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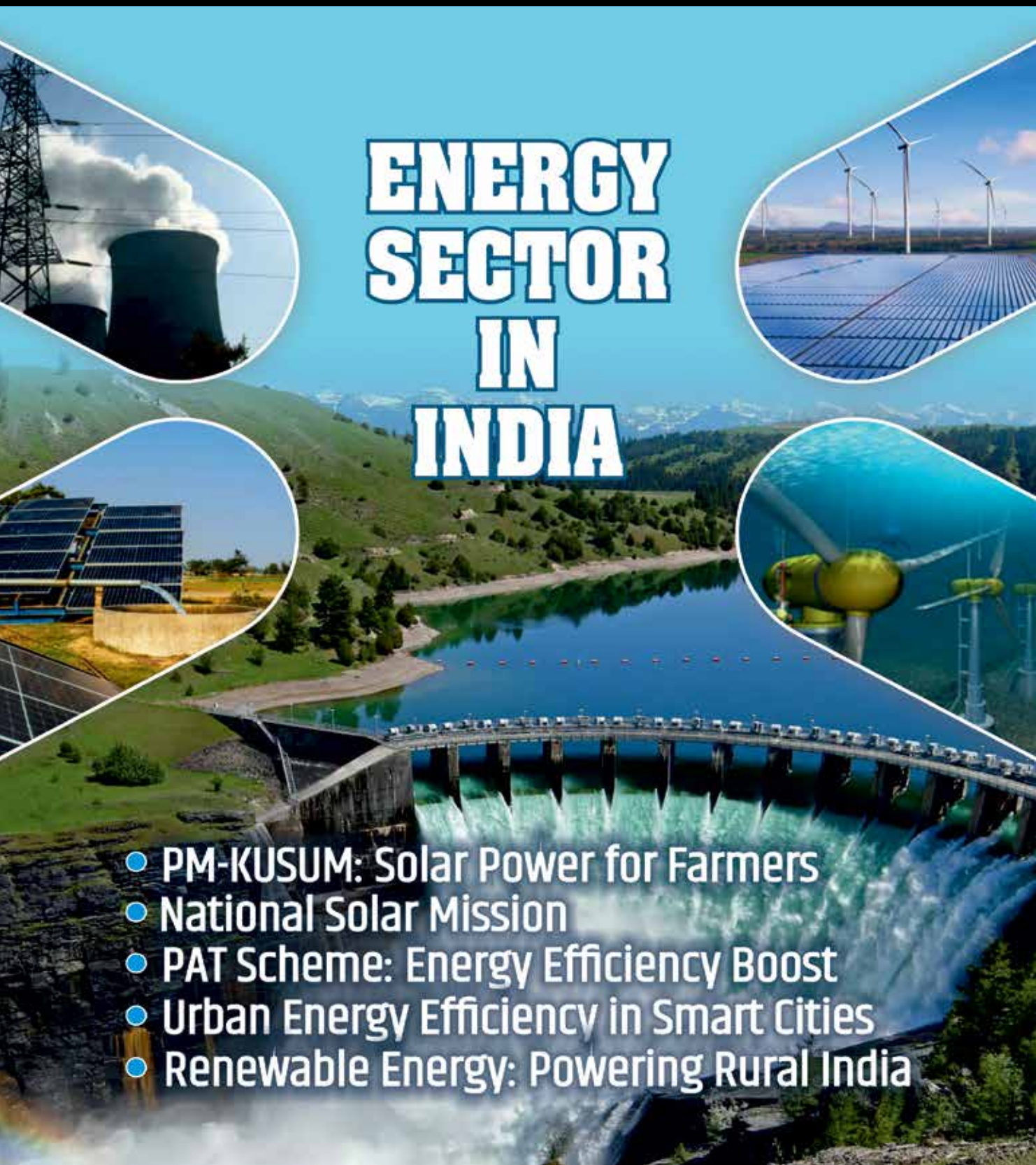

ENERGY SECTOR IN INDIA

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Smart Cities Mission and the Role of Energy Efficiency in Urban Development

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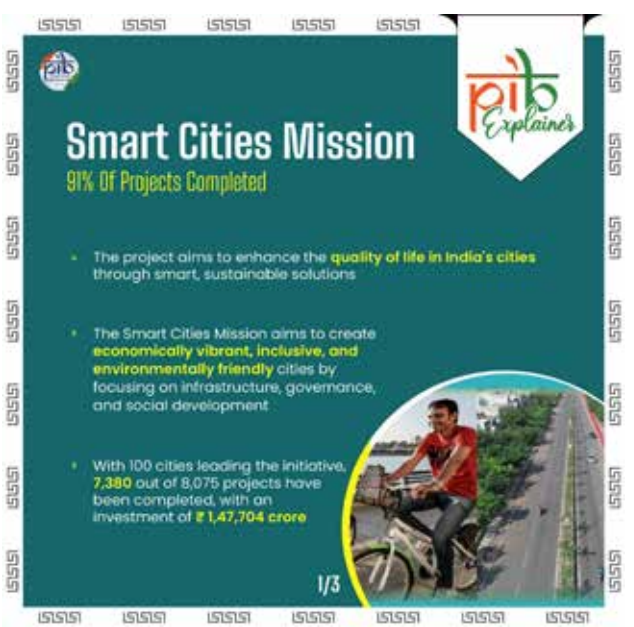
India's Smart Cities Mission (SCM), launched in 2015, seeks to integrate infrastructure and technology for effective urban growth. Cities account for 50–60% of global GHG emissions, raising the need for a low-carbon economy through efficient energy supply and consumption. Effective waste management relies on energy efficiency, which reduces heavy energy consumption during collection, processing, and disposal of waste. The shift from conventional frameworks such as the Energy Conservation Act (2001) towards greater industry- and consumer-oriented programs, reflects an evolving trajectory of energy efficiency focused policy paradigm. Taking cognisance of energy efficiency measures addressed through the SCM, there is a need to upscale these across cities in India.

Cities account for 50–60% of global GHG (Greenhouse Gas) emissions, raising the need for a low-carbon economy through efficient energy supply and consumption. Urbanisation contributes to making India the third-largest energy consumer, with 80 per cent of the energy generation from conventional sources. The coal-based energy generation contributes to around 70 per cent of emissions. To ensure affordability and accessibility in urban networks, the government has been promoting integration of energy-efficient practices. India's Nationally Determined Contributions (NDC) and Long-Term Low-Emissions Development Strategy (LT-LEDS) focus on building climate-resilient and energy-efficient urban infrastructure. Energy efficiency, a cornerstone of the smart city framework, enhances a city's smartness through robust information and communication systems (ICT), minimising household costs, reducing pressure on utilities by balancing energy demand and supply while minimising emissions

and strengthening climate resilience.

Power demand in India is expected to double by 2030 due to the country's rapid economic expansion and urbanisation. The capacity of DISCOMs (Distribution Companies) to deliver reliable and affordable power to cities while sustaining their financial stability is an ever-increasing challenge. The propelling demand necessitates capacity expansion, thereby exerting additional financial stress on utilities and negative externalities on the environment. Energy-efficient techniques are critical towards minimising consumption, enhancing distribution processes, and transforming consumer behaviour in an economically viable and environmentally sustainable manner. India's Smart Cities Mission (SCM), launched in 2015, seeks to integrate infrastructure and technology for effective urban growth. SCM had been aiming to improve the quality of life in cities through affordable housing, sustainable mobility, waste management, dependable power and water. The mission has raised the emphasis on energy efficiency to ensure sustainable resource usage and lower the expenses and emissions. The ecosystem-based adaptation initiatives and green infrastructure development further complement the energy demand management in cities. Smart and sustainable urbanisation in India demands energy efficiency-centered strategies for optimising resources, reducing costs, and enhancing 'smartness' in cities across four key sectors, identified through research and consultations:



Energy-efficient buildings: The building sector, undergoing phenomenal growth, accounts for more than a third of the country's energy consumption, and it is estimated that around 40 per cent of the building stock that shall exist over the next two decades is yet to be constructed. Currently this is and shall continue to be high-density construction for both commercial and residential buildings in and around the metropolitan and smart cities in the coming years. The energy demand for ageing building stock as well as for new construction needs to be optimised. Technological advancements in energy efficiency are crucial for optimising the energy consumption of building infrastructure, including hospitals (which account for 14 per cent of the country's energy use). Retrofitting of existing buildings, including healthcare facilities, with energy-efficient systems for HVAC (Heating, Ventilation, and Air Conditioning), lighting, water supply, and waste management, and application of energy-efficient appliances for uses such as air filtration, can significantly reduce energy consumption. Through targeted policies under the National Program for Climate Change and Human Health (NPCCHH), hospitals can prioritise energy efficiency, ensuring sustainable operations and aligning with broader climate resilience goals.

This urgently requires capacity enhancement of existing and new cadre of professionals. Leveraging efficient systems and renewable energy under the national climate-health program, can reduce operating costs, enhance sustainability, and ensure climate-resilient, future-ready public health infrastructure. Under the SCM, around 525 projects have been established across the smart cities, focused on energy and green buildings area with emphasis on improving energy efficiency and using renewable energy sources. Enhanced focus on green public procurement in the building sector shall further assist in lowering the energy footprint. Green building standards, such as GRIHA (Green Rating for Integrated Habitat Assessment) and LEED (Leadership in Energy and Environmental Design), ensure energy efficient sustainable construction practices. All such initiatives need to be scaled up for adaptation across cities.

Energy-efficient water management: The CSCAF 2.0 (Climate Smart Cities Assessment Framework) has introduced the 'Energy Efficient

Water Supply' indicator to guide cities in reducing energy consumption, GHG emissions, and costs while promoting sustainable, efficient, and profitable urban water systems. Sustainable water management initiatives can be strengthened through a focus on energy efficiency by technological interventions such as integrating SCADA (Supervisory Control and Data Acquisition) automation, optimising pumping systems with Variable Frequency Drives (VFDs). In smart cities it is vital to enhance energy efficiency in water management by initiatives such as regular energy audits, integrating renewable energy sources like solar and micro-hydro, retrofitting dilapidated water supply infrastructure and applying hydraulic modelling. Further, techniques such as real-time monitoring and decision support systems for demand management and for reducing non-revenue water (NRW), bulk metering for precise water accounting, and pressure management to minimise energy and water losses shall help in establishing efficient water supply networks and strengthening the water-energy nexus. The rising demand for treated water entails incorporation of digital solutions through usage of IoT, AI and ML technologies.

Energy-efficient waste management: Effective waste management relies on energy efficiency, which reduces heavy energy consumption during collection, processing, and disposal of waste. Technologies like IoT, sensor-based mechanisms, GPS navigation, RFID (Radio Frequency Identification), and data management optimise collection as urban waste generation rises 5 per cent annually along with a 3-3.5 per cent urban population growth to reach 436 MMT by 2050. The AI technologies, when combined with chemical analysis, can improve waste pyrolysis. AI integrated in waste logistics can reduce transportation distance and optimise the energy consumption required in transportation. Mechanical biological treatment and refuse-derived fuel (RDF) systems in waste treatment facilities ensure the safe disposal of hazardous waste. Waste can be turned into energy while lowering costs with methods like sanitary and bioreactor landfills and solar integration. Compared to creating new materials, recycling and reusing commodities like steel, wood, and concrete from construction and demolition waste greatly reduces energy requirements. During construction, source reduction techniques like modular design and careful material planning reduce energy consumption and waste production thereby promoting energy-efficient waste management in cities.

Energy-efficient Transportation: The transportation industry in India is the third-largest emitter of greenhouse gases, consuming 94 MTOE (18 per cent of energy use) and contributing 14 per cent of energy-related CO_2 emissions. An integrated, sustainable transportation ecosystem is produced by cooperative multimodal networks and renewable energy projects, such as

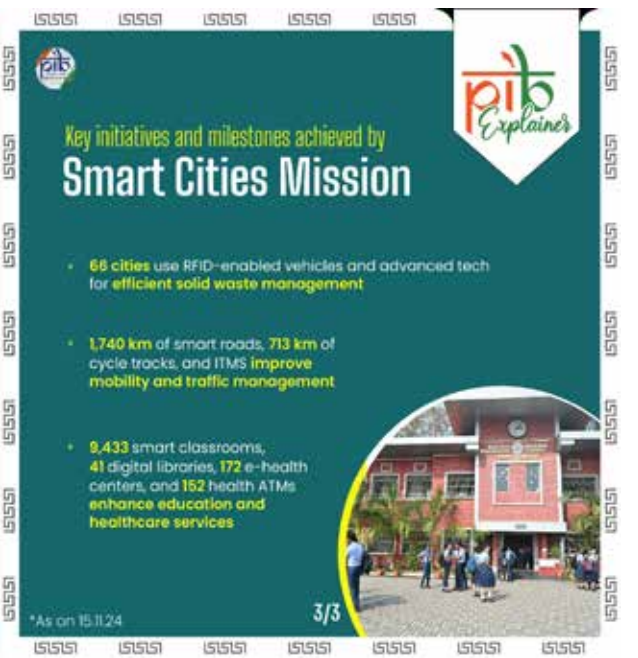


Table 1: Transforming policy environment with direct & indirect contribution to energy efficiency in cities

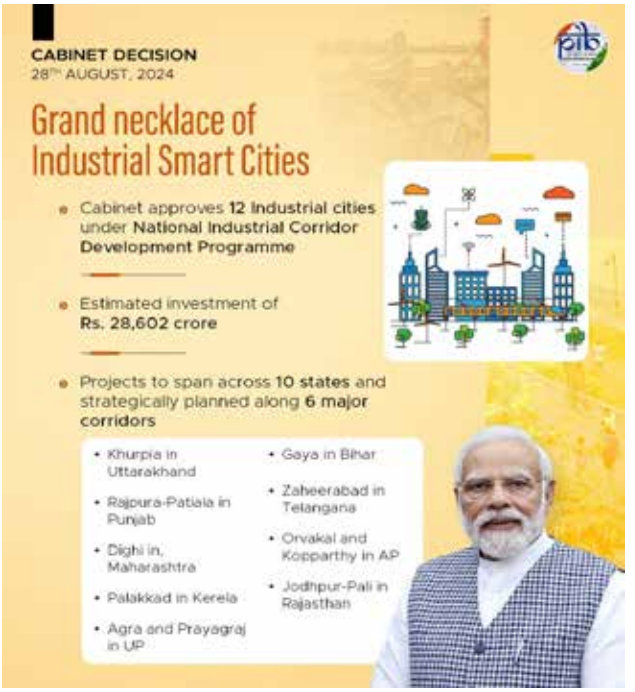
Policy/Programme	Year	Emphasis
Energy Conservation Act (EC Act)	2001, Amended 2010	Establish energy efficiency standards, promote energy conservation, regulate high energy-use industries.
National Mission on Enhanced Energy Efficiency (NMEEE)	2010	Enhance industrial energy efficiency through Perform, Achieve & Trade (PAT), and financial instruments like Energy Savings Certificates.
National Mission for Sustainable Habitat (NMSH)	2010	Promote sustainable urban development, energy-efficient buildings, and urban waste management.
National Solar Mission (NSM)	2010	Scale up solar power generation with targets for grid-connected and off-grid solar installations.
Perform, Achieve, and Trade (PAT) Scheme	2012	Market-based mechanism for enhancing energy efficiency in industries
National Electric Mobility Mission Plan (NEMMP)	2013	Development and promotion of electric vehicles that contribute to net zero emissions by reducing vehicular pollution
Smart Cities Mission (SCM)	2015	Foster energy-efficient, sustainable urban development with integrated technologies and green infrastructure.
National Smart Grid Mission	2015	Modernises India's power distribution network using smart grids and enables grid decarbonisation for net zero carbon goals.
Unnat Jyoti by Affordable LEDs for All (UJALA)	2015	Encourages the production and use of energy-saving LED lights and appliances. Lowers the amount of electricity used in homes and businesses.
Energy Conservation Building Code (ECBC)	2017 (Updated)	Sets energy efficiency standards for commercial buildings to boost climate resilience in Urban Development.
Draft National Energy Policy (NEP)	2017	Provide universal energy access, reduce fossil fuel dependency, and promote low-carbon development.
Draft National Cooling Action Plan (NCAP)	2018	Manage cooling demand, reduce carbon footprint, and increase energy-efficient cooling technologies.
National Program for Climate Change & Human Health (NPCCHH)	2019	Ensuring environmentally sustainable and climate-resilient health services
Steel Scrap Recycling Policy (SSRP)	2019	Promotes the use of scrap steel in manufacturing to lessen the emissions and effects of mining. Encourages the steel sector to use sustainable manufacturing practices.

solar-powered infrastructure. Energy-efficient urban mobility incorporates cutting-edge technologies and creative methods. Emissions are decreased by improved public transportation, non-motorised modes, and electric cars with robust charging infrastructure. Traffic operations can be optimised using artificial intelligence and big data analytics that enable energy efficiency by reducing the energy demand for sustainable urban freight. Drones, ridesharing, adaptive traffic systems, and autonomous delivery vehicles can all increase productivity while contributing to a reduction in energy consumption.

Trajectory of Policy and Regulatory Framework

Integrating energy-efficient solutions across various sectors in cities is catered to by various national policies and programs. A few key policy initiatives influencing the present course of energy efficiency in Indian cities are presented in Table 1.

The shift from conventional frameworks such as the Energy Conservation Act (2001) towards



greater industry- and consumer-oriented programs reflects an evolving trajectory of energy efficiency focused policy paradigm. The trajectory showcases increasing emphasis on aligning energy efficiency dimensions with overarching goals of sustainability, climate resilience, and low-carbon development in cities.

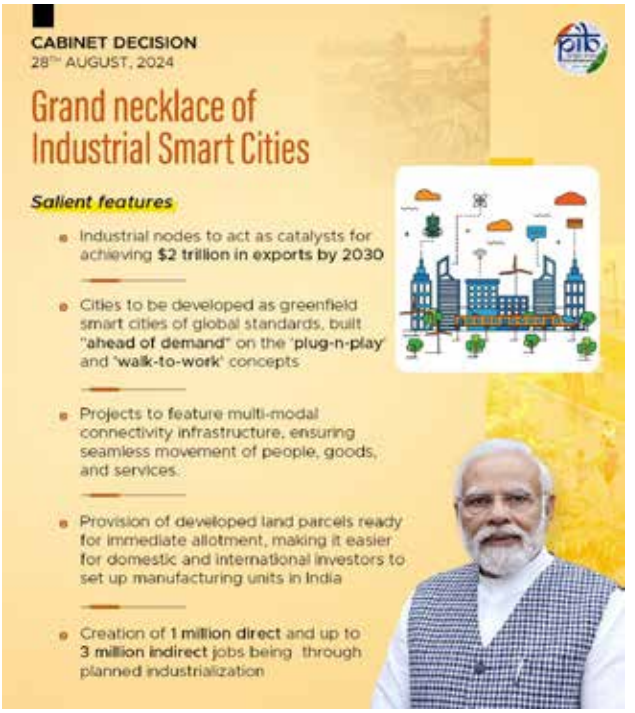
Harnessing momentum for the way forward

To minimise the emission intensity through the urban development sector, India is progressively focusing on energy demand management, enhancing renewable energy capacity and maximising energy efficiency. A systems approach shall assist in providing impetus to the efforts towards energy efficiency, particularly in the high-potential areas in smart cities through greater emphasis on a few critical overarching dimensions:

Co-production of knowledge for policy and governance: A co-production approach needs to be adopted for the establishment of ever-evolving knowledge system for energy efficiency in smart cities through engagement of key stakeholders such as think tanks, academic and research institutions, technology innovation hubs, NGOs and CBOs (Community-Based Organisations), the business sector, regulatory and statutory bodies, public utility providers, international organisations and funding agencies, and urban planning and development organisations. The targets of national initiatives like NAPCC, and NMEEE need to be explicitly integrated and addressed in city & regional master plans. Enabling a conducive policy ecosystem pertaining to sourcing and procurement of renewable energy by local government utilities and strengthening institutional capacity of urban local bodies shall assist in effective decentralised governance for energy management. Inter-sectoral coordination needs to be significantly strengthened to overcome barriers and streamline integration and collaboration across key stakeholders mandated to manage energy-intensive sectors of smart cities.

Cutting-edge technologies for energy efficiency: The widespread adoption and upscaling of energy-efficient and clean energy projects, supported through various schemes by the Department of Science & Technology (DST), Government of India, Bureau of Energy Efficiency (BEE), and Ministry of New & Renewable Energy (MNRE), Government of India, shall strengthen the research ecosystem, necessary for technological advancement. This will help reduce import and capital costs, enhance revenue streams for smart energy companies, and drive the development of cutting-edge technologies like smart grids, advanced energy storage, blockchain energy trading, IoT-enabled sensors, AI-driven predictive systems, renewable energy integration, Geographic Information System and Global Positioning System-integrated public utility systems and district energy systems. This shall also provide impetus for widespread adoption for energy efficiency in sector-specific technologies such as waste-to-energy solutions, Building Integrated Photovoltaics (BIPV), Building Automation and Control Systems (BACS), EV infrastructure, smart lighting, soft sensing for wastewater treatment, and advanced metering.

Strategic financing for energy management: The financial instruments for scaling up energy efficiency in urban development entail innovative and blended financing mechanisms to address funding challenges and foster smart energy initiatives. National programs like the National Mission for Enhanced Energy Efficiency (NMEEE) can be hybridised with instruments such as Energy Efficiency Financing Platform (EEFP), Venture Capital Fund for Energy Efficiency (VCFEE), the Partial Risk Guarantee Fund for Energy Efficiency (PRGFEE)



and Green Growth Equity Fund (GGEF) that shall incentivise investments and reduce financial risks by harnessing public and private capital for projects relating to renewable energy and clean transportation. Financial tools like green bonds that enable cities to raise funds for sustainable energy projects and market-based mechanisms such as the Perform, Achieve, and Trade (PAT) scheme need to be revisited and strengthened towards upscaling into high-energy-consuming sectors. Strengthening these mechanisms through strategic domestic and international collaborations shall further enable cities to leverage resources for prompt adoption of energy-efficient practices spanning from smart grids to advanced energy storage systems.

Targeting performance measurements: Defined performance targets, benchmarks and outputs are necessary for the effective execution of policies. These could include both action-oriented (such as facility upgrades and awareness campaigns) and quantitative targets (such as energy usage, percentage renewable energy deployment, and GHG emission reduction) at the city level. Creation of energy-efficient assets must be guaranteed by a long-term performance structure (including robust database management, MIS, and sector-specific annual reports) that assigns accountability for goal-setting, tracking, and reporting on a continual basis.

Taking cognisance of energy efficiency measures addressed through the SCM, there is a need to upscale these across cities in India. Through enabling policy and regulatory environments, the integration of advanced technologies, and innovative financing mechanisms, India can accelerate transitioning towards energy-efficient smart cities. ❑

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