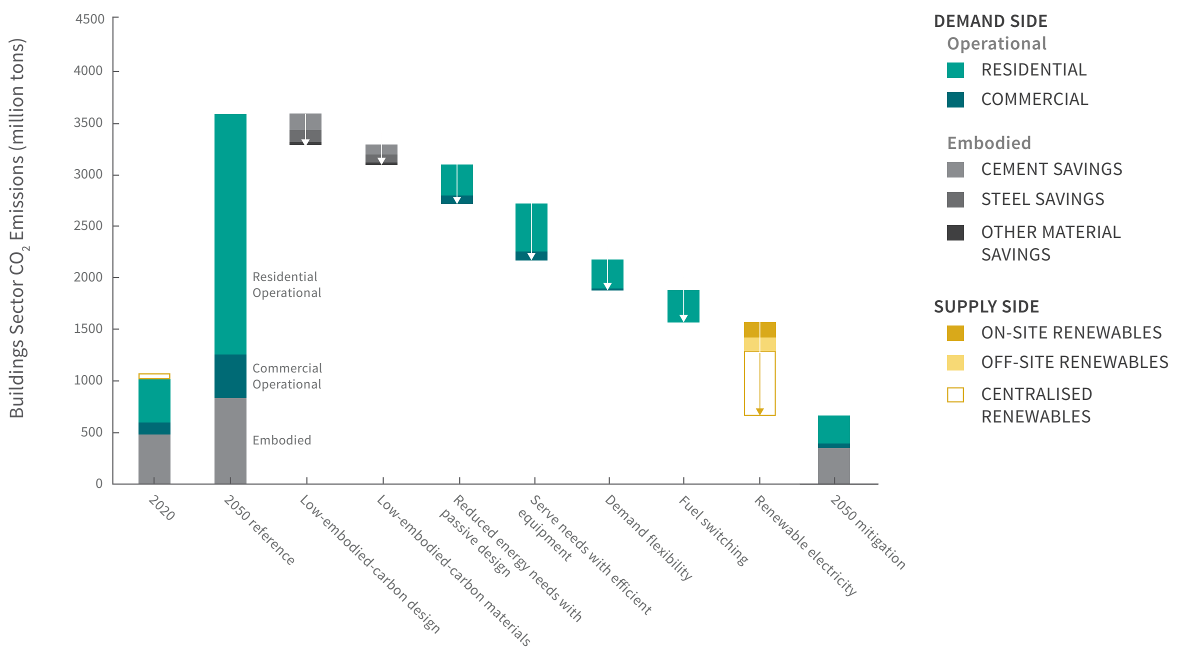
- **Address embodied energy and carbon in the buildings sector**. Low-embodied-carbon design and construction practices as well as low-carbon-material production should become the norm to reduce the oft-overlooked embodied carbon in the building sector.

- **Address operational energy and carbon through sequential strategies**. While each of the following three strategies is important on its own, the right sequence is key because reducing and managing the demand before providing supply will lead to the goal most cost-effectively.
  - First, reduce building-energy needs through climate-responsive, passive, and energy-efficient building design in new and existing buildings.
  - Then, serve the energy needs as efficiently as possible, with appropriate and efficient equipment and smart building systems.
  - Finally, optimise and clean the energy supply, leveraging demand flexibility, fuel switching, and clean-energy procurement.

This is delivered in a holistic and integrated sequence of actions within the buildings sector sphere of influence, with cascading benefits that unlock a significant total outcome, resulting in the technical potential to trim energy and carbon by more than half by 2050. Coupled with discom-led supply decarbonisation — now with buildings sector demand for renewable generation reduced to half — this puts the buildings sector on a path to net zero (see Exhibit 10).

Exhibit 10 Buildings sector technical potential for 2050 carbon reduction

Buildings Sector Waterfall Diagram

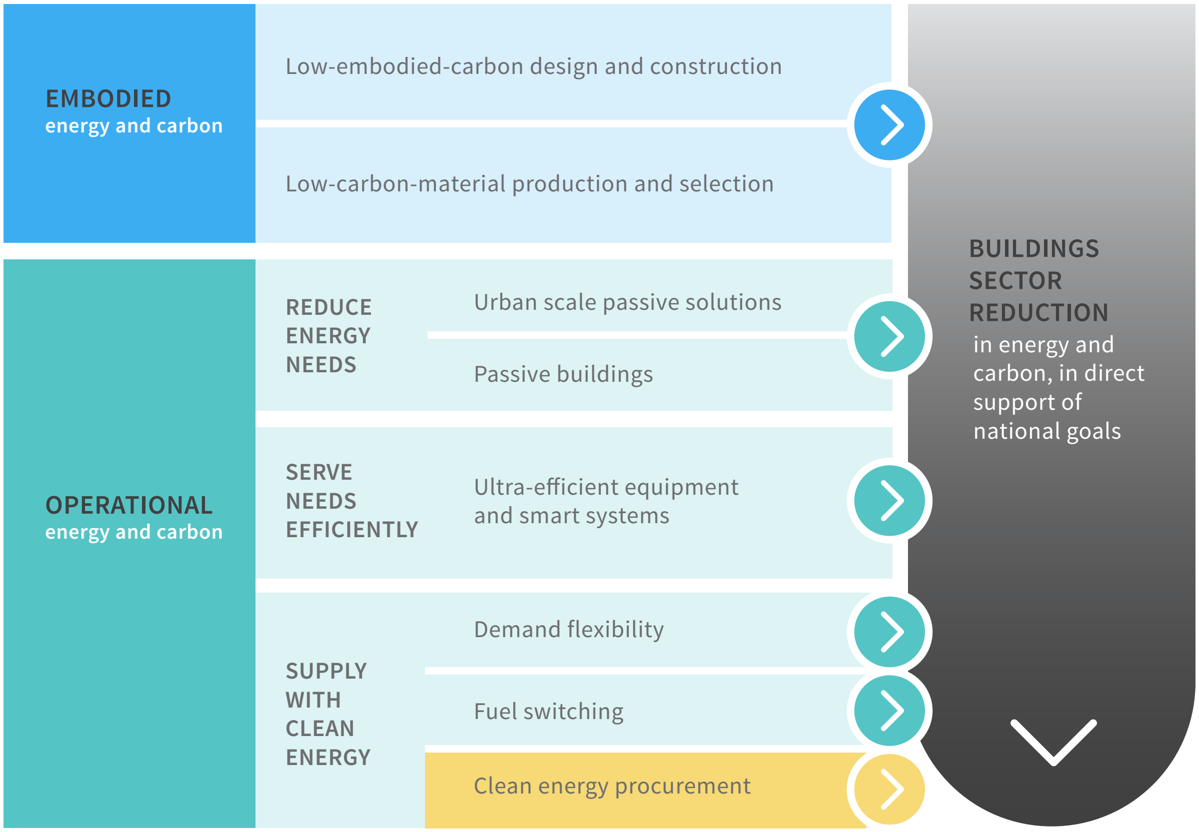


Source: Lawrence Berkeley National Laboratory, RMI Analysis

Motivated individual actors can implement these technical solutions, and in fact, many of these were identified by speaking with leaders active on these topics. However, the sector-wide transition can move more quickly and comprehensively, aided by whole-system accelerators to jump-start and scale, as laid out in Exhibit 11, next page. Some of these accelerators are aimed at advancing specific technical solutions, while others have a crosscutting impact across multiple end uses. Some are leadership collaboratives to “raise the ceiling,” wherein targets are adopted first by government agencies, corporations, finance, and discom planners. Others are statutory mechanisms to “raise the floor” for all, wherein targets are subsequently adopted by a statute within codes and standards by central, state, and local government authorities.

Exhibit 11

Buildings sector whole-system transition: Technical solutions, accelerators, and targets



These accelerators require extensive collaboration with various buildings sector actors, but government policymakers and task forces at the national, state, and local levels can play crucial leadership roles to catalyse the transition by initiating high-impact market accelerators and conducting the symphony to its measurable outcome.

Conduct the symphony

Achieving India's ambitious goals announced at COP26 requires deliberate calibration of sector and subsector goals. The government can lead this by structuring, calibrating, and tracking the whole-system components. The elements of the transition are intertwined and support each other, ensuring maximum potential contribution of the buildings sector towards national, economy-wide energy, and climate goals. However, it must also be built with discreet, measurable, and time bound sub-elements, with accountable parties and deliberate coordination. The two tenets of RMI's Factor 10 Engineering Design Principles are "use measured data and explicit analysis, not assumptions and rules" and "include feedback in the design." Adopting empirical, quantified targets will mobilise action, focus innovation, and create rapid feedback loops to ensure success. These principles apply across scales, from designing products and buildings to managing the sector-wide energy transition.

They are particularly relevant in the face of an energy and climate resilience emergency, where prioritisation and accountability are paramount to achieving accelerated and cost-effective results. The stepwise components of Exhibit 10, previous page, represent macroeconomic technical potential, which can be translated to actionable, trackable parameters. Exhibit 11 illustrates a set of quantifiable targets that actuates a collectively exhaustive buildings sector transition. Targets can be categorised into technology subtargets and impact targets with a wide purview, which together make up the total buildings sector contribution towards national carbon reduction goals. The adoption of these metrics can serve as an intrinsic mechanism to coordinate and focus efforts across ministries and government agencies, each with important responsibilities within its jurisdiction. Adopting these metrics also gives direction to manufacturers, investors, designers, and solution providers who implement the transition on the ground.

A comprehensive and specific target roadmap serves another crucial function that unlocks whole-system benefits. It, in effect, creates a nationwide, targeted market transformation programme, allowing intrinsic coordination across incentive, rebate, tax credit, and finance programmes crucial to scaling emerging products and solutions in the marketplace. The roadmap focuses on finance across levels and applications, from the largest banks to microfinance services. It pools the efforts of myriad levels of the government and can tie to discom regulations and programmes that capitalise on reliable demand-side reductions for incorporation within energy supply-side integrated resource planning. Together, this can realise widespread energy prosperity amid India's unprecedented growth and leadership moment in a post-carbon global economy.

III. Whole-System, High-Impact Technical Solutions

This section details specific, high-impact solutions that show promise within each of the technical categories. The highlighted solutions are not meant to be an exhaustive documentation of all elements of technical potential described above. This report should complement important technology, programme, and policy work underway across many of the current focus areas, such as those described above. It highlights solutions that ensure the following:

- Fill a gap and are not already happening at scale.
- Address the current specific needs such as urbanisation or broadening the reach of energy benefits.
- Influence the population with substantial socioeconomic and environmental benefits.
- Are highly actionable in the near term, capitalising on enabling conditions or overcoming barriers.

The solutions highlighted here are a result of decades of global research and collaboration with interdisciplinary thought leaders. Within this priority set is an emphasis on whole-system thinking and integrative design, often returning to fundamental principles such as those enumerated in *RMI's Factor 10 Engineering Design Principles* and realising that the whole is greater than the sum of its parts.[5]

Exhibit 12 **High-impact technical solution details**

MINIMISE EMBODIED ENERGY AND EMISSIONS		
1	Low-Embodied-Carbon Design and Construction	• The current embodied carbon emissions from construction are approximately of the same magnitude as building operational carbon emissions. The buildings sector has a crucial demand-side role in driving embodied carbon savings. • Consider the capital cost savings associated with material-efficient design. • Rightsize the quantity of construction through careful building programming. • Reuse structures and materials where possible. • Integrative design can improve performance with few materials and reduced costs. • Modular and premanufactured systems can minimise waste and speed up construction while improving quality. • Design for end-of-life deconstruction, cradle-to-cradle material life cycle, and a circular economy.
2	Low-Carbon-Material Production and Selection	• Low-carbon options exist for key material types such as concrete, steel, brick and other wall constructions, and insulation (see Exhibit 15, page 40, for a sample). • Environmental Product Declarations (EPDs) by manufacturers and suppliers, fed into open databases and accounting tools, will be a crucial data foundation for scaling demand for low-carbon materials.
MINIMISE ENERGY AND EMISSIONS FROM BUILDING OPERATIONS		
Reduce energy needs in buildings		

3	Urban-Scale Passive Solutions	• Jurisdictions should incorporate heat-minimising and heat-resilience requirements into urban planning and building requirements, reducing urban temperatures while improving resilience, cooling equity, and energy costs. Take immediate, no-regrets solutions:
		  ◦ Enabling policies/mandates in place: stringent codes, procurement standards, etc.
		  ◦ Immediate programmes: cool roof programmes, shading, green cover, etc.
		• Where feasible, aggregate new cooling demand through district cooling systems.

4	Integrative, Passive Building Design	• Passive building strategies can make occupants feel 10°C to 20°C cooler, reducing or eliminating the need for mechanical cooling, while increasing resilience and reducing energy-supply strains.
		• Integrative design of high-performance buildings can reduce first costs by "tunnelling through the cost barrier."
		• Indigenous techniques and materials provide a pathway for beneficiary-led and informal housing sectors.
		• The professional sector needs:
		  • Knowledge base of case studies and costs and benefits of passive, integrative design.
		  • Tools and trainings to shift towards performance-based design.
		• The beneficiary-led sector needs distinct technology, workforce, and market development efforts.

Serve energy needs as efficiently as possible		

5	Super-Efficient Cooling Equipment	• The Global Cooling Prize demonstrated technologies with five times (5X) less climate impact than traditional RACs. These can reduce India's peak electricity by 400 GW in 2050. Scaling advanced 5X-efficient RACs requires the following:
		  • Rewriting rating test standards to account for the full range of cooling, including humidity.
		  • Collaboration with manufacturers to accelerate the transition to leapfrog efficiency.
		  • Bulk purchasing and other market transformation initiatives.
		  • Mass-market awareness of personal and societal benefits.
		• Fans remain the first cooling access for much of India, in low-income and weak-grid-connected communities, and will remain the largest contributor to residential energy demand. Scaling high-efficiency fans has the following requirements:
		  • Revising fan ratings such that the current five-star rating becomes the minimum one-star rating.
		  • Strategies to spur demand, building on examples of procurement policies, financing, and incentives.
		  • Communications tailored to specific target groups (e.g., low-income, institutional buyers).

6	Other Appliances, Equipment, and Control Systems	• Residential: ◦ Residential energy use is spread across many appliances, with cooling, cooking, and water heating using the most energy. Furthermore, efficiency advancements are needed across all. ◦ Advancing equipment efficiency requires a long-term roadmap for MEPS to stay coordinated with market development programmes, for example, replicating the success of EESL's LED programme and supporting manufacturers. ◦ Solar water heaters and heat pump water heaters use next-generation technology, with leapfrog potential and a history of success elsewhere. ◦ Home energy visibility and automation offer exciting opportunities to drive behavioural change and identify high-priority efficiency opportunities for homeowners and programme designers. • Commercial: ◦ Building controls and automation are low-cost, high-impact opportunities for efficiency improvements by optimising system turndown controls and implementing other new controls integration or smart solutions. ◦ Codes and rating systems can emphasise or require building controls and automation, commissioning (Cx), and retro-commissioning (RCx).
Optimise Clean Energy Supply		
7	Demand Flexibility	• Demand flexibility drives clean energy by shifting energy demand when RE power is higher in the generation mix, reducing renewable curtailment and improving the economics of incremental renewables. It can also benefit customers and discoms in terms of cost and resilience. • There is a wide range of flexibility across residential appliances, commercial systems, electric vehicle charging, and energy storage (see Exhibits 27 and 28, page 73). • Demand flexibility adoption can be accelerated by developing the following: ◦ Standards and communication protocols across a range of products. ◦ Value potential studies and implementation toolkits for specific customer segments. ◦ Variable rates, incentives, and other signals tailored to drive specific demand flexibility by customers.

8	Fuel Switching	• Fossil fuels for cooking and water heating make up about a quarter of urban residential energy consumption and most of the rural residential energy. The magnitude and health implications mean no crucial target of clean-energy planning should be disregarded. • Cooking fuel infrastructure strategy should be co-optimised for resilience, health, financial risk mitigation, and environmental considerations. • This requires expanding the availability and public awareness of the latest clean cooking and water heating technologies — plug-in induction stoves, solar water heaters, heat pump water heaters —and understanding the applications and limitations of clean hydrogen and renewable biofuels.

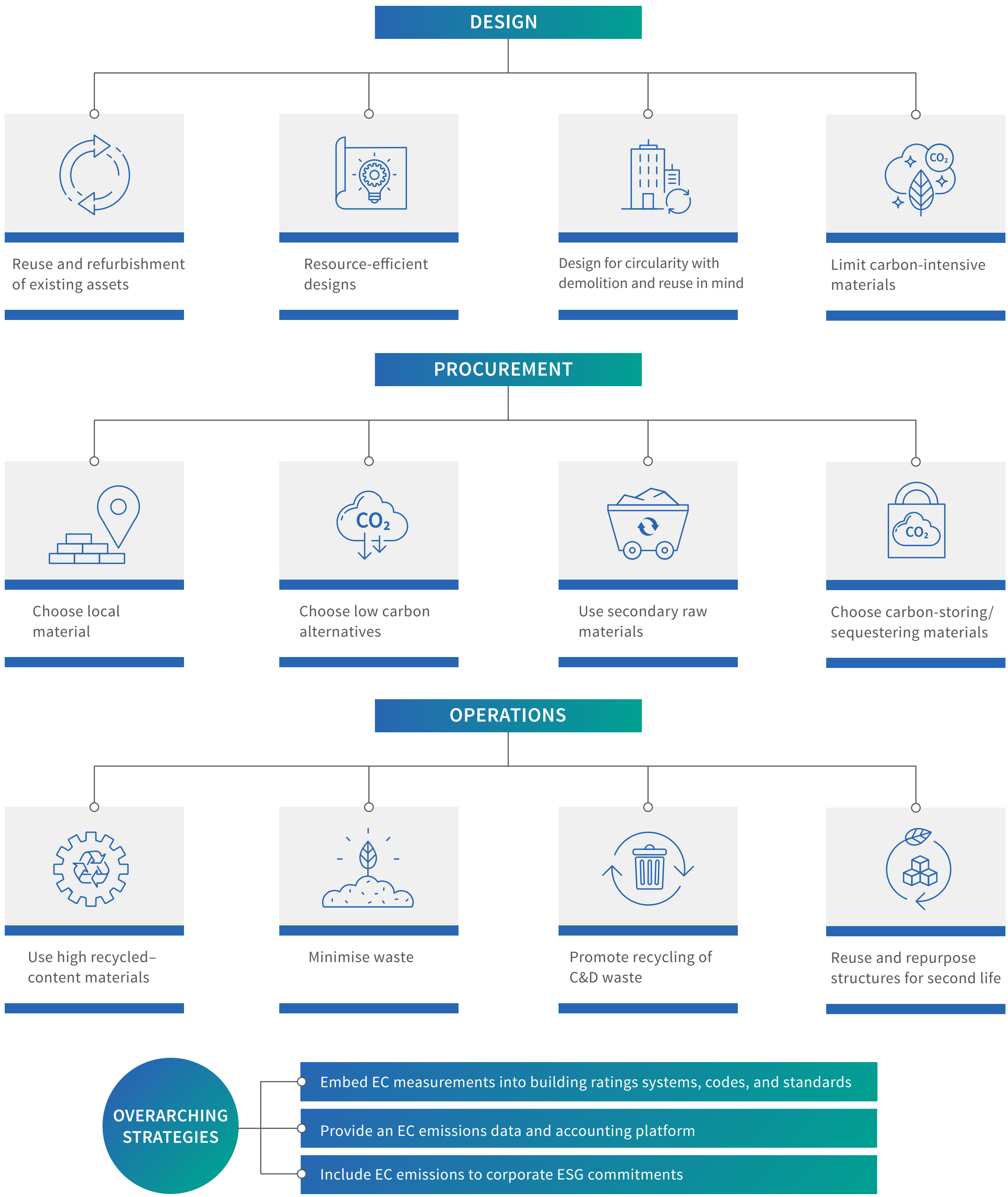
9	Clean Energy Procurement	• The buildings sector can play a key demand-side role in advancing India's national RE goals.
		• Renewable electricity procurement models exist for most, if not all, customer segments today, using the following combinations:
		  ◦ On-site versus off-site.
		  ◦ Owning versus contracting versus market mechanisms.
		  ◦ Green leases and integrated energy service provider models for tenants (see Exhibit 30, page 77).
		• A building renewables procurement coalition can ensure access for all customer segments and expand market awareness, supporting procurement pathways for maximum impact and additionality on the grid.
		• Mandating renewable energy usage for certain building categories such as government buildings can help aggregate demand for RE and further unlock economies of scale, resulting in significant savings for respective buildings.

Minimise Embodied Carbon Footprint

Over 40% of India's non biomass energy consumption and carbon emissions are embodied carbon (see Exhibit 5A, page 16; Exhibit 7A, page 18; and Exhibit 10, page 26). While India's buildings-related CO_2 emissions more than doubled between 2000 and 2017, these indirect embodied emissions almost tripled.[6] Over the next 20 years, India's total building space is projected to more than double and existing stock at its end of life (see Exhibit 4, page 15) will be replaced, meaning embodied carbon emissions will continue to increase drastically if not addressed urgently. As embodied emissions occur at the beginning of the building life cycle, they will be responsible for approximately half of the new construction emissions during the crucial window of India's urbanisation development and energy transformation and the global fight against climate change.[7]

Embodied carbon refers to the indirect emissions associated with procurement, manufacturing, construction use, and disposal of building materials over the life cycle of a building. The carbon reduction imperative does not rest solely on material producers. Buildings sector leaders can contribute through cost-effective low-embodied-carbon design decisions and material selection while playing a crucial role in driving the demand for upstream industrial supply chain transformation. A broad range of strategies can be adopted at various stages of project execution to reduce embodied carbon, as summarised in Exhibit 13, next page, and the following sections.

Exhibit 13 Building-sector strategies to reduce embodied carbon



1. Low-Embodied-Carbon Design and Construction

Start saving carbon at the beginning, or earlier

CONTEXT

- Embodied carbon is not yet addressed by energy codes and had barely entered the design process until recently, aside from qualitative material source considerations within some rating systems. It was notably absent during the early programming, planning, and conceptual design phases when the most impactful decisions are made (see Exhibit 14, page 38).
- India's buildings sector emits nearly 500 million metric tons of carbon dioxide (CO_2) in embodied carbon annually, a rate that if unabated could nearly double amid the growing urbanisation (see Exhibit 10, page 25).
- Certain solutions can rapidly lower embodied emissions up to 50% with marginal capital investment.
- This can be achieved if careful predesign and design considerations that optimise material usage and design with low-carbon materials become the norm.

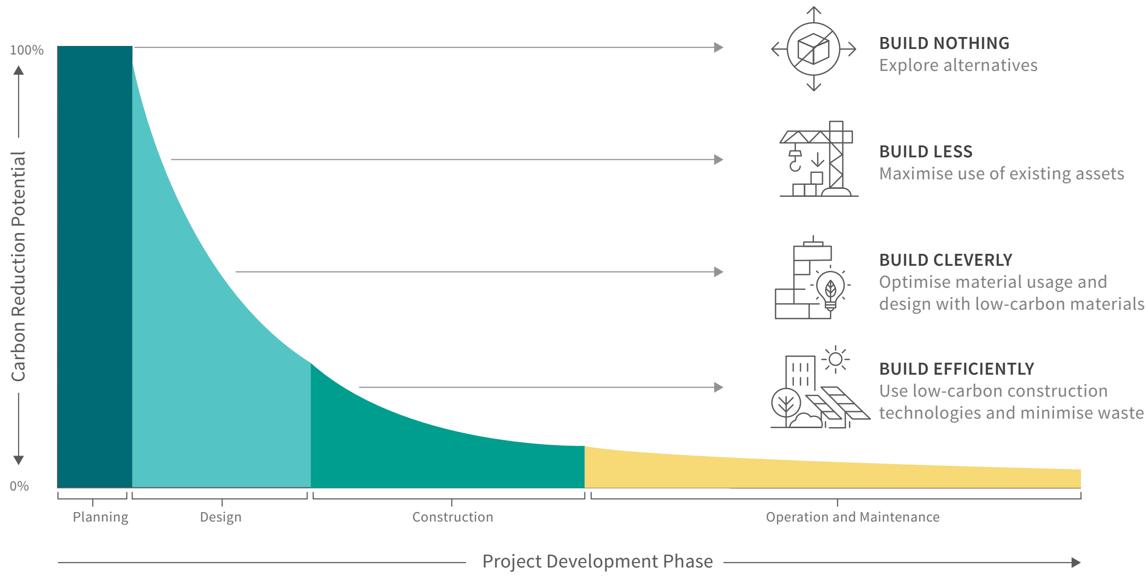
SOLUTION

Design and real estate planning professionals can begin by considering key questions and concepts:

- **Testing the program:** How does the proposed project most efficiently meet the programme needs? Do we need additional space to accommodate the uses? Can the uses be shared with other programme needs? For example, an office building that uses parking during the day could share parking with restaurant or cultural facilities that need parking at night.
- **Consider existing resources:** Can existing buildings be reused to accommodate this need? Is it possible to renovate or add to an existing structure rather than start from scratch? Optimise existing resources and urban design. Repurpose, infill, densify, and upgrade urban areas and existing buildings instead of constructing new infrastructure. Can the use be "colocated" to make better use of existing infrastructure and amenities?
- **Challenge design assumptions:** How can the programme be built with a few materials? Are there structural efficiencies to consider? Are there local or low-embodied-carbon materials that could be used? Use local, traditional, agricultural, and recycled materials when available, and design buildings for deconstruction. The design can be adjusted to reuse the material salvaged after another project is disassembled.

Exhibit 14

Embodied carbon–reduction potential at each stage of construction



Source: Adapted from HM Treasury, *Infrastructure Carbon Review*

These approaches can result in exciting architectural solutions, which are cost-effective and significantly reduce the impact of embodied carbon, to meet programme needs. Several studies show the careful specification of materials may result in embodied carbon reduction of 30–50% with a 1% or less impact on cost, using widely available material.[8] Optimising ready-mix concrete design, sourcing rebar and structural steel with high recycled content, choosing glazing products and finish materials with low-embodied-carbon footprint, and considering low-embodied-carbon or carbon-sequestering insulation options are the most impactful no-cost measures to reduce embodied carbon. Reduction in material quantities and use of more regional resources also lead to potential cost savings.

Integrated design and optimisation of structural systems can also reduce the use of materials. For example, a more efficient building envelope will need less mechanical space and allow for more usable space with a few materials needed for construction (see 4. Integrative, Passive Building Design section case studies). Small mechanical equipment will also reduce the associated cost and embodied carbon. Modular and premanufactured materials, components, and assemblies can be produced off-site with little to no waste and assembled on-site efficiently, with ancillary benefits of tight quality control, reduced call-backs, fast on-site construction, and simplified staging.

As designers get facile with the opportunities provided by low-embodied-carbon design, there is significant economic opportunity to be gleaned. Economic benefits may manifest in the types and skills of jobs created, in the production and manufacture of new and better materials, and in the increased demand for designers who can deliver low-embodied-carbon projects.

The economics of low-embodied carbon will also encourage increased recycling, supporting resource-efficiency policy efforts underway in India around construction-and-demolition waste management, recycled content in procurement, and scrap recycling. Advanced strategies move towards cradle-to-cradle design and certifications and, ultimately, the end goal of a circular economy.[9]

In the professional sector, the efficacy of these strategies can be demonstrated through built pilot projects, which can then influence standards by design professionals and portfolios. In the beneficiary-led sector, creative design and programming are needed to catalyse localised, indigenous solutions with low cost, ease of construction, improved quality of life, and adaptability while inherently lowering embodied carbon as an ancillary benefit.

NEXT STEPS

Targeted Accelerator: Embodied-carbon design force accelerator.

Who: *Developers, designers, builders, government task force supported by NGOs.*

Developers, designers, and builders adopt low-embodied-carbon design strategies within their practices:

- Rightsize the quantity of construction and the amount of materials required to build.
- Reduce the impact of building materials through careful consideration of programmatic and design decisions. Do not repeat what was done last time. Education can help people build better.
- Make the case for profitable low-embodied-carbon construction through integrative design to improve performance with few materials and reduced costs.

The most promising near-term scaling mechanisms may be a targeted, government-sponsored initiative such as a workforce and market development design accelerator. This would help real estate, design, and construction stakeholders collaborate on awareness, tools, trainings, resources, and ratings towards deliberate outcomes of quantifiable, voluntary embodied carbon reductions at the leading edge.

Currently, there is no clear place to codify low-embodied-carbon design techniques and construction practices by statute or a single leadership authority to proactively drive it. Overarching low-embodied-carbon goals may be captured in corporate and government agency commitments and, ultimately, in embodied carbon elements of building codes or mandates.

2. Low-Carbon Material Production and Selection

Demand for a clean supply chain

CONTEXT

The manufacturing of building materials is a resource- and energy-intensive process. Estimates suggest that 40–50% of the resources extracted across the world for materials are used for housing, construction, and infrastructure.[10] Approximately 10% of India's total energy demand comes from the building materials-manufacturing industries.[11]

Buildings sector embodied energy and carbon are dominated by concrete, steel, and bricks, and India is the second-largest producer of these materials in the world. Reinforced concrete and steel frames underpin most of the construction in India's buildings today — around 60 million tonnes of cement and 14 million tonnes of steel were consumed for urban construction in 2020.[12] Building construction is the largest driver (accounting for 78%) of cement production in India.[13] In the case of steel, building and infrastructure construction represents 40% of India's steel consumption.[14] The country's urbanisation rate is expected to rise to 40% by 2030–31, and this massive urban transition underpins the rapid consumption of energy-intensive materials such as steel and cement:[15]

- **Steel —** In the next 30 years, India's steel demand is estimated to more than quadruple, from around 111 million tonnes to 489 million tonnes, and the corresponding CO_2e emissions are projected to rise from around 300 million tonnes to 837 million tonnes.[16]

- **Bricks —** In the next 20 years, India's brick demand is projected to increase three to four times and reach 750 billion to 1 trillion bricks per year.[17] Brick kilns are responsible for about 66 million tonnes of CO_2e emissions and other harmful carbon monoxide, sulphur dioxide, nitrogen oxide, and particulate matter emissions across the country.[18]

- **Cement —** India produced 337 million tonnes of cement in 2019, corresponding to around 250 million tonnes of CO_2e emissions.[19] This could increase three to six times by 2050. At the same time, the Indian cement industry aims to achieve a 45% reduction in emissions intensity by 2050 from its 2010 levels.[20]

  In cement production, about 40% of the emissions come from burning fossil fuels to heat kilns to high temperatures needed for the calcination process to produce clinker, an intermediary component of cement. Around 50–60% of the CO_2 emissions result from a chemical reaction (calcination) during clinker production.[10] Since these emissions are released by a chemical reaction, they cannot be reduced or eliminated by changing fuels or with energy-efficiency improvements but by other strategies such as optimising and reducing the quantity of concrete, using clinker-free alternatives to cement, and introducing supplementary cementitious materials (SCMs) such as fly ash and slag in the concrete mix.

Reduction of embodied carbon in materials has just begun to take shape in India as in the entire world. The industrial infrastructure required to build a growing, urban India is an opportunity to invest in globally leading practices and technologies that represent a competitive edge, rather than stranded asset risks. However, this opportunity can be availed by overcoming the following real challenges:

- Emerging low-carbon material production technologies, even where ultimately cost-effective, must be financed, grow, and compete for market share amid incumbent competitors at scale.

- Consumer awareness of and demand for lower-carbon-material alternatives are still relatively low. Energy codes and standards do not currently mandate embodied-carbon reductions.

- The informal and beneficiary-led sector represents the largest share of construction activity and is highly fragmented and diverse, presenting additional major challenges to knowledge dissemination and centralised market-transformation programmes.

- Some material alternatives require technical adaptation. For example, alternative concrete mixtures may increase the curing time to achieve design strength, necessitating strength monitoring sensors to subsequently optimise construction timelines.

SOLUTIONS

Discussions on embodied carbon in materials often focus upstream on the industrial supply chain. While not detailed in depth in this report, a sample of decarbonisation strategies and technologies for adoption by specific material industries is included in Exhibit 15, and more industry-focused sources of information are available in *Annexure 2: Additional Resources*. Low-carbon options exist within virtually every material category, and rapid innovation is expected in the coming years. Carbon Leadership Forum's recent study on carbon-storing materials shows a 60% reduction in embodied carbon is possible in two to three years by bringing readily available low-carbon materials into wide use across the globe.[21] A recent RMI report showed reductions of 30–50% in embodied carbon are possible with a 1% or less impact on cost.[10]

Exhibit 15 **Sample of solutions to reduce carbon emissions upstream in material supply chains**

BUILDING MATERIALS	SOLUTIONS FROM TODAY'S BEST PRACTICES			
	NEAR TERM	MID TERM	LONG TERM	OTHER COMMENTS
Concrete	• Reduce emissions from process heat by retrofitting existing kilns with efficiency upgrades. • Embrace a circular economy. • Increase collection, segregation, and usage of construction and demolition waste.	• Use SCMs from nonfossil fuel sources such as glass pozzolan and rice husk. • Test high concentration of SCM in concrete and clinker substitutes.	• Decarbonise kiln technology by using alternative fuels for the heating process during the production of clinker for ordinary Portland cement. • Make concrete a net-carbon sink through: • CO_2-injected cement products	New business models may emerge, not selling by the tonne, but rather leasing the structural service.

	• Mix it up — optimise concrete mixes and constituents. • Increase the connectivity between SCMs and concrete manufacturers. • Reevaluate the existing prescriptive specification set on SCM content limitations in codes and standards with performance-oriented specifications. • Facilitate transportation, enhance availability of quality SCMs, and improve their connection with cement manufacturers. • Reduce emissions from process heat through the use of alternative fuels. Alternative fuels already demonstrated today in India include rice husk, coffee husk, nut shells, tire chips, rubber dust, pet coke, coal dust, processed municipal solid waste, pharmaceutical waste, excess grease and lubricating oil, saw dust, and animal waste.	• Assuage safety concerns on the strength of blended products through real-time validation and on-site monitoring by using affordable, off-the-shelf sensors. • Recycle concrete for aggregate. • Waste heat recovery using processes implemented in multiple plants in Andhra Pradesh and Rajasthan.	• CO_2-sequestered curing or aggregates Examples of companies working on this: CarbonCure, Solidia, Blue Planet, Carbicrete, Biomasons, Carbon Engineering, Svante. • Use solar-heated cement kilns. • Use carbon capture and storage. • Recycle cement. • Use cement with electrical conductivity. • tore excess renewable electricity to generate high temperatures. Example of a company working on this: Rondo.	
Steel	• Maximise energy efficiency. • Reduce the usage of virgin steel through reuse and recycling. • Accelerate the growth of scrap-based production. • Facilitate greater resource efficiency. • Use electric-arc furnaces instead of blast furnaces.	• Adopt Hisarna technology. • Use molten oxide electrolysis or green hydrogen to produce steel.	Explore flash iron making technology.	The existing fleet of highly polluting iron-ore blast furnaces needs to be upgraded to electric-arc furnaces, which will be essentially as clean as their decarbonising energy source.

Wall material	• Use solid burnt-clay bricks fired in cleaner kilns. • Use prefabricated straw bale wall panels. • Use magnesium oxide wall boards.	• Use solid burnt-clay bricks fired in cleaner kilns. • Use perforated and hollow burnt-clay bricks, autoclaved aerated concrete blocks, cellular lightweight concrete blocks, pulverised fuel ash-cement, or lime bricks.	• Use bamboo lumber products.	
Insulation	• Use plant-based insulation products. • Heed the emission intensity of various insulation products. Bio-based insulation generally has negative or very low emissions, lower than batt insulation, expanded polystyrene, or spray foam. Extruded polystyrene generally has the highest emissions.		• Explore carbon-sequestering insulation options.	Petrochemical-based insulation products (rigid or spray foam) have higher associated emissions than biological-based materials such as cellulose and cotton products.

Source: Adapted from Charles Cannon, Valentina Guido, and Lachlan Wright, *Concrete Solutions Guide: Actionable Solutions to Lower the Embodied Carbon of Concrete*, RMI, 2021, https://rmi.org/our-work/concrete-solutions-guide/; Amory B. Lovins, *Profitably Decarbonizing Heavy Transport and Industrial Heat: Transforming These "Harder-to-Abate" Sectors Is Not Uniquely Hard and Can Be Lucrative*, 2021, https://www.rmi.org/profitable-decarb/; and Mission Possible Partnership, RMI, and Energy Transitions Commission, 2021, *Net-Zero Steel Sector Transition Strategy.* *https://missionpossiblepartnership.org/wp-content/uploads/2021/10/MPP-Steel_Transition-Strategy*-Oct19-2021.pdf

NEXT STEPS

Targeted Accelerators: Embodied carbon design force accelerator, supply chain disclosures and targets.

Who: *Material manufacturers and suppliers, designers, building rating system administrators, code development officials, other government embodied carbon task forces, with NGO support.*

In parallel to the ongoing supply-side advancements, the buildings sector and its regulators play a crucial role in driving the demand for low-embodied-carbon materials in procurement processes. A diverse coalition of interrelated actors must take action to scale up the market for low-embodied-carbon materials through mandatory disclosures, industry carbon targets, and embodied carbon codes.

- **Manufacturers and suppliers** must develop and disclose EPDs that are the data foundation for a low-embodied-carbon transition. In addition to facilitating project lifecycle accounting, EPDs can also ultimately become the accounting tool to enforce progress towards zero-carbon policy goals, statutes, or codes.

- **Industry working groups** can develop protocols, databases, and tools to facilitate this accounting and disclosure process. A research partnership between RMI and SINAI Technologies is working to provide open-source primary data on emissions from complex industrial supply chains and improve carbon tracking and measurement for Scope 3 emissions of products.[24] Software to quantify life-cycle carbon accounting of materials must be readily available and easy to use, drawing on rigorous, open databases of vetted product data.

- **Designers** can then more easily include embodied carbon accounting in their design processes, identifying and specifying lower-carbon-material choices.

- **Building rating systems** can increase emphasis on embodied carbon via mandatory and elective rating components. This expands on the efforts of green building rating systems such as GRIHA, LEED, and IGBC to encourage the usage of sustainable building materials, waste material, and SCM in construction.[20]

- **Regulatory task forces** at the regional or national level can develop mandates and processes for the following:

  - Material carbon disclosures for building projects (e.g., as required in the US state of Colorado).

  - Decarbonisation of specific material production industries (e.g., as mandated for the concrete industry in the US state of California).

- More specific interventions such as usage of construction and demolition waste recycling products or other low-carbon alternatives in new construction.

- Code authorities can develop a roadmap to expand the purview of the energy code to include embodied carbon. Sustainability parameters such as embodied-energy and lifecycle assessment are not considered under current Indian building codes. However, the Energy Conservation Building Code for the Residential Sector mentions the embodied energy of building materials and structural systems will be considered in future revisions. Communicating codes and standards in simple language to ULBs and developers is fundamental to driving change.

- Governments at the sub-national or national level can adopt a "buy clean" preferential purchasing policy for government buildings and establish clear procurement guidelines and incentives to promote green products and sustainable construction practices by setting a threshold (x $kgCO_2/m^2$) for the carbon content of the materials used. The government can also encourage the disclosure of embodied carbon data of products listed on Government e-marketplace , the national public procurement platform {especially for products in high-priority sectors such as concrete, steel, glass, and aluminium). This will also aid in creating an India-specific embodied carbon database and drive the supply chain towards data transparency.

To jump-start the process, a government-led task force can convene stakeholders to develop an expedited and coordinated pathway to drive the market for low-embodied carbon materials. This pathway can begin with labelling the embodied energy and carbon content of widely used materials such as concrete, steel, glass, and aluminium, which would lay the ground work for clean procurement policies, voluntary carbon-reduction commitments by large public and private entities, and incorporation of embodied carbon reduction mandates into building codes for new construction. This is a leapfrog opportunity for India to be a world leader in developing capacities for manufacturing low-carbon materials and compete in the global supply chains.

Minimise Operational Energy and Carbon in Buildings

India is projected to more than double its built floor area by 2050 while replacing a substantial portion of its existing stock (see Exhibit 4, page 15). The decisions made by buildings sector leaders and practitioners today will have a lock-in effect for decades to come. Buildings constructed now must be designed to thrive across the national and global energy-system transformation, and ensure occupant well-being while addressing the strain of climate change.

Climate change will affect the less-resourced population the most, and solutions must be crafted to serve not only the better-resourced, professional-led sectors but also the broad and diverse beneficiary-led, informal construction sectors. India has the opportunity to build right the first time for all citizens, leapfrogging to a resilient and high-performance built environment while capitalising on integrative savings of energy and first costs.

Decarbonising operational energy and maximising value require broad-boundary, integrated-system thinking that jumps scales — building systems and equipment, and building city, and energy-supply infrastructure. The solutions can be classified into a holistic and integrated series of actions with cascading benefits:

Reduce energy needs. → Serve energy needs efficiently. → Supply with clean energy.

Reduce Energy Needs in Buildings

3. Solutions to Help Cities Beat the Heat

Holistic solutions to sustainably cool cities can improve urban resilience, equity, and quality of life in cities, while reducing overall societal cooling costs.

CONTEXT

- India is experiencing rapid urbanisation. By 2045, the rural–urban split will be 50–50 from roughly 67–33 today. The number of urban agglomerations comprising more than 1 million people is expected to double by 2035 from 40 in 2020.
- As India's cities experience rapid population increase, necessitating new development and land-use changes, the effect of urban heat islands is worsening. Combined with the impact of climate change, cities could get as much as 4°C warmer and be increasingly vulnerable to deadly heat waves.[25]
- In the absence of focused policy and market-based interventions, increasingly populous and hot urban environments drive the demand for mechanical cooling. This typically means vapor-compression-based air conditioners — a quick and localised fix for those who can afford it but one that comes with severe consequences. Emissions and anthropogenic heat from air conditioners perpetuate a vicious cycle wherein mechanical cooling further warms cities, necessitating even more cooling.

- In this context, the need for human thermal comfort — protecting populations from extreme heat in the urban environment — is emerging as a significant challenge. Existing inequity issues make the challenge even more complex, as the impact of excessive urban warming is placed disproportionately on those least likely to be able to afford or access thermal comfort.

SOLUTIONS

Proactively managing excess warming in India's rapidly urbanising cities by mitigating heat islands and adopting more climate-friendly cooling practices is critical to ensure equitable access to cooling and support crucial development goals without further warming the city environment. The following strategies will enable this:

- **Reducing heat at the urban scale,** through heat-resilient urban planning and infrastructure.

- **Reducing cooling needs in buildings**, through energy-efficient and thermally efficient buildings.

- **Serving cooling needs in buildings efficiently**, through efficient and best-fit cooling technologies and operations.

These strategies together have a powerful compounding effect and should be applied to the fullest extent possible to accelerate the shift to sustainable and cool cities. A range of actions and interventions can be undertaken within each of the three strategies, and the optimal combination of these actions will have to be carefully planned for each city's unique context.However, the following immediate actions will benefit most cities in their journey towards heat-resilience and sustainable cooling:

- **Cohesive planning for heat mitigation and adaptation that is well integrated with the city's development plans.** A macro-level cooling baseline assessment is foundational for any city as a starting point for holistic citywide action towards sustainable urban cooling.[26] While cities may or may not choose to develop a stand-alone cooling action plan, the key is to appropriately integrate considerations for thermal comfort and heat-resilience with the city's planning initiatives and climate actions. This would include actions such as, but not limited to, incorporating blue-green infrastructure into development plans; heat mapping to identify hotspots for targeted action; increasing green cover where possible, particularly in heat-vulnerable areas; and designing zoning and urban design strategies by taking urban heat mitigation and equitable access to cooling into account.

- **Undertaking immediate implementation of low-cost/no-cost urban interventions.** This refers to interventions that are cost-effective and relatively simple to implement in terms of requisite dependencies and have substantial environmental and social benefits.[27] Thus, these are recommended as no-regrets actions that should be taken immediately. Although enabling policies may be needed to make these interventions widespread, a city can realise immediate cooling benefits by leading actions and voluntary efforts. Exhibit 16, next page, includes typical examples of low-cost/no-cost urban cooling measures.

Exhibit 16 **Typical examples of low-cost urban cooling measures**

- Increase street tree coverage in high-priority areas.
- Add shading structures or devices in key public areas.
- Apply cool roofs to all city-owned buildings.
- Implement cool roof programs for heat-vulnerable communities.
- Use heat-reflective or permeable surfaces for pavements.
- Enforce low-climate-impact performance standards for all new city assets (or during regular maintenance and retrofit cycles).
- Identify and make available cooled spaces that are accessible to heat-vulnerable communities during heatwaves.
- Establish a heat alert system to notify the public of anticipated periods of heat.

Such measures bring immediate benefits and potential cobenefits for urban regions. For instance, a study estimates that increasing the albedo of roofs and pavements in all major hot cities of the world could provide a one-time offset of the warming effect of 44 gigatonnes (Gt) of emitted CO_2e,[28] (this offset is greater than one year's worth of the projected emission of 37 Gt of CO_2e worldwide by 2025). In addition, incorporating permeable surfaces in urban areas by increasing vegetation cover and using porous materials facilitates evaporative cooling and reduces the need for storm runoff infrastructure.

Undertaking preparatory measures to establish/ensure the authority to act when appropriate trigger points occur. Typically, cities will note reduction in trigger points within the following categories: planned new development or major redevelopment, introducing or initiating city planning processes, establishing new or updated codes or zoning requirements, evaluating or initiating major city infrastructure projects, and assessing city land acquisition or sale. These trigger points are logical catalysts for cost-effectively dovetailing specific urban cooling interventions such that they build on past and pending actions and pave the way for a sustainable urban cooling future.

Examples of preparatory measures that cities can take:

- Ensuring zoning and urban design strategies account for thermal comfort.
- Establishing the authority to apply covenants on land to be developed or redeveloped that lay down conditions beyond code and district cooling connection.
- Establishing procedures to trigger the evaluation of district cooling opportunities when cooling systems within large public facilities approach their end of life and replacements are being planned.
- Assessing and establishing procurement practices for transitioning to more sustainable cooling approaches in city assets.

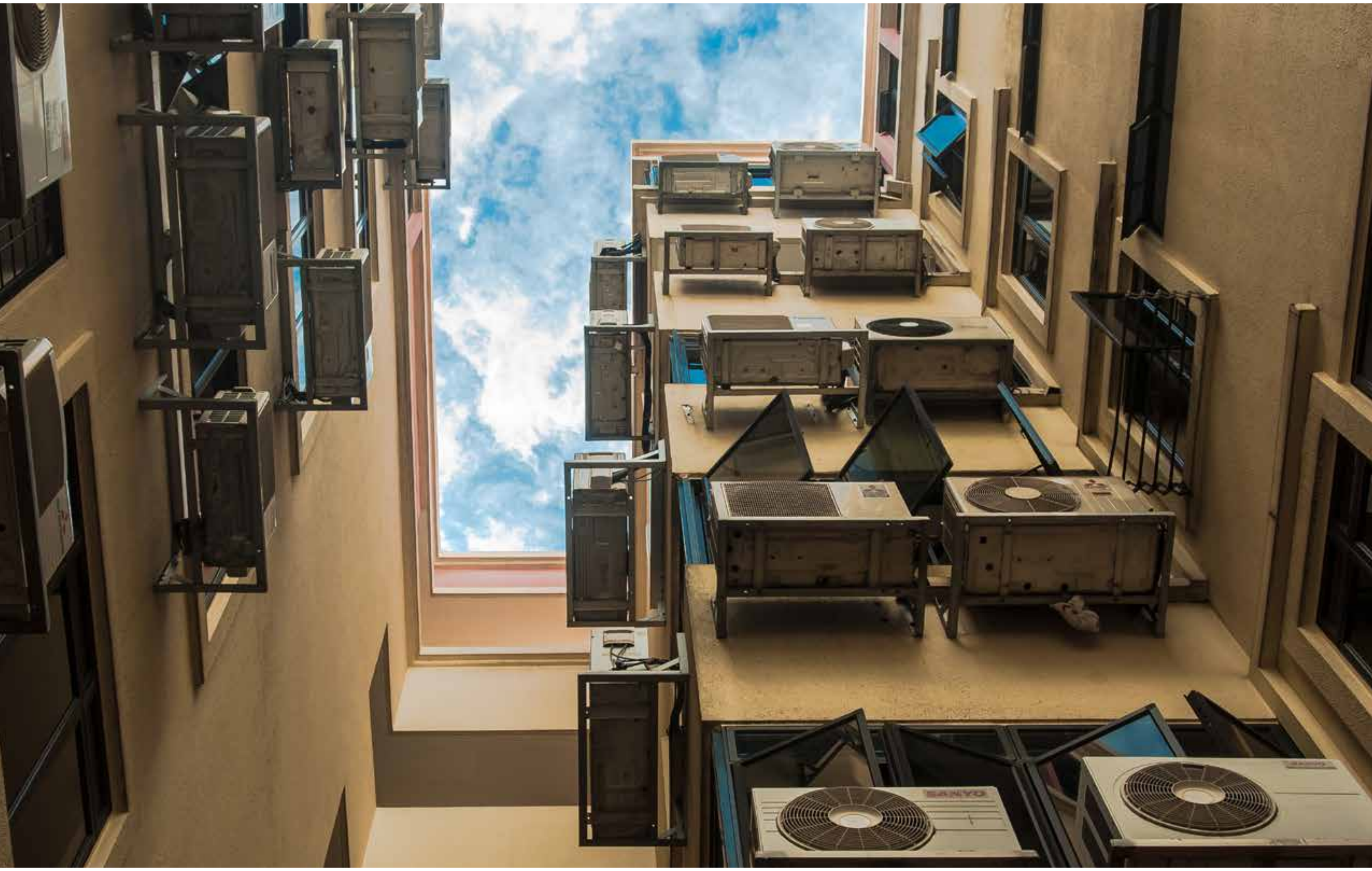
These foundational actions can help mitigate future heat challenges, which can be crucial to avoiding high costs, especially in low-capacity urban regions.

NEXT STEPS

Targeted Accelerators: City cooling planning (starting with baseline assessments).

Who: *City leaders and planners, government task force supported by NGOs.*

City-level cooling solutions have a unique scale and format of policy coordination and programme administration executed by city leadership. A national, targeted government-driven initiative, such as the Smart Cities Initiative by MoHUA, can create a launch pad to build awareness and prompt city cooling planning that incorporates crucial urban-scale, nature-based, and passive-design solutions. In parallel, capacity-building efforts supported by civil society organisations and multi/bilateral entities will be essential.



4. Integrative, Passive Building Design

Integrative, passive design can result in better quality, comfort, and energy performance at low capital cost.

CONTEXT

Over the next decade, India — arguably the world's most heat-stressed country with the most number of people consistently exposed to extreme heat risk beyond workability and survivability thresholds — will get much hotter. Left unchecked, this heat could expose up to 200 million people to lethal heatwaves in the 2030s, rob 2% of the gross domestic product (GDP) and 34 million jobs, and make it extremely difficult for 220 million people to escape poverty. With summer temperatures routinely soaring well above 37°C (100°F) and only 8% of the population having air conditioning, ensuring bearable living conditions for India's urban poor is vital to public health and well-being.

Discussions on expanded cooling access often focus solely on mechanical solutions such as RACs, air coolers, and fans. Commercial buildings tend to oversize and overcomplicate cooling plants and air-based distribution systems. In addition to massive cost hurdles for households and businesses, mechanical solutions alone fail to resolve issues such as cooling resilience in case of power outages; grid strain from increased peak demands; deadly air pollution from diesel generators to run RACs; and massive supply-side investment to meet increased peaks, particularly with new, intermittent, renewable-energy capacity.[29]

SOLUTIONS

Fortunately, passive building design strategies often bring full cooling comfort within reach using little or no mechanical cooling. Passively designed buildings better ride through poweroutages without compromising heat safety. From the grid-planning perspective, they inherently reduce peak demand and effectively shape and shift load in coordinated demand response to reduce grid strain.

There is a wealth of such passive cooling solutions across historic, Indigenous building techniques as well as modern integrative designs (see Appendix C: Examples of Passive, Integrative Design). These approaches are, to varying degrees, recommended or implied in rating systems (e.g., GRIHA, LEED, EDGE, IGBC, BEE star rating), policies (e.g., ICAP), and energy codes (ECBC, ENS). With the massive expansion of new construction looming, it is crucial for India's buildings sector leaders to accelerate efforts to realise the full potential of passive energy reduction and its compounding benefits to cost, resilience, and occupant well-being.

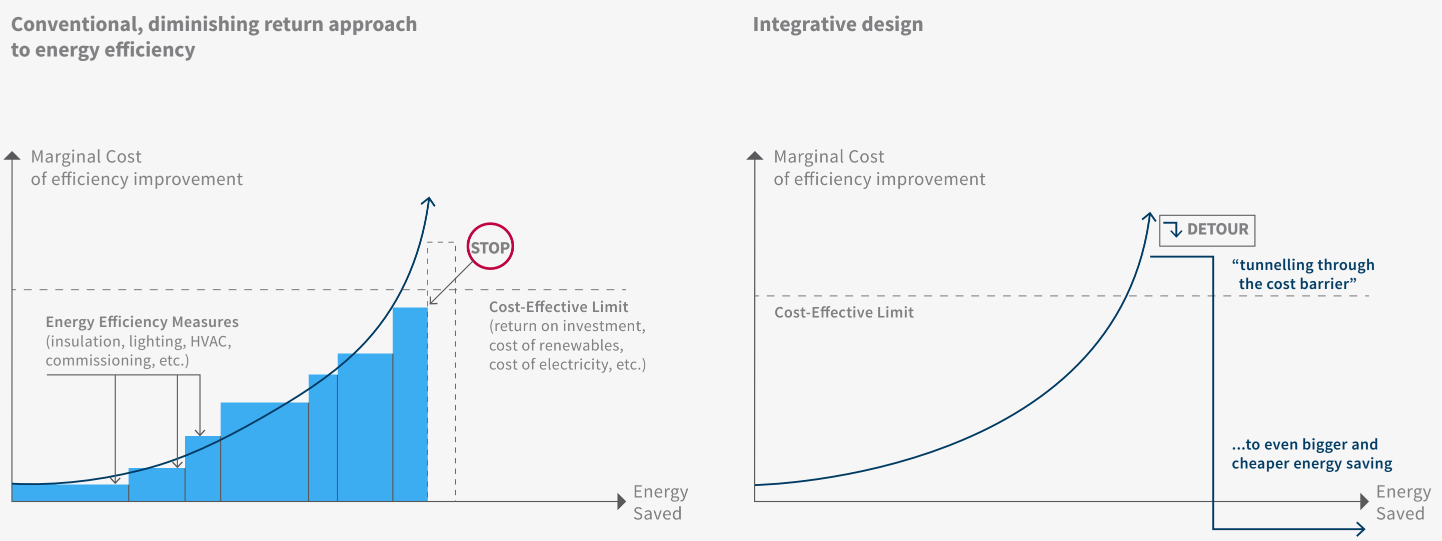
The following four initiative areas can achieve this:

Knowledge Base — While the energy savings brought about by integrative, passive design are fairly well known, it is the capital-cost savings and whole-system value proposition that can unlock mass adoption. Deeply energy-efficient buildings do not have to cost more. Conventional energy efficiency analysis measures such as insulation, lighting, or cooling equipment in isolation from one another, and they are rejected if their individual cost-effectiveness exceeds some threshold such as return on investment or alternative cost of electricity. An integrative, passive design approach pushes onward and “tunnels through the cost barrier” (see Exhibit 17, page 51), unlocking cost-effective package solutions by quantifying the following ancillary benefits:

- Downsizing or eliminating mechanical systems.
- Reducing size and operational costs of backup powers systems.
- Reclaiming useful floor space.
- Reducing floor-to-floor height to enable additional floors.
- Other building structural cost savings.
- Radical simplification and streamlining of designing, building, and operating buildings.
- Reducing maintenance concerns and costs.
- Downsizing peak electricity demand.
- Providing grid load management services.
- Increasing revenue by increasing worker productivity.
- Reducing heat- and pollution-related health costs.
- Increasing property value due to energy savings, resilience, comfort, and satisfaction.
- Prefabricated/modular construction that improves speed and quality control; reduces rework; and represents a new business frontier of eco-industrialised, upskilled construction for India.[30]
- Reduced urban heat island (see 3. Solutions to Help Cities Beat the Heat).
- Upstream, shared, supply-side value (see D. Integrated Resource Planning).

Efforts are needed to raise awareness and quantify these value propositions for the professional-led and beneficiary-led sectors. They should be captured in public knowledge bases of project capital-cost (and savings) case studies, system cost and benefit quantification, quantified ancillary non-energy benefits, design guidelines, and whole-system and upstream value studies, providing a critical resource for industry players and policymakers.

Exhibit 17 Tunnelling through the cost barrier



Professional tools and training — Breakthrough tools and training initiatives are being implemented in India's design and formal construction sector. Tools by Eco-Niwas and EDGE and design guides within ECBC demystify integrative, passive design for a broad audience.[31] BEE is training more than 15,000 architects and government officials onbuildings sector energy efficiency.[32] These efforts are transformational and provide a ready channel to incorporate a new knowledge base of ancillary benefits, as described above.

As the energy analysis and net-zero-project delivery skill set expands, the industry can move towards rigorous, data-driven, and performance-based design. Setting quantified, trackable energy performance targets early in design or better yet during procurement or owners' project requirements, forces data into the design process. It ensures a rigorous, analytical design approach that keeps energy equal in priority to the myriad other design criteria, particularly during impactful, broad-stroke early decisions.
The performance target is confirmed at every step of design and construction administration to ensure follow-through on design intent. Measurement and verification confirm contractual performance obligations and may identify further commissioning needs or performance adjustments.

Beneficiary-led training and supply chain — The propagation channels for the beneficiary-led sector are less defined and more diverse and complex. Separate from the professional-led sector, a task force needs to address how to build awareness, skills, and the supply chain to deliver passive, integrative design through a multitude of small, informal builders. With the correct interventions, this could be a self-reinforcing movement since beneficiary-led solutions are inherently place-based and Indigenous. They should lead to local jobs, local economic development, local resource management, and localised cultural architecture.

Programs and policy roadmap — Delivering the items above initially includes programme funding, supply chain financing, and customer incentives. Planning and justification for those investments become clear when placed on a roadmap to ultimate, whole-system societal value of cooling access, health, energy security, system resilience, supply-side capacity, economic development, and more. Ultimately, these strategies need to become default and without exception, leading down a statutory path within ECBC and ENS and supported by performance-based data feedback.

NEXT STEPS

Targeted Accelerators: Integrative passive design hub, Indigenous design, and workforce challenge.

Who: *Design and construction industry leaders, government task force supported by NGOs.*

Integrative passive design hub — Government and industry thought leaders can collaborate to motivate and elevate leading-edge pilot projects that exemplify the energy, economic, and functional benefits of integrative, passive design. These learnings can be published in a knowledge base, with special emphasis on ancillary benefits that make high efficiency viable. This can facilitate the integration of whole-system design and costs into professional sector tools and trainings, accelerating the impact of significant workforce training efforts underway on the national scale.

Indigenous design and workforce challenge — The beneficiary-led sector may prove uniquely difficult to influence via energy codes and may be stretched to benefit from advanced technologies due to cost and financing access hurdles. It may also be a natural fit for passive, localised, and Indigenous techniques that reduce embodied carbon and operational energy while improving comfort and well-being. Driving this is a technological and scaling innovation challenge. Government-led targeted challenge initiatives, with financing and communications resources, can focus on entrepreneurship and generate crucial public awareness. The transformation of the building practices in the beneficiary-led sector would be cathartic for India's energy prosperity.

The technical potential of passive design energy savings should also be accounted for within the performance commitments of corporate, finance, and government buildings at the leading edge. Ultimately, they should be accounted for within advancing energy codes on a roadmap to zero energy, which is calibrated to bring about maximum whole-system energy and economic benefits.

Serve Energy Needs Efficiently

5. Rethinking Cooling Equipment

Scaling radically efficient and low-climate-impact cooling technologies can neutralise the impact of the escalating demand for cooling, broaden access to thermal comfort while enhancing resilience to increasing heat threats, and support the prime minister's vision of India taking a leadership role in global climate-change mitigation.

CONTEXT

- Population growth, economic progress, urbanisation, and soaring temperatures are driving exponential growth in India's demand for RACs — expected to increase nine times between 2017–18 and 2037–38 — to fulfil the country's developmental needs.[33] RACs, currently at less than 10% penetration in the residential sector, are a dominant contributor to this growth — India is projected to hold over 20% of the global installed stock of RACs (at nearly 1.2 billion units) by 2050.
- Members of the increasingly affluent lower-middle class — a substantial population — are on the verge of buying their first RACs —the unit that is typically the most affordable and likely the least efficient on the market, locking in high energy use, emissions, and high costs to consumers.
- While RACs represent a quick and localised fix for those who can afford it, the emissions and rejected heat from RACs perpetuate a vicious cycle wherein mechanical cooling further warms cities, necessitating even more cooling and further compounding the equity divide for those who cannot afford access.
- Under the business-as-usual trajectory, India is set to become the world's largest emitter of greenhouse gas (GHG) emissions from cooling appliances by 2050.
- Active policies and actors advance energy efficiency of space cooling equipment. A key driver is India's fairly mature Standards and Labelling (S&L) programme — an important thrust area of the BEE under the Ministry of Power. Among space cooling appliances, the S&L programme has had a dominant focus on RACs, with mandatory labelling in place for fixed-speed and inverter RACs. Mandatory labelling for fans is a recent addition (with effect from July 2022). S&L programmes brought about steady and positive change and will continue to do so, but this change is incremental and outpaced by the cooling growth. Studies show that accelerating the efficiency of cooling equipment alone will not be enough to neutralise the impact of growth on the space cooling demand. The ICAP emphasises accelerating the ambition of MEPS and expanding the scope of the S&L programme.
- Even with the exponential growth in RACs, thermal comfort needs will not be completely met — only about half the population is projected to have access to ACs by 2050. A case in point is that cooling and thermal comfort in a developing country such as India are not synonymous with air conditioning. "Cooling for all" is an urgent priority, and diverse strategies will be needed to enable this in a way that does not contribute to further warming.

SOLUTIONS

India's space cooling challenge has two distinct aspects: (1) sustainably addressing the mounting demand for RACs and (2) expanding cooling access and bringing efficient and affordable cooling to those who cannot access RACs — all without causing further warming and energy-system impact.

To address this challenge, we recommend the following twin priorities — in parallel with the ongoing policy actions — to accelerate the pace and ambition of cooling equipment efficiency and expand access:

1. Push for radical improvements in the cooling efficiency of RACs, leveraging the successful technology demonstration of a 5X solution in the Global Cooling Prize (GCP) hosted in India.

2. Recognise fans as the first point of cooling access for many, prioritise high-efficiency fans, and parallelly establish market mechanisms to advance their adoption.

RACs: With the majority of AC and refrigerant volume yet to be recorded, India has the critical window of opportunity to leapfrog to radically efficient cooling technologies that can effectively neutralise the impact of the exponential increase in the demand for RACs. The GCP demonstrated the existence of technology that provides cooling with five times less climate impact and lower lifetime costs compared with the current typical RACs. Although commercialising the 5X technology will take a few years, it is important to create supporting conditions and prime the market for these radically efficient cooling products in the meantime.

The immediate actions include the following:

- A critical foundational step is to inform test standards for RAC technologies to better reflect real-world operation in India's climate zones. The learnings from the GCP can be leveraged for developing and standardising new test procedures better aligned with India's climate conditions (factoring for humidity) as well as the evolving technology.

- India is a signatory to the SEAD Initiative, launched at COP26, which aims to double MEPS by 2030. Building upon the momentum generated during the GCP — in which several Indian manufacturers participated — the opportunity to work with key manufacturers will help push for accelerating this timeline, such that the industry receives the necessary signal and has sufficient time to prepare for mass production of high-efficiency products.

- In parallel, raising mass awareness not just among consumers but across stakeholder entities is key, making the lifecycle advantages as well as broad societal benefits of radical efficiency easily understood.

Analysis suggests the 5X technology could reduce India's estimated peak load by around 400 GW in 2050 while lowering electricity consumption by RACs by 70% compared with business as usual.[34] This strongly supports India's commitment at the COP26 to become carbon neutral by 2070.

Fans: Fans are and will continue to remain the first point of access to cooling for many in India, particularly in low-income and weak-grid communities. Under business as usual, the demand from fans is expected to be the single-largest contributor to India's residential electricity demand in 2030.[35]

Currently, only a small share of ceiling fans stock has BEE star rating. Available technologies such as brushless DC fans consume half the energy used by a typical fan available today, but the market signals driving the supply and demand of energy-efficient fans are missing.

The Collaborative Labeling and Appliance Standards Program recently completed important policy work on ceiling fans — revising policy scales such that the existing five-star rating becomes the new one-star minimum.[36] Additionally, the policy transitioned from a voluntary status to a mandatory regulation in July 2022.

The policy push has to be coupled with the necessary efforts to catalyse market demand. For this, the next steps include the following:

- Market strategies to spur demand, such as stringent public procurement policies for widespread adoption of superefficient fans (allowing government entities to lead by example), carefully planned bulk-purchase initiatives (leveraging learnings from the EESL's LED lighting programme [UJALA] scheme for market transformation on LED lights), targeted incentives, or discom on-bill payment schemes for low-income buyers. Recent pilots from utilities promoted brushless DC fans at highly subsidised rates (50–60% less than the retail price), including the BSES Rajdhani Power Limited (BRPL) fan replacement scheme launched in 2020 for domestic consumers in Delhi[37] and the Tata Power BLDC Super-Efficient Ceiling Fan Program launched in November 2021 for residential consumers in Mumbai.[38] Building on their learnings, such initiatives will have to be rapidly scaled to bring a meaningful market shift.

- Communications — tailored to specific stakeholder groups such as low-income, heat-vulnerable communities or institutional buyers — to enhance awareness about lifecycle costs and benefits of energy efficiency.

Aggressively promoting the uptake of super energy-efficient fans by 2050 can result in cumulative reduction of 300 million tonnes of CO_2e in GHG emissions.[39] Potential supply-side benefits are impressive, reducing India's energy consumption by 40 terawatt-hours per year or TWh/y (15%) and peak power generation by 14 GW (7%).[40]

NEXT STEPS

Targeted Accelerators: Demand aggregation programmes, appliance and equipment roadmap for cooling equipment (fans and RACs), consumer awareness campaigns.

Who: *Bureau of Indian Standards, Standards and Labelling Program and ECBC/ENS under BEE, India Cooling Action Plan (ICAP) under MoEFCC, cooling equipment manufacturers, discoms, Energy Service Companies (ESCOs), developers, institutional (bulk) buyers.*

- **Appliance and equipment roadmap —** Integrate leapfrog efficiency into an appliance and equipment roadmap across ratings, standards, and building-energy codes. This includes crucial rating consideration of total cooling efficiency — including air temperature, humidity, radiant temperatures, and air movement. Performance should be measured on a seasonally integrated basis, and the global warming potential of refrigerants should be included. High-efficiency fans should be included as the first solution. Similar to a code roadmap, a long-term appliance and equipment roadmap would set the trajectory for transforming the manufacture and market share of high-performance equipment. Equipment rating systems represent the leading-edge and can be coordinated with subsequent statutory efficiency standards, both ratcheting in lockstep. In collaboration with manufacturers and distributors, with data feedback loops, an appliance and equipment roadmap can support timely research and development, standardisation, and supply chain cost compression, and prevent poor performers from holding back competitors.

- **Consumer awareness —** Aggressive data-backed campaigns to demonstrate the benefits and raise mass awareness of the urgency to transition to efficient cooling appliances.

- **Demand aggregation —** Jump-start product development, supply, and demand via organised bulk purchasing and other government-organised market-transformation efforts. This can also be achieved by targeted energy-efficiency programmes within discom integrated resource plans (IRPs). Providing guaranteed demand for ultra-efficient equipment and smart appliances will allow manufacturers to make investments and achieve cost compression. Targeted government programmes can aggregate large government, corporate, and programme purchases, as well as initiate discom-targeted incentive programmes as precursors to broad integrated resource plans. These can be wrapped together into public awareness market-transformation efforts akin to the successful EESL LED programme. This will eventually give way to large-scale deployment and unlock the full range of superefficient equipment and demand flexibility benefits to all stakeholders as the market and technology mature. Cooling product demand aggregation can be coordinated with the parallel need to unlock economies of scale for renewable energy integration and demand response.

6. Efficient Appliances, Equipment, and Optimisation

Targeted demand-side programmes can commoditise products on a path to codes and standards updates.

CONTEXT

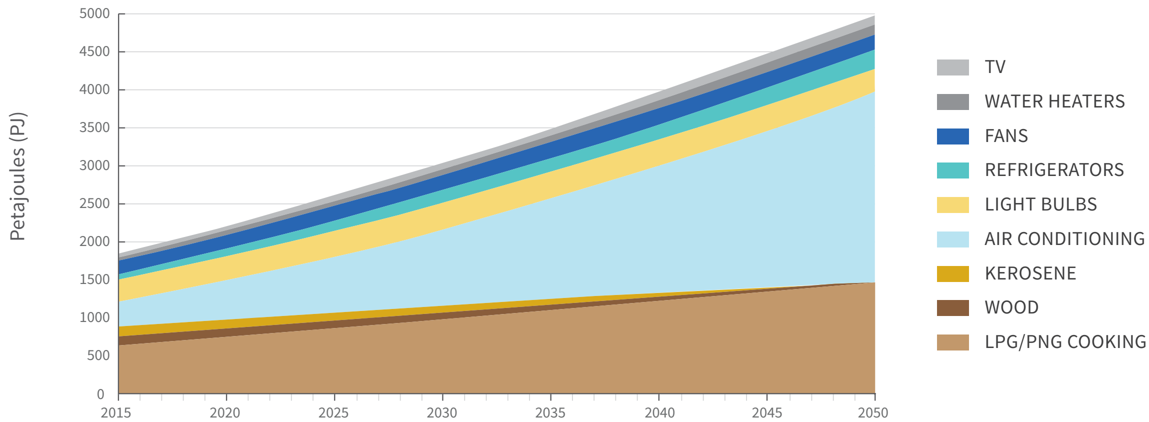
Since the announcement of the Energy Conservation Act in 2001, India has been increasingly proactive in recognising the need for energy-efficient appliances.[41] For instance, the act established the Bureau of Energy Efficiency, assigning it tasks that led to the development of the S&L programme for appliances and the Energy Conservation Building Code. The programmes led by BEE and EESL have since helped create consensus on the importance of efficiency, generate awareness, and lower unit costs.

In the coming decades, urban residential energy consumption is expected to rise exponentially. Rural energy consumption may reduce overall, considering an expected decline in the use of biofuels, but electricity and fossil-fuel consumption are expected to increase significantly. The largest residential-equipment energy-efficiency opportunities are driven by expanding cooling demands, including RACs, fans, and refrigerators. Cooking and water heating unexpectedly account for the second-largest residential energy demand, dominated by fossil fuels in an unmitigated baseline scenario but with opportunities to switch to high-performance new technologies. Commercial buildings are expected to contribute increasingly to energy demand and emissions, with retail, office, education, and hospital buildings, in particular, warranting increasing focus. Exhibits 18 and 19, pages 58 and 59, illustrate energy end-use breakdowns under a scenario previously modelled by Lawrence Berkley National Laboratory (LBNL) with a slightly different scope from the scenarios in the current paper but illustrative of the key
priority areas.[42]

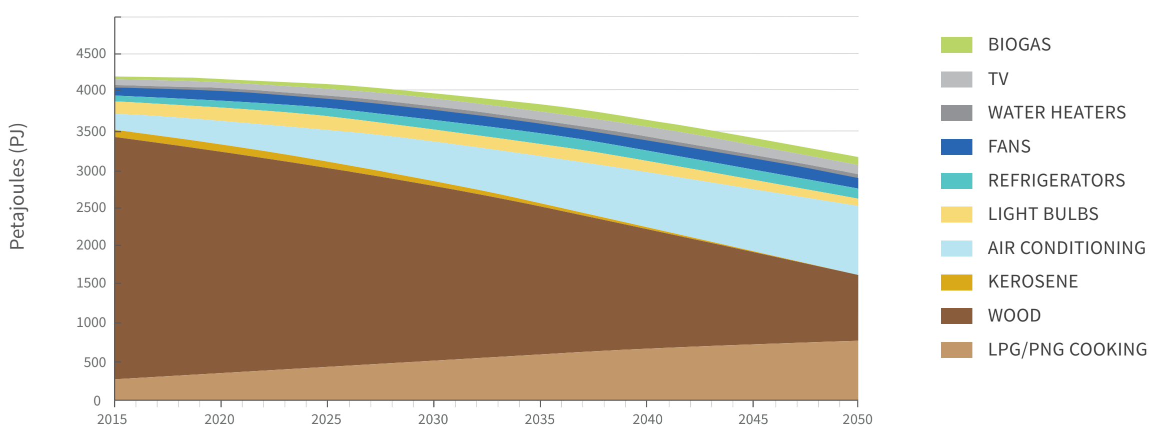
Exhibit 18

Residential-buildings energy-use projection in India, 2015–50

Urban Residential



Rural Residential



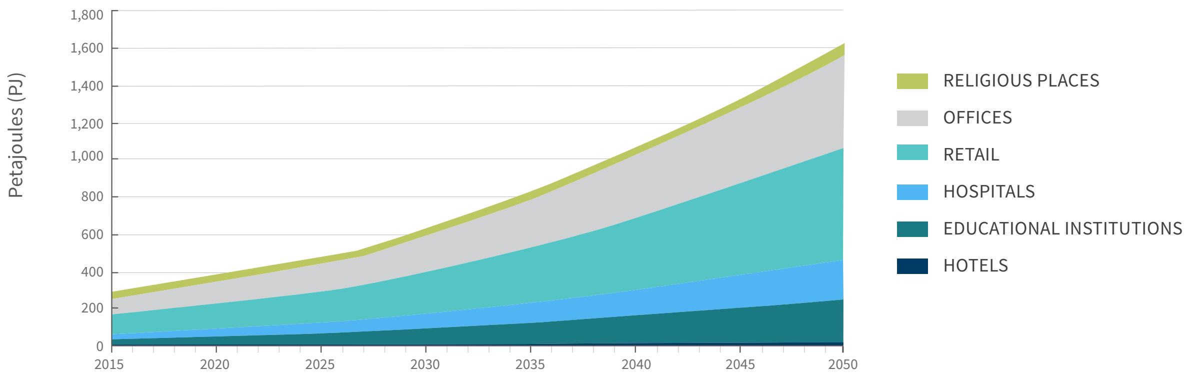
Source: Applied Energy

Note: These scenarios are based on a 2019 study by LBNL with a different scope from other analyses represented in this report but are included here for illustration of end-use breakdowns and priority areas.[42]

Exhibit 19

Commercial-buildings energy use in India, 2015–2050

Commercial



Source: Applied Energy

Note: These scenarios are based on a 2019 study by LBNL with a different scope from other analyses represented in this report but are included here for illustration of end-use breakdowns and priority areas.[42]

To manage this demand effectively, leading programmes by BEE and EESL need to achieve wide market penetration and be augmented by technological innovation. Furthermore, through improved energy visibility and automation, behaviour change can be influenced.

Political and administrative consensus on the importance of energy efficiency is increasing. BEE and EESL's efforts to mainstream superefficient appliances helped energy efficiency be accepted as the "first fuel" in meeting the growing demand. S&L and bulk procurement programmes are recognised as successes with potential to be replicated. The recent development of the National Level Policy Roadmap on Home Automation further indicates willingness of key government stakeholders to pursue ambitious action. An overarching policy roadmap can build on this to create a market signal and inform future programmes.

There is similarly growing corporate awareness around energy-efficient appliances and equipment. Leading firms are beginning to make an inventory of their energy use and carbon emissions and declare commitments to reduction targets over time. Adoption of high-rated equipment in procurement standards is a relatively straightforward initial step, and building automation and management systems are important elements of understanding and prioritising energy interventions.

However, financial challenges are still significant, and the market for third-party commercial solution providers in India is relatively nascent. There is often a cost premium on more efficient equipment, and consumer product decisions are frequently driven by the lowest purchase cost rather than life-cycle cost. Currently, few incentives or rebate programmes are available to offset first-cost premium. Appliance financing is sought after but less commonly available. While ESCOs offer a pathway to improve the affordability of appliances, the ESCO market is still small — only 5% of the 1.5-lakh-crore market opportunity has been tapped into.[43]

Additional capacity building is needed within discoms on DSM models that can help customers overcome financial hurdles while benefiting discoms. It is essential to make the business benefits of energy-efficiency behaviour-change programmes clear to discoms. State electricity regulatory commissions can be proactive in helping discoms realise this potential.

SOLUTIONS

1. Push strategies (policy and regulations) to drive efficiency in technology coupled with pull strategies (market mechanisms) to spur the uptake of high-efficiency products.

The transformation of the appliance market towards less energy-intensive variants requires incremental efficiency and fundamentally innovative technology. Proactive policy and government leadership can act as catalysts to enable this transformation. Some of the most promising areas include the following:

MEPS roadmap — BEE's existing S&L programme currently mandates minimum energy performance standards for 11 appliances, including different types of RACs, refrigerators, lamps, colour TVs, and electric geysers; voluntary standards exist for 19 other appliances (see Exhibit 20).

Exhibit 20 **List of appliances under the BEE S&L programme.**

MANDATORY APPLIANCES	VOLUNTARY APPLIANCES
• RACs • Frost-free refrigerators • Tubular fluorescent lamps • Distribution transformers • RACs (cassettes, floor-standing) • Direct cool refrigerators • Colour TVs • Electric geysers • Variable-capacity inverter air conditioners • LED lamps • Ceiling fans	• Induction motors • Pumps sets • LPG stoves • Washing machines • Computers (notebooks/laptops) • Ballasts (electronic/magnetic) • Office equipment (printers, copiers, scanners, multifunctional devices) • Diesel-engine-driven mono-set pumps • Solid-state inverter • Diesel generator sets • Chillers • Microwave ovens • Solar water heaters • Light commercial air conditioners • Deep freezers • Ultra-High Definition (UHD) Televisions • Air Compressors • Tyres • High Energy Li-Battery

Source: Bureau of Energy Efficiency

Enhancing the MEPS periodically is a part of BEE's mandate. Moving forward, as India's energy-efficiency ambition ramps up, BEE can also consider the creation of a roadmap providing a timeline of when it expects to raise the MEPS floor for mandatory appliances, when it expects voluntary appliances to move to mandatory status, and which appliances it is exploring, adding to the S&L programme. This can help manufacturers plan for expected standards, accelerating their adoption and market proliferation. Economies of scale can then be attained on a predictable path.

Market strategies that address the first-cost barrier to accelerate consumer demand for high-efficiency products — In many appliance categories, superefficient technology exists but adoption is limited. In India's highly price-sensitive market, purchasing behaviours are typically skewed towards lower first cost instead of lower life-cycle costs. Thus, while policy levers create a push for high-efficiency products, in parallel, market solutions are needed to aggressively drive consumer demand. Some strategies that have been tried in limited measures and can be further scaled are subsidies, demand aggregation programmes, and more recently, servitisation models such as pay-as-you-use.

The success of UJALA provides a leading example of market and programme convergence to rapidly transform the market. EESL also explored demand aggregation and servitisation models in other appliance and technology categories with mixed results. Its experience offers a solid foundation to explore what has worked and what has not to accordingly create pathways for scaling such strategies to unlock market demand. While this measure alone will be insufficient, it can contribute to market transformation when the major barrier for a target appliance is financial. Such market models, coupled with fiscal incentives and tax concessions, can contribute to market transformation when the upfront cost is a major barrier for adoption.[44]

Using the example of ceiling fans, the Council on Energy, Environment and Water (CEEW) describes a comprehensive approach to jump-start markets for superefficient appliances with reach across income levels, incorporating bulk procurement collaboration with the supply chain to drive cost compression, flexible payment options such as on-bill financing, and tax- or discom/DSM-related financial incentives, all managed strategically via a management information system.[45]

One technology that may benefit from a combination of bulk procurement and enhanced incentives is solar thermal water heating, which has achieved impressive early adoption but not maturity (see Exhibit 21). Only a few state and city governments currently offer incentives.[46] In Germany, for example, growth in the solar thermal market has been largely led by a lucrative subsidy scheme for replacing old burners with solar water heaters.[47]

Exhibit 21

Next-generation water heating technology

Currently, electric geysers are the dominant form of water heating in India, but improvements to their efficiency are inherently limited by the nature of electric resistance heating elements. Two promising water heating technologies offer the potential for major leaps in efficiency, one by sourcing heat directly from the sun and another by using electricity to move heat rather than create it:

Solar water heaters: Solar-powered thermal systems use a heat exchanger and heat transfer fluid to supply hot water to households. They are especially viable in regions with year-round hot water demand and good winter solar radiation, such as western and southern India. In 2019, installed solar water heating capacity was 10,433 megawatts thermal, representing annual energy savings of 1.38 million tonnes of oil equivalent. With over 70% of the market share, evacuated tube collectors are the dominant technology due to their high efficiency.

Although solar water heaters are not commonplace, this early adoption over the past decade shows promise. Adjusted for GDP and population, water heating is the second-largest market for the technology, accounting for 1.3 kilowatts thermal per GDP per 1,000 inhabitants. Analysis suggests solar water heaters have the potential to deliver 76 TWh of annual useful energy by 2032. This can be achieved through provision of subsidies, concessions, and awareness programmes. Indigenous manufacturing and further R&D should also be pursued while strengthening institutional capacity. The S&L programme for solar water heaters can be made mandatory.[47]

Heat pump water heaters: Heat pump water heaters extract ambient energy from air to heat water using a refrigerant cycle. Energy consumption is low, driving the compressor used to exchange heat with water. It can provide an ancillary benefit of space cooling and dehumidification and can be integrated with grid-interactive controls to allow for off-peak "charging" or demand response. Heat pump water heater technology has started gaining traction in other markets but has not been widely tested in India. Initial investment required is also higher than that needed for solar water heaters at present due to technology costs and lack of scale. Further R&D will be needed to understand the applications of heat pump water heaters in the Indian context, especially to optimise unit costs and extend life expectancy.[48]

Innovation and manufacturing support — Appliances where superefficient variants are limited or lacking in India need to be identified to direct policy and public support. This can include dedicated R&D funds, grants, interest-free loans, and loan guarantee programmes for manufacturers and innovators.

Incentivising superefficient appliances before mandating MEPS can create early demand and encourage first-moving manufacturers. Synergies can be explored with existing schemes such as Make in India and the Production-Linked Incentive Scheme. Government support for manufacturing can be limited to appliances that meet MEPS.

2. Home energy visibility and automation — Making energy use visible and easy to manage

Domestic energy consumption is rarely tangible beyond monthly electricity bills, leading households to often be unaware of their energy waste. Increased visibility of energy use can influence behavioural change among end-users, driving efficiency at scale. Smart appliances can parallelly work with energy visibility to automatically optimise energy use using state-of-the-art automation technology.

The following promising methods are ripe for scaled deployment in India:

Home energy reports (HERs) — A HER is a periodically conveyed summary of a home's present and historical energy use, with personalised energy efficiency recommendations. HER programmes have the potential to create energy savings almost immediately after their commencement with limited discom resources or infrastructure. Exhibit 22, next page, provides the typical design of a HER.

Exhibit 22 Typical design of a home energy report

Home Energy Report (HER) Design: Fast Path to Insight and Action

Reads like a story

Bold graphic headers help tell a consistent and accessible narrative about each customer's energy use.

Connecting data analytics to behavioural insights

Highlights the two most important insights using proven behavioural science levers: normative compasion and loss aversion.

Tailored tips lead customers to action

Quick & easy tips from neighbors leverage other behavioural science drivers: choice architecture and social proof.

Source: Alliance for an Energy Efficient Economy

A 2019 white paper estimated the adoption of HER programmes at scale in India could result in a cumulative electricity demand reduction of 25,400–76,000 GWh over 10 years. This translates to an emissions reduction potential of 14,000–41,900 kilo tonnes of CO_2e and energy savings of INR17–51 billion.[49] Moreover, consumers receiving HERs are also more likely to participate in other energy-efficiency programmes. HERs can be the building block of discom-consumer interfacing programmes and can eventually be scaled to large-scale, demand-side management and smart appliance programmes.

Energy disaggregation and monitoring — Energy monitoring systems can disaggregate energy use in real time and provide consumers the estimated consumption of identified appliances. Live alerts and summarised data can be directly provided on smartphones or computer software. While HERs would function at the household level, energy monitoring systems work at the appliance level and are controlled by the user. Heavy-load appliances can be monitored, and energy waste can be directly avoided.

Primarily, three types of energy monitoring systems are available:

1. Nonintrusive monitoring, which uses main meter data to report aggregated consumption and disaggregate individual device consumption.

2. Circuit-level monitoring, which monitors specific heavy-load appliances and can be used for scheduling.

3. Plug-load monitoring (including smart plugs), which monitors specific plugged-in appliances and can support scheduling and automation.

Most energy monitoring systems require consumers' manual intervention to reduce their energy consumption. Thus, the quantum of energy savings depends heavily on the consumer's motivation to act on the real-time data provided. However, the provision of disaggregated data and identification of energy-guzzling appliances can create a powerful feedback loop. This can influence behavioural change and enable eventual investment in smart appliances.

Smart appliances — Two kinds of appliances can be considered smart: those connected to the user through the Internet of Things and those additionally enabling advanced automation through artificial intelligence and machine learning. Connected appliances can be controlled or scheduled by the user for better efficiency; automated devices can typically perform these tasks while learning about user preferences and their external environment. Although smart appliances are still nascent and smart features are only available in premium products in India, they promise significant energy savings (see Exhibit 23). Economically, the smart-home market is expected to achieve US$62.8 billion by 2030 with a supportive policy in place.[50]

Exhibit 23 **Energy saving potential of smart-home devices in India and associated payback period.**

DESCRIPTION OF SMART MEASURES	PERCENTAGE ENERGY SAVINGS	SIMPLE PAYBACK PERIOD (IN YEARS)
SMART APPLIANCES OR DEVICES		
Smart geyser	9%–16%	1.6–3.4
Smart AC	17%	3.8
Smart washing machine	19%	3.9
Smart lighting	40%	3
Smart external blinds	29%–38%	4.7–7.2
SMART RETROFITS		
Smart plug–enabled geyser	1%–8.5%	0.25–0.6
Smart plus–enabled washing machine	20%	0.8
Occupancy sensor for light and exhaust fan control	46%	2.7
Energy monitoring system	4–12%	3
IR (infrared) blaster–enabled AC	9%	1.2

Source: IEA

Smart appliances require a software and hardware investment from the user. Thus, at present, they are most suitable for high-consumption, high-income households where they can also deliver maximum energy savings. There is also limited awareness among consumers regarding energy savings and uncertainty around the return on investment. Developers may thus be well-placed to communicate benefits and aggregate smart-appliance demand for users.

In addition to energy-efficiency improvements, smart equipment can also include grid interactivity and demand response capabilities to support electricity system resilience and renewables integration, as described in the following sections.

3. Commercial building automation and controls

Building controls and automation represent a low-cost, high-impact opportunity for immediate efficiency improvements in new and existing buildings, with savings improvement of 10% commonplace and often far greater at minimal capital cost. Multi-system retrofit projects can typically see simple paybacks of less than five years, as demonstrated in retrofit projects such as Godrej Bhavan in Mumbai, Sant Parmanand Hospital in Delhi, and the Mahindra Towers in Worli, Mumbai.[51] Projects can leverage various ESCO models and deploy a range of strategies across multiple end-uses:

Cooling and Ventilation — There are various opportunities for control optimisation in commercial cooling and ventilation systems, with a range of complexities depending on the system type. Almost universally, systems should be optimised based on building schedules, or ever better, on real-time occupancy, leveraging CO_2-based demand control ventilation or occupancy sensors. A growing array of sensor products monitor various indoor air pollutants, improving building health while optimising energy usage. More complex systems require optimised modulation across a wide variety of settings — coordination of terminal units, supply-air temperature, supply-air pressure, chilled water-supply and condenser-loop temperatures, chiller input/output and part-load optimisation, and sequencing and staging of chillers and condensers.

Emerging technology systems will optimise across the complete range of thermal comfort factors and related equipment — air temperature, humidity, radiant surface temperatures, and air movement — and incorporate thermal storage to take advantage of diurnal swings and optimise ramping and part loads.

Variable-Speed Drives — Many of these control settings capture savings from performance-curve efficiencies of chiller compressors, fans, and pumps, which record exponential savings from fractional part-load or part-flow turndowns using variable-speed drivers. Variable-speed drivers are available for most large and small applications. They are a relatively low-cost, high-return retrofit for old systems and should be the standard for new equipment where they are not already. Variable speed-drive retrofits have also been major contributors to DSM programmes globally.

Lighting — The rapid growth of low-cost, high-performance commercial LED tubular lighting represents a straightforward path for up to 50% lighting power reduction compared with antiquated linear fluorescents, a major win for commercial energy codes. In existing buildings, lighting-as-a-service (LaaS) delivery models can cut lighting power to half at no upfront cost to customers with good returns for ESCOs. LEDs provide superior lighting quality and do not require maintenance for over a decade. They are more adept than legacy commercial lighting technologies at rapid on/off switching and can dim with proportionate energy savings. This moment of lighting retooling, therefore, also represents an opportunity to capitalise new control technologies such as dimming, reliable daylight sensors, fixture-level occupancy sensors, networked lighting, and integration with building automation systems.

Integrated Systems — Lighting and space conditioning can be networked together for further optimisation using shared sensors and controls that communicate occupancy, air and surface temperatures, and light levels with improved granularity and precision to lighting, cooling, ventilation, and even operable envelope shading systems.

Commissioning and Retro-Commissioning — Specifying physical hardware and controls is only the first step. Formal commissioning and periodic retro-commissioning are important to ensure building systems function as intended at initial occupancy. These practices confirm functional settings, routines, and system calibration, including addressing maintenance concerns and ensuring energy efficiency and functionality in terms of comfort, ventilation, light levels, and operational cost savings. Global best-practice green-building ratings and energy codes require fundamental commissioning at initial building occupancy, preferably by a third party, and offer additional credit for advanced commissioning with further testing after a certain period of initial occupancy.

Open Access Controls, Artificial Intelligence, Machine Learning — Significant research and development are globally underway on advanced automation that collects an abundance of data points from building systems and performs algorithms to optimise operation, incorporating many of the items described above. These systems take various forms —leveraging existing data, adding sensors and hardware, operating remotely, and requiring hands-on improvements. Open access, nonproprietary data and controls programming are crucial prerequisites, warranting further consideration for common practice and standards in the Indian market.

Many of the technology areas above can be prioritised to position India as a global leader in efficient equipment and building controls. Moreover, these are “low-hanging fruits” for deployment via DSM discom programmes, allowing quick value capture and proof of concept for programme pilots. In a slightly long purview, such DSM can leverage advanced-metering-infrastructure data for targeting and become a capacity tool in an expanding and increasingly renewable electricity system. The potential can be accelerated by standardising communication protocols, expanding access to ESCO financing, and communicating a clear industry roadmap for ratcheting efficiency and controls standards.

NEXT STEPS

Targeted Accelerators: Appliance and equipment roadmap (including building automation and control), demand aggregation programmes.

Who: *Ratings, standard and code developers, manufacturers, targeted government initiatives, discoms.*

Government agencies or discoms can commission status quo assessments of the existing appliance market to fully understand the areas where technical potential exists for greater efficiency, incentives or bulk procurement will be relevant, and further innovation is necessary in the Indian context. Comprehensive market research and techno-economic modelling can create a clear direction for the country’s appliance market, forming the backbone of a MEPS roadmap and incorporation of appliance efficiency into integrated energy resource planning.

Smart meter data can be used to target geographic areas or customer segments with high per-household residential consumption for immediate deployment of HERs, followed by other energy-efficiency programmes. Furthermore, discoms and government initiatives can collaborate and innovate on programme design and implementation around consumer awareness of energy-saving behaviour and smart, high-efficiency products.

Code development authorities can explore opportunities around building controls, management, and automation. The National Level Policy Roadmap on Home Automation can be complemented by a roadmap on commercial automation, developed and incorporated into BEE’s mandate.

Supply with Clean Energy

7. Demand Flexibility

Buildings can flex and store energy to their own benefit and in support of grid resilience and decarbonisation.

CONTEXT

Demand flexibility can drive clean energy within buildings by reducing energy demand at peak hours and shifting electricity energy demand when RE power is higher in the generation mix, lowering renewable curtailment and improving the project economics of incremental renewable build-out. Demand-side technologies and market mechanisms can play a pivotal role in grid balancing to address intermittency challenges arising from high variable renewable-energy penetration on the power grid. As grids with high penetration of variable RE face integration challenges, policies valuing grid balancing will be implemented to increase the use of RE. Simultaneously, air conditioners are projected to increase the share of cooling demand in the total peak load in India from 10% currently to 45% by 2050, driving a "peakier" national load profile.[52]

Two of the main reasons cited for low demand side flexibility adoption are lack of supportive regulatory structures and poor financial health of most discoms, which pivots their attention towards reducing aggregate technical and commercial losses and ensuring reliable power supply. However, as India plans its future smart-grid investments, demand-side flexibility services can reduce massive investments associated with expanding grid infrastructure, which would otherwise be used only for a small portion of the year. Demand-side flexibility measures are a cost-effective solution to meet the grid's balancing needs, minimise peak power procurement costs for discoms, and help consumers reduce their electricity costs.

Indian discoms used DR to mitigate power purchase costs and grid-balancing issues by implementing time-varying retail tariffs as well as incentive-based programmes with aggregators, primarily for large industrial consumers. If dynamic pricing, smart meters, and automated-demand-response technologies are rapidly deployed at scale, commercial and residential consumers can participate in such programmes and trim their electricity bills. Expanding the scope of DSM programmes to residential and commercial classes requires an understanding of the key system barriers faced by providers in areas such as customer behaviour, technologies, grid integration, tariff structures, and incentives structures. Needs significantly differ between the residential and commercial/industrial sectors owing to varying levels of awareness, technology penetration, and possible degrees of available load flexibility in each user group.

- Although traditional DR has existed for many years, the proliferation of distributed assets such as EVs, rooftop solar photovoltaic (PV), smart equipment, and building-energy storage systems has increased the focus on DR.

- Ancillary markets are poised to open up new avenues to generate revenue for trading DR.

- Increasing instances of variable electricity rates, such as time-of-day tariffs, can provide motivation for "prosumers" (consumers who also produce energy) to independently shift their energy consumption to off-peak periods.

SOLUTIONS

Residential and commercial buildings, due to their size and complexity, can provide flexibility through a wide range of options, including using the building's passive thermal mass, active thermal energy storage (TES), and battery electric storage, coupled with on-site electricity generation from solar PV or other generators. Behavioural strategies and other automation technologies can shift the consumption of energy in noncritical appliances and equipment or in EV charging. The demand flexibility potential of a building will be influenced by internal factors, such as the form or function of a building; external factors, such as local climatic conditions; and composition and capacity of local electricity grids. Some typical flexibility sources in a building are tabulated in Exhibit 24.

Exhibit 24 **Sources of demand flexibility in buildings**

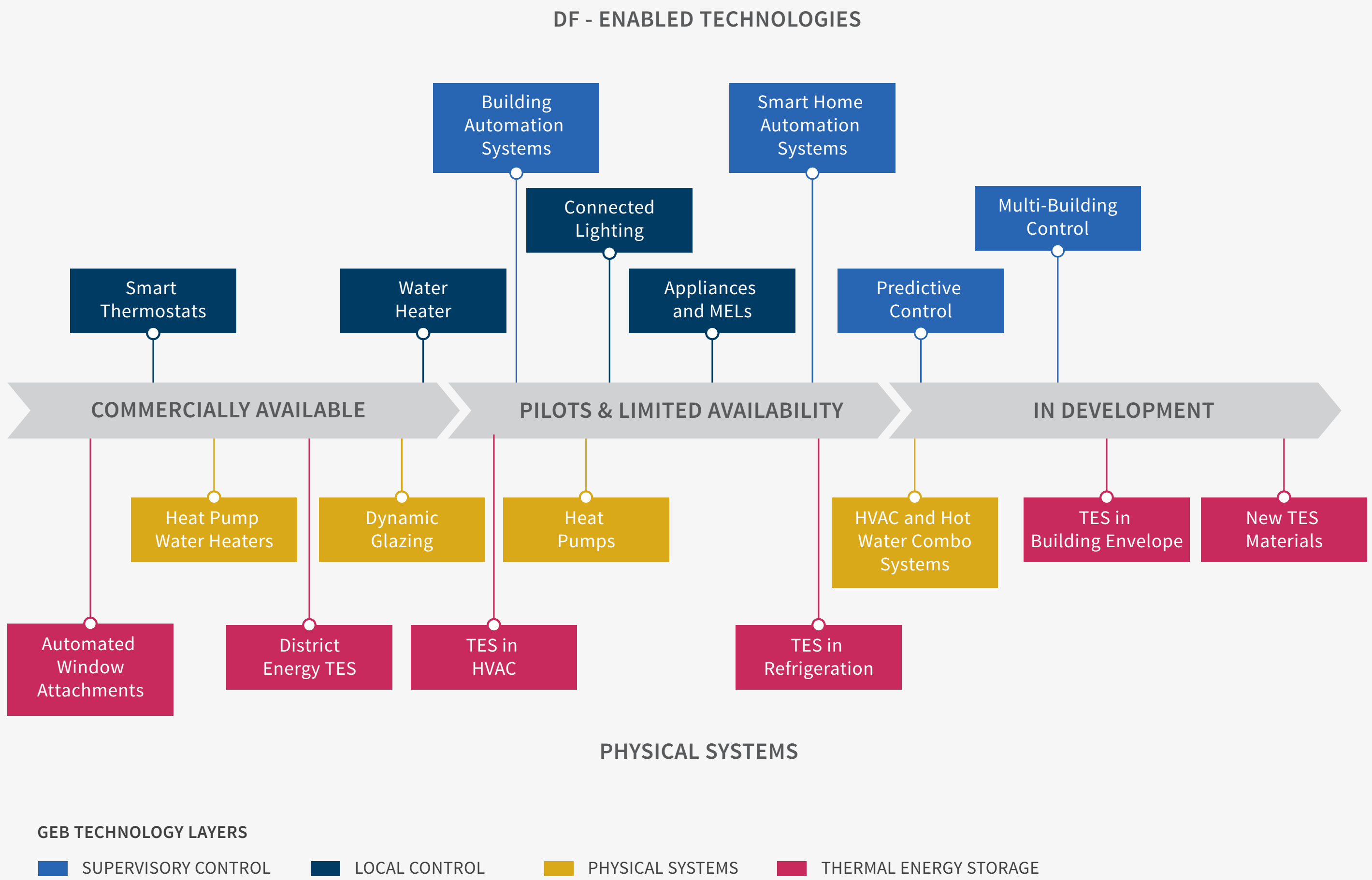
PLUG LOADS	HVAC EQUIPMENT	THERMAL STORAGE	OTHER
Washing machines and dryers	Heat pumps	Domestic hot water tanks	Solar photovoltaic system
Refrigerators	Air conditioners	Thermal mass of the building (walls, floors, ceilings)	Electric vehicle charging
TV and entertainment systems	Fans	Dedicated water, ice, brine, or other phase-change material buffer tanks in combination with heating and cooling systems	Electric vehicle to grid
Water pumps		Building-integrated phase-change materials	Electrochemical battery storage
Dishwashers		Indoor swimming pools	
Computers and IT systems			
Lighting			
Ovens/ microwaves			
Water heaters			

INTERRUPTIBLE DEVICES CONTROLLABLE DEVICES CRITICAL DEVICES

The US Department of Energy recently produced a grid-interactive buildings (GEB) roadmap describing the range of building technologies that can deliver demand flexibility.[53] Some are new physical systems or components, while others are controls layers on top of existing systems (see Exhibit 25). They range from broadly commercial technologies available today (e.g., smart thermostats) to those still in development (e.g., emerging TES systems).

Exhibit 25

US GEB roadmap technology overview



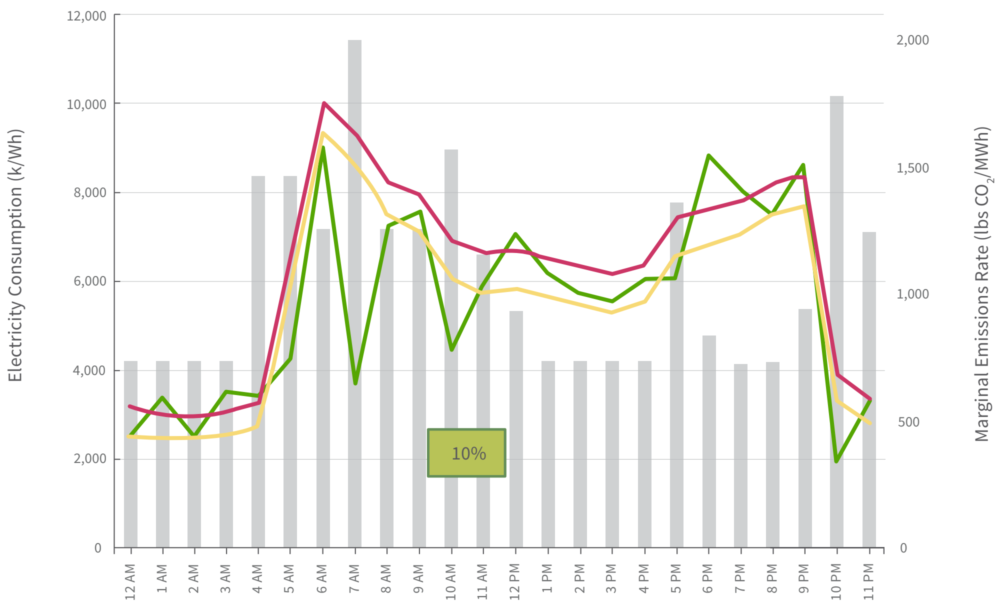
Source: US Department of Energy

Such technologies can shape demand such that it serves the goal of reducing attributed carbon emissions by a building. An RMI study found a commercial building could reduce carbon by 10% and 11% in highly renewable grid scenarios dominated by wind and solar, respectively (see Exhibit 26, next page).[54]

Exhibit 26

Carbon reduction potential in high renewables grid scenarios. (Daily carbon reduction indicated in green box)

A. Wind-dominated grid



B. Solar-dominated grid

The efficacy of such technologies depends on implementation, market dynamics, policy support, and customer engagement. While demand flexibility technologies may be mature, discoms and service providers face underlying challenges that need to be addressed across interlocking regulatory, market, and technology spheres to launch and scale customer participation in demand flexibility programmes.

- Significant effort is required to build awareness, technology familiarity, and confident operation by building owners and end-users across a wide spectrum — from sophisticated building operations to smart-home customers. Programmes need to educate and motivate based on the range of customer value propositions (see Exhibit 28, page 73). An equitable distribution of the rewards and cost savings associated with the deployment of such enabling technologies is necessary for wide-scale acceptance, market participation, and momentum building.

- Discoms and integrators need to build capacity to understand and begin implementing demand flexibility programmes.

- Geographical studies are essential to understand the load flexibility potential for different consumer classes (residential, commercial/industrial) and identify baseline consumption and potential contribution to reducing the overall demand profile. Surveys can aid in understanding consumer preferences on dynamic pricing and payment/incentive ranges that can trigger DR participation.

- Technology infrastructure, including hardware (smart meters), software (meter data acquisition and management systems), and firmware/communication links for programme design and implementation, is a requisite. Advanced metering infrastructure, which encompasses all three components, can help unlock load flexibility while gathering data on energy usage and driving improvement in billing efficiency. Measurement and verification are required for evaluating performance and compensation for demand flexibility participation. This will require investment in granularity and accuracy in metering and telemetry to adequately capture demand reduction data, for example, in 5-minute or 15-minute intervals.

- Protocols and product standardisation, essential for interoperability and data sharing, are emerging in the global market. These include ANSI/CTA 2045-B, a modular communications interface for energy management of equipment by demand flexibility aggregators; OpenADR, which standardises communication among utilities, aggregators, and end-users for DR and distributed energy resource (DER) systems; and IEEE 2030.5, an application protocol to manage DERs.[55] Major controls manufacturers are also increasingly realising the importance of making crucial data control points openly available to developers and aggregators for integration.

- Most importantly, today's electricity rate structures often provide weak incentives for demand flexibility. This is a complex issue with a range of causes, but current regulatory and market structures likely undervalue the potential of demand-side services and may not align cost with carbon. This is likely to change as energy consumption and RE variability increase in the coming years. Where flexibility is valued, it should also be adequately translated into rate structures or other aggregation signals and methods to drive demand-side responses. It is important to craft demand-flexibility solutions in a collaborative fashion between end-users and the supply side across the full range of demand flexibility functionality modes:

    - Management of peak demand charges within a billing cycle.

    - Demand response events with manual, automated, or third-party control.

- Routine grid-interactive load shedding and shifting in response to time-of-use varying prices or other signals (e.g., real-time grid carbon intensity (see Exhibit 27).
- Grid ancillary services.
- Islanded microgrid scenarios as a localised resilience measure.

Exhibit 27 **WattTime**

WattTime™ is a nonprofit technology company offering web-based data on real-time, location-specific carbon emissions intensity from the electricity grid.[56] WattTime aggregates generation data and shares emissions factors, including via an application programming interface (API) that allows developers to reference WattTime data automatically. WattTime partnered with a range of solution providers, including Google Nest, which will enable customers to automatically shift home energy consumption to align with low-carbon, high-renewable electricity supply.

Exhibit 28 **Demand flexibility benefits to customers**

MONETARY BENEFITS	ENERGY BENEFITS	NON-ENERGY BENEFITS
• Consumers can schedule their energy usage to coincide with periods of high rooftop solar generation, which will reduce their grid demand and allow them to move to a cheaper tariff slab. • Additional revenue from participating in incentive-based DSM programmes.	• Self-awareness of usage pattern and load profile. • Improved localised, building-level resilience and reliability. • Improved system-wide grid resilience and reliability.	Lower attributed emissions: • Reduce operation of more expensive and polluting power plants. • Support renewable deployment by matching intermittent generation and reducing curtailment. • Clean air due to less use of thermal power plants to meet peak energy requirements.

NEXT STEPS

Targeted Accelerators: Demand Flexibility (DF) coalition.

Who: *Discoms, central and state regulators.*

The technologies that enable demand flexibility are available and ripe for deployment but adoption among discoms and consumers remains sluggish. Discoms, regulators, and other nodal agencies need to assess the supply-side system value of demand flexibility and design the appropriate incentives and regulations to spur DF adoption.

A DF coalition can bring all relevant stakeholders from the DF ecosystem to highlight the opportunities and challenges and develop solution pathways to enable demand flexibility. It can act as a platform supporting state-specific assessment of demand flexibility, helping states design demand flexibility programmes, and creating a knowledge base through pilots and best practices for all stakeholders.

The DF coalition can help develop toolkits that incorporate data standards and communications protocols for grid interactivity across various products such as rooftop solar, residential appliances, commercial equipment and controls systems, EV chargers, and battery storage, which can be incorporated into an appliance and equipment standards roadmap, alongside energy-efficiency requirements. These toolkits can also enable manufacturers to shape DF solutions needed to drive the adoption of DF within buildings.

To accelerate DF adoption, discoms need to integrate DF at scale within their integrated resource plans. Demand aggregation programmes can drive mass adoption and improve the economic viability of DF for consumers and discoms.

8. Renewables Procurement

Renewables can become widely accessible.

CONTEXT

India recorded a rapid uptake of renewable over the last decade and set an ambitious target of 50% power generation capacity from nonfossil fuel generators by 2030. Buildings sector adoption of RE will play a key role in meeting this target and proliferate net-zero energy buildings. India's buildings stock can increase to meet the housing demand while lowering associated CO_2 emissions through a combination of demand reduction, on- and off-site renewables procurement, and centralised renewables (see Exhibits 4 and 10, pages 15 and 26).

Unused rooftop space has major untapped potential for solar power generation. Although India's overall rooftop solar (RTS) market is estimated to be over 120 GW, the country has deployed only 7.9 GW of solar rooftop thus far.[57] Driven by India's recent COP26 announcement to deploy 500 GW of nonfossil-fuel generation capacity by 2030, RTS penetration could grow well beyond the anticipated forecast of over 16 GW by 2030.[58]

India has made significant strides in electricity access over the recent years. Renewables in buildings can follow the same trajectory with growing cost competitiveness of RE systems, rising electricity tariffs, and various adoption models available in the market for different consumer classes. The adoption of RE by the buildings sector relies on attractive economic incentives, streamlined net-metering arrangements, and accessible deployment models. Feed-in tariffs, direct capital subsidy, soft loans, tax credits, and municipal programmes have been instrumental in encouraging the consumer adoption of RE systems globally.

SOLUTIONS

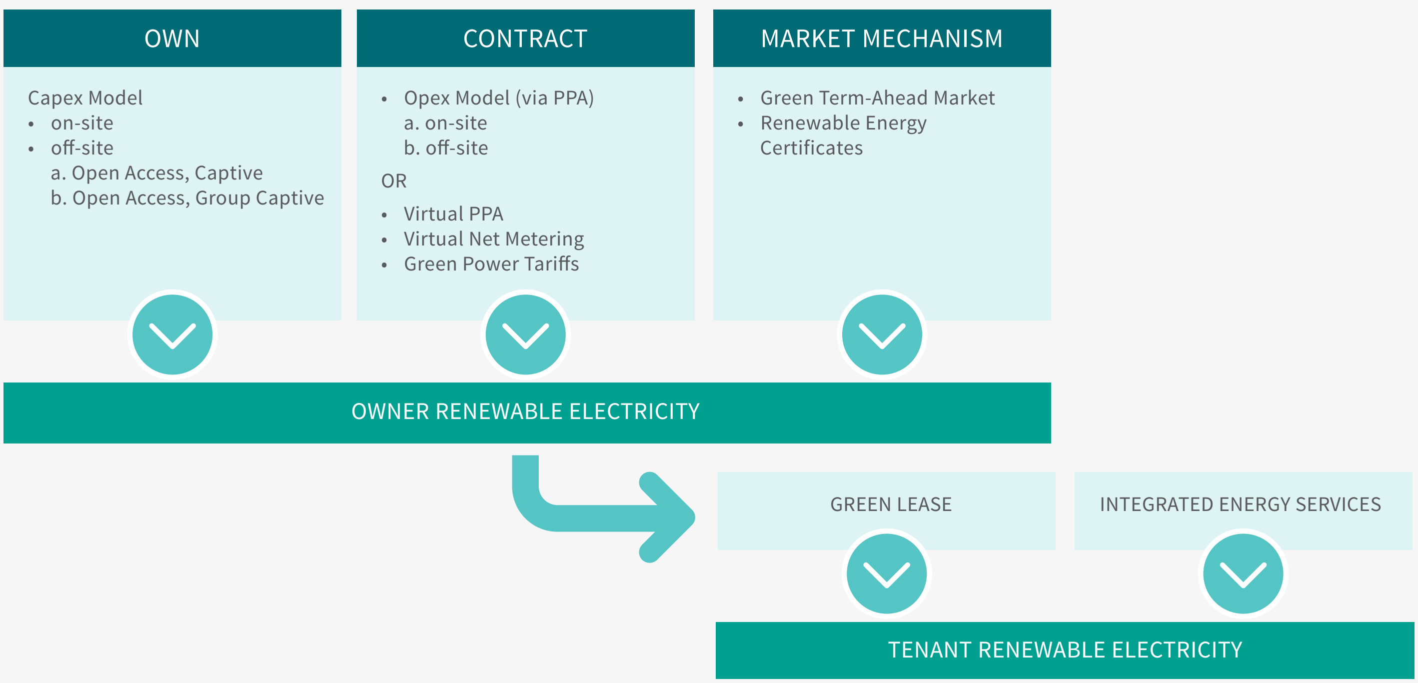
A host of options are available for corporate buyers to purchase RE power, reduce their electricity costs, and offset carbon emissions (see Exhibit 29). Depending on the desired level of ownership and capital investment, the available options can be broadly categorised as follows.

a. **Ownership (capital expenditure):** on-site, off-site (open access, captive/group captive models).[59]

b. **Type of contracts (operational expenditure):** power purchase agreements (PPAs), virtual PPAs, green power tariffs, virtual net metering.[60]

c. **Market mechanisms:** Green term-ahead markets (GTAM), renewable energy certificates (RECs).[61]

Exhibit 29 **Renewable energy procurement methods for the building sector**



Source: RMI

Consumers interested in directly procuring electricity from RE generators can own RE assets on-site (capex model) under a net-metering arrangement and have their electricity bills offset against the RE power generation. Moreover, commercial and industrial consumers are eligible to claim tax benefits through accelerated depreciation under the capex model. Buyers qualifying as open access consumers also have the option of owning RE assets off-site under the captive and group captive models. Open access power is a regulatory mechanism that provides grid-connected consumers (with a minimum contract demand of 1 MW or more) an opportunity to meet their entire electricity demand with green electricity. In the open access captive/group captive model, a single business or multiple buyers can own RE assets off-site and receive the direct benefits of RE generation.

Large commercial and industrial consumers not looking to invest in noncore operations can reap the benefits of RE generation under the opex model, wherein a renewable energy service company (RESCO) builds, operates, and owns an RE generation asset on-site or off-site. The buyer pays only for the power generated under a long-term PPA for a fixed tenure at a rate lower than the grid tariff.

Beyond these models, buyers can explore various contract mechanisms that fit their needs:

Virtual PPAs: Unlike PPAs, virtual PPAs are purely a financial contract bought and sold on the power exchange to secure RECs.[62] There is no physical power exchange, but green credits for the RE generated are transferred to the buyer.

Green Power Tariff: Consumers can also choose a green power tariff that allows them to source 100% green energy to meet their electricity demand. For a tariff slightly higher above the normal tariff, discoms procure green power from RE generators on behalf of consumers. Currently, green power tariffs are available only in a few states in India.

Virtual Net Metering: Consumers who do not have a suitable roof for installing a solar power generation system have virtual net metering options in some Indian states and union territories.[63] Through virtual net metering, consumers may acquire a piece of a communally owned solar power generation system, and all the energy generated will be fed into the grid directly. The exported energy will be credited to each participating consumer's electricity bill based on beneficial ownership.

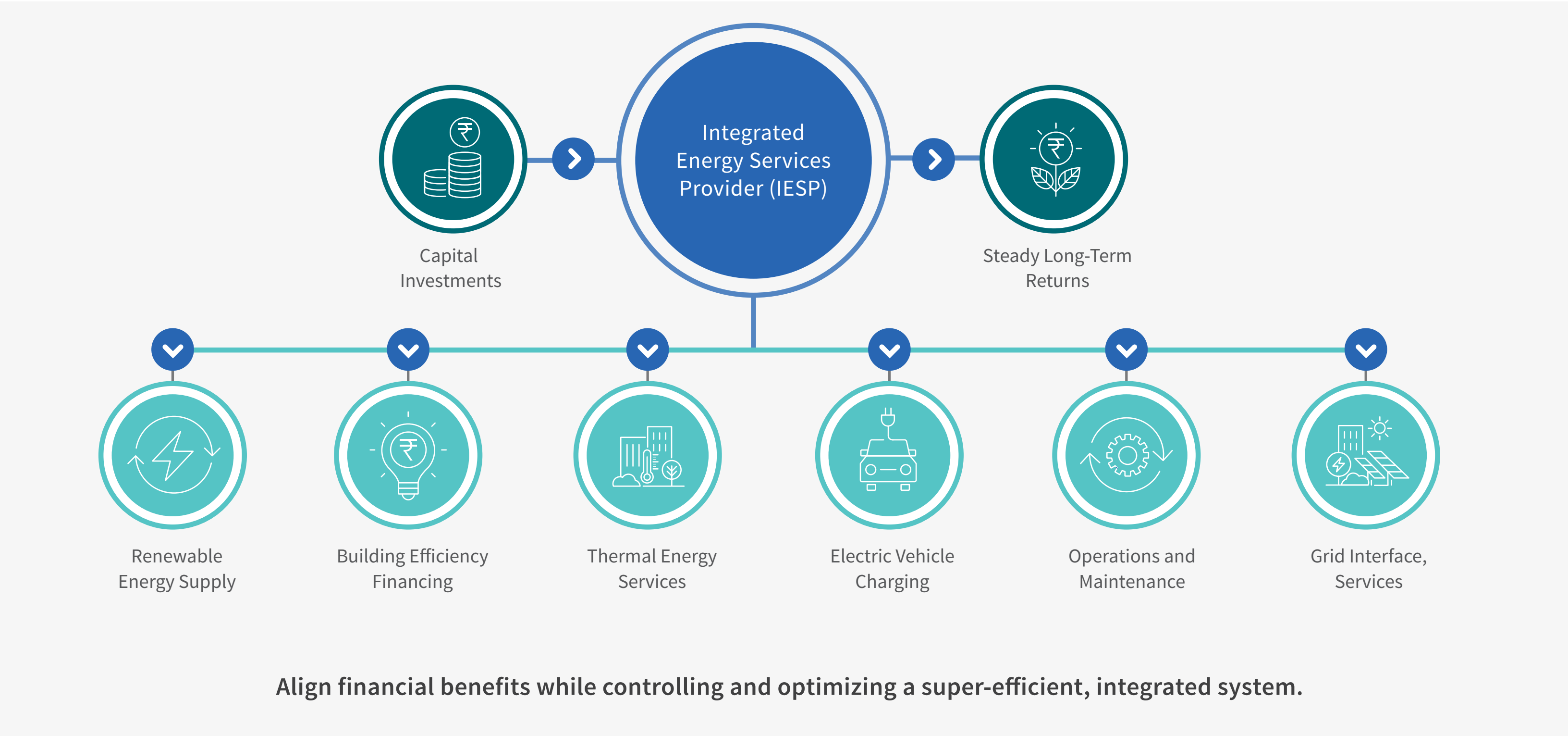
Large electricity consumers can also tap the open market to meet their green electricity needs. GTAM is a market-based mechanism that allows RE developers and corporate buyers to trade green power in the open market on an *intraday, day ahead, daily, or weekly* basis without signing long-term PPAs. Through GTAM, buyers can meet their short-term demand at competitive prices while fulfilling their sustainability targets and renewable purchase obligations (RPOs).

Consumers may also opt to purchase RECs to fulfil their RPOs and offset emissions. RECs are traded on power exchanges and represent the green attribute of electricity generated from RE sources.[64] About 60% of the recent RECs were purchased by discoms, followed by captive power projects and open access consumers (about 39%) and voluntary purchase (less than 1%).[65]

Furthermore, real estate companies could extend these green benefits to their tenants through green lease agreements, wherein electricity bills are included in the rent. Real estate developers can also take on the role of an integrated energy services provider (IESP) — a third-party developer who owns and operates the energy asset behind the meter and acts as a utility to tenants, a model that can be extended to include demand-side building equipment services (see Exhibit 30, next page).[66]

Exhibit 30

Integrated energy services provider

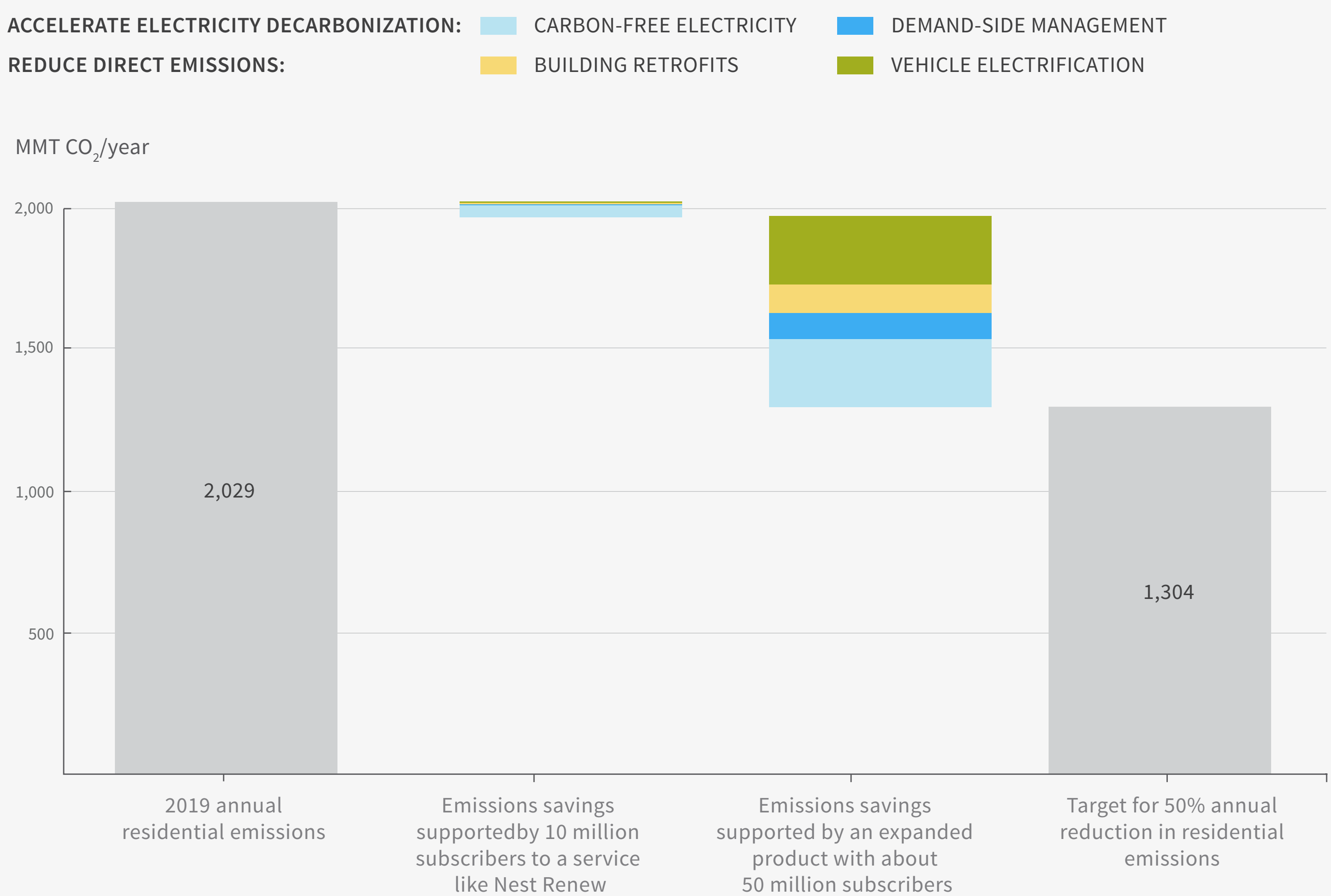


Source: RMI

Renewables procurement is an area of ongoing business model innovation. At the largest scales and leveraging a range of procurement mechanisms, major institutional energy consumers such as Google and the US federal government have begun charting a path to 24/7 RE procurement, geographically and temporally matched to their load profiles.[67] At the smallest scale, new products are emerging to simplify and scale renewables procurement for individual homeowners (see Exhibit 31, next page).

Exhibit 31 **Google Nest Renew**

Google's newly announced service, Nest Renew, is free to join, and enables residential customers to choose to manage energy use based on emissions or local electricity prices. Available only in the United States, it also offers a platform to educate households about their energy use and identify changes that help lower household emissions. For premium subscribers, Google will match a home's estimated fossil electricity use to RE credits that support generation from wind and solar. The premium service could help reduce CO_2 emissions for an average household by approximately 30%. RMI analysis found the RE and DSM supported by such a service could address approximately 7% of the gap between the level of household emissions in the United States today and the 50% reduction from 2005 levels needed to reach President Biden's overall policy target.[68] This is the equivalent of powering about 50 million EVs with a clean grid each year, as opposed to today's fossil-fuel-heavy grid.



Source: Google

NEXT STEPS

Targeted Accelerators: Building sector renewables coalition, building sector renewables mandates.

Who: *Ministry of New and Renewable Energy, discoms, regulators.*

The buildings sector will play a vital role in helping India meet its ambitious goal of achieving 50% nonfossil fuel power generation capacity by 2030. While extensive work is underway at the national and state levels to drive RE adoption within buildings, further assessment and deployment of procurement models, mandates, and incentives are needed to promote RE adoption. A few states such as Gujarat and Maharashtra have recorded rapid adoption of rooftop solar but that across most states remains slow. Developing a forum of stakeholders, including discoms, regulators, solar developers, and consumer groups, to share best practices, innovative reforms, models, and incentives from various parts of the country can enable cross learning and provide insights for states struggling with RE adoption among consumers.

A forum of stakeholders could engage on the following topics:

- **Streamlining regulatory reforms:**
  - To increase stability and certainty around net metering regulations and its implementation at the state and central levels.
  - To encourage states to adopt explicit buildings-integrated RE generation via RTS and other procurement models.
  - To design mandates and incentives encouraging RE uptake.
- **Streamlining administrative reforms:**
  - To fast-track net metering and interconnection processes by creating a single-window clearance.
  - To design efficient subsidy disbursal systems.
- **Unlocking RE financing for consumers:**
  - To improve access to finance for consumers from banks and nonbanking finance companies (NBFCs) through lower interest rates and collateral free loans and partial risk guarantee and first loss default guarantee models.
- **Unlocking innovative adoption models:**
  - To encourage adoption models such as green tariffs, virtual net-metering, group net-metering, and peer-to-peer trading for consumers with limited or no roof space.
  - To accelerate deployment of new models such as green energy open access.

- **Strengthening capacity building:**
    - To provide training modules for personnel of discoms and relevant nodal agencies managing the deployment of RE assets at the building level.
    - To introduce policies that create equitable, high-quality clean-energy jobs.

Mandating RE for certain categories such as government buildings can help aggregate the demand for RE to further unlock economies of scale and result in significant savings for respective buildings. Moreover, discoms can include buildings-integrated RE capacity in their integrated resource plans to help promote sustained RE growth.

9. Fuel Switching — Cooking and Water Heating

Cooking and water-heating fuel infrastructure planning benefits from the whole-system perspective.

CONTEXT

Fossil fuels used for cooking and water heating represent around a quarter of urban residential energy consumption, making it a crucial target of clean energy planning. Combustion cooking and water heating also represent the vast majority of rural residential energy (see Exhibit 18, page 58). Urban cooking is currently dominated by LPG, and efforts targeting universal LPG access in rural areas are underway to replace traditional fuels that have major health, environmental, and quality of life detriments. LPG in India is currently 54% imported.[69] Efforts are being taken to expand domestic piped natural gas (PNG) connections to up to 20 million by 2030, an increase of three to four times compared with today's PNG access. About half of the natural gas in India is also currently imported. In parallel, major investments are in progress to expand and improve electricity access and transition to renewable generation, presenting a growing opportunity to provide affordable and reliable electric cooking to broad segments of the population.

SOLUTIONS

India is positioned for whole-system optimisation of infrastructure planning and market development, balancing risks and benefits and finding opportunities to leapfrog pitfalls experienced by other countries burdened by costly, unhealthy, and volatile gas systems.

Electric cooking and water heating can have a place in India's kitchens — particularly high-performance induction cooking (see Exhibit 32, page 81), solar hot water heaters, and heat pump water heaters (see Exhibit 21, page 61) — and reduce consumption of fossil fuels in the home. As electricity generation transitions to clean sources, this will reduce net fossil-fuel consumption and related GHG emissions. It can also provide resilience and risk mitigation against future fuel access concerns or price volatility.

Expanded natural gas infrastructure, in particular, comes with several risks. Infrastructure maintenance costs and safety management are growing public concerns in other nations with high dependence on PNG and infrastructure approaching the end of its useful life.[70]

For instance, methane (the primary component of natural gas) is a highly potent GHG. Modest leakage rates can eliminate any climate benefit compared with otherwise worse fossil-fuel alternatives, and leakage rates throughout the gas system have been notoriously difficult to pinpoint. Green hydrogen presents a potential piped fuel alternative but is likely technically limited for PNG piping infrastructure and may be functionally and economically better suited for other industrial and transportations applications in India's economy. In the long term, PNG is at a risk of becoming a stranded asset as global fuel supply transitions.

Most importantly, electric cooking can ease health detriments and societal costs associated with LPG and natural gas cooking. An increasing body of research demonstrates cooking with these fuels produces indoor nitrogen dioxide (NO_2) pollution levels exceeding indoor and outdoor health guidelines.[71] Exposure to excessive NO_2 is known to cause respiratory, cardiovascular, and even cognitive health issues, especially among children.[72] In a recent study in Peru, switching from biomass to LPG did reduce NO_2 but not enough to adhere to the recommended health guidelines.[73]

Exhibit 32

High-performance, affordable induction cooking

Induction cooking technology has existed for many decades but has only recently gained significant attention as a high-performance cooking technology. Unlike electric resistance cooking, which warms the cooktop with a simple resistance element, induction cooktops heat the pot directly and nearly instantaneously. This makes cooking fast, targeted, and highly efficient. As a result, induction stoves give off less heat in the kitchen space, creating an ancillary benefit of improved comfort and reduced cooling need. The cooktop does not heat up, providing another ancillary benefit of kitchen safety. While large, high-end induction appliances are used in gourmet restaurants and luxury homes, plug-in induction burners are available at relatively low prices. A programme in Indonesia promotes LPG-to-induction conversion for multiple converging reasons —reducing cooking costs by more than 50% at the household scale and improving energy independence amid high fuel import prices at the macroeconomic scale.

Source: Antara News

NEXT STEPS

Targeted Accelerators: Clean cooking–access plan.

Who: *Targeted government initiative on clean-cooking access.*

Extensive work on cooking transformation in the rural and urban contexts is underway on the national scale. This effort can further national clean energy and carbon mitigation goals. Specifically, clean-cooking access planners, along with public health experts and electricity grid resource planners, can commission whole-system studies of a future clean-energy cooking scenario with the following quantified societal benefits, detriments, and risks:

- Applications and techno-economic potential for leapfrog technologies, such as electric induction cooking, heat pump water heaters, and solar hot water heating in India, under business-as-usual and targeted policy and programme scenarios.
- Societal health impact and costs of fossil-fuel cooking and water heating.
- Potential to deliver green hydrogen or other renewable biofuels using current fossil-fuel delivery systems.
- Infrastructure investment risks — fuel supply chain disruptions, customer fuel preference, tipping point prices, maintenance and replacement costs, methane leakage, safety, etc.

Planners and programme implementers can then develop targeted campaigns to expand availability and public awareness of the latest clean-cooking technologies in Indian cuisines and their range of benefits, along with clean water heating technologies.

IV. Crosscutting Impact Leadership Collaborative

Providing the whole system of technical solutions requires a range of catalytic initiatives. Some are aimed at advancing specific technical solutions, as included in prior sections, while others have a crosscutting impact across technical end uses, as described in the following sections. Some of these are leadership collaboratives to “raise the ceiling,” wherein targets are adopted first by government agencies, corporations, finance, and planners. Others are statutory mechanisms to “raise the floor” for all, wherein targets are subsequently adopted by statute within codes and standards by central, state, and local government authorities.

Exhibit 33 **High-impact, crosscutting impact leadership collaboratives**

A	Government Agency Commitments	• Government agencies can ensure the following: • Adopt net-zero energy mandates for new public buildings owned by ministries, states, cities, and public-sector undertakings. • Implement deep energy retrofits in existing public buildings using performance incentive grant structures.
B	Corporate Commitments	• Buildings sector corporations can ensure the following: • Publicly commit to sustainability targets. • Adopt carbon accounting protocols across Scopes 1, 2, and 3, along with climate risk assessments within business planning. • Take action, tracking towards intermediate goals and key metrics. In addition to the company's practices, consider procurement processes and RE. • Engage in policy forums to unlock more opportunities and scale in the market.
C	Finance Innovation and Focus	• Financiers and the real estate industry can offer innovative financing products: • Preferential mortgages linked to the energy performance of buildings. • Net-zero energy commercial leases designed to overcome split incentives to implement efficiency and renewable energy. • Specialised ESCO financing and as-a-service business models. • Policymakers and industry groups can develop supporting tools: • Defined net-zero and deep retrofit taxonomies and disclosure processes to provide insights into financial performance. • Financing incentive structures. • Collaborative industry platforms and government-led programmes for early movers.

D	Integrated Resource Planning (IRP)	• Utilities can ensure the following: • Integrate demand-side flexibility solutions and RE for buildings with IRP to provide improved energy services at low total cost and low emissions. • Deliver DSM solutions within today's business models. • Offer an expanded range of energy efficiency and demand flexibility programmes, drawing from abundant global programme examples. • Regulators can support IRPs in the following ways: • Demand-side resource potential studies to quantify the potential financial value of an expanded range of DSM. • New regulatory frameworks to unlock and administer the full range of DSM within new business models for discoms.
E	Statutory Mechanisms	• While these leadership efforts "raise the ceiling," central, state, and local government authorities can "raise the floor" through three statutory mechanisms: • Building code roadmap to zero. • Embodied carbon codes. • Building performance standards.

A. Government Leadership Commitments

The public sector can lead by example and jump-start the market.

Several challenges associated with transforming the buildings stock — for example, low-carbon materials, practitioner knowledge, skilling, public awareness — require the rapid creation of economies of scale in the Indian context. The Government of India, state and city governments, and public-sector undertakings (PSUs) can actualise this by acting as early adopters of net-zero energy buildings (NZEBs).

About 30% of the commercial space in India is owned by the public sector.[74] Committing to energy-efficiency retrofits of existing buildings and NZEB mandates for new construction can act as an important demand signal to architects, engineers, developers, financiers, and other stakeholders in the ecosystem. This can help push for appropriate technical capacity of the industry while driving down material and equipment costs for future NZEBs. Energy-efficient buildings will have the added advantage of reducing operational expenses for government entities, freeing up public funding in the long term for other priority areas.

RECOMMENDATIONS

1. Phased new construction mandates for public buildings and housing schemes

The Government of India can announce mandates for all new public buildings to be net zero in their operational energy using a combination of passive design, efficient equipment, and clean energy supply. The mandate should also include low-embodied-carbon requirements in the design and preferential material procurement for new construction. This can follow a phased approach, starting from a certain percentage of new buildings, moving to 100% over time as capacities are developed and cost savings are realised. Net-zero energy leases can be made mandatory for buildings where government entities are either lessees or lessors. To lead by example, there can be strict mandates first for central government ministries and PSUs. Moreover, there can be consideration for states to set timelines matching their existing policies and priorities, while progressive cities are engaged through cohort-based models.

This approach has proved successful in several countries. For example, in 2014, China's Ministry of Housing and Urban Development mandated all public buildings in major cities to be certified according to its national Green Building Energy Labelling certification.[75] The United States recently announced an ambitious executive order to achieve net-zero emissions across facets of federal operations by 2050, including in buildings by 2045 and a 50% reduction by 2032.[76] Currently, in India, GRIHA compliance (three stars) is compulsory for all new buildings and campuses constructed by central government organisations and PSUs. States such as Maharashtra have similarly pursued IGBC- and LEED-based compliance for new and renovated government buildings. Such mandates can be substantially enhanced, and their implementation can be made more transparent by creating online dashboards.

2. Deep-energy retrofits through performance incentive grants

Retrofitting of public buildings is gaining steam in India, with EESL playing a key role in providing capital, capacity, and project management services for energy-efficient appliances (see Exhibit 34).

Exhibit 34 EESL's national Building Energy Efficiency Programme

EESL launched the national Building Energy Efficiency Programme (BEEP) in 2017. BEEP aims to invest in retrofitting large public and private buildings. An estimated 1 crore LEDs, 15 lakh energy-efficient ceiling fans, and 1.5 lakh energy-efficient ACs are expected to be supported under this programme. EESL has also signed several memoranda of understanding with states, including Maharashtra, to execute this programme. Retrofits are implemented either at an upfront cost to the beneficiary or through an energy savings model. EESL functions as an ESCO as well as a project manager. Highlights as of late 2021 include the following:

- Total appliances retrofitted: 14,11,000 lights, 2,90,000 fans, and 35,000 ACs
- Public energy demand avoided: 30 MW (central government) and 45.5 MW (states and union territories)
- Cumulative emission reductions: 5,00,000 tonnes CO_2e

Source: Business Standard

The Government of India is poised to capture the momentum created by EESL towards deep energy retrofits that can generate significant savings and occupant comfort. Following comprehensive energy audits, public buildings can consider implementing the following measures over time:

- Building envelope enhancements (e.g., insulation, roofing, windows, doors).
- Lighting system enhancements (e.g., occupancy sensors, timers).
- Electrical system enhancements (e.g., installation of RTS and integration of DSM controls).
- Replacement of other end-use appliances (e.g., refrigerators, TVs).[77]
- A range of proven and emerging commercial building automation and control strategies, as described in this report.

The government may choose to encourage early movers through a performance incentive grant programme. First, energy consumption monitors can be installed to track performance of each participating public building. Since deep-energy retrofits tend to be long-term endeavours for building owners, the incentive can be tied to the percentage improvement of building performance compared with that in the previous fiscal year. Top performing buildings can be awarded grants for further energy upgrades. Cities, states, and ministries with best aggregate performance across several buildings can also be awarded. This performance-based incentive grant structure has previously been successful in the sanitation sector as a part of the Swachh Bharat Mission.[78]

NEXT STEPS

Who: *Government agency procurement and property managers.*

National, state, and local government agencies can use their positions as large purchasers and portfolio owners to move the market by aggregating demand for low-carbon products and services. National leaders can organise collaboratives to initiate and coordinate across myriad types and levels of government entities. Commitments can extend to government-led housing schemes as well.

1. Setting a vision, a baseline, and processes:

The Government of India can first set a vision for public NZEBs, including a phased new construction mandate and benchmarking/auditing programme for existing buildings. After evaluating this baseline, it can explore the feasibility and structure of a performance-incentive grant programme. Simultaneously, nodal agencies can be identified throughout states and cities to oversee the execution and implementation of the vision. A resource hub, guidebooks/manuals, and workshops on NZEBs can be developed for training public officials.

2. Creating "lighthouse" agencies and cities:

The national vision of public NZEBs can be supported by regional leadership in front-runner agencies and cities. Through cohort-based programmes, several government teams can benefit from hand-holding in the processes and nuances of net-zero energy tendering and deep-energy retrofits. Furthermore, peer-to-peer learning can be facilitated through a central lighthouse platform. Achievements by forward-thinking government entities can be showcased and highlighted to generate public awareness and create proof points for the public and private sectors. Data-driven documentation of these NZEB journeys can create a replicable pathway for the rest of the country.

B. Corporate Leadership Commitments

Corporate investment can favour low-risk, low-carbon solutions.

Progressive and forward-looking real estate players increasingly support the move towards net zero with ambitious sustainability commitments. Companies that do not proactively plan and implement sustainable business practices might see their businesses and valuations suffer, while those that manage this sustainability transition well may gain a commercial advantage.

RECOMMENDATIONS

1. Publicly commit to sustainability targets.

As companies set voluntary targets for reducing GHG emissions, the use of science-based targets is becoming a mainstream business practice. Numerous real estate companies globally have announced sustainability commitments using frameworks such as the Science Based Targets initiative (SBTi), World Green Building Council's Net Zero Commitment, the Better Buildings Partnership, the Architecture 2030 Challenge, the RIBA 2030 Climate Challenge, and The Climate Pledge (see Exhibit 35, page 90). Major private equity players have also begun standardising environmental, social, and governance reporting.

Publicly announcing sustainability targets can not only enhance public perception but also drive systemic change by raising market standards in the construction and buildings sectors. Being transparent about and accountable for progress towards those targets also builds trust and credibility among customers, stakeholders, and employees.

Climate-related risks will eventually manifest as business risks, and sustainable buildings offer significant economic savings potential. As markets evolve, the threats are not just limited to physical risks from natural calamities — equally important transition risks also need to be considered. The rising tide of climate-related regulations and penalties, technological advancements, changing customer behaviours, and stakeholder pressure can translate to legal, reputational, and market risks. In this context, initiatives such as the Task Force on Climate-Related Financial Disclosures provide comprehensive frameworks for risk assessment.[79]

According to an Oxford research initiative called the Net Zero Tracker, currently, about one of the three largest public companies in G20 countries have a net-zero target, including almost 20 Indian companies.[80] According to SBTi, one in five companies with net-zero goals are aligned with restricting global temperature rise to within 1.5°C.[81]

Exhibit 35 **Examples of corporate commitment frameworks**

FRAMEWORK	COMMITMENT	SCOPE	CORPORATE COMMITMENTS (AS OF LATE 2021)	ENERGY BENEFITS
SCIENCE-BASED TARGETS	Science-based targets tied to estimates of the global warming potential of activities and limiting global temperature rise to 1.5°C or 2°C.	• Scope 1 and 2 targets must be consistent with the level of decarbonisation required to keep the global temperature increase to well below 2°C compared with the preindustrial levels.[31] Companies are encouraged to aggressively pursue a 1.5°C trajectory (e.g., linear annual reduction rate of 4.2% per year for absolute reduction targets).[83] • A Scope 3 emissions target is required if a company's Scope 3 emissions constitute 40% or more of the total emissions (Scopes 1, 2, and 3).[83] • The use of offsets must not be counted as emissions reduction towards the progress of companies' science-based targets. The SBTi requires companies to set targets based on emissions reductions through direct action within their operations and/or their value chains.[82]	2,139 signatories.[82]	Targets are customised. This likely requires reducing majority of the Scope 1 and 2 emissions and a large portion of indirect Scope 3 tenant energy by the mid-2030s. See SBTi real estate sector examples.[81] Nonrenewable offsets are not counted.

FRAMEWORK	COMMITMENT	SCOPE	CORPORATE COMMITMENTS (AS OF LATE 2021)	ENERGY BENEFITS
ADVANCING NET ZERO	Net-zero carbon in operations for all assets by 2030. All buildings to be net-zero carbon in operations by 2050.	Applies to Scope 1 and 2 emissions (operational carbon) of buildings over which the entity has direct control and highly encourages including Scope 3 emissions.[84]	122 businesses, 28 cities, 6 states/ regions.[85]	By 2030, building areas under direct developer/ owner control must use 100% RE. Offsets are counted where 100% RE is not possible. WGBC has signalled it will likely expand its scope in the coming years to target corporate operations, tenant energy, supply chain, etc.[86]
BETTER BUILDINGS PARTNERSHIP	Real estate sector commitment to net zero by 2050.	Delivering net-zero buildings, including Scopes 1, 2, and 3 emissions, and operational and embodied carbon.[86]	30 signatories.[87]	Includes tenant and embodied carbon, has a long time frame of 2050, and offsets are counted.
THE CLIMATE PLEDGE	Achieve net-zero annual carbon emissions by 2040.	Net-zero carbon through efficiency improvements, RE, materials reductions, and other carbon emissions elimination strategies. Neutralise the remaining emissions with additional, quantifiable, real, permanent, and socially beneficial offsets.[89]	213 signatories.[88]	Does not specify scope but requires some net-zero carbon emissions by 2040, following an industry best-practice methodology. Offsets are counted.
ARCHITECTURE 2030	Design firms' commitment to make all new buildings, developments and major renovations to be carbon-neutral by 2030.	Building-energy consumption and GHG emissions.[90] These targets may be met by innovative sustainable design strategies, generating on-site RE, and/or purchasing (20% maximum) off-site RE.[91]	1,004 signatories.[92]	Carbon-neutral building operations in all designed buildings by 2030. Design-firm-focused commitment with widespread US-based architecture and engineering-firm adoptees. Separate commitment created for embodied carbon.[93]

FRAMEWORK	COMMITMENT	SCOPE	CORPORATE COMMITMENTS (AS OF LATE 2021)	ENERGY BENEFITS
RIBA	Design firms' commitment to net-zero operational energy and significant reductions in embodied carbon and potable water.	Achieve four targets by 2030:[94] • Reduce operational energy demand by at least 60%, before offsetting the remainder. • Reduce embodied carbon by at least 40%, before offsetting. • Reduce potable water use by at least 40%. • Achieve core health and well-being targets on temperature, daylight and indoor air quality.	330 signatories.[94]	Offered only to RIBA-chartered design practices but may serve as a relevant reference framework.

Sources: Science Based Targets, World Green Building Council, Better Buildings Partnership, The Climate Pledge, Architecture 2030, and RIBA

RECOMMENDATIONS

2. Adopt carbon accounting protocols across Scopes 1, 2, and 3.

Companies should follow internationally recognised GHG Protocol's accounting standard for Scope 1, 2, and 3 emissions to improve transparency and establish a baseline emissions inventory.[95] Comprehensive understanding of an organisation's emissions inventory positively influences decision-making and guides business interventions with the greatest priority. Following international frameworks, leaders can take direct action on Scope 1 and 2 emissions within the group's direct control by implementing various approaches described throughout this report.

While direct operational energy consumption often gets the most focus in real estate sustainability discussion, companies must also immediately begin addressing Scope 3 emissions within their spheres of influence, such as tenant energy, transportation, and embodied carbon. In fact, Scope 3 emissions likely make up the largest component of a real estate company's emissions inventory and put corporate influencers in a unique and crucial leadership position. As about 250 ancillary industries, including cement, steel, brick, timber, and other building materials, depend on the real estate industry, decarbonisation of buildings has the ancillary benefit of driving sustainability in the industries upstream and downstream in the value chain.[96]

3. Take action

For a corporate leader, the path towards a net-zero portfolio is a multiyear journey. Defining overarching north star goals for sustainability, organisations can create long-term value and receive support from various stakeholders in this transformative journey. While the north star goals serve as a long-term vision for the organisation, intermediate short-term goals and key metrics to measure sustainability must be defined. Following internationally recognised standard approaches and guidelines, companies should delineate savings solutions and put forth a sustainability roadmap for the company. This ambitious goal must be substantiated through ongoing assessment and a pragmatic approach, achieving milestone improvements within intermediate cycles with a feedback loop for continuous improvement.

Pilot projects and sustainability initiatives with a special focus on energy efficiency, operational energy, embodied carbon, waste, water, and transportation must be undertaken in short cycles. Successful pilot projects will provide opportunities to scale up feasible solutions and achieve significant emission reductions for the overall buildings' portfolio.

Tracking embodied carbon emissions in terms of kg of CO_2e per square foot is key to quantifying the benefit of material quantity reductions. Companies should go beyond reducing the impact of their operations (Scope 1 and 2 emissions) and look into Scope 3 emissions along the value chain, upstream and downstream. They can ensure the following:

- Set embodied carbon budgets for projects based on life-cycle assessment calculations.
- Specify material characteristics that lower embodied carbon.

- Encourage suppliers to transition to sustainable practices and obtain EPDs for their products.
- Design a supplier selection process that requires bidders to offer low-embodied-carbon products, and request embodied carbon data and EPDs from all vendors.
- Establish clear embodied-carbon-reduction targets, contracts, and guidelines to reduce construction waste.

Many large-scale buyers continue to accelerate India's clean-energy transition. Corporate leaders can commit to procuring only green products, thereby triggering demand to make emerging clean products and technologies accessible and scalable. Companies can use their purchasing power to initiate market demand for these green products. Similarly, large companies can pioneer the acceleration of deep decarbonisation efforts because of the availability of dedicated energy managers, large-volume energy demands, and appetite for innovation and adoption of new technologies that can decarbonise operations and supply chains.

In addition to committing to manufacture green products, building green, and purchasing clean energy, corporate leaders can engage in policy forums to drive change (e.g., case study: the Grain Belt Express Project[97]). Given the direct correlation between policymaking and customer impact, corporations can stimulate market opportunities for rooftop solar adoption, smart meter rollout, net metering, third-party financing for retrofitting, etc. They can also help expand and accelerate these efforts to match the scale and pace of climate action needed.

NEXT STEPS

Who: *Corporate C-suite leadership; environmental, social, and governance managers, government collaborating with NGO support.*

1. Publicly commit to sustainability targets.

2. Adopt internationally recognised GHG accounting protocols across Scopes 1, 2, and 3.

3. Take action: Draft a net-zero roadmap, develop administrative procedures and metrics, execute pilot projects, change corporate procurement and design practices, and engage in supporting policy and finance forums.

To jump-start corporate action, national, state, and local government leaders, with the support of NGOs, can convene corporate participants in a collaborative programme to build awareness, capacity, and momentum, initiating corporate commitments and aggregating private-sector demand.

C. Finance Innovation and Focus

Innovating financing and business models can overcome capital cost hurdles and split incentives, and prioritising financing flows can encourage net-zero buildings

The capital cost premium associated with net zero compared with conventional building is seen as one of the key challenges to mass adoption, even where efficiency and on-site generation result in lower operational costs and prove attractive in the long term. Another challenge of "split incentives" arises when the higher cost of construction is borne by the property developer, but the savings manifest only in the operational phase to benefit of the occupant.

Innovative financial instruments and business models can overcome this dissonance by realizing benefits for all key stakeholders:

Developers: Creating market incentives to help developers realise profits through net-zero construction.

Occupants: Helping buyers and tenants tap into mainstream finance to reduce both capital costs and ongoing energy costs.

Investors and financiers: Capitalising on low-risk investment opportunities estimated to be worth a cumulative $1.4 trillion (INR103 lakh crores) over the coming decade.[98]

RECOMMENDATIONS

1.Sustainable debt instruments.

The recent increase in sustainability initiatives from corporates in India resulted in rising interest in thematic sustainable debt instruments such as green or sustainability-linked bonds (SLBs). These bond issuances have several advantages over conventional debt, including the following:[99]

- Introduction of new pools of domestic and international capital from investors looking for long-term sustainability-aligned investments.
- Slight "premium" at the time of issuance such as lower debt costs and higher yields.
- Significant oversubscription levels of around 2–6x.
- Close interaction between the issuer and investor, and participation from impact-focused investors creating room to negotiate coupon rates.

In 2021, the market for green bonds in India stood at $7 billion, while that for SLBs totalled $1.2 billion. In real estate, issuances thus far have been limited to financial institutions creating loan products for green buildings or corporates developing green buildings for own use. This provides developers a strong opportunity to leverage innovative finance and emerge as leaders by tapping into the sustainable debt market. Exhibit 36, next page, explains the characteristics of green bonds and SLBs and proposes example structures for developers.

Exhibit 36 **Characteristics of green bonds and SLBs**

BOND TYPE	GREEN BONDS	SUSTAINABILITY-LINKED BONDS (SLBS)
Mechanism [100]	The proceeds from green bonds are used to finance new or existing projects with a positive environmental impact.	SLBs are linked to the achievement of specific climate or sustainability goals, such that progress (or lack thereof) towards predetermined indicators affects the instrument's coupon.
Use of proceeds (UOP)	Project categories eligible for green bond issuance include renewable energy, green buildings, and clean transportation.	Bond proceeds can be used for any project that helps meet predetermined indicators, such as carbon/GHG intensity of a real estate portfolio or product, or renewable energy procured.
Prominent examples [101]	*Adani Green Energy* — $2.1 billion (2021) towards wind and solar energy. *Axis Bank* — $500 million (2016) where UOP included the construction of LEED Platinum Axis House and installation of rooftop solar on other branches.[102]	JSW Steel — $500 million (2021), setting a KPI to reduce crude steel emissions intensity (Scopes 1 and 2) by 23% by March 2030 compared with a 2020 baseline.
Example structure for developer	Developer issues a green bond at project level to implement rooftop solar, EV charging, cooling equipment, etc.	Developer issues an SLB linked to existing Science-Based Targets Initiative commitments.

2. Net-zero mortgages and construction finance.

India's financial institutions — scheduled commercial banks, housing finance companies (HFCs), and NBFCs — are important stakeholders in its housing market, providing retail lending to buyers in the form of mortgages. They also contribute to developer- and beneficiary-led construction on the supply front by extending construction finance loans. These two products together form a large market: in March 2018, outstanding mortgage finance credit stood at INR16.5 lakh crores, while outstanding construction finance stood at about INR4 lakh crores.[103]

This financing market can play a catalytic role in India's buildings transformation by offering dedicated net-zero mortgages and construction loans as a part of retail offerings. Such mortgages and loans link to the energy performance or certification of a building to offer preferential interest rates, long tenures, and extended grace periods or cut down payments, justified by low total cost of ownership and reduced financing risk.

Financing terms help borrowers spread cost premiums over time with, at most, minor increases in equated monthly instalments that are offset by operational cost savings realised simultaneously. In the case of developers opting for net-zero construction finance, preferential financing can help offset incremental capital costs and overcome developer/occupant split incentives. Due to high principals and low risk, net-zero or other green mortgages can be structured such that financiers can enhance their income while improving the affordability of the asset. Microfinance institutions can explore similar approaches for beneficiary-led housing.

Green mortgage products, linked to GRIHA, IGBC, or EDGE buildings certifications, are starting to enter the market. Agence Française de Developpement and National Housing Bank's SUNREF programme is facilitating affordable green housing worth INR800 crore for local financiers.[104] Other international development finance institutions, such as IFC, KfW, the Asian Development Bank, and the CDC Group, also support local financiers such as the State Bank of India, HDFC Bank, and IIFL Home Finance through credit lines and technical assistance (see Exhibit 37).

Exhibit 37

IIFL Home Finance's Kutumb and Green Value Partnership programmes

IIFL Home Finance Ltd is one of India's largest HFCs, with a loan book of INR1.28 lakh crore ($1.7 billion) and 127 branches across the country. Recognising the impact its mortgages can have on adoption of green housing, IIFL launched the *Kutumb* initiative in 2018. Through *Kutumb* chapters conducted in five cities (and one virtual event), IIFL brought together local real estate stakeholders to disseminate information on the value of green buildings. Top architects, including IGBC, EESL, IFC, ADB, and CDC, among others, provided their technical expertise, and over 400 developers were engaged.

To sustain the momentum built via Kutumb, IIFL then established in-house expertise on IGBC, GRIHA, and EDGE certification through its Green Value Partner Programme. The Green Value Partner team assists first-mover developers throughout the life cycle of green-building projects. In 2020, it facilitated over 2,000 affordable green dwellings. IIFL provides construction finance to these and other green-certified dwellings. Thus, the company is establishing itself as a leader in the green-buildings space, driving impact across the value chain.

Sources: IIFL Home Finance Ltd and Asian Development Bank

With an abundance of rating systems and terminologies used to define transformative buildings (e.g., energy-efficient green, sustainable, net zero), financiers and developers lack a clear direction regarding the future of the market. The data required to justify the long-term value of net-zero *buildings* are often incomplete, especially given the lack of lessons-learnt platforms. Cost misconceptions are also common. Partnerships, such as IIFL's, between financiers and green-building experts can provide a much-needed level of rigour and quantification, ultimately improving the quantification of the benefits of net zero and real-world project financial performance.

Ultimately, such benefits and opportunities could be amplified to financiers by specifically providing subsector reporting of green buildings within the broad real estate industry reporting.

3. Net-zero energy leases

In 2019 before COVID-19, new commercial leases for office spaces across India's six largest cities totalled approximately 56 million square feet.[105] Net-zero leasing offers a pathway to leverage this growing use case for energy and cost savings in new and existing buildings.

These specially designed leases include six components:

- Electricity costs included in lease.
- Energy efficiency or solar PV project costs passed to tenants based on modelled energy savings as an operational expense.
- Submetering and energy data disclosure.
- Regular appliance and equipment recommissioning passed to tenants as an operational expense.
- Allocation of an energy budget to each tenant based on renewable energy generation or energy use intensity.
- Exceeding the energy budget triggers additional charge, RECs procurement, additional auditing, and corrective action.

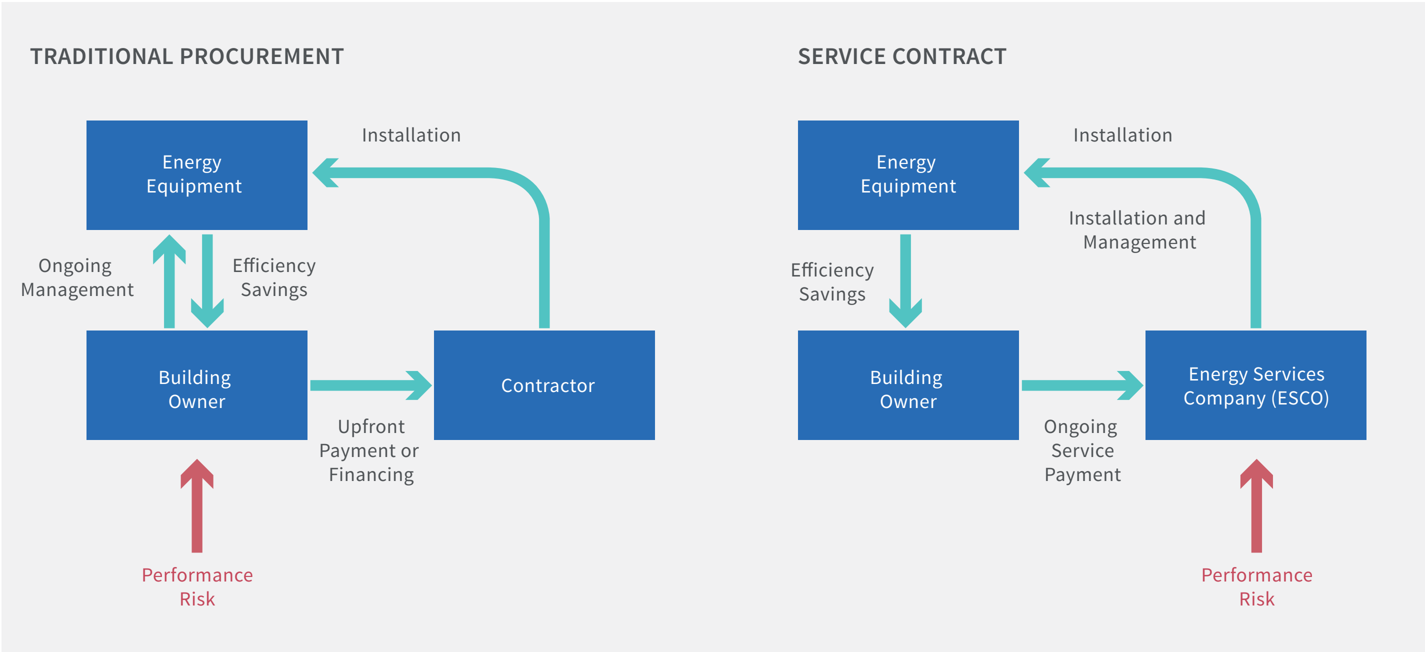
The above net-zero energy language in leases helps increase landlords' operating cash flow and sale value premium, eliminating issues presented by split incentives. Tenants can pay a market rate on their lease with lower operating costs even after accounting for expenses passed down from efficiency investments.[106] Execution of energy efficiency, solar PV, and recommissioning can also be done by ESCOs on shared or guaranteed savings contracts.

For district-scale developments such as large office parks, IESP business models present attractive financial returns for developers and their investors with low costs for tenants. This is done through third-party ownership of on-site solar PV, use of district cooling or other third-party cooling to move capital costs out of buildings, and on-bill financing for energy efficiency.[107]

4. Service contracts for energy efficiency

In case of purely operational energy, alternative business models are necessary to make efficiency more affordable for new buildings and retrofits. Service contracts shift upfront cost, project management, and performance risk from building owners or occupants to third-party ESCOs (see Exhibit 38, page 100).

Exhibit 38 Mechanisms of traditional procurement and service contracts



Source: Modified from US Department of Energy

Energy service performance contracts (ESPCs) and efficiency-as-a-service (EaaS) models are the two types of service contracts. There can be different contract structures within ESPCs but the shared savings model is most commonly used in India.[108]

Shared savings ESPCs — The ESCO provides the financing required for implementation. The agreement between the ESCO and the owner/occupant determines the ratio at which the two parties will split the resulting energy and cost savings. At the end of the contract, once the ESCO recoups its investment, the energy and cost savings solely belong to the owner/occupant. This model is highly appealing to the owner/occupant, although the shifting of technical and credit risk to the ESCO poses its share of challenges. Particularly for large projects with long contracts, ESCOs struggle to raise capital and financing to foot the upfront costs required. Baselining of energy consumption before implementation and monitoring, and verification afterward are key to successful contracting and require effective deployment of an ESCO's resources.

Efficiency-as-a-service — Owner/occupants in EaaS contracts do not intend to own equipment and instead purchase energy savings from ESCOs for a predetermined duration. This is an asset-heavy business model for ESCOs that own efficiency equipment in the long term. For owners/occupants, efficiency is paid for on the performance as baselined before the contract. At the end of the contract, they may choose to extend the agreement, purchase the equipment at a fair market value, or return the equipment. The flexibility afforded by the EaaS model is ideal for commercial buildings where tenants may initially be hesitant to invest in efficiency. However, it requires financially strong ESCOs, similar to ESPCs.

India's ESCO market for residential energy efficiency is significantly supported and scaled by the government. Investors and financiers seek strong signals and commitment from the union territories and state governments, including targets and fiscal/nonfiscal incentives. Recognising the importance of financiers in developing this market, BEE established the Partial Risk Sharing Facility for Energy Efficiency and the Venture Capital Fund for Energy Efficiency in 2016.[109] These facilities can complement the development of net-zero lease programmes in India. To further support ESCOs, more dedicated credit lines can also be developed, hosted by entities such as BEE.

NEXT STEPS

Who: *Reserve Bank of India (RBI), Government of India, finance industry associations.*

Financial policy can direct resources towards carbon mitigation solutions in the buildings sector, including coordination and financial product development with private-sector finance, supported by collaboration with policymakers and industry groups:

1. Developing taxonomies: The RBI can consider setting definitions and baselines on building types that can qualify as net-zero energy and deep-energy retrofits. Notifying net-zero mortgages as a separate sector for credit reporting will enable disclosure and thus help develop insights into the financial performance of high-performance buildings.

2. Creating supportive incentive structures: The Government of India can implement tax deductions for interest paid on net-zero mortgages (similar to Section 80EEB deductions for interest paid on EV loans in the Income Tax Act). Interest rate subventions can also be explored.

3. Hosting industry platforms and forums: Entities such as the Indian Banks Association, National Housing Bank, and RBI can host convenings on net zero to share learnings and increase collaboration between financiers and developers. Programmes such as the Green Lease Leaders, organised by the US Department of Energy to recognise high-performance leases and model green bonds/SLBs, can be established to encourage early adopters. The government can also focus on creating awareness of benefits of net-zero financing and produce replicable guides that industry can use.

D. Integrated Resource Planning

As buildings consume and produce significant amount of energy, they will play a crucial role in grid stability and energy security of future energy systems through active participation in distributed generation, energy efficiency improvements, DSM solutions, and flexibility services. Integrated resource planning captures and redirects the whole-system value of demand-side solutions within supply-side planning. Because of its complex policy, regulatory, and programme nature, the transformation would be led by the government collaborating with utilities, regulators, service providers, and others.

“Negawatts” can be the first grid resource.

Amory Lovins, RMI’s cofounder and chairman emeritus, says, “Energy efficiency is empirically an expanding-quantity, declining-cost resource. Its adoption is increasingly motivated by positive externalities but constrained by strong, diverse, complex, and challenging market failures requiring both policy intervention and business innovation.” India is at a crucial juncture in terms of floor area growth (expected to more than double, as per Exhibit 4, page 15), cooling access (expected to comprise 45% of the peak load), high-quality electrical service, and infrastructure strain due to climate change.[110] India has the opportunity to look holistically at its historically expanding and improving electricity sector and “plan it right the first time,” maximising energy services, minimising whole-system capital investment, reducing operational costs, and eliminating carbon emissions. It can provide better energy services at low cost and ensure low emissions through integrated resource plans (IRPs) that include the so-called *negawatts*, or DSM, as the first grid resource.

DSM solutions have already begun to take shape in India. Recent policies are beginning to acknowledge the pivotal role demand-side technologies and transformative market mechanisms can play in achieving deep decarbonisation and addressing the challenges arising from high variable renewable energy penetration. For instance, the recently published Draft National Electricity Policy 2021 issued by the Ministry of Power emphasises the importance of energy conservation and DSM. State electricity regulatory commissions will soon be required to mandate discom-driven DSM programmes and notify incentives for DR.[111] To encourage DSM solutions, the National Tariff Policy envisages the introduction of a differential tariff between peak and nonpeak hours.[112] Realising the potential of these flexibility services can be an important strategy in integrated resource planning because it can save investments associated with expanding grid infrastructure and reduce the overall cost of electricity for end-users.

Advanced-metering-infrastructure rollout will enable high-value, targeted DSM programmes, and their measurement and verification will help DSM solutions empirically solve grid investment and reliability challenges. Leading discoms are beginning to pilot DSM programmes, including limited examples targeting energy efficiency, which can guide the policy that broadens the application of DSM within IRPs. These demonstrate that programmes and their guiding regulations can be crafted to the mutual benefit of utilities with business models crafted to deliver high-quality energy services; customers who save on energy bills while receiving high-quality energy services; and the broad society, which benefits from energy-system externalities such as health, environment, and resilience.

DSM can go much further with whole-system, integrative approaches to overcome discom, regulatory, and business barriers. India's discoms currently have insufficient financial mechanisms or motives to engage in the full suite of DSM solutions to grid needs. Additionally, discoms are generally financially constrained, with many operating at a loss, making discom incentives challenging without fundamentally new business models. By taking a whole-system approach to regulations and business models, discoms could benefit from an expanded suite of DSM programming investments directly and indirectly (see Exhibit 39, page 103).

Exhibit 39 **DSM programme benefits to discoms**

MONETARY BENEFITS	ENERGY BENEFITS	NON-ENERGY BENEFITS

• Delivering and receiving compensation for negawatts as an alternative to megawatts of new generation capacity.
• Deferred capital expenditure.
  ◦ From grid expansion (distribution transformers, high voltage cables, etc.) to accommodate increasing peak loads.
  ◦ From additional generation capacity.
  ◦ From expansion of distribution assets, especially in land-constrained cities
• Avoided costs from blackout-related system damages.
• Lower peak power purchase costs.
	• Reduced peak power demand.
	• Reduced supply-side reserve capacity requirements.
	• Efficient incorporation of variable renewable energy resources and minimising fossil-based power generation to meet peak hour demand.
	• Extended asset life by preventing excess loading and overheating of distribution assets (transformers, cables, etc.).
	• Mitigation from fuel price shock risks.
		• Improved power quality and reliability.
		• Increased customer satisfaction due to fewer power outages.
		• Reputational benefits from promoting renewable energy generation and -distributed renewable energy generation and reducing the share of fossil-based generation.
		• Societal benefit of reducing the carbon footprint of the electricity sector.
		• Mitigation of infrastructure risks related to climate change.

RECOMMENDATIONS

The power generation mix is evolving to accommodate the growing share of renewable energy required under the government's ambitious target to install 500 GW of nonfossil fuel capacity by 2030. International experience indicates managing the electricity demand entails an array of supply-side measures and DSM.

Supply-side measures: India has significant potential for power generation from renewable energy sources, and all efforts must focus on the integration of RTS, battery storage, and other types of DERs into IRPs. Considering the economics of generation and transmission, system losses, load centre requirements, energy security, and environmental considerations, including rehabilitation and resettlement, RTS deployment can be an important strategy in IRPs because it can avoid investments associated with expanding grid infrastructure and reduce the overall electricity cost for end-users.

Demand-side measures: Expanding DSM, especially energy efficiency, into IRPs and new business models for discoms would require unprecedented coordination across a range of stakeholders and contributors — discoms, regulators, policymakers, and solution providers such as ESCOs and manufacturers.

These parties would engage in a series of collaborative actions:

- **Demand-side resource assessment —** Quantified characterisations of the energy efficiency and DR resources within a state, discom service area, or other programme jurisdiction can be used for resource planning, policy development and programme budgets, and indicate emerging priorities for market-solution providers. A detailed assessment and comprehensive understanding of consumer behaviour, granular techno-commercial data on the penetration of appliances, and implications of tariff approaches could identify opportunities for high levels of energy efficiency and load flexibility.
- **Regulatory framework for:**
  - Continual assessment of the societal cost/benefit of DSM resources, in comparison with supply side–only approaches. This can include avoided capacity and non-energy benefits such as resilience, health, and end-use energy service, as well as energy costs.
  - Ensuring the capture and sharing of whole-system benefits across relevant entities — DSM programme participants, all ratepayers, service providers, utilities.
  - Rate-basing of cost-effective DSM programmes.
  - Fully performance-based discom regulation, including demand-side imperatives.
- **Implementation** of energy efficiency and demand flexibility programme offerings by utilities or in formal collaboration with dedicated, ratepayer-funded agencies.

Examples of demand-side programme implementation are abundantly available internationally and generally fall into two broad categories of activity — energy efficiency and demand flexibility:

Energy efficiency is the permanent and continuous reduction of energy consumption. As detailed elsewhere in this report, energy efficiency is achieved by a range of technical measures in new and existing buildings:

- Designing or retrofitting for passive energy efficiency.
- Selecting premium efficiency fixtures and equipment.
- Retro-commissioning or adding controls and automation to building systems for more efficient operation.
- Motivating energy-efficient behaviours by building occupants using gamification and other behaviour motivators.

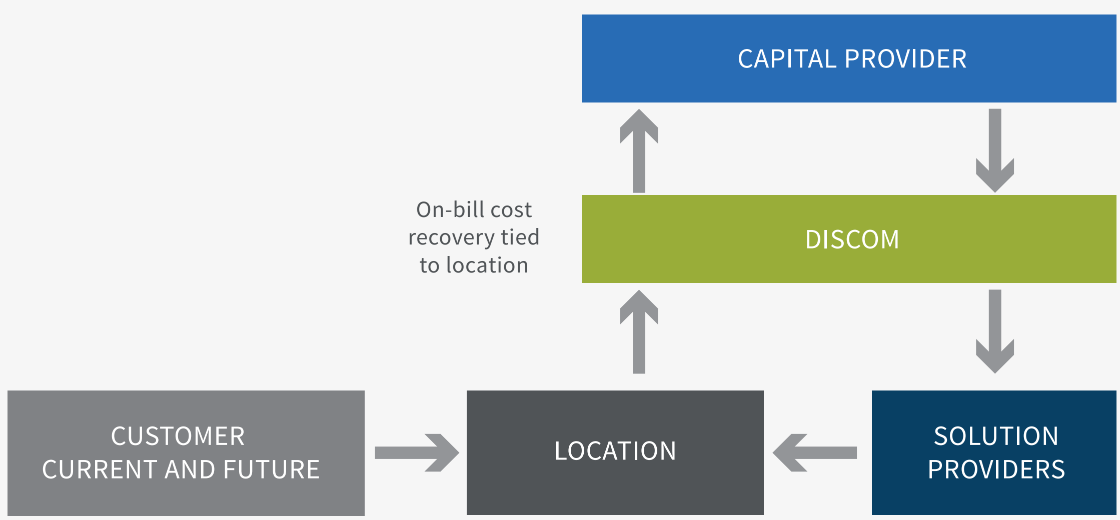
DSM can drive these energy-efficiency improvements via a range of programme types:

- Equipment rebates and other types of incentives to reduce the incremental cost of efficient investments.
- Energy-efficiency financing (see Exhibit 40).
- Awareness, labelling, and marketing campaigns.
- Creation of solution provider networks to increase market availability of energy-efficient products and services.
- Funding R&D of new technologies, solutions, or pilot programmes.
- Market transformation partnerships that coordinate all of the above — technology-targeted policies and other market development — to accelerate broad solution uptake.

CEEW describes such a coordinated approach for the example of superefficient ceiling fans, capable of reducing peak power generation in India by 14 GW (7%).[113]

Exhibit 40 Pay As You Save®

Pay As You Save® (PAYS®) is an example of a targeted financing DSM programme offering crafted to overcome capital-cost barriers to deep-energy efficiency in buildings and equipment. India could potentially adapt PAYS and accelerate the rollout of superefficient cooling, benefiting both the customer and the discom planning for exponential growth in cooling demand. Building on discom investment models, PAYS offers energy efficiency and clean energy upgrades on-site to any customer segment, without a loan, credit check, or customer debt. The dicom pays for the installations, and its investment is recouped via a fixed tariff on the customer's monthly bill. The upgrades must be cost-effective and crafted so that the tariff is more than offset by monthly energy bill savings, resulting in a net savings for the customer. In the case of a change in occupant, the tariff stays with the meter location and automatically transfers to the next occupant.



Source: EEtility

Demand flexibility temporarily shifts or sheds electricity demand in response to grid conditions to save energy costs, reduce fossil-fuel consumption and carbon emissions, help balance grid loads to ensure electricity service, and provide resiliency services in the event of power outages. Time scales vary from daily energy shifting to hourly load shaping to near real-time load balancing services.

Examples of demand flexibility measures include the following:

- Cooling arbitrage: cooling setbacks or pre-/post-cooling
- Grid-optimised electric vehicle charging
- Electrochemical battery storage
- Thermal energy storage
- Staged HVAC ramp-up or equipment charging
- Storage water heaters
- Off-peak appliance operation
- Variable modulation of other flexible loads
- Island-mode storage and load control during power outages

DSM can drive demand flexibility to varying degrees via a range of programmes and signals:

- Demand response calls for isolated events
- Dynamic real-time or time-of-use signals
- Peak demand charges or other tiered or slabbed rate structures
- Direct load control by DR operators and aggregators
- Other manual and automated aggregation signals and methods

A number of data solutions are emerging to make DSM more impactful and cost-effective, much of which can leverage the advanced metering infrastructure currently rolling out across India. Advanced-metering-infrastructure data can identify high-priority customers, customer segments, and even end uses, informing DSM programme design and targeting, and supporting aggregators and solution providers. High resolution data can also inform demand-side investments in grid planning, which will be crucial in orchestrating intermittent renewables and flexible demand in an evolving grid. Open sourcing data and analytics, with protocols for customer privacy, will maximise value and ensure insights are investment-grade.

NEXT STEPS

Who: *Discoms, regulators, energy efficiency, and demand-flexibility service providers.*

India is experiencing remarkable economic growth and electrification. Rise in the electricity demand, industrial growth, cooling loads, and popularity of EVs may pose a potential supply–demand mismatch challenge to the electricity grid in the near future. Moreover, growth in rooftop solar and battery storage as well as smart and superefficient appliances and equipment presents new technological opportunities. Discoms in India have the opportunity to aggregate various DER assets through energy efficiency and demand flexibility programmes, helping reduce power procurement costs, defer capacity expansion, and minimise peak loads in a more resilient power grid.

Discoms can explore opportunities for demand-side programmes and services within their regulatory frameworks and business plans. Although the development of IRPs at the discom level is currently limited, IRPs can be initially coupled with large capacity expansion plans in the state, showing immediate benefits of reduced peak loads and low power purchase costs. Discoms may find value in phase-wise deployment and scaling of energy efficiency, demand flexibility, and RTS for particular consumer classes. Custom auditing of high-energy consumers or customer segments to identify energy savings measures can resolve particular power issues.

A recommended next step is collaboration among discoms, regulators, and efficiency experts to conduct a sizing study at the state level to quantify the generation potential of DER assets such as RTS and supply-side value of DSM solutions, including energy efficiency and demand flexibility. These state-specific sizing studies and IRPs should be aligned with the national IRP, which can be subsequently foundational for policy and programmes to motivate and share the financial benefits of such a whole-system approach, enacted within IRPs by utilities and their regulators.

E. Crosscutting statutory mechanisms

Much already has been studied, written, and implemented regarding energy codes. Energy Conservation Building Code (ECBC) and Eco-Niwas Samhita (ENS) are expected to help building performance take a massive leap forward, setting a legal floor and altering the direction of the industry. The codes also include annexures indicating their likely future direction. Building on these advances, three mechanisms will ensure this progress continues and maximises the buildings sector's contribution to India's NDCs: a code roadmap to zero, embodied carbon codes, and building performance standards. This long-term statutory target setting can begin now even if, *or especially* if, winning technology solutions are not necessarily known today.

Building code roadmap to zero

A code roadmap to zero would create official policy to arrive by a target date at the destination of a zero-energy code, with an official definition by design energy use intensity. This sets the overall direction and speed for the industry. A collaborative stakeholder and data-driven process can be used to develop code updates with intermediate time steps on a regular, known cadence. This collaborative visibility will allow the real estate, design, and construction industries to adapt in a timely and cost-effective manner through workforce development, innovation, investment, and cost compression. It will provide a similar focus for academia, enforcement bodies, NGOs, and all actors within the building space.

Rigorous and transparent cost-effectiveness and market-readiness tests are best practices internationally in the continual development of energy codes and equipment standards, helping achieve industry and policymaker consensus while staying at the leading edge of adoption. Regular national and regional inventories of building stock, equipment and energy end uses (e.g., the US Energy Information Administration's Commercial Buildings Energy Consumption Survey and Residential Energy Consumption Survey) gauge the speed and success of the transition and provide crucial market characterisation data for policy and programme implementers and market solution providers.[114] The code enforcement process can also be a feedback loop on progress. Tools such as RESCheck or COMCheck can simplify compliance processes while tracking key prescriptive elements — leveraging easy-entry equipment efficiency ratings, wall assembly standard values, standardised glazing compliance documentation, etc.[115]

Optional annexures within model codes would allow leading jurisdictions to advance ahead of their peers for competitiveness, environmental, or energy prosperity reasons. Alternatively, these appendices could be used as stretch codes tied to incentive programmes.

The code roadmap can also expand the scope of the code stepwise to include key items such as controls and automation, demand flexibility, fuel switching, renewables procurement, and embodied carbon. Renewable requirements, in particular, are key sub-components of zero codes gaining traction in leading jurisdictions globally. As regulations, business models, and markets mature for on-site or off-site renewables procurement by the buildings sector, renewables or solar-ready construction could become mandatory for certain market segments, building typologies, or city/regional planning situations.

Embodied carbon codes

Embodied carbon was not historically included within energy code jurisdiction or other statutes but doing so can help India progress most cost-effectively towards its ambitious climate goals. Embodied carbon codes would be the culmination of foundational efforts: embodied carbon design force development, supply chain disclosure and targets, and voluntary accounting and commitments by government and corporate leaders. Data and protocols would be incorporated into energy codes for new construction, described in terms of materials, systems, and whole-building accounting, recognising low-carbon design and construction, as well as low-carbon-material selection.

Building performance standards

A building performance standard can be the ultimate driver of realised energy efficiency. While codes and standards drive design, a building performance standard ensures actual operation. The first step is an energy benchmarking ordinance. Benchmarking requires buildings over a certain size threshold to publicly submit their actual energy performance — normalised by size, weather, and occupancy — enabling comparisons among peer building groups. This, by itself, allows investors and occupants to differentiate and create market preference for high-performance buildings on normalised energy benchmarking data. A national database platform and discom data exchange protocols can simplify administration and benchmarking compliance processes.

In a game-changing recent advancement, a growing number of leading cities are leveraging energy benchmarking data to adopt building performance standards — statutory maximum energy consumption limits for buildings. Buildings exceeding energy quotas are required to remediate or pay fines.[116] Performance criteria can be calibrated to trigger improvements among worst performances first or across a broad swath of the building stock, and energy consumption limits generally ratchet down on a publicised cadence towards a long-term, sector-wide policy goal. In conjunction with or as a result of such a coordinated policy impetus, groundswell ecosystems of public programmes and private solutions converge to meet the financial and implementation demands of mass-market energy improvements.

A building performance standard has a tremendous regional rallying effect, focusing real estate investment, design services, innovation of solution providers, and policy development on timely carbon reductions. This rallying effect can be even larger via a coordinated national-level coalition, such as that recently announced by US President Joe Biden's administration.[117]

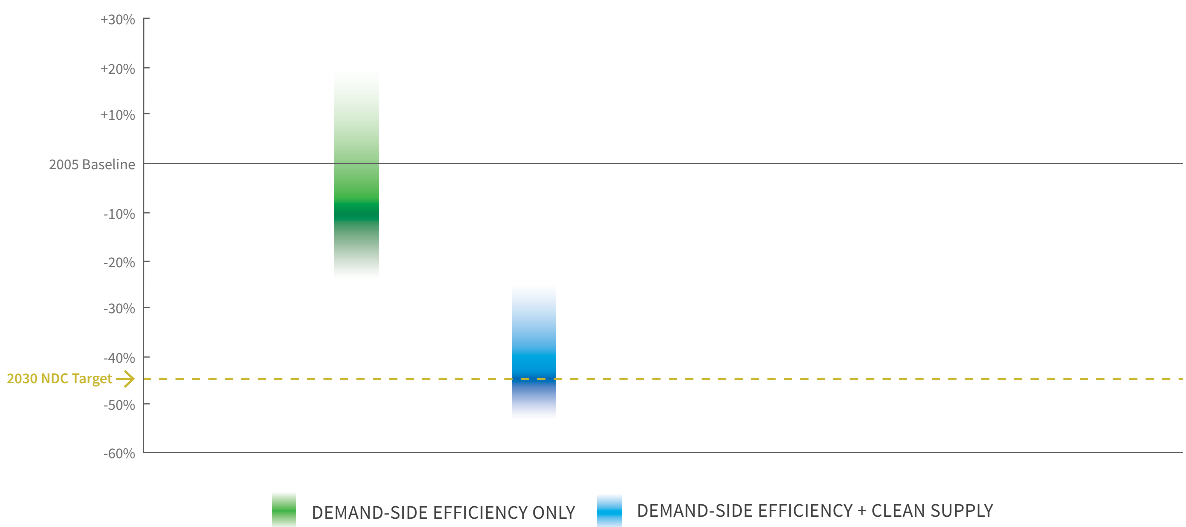
Appendix A: Buildings Sector Contribution to India's NDCs

Transforming the buildings sector can be a cornerstone to realising the ambitious NDC commitment of reducing India's emissions intensity by 45% by 2030 from that in 2005. Exhibit 41 below represent the buildings sector's carbon reduction potential in terms aligned to this NDC for decreasing the carbon intensity per gross domestic product (GDP). This methodology for building operational energy includes Scope 1 and Scope 2 emissions, with carbon-saving measures within the buildings and on the supply side of the electric grid for total reduction.

Exhibit 41 focuses on the analysis included in this report, showing integrated applications of the latest technologies bending the energy growth curve while GDP increases and the electricity sector approaches the 50% renewable energy NDC target. Together with the whole-system approach, the buildings sector has the potential to cut carbon emissions intensity by 45% by 2030 compared with that in 2005, in line with the NDC.

Exhibit 41

Change in building sector operation emissions intensity (CO_2 per GDP) by 2030 from 2005 baseline



Note: Fade indicates a range of sensitivities and outcomes under two 2030 secnarios

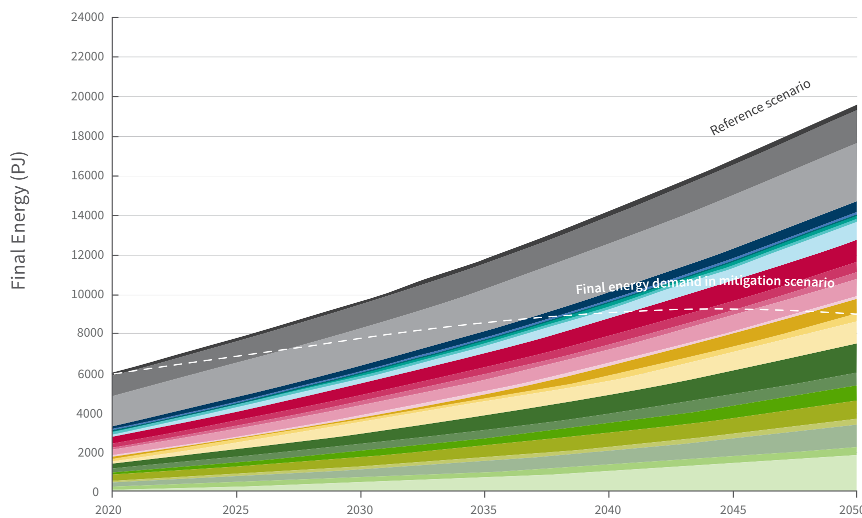
Exact reduction calculations are sensitive to ranges and uncertainties across inputs and assumptions. Range fields in Exhibit 41 reflect operating CO_2 that can vary from approximately flat energy use per floor area from the current levels (despite significant improvements in energy services) to the unmitigated reference energy growth scenario used in this report. Due to the increase in cooling access and other energy uses in India since 2005, an unmitigated scenario would show a rise in carbon intensity compared with the baseline, which is included at the top of the range field below. In the analysis following Exhibit 41, the 2030 GDP is given a range field of +/-10% from this report's core GDP assumption. The 2005 baseline represents another potential source of uncertainty in this analysis. However, for the purpose of this illustration, the baseline is defined and fixed without a range field (using India GDP of $820 billion and operational CO_2 emissions of 190 billion tons in 2005).[118] Further work and intersectoral collaboration will be required to determine official baseline values, calculation methodologies, sectoral attributions, reduction potential, calibrated targets, and sensitivities that collectively roll up to achieve India's NDCs by 2030.

Appendix B: Detailed Projections of India's Building-Energy Demand and Emissions Mitigation Scenarios from the Bottom-Up Model

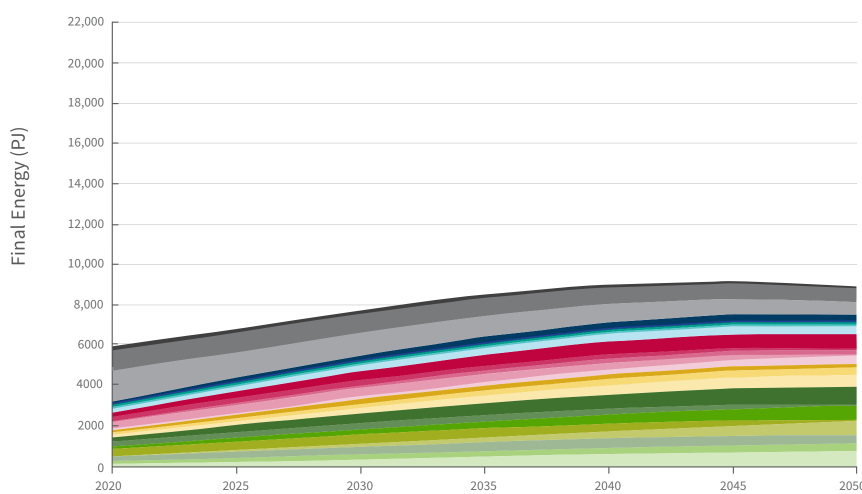
Exhibit 42

Buildings sector final energy consumption through 2050

A. Unmitigated reference scenario



B. Mitigated, aligned with COP26-announced goals (Demand-side efficiency)



EMBODIED (OTHER)
EMBODIED CEMENT
EMBODIED STEEL

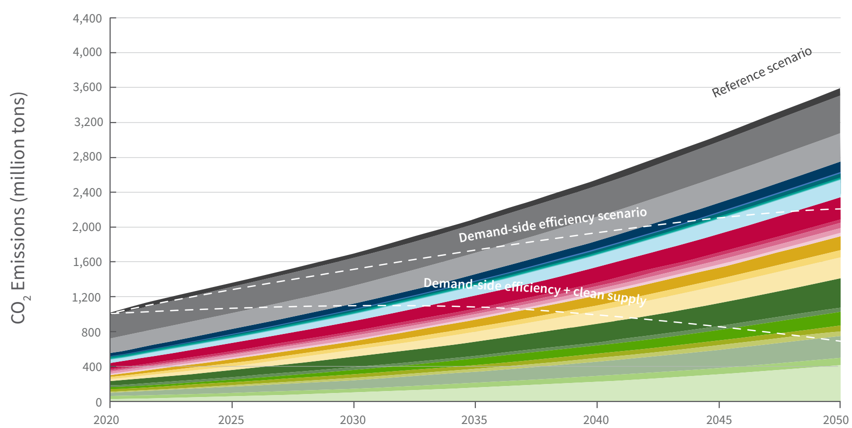
COMMERCIAL
APPLIANCE/PLUG
LPG/PNG WATER HEATING
ELECTRIC WATER HEATING
LIGHTING
FANS
AIR CONDITIONING

RURAL RESIDENTIAL
APPLIANCE/PLUG
LPG/PNG WATER HEATING
ELECTRIC WATER HEATING
LPG/PNG COOKING
ELECTRIC COOKING
LIGHTING
FANS
AIR CONDITIONING

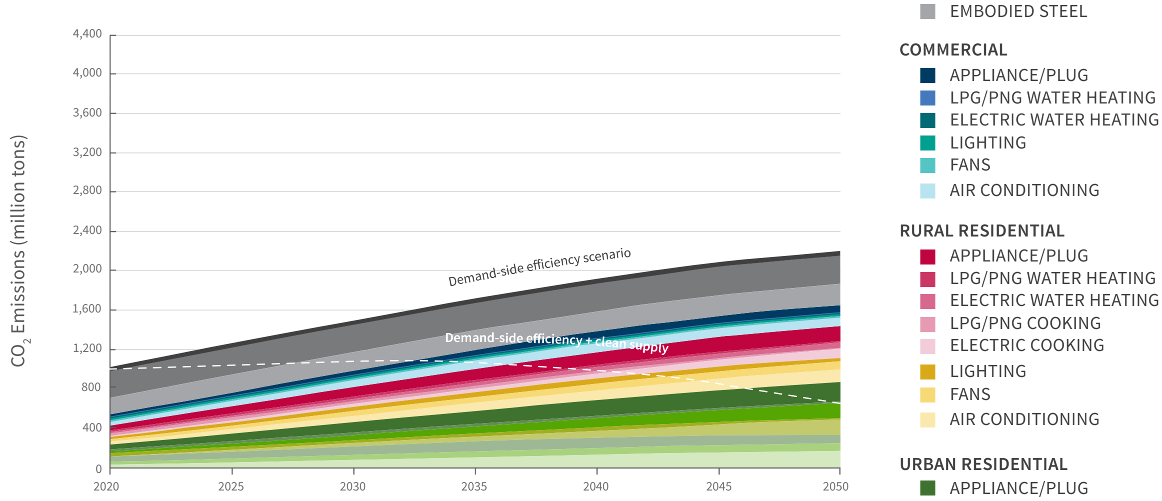
URBAN RESIDENTIAL
APPLIANCE/PLUG
LPG/PNG WATER HEATING
ELECTRIC WATER HEATING
LPG/PNG COOKING
ELECTRIC COOKING
LIGHTING
FANS
AIR CONDITIONING

Exhibit 43 Buildings sector carbon emissions through 2050

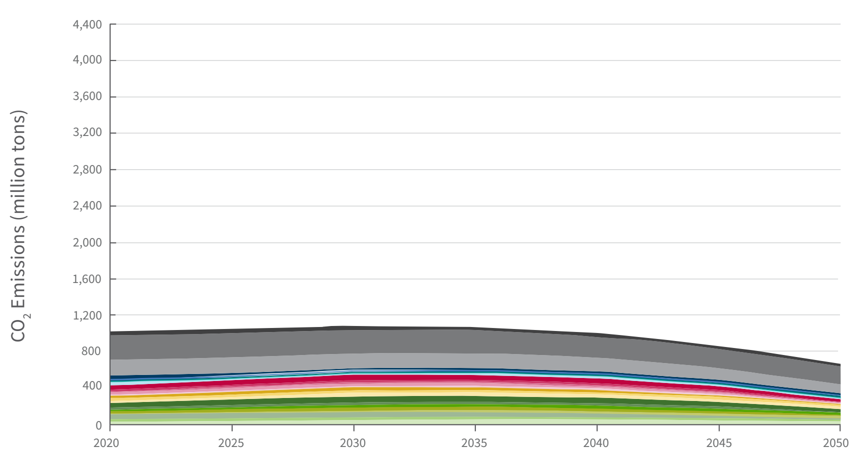
A. Unmitigated reference scenario



B. Mitigated, aligned with COP26-announced goals



C. Mitigated, scenario (Demand-side efficiency + clean supply)



The analysis in this report uses a five-step process to estimate the reduction potential compared with a reference scenario:

- **Building stock projection —** Quantify building stock today and its future projections using macroeconomic indicators, as described below. Stock is divided into three subsectors: commercial, urban residential, and rural residential.

- **Current subsector energy consumption —** Estimate energy consumption today for each sector by calibrating building stock floor area to top-down energy data and verifying reasonableness against energy performance index (EPI, in kWh/m^2-yr) estimates from other studies/benchmarks.

- **Subsector energy consumption projections**

  - **Reference scenario —** Project subsector energy consumption in the reference scenario by trending towards EPIs that reflect the build-out of code-compliant new construction.

  - **Demand-side-only scenario —** Project subsector energy consumption in the mitigated scenario by trending EPIs towards best practices.

- **Correlation of carbon emissions for scenarios —** Generate carbon emissions projections for scenarios in item 3. First, use today's grid electricity emissions factors to isolate and illustrate the demand-side potential for this report. Next, generate carbon emissions for a demand-side + clean supply scenario using grid emissions factors that trend towards compliance with India's clean power NDC. Emissions factors for Scope 1 fossil fuels are consistent between scenarios.

- **End-use breakdown —** Further divide subsector EPIs into end uses by utilising methodologies described in a previous publication by the report's analysis partners, with additional calibration to sectoral consumption from item 2 by individual fuels.[119]

This top-down methodology and comparison to a reference future scenario are intended to underscore the building sector's maximum potential decarbonisation impact if it were to act upon its whole-system range of influence and realise industry best practices.

Moving forward from this study, further analysis is recommended — and some already undertaken — to inform nuanced policy decisions and investments. This can include the following:

- More comprehensive and granular measurement and tracking of current building stock energy performance.

- Detailed target setting across building subtypes, geographies, and operating modes.

- Detailed study and ranges of code compliance and adoption scenarios.

- Translation of normalised energy performance into equipment efficiency subroadmaps.

- Ranges related to uncertainties in renewable energy tariff.

- Future and urban climate scenarios and their impact on energy consumption and stock characteristics.

Building stock projection using macroeconomic drivers

Building floor space is driven by a country's macroeconomic conditions, as illustrated in Exhibit 44. We first model India's macroeconomic development and urbanisation process. We assume the country's GDP will grow 5% on average per year and its population will increase 1% from 2020 to 2025 before gradually slowing down to 0.5% from 2045 to 2050.[120] The urbanisation rate assumes a continued shift in population from rural to urban, increasing from 36% of urban in 2020 to 50.3% in 2050.[121,122] In 2050, about 843 million people are expected to live in cities compared with 492 million in 2020.

Exhibit 44 Indian major macroeconomic indicators forecast assumed in analysis

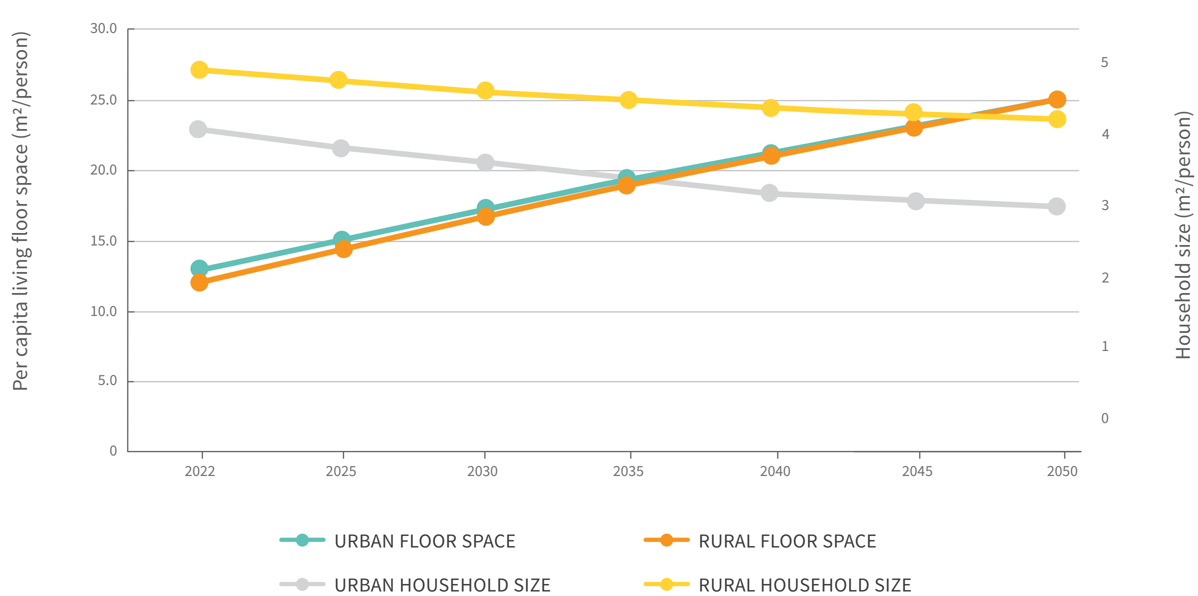
	2020	2025	2030	2035	2040	2045	2050
Population (million)	1366.8	1429.4	1487.5	1540.3	1587.0	1635.2	1676.5
Per capita GDP ($ k)	2.114	2.580	3.164	3.900	4.831	5.927	7.308
GDP ($ billion)	2889.6	3687.9	4706.8	6007.2	7666.8	9692.2	12252.6
Urbanisation rate (%)	36	38.8	41.2	43.5	45.8	48.1	50.3
Urban population (million)	492.0	554.6	612.8	670.0	726.9	786.5	843.3
Rural population (million)	874.7	874.8	874.6	870.3	860.2	848.7	833.2
Service sector GDP share (%)	50	52	54	56	58	60	62
Service sector GDP ($ billion)	1444.8	1917.7	2541.7	3364.0	4446.8	5815.3	7596.6
Service sector GDP/employee ($ k /person)	8.5	9.4	10.9	12.8	15.1	18.0	21.7
Urban per capita floor space (m^2 per person)	12.4	15.0	17.3	19.3	21.2	23.1	25.0
Rural per capita floor space (m^2 per person)	11.5	14.5	16.8	18.9	21.0	23.0	25.0
Commercial per capita floor space per employee (m^2 per person)	10.7	10.7	10.7	10.7	10.7	10.7	10.7

	2020	2025	2030	2035	2040	2045	2050
Annual rate of new construction addition (billion m²)							
Urban Residential	0.52	0.57	0.62	0.69	0.76	0.86	0.95
Rural Residential	0.60	0.69	0.66	0.66	0.66	0.65	0.65
Commercial	0.13	0.17	0.20	0.23	0.27	0.30	0.31
Total	1.25	1.43	1.48	1.59	1.70	1.81	1.91

Per capita living floor space is an important parameter in modelling residential building stock. In 2020, the average household floor size was 54 m^2/household in rural areas and 49.4 m^2/household in urban areas, and the average household size was 4.5 people in rural areas and 3.8 people in urban areas. Moreover, the per capita living floor space in rural and urban areas was 11.5 m^2/person and 12.4 m^2/person, respectively. In 2050, due to economic growth, people's living conditions will improve significantly, and per capita living floor space is assumed to increase to 25 m^2/person in rural and urban areas (Exhibit 45). These assumptions are based on official dwelling unit surveys and comparisons of India's per capita residential floorspace to historic trends in other countries.[123]

Exhibit 45

Per capita living floor space in urban and rural areas assumed in analysis



The employee workspace in commercial and public buildings is assumed to correlate with the country's per capita GDP.[124] Due to dense city profiles in Asian countries, the per employee workspace is smaller than that in most Western countries. Corporate office spaces tend to have higher floorspace per employee than business process outsourcing (BPO) office spaces. In this analysis, we modelled the Indian commercial building sector with the average per employee workspace at 10.7 m^2 in 2020 and holding steady through 2050, reflecting factors such as urban land prices constraining corporate real estate and evolving collaborative office design.[125, 126]

Subsector normalised energy consumption

This report uses a calculation methodology with national average EPIs to estimate reduction potential at the national scale. These EPI baselines and mitigation scenarios are summarised in Exhibit 46. Today's subsector EPIs are calibrated from a top-down perspective using International Energy Agency (IEA)'s 2020 data.[127] As such, these EPIs are useful only for estimating the national subsector savings potential and do not represent the performance reality of individual buildings. Actual performance will significantly vary based on building characteristics, equipment, operation, climate, etc. Benchmarking data on existing building performance is generally nonexistent in India and results in a range of actual performance estimates, some of which are illustrated below. This is a crucial area for future research.

Exhibit 46 **Modelled energy performance indexes (kWh/m²/yr)**

	2020	2025	2030	2035	2040	2045	2050
Commercial							
Baseline	83.0	93.0	103.0	113.0	123.0	133.0	143.0
Mitigated - Efficiency Only	83.0	87.2	90.0	89.8	86.8	80.8	72.0
Mitigated - Efficiency + Distributed Renewables	83.0	86.6	88.8	87.7	83.6	76.8	67.0
Urban Residential							
Baseline	66.4	71.9	77.3	82.7	88.1	93.6	99.0
Mitigated - Efficiency Only	66.4	68.0	68.7	67.4	64.2	59.0	52.0
Mitigated - Efficiency + Distributed Renewables	66.4	67.8	68.2	66.4	62.5	56.7	48.7
Rural Residential							
Baseline	33.7	39.7	45.8	51.8	57.9	63.9	70.0
Mitigated - Efficiency Only	33.7	32.9	36.9	39.3	40.4	40.0	38.2
Mitigated - Efficiency + Distributed Renewables	33.7	32.8	36.4	38.4	38.7	37.6	34.9

Calibrating commercial energy consumption to IEA data for commercial and public services results in electricity consumption of around 63 kWh/m^2-yr, and electricity accounts for majority of the commercial energy consumption. The assumed commercial EPIs in our analysis represent an average of the current existing commercial building stock, including substantial amounts of mixed-mode or partially cooled building stock. As a check of reasonableness, our assumed 2020 commercial EPI number falls within BEE, GRIHA, and AEEE benchmarks for new construction of office spaces.[128,129,130] As commercial building stock expands and transitions to new construction built based on novel standards, the baseline will trend towards alignment with high ranges of the benchmarks. This is also aligned with approximations for ECBC-compliant construction per previous study by this study's analysis partners. Commercial building average EPIs are classified into business as usual, energy code and standard compliance, low energy demand, and best-in-class design. In this analysis, we assume the EPI in commercial buildings will meet the energy code and standard compliance level of performance in the reference scenario in 2050. In the deep mitigation scenario, we assume buildings will achieve best-in-class design EPI performance.[131]

Calibrating residential fuel consumption to IEA data suggests a nationwide average of around 43 kWh/m^2-yr across India's residential sector. traditional rural biofuels are not included in this report, rural residences are assumed in the analysis to have EPI lower than that average. Urban residences are assumed to have higher than that average, approximately aligned with mid-ranges of today's BEE's benchmark and examples from new residential construction with mixed penetration of air conditioning. Best practice low EPIs are approximately aligned with advanced BEE benchmarks and are reflected in the EPI trajectory for the mitigated scenario. This is despite an anticipated significant growth in residential energy consumption due to an increase in air conditioning and other appliances, concurrent with India's economic development. This study uses an EPI-based, top-down sectoral estimation methodology to represent aggregate reduction potential between two scenarios. Further study and calibration is recommended, noting particular importance and sensitivity to market penetration of air conditioning, as discussed at length in the main report.

Exhibit 47

Example of measured EPI in high-performance new construction in hot/humid climate

	MEASURED ENERGY PERFORMANCE INDEX (kWh/m^2/yr)
Residential Flat	35–45
Residential Common Area	15
Schools	14
Mixed Amenity/Recreation	101
Retail and Other Commercial	130–150

Source: RMI interviews

Power Sector Assumptions

Assumptions of power sector emissions for 2020 are based on recent studies, projections, and general alignment with India's national decarbonisation commitment (Exhibit 48). In the reference scenario and demand-side efficiency scenario in this report, the 2020 emissions factor is kept constant to first isolate and illustrate the potential of building sector demand-side energy efficiency and solar contributions. Complete mitigation scenarios are illustrated with a decarbonising electricity sector. The decarbonisation trajectory approximately correlates to the decarbonisation goals announced by Prime Minister Narendra Modi during COP26 in 2021, including complete decarbonisation in 2070, for which intermediate carbon intensity goals are still forthcoming.

Exhibit 48 **Power sector emissions factor assumptions (kgCO_2/kWh)**

	2020	2025	2030	2035	2040	2045	2050
Reference Scenario	0.79	0.79	0.79	0.79	0.79	0.79	0.79
Mitigation Scenario	0.79	0.59	0.47	0.39	0.31	0.23	0.15
Estimated Renewable Energy Penetration in Mitigation Scenario	21%	41%	52%	61%	69%	77%	85%

The projections for power section emissions were developed in consideration of the following:

- IEA's India Energy Outlook presents a more aggressive decarbonisation trajectory than that assumed here. In IEA's sustainable development scenario (SDS), 86% of the electricity will come from clean energy in 2040. This includes 214 mt of CO_2 emissions to generate 3,601 TWh electricity, yielding an emissions factor of 0.06 kgCO_2/kWh.[133]
- In Pacific Northwest National Lab's GCAM-IIMA model, clean energy will hold around 50% share in the power system in 2050, which is less aggressive than that suggested in IEA data and this report.[134]

Appendix C: Examples of Passive, Integrative Design

Infosys Office Complex (Hyderabad)	Radiant hydronic cooling system, high-performance glazing and shading, daylighting design to eliminate need for daytime electric lighting loads. Low construction cost, high occupant satisfaction and productivity, 40% less energy than conventional buildings.[135]
3 for 2 Office Design (Singapore)	Radiant cooling ceiling panels, dedicated outdoor air system, recirculating fan coil units. Mechanical and electrical systems integrated with floor and façade structure. Eliminates need for air plenums, allowing additional floors within same building height. Eliminates mechanical rooms, reclaiming floor area. Low construction cost with large leasable floor area and low energy cost.[136]
Passive cooling midrise apartment by Dhiru Thandani, AIA (Mumbai)	Drawing on traditional cooling technology, uses convectively cooled, double-wall building envelopes with efficient ceiling fans, making occupants feel 16°C to 19°C cooler. Little or no air conditioning is needed. Case study is also a cautionary tale for importance of training, as poorly detailed imitations did not perform as well.
Balkrishna Doshi, architect (India, various)	The bioclimatic, place-based, Indigenous-inspired body of work across typologies and income levels won Doshi the 2018 Pritzker Prize, the so-called "Nobel Prize" of architecture.[137]
Ashok Lall, Architect (India, various)	This leader in sustainable and affordable building practices in India demonstrates a wide range of integrative, passive design strategies, including various exterior shading strategies, radiative cooling, interior design for natural ventilation and active/passive mixed-mode buildings. Lall's work also deploys low-embodied-carbon strategies such as compressed earth blocks and timber fenestration to replace aluminium or vinyl.[138]
CII-Sohrabji Godrej Green Business Centre	By architecture firm Karan Grover and Associates, this first LEED Platinum building in India uses a range of bioclimatic and Indigenous techniques, including orientation to capture prevailing winds, evaporative cooling, wind towers, green roof, and "Jali walls."[139]
Research Centre for Climate Change (Pune)	This building at the Indian Institute of Tropical Meteorology in Pune uses several integrative and passive design strategies, including radiant cooling in the floor and ceiling, an underground air channel for natural cooling of incoming fresh air, hot air exhaust chimney in building atrium, and concrete mass to store the night-time's cooling effect.[140]

Office of Green Space Realtors, Nashik, Maharashtra	This small-scale building operates better than BEE's 5-star benchmark thanks to several passive design strategies. The building is passively cooled via stack ventilation with turbo ventilators, shaded windows, highly reflecting roof paint, and a fly ash brick double wall with air gap. Radiant floor piping further conditions spaces by circulating cooled water stored in rooftop and underground tanks that take advantage of daily temperature swings to reject heat via an outdoor radiator. HVAC capital costs were significantly less than a traditional system.[141]
Hawa Mahal (Palace of Winds), Jaipur	This historic building from 1799 has a honeycomb-like façade oriented eastwards to capture wind in 953 small windows. Water fountains in corridors behind windows deliver evaporative cooling. The project is also an example of embodied-carbon reduction, using locally available red limestone and wood.[142]
Pearl Academy of Fashion, Jaipur	This contemporary passive-design building takes inspiration from the Hawa Mahal (Palace of Winds) and has an offset external skin with orifices that allow wind and daylighting. A base level slightly below the ground has rain-fed water bodies that provide evaporative cooling. Fans drive stack ventilation, and hollow inverted clay pots insulate the roof. All building materials were procured within a 300-km radius.[143]
Torrent Research Center, Ahmedabad	This laboratory building utilises passive down-draft evaporative cooling (PDEC) via three central towers that feed into lab spaces. An occupant survey confirmed occupant comfort year-round, almost as well as a mechanically conditioned equivalent.[144]
Empire State Building retrofit (New York)	This now-archetypal deep retrofit project remanufactured 6,514 super-windows on-site, added a radiative barrier, upgraded controls, and reduced internal loads. This eliminated the need for a $17.4-million chiller retrofit while saving $4.4 million in energy costs annually, resulting in a three-year simple payback. [145]

Appendix D: Additional Resources

MINIMISE EMBODIED CARBON FOOTPRINT

1. Low-Embodied-Carbon Design and Construction

1. Matt Jungclaus, Rebecca Esau, Victor Olgyay, and Audrey Rempher, *Reducing Embodied Carbon in Buildings: Low-Cost, High-Value Opportunities*, RMI, 2021, **http://www.rmi.org/insight/reducing-embodied-carbon-in-buildings**.
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MINIMISE OPERATIONAL ENERGY AND CARBON IN BUILDINGS

3. Solutions to Help Cities Beat the Heat

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4. Integrative, Passive Building Design

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SUPPLY WITH CLEAN ENERGY

7. Demand Flexibility

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RMI Innovation Center
22830 Two Rivers Road
Basalt, CO 81621

www.rmi.org