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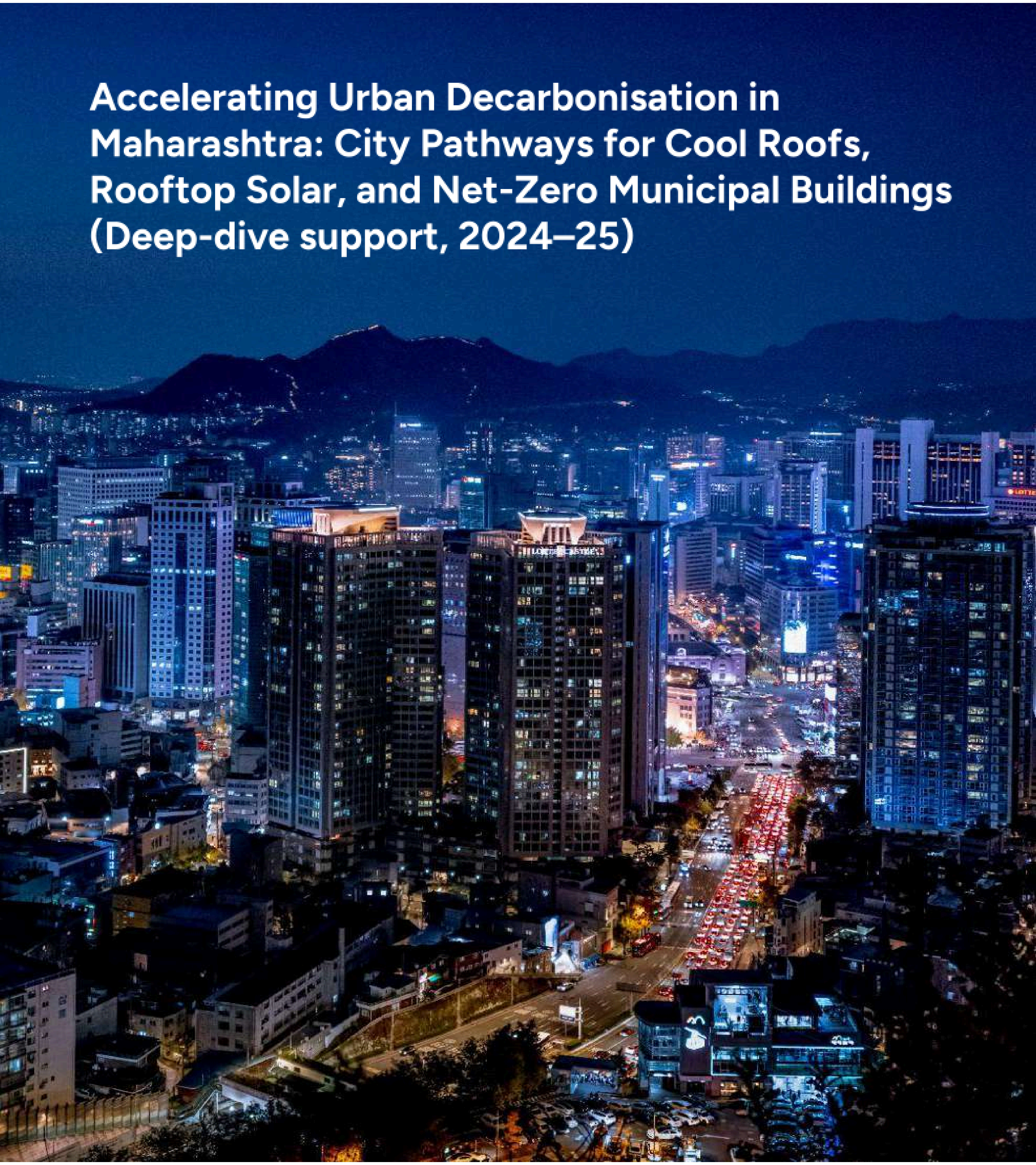
Accelerating Urban Decarbonisation in Maharashtra: City Pathways for Cool Roofs, Rooftop Solar, and Net-Zero Municipal Buildings (Deep-dive support, 2024–25)



Technical Partners: eds, Alliance for an Energy Efficient Economy, Global Evolutionary Energy Design

Disclaimer

This report and the compilations has been prepared as part of the Maharashtra City Decarbonisation Roadmap implementation support and is intended to provide strategic insights, technical analysis, and illustrative recommendations to support urban climate action planning and implementation in the participating cities.

The findings, interpretations, and conclusions expressed in this document are based on information available at the time of preparation, including data provided by city governments, stakeholders, and secondary sources. While reasonable efforts have been made to ensure the accuracy of the information presented, C40 Cities Climate Leadership Group and its partners make no representations or warranties, whether express or implied, as to the completeness or ongoing accuracy of the data and accept no liability for any errors, omissions, or changes in circumstances after publication.

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Message

Smt. Pankaja Gopinath Munde
Honourable Minister for Environment and Climate Change,
Animal Husbandry, Government of Maharashtra

Maharashtra has set a clear and ambitious vision for its future—one that balances economic growth, social equity, and environmental sustainability. Under the state's long-term development agenda, including Vikasit Maharashtra 2047 and the State Action Plan on Climate Change, the Government of Maharashtra is committed to building climate-resilient cities, strengthening energy security, improving quality of life for citizens, and positioning the state as a national and global leader in low-carbon development.

Cities lie at the heart of this vision. As engines of growth and innovation, Maharashtra's urban centres also account for a significant share of energy demand and greenhouse gas emissions, particularly from the buildings and energy sectors. Addressing these challenges is not only essential for meeting climate goals, but also for reducing energy costs, improving thermal comfort, enhancing public health, and ensuring inclusive urban development—especially for communities vulnerable to heat.

The report presented here represents a meaningful step in translating the state's climate and development vision into city-level action. Developed through close collaboration between the Environment and Climate Change Department, the State Climate Action Cell, urban local bodies, and C40 Cities, this work focuses on moving decisively from planning to implementation. By advancing High Impact Actions on decarbonisation through net-zero municipal buildings, rooftop solar deployment, cool and green roofs, behavioural energy efficiency and green municipal procurement, the programme supports Maharashtra's priorities on clean energy transition, climate adaptation, and sustainable urban infrastructure.

The successful notification and implementation of Cool Roof Bye-laws in Amravati stands as a strong example of how evidence-based planning, sustained technical support, and effective state–city coordination can translate climate priorities into enforceable urban policy aligned with Maharashtra's goals on heat resilience and low-carbon growth. This leadership is further reinforced by parallel successes in other cities, including the development of Net Zero Municipal Buildings Action Plans in Mumbai and Panvel, behavioural energy efficiency and rooftop solar programmes in Navi Mumbai and Thane, and household-level cooling pilots in Chandrapur demonstrating measurable reductions in indoor temperatures and energy demand. Together, these implementation-ready roadmaps highlight Maharashtra's ability to move from pilots to policy, and position the state as a national leader in delivering scalable, replicable urban climate solutions for cities across India and the Global South.

I commend the Environment and Climate Change Department, the State Climate Action Cell, the Urban Development Department, the Energy Department participating municipal corporations, and our technical partners for their commitment and collaborative spirit. These reports are not an end in themselves, but practical tools to support cities as they deliver on Maharashtra's broader vision of resilient, energy-efficient, and people-centred urban development. I am confident that the learnings from this initiative will inform future policies and inspire cities across India and the Global South.

Message

Smt. Jayashree Bhoj
Secretary, Department of Environment and Climate Change
Government of Maharashtra

The Government of Maharashtra's climate and development agenda recognises that effective implementation of climate actions at the city level is critical to achieving the state's long-term goals on sustainability, resilience, and economic competitiveness. As articulated through Vikasit Maharashtra 2047, the State Action Plan on Climate Change, and sectoral policies on energy and urban development, the state is committed to enabling cities to adopt low-carbon pathways while strengthening institutions, improving service delivery, and safeguarding vulnerable communities.

This set of project reports reflects a deliberate effort to operationalise that vision. Built upon the Maharashtra City Decarbonisation Roadmap, in partnership with C40 Cities, the work moves beyond aspirational targets to provide cities with implementable High Impact Actions, institutional arrangements, and monitoring frameworks in the energy and buildings sector. The emphasis throughout has been on alignment—between city priorities and state policy levers, between climate objectives and development outcomes, and between technical ambition and administrative feasibility.

Four cities—Mumbai, Panvel, Nashik, and Amravati—now have implementation-ready roadmaps of selected high impact actions that support state priorities such as scaling renewable energy, improving energy efficiency in public assets, enhancing thermal comfort, and strengthening procurement systems. Three additional cities—Thane, Navi Mumbai, and Chandrapur—have been supported on immediate actions that build readiness while drawing on the tools and learnings from the deep-dive cities. This tiered model reflects a scalable pathway for extending climate action across Maharashtra's diverse urban landscape.

Equally significant is the strengthening of institutional capacity at both city and state levels. Through sustained consultations, knowledge-sharing sessions, and thematic discussions, officials have been better equipped to integrate climate considerations into budgeting, planning, procurement, and regulatory processes. The development of state-level knowledge products on rooftop solar and green municipal procurement, as well as formal policy inputs to the Urban Development Department, further embeds these learnings within government systems.

Anchored by the State Climate Action Cell, this initiative has also fostered a collaborative ecosystem—bringing together cities, state agencies, utilities, financial institutions, and knowledge partners—to support coordinated action and continuous learning. This foundation will be critical as Maharashtra advances its clean energy transition, explores innovative financing mechanisms, and engages with national and international climate initiatives, including Just Energy Transition frameworks.

These reports are intended as living documents that support ongoing implementation and policy refinement. They reflect Maharashtra's commitment to evidence-based decision-making and climate action that delivers tangible benefits for citizens while advancing the state's long-term development vision.

Message

Shri Abhijit Ghorpade
Director, State Climate Action Cell (SCAC)
Department of Environment and Climate Change
Government of Maharashtra

Maharashtra, India's one of the most industrialised and urbanised states, has drafted its Viksit Maharashtra 2047 vision to achieve a USD 5-trillion economy through a sustainable and inclusive approach, while managing rapid infrastructure and construction expansion. Reflecting its leadership and commitment, Maharashtra has mobilised climate action across cities, with 43 AMRUT cities formally committing to the global Race to Zero initiative. The buildings sector accounts for nearly 37 percent of India's annual primary energy consumption, a share that is projected to increase substantially in the absence of timely and effective interventions.

Cities assume a critical role in shaping the trajectory of climate action, particularly as building stock is expected to grow significantly by 2030. In response, the Department of Environment and Climate Change, in collaboration with C40 Cities and with technical support from Environmental Design Solutions (EDS), developed the Maharashtra City Decarbonization Roadmap for the Energy and Building Sector in 2023, covering 43 AMRUT cities across the State, supporting cities in achieving net-zero emissions by 2050. As part of the roadmap's implementation, seven cities were supported on high-impact actions aligned with local priorities, while remaining consistent with state and national objectives.

This resulted in the development of: 'Net-zero energy action plans for public buildings in Mumbai and Panvel cities', 'Roadmap for accelerating rooftop solar deployment in Nashik city', 'Cool / Green roof policy roadmap for Amravati city', 'Identification of cooling pathways for low-income settlements in Chandrapur city', 'Development of behavioural energy efficiency and renewable energy adoption programmes for municipal buildings in Navi Mumbai and Thane cities.'

In addition, policy notes and guidance documents addressing cross-cutting challenges were also developed. This included 'Road to Renewable Cities', a knowledge product supporting cities in their clean energy transition and 'Greening Municipal Procurement', a step-by-step guide for urban local bodies, that centres "procurement" in the climate action dialogue.

This body of work has been undertaken through close coordination with urban local bodies, relevant state departments and agencies, technical experts, and partner organisations. It reflects an evolving approach towards action-oriented and implementation-focused climate planning, grounded in local realities, informed by analytical evidence, and designed to support scalability and replication across the State.

The Maharashtra State Climate Action Cell remains committed to supporting cities in mainstreaming climate considerations within the urban built environment and strengthening institutional capacities for sustained climate action. The roadmaps, action plans, policy recommendations and knowledge products presented herein are expected to facilitate accelerated implementation, promote innovation, and contribute meaningfully to Maharashtra's transition towards a low-carbon and climate-resilient future.

Foreword

Naim Keruwala
Regional Director, South and West Asia
C40 Cities

Maharashtra's cities are at the forefront of India's urban climate transition. Through the Maharashtra City Decarbonisation Roadmap for the Energy and Buildings Sector, 43 cities across the state have committed to ambitious, city-led pathways that align with India's long-term climate goals and demonstrate how subnational leadership can drive climate action at scale. This collective approach positions Maharashtra as a model for other states accelerating India's clean energy transition.

Rapid urbanisation, rising energy demand, and increasing exposure to extreme heat and climate risks underscore the urgency of accelerating urban climate action that delivers tangible benefits for residents while supporting long-term economic growth. C40's support to seven cities (Mumbai, Panvel, Nashik, Amravati, Thane, Navi Mumbai and Chandrapur) through development of high impact action roadmaps and critical actions on energy transition and knowledge products are aimed at advancing implementation, and providing cities with the necessary tools and frameworks. .

This suite of reports marks an important milestone in Maharashtra's urban decarbonisation journey. Developed in collaboration with the Government of Maharashtra, seven municipal corporations, and technical experts; these roadmaps demonstrate how cities can use their regulatory, operational, and purchasing power to drive systemic change at scale. Together, they outline practical and implementable pathways to reduce emissions, improve energy efficiency, and strengthen resilience across the energy and buildings sector; one of the most critical and cost-effective areas for urban climate action. The reports focus on key levers available to cities today, including cool and green roofs, rooftop solar, net-zero municipal buildings, behavioral change, and sustainable procurement, translating ambition into clear, actionable steps.

I commend the Environment and Climate Change Department of Government of Maharashtra, Climate Action Cell on its efforts in achieving this significant milestone and collaboration. C40 also acknowledges the engagements and support extended by the Departments of Urban Development, Energy Department along with the Maharashtra Institution for Transformation (MITRA) and seven cities in developing these roadmaps.

C40 looks forward to further supporting Maharashtra's cities to implement and mainstream climate actions supporting objectives of Vikasit Maharashtra 2047 and State Action Plan on Climate Change.

Acknowledgements

This report has been developed as part of the Maharashtra City Decarbonisation Roadmap, with the aim of supporting cities in advancing high-impact action in the energy and buildings sector. The preparation of this compilation would not have been possible without the collective efforts, insights, and collaboration of multiple institutions and individuals across city, state, and national levels.

We would like to express our sincere appreciation to the Environment and Climate Change Department, through the State Climate Action Cell (SCAC), the Urban Development Department, the Energy Department of Government of Maharashtra, , and the Maharashtra Institution for Transformation (MITRA) for their leadership, guidance, and continued support throughout the programme. Their commitment has been instrumental in enabling cities to translate climate ambition into actionable and implementable pathways.

We are deeply grateful to the municipal leadership and officials of Mumbai, Amravati, Panvel, Nashik, Chandrapur, Navi Mumbai, and Thane, whose active participation, data sharing, and strategic inputs shaped the High-Impact Action Roadmaps and implementation frameworks reflected in this report. Their openness to innovation and sustained engagement have been central to the outcomes achieved under this phase of work.

We also extend our sincere appreciation to the technical partners and subject-matter experts such as Environmental Design Solutions (EDS), Alliance for an Energy Efficient Economy (AEEE), and Global Evolutionary Energy Design (GEED) for their valuable contributions to analysis, stakeholder engagement, and the development of the roadmaps across the seven cities.

Finally, we thank all stakeholders; public institutions, practitioners, and partners for contributing their time and perspectives. This report reflects a shared commitment to advancing clean energy, low-carbon buildings, and climate-resilient urban development across Maharashtra.

Preface

C40's prior engagement on structuring Mumbai's Paris Agreement aligned Climate Action Plan (MCAP) highlighted the Energy and Buildings sector as one of the major contributors of GHG emissions in the city. Taking cues from MCAP and building on the commitment by 43 cities in Maharashtra to prepare and implement city-level decarbonization roadmap; C40 supported development of a roadmap for transition of the energy and building sector. Launched by the Environment and Climate Change Department of Maharashtra in December. 2023 this Decarbonization Roadmap is a city-level template that outlines a pathway to decarbonisation supporting the energy transition, upscaling energy efficiency, reducing GHG emissions, and reliance on fossil fuels, and lowering energy operation costs.

Building on the Maharashtra City Decarbonisation Roadmap, C40 supported seven (Mumbai, Amravati, Panvel, Nashik, Chandrapur, Navi Mumbai, Thane) out of the 43 cities included in the first phase of this work which was focused on developing implementation frameworks for clean energy and low-carbon buildings during 2024-25. These roadmaps focus on identifying priority actions with the greatest mitigation and co-benefits potential, grounded in local data, institutional realities, and market conditions, while embedding considerations related to governance, financing, and delivery.

Collectively, the seven city roadmaps reflect the diversity of urban contexts across Maharashtra—from metropolitan regions to rapidly growing cities, and from municipal building portfolios to low-income housing and neighbourhood-scale interventions. While each city's pathway is tailored to its specific challenges and opportunities, the roadmaps share a common objective: to translate climate ambition into data driven, action-oriented, implementable solutions that can be delivered within existing policy frameworks and administrative capacities.

This compilation of HIA roadmaps and knowledge products presents a consolidated view on how cities across Maharashtra are translating the Maharashtra City Decarbonisation Roadmap into on-ground action, in alignment with the Viksit Maharashtra 2047 vision. By highlighting priority investments, scalable implementation pathways, and city-led innovations in clean energy and low-carbon buildings, the document supports the state's broader objectives of sustainable economic growth, climate-resilient infrastructure, inclusive urban development, and good governance. It is intended to serve as a practical resource for city officials, state agencies, implementation partners, and financiers seeking to accelerate decarbonisation while advancing Maharashtra's transition towards a competitive, resilient, and low-carbon economy by 2047.

Introduction

Indian cities are at the forefront of the climate challenge—and the climate opportunity. Rapid urbanisation, rising energy demand, increasing heat stress, and growing infrastructure needs are converging at a time when cities are also being called upon to deliver tangible progress toward net-zero and climate-resilient development. While many cities have articulated long-term climate goals and action plans, the critical next step lies in translating these commitments into implementable, high-impact actions that can be delivered within existing institutional, financial, and governance constraints.

This document brings together compilations of **four deep dive cities—Mumbai, Panvel, Amravati, Nashik, —each of which has developed a High-Impact Action Roadmap focused on priority interventions in the buildings and energy sectors**. Collectively, these roadmaps demonstrate how cities can move from broad climate ambition to sector-specific, investment-ready pathways that deliver measurable emissions reductions, energy savings, and co-benefits such as thermal comfort, improved public services, and reduced operating costs.

Developed with technical support from C40 Cities and partner institutions, the roadmaps respond to diverse urban contexts—ranging from megacities to fast-growing secondary cities, and from municipal building portfolios to low-income settlements. Despite these differences, they share a common approach: identifying the **highest-impact levers** for decarbonisation and resilience, grounding solutions in local data and institutional realities, and embedding implementation considerations—such as financing mechanisms, governance structures, and monitoring frameworks—directly into the planning process.

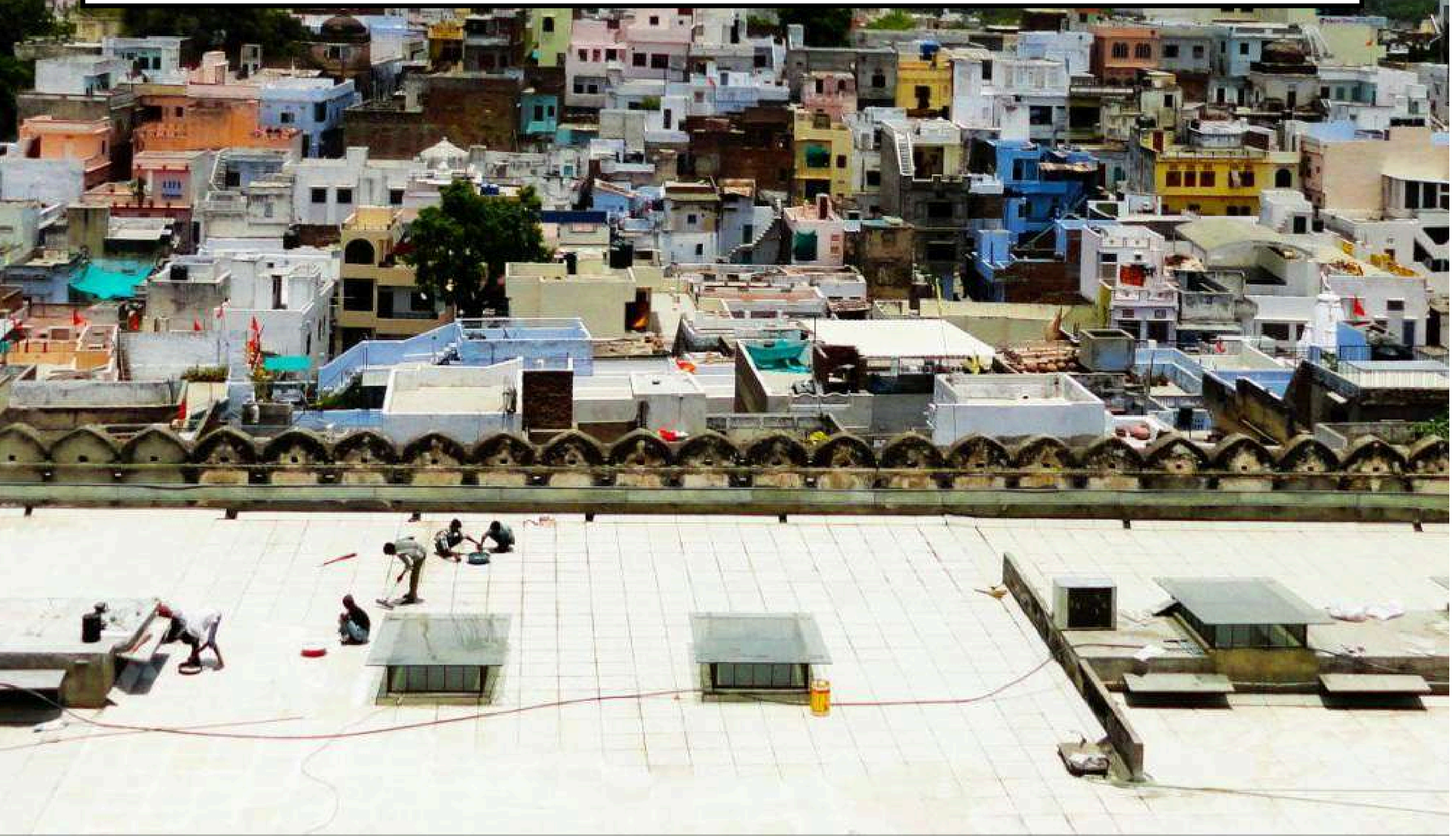
Across the four cities, the focus areas span **net-zero municipal buildings, rooftop solar acceleration, and cool and green roofs.** Each roadmap prioritises actions that are technically feasible today, aligned with state and national policy frameworks, and capable of being scaled through municipal systems and market mechanisms. Rather than treating climate action as a standalone agenda, the reports position it as integral to urban service delivery, fiscal efficiency, and long-term development outcomes.

During Phase 2 of the Maharashtra City Decarbonisation work, **a series of structured workshops, focus group discussions (FGDs), and stakeholder consultations** were conducted across participating cities to support the development of High-Impact Action (HIA) Roadmaps for the energy and buildings sector. These engagements brought together municipal leadership, technical departments (including environment, engineering, planning, electricity, and housing), state agencies, utilities, and implementation partners to validate baseline assessments, identify priority intervention areas, and align proposed actions with city development priorities and institutional capacities. City-level workshops were complemented by state-level consultations to ensure coherence with the Maharashtra City Decarbonisation Roadmap and relevant policy frameworks.

In parallel, **thematic FGDs and targeted stakeholder meetings** were organised to deepen understanding of sector-specific challenges and opportunities, including rooftop solar deployment, energy efficiency in municipal and residential buildings, cool and green roofs, and low-income housing interventions. These discussions helped surface on-ground constraints related to data availability, financing, governance, and market readiness, while also capturing user perspectives and implementation insights from frontline staff, community representatives, and technical experts. Collectively, these engagements strengthened ownership of the roadmaps, informed realistic sequencing of actions, and ensured that the proposed HIAs were both technically sound and implementable within existing administrative and financial systems.

This compilation integrates strategic roadmaps from Amravati, Nashik, Mumbai, and Panvel, developed as part of Maharashtra's state-wide commitment to achieve net-zero emissions by 2050. Recognizing that Maharashtra's urban centers face escalating energy demands and intensified urban heat island effects, these reports provide evidence-based pathways for scaling high-impact interventions such as cool and green roofs, rooftop solar (RTS) deployment, and net-zero municipal building transitions. By synthesizing local geospatial data, regulatory analysis, and stakeholder consultations, the compilation offers a replicable blueprint for municipal governance. Together, these roadmaps empower city administrations to mainstream energy-efficient practices and passive cooling strategies into urban planning, ultimately positioning these four cities as leaders in equitable, low-carbon, and climate-resilient urban transformation in India.

Cool and Green Roof Policy Roadmap for Amravati City



Technical Partner: GLOBAL EVOLUTIONARY ENERGY DESIGN

Executive Summary

The Cool and Green Roof Policy Roadmap for Amravati City has been developed under the Maharashtra City Decarbonisation Roadmap, launched by the Environment and Climate Change Department in collaboration with C40 Cities. Building on C40's experience from the Mumbai Climate Action Plan (MCAP) and the state-wide commitment of 43 cities to achieve net-zero emissions, this roadmap provides a structured implementation framework to advance clean energy transition and climate-resilient urban development in Amravati. As one of the seven cities receiving focused technical support, Amravati has prioritized cool and green roofs as a cost-effective, scalable, and high-impact intervention to mitigate urban heat, enhance thermal comfort, and reduce building energy demand.

Amravati's hot-dry climate, rapid urbanization, and growing impervious surface cover have intensified urban heat island effects, with summer surface temperatures exceeding 50ºC in dense built-up areas. The Baseline Assessment conducted under this initiative revealed significant potential for passive cooling, with simulations showing that cool roofs can reduce cooling energy consumption by up to 30% and green roofs by up to 22%, contributing to an estimated 23% reduction in city-wide cooling-related electricity demand by 2041. These findings guided the formulation of the Amravati Cool Roof Bye-Laws 2025, introduced under the Chief Minister's 150-Day Action Plan, making Amravati the first city in Maharashtra to institutionalize cool and green roof as passive cooling measures in roof design through regulation.

This roadmap outlines a clear policy vision to mainstream cool and green roofs across Amravati's urban planning, construction, and governance systems. It sets phased implementation targets, achieving 5 km^2 of cool and green roof coverage by 2030, 12-14 km^2 by 2035, and 80% citywide adoption by 2041, supported by regulatory enforcement, incentive mechanisms, and public-private collaboration.

To operationalize this vision, this report reviews existing provisions under the Unified Development Control and Promotion Regulations (UDCPR) and the State Schedule of Rates (SSR) to identify opportunities for integrating cool and green roof measures. The framework recommends strengthening thermal performance criteria, expanding approved material categories, and enabling co-located roof systems that combine solar, reflective, and vegetated elements. It further proposes incorporating compliance checkpoints within building plan approvals and occupancy certification processes, along with sustainability clauses in public procurement.

A robust institutional and governance framework anchors this roadmap. The Amravati Municipal Corporation (AMC) shall serve as the nodal authority, supported by a cross-departmental Steering Committee and a dedicated Cool Roof Cell (CRC) within the Town Planning Department. Together, these bodies shall ensure coordination, accountability, and evidence-based decision-making through clearly defined Key Performance Indicators (KPIs), digital monitoring systems, and inter-agency protocols.

Building on this institutional foundation, this roadmap emphasizes local capacity development and market readiness as key enablers of successful implementation. Workforce training programs, professional certification schemes, and targeted stakeholder engagement shall help strengthen technical expertise and supply chain resilience.

Strategic partnerships with the Indian Green Building Council (IGBC), the Bureau of Energy Efficiency (BEE), and local technical institutions shall further support skill development and expand the availability of quality-assured materials.

Recognizing that widespread adoption depends on community involvement and engagements, this roadmap places strong emphasis on citizen participation and public awareness. Multi-channel communication through media campaigns, community workshops, and digital platforms shall promote understanding of the economic, health, and environmental benefits of cool and green roofs.

Incentive mechanism, such as property tax rebates, ought to encourage voluntary uptake as well as to ensure transparency and continual improvement, a comprehensive Monitoring, Reporting, and Verification (MRV) framework shall reinforce the implementation process. In addition, by leveraging remote sensing, GIS mapping, IoT sensors, and administrative data, the MRV system shall be able to track thermal performance, roof coverage, vegetation health, and energy savings. Regular progress reviews and annual third-party audits will support adaptive management and evidence-based policy refinement.

Together, these institutional, technical, and community-driven measures make this roadmap a replicable model for city-scale passive cooling integration. By embedding cool and green roofs within Amravati's urban governance ecosystem, aligning them with state decarbonization goals, and fostering sustained citizen participation, the city positions itself as a pioneer of equitable, low-carbon, and climate-resilient urban transformation in Maharashtra and beyond.

Section I - Context and Rationale

1 Introduction and Purpose

The project "Development of Cool/Green Roof Policy Roadmap for Amravati City focusing on Clean Energy Transition" is a part of Maharashtra's state-wide City Decarbonisation Roadmap supported by the Environment and Climate Change Department and C40 Cities. This initiative builds upon the commitment of 43 cities in Maharashtra, including Amravati, to achieve net-zero emissions by 2050 under the Cities Race to Zero campaign. Within this framework, Amravati has been identified as one of the cities receiving structured implementation support to integrate energy-efficient and climate-resilient building measures.

Amravati, located in Maharashtra's hot-dry climatic zone, faces intensifying urban heat stress and growing cooling energy demand. The city experiences around 583 hours annually where temperature is in the range of 35 - 40ºC, a threshold associated with increased health risks. Rapid urbanization and the spread of impervious surfaces have amplified the Urban Heat Island (UHI) effect. Land Surface Temperature (LST) mapping conducted during summer 2024 showed surface temperatures as high as 53.71ºC, with metal-roofed areas exceeding 47ºC, compared to 38ºC in vegetated zones, illustrating how material choices and surface cover directly influence urban heat intensity.

The baseline assessment report on cool and green roofs in Amravati presented a comprehensive assessment of Amravati's rooftop landscape, building typologies, and thermal performance. It analysed climate vulnerabilities, land use, and policy frameworks while estimating the technical and energy-saving potential of cool and green roofs. The assessment revealed that Amravati's total roof area, 14.92 km^2 in 2025, projected to rise to 27.8 km^2 by 2041, offers a vast opportunity for passive cooling interventions. Simulation studies conducted for representative building types demonstrated that cool roofs could reduce cooling energy use by up to 30% and green roofs by up to 22%, alongside significant reductions in roof surface temperatures. At the city level, these interventions could collectively lower cooling-related electricity demand by approximately 23%.

The baseline assessment also highlighted several institutional and regulatory challenges, including the absence of explicit provisions for cool and green roofs in the Unified Development Control and Promotion Regulations (UDCPR), limited availability and recognition of locally certified roofing materials, such as high solar reflectance (SRI) paints, reflective tiles, and waterproofing membranes for cool roofs, as well as locally available green roof substrates, drainage mats, and native plant species for green roofs. In addition, low public awareness and fragmented institutional responsibilities across city departments further constrain adoption.

Building upon the findings of the baseline assessment, Amravati became one of the first cities in Maharashtra to formally institutionalize passive cooling through the launch of the Amravati Cool Roof Bye-Laws 2025 under the 150-day Chief Minister's Action Plan. The bye-laws were guided by the baseline study's geospatial heat-mapping and energy simulations.

The bye-laws mandate cool roofs for all new public, commercial, institutional, and high-rise residential buildings, while providing voluntary and incentive-based adoption mechanisms for existing structures. Implementation is supported through both regulatory provisions and fiscal incentives, including property tax rebates of 10% for residential/public and 5% for commercial buildings. In addition, the regulation establishes different options for materials, such as reflective coatings, membrane-based cool roofs, cool roof tiles, and green roofs.

1.1 Policy Vision and Goals

Objectives

The Cool and Green Roof Policy for Amravati shall pursue three primary objectives:

1. **Mitigate Urban Heat Island (UHI) effects**: Reduce surface (Overdeck and underdeck both) and ambient temperatures through the use of high-albedo materials and vegetated roofs, thereby improving the city's microclimate, enhancing outdoor thermal comfort, and safeguarding public health.

2. **Enhance Indoor Thermal Comfort and Energy Efficiency**: Lower indoor air temperatures and improve thermal comfort for occupants through passive roof design measures, resulting in reduced dependence on mechanical cooling systems and achieving an estimated annual energy savings potential of up to 23% in cooling-related electricity demand by 2041.

3. **Mainstream Passive Cooling in Urban Governance:** Integrate cool and green roof strategies into city planning, building bye-laws, and procurement frameworks, thereby aligning local action with State and National commitments on climate resilience, energy efficiency, and low-carbon development.

Targets

The Cool and Green Roof Policy shall establish measurable and time-bound targets to guide implementation across Amravati, aligned with the Amravati Cool Roof Bye-laws 2025 and the city's projected increase in total roof area from 14.92 km^2 in 2025 to 27.8 km^2 by 2041. The targets shall distinguish between new buildings, where cool roofs are mandatory, and existing buildings, where adoption will be achieved through incentives, awareness campaigns, and structured retrofit programs.

In the near and medium-term, the targets shall also include a defined proportion of existing buildings expected to adopt cool or green roofs, recognising that retrofits form an essential part of the city's immediate heat-resilience strategy. Additionally, green roofing shall be progressively integrated into the medium and long-term targets, ensuring a gradual but sustained increase in vegetated roofs as part of Amravati's broader climate-adaptation pathway.

Near term (0 - 5 years, by 2030): In the near term, the focus shall be on demonstrating and scaling up cool and green roof adoption across Amravati through a mix of mandatory and voluntary measures. As per the bye-laws, all new municipal, institutional, commercial, and high-rise residential buildings must use cool roofs, while existing buildings such as government offices, schools, hospitals, and commercial spaces will be encouraged through incentives and awareness programs.

Table 1 Near-Term Implementation Targets: Roof Area, Coverage, and Savings

Near Term Implementation						
Building Type	**Roof Area Bracket (m^2)**	**Total Roof Area (km^2) in 2030**	**Roof Area Taken for Near Term (km^2)**	**Share of Roof Area (%)**	**Energy Savings (GWh/yr)**	**Monetary Savings (INR Lakh/yr)**
Residential	0 - 50	2.18		**14.03**	**4.09**	**541.22**
	50 - 200	8.67	**0.13**			
	200 - 500	1.44	**1.44**			
	>500	0.18	**0.18**			
Subtotal (Residential)	-	**12.47**	**1.75**			
Non-Residential	0 - 50	0.17		**50.15**	**6.60**	**872.56**
	50 - 200	3.19	**0.13**			
	200 - 500	1.79	**1.79**			
	>500	1.33	**1.33**			
Subtotal (Non-Residential)	-	**6.48**	**3.25**			
Total (Amravati)	-	**18.95**	**5.00**		**10.69**	**1413.77**

By 2030, the city aims to cover about 5 km^2 of roof area with cool or green roofs. This effort will help reduce indoor heat, improve comfort, and lower energy use, setting the stage for wider city adoption and long-term energy savings.

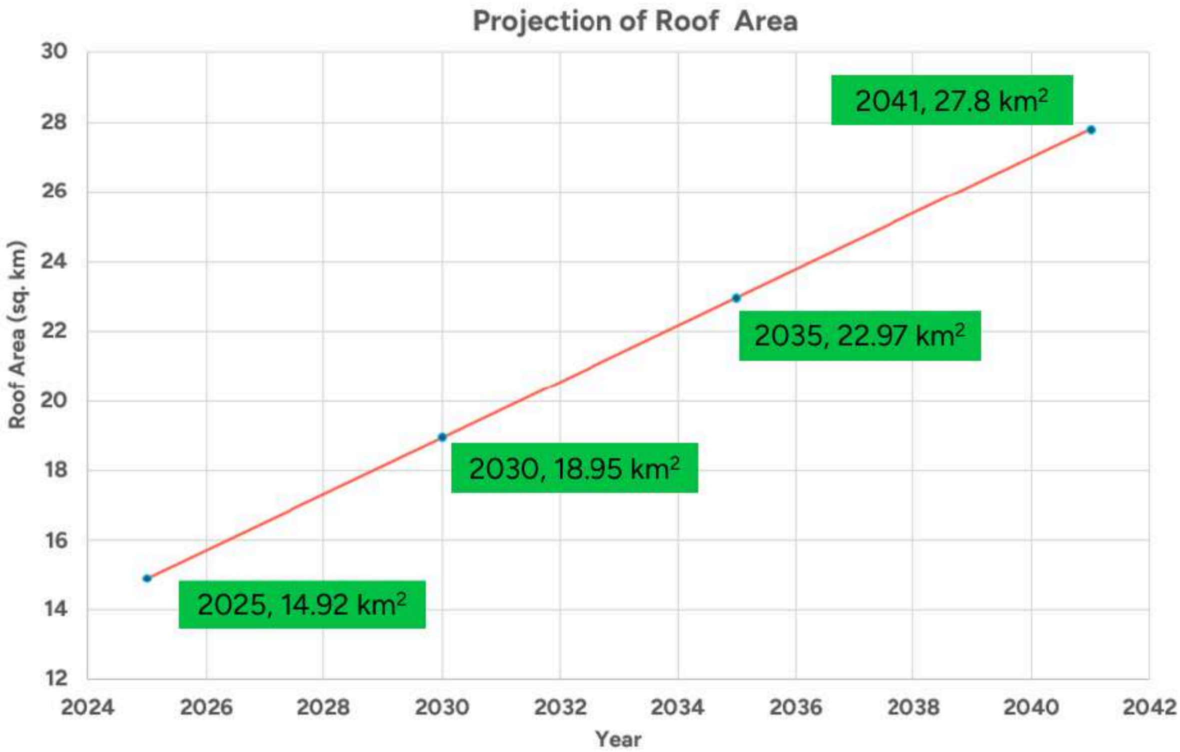


Figure 1 Projected Growth of Total Roof Area (2025-2041)

Medium term (5 - 10 years, by 2035): In the medium term, implementation will expand significantly. All new constructions will continue to comply fully with the bye-law requirements, ensuring every new commercial, institutional, and high-rise residential building includes a cool or green roof.

As the city's total roof area is projected to reach approximately 23 km^2 during this period, the city should aim for 50-60% coverage, or roughly 12-14 km^2, achieved through a mix of new constructions and retrofitted buildings.

Table 2 Medium-Term Implementation Targets: Roof Area, Coverage, and Savings

Medium Term Implementation						
Building Type	**Roof Area Bracket (m^2)**	**Total Roof Area (km^2) in 2035**	**Roof Area Taken for Medium Term (km^2)**	**Share of Roof Area (%)**	**Energy Savings (GWh/yr)**	**Monetary Savings (INR Lakh/yr)**
Residential	0 - 50	2.65		**36.95**	**10.77**	**1424.86**
	50 - 200	10.52	**3.63**			
	200 - 500	1.74	**1.74**			
	>500	0.22	**0.22**			
Subtotal (Residential)	-	**15.13**	**5.59**			
Non-Residential	0 - 50	0.2		**94.52**	**12.43**	**1644.45**
	50 - 200	3.86	**3.63**			
	200 - 500	2.17	**2.17**			
	>500	1.62	**1.62**			
Subtotal (Non-Residential)	-	**7.85**	**7.42**			
Total (Amravati)	-	**22.98**	**13.01**		**23.20**	**3069.30**

Incentive mechanisms such as property tax rebates, inclusion in building maintenance programs, and technical support will be key drivers for large-scale adoption, especially among existing residential and commercial properties.

Long term (beyond 10 years, by 2041): By the long term, the aim is to achieve universal adoption of cool and green roofs across the city. Given that the total roof area is expected to expand to about 27.8 km^2, the city should aim for 80% coverage, translating to nearly 22 km^2 of cool and green roofs. This includes continued 100% compliance for new buildings and widespread adoption among existing ones through sustained enforcement, financing mechanisms, and certification programs.

Table 3 Long-Term Implementation Targets: Roof Area, Coverage, and Savings

Long Term Implementation						
Building Type	**Roof Area Bracket (m^2)**	**Total Roof Area (km^2) in 2041**	**Roof Area Taken for Long Term (km^2)**	**Share of Roof Area (%)**	**Energy Savings (GWh/yr)**	**Monetary Savings (INR Lakh/yr)**
Residential	0 - 50	3.2		**73.06**	**21.30**	**2817.60**
	50 - 200	12.73	**11**			
	200 - 500	2.11	**2.11**			
	>500	0.26	**0.26**			
Subtotal (Residential)	-	**18.30**	**13.37**			
Non-Residential	0 - 50	0.24		**90.33**	**11.88**	**1571.44**
	50 - 200	4.68	**4**			
	200 - 500	2.63	**2.63**			
	>500	1.96	**1.96**			
Subtotal (Non-Residential)	-	**9.51**	**8.59**			
Total (Amravati)	-	**27.81**	**21.96**		**33.17**	**4389.04**

By this stage, Amravati is expected to realize a 23% reduction in cooling-related electricity demand and contributing substantially to the city's climate resilience and energy efficiency goals.

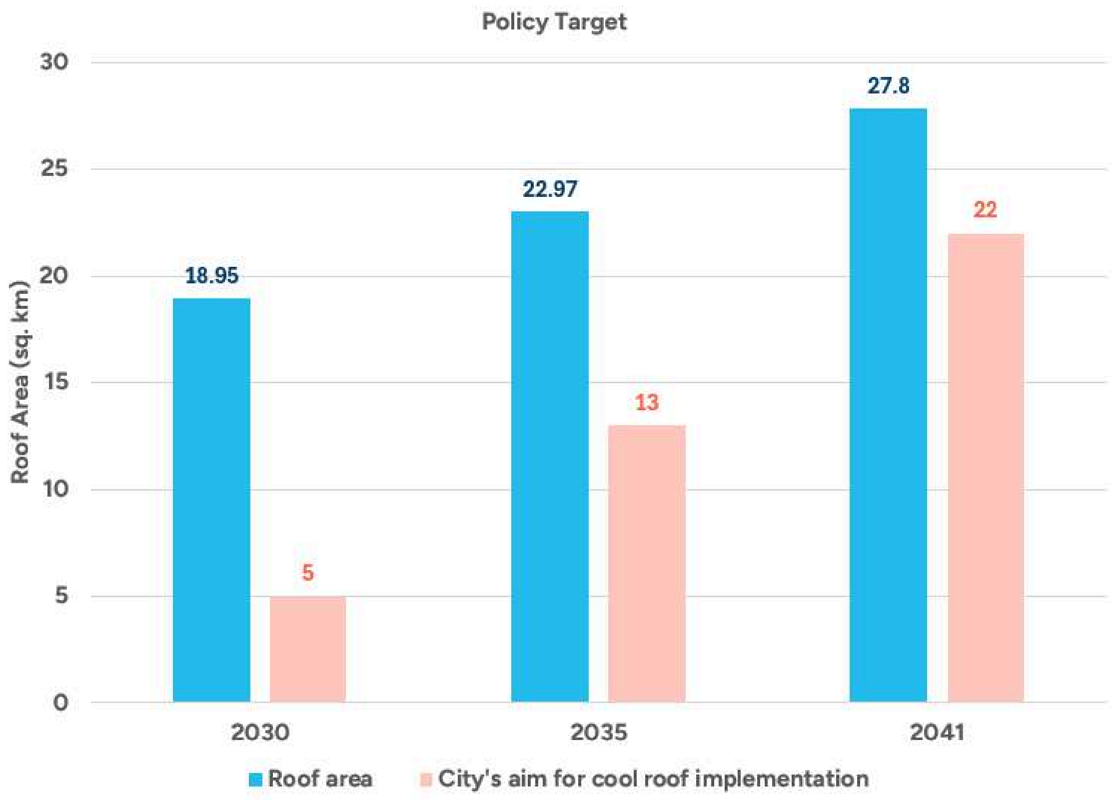


Figure 2 City's Policy Targets for Cool Roof Implementation (2030-2041)

Timelines

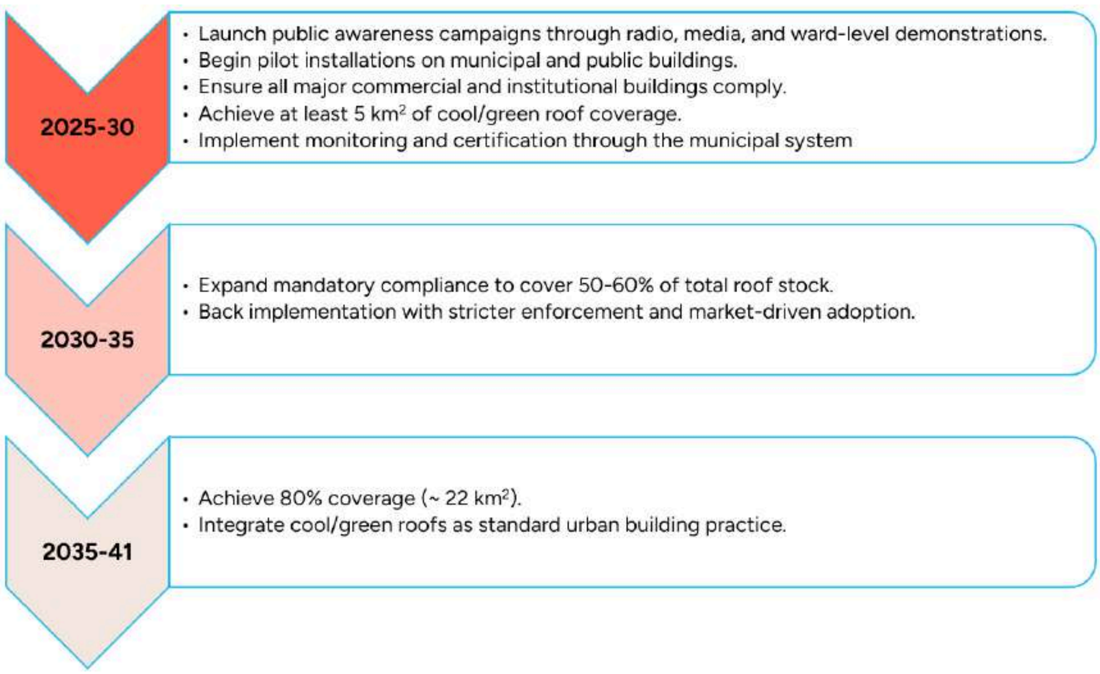


Figure 3 Timelines for project implementation

The Key Performance Indicators to measure these targets over different periods of time are presented in the following table.

Table 4 Key Performance Indicators to measure the targets over different periods

Implementation Period	Key Performance Indicators (KPIs)
2025-30	• Number of public awareness events, media campaigns, and ward-level demonstrations conducted. • Number of municipal and public buildings with pilot cool/green roof installations. • Compliance rate among major commercial and institutional buildings. • Annual increase in cool/green roof coverage toward the 5 km^2 target. • Number of buildings certified per year under the municipal monitoring system. • Efficiency of monitoring and certification processes (processing time, audit frequency). • Share of new vs. existing buildings contributing to total coverage.
2030-35	• Percentage of total roof stock brought under mandatory compliance (progress toward 50–60%). • Annual compliance rate for all eligible buildings. • Number of enforcement actions conducted, and compliance improvements achieved. • Annual number of voluntary retrofits and market-driven cool/green roof installations. • Growth rate of the cool/green roof market (installation volume or economic value). • Reduction in material or installation costs due to increased market participation. • Third-party audit performance and verification outcomes.
2035-41	• Percentage of buildings adopting cool/green roofs as standard practice without municipal prompting. • Integration of cool/green roofs into planning regulations, building codes, and zoning guidelines. • Increase in green roof share (m^2/year) as part of total coverage. • Number of certified installers, contractors, and product suppliers operating in the city.

Category	Key Action	Impact	Ease of Implementation	Target Group/ Sector	Implementation Instrument
Quick Wins (High Impact, Easy to Implement)	Mandatory cool roofs in all new municipal, institutional, and commercial buildings	High	Easy	New construction	Bye-law enforcement, inclusion in building permissions & occupancy certificates
	Cool roof demonstration on existing public buildings (schools, hospitals, markets)	High	Easy	Existing public buildings	AMC-led pilots, public procurement
	Citywide awareness and outreach campaigns		Easy	General public, RWAs	IEC campaigns, media partnerships
Moderate Measures (Medium Impact, Moderate Effort)	Incentive schemes for existing private buildings (tax rebate, permit fee discounts)	High	Moderate	Residential, commercial	Municipal finance & policy instruments
	Capacity building for contractors and material suppliers	Medium	Moderate	Construction ecosystem	AMC training and certification programs
	Development of standard cool roof material specifications	Medium	Moderate	Suppliers, builders	AMC & BIS collaboration
Transformational Measures (High Impact, Requires Strong Institutional Coordination)	Large-scale retrofitting of existing residential and commercial stock	Very High	Difficult	Private sector	Incentives + low-cost finance + awareness
	Integration of green roofs into long-term DCR and sustainability codes	High	Difficult	Urban development sector	Policy amendment, inclusion in city planning
	Establishment of a Cool & Green Roof Cell for monitoring and R&D	High	Difficult	Institutional	AMC institutional setup, university partnerships

Table 5 Impact-ease matrix for cool & green roof implementation in Amravati

2 Economic and GHG Mitigation Aspects of Cool/Green Roof Implementation

For the near-term implementation of cool roofs, the Amravati Cool Roof Byelaws, 2025 set a target to achieve approximately 5 sq. km of cool roof coverage within the next five years, by 2030. Based on the baseline assessment, data on energy savings are available for scenarios where cool roofs are applied to 24.33%, 50%, and 80% of the total mapped roof area. Using linear interpolation, the estimated energy savings for 5 sq. km of cool roof application are calculated to be approximately 13.4 GWh.

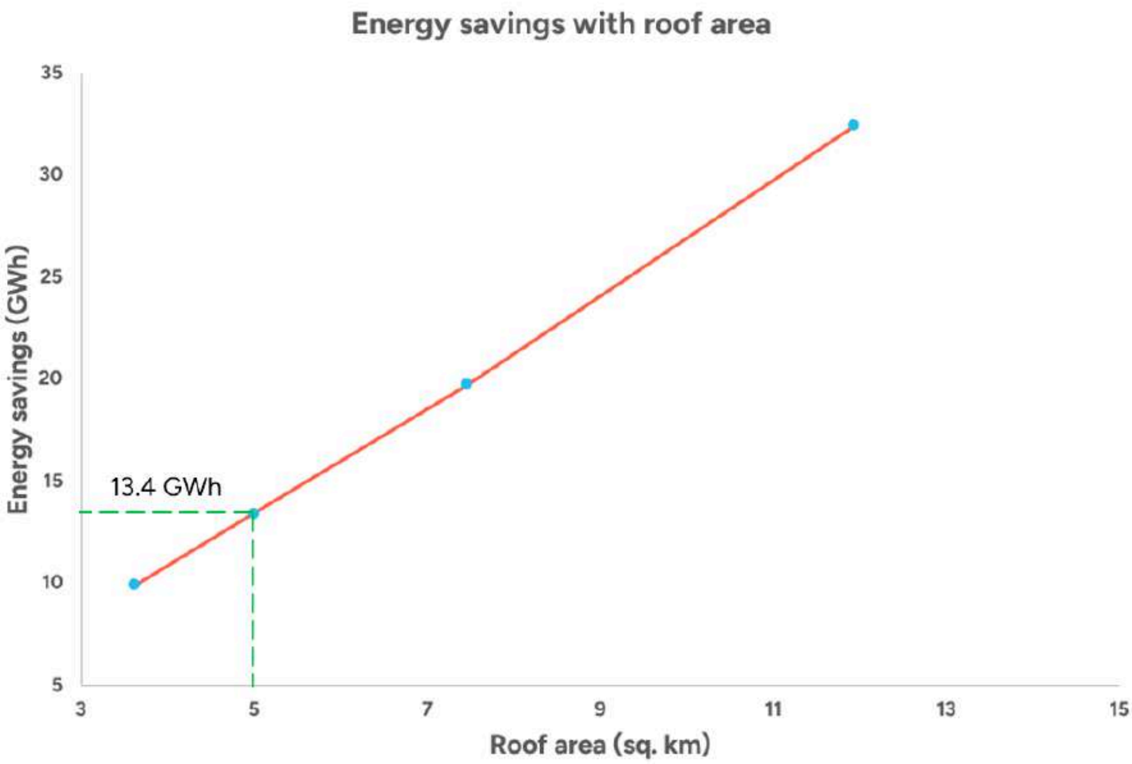


Figure 4 Savings in energy with the application of cool roof

The sectoral analysis of potential savings further illustrates the economic benefits of cool and green roof adoption.

The Amravati Cool Roof Program represents a tangible contribution to the state's climate action goals. Comprehensive adoption of cool roof technologies across all residential and non-residential buildings in Amravati could deliver a one-time radiative forcing offset of **1.49 million tonnes of CO_2e**, that is, a single, large-scale reduction in the Earth's heat absorption caused by increased surface reflectivity. In simpler terms, this offset captures the long-term cooling benefit achieved once the city's roofs are converted to reflective surfaces.

Beyond its climate mitigation benefits, the program enhances thermal comfort, reduces peak cooling demand, and strengthens urban heat resilience, positioning Amravati as a leading demonstration city for passive cooling interventions within the state's decarbonisation roadmap.

Table 6 Monetary and emission reduction benefits from cool roof implementation for year 2025

Building Type	Roof Area Bracket (m^2)	Total Roof Area (km^2)	Share of Roof Area (%)	Energy Savings (GWh/yr)	Monetary Savings (INR Lakh/yr)	GHG Reduction (tCO_2e)
Residential	0 - 50	1.72	17.52	5.11	675.48	172420.58
	50 - 200	6.83	69.55	20.27	2682.30	682868.73
	200 - 500	1.13	11.51	3.35	443.78	112761.04
	>500	0.14	1.43	0.42	54.98	14399.69
Subtotal (Residential)	-	**9.82**	**100.00**	**29.15**	**3856.55**	**982450.04**
Non-Residential	0 - 50	0.13	2.55	0.34	44.35	12978.89
	50 - 200	2.51	49.22	6.47	856.23	251221.38
	200 - 500	1.41	27.65	3.64	480.99	140847.16
	>500	1.05	20.59	2.71	358.18	104918.09
Subtotal (Non-Residential)	-	**5.10**	**100.00**	**13.15**	**1739.75**	**509965.52**
Total (Amravati)	-	**14.92**	-	**42.30**	**5596.29**	**1492415.56**

3 Guidelines for Roof Types and Installation Techniques

3.1 Roof Types

For the successful implementation of cool and green roof systems, it is important to align design and material choices with performance benchmarks that ensure both thermal efficiency and long-term durability. The following recommended values represent standard, widely accepted thresholds for Solar Reflectance, Thermal Emittance, and Solar Reflective Index (SRI). These benchmarks are intended to guide decision-making during the design, construction, and retrofitting of buildings across different typologies.

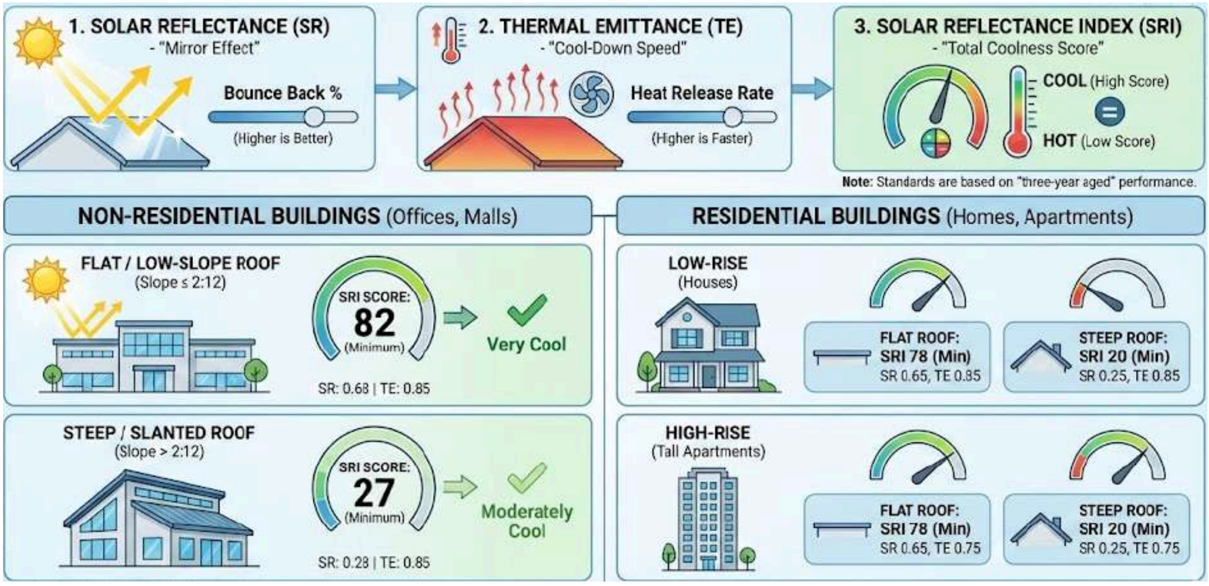


Figure 5 Cool roof rating guide: Required SRI thresholds for flat and sloped roofs across building categories

These recommended performance thresholds are consistent with internationally recognized standards for cool roof materials and coatings. Adoption of these benchmarks in local design guidelines, procurement criteria, and building regulations will ensure that roofing systems contribute effectively to reducing surface temperatures, improving indoor comfort, and supporting urban heat resilience objectives.

Table 7 Thermal and reflective characteristics of building roofs

Building Typology	Roof Slope	Solar Reflectance (SR)	Thermal Emittance (TE)	Solar Reflectance Index (SRI)
Non-Residential	Low-sloped	0.68	0.85	82
Non-Residential	Steep-sloped	0.28	0.85	27
Residential (Low-Rise)	Low-sloped	0.65	0.85	78
Residential (Low-Rise)	Steep-sloped	0.25	0.85	20

Residential (High-Rise)	Low-sloped	0.65	0.75	78
Residential (High-Rise)	Steep-sloped	0.25	0.75	20

3.2 Installation Techniques

Proper installation is essential to ensure the effectiveness, durability, and safety of cool and green roof systems. The following step-wise guidance shall serve as the roadmap for implementing these measures:

3.2.1 Cool Roofs

While application procedures for cool roof paint prescribed by the manufacturer may vary from product to product, some processes of cool roof application must always be adhered to:

1. The surface must be properly swept, cleaned and prepared.
2. All cracks and joints on the surface must be reinforced with caulk and polyester fabric strips. All cracks and joints on the surface must be reinforced with caulk and polyester fabric strips.
3. The coating must be applied through an airless sprayer or roller at a rate (or to a thickness) specified by the manufacturer.
4. The second coat must be applied after the first coat is totally dry to the touch.
5. Do not apply the cool roof coatings if precipitation is imminent, or likely to occur before all coats are expected to be completely dry.

The step by step process for the application of cool roof paint to a roof surface that is new or does not need any repairs are as follows:

1. Roof surface ready for the application of cool roof layer.
2. Roof surface being cleaned for application of primer.
3. Primer for elastomeric high-albedo paint.
4. Application of primer at the seams.
5. First coatings of elastomeric high-albedo paint.
6. Second coating being applied.

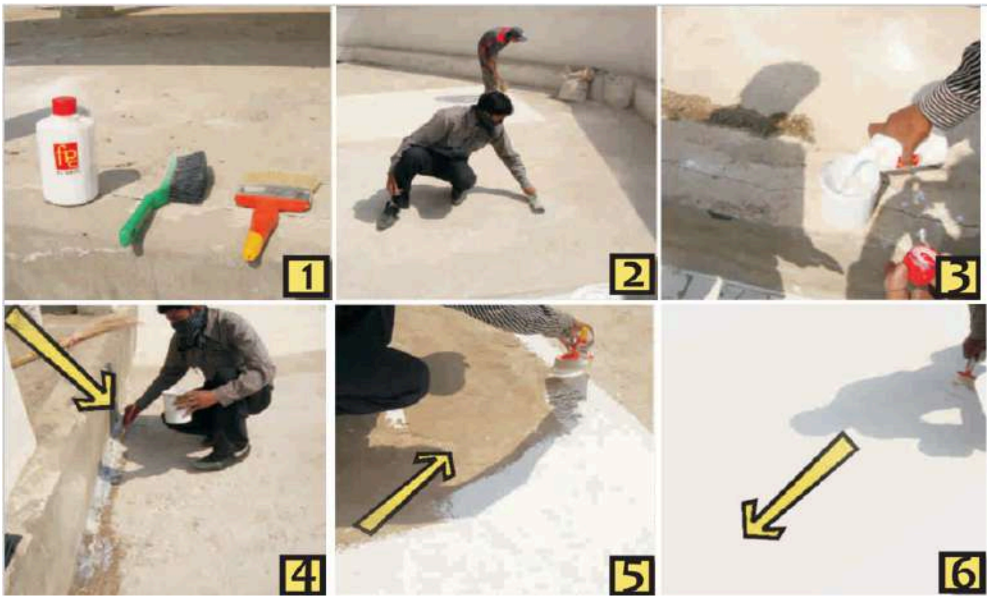


Figure 6 Step by step process for the application of cool roof paint

3.2.2 Green Roofs

Green roofs are an effective nature-based solution that provide multiple co-benefits, including stormwater management, energy efficiency, biodiversity enhancement, and mitigation of urban heat island effects. Achieving these benefits depends on correct installation in line with recognised industry guidance such as the Green Roof Organisation (GRO) Green Roof Code of Best Practice (2023).

The installation of a green roof can be explained in following steps:

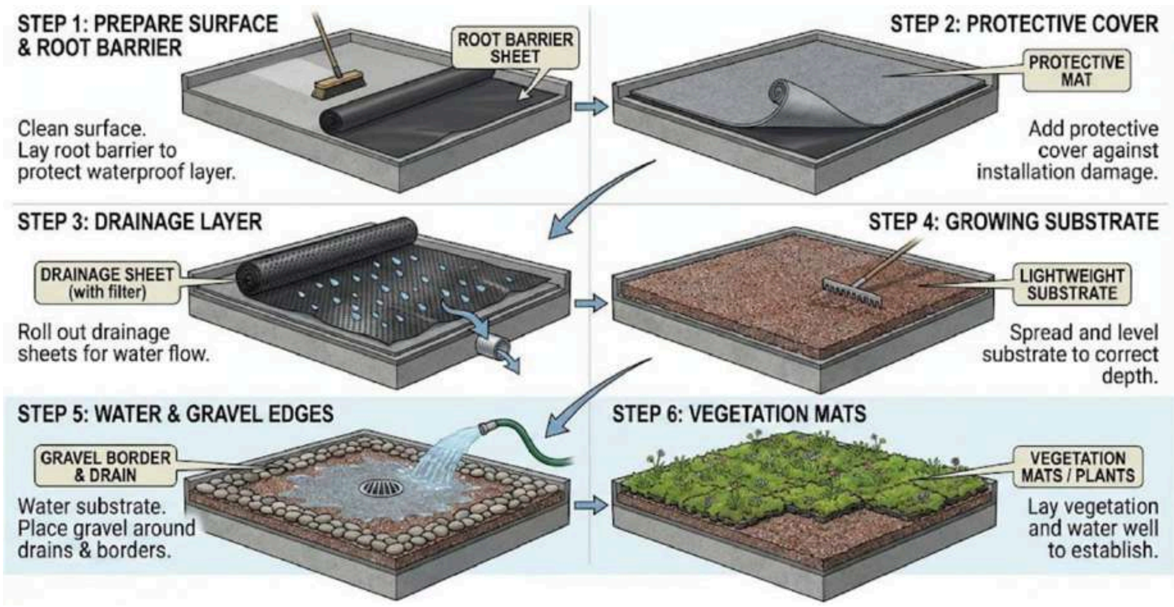


Figure 7 Step-by-step process of green roof installation

Section III - Implementation Mechanisms Including Technical Specifications and Standard Integration

4 Market Readiness

4.1 Findings from market readiness survey

Figure 8 Local paint retailer showcasing availability of cool roof products

The market-readiness survey for cool and green roofs in Amravati included interactions with 10 paint vendors operating in the market area near Chitra Theater. The findings indicate a nascent but promising level of local market awareness and readiness to adopt cooling measures, building on existing household practices. The detailed questionnaire format used for this survey is provided in Annexure 2.

The survey confirmed that households are already experimenting with simple, cost-effective solutions to manage heat:

- **Damp Proof Paints:** A common practice observed is the use of damp proof paints on roofs. While primarily purchased for moisture protection, residents are aware these paints also provide a noticeable cooling effect. This reflects a basic understanding of the concept behind cool roofs, even if not by name or technical specification.
- **Green Net Shading:** The widespread use of green net shading across residential areas was a significant finding. Households frequently purchase and install these nets as a practical measure to reduce indoor heat, demonstrating that the solution is both accessible and well-accepted among residents.

Figure 9 Walkthrough survey observation of rooftop green net shading, a widely adopted household measure for reducing indoor heat in Amravati

Figure 10 Local shop in Amravati selling green nets

The familiarity with these practices suggests that residents are open to adopting technologies that reduce heat exposure when it is affordable and easily available.

4.2 Detailed Analytical Findings from the Market-Readiness Questionnaire

The market readiness survey utilized a questionnaire to gauge the current engagement, awareness, drivers, and barriers related to cool/green roof technologies among participants.

Participants were asked about the current market activity for cool-roof (reflective) and green-roof (vegetated) solutions, and their responses indicate a robust and increasingly specialized market.

1 **Enquiries/Orders:** Participants were asked if they had received enquiries or orders for cool-roof (reflective) or green-roof (vegetated) solutions in the past 12 months.

Participants reported a high rate of engagement, with the majority confirming they had received enquiries for both cool-roof and green-roof solutions, suggesting customers view these as complementary strategies for thermal mitigation.

2 **Volume of Enquiries:** Responses regarding the approximate number of enquiries/orders handled in the last year (options ranged from None to More than 10) indicate that some market actors are already receiving specific, high-volume requests. The findings here were extremely positive, with participants overwhelmingly reporting "More than 10" enquiries/orders, signalling that consumer interest has moved rapidly from niche curiosity to sustained commercial demand.

3 **Source of Information:** Participants were asked to identify their clients' primary sources of learning about cool/green roofs, including Word of mouth, Online/social media, Government/NGO outreach, and Industry event or demo. The results underscore the organic strength of the market, as Word of mouth emerged as the most prominent source. This prominence suggests that early adopters and community networks are successfully driving awareness, validating the tangible benefits of these solutions through trusted networks.

4 **Reasons for Adoption:** When asked about the top reasons clients ask about cool/green roofs, the responses confirmed that adoption is primarily driven by direct, tangible benefits. The top reason identified was improved comfort. This clear focus indicates that consumers are well-informed about the immediate improvement in living conditions.

5 **Current Offerings:** Participants indicated whether they currently offer both cool/green roof materials/services, only one type, or none. The spread of responses demonstrates a clear market specialization, with the majority of participants indicating they currently offer only cool-roof solutions.

6 **Main Barriers:** For those not yet offering these materials, the main barriers identified included Lack of trained installers, High material costs, Uncertain demand, and Certification/standards unclear.

7 **Role of Subsidies:** When asked if they would stock/install systems if a simple government subsidy or grant were available, participants' responses provided a clear and positive indication of the potential effectiveness of financial incentives. The responses were overwhelmingly "Definitely" or "Probably," validating that policy support is critical.

4.3 Work-On Areas and Recommendations

Based on the analytical findings, the following areas need to be addressed to accelerate adoption:

- **Installer Training and Standards:** The identified barrier of Lack of trained installers must be addressed. A program to certify and train local workers is essential to ensure quality installation and build market capacity.
- **Policy Support and Financial Incentives:** The survey confirms that a government subsidy or grant is likely to encourage market actors to stock and install systems. Policy support should focus on simple, accessible financial mechanisms to de-risk investment for suppliers and reduce the initial purchase price for consumers.
- **Market Communication:** Messaging should shift from generic "cooling" to the specific, tangible benefits of Lower energy bills and Improved comfort.

Section IV - Governance, Outreach, and Monitoring

5 Governance Mechanisms for Policy Implementation

The effective implementation of the Cool and Green Roof Policy in Amravati requires a robust governance framework that clearly defines institutional responsibilities, establishes anchor institutions, and facilitates inter-agency coordination. This framework shall ensure that policy directives are translated into actionable programs with measurable outcomes, supported by technical expertise, financial mechanisms, and citizen participation.

5.1 Institutional Framework

The governance structure will operate across four levels:

1 **Municipal Level (Amravati Municipal Corporation):** Lead implementation and enforcement through its key departments.
2 **State & Regional Level:** Provide policy alignment, financial incentives, and technical assistance.
3 **Professional & Industry Level:** Strengthen design, engineering, and construction standards, ensuring industry-wide adoption.
4 **Community Level:** Encourage public participation and localized action through Resident Welfare Associations and citizen groups.

5.2 Policy Anchor Institution: Roles and Coordination

The Amravati Municipal Corporation (AMC) shall act as the nodal agency for implementing the Cool and Green Roof Policy, operating through a dedicated Cool Roof Cell (CRC). This cell will be housed within the Town Planning Department but managed through a cross-departmental Steering Committee.

Core Responsibilities of the AMC Steering Committee:

- **Policy Integration:** Ensuring policy provisions are mandatory in all new building permits and major renovations.
- **Incentive Management**: Overseeing the application, verification, and disbursement of tax rebates and financial subsidies.
- **Monitoring & Reporting:** Collecting data on installed area, energy savings, and thermal comfort to report progress to State agencies.

5.3 Governance Matrix: Key Agencies and Functions

To ensure accountability and streamline implementation, the following matrix details the specific roles and coordination points for each anchor institution across the four governance levels.

Table 8 Governance matrix: Key agencies and their functions

Governance Level	Anchor Institution	Primary Role	Key Responsibilities & Coordination Points
Municipal (Nodal)	Town Planning Department	Policy Integration & Approval	Recommend the inclusion of Cool/Green Roof provisions in the Unified Development Control and Promotion Regulations (UDCPR) through coordination with the State Town Planning Department. Ensure local development permissions and building plans comply with the approved provisions once notified by the State.
	Construction/ Engineering Dept	Technical Enforcement & Quality	Site inspection and enforcement of technical standards during construction. Ensuring material quality and installation standards are met.
	Tax Department	Financial Incentive Delivery	Process and approve property tax rebates for certified compliant buildings. Annual verification of continued compliance.
	Environment & Garden Dept	Monitoring & Plant Expertise	Provide guidance on native and suitable plant species for green roofs. Monitoring the urban heat island effect and environmental impact.
State Level	Maharashtra Energy Development Agency (MEDA)	Technical & Financial Support	Channel state and central subsidies. Provide technical guidelines and training modules for AMC staff.
	Public Works Department (PWD)	Lead by Example	Ensure all new state-owned buildings and major public infrastructure projects incorporate Cool and Green Roof components as standard.
	MahaVitaran (MSEDCL)	Energy Alignment & Rebates	Coordinate energy efficiency programs. Potentially offer energy consumption rebates for buildings with documented energy savings from cool roofs.
Professional & Industry Level	CREDAI / Institute of Architects (IIA)	Capacity Building & Standards	Develop training programs and technical specifications for contractors, architects, and engineers. Promote best practices and voluntary compliance reporting.
Community Level	Resident Welfare Associations (RWAs)	Local Mobilization & Feedback	Mobilize local participation, especially for existing buildings and residential communities. Serve as the primary feedback channel for policy effectiveness and incentives.

5.4 Inter-Agency Coordination, Performance, and Accountability

Effective governance requires moving beyond defined roles to establishing clear accountability, robust coordination protocols, and transparent enforcement mechanisms.

5.4.1 Institutional Hierarchy and Coordination Protocols

The governance hierarchy is led by the AMC Steering Committee, ensuring the effective translation of policy into action and resolving inter-departmental conflicts.

- **Coordination Meetings:**
  1. AMC Steering Committee: Convenes monthly meetings with all Municipal Department Heads to review pipeline progress and approve incentive disbursements.
  2. State-Municipal Alignment: Convenes quarterly meetings with State Anchor Institutions (MEDA, PWD) to resolve strategic bottlenecks, align budgets, and integrate with state-level energy initiatives.
- **Conflict Resolution Process:**
  1. Operational conflicts (e.g., disputed compliance certification) are first handled by the Cool Roof Cell (CRC).
  2. Policy or financial disputes that affect multiple departments are escalated to the AMC Steering Committee for final, binding resolution.
- **Shared Data System (Digital Integration):**
  1. A common digital platform, managed by the AMC Town Planning Department, shall act as the single source of truth, tracking building permits, compliance status, incentive applications, and energy monitoring data, ensuring transparency across all governance levels. This system shall be accessible (read-only) to all State and Professional anchor institutions for reporting purposes.

5.4.2 Performance Management System

A performance management system shall track agency-level implementation progress against defined Key Performance Indicators (KPIs).

Table 9 Agency-level performance tracking framework for cool/green roof implementation

Agency / Level	Key Performance Indicators (KPIs)	Reporting Cadence
Town Planning Dept (AMC)	Percentage of new building permits compliant with Cool/Green Roof requirements.	Quarterly
Tax Department (AMC)	Average turnaround time for processing incentive applications (days). Number of property tax rebate beneficiaries for cool/green roof adoption.	Quarterly
Construction Dept (AMC)	Percentage of non-compliant structures identified and issued rectification notices.	Monthly

General Administration/Engineering Department (AMC)	Number and percentage of government/AMC-owned buildings that have adopted cool or green roofs	Bi-annually
MEDA / PWD (State)	Financial subsidy utilization rate for Amravati's policy.	Bi-annually
CREDAI / IIA (Professional)	Number of professionals (architects, contractors) trained/certified.	Annually

The AMC Steering Committee will maintain a Policy Scorecard based on these KPIs.

5.4.3 Enforcement and Compliance Mechanisms

Compliance is ensured through mandatory verification protocols and tiered penalties, reinforcing the policy's efficacy.

Compliance Verification Protocols:

- **Plan Approval (Pre-Construction):** Town Planning Department verifies compliance with UDCPR requirements during the plan approval stage.
- **Site Inspection (Post-Construction):** Construction/Engineering Department conducts mandatory final site inspection prior to issuing the Occupancy Certificate (OC). No OC will be issued without CRC sign-off on cool/green roof features.
- **Annual Verification:** The Tax Department carries out periodic spot checks for properties availing incentives or property tax rebates. Verification includes geo-tagged photographs as evidence of continued maintenance, along with on-site surface and indoor temperature measurements to confirm ongoing performance of the cool/green roof system.

Enforcement and Penalties:

- **New Buildings (Non-Compliant):** Withholding of the Occupancy Certificate (OC) until full compliance is achieved.
- **Existing Buildings (Non-Maintenance):** Immediate withdrawal of property tax rebates/incentives, retroactive recovery of incentives, and issuance of fines equal to 50% of the lost tax incentive for the relevant year.
- **Appeals Process:** Property owners may appeal enforcement decisions to a designated Appeals Sub-Committee within the AMC, composed of the Municipal Commissioner, a technical expert from AMC, and an urban planning representative.

6 Technical Specifications

6.1 Cool Roof Coatings: Performance Standards for Reflective Coatings

Urban heat in Amravati is worsened by high solar radiation, long periods of sunny weather, and hot-dry summers followed by intense monsoon rains. Cool roof coatings are a cost-effective measure to reduce roof surface temperatures, lower indoor heat gain, reduce energy consumption, and mitigate the urban heat island effect. To ensure effectiveness, coatings must meet well-defined performance criteria.

6.1.1 Recommended Performance Standards for Amravati

To ensure that cool roof coatings provide effective thermal comfort, durability, and long-term cost efficiency under Amravati's climatic conditions, it is essential to adopt recognized benchmarks. The following table outlines the relevant National codes and rating systems that prescribe performance criteria for cool roofs.

These standards serve as a reference for minimum requirements on parameters such as Solar Reflectance (SR), Thermal Emittance (TE), and Solar Reflectance Index (SRI), thereby guiding consistent implementation across projects.

Table 10 National code and rating systems

Std.	Type of Building	SR	TE	SRI	Mandatory or Optional	Ambiguities	Enabling Conditions
ENS	Residential (Roofs < 20° slope)	≥ 0.60	≥ 0.90	-	Mandatory for prescriptive compliance	No clear SRI value or product testing standards. Regional climatic factors not explicitly considered.	Aligned with PMAY-U. Provides incentive for energy efficiency in residential housing
ECBC (2017)	Commercial (Low-slope roofs)	≥ 0.70	≥ 0.75	≥ 78	**Mandatory** for ECBC buildings	No mention of aged reflectance or long-term durability under Indian climate conditions	Forms basis for State ECBC notification. Linked to green building mandates
IGBC Rating	Commercial & Residential	≥ 0.65	≥ 0.75	-	**Optional** (credit-based)	Suggested values-not binding, lacks contextual adaptation for Indian heat stress patterns	Awards point under Green Building criteria encourages integration into the design approach
GRIHA Rating	Commercial & Residential	≥ 0.65	≥ 0.75	-	**Optional** under-point system	No minimum area defined for roof coverage; lack of guidance on product verification	Credits for sustainable roof materials and passive cooling measures

6.2 Green Roof Systems: Requirements for Soil Depth, Vegetation, and Irrigation

Green roof systems provide stormwater retention, thermal regulation, and biodiversity benefits. Their performance depends on correct design of the substrate (soil), appropriate vegetation choice, and provision for irrigation adapted to local climatic conditions.

6.2.1 Soil/Growing Medium Depth

- Green roof substrates must be engineered growing media, not natural topsoil, designed to balance porosity, water retention, and load-bearing capacity.
- Recommended installation depths (minimum) are as follows:
  - Sedum pre-grown blanket/mat: 60 mm + blanket thickness (20 mm).
  - Sedum from plugs/cuttings: 80 mm.
  - Wildflower / meadow blanket: 100 mm (or deeper depending on species).
  - Biodiverse roofs: 80–150+ mm, aligned with ecological design intent.
  - Herbaceous plants: 150 mm.
  - Lawns: 200 mm.
  - Medium shrubs: 400 mm.
- All intensive roofs must have at least 200 mm depth, with deeper profiles for larger vegetation.
- Substrate design must allow for 10% settlement post-installation.

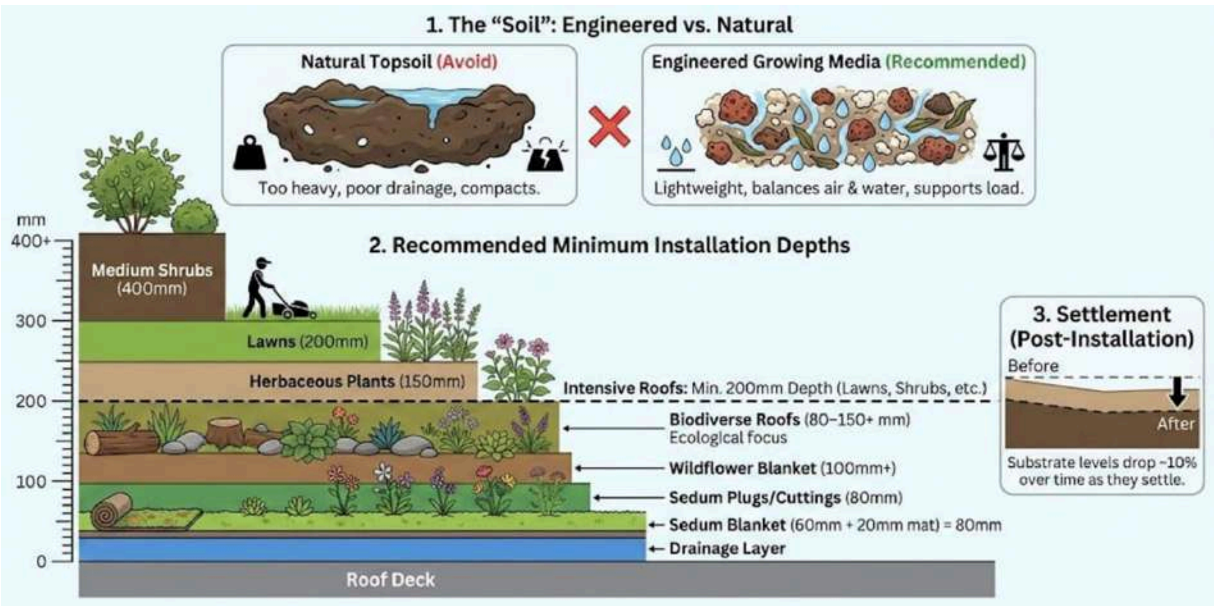


Figure 11 Typical substrate depths for different green roof types

6.2.2 Vegetation Selection

- Vegetation should be selected based on roof type and ecological objectives, while ensuring climate resilience in Amravati's hot summers and intense monsoon rainfall.
- Sedum blankets: At least 9+ sedum species, ≥90% coverage, grown over a full season, and free of invasive weeds.
- Wildflower/meadow mats: At least 16+ species, ≥85% coverage, with non-invasive grasses; mats ≥25 mm thick.
- Seed sowing: Not recommended for sedum roofs; acceptable for wildflower roofs with a sowing density of 3-4 g/m^2, minimum 15 species mix, sown in spring or autumn.
- Plug planting: 16-25 plugs/m^2 (or 12-16 plugs/m^2 when combined with seeding); plugs must be saturated before planting and placed flush with the substrate.

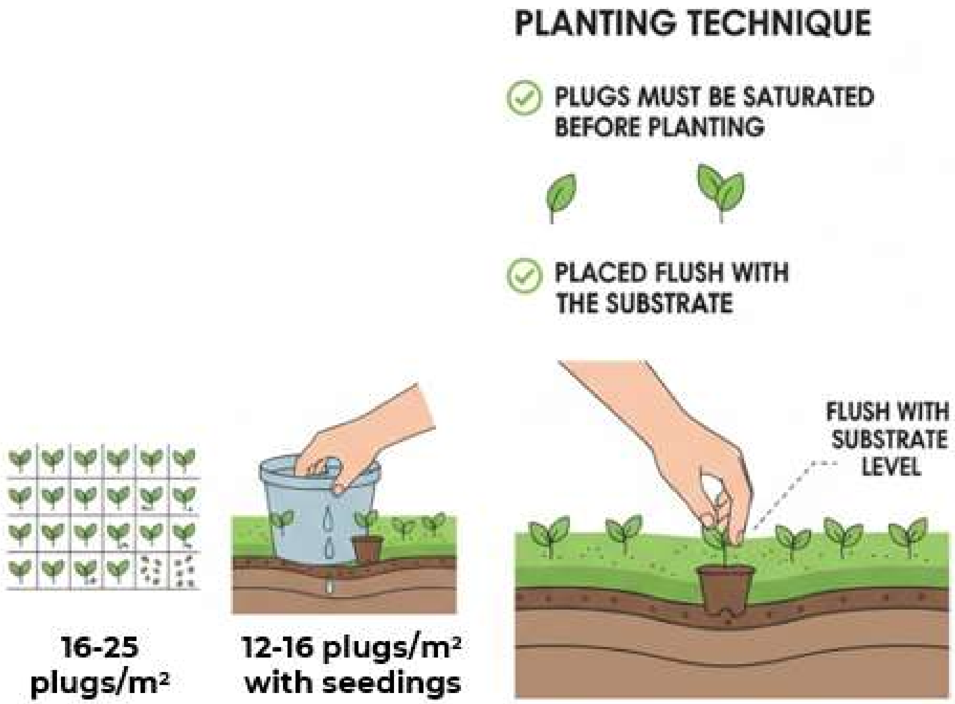


Figure 12 Recommended planting technique for green roofs

- Vegetation must be non-invasive, pest-free, and peat-free to align with sustainable procurement practices.
- For Amravati, emphasis should be placed on drought-tolerant succulents, native grasses, and flowering perennials that can withstand seasonal extremes.

6.2.3 Irrigation Methods

- Establishment Phase: All green roofs must be irrigated for 6-8 weeks post-installation, until vegetation is rooted.
- Long-term needs:
  - Extensive sedum/wildflower roofs: Minimal irrigation; only during extended droughts (>6 weeks without rain).

- Intensive/biodiverse roofs: Require permanent irrigation systems (e.g., drip irrigation).

- Irrigation demand depends on plant choice, substrate depth, water storage, rainfall, and roof exposure.
- To reduce water demand, rainwater harvesting and treated greywater reuse are recommended for irrigation.

6.3 Maintenance: Guidelines for Routine Upkeep of Cool and Green Roofs

The effectiveness and durability of cool and green roofs depend on routine maintenance. Proper upkeep ensures continued thermal performance, extends service life, and prevents risks to building integrity. Building owners and facility managers in Amravati shall adhere to the following minimum maintenance standards.

6.3.1 Cool Roofs

Cleaning

- Roof surfaces shall be cleaned at least once a year, preferably before summer, to remove dust, algae, or debris that reduce reflectivity.
- After the monsoon season, roof surfaces shall be inspected for waterlogging or sediment accumulation and cleaned if necessary.

Inspection

- Coated surfaces must be inspected every 2 years for peeling, chalking, cracks, or loss of adhesion.
- Any sections with degraded coatings must be re-treated immediately.

Repair and Recoating

- Minor cracks or damage should be repaired with compatible sealants or patch coatings.
- Full recoating shall be carried out every 5 - 7 years, or earlier if Solar Reflectance (SR) falls below 0.55 as verified by accredited testing or visual assessment.

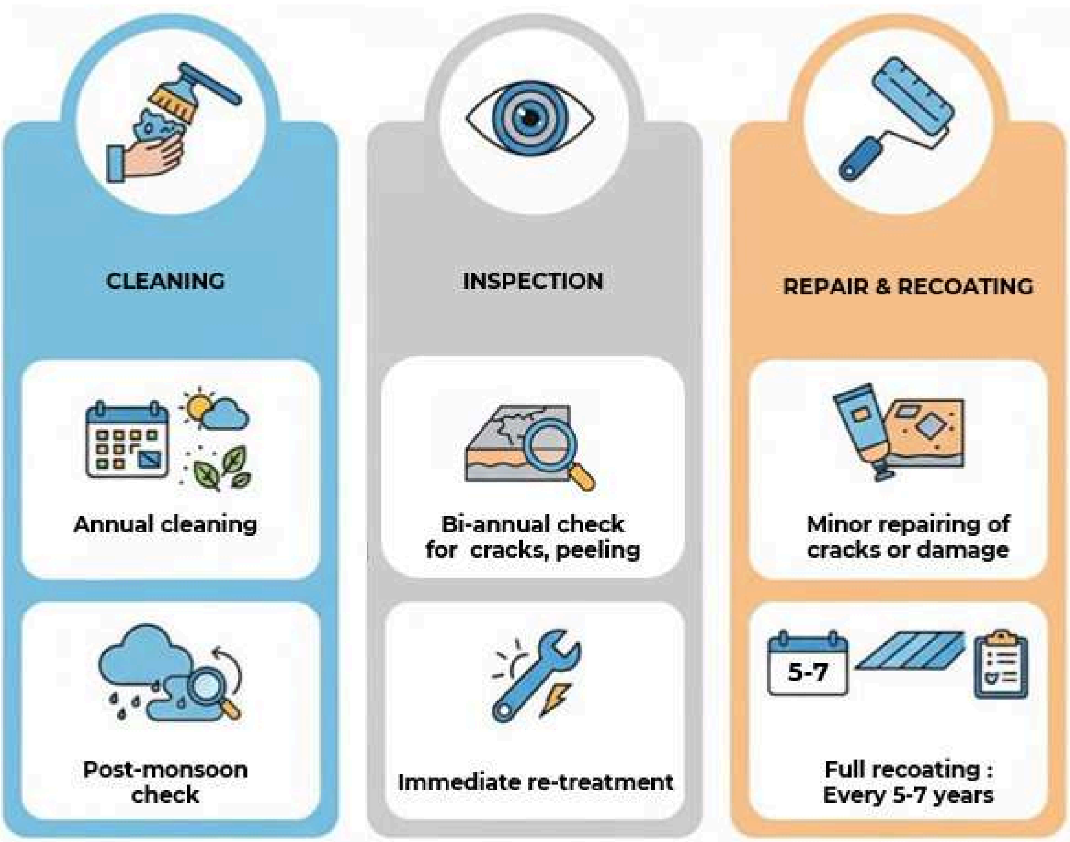


Figure 13 Recommended maintenance schedule for cool roofs

6.3.2 Green Roofs

Vegetation Care

- Routine checks at least quarterly to assess plant health, coverage, and the presence of invasive weeds.
- Irrigation to be provided during dry periods, especially in Amravati's summer (April–June) and during prolonged droughts (>6 weeks without rain).
- Fertilisation only if required, using low-nutrient, sustainable formulations suitable for extensive roof systems.

Drainage and Substrate

- All drains, inspection chambers, and gravel margins must be checked every 3 - 6 months and kept clear of debris to prevent waterlogging.
- Substrate should be topped up or adjusted if settlement exceeds 10% of design depth.

Waterproofing Integrity

- Formal inspection of waterproofing membranes and root barriers shall be conducted every 5 years, or sooner if leaks are detected.
- Leak detection systems, if installed, should be tested annually.

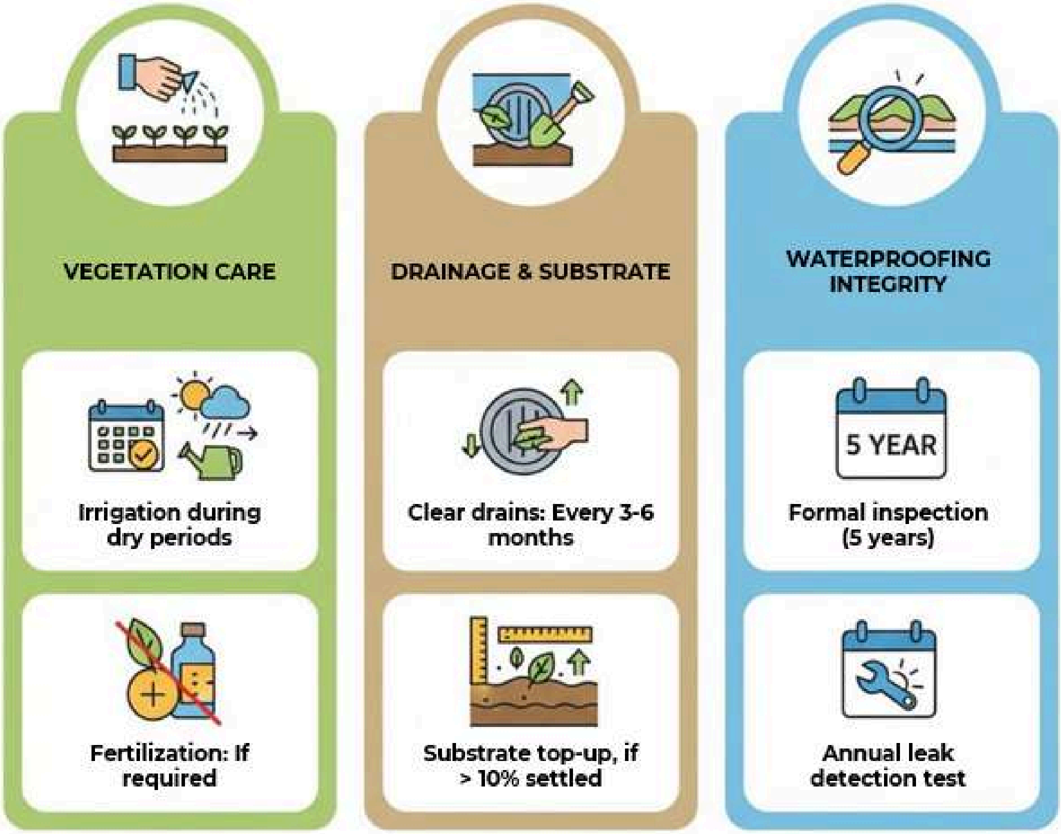


Figure 14 Recommended maintenance schedule for green roofs

6.4 Safety Standards: Compliance for Cool and Green Roof Installations

All cool and green roof installations in Amravati must comply with applicable safety regulations to protect building users, maintenance personnel, and surrounding communities. Safety considerations extend across structural integrity, fire safety, occupational health, and drainage design.

6.4.1 Cool Roofs

Cool roofs generally present fewer direct safety challenges compared to green roofs. Nevertheless, the following measures shall be observed to ensure safe installation and maintenance:

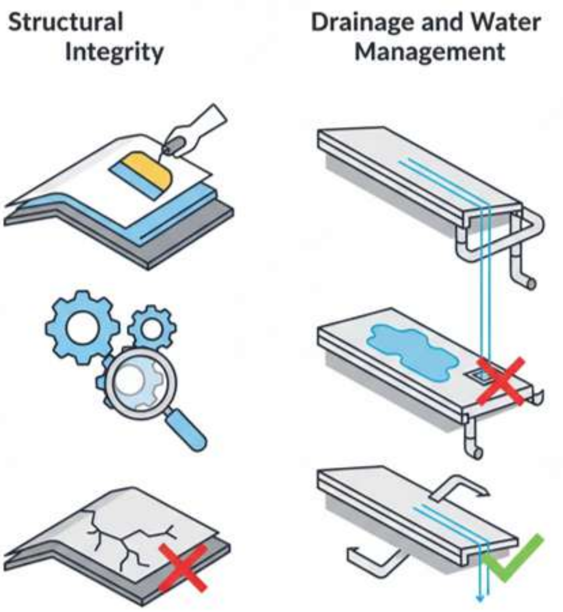


Figure 15 Key Pre-installation checks for cool roofs

- **Structural Integrity:** Coating and overlay systems shall be compatible with the existing roof structure, ensuring that surface preparation and application do not compromise waterproofing layers or structural components.
- **Drainage and Water Management:** Installation shall not impede roof drainage. Standing water shall be avoided through proper slope and detailing to reduce risks of leakage or water damage.

6.4.2 Green Roofs

To safeguard occupants, maintenance staff, and the integrity of the building, all green roof installations in Amravati shall adhere to the following safety protocols:

- **Fire Safety:** A no-smoking and no hot-work policy (such as welding, grinding, or soldering) shall be strictly enforced on all green roofs. Firebreaks shall be incorporated at the perimeter of the system, and adequate separation shall be maintained between plant holders and walls. Substrates must be selected for their capacity to absorb and retain water, and preference shall be given to drought-tolerant and high water content plants that reduce flammability.
- **Water Penetration:** Roof systems shall utilize a shallow growing medium to minimize deep root growth. Plant species shall be hardy, drought tolerant, and capable of storing excess water while limiting transpiration. A waterproofing membrane shall be installed at the base and junctions of the roof system, supplemented by electronic water leak detection. Flood and leak tests shall be conducted immediately after installation and at prescribed intervals thereafter.
- **Wind Exposure:** Prior assessment of wind and gust conditions shall be conducted, and measures adopted to resist uplift of plants and equipment while minimizing debris risks.
- **Common Space Safety:** All entry and exit points shall remain well-lit and clearly marked during periods of use. Walkways shall be maintained free of debris, obstructions, or other hazards to ensure safe movement across the roof.

7 Implementation and Alignment Considerations

The successful implementation of the Cool/Green Roof Policy requires its seamless integration into the existing regulatory and governance frameworks. The Unified Development Control and Promotion Regulations (UDCPR 2020) of Maharashtra already provide a foundation through provisions on solar rooftop installations, rainwater harvesting, greywater recycling, energy efficiency, and green building incentives. Similarly, tendering and procurement processes for government and municipal projects incorporate sustainability clauses that can be leveraged to promote cool and green roofs.

To ensure that the policy achieves widespread adoption and long-term impact, it is essential to identify specific areas within **building byelaws**, as well as **tendering and procurement documents**, where alignment with cool/green roof recommendations can be formalized.

7.1 Building Byelaws: Existing Provisions and Alignment

7.1.1 Existing Provisions in UDCPR

a) **Solar Rooftop / Solar Assisted Water Heating (SWH) Requirements:** Buildings on plots >4000 sq.m. must provide open sunny roof space, minimum loading capacity of 50 kg/sq.m. and allocate at least 25% of roof area for solar systems.

13.2 INSTALLATION OF SOLAR ASSISTED WATER HEATING (SWH) SYSTEM/ ROOF TOP PHOTOVOLTAIC (RTPV) SYSTEM

SWH or RTPV systems shall be mandatory in all types of buildings to be constructed on plot area of more than 4000sq.m.

In order to facilitate the installation of SWH/RTPV System, the new buildings shall have the following provisions:-

i) All such buildings where SWH/RTPV are to be installed will have open sunny roof area available for the installation of SWH/RTPV.

ii) The roof loading adopted in the design of such building should be at least 50 kg. Per Sq.m. for the installation of SWH / RTPV.

iii) At least 25% of the roof area shall be utilized for installation of the SWH/RTPV system.

Figure 16 Provision of solar rooftop and solar assisted water heating in UDCPR

b) **Rainwater Harvesting:** Mandatory for plots >500 sq.m., with levy/penalty for non-compliance.

13.3 RAIN WATER HARVESTING

The provision for Rain Water Harvesting shall be made as under:-

a) All the layout open spaces/amenity spaces of housing societies and new constructions/ reconstruction/ additions on plots having area not less than 500 Sq.m. shall have one or more Rain Water Harvesting structures having a minimum total capacity as detailed in Schedule.

Provided that the Authority may approve the Rain Water Harvesting structures of specifications different from those in Schedule, subject to the minimum capacity of Rain Water Harvesting being ensured in each case.

b) The owner/society of every building mentioned in the (a) above shall ensure that the Rain Water Harvesting System is maintained in good condition for storage of water for non-potable purposes or recharge of groundwater at all times.

c) The Authority may impose a levy of not exceeding Rs.1000/- per annum for every 100sq.m. of built-up area for the failure of the owner of any building mentioned in the (a) above to provide or to maintain Rain Water Harvesting structures as required under these regulations. Failure to provide Rain Water Harvesting System shall deemed to be breach of the conditions on which the development permission has been granted.

Figure 17 Provision of rainwater harvesting in UDCPR

c) **Greywater Recycling:** Required for large layouts (≥10,000 sq.m.), with space earmarked for greywater treatment plants.

13.4 GREY WATER RECYCLING AND REUSE

Grey Water - It means waste water from bathrooms, sinks, shower and wash areas, etc.

Applicability -These Regulations shall be applicable to all Developments/ Redevelopments/part Developments for the uses as mentioned under Regulation No. 13.4.1 to 13.4.6 shall have the provision for treatment, recycling and reuse of Grey Water. The applicant shall along with his application for obtaining necessary layout approval/ building permission shall submit a plan showing the location of Grey Water Treatment Plant, furnishing details of calculations, implementation, etc. This Plan shall accompany with the applicant's commitment to monitor the system periodically from the date of occupation of the respective building.

13.4.1 For Layout Approval/Building Permission

i) In case of Residential layouts, area admeasuring 10000 Sq.m. or more, in addition to 10% open space, prescribed in the bye- laws, a separate space for Grey Water Treatment and Recycling Plant should be proposed in the layout. This may be proposed in amenity space as per Regulation No. 3.5.

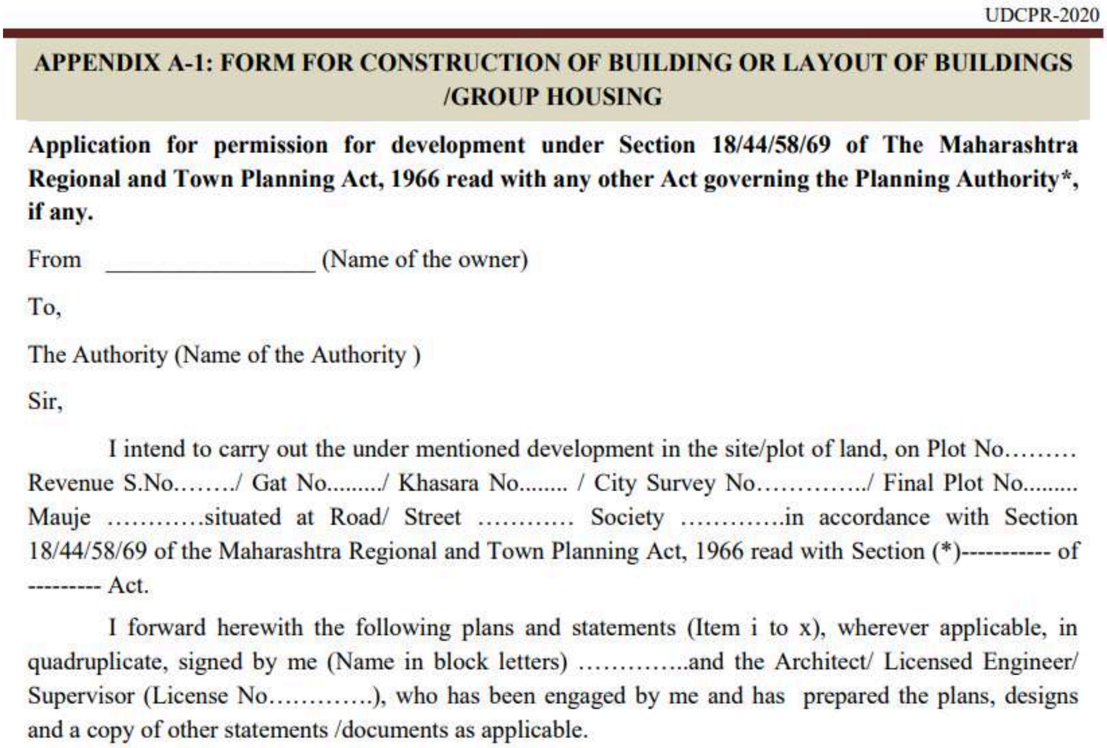
Figure 18 Provision of greywater recycling and reuse in UDCPR

d) **Roof Drainage:** Regulations already ensure rainwater pipes, drainage, and terrace access.

7.1.2 Alignment Opportunities

The existing UDCPR provisions offer a strong foundation for integrating cool and green roof measures within the broader sustainable building framework. However, targeted amendments and alignments can ensure that thermal comfort, climate resilience, and energy efficiency goals are more comprehensively addressed. The following opportunities are recommended:

- **Introduce Cool Roof Standards within Structural and Solar Provisions:** The UDCPR currently specifies roof loading and area allocation for solar systems, which can be expanded to include minimum thermal performance criteria for roofs.
- **Facilitate Integrated Roof Systems (Solar + Cool + Green Roofs)**: To avoid conflicts between multiple sustainability mandates, UDCPR can explicitly permit co-location of systems, for instance, combining photovoltaic panels with reflective membranes or partial green roof sections.



UDCPR-2020

APPENDIX A-1: FORM FOR CONSTRUCTION OF BUILDING OR LAYOUT OF BUILDINGS /GROUP HOUSING

Application for permission for development under Section 18/44/58/69 of The Maharashtra Regional and Town Planning Act, 1966 read with any other Act governing the Planning Authority*, if any.

From ________________ (Name of the owner)

To,

The Authority (Name of the Authority)

Sir,

I intend to carry out the under mentioned development in the site/plot of land, on Plot No……… Revenue S.No……../ Gat No........./ Khasara No........ / City Survey No…………../ Final Plot No......... Mauje …………situated at Road/ Street ………… Society ………….in accordance with Section 18/44/58/69 of the Maharashtra Regional and Town Planning Act, 1966 read with Section (*)----------- of --------- Act.

I forward herewith the following plans and statements (Item i to x), wherever applicable, in quadruplicate, signed by me (Name in block letters) …………..and the Architect/ Licensed Engineer/ Supervisor (License No…………), who has been engaged by me and has prepared the plans, designs and a copy of other statements /documents as applicable.

Figure 19 Building plan submission format (Appendix A-1, see Annexure 3 for template)

- **Mandate Thermal Comfort-Oriented Roof Design in Public Buildings:** Public and institutional buildings can serve as demonstration sites for climate-responsive roofing. UDCPR can introduce a mandatory clause for reflective coating, insulation, or vegetative cover in all government and semi-public buildings above a certain roof area.
- **Integrate Green Roofs with Rainwater Harvesting Systems:** Green roofs inherently capture and store rainfall, reducing runoff and enhancing water retention. UDCPR can allow dual compliance by recognizing green roof systems as partial fulfilment of rainwater harvesting obligations, provided that appropriate storage, filtration, and reuse mechanisms are in place.
- **Update Building Plan Submission Formats (Appendix A-1 / A-2)**: To institutionalize compliance and monitoring, the building plan application forms can be revised to include fields for cool/green roof specifications, including roof material type, reflectance/emittance values, insulation details, and intended vegetation or solar layout. This will help local authorities verify compliance at the design approval stage and build a database of thermally efficient roofs for monitoring future performance and policy impact. Annexure 3 provides a draft text and format.

UDCPR-2020

APPENDIX A-2: FORM FOR SUB-DIVISION OF LAND AS PLOTTED LAYOUT

Application for permission for development under Section 18/44/58/69 of The Maharashtra Regional and Town Planning Act, 1966 read with any other Act governing the Planning Authority, if any.*

From ________________ (Name of the owner)

To,
The Authority,(Name of the Authority.)

Sir,

I intend to carry out the under mentioned development in the site/plot of land, bearing S.No./Gat No./City Survey No/Final Plot No.……………………,Mouje …………………, situated at Road/ Street ……………………… in accordance with Section 18/44/58/69 of The Maharashtra Regional and Town Planning Act, 1966 read with Section (*)----------- of --------- Act.

I forward herewith the following plans and statements (Item 1 to 7), wherever applicable, in quadruplicate, signed by me (Name in block letters) …………………………… and the Architect / Licensed Engineer / Supervisor (Registration/ License No………………………), who has been engaged by me and has prepared the plans, designs and a copy of other statements /documents as applicable.

Figure 20 Building plan submission format (Appendix A-2)

7.2 Tendering and Procurement: Existing Provisions and Alignment

7.2.1 Existing Provisions in State Scheduled of Rate (SSR)

- **High Albedo / Cool Roof Paint (SSR Item 48.19):** Two coats of high albedo paint with minimum SRI 108 (ASTM C1549 & C1371 tested), VOC less than 10 cc/gm, guaranteed durability and SRI performance.

Sr. No.	Chapter	SSR Item No.	Reference No.	Description of the item	Additional Specification	Unit	Completed Rate for 2022-23 excluding GST In Rs.	Labour Rate for 2022-23 excluding GST In Rs.
1637	Roofing	48.19	As directed by Engineer in charge	Providing and applying two coats of High Albedo paint having minimum Solar Reflective Index (SRI) 108 (with solar reflectance & thermal emittance tested as per ASTM) C 1549 and ASTM C 1371 respectively. VOC less than 10 cc/gm. The coating thickness and the methodology of application shall strctly as per manufacturer's specifitions and as approved by engineer in charge. Surface preparation includes cleaning with metal wire brush to remove all dust, fungus etc, washing with water all complete.The contractor shall give guarantee for the performance of SRI and also the durabitity of coating, all complete as per direction of Engineer - in- incharge.	As directed by Engineer in charge	One Square Metre	410	78

Figure 21 Roofing section in existing SSR

- **Roof Waterproofing (SSR Item 50.10):** High-performance 100% acrylic, waterproof, anti-fungal, anti-carbonation, heat-insulating external paint, applied in three coats of 100% acrylic waterproof heat insulating breathable decorative external coating. Solar Reflectance (tested EN 410:2011) = 107.

Sr. No.	Chapter	SSR Item No.	Reference No.	Description of the item	Additional Specification	Unit	Completed Rate for 2022-23 excluding GST In Rs.	Labour Rate for 2022-23 excluding GST In Rs.
1729	Water proofing	50.10		Clean the surface to remove dirt, loose particles. Examine the surface closely for any cracks. Clean the cracks. Provide and fill a pure acrylic, polymer modified ready to use paste Polyfill AR of approved make & approved by Engineer in charge having a cream coloured viscous emulsion ready to use acrylic polymeric non-shrink crackfiller putty with auto suction properties and requiring no bonding agent, no curing and no requirement for opening the existing cracks finishing with subsequent filling as required. Provide and apply three coats of 100% acrylic waterproof heat insulating breathable decorative external coating Sunext 8 of approved make & approved by Engineer in charge, in the desired shade. Stir well and apply by brush for three coats. Applying three coats at an interval of 4-6 hours between each coat. High Performance 100% Acrylic, Waterproof, Anti-fungal, Anti-carbonation, Heat Insulating External Paint should have following minimum properties: 1. Specific Gravity: 1.3 ± 0.1 at 25°C 2. pH: 7.0 to 10.00 3. Viscosity: 18 to 30 sec. at 25°C by Ford Cup One Number B-4 (Dilute 2 parts of product with 1 part of water) 4. CO2 diffusion resistance co- efficient (DIN EN 1062-6 (2002-10): 7.59 x105 5. CO2 diffusion equivalent air layer thickness (DIN EN 1062-6 (2002-10): 127m @ 190 microns DFT 6. Adhesion (ASTM D 4541): 2.3 N/mm2 (Concrete / Substrate Failure) 7. Solar Reflectance Index (ASTM E 1980 11,EN 673:2011, EN 410:2011): 107 It shall be applied as per manufacturers specification.	As directed by Engineer in charge	One Square Metre	251	163

Figure 22 Water proofing section in existing SSR

7.2.2 Alignment Opportunities

Cool Roofs:

- SSR 48.19 (SRI 108) and SSR 50.10 (acrylic heat-insulating paint, SRI 107) already provide strong base provisions.
- Can be expanded to cover reflective membranes, cool roof tiles, reflective metal sheets, and spray-applied reflective coatings.
- Link tendering to require performance testing of SRI after 3 years (aged value compliance).

Green Roofs:

- Leverage SSR 50.10 waterproofing as the base protection layer before adding green roof assemblies.
- Introduce new SOR items for: root barriers, drainage mats, filter fabrics, lightweight soil medium, and vegetation layers (see Annexure 4 for some draft provisions).

Integrate with rainwater harvesting through retention/detention layers for co-benefits.

8 Outreach, Awareness, and Capacity Building

Successful implementation of cool and green roof initiatives requires strong outreach, effective awareness campaigns, and dedicated capacity building efforts. Public engagement through information campaigns, demonstration projects, and community workshops can increase acceptance and adoption of these technologies. At the same time, workforce development and specialized training programs for architects, contractors, and construction workers ensure that the necessary skills and technical expertise are in place to deliver high-quality and scalable applications.

To support widespread adoption, the policy may also promote Cool-Roof Kits - IS 17218 compliant, high-SRI (≥ 80), typically costing ₹200 per liter. These standardized kits simplify procurement, guarantee performance, and help property owners adopt cool roofs with confidence. A curated list of empanelled vendors supplying IS 17218 - compliant cool roof kits (including manufacturers of high - SRI coatings, primers, and application accessories) should be published on the AMC website for public reference.

8.1 Media Outreach

An effective media outreach strategy for promoting cool and green roofs in Amravati should combine broad awareness campaigns with targeted digital engagement. The communication should aim to (i) inform citizens of the benefits, (ii) inspire local adoption through relatable stories and visuals, and (iii) influence builders and housing societies to integrate cool/green roofs in upcoming projects.

A two-tiered outreach strategy is proposed:

1. **Mass Awareness through Traditional Media**
   - i. **Newspapers & Radio:** Regular features and interviews highlighting successful local examples, cost savings, and health benefits during peak summer months.
   - ii. **Local Television & Cable Channels:** Short explainer segments or infographics demonstrating how cool roofs reduce indoor heat and save energy.
   - iii. **Press Releases & Articles:** Distributed through the Amravati Municipal Corporation's Public Relations Office to ensure consistent city-wide messaging.

2. **Targeted Engagement through Digital & Social Media:** Digital platforms can help the municipal corporation and partner agencies sustain engagement and track public response.

8.1.1 Key Channels and Tactics

- **Facebook & Instagram:** Use short videos, photo stories, and "Before-After" visuals of cool/green roof retrofits. Run hashtag campaigns such as #CoolRoofsAmravati and #GreenRoofsForAll to build visibility.
- **Twitter (X):** Share technical updates, policy news, and partnerships; tag relevant agencies like the Maharashtra Energy Development Agency (MEDA) and local builder associations.
- **YouTube:** Host 2-3 minute awareness videos explaining installation steps, benefits, and testimonials from residents.
- **WhatsApp & Telegram Groups:** Distribute short infographics and FAQs via Resident Welfare Associations (RWAs) and municipal ward offices.
- **Enhancement of AMC Website:** Develop a dedicated "Cool & Green Roof" webpage within the existing Municipal Corporation website, featuring downloadable resources, FAQs, case studies and success stories, key guidelines, and direct links to incentive and rebate programs.

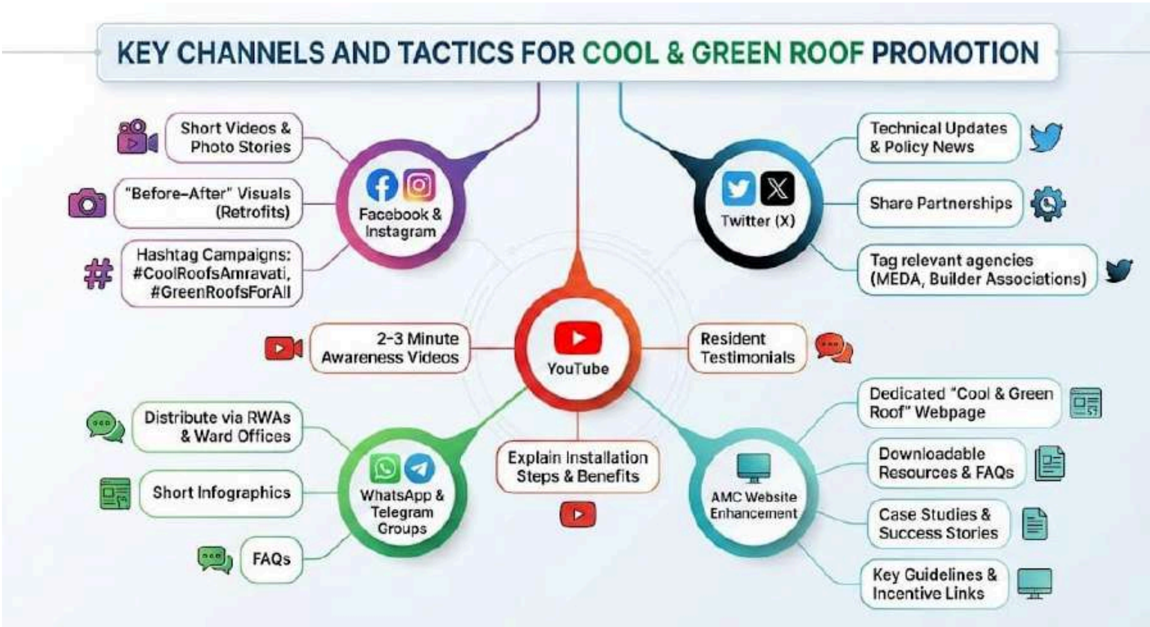


Figure 24 Key channels and tactics for cool and green roof promotion

8.1.2 Key Messaging Themes

Messages should be localized, easy to understand, and emotionally resonant. Suggested themes include:

- **Economic Benefit:** "Cool roofs cut your cooling bills by up to 20%. A small step for your roof, a big saving for your home."
- **Health & Comfort:** "Stay cooler this summer, reduce indoor heat by 2-4°C naturally."
- **Environmental Impact:** "Each cool roof reflects the sun and helps lower the city's heat."
- **Civic Pride:** "Let's make Amravati a Cool Roof City by 2041, every roof counts!"

Some sample posters are attached in ***Annexure 1*** for reference.

8.2 Public Awareness Campaigns

To support widespread adoption, AMC will plan and implement targeted public awareness campaigns and community outreach programs that educate citizens about the multiple benefits of cool and green roofs. The core strategy is to tailor the message to resonate with distinct consumer categories and stakeholders.

Table 11 Targeted messaging and strategy

Consumer Category	Primary Motivation or Key Message	Recommended Strategy or Channel
Individual Homeowners & Housing Societies	Energy savings, indoor comfort, and lower electricity bills. Message: "Keep your home cooler and your energy bills lower, switch to a cool or green roof."	Local awareness drives through RWAs and ward offices, community workshops, short social media videos, simple brochures, and testimonials from early adopters.
Commercial / Industrial Building Owners	Return on investment, operational efficiency, and green certification benefits. Message: "Boost your property value, reduce cooling costs, and meet green standards with smart roofing."	Partnership with business associations, technical webinars, trade magazine articles, and success-story videos featuring commercial adopters.
Real Estate Developers & Builders	Market differentiation, compliance, and branding as sustainable developers. Message: "Build smarter, greener projects, attract buyers with eco-friendly, high-performance roofs."	Developer roundtables, technical toolkits, training sessions with architects/engineers, and visibility through digital real estate platforms.
Students, Youth & Community Volunteers	Environmental awareness and civic pride. Message: "Be a change-maker, help make your city greener and cooler."	School and college outreach programs, social media challenges, art/poster competitions, and youth-led awareness campaigns.

Some draft posters are added in the Annexure 5

8.3 Workforce Development and Training Opportunities

Building the technical capacity of professionals is essential for the successful implementation of cool and green roof initiatives. Targeted training programs should be designed for architects, builders, contractors, municipal officials, and maintenance staff to enhance their knowledge of cool/green roof technologies, materials, design standards, and maintenance practices. These programs shall include:

- Orientation sessions on policy provisions, enforcement mechanisms, and inspection protocols.
- Hands-on technical training on materials, design standards, thermal performance assessment, and maintenance of cool/green roofs.
- Certification and refresher programs to ensure ongoing professional development and compliance with evolving standards.
- Annual training calendar with quarterly modules covering design, construction, maintenance, and monitoring aspects.

By integrating workforce development with continuous professional education, AMC can create a skilled pool of experts capable of delivering high-quality projects at scale. Such initiatives not only strengthen implementation capacity but also generate green jobs and promote innovation in sustainable building practices.

To enhance the effectiveness of training programs, AMC can collaborate with reputed institutions and leverage existing training opportunities, including:

- **Indian Green Building Council (IGBC)** - for certified green building professional courses.
- **Bureau of Energy Efficiency (BEE)** - for energy efficiency related training.
- **Technical universities and polytechnics** - for applied workshops and demonstrations.

9 Monitoring, Reporting and Verification (MRV) Framework

A robust MRV system is essential to ensure that the Cool/Green Roof Policy delivers measurable thermal, environmental, and socio-economic benefits. The framework integrates data-driven monitoring, independent verification, and policy feedback loops to enable adaptive management and transparent evaluation over time.

9.1 Framework Overview

The MRV framework shall operates on a three-tier system:

Table 12 Monitoring, Reporting and Verification (MRV) framework

Tier	Focus	Responsible Entity	Output
Tier I (Monitoring)	Continuous collection of implementation and performance data through physical measurements, GIS mapping, and remote sensing	AMC Environment & Energy Cell	Real-time dashboard and monthly data updates
Tier II (Reporting)	Aggregation, analysis, and interpretation of data into structured performance reports	AMC technical team	Annual progress reports
Tier III (Verification)	Independent validation of data quality, performance metrics, and claimed benefits	Accredited third-party auditors / universities	Annual verification and policy feedback report

9.1.1 Monitoring System Design

A hybrid monitoring system shall combine remote sensing, IoT-based ground data, and administrative records to track progress at building and city scale.

Table 13 Monitoring system design

Monitoring Domain	Data Type	Tools/Methods	Frequency
Thermal Performance	Surface temperature, albedo, emissivity	Satellite data, rooftop sensors	Monthly
Energy Performance	Cooling energy demand, peak load reduction	AMC-DISCOM data linkage	Quarterly
Green Roof Health	Vegetation cover, soil moisture, runoff volume	Satellite data, field sampling	Monthly
Adoption and Coverage	Roof type, area covered, compliance with specs	Building permit registry, GIS digitization	Quarterly
Socio-economic Impacts	Occupant comfort, energy bills, awareness levels	Structured surveys, field studies	Annual

Each dataset shall feed into a Centralized MRV Data Portal, managed by AMC's Environment/Energy Cell, integrated with the Smart City data backbone.

9.1.2 Reporting Framework

A robust reporting framework is essential to track progress, ensure accountability, and communicate the impact of the Cool and Green Roof Policy. Regular reporting enables data-driven decision-making, transparency among stakeholders, and continuous policy refinement. The framework outlined below specifies the frequency, key indicators, and visualization tools required for systematic monitoring and public dissemination of outcomes.

1. **Frequency and Format**
   - **Quarterly Monitoring Updates:** Visual summaries of temperature trends, coverage expansion, and sensor performance.
   - **Bi-Annual Reports:** Analytical reports for internal review by AMC and partner departments.
   - **Annual Public Report**: Simplified visual publication detailing heat reduction, energy and emission savings, adoption rate, and citizen benefits.
2. **Key Metrics and Reporting Indicators**
   - **Thermal Metrics:** Average surface temperature reduction, reduction in UHI intensity, extreme-heat-day frequency.
   - **Energy Metrics:** Cooling energy saved, total electricity saved, avoided peak load.
   - **Environmental Metrics:** Annual CO_2e reduction, green cover gain.
   - **Implementation Metrics:** Roof area retrofitted, number of compliant installations.
   - **Economic & Social Metrics:** Energy cost savings, comfort improvement index, awareness penetration.
3. **Data Visualization Tools**
   - City-level heat maps (before/after scenarios).
   - Ward-wise adoption dashboards.
   - Energy savings trendlines and CO_2 abatement charts.

9.1.3 Verification Protocols

A robust verification system is essential to maintain transparency, credibility, and accuracy in the MRV framework. The following verification approach shall ensure that all reported outcomes are authentic and data-driven.

- Cross-check between building completion certificates and installed roof types.
- Validation of energy and billing data against DISCOM datasets.
- Sensor calibration checks and remote-sensing ground truthing.
- Random sampling of installations each year.
- Comparison of modelled vs. observed performance.
- Annual verification by an accredited body.

10 Pilot Project Profiles

10.1 Introduction

Two representative public buildings in Amravati were selected to demonstrate the practical, financial, and operational benefits of cool and green roof interventions. These pilot sites were chosen based on roof typology, accessibility, public visibility, and potential for scaling within municipal infrastructure. Each pilot underwent a techno-economic assessment to quantify cooling energy reduction, annual monetary savings, installation costs, and payback periods.

The analysis provides evidence-based insights to support citywide adoption and inform policy, procurement, and budgeting decisions.

10.2 Pilot Project - Cool Roof Application (MHADA, Maltekdi)

Figure 26 Pilot project -1

Building Name: MHADA, Maltekdi

Technology: Cool Roof Paint

Roof Area: 430.96 sq.m

Location: Gruh Nirman Bhavan, Maltekdi Road, Amravati (20.931°N, 77.770°E)

Technical Assessment

- Cooling energy consumption with existing RCC roof: 23,835 kWh/year
- Cooling energy consumption with Cool Roof Paint (SRI 0.85): 16,261 kWh/year
- Annual cooling energy savings: 7,574 kWh

Economic Assessment

- Average electricity tariff: ₹13.23/kWh
- Cost of cool roof paint: ₹1,076.39/sq.m
- Total installation cost: ₹4,63,881
- Annual monetary savings: ₹1,00,204

- Payback period: 4.63 years

Summary

This pilot demonstrates strong financial viability for cool roof applications in public buildings. With a moderate investment and a payback period under five years, cool roofs offer an attractive option for rapid, large-scale adoption. The energy savings achieved in this building highlight the significant reduction in cooling loads possible through high-SRI surfaces, especially in dense urban microclimates like Maltekdi.

10.3 Pilot Project - Green Roof Application (Urban Health Post, Paki Pura)

Figure 27 Pilot project - 2

Building Name: Urban Health Post, Paki Pura

Technology: Extensive Green Roof

Roof Area: 328.94 sq.m

Location: Paki Pura, Amravati (20.937°N, 77.743°E)

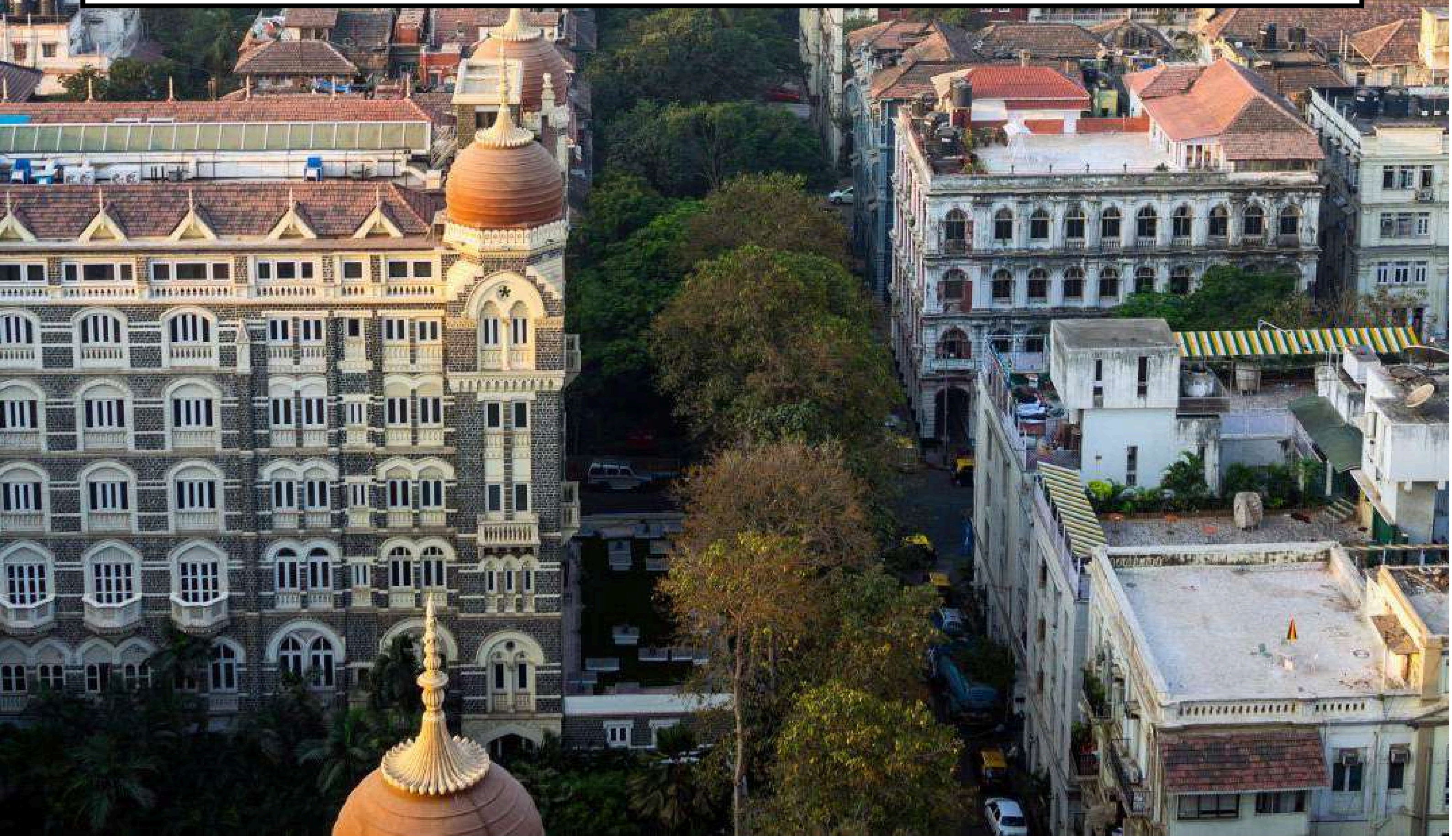
Technical Assessment

- Cooling energy consumption with RCC roof: 19,912 kWh/year
- Cooling energy consumption with Green Roof: 15,260 kWh/year
- Annual cooling energy savings: 4,652 kWh

Economic Assessment

- Average electricity tariff: ₹13.23/kWh
- Cost of green roof material: ₹2,690.98/sq.m
- Total installation cost: ₹8,85,170
- Annual monetary savings: ₹61,545
- Payback period: 14.38 years

Net Zero Action Plan for Municipal Buildings of Mumbai and Panvel



Technical Partner: Alliance for an Energy Efficient Economy

Executive Summary

The Net Zero Action Plan for Municipal Buildings presents a comprehensive framework for the Brihanmumbai Municipal Corporation (BMC) and Panvel Municipal Corporation (PMC) to transition its municipal building portfolio toward net-zero energy and carbon targets by 2050. The plan addresses both existing and new municipal buildings, focusing on strategies that combine technical, financial, and governance interventions to achieve measurable emission reductions in alignment with the Mumbai Climate Action Plan and Maharashtra's Net Zero Roadmap by 2050 objectives.

Scope and Objectives

The action plan covers four major municipal building categories **schools, offices, hospitals, and auditoriums** which together account for approximately **14.7% of BMC's total electricity consumption**. For **existing buildings**, the goal is to achieve **net-zero energy**, emphasizing operational energy efficiency and renewable energy integration. For **new buildings**, the target is **net-zero carbon**, incorporating both operational and embodied carbon reductions through the use of low-carbon materials, efficient building design practices, energy efficient appliances, rooftop solar PV and clean energy procurement.

Net Zero Strategies for Existing Building

Walkthrough energy audits were conducted for representative buildings within each identified typology to identify **Energy Conservation Measures (ECMs)**. The results were extrapolated to estimate stock-level impacts across BMC's building portfolio. Walkthrough audit of the sampled buildings shows that the most effective ECMs include **rooftop solar PV installation**, **replacement of conventional fans with BLDC fans**, and **upgrading inefficient air-conditioning systems** to high-efficiency models.

The impact analysis of the identified ECMs across building typologies indicates that, if implemented effectively, these measures can substantially reduce current energy consumption. In some cases such as **schools** and **auditoriums** they could enable a **net zero energy** status, while **office buildings** could achieve **near-net zero performance** (as shown in Figure E.1).

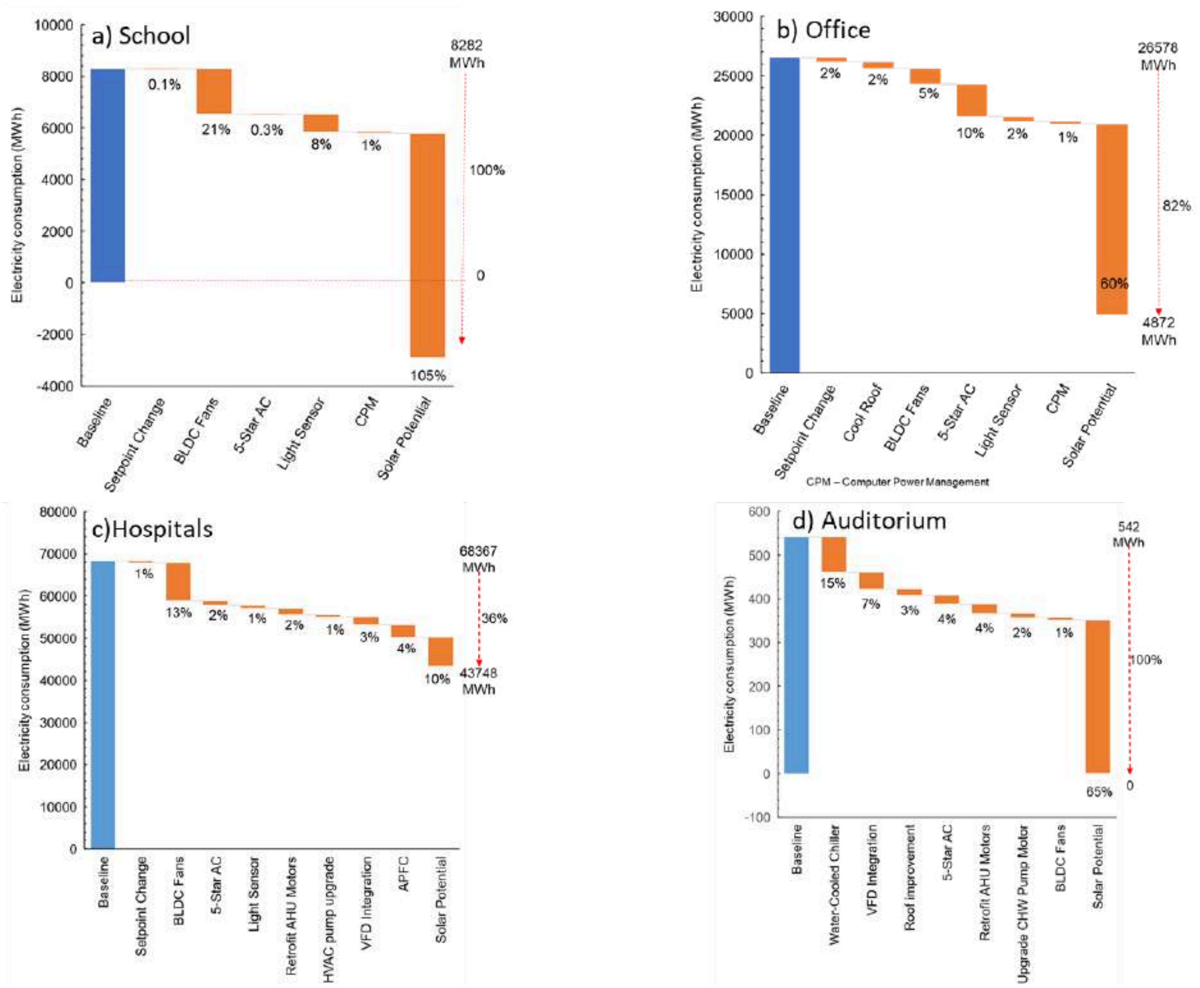


Figure E1: Stock-level impact of energy conservation measures (ECM's) across building typologies

The analysis indicates that **retrofitting existing inefficient appliances** with energy-efficient alternatives and **installing rooftop solar systems** are key strategies to reduce energy consumption in existing buildings and, in some cases, achieve **net zero energy status**.

For certain building typologies, such as **offices** and **hospitals**, where net zero energy cannot be achieved solely through efficiency upgrades and rooftop solar, **procuring green power from the open market under the Green Tariff Policy** can help bridge the gap and enable them to reach **net zero energy status**.

Net-Zero Strategies for New Buildings

Net zero strategies for new municipal buildings is structured around five key pillars:

Passive Design Strategies – Optimized building orientation, high-performance envelopes, shading devices, and cool roofs to reduce cooling loads.

Active Design Strategies – Integration of efficient lighting, BLDC fans, 5-star or VRF HVAC systems, and advanced controls for load management.

Low-Carbon Materials – Use of low-emission cements (PPC, PSC, LC3), high-recycled-content steel, and alternative walling materials such as fly ash or Agrocrete blocks.

Rooftop Solar Integration – Early-stage planning to ensure adequate roof strength, orientation, and capacity for on-site renewable generation.

Clean Energy Procurement – Adoption of the **MERC Green Tariff Policy** and open-access renewable energy to offset residual grid emissions.

Recognizing fiscal constraints at the municipal level, the action plan outlines diverse **financing mechanisms** tailored to different investment scales such as **self-financing** for low-cost measures (LED retrofits, BLDC fans, cool roofs) through the municipal climate budget, revolving funds, or on-bill recovery, **ESCO-based performance contracting** for medium-cost interventions such as air conditioning units and centralized cooling system upgrades, **RESCO and Cooling-as-a-Service (CaaS) models** for capital-intensive measures like rooftop solar and centralized HVAC retrofits and **innovative financing instruments**, including municipal and green bonds, concessional loans, and public–private partnerships (PPPs), for large-scale deployment (Shown in Figure E.2). The report suggests that implementation be overseen by a **Climate Budget Steering Cell**, housed within the Environment Department in coordination with the M&E and Finance Departments through a robust **Measurement, Reporting, and Verification (MRV) Framework**.

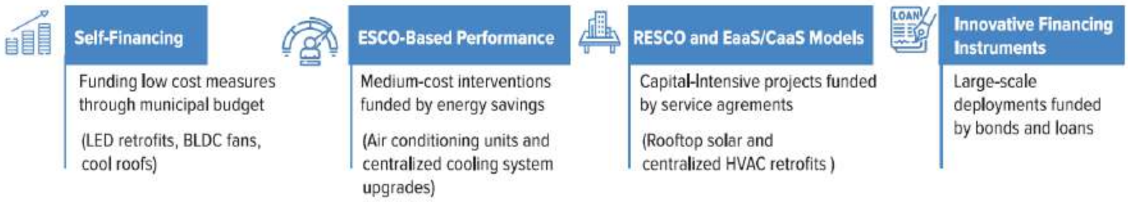


Figure E2: Financing mechanism for implementing ECMs

Finally, for implementation the roadmap outlines **phased implementation targets**, **by 2030 it proposes to** complete baseline audits and implement all no-cost and low-cost ECMs across priority building categories, **by 2040, a**chieve 50% portfolio coverage under net-zero energy through rooftop solar and efficiency measures and by 2050 achieve full transition to **net-zero energy for existing buildings** and **net-zero carbon for all new municipal buildings (Shown in Figure E.3).** Pilot action plans for the **RC Ward Municipal Office** and **Nair Hospital** illustrate the integration of identified ECMs, financial models, and institutional roles to serve as scalable prototypes for all municipal building typologies.

01 Scope of Net Zero Municipal Buildings

Over its lifecycle, a building generates substantial greenhouse gas (GHG) emissions, which can be categorized into **embodied emissions**, **operational emissions**, and **end-of-life emissions**. The stages of buildings' lifecycle emissions, as defined by ISO 14040/14044, are illustrated in **Figure 1**.

Understanding of Emissions Across Building Life Cycle

Embodied Carbon: Comprises of upfront embodied carbon emissions (from the extraction of the constituent raw materials, transportation to the manufacturing plant, manufacturing process, transportation of materials to the construction site and emissions during the construction stage of the buildings), use phase embodied carbon (from materials used during repair, replacement and refurbishment of the buildings) and end of life cycle emissions resulting from building demolition activities and its recycling and disposal.

Operational Carbon: Results from building operations, once the building is occupied and is associated with building day-to-day energy needs such as lighting, ventilation, cooling/heating, operating electrical appliances and equipment.

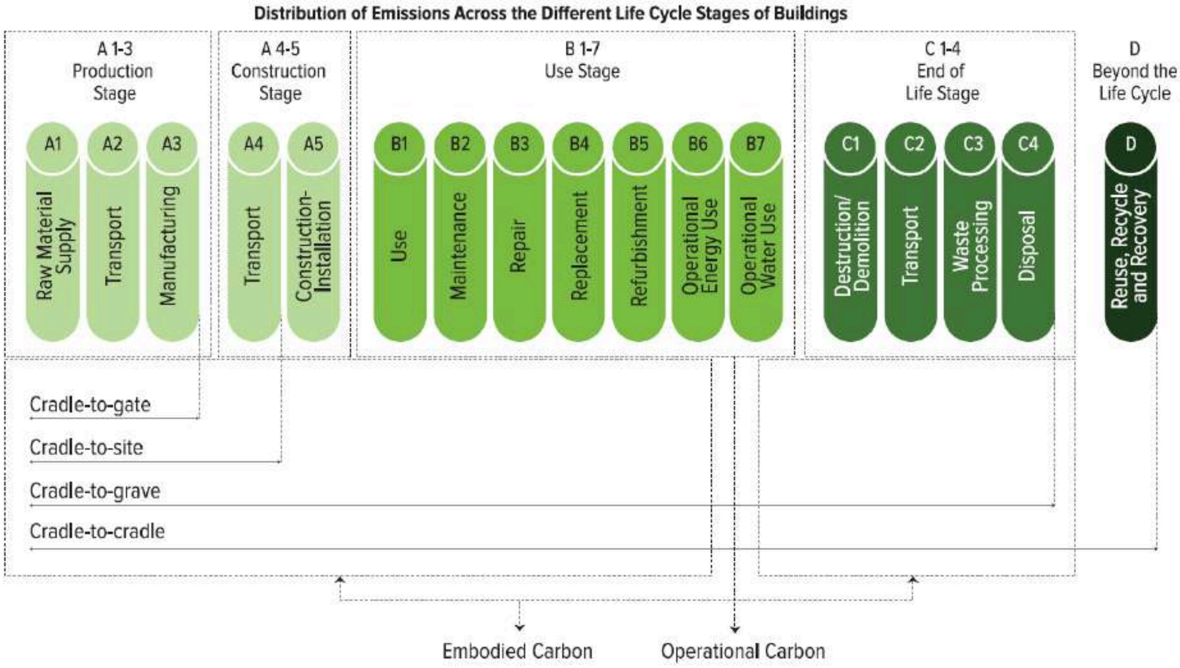


Figure 1: Emissions across building lifecycle[1]

Approaches to Achieve Net Zero Energy/Carbon Buildings

The following table captures the approaches through which net zero energy/carbon building status can be met.

Table 1: Approaches for net zero energy/carbon buildings[2]

Net Zero Status	**High level of energy efficiency with limited adoption of renewable energy due to feasibility constraints**	**High levels of energy efficiency with operational energy demand met through renewable energy on site**	**Highest levels of energy efficiency supplemented with low embodied carbon materials and efficient building envelope design; life-cycle emissions mitigated by on-site and off-site renewable energy interventions**
Near Net Zero Energy Building	✓		
Net Zero Energy Building		✓	

[1] B. Pandey and S. Jayram, Life Cycle Assessment of Carbon Emissions: Progress and Barriers in Indian Building Sector (SGRI & AEEE, 2024)
[2] ICLEI – Local Governments for Sustainability South Asia, Zero Carbon Buildings Action Plan – Nagpur (New Delhi: ICLEI South Asia, 2024)

Net Zero Carbon Building			✓

This report focuses on developing a Net Zero Action Plan for both existing municipal buildings and new upcoming municipal building stock. For **existing buildings**, the scope is limited to achieving ***net zero energy***, as their embodied carbon is already locked in through materials used over the building lifecycle. In contrast, for **new municipal buildings**, the target is *net zero carbon*. This is because upcoming projects have the opportunity to incorporate low-carbon materials, reduce embodied emissions across the lifecycle, and achieve net zero operational energy together resulting in net zero carbon buildings.

The baseline assessment of municipal buildings under the Brihanmumbai Municipal Corporation (BMC) jurisdiction indicates that these buildings account for **19% of total municipal electricity consumption**. Within this, municipal offices, hospitals, schools, and auditoriums contribute **3.8%**, **9.8%**, **1.2%**, and **1%** respectively (Figure 2). Based on these findings, this report prioritizes these key building categories for developing a **Net Zero Energy/Carbon Building Action Plan**. The plan is informed by energy conservation measures identified during walkthrough energy audits of representative buildings within each category and is designed to be scaled up across other municipal building types in subsequent phases.

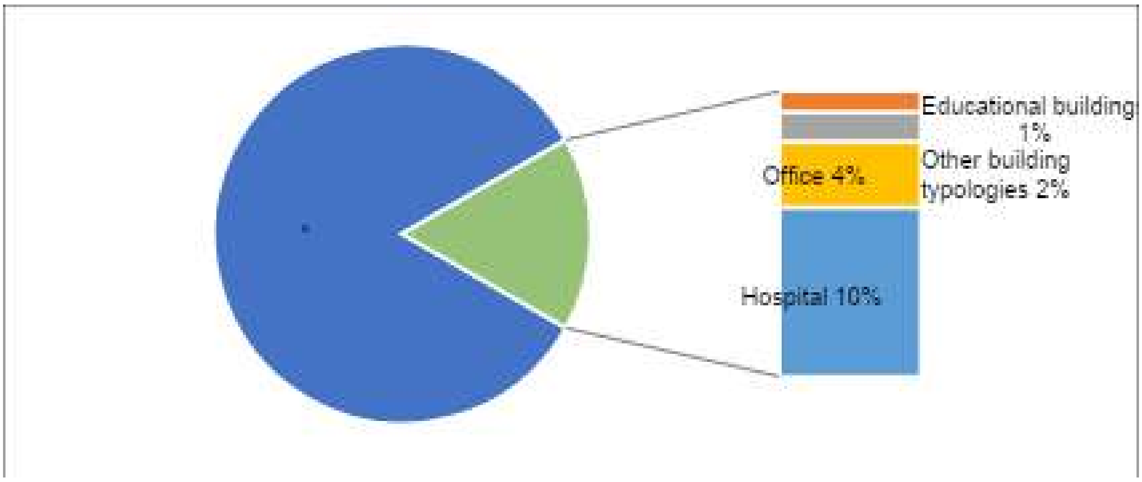


Figure 2: Distribution of electricity consumption for different municipal building typologies
Source: authors

Within municipal buildings in Panvel Municipal Corporation (PMC) jurisdiction, municipal offices, hospitals, schools and auditoriums accounts for 45%, 24%, 11% and 20%, respectively (shown in Figure 2). Based on this analysis, this report prioritizes these key building categories for developing a Net Zero Energy Building Action Plan. The plan is informed by energy conservation measures identified during walkthrough energy audits of representative buildings within each category and is designed to be scaled up across other municipal building types in subsequent phases.

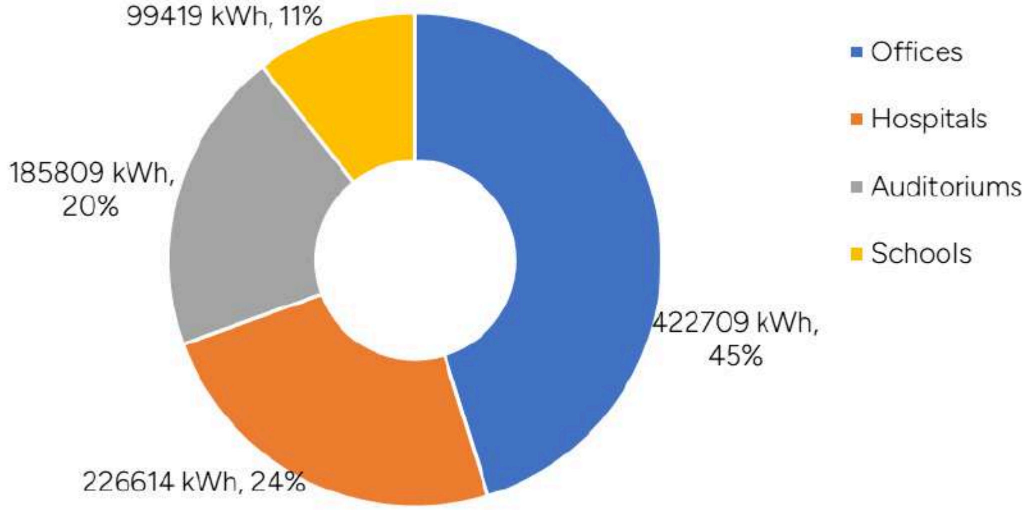


Figure 2: Distribution of the energy consumption across the building typologies
(Source: authors)

02 Prioritization of Strategies

To identify energy conservation measures (ECMs) across municipal building stock, municipal building categories were first classified based on their share of total electricity consumption. Through this analysis, **hospitals, municipal offices, schools, and auditoriums emerged as priority categories**. Walkthrough energy audits were then conducted for sample buildings within each identified municipal building category to identify the ECMs. The electricity-saving potential from ECMs identified at the individual building level was subsequently scaled up to estimate the total energy saving potential across the entire municipal building stock for identified municipal building category. The detailed results, including category-wise ECMs and their aggregated impacts at the stock level, are presented in the following sections.

Energy Conservation Measures in Municipal School Building Category

The walkthrough energy audit of the three municipal school buildings namely "LK Waghji Mumbai Public School, "Chhatrapati Shivaji Maharaj Nag. School No1" and "Sodawala Municipal School" have been conducted and the list of identified ECMs and its impact on energy savings, investment required to implement the ECMs and payback period estimated through energy saving potential has been presented in the following table.

The impact of the above ECMs have been averaged out and scaled up for the whole municipal school building stock to analyse the impact of the ECMs. Figure 3 shows the impact of each ECMs at the stock level in terms of electricity reduction from the baseline electricity consumption.

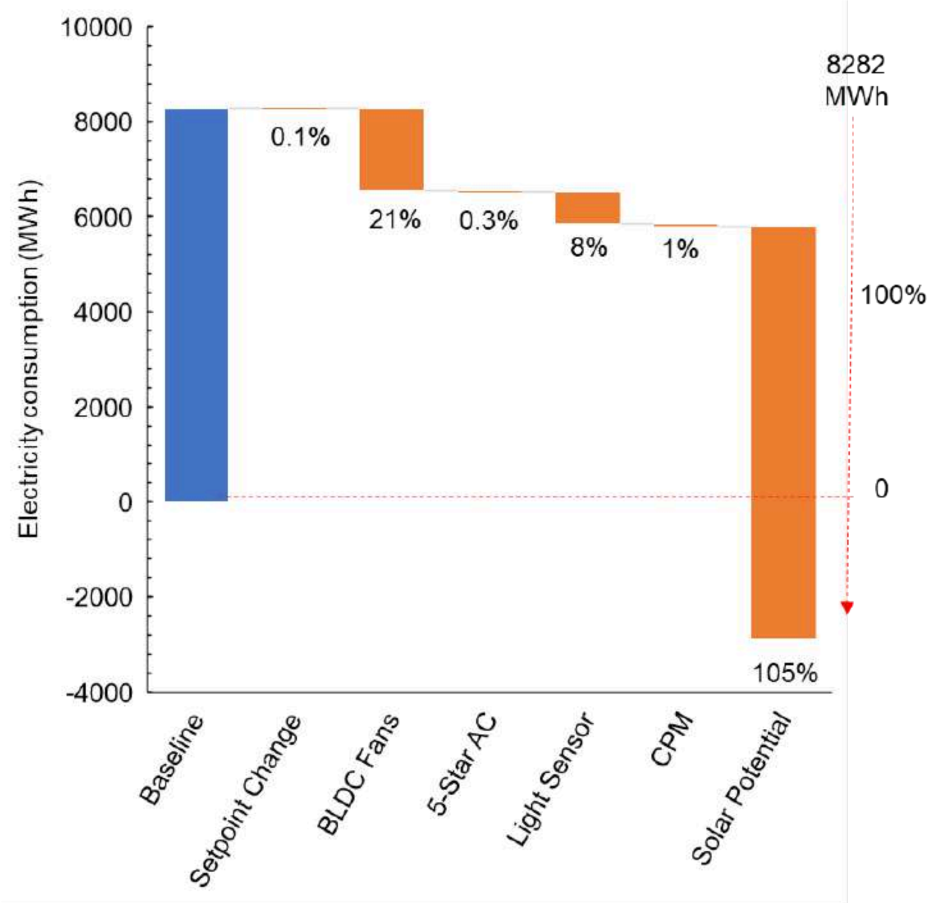


Figure 3: Impact of ECMs at stock level for municipal school buildings BMC

Source: authors

The analysis of ECMs for individual school buildings and their stock-level impact indicates that behavioural measures, such as adjusting the air-conditioning setpoint, can reduce electricity consumption by approximately **5 MWh** from the baseline. Replacing conventional ceiling fans with **5-star rated BLDC fans** shows a substantial reduction potential of **1,733 MWh**. Additional ECMs, including the installation of occupancy sensors and improved plug load management for computers in offices and laboratories, contribute to savings of **665 MWh** and **63 MWh**, respectively. Furthermore, installing rooftop solar PV systems utilizing **50% of the available roof area** could enable the municipal school building stock to achieve **net-zero energy status**.

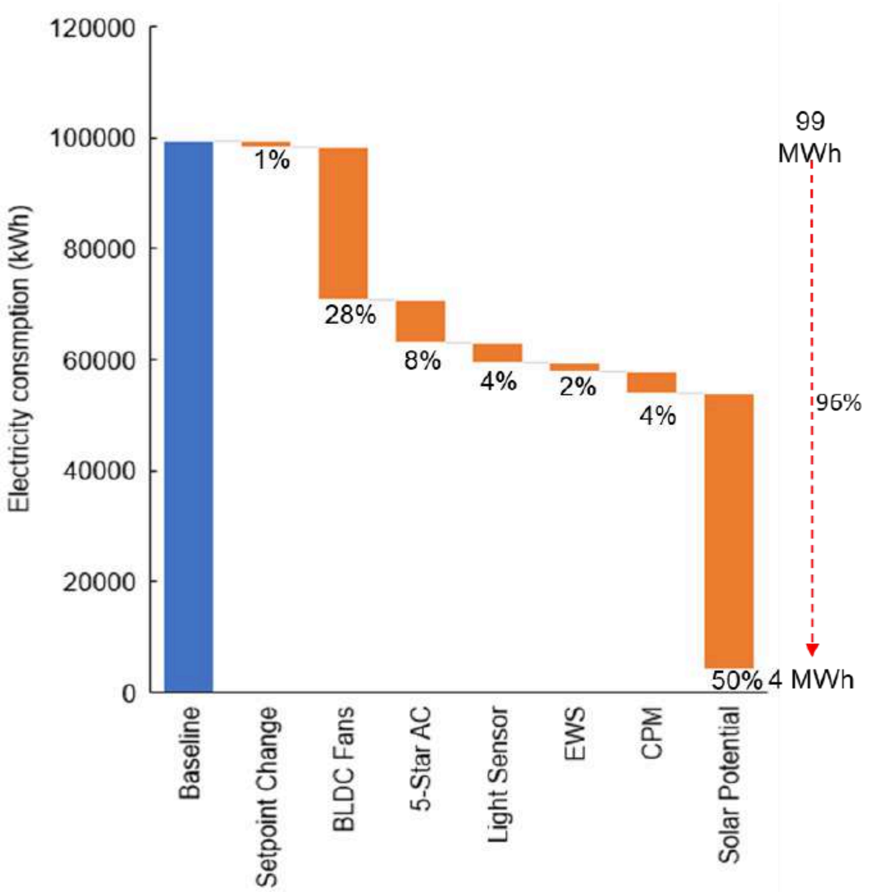


Figure 6: Impact of ECM at stock level for Municipal school PMC

(Source: authors)

The stock-level impact analysis of ECMs for school buildings indicates that small behavioural changes, such as adjusting air-conditioning setpoint temperatures, can result in approximately 1 MWh of energy savings. Medium-cost measures including the replacement of conventional ceiling fans with BEE 5-STAR fans result in further reduction of 27.5 MWh, substitution of old air-conditioning units with 5-star energy-efficient models yield 7.8 MWh savings, installation of lighting occupancy sensors help reduce it by 3.5 MWh, external window shading by 1.5 MWh and simple measures like switching computers off instead of leaving on standby can help in saving around 4 MWh energy.

Notably, adding 50% solar rooftop yields 49.71 MWh savings and can make school buildings nearly net-zero energy buildings.

Energy Conservation Measures in Municipal Office Building Category

To identify the ECMs in the municipal office category buildings, the walkthrough energy audit of the RC ward municipal office and H-West ward municipal office buildings have been conducted. The impact of the ECMs in terms of energy saving potential and annual monetary savings, investment required for the identified ECMs and payback period for that investment has been presented in the table below. Further the impact of the identified ECMs have been scaled up for 245 municipal office building categories to identify the impact at the stock level.

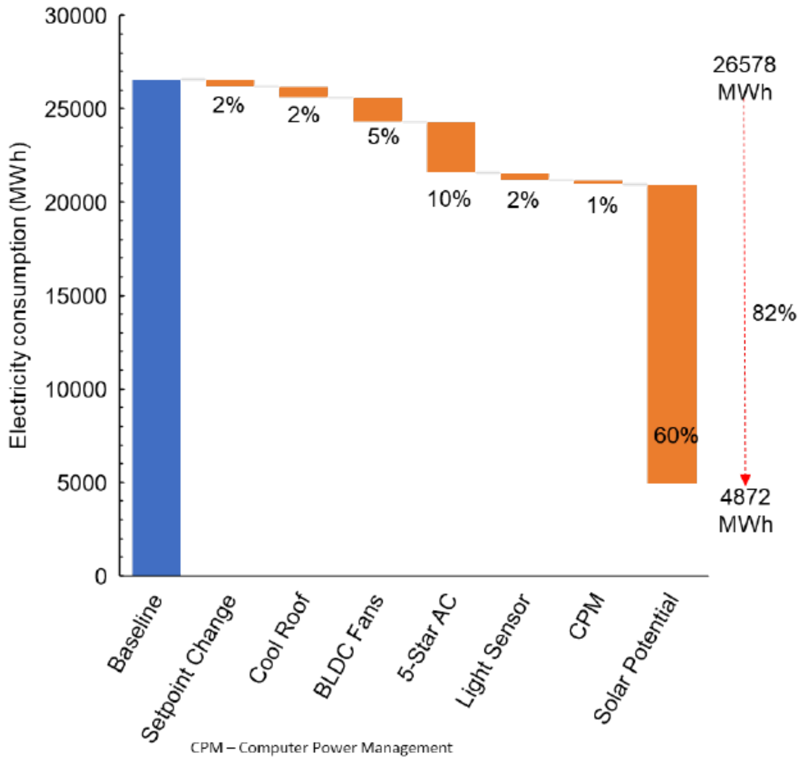


Figure 4: Impact of ECMs at stock level for municipal office buildings BMC

Source: authors

The analysis at both individual building and stock levels indicates that simple measures such as adjusting temperature setpoints, installing lighting and occupancy sensors, and implementing cool roofs can yield electricity savings of approximately **402 MWh** and **567 MWh**, respectively, from the baseline stock-level consumption. Medium-cost measures, including the replacement of conventional ceiling fans with **BLDC fans** and the substitution of old air-conditioning units with energy-efficient models, offer additional savings of **1,327 MWh** and **2,684 MWh**. Installing rooftop solar PV systems utilizing **50% of the available roof area** can further offset around **16,077 MWh** of annual electricity demand. Achieving net-zero energy status for the municipal office building category, however, would require procuring additional renewable electricity through **green tariff mechanisms** offered by DISCOMs.

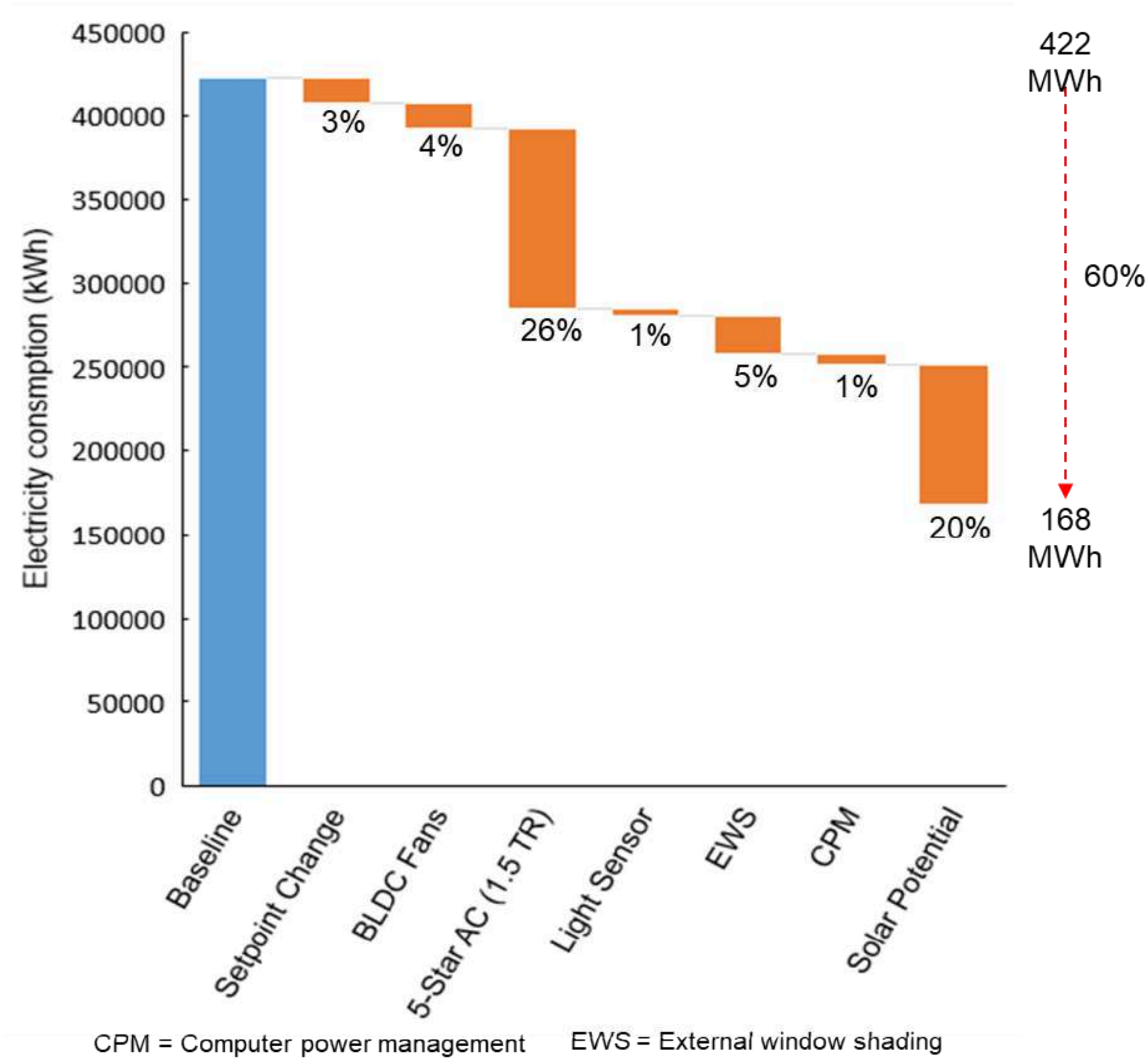


Figure 3: Impact of ECMs at stock level for offices PMC

(Source: authors)

The analysis of ECMs for municipal office and its stock-level impact indicates that behavioural measures, such as adjusting the air-conditioning setpoint, can reduce electricity consumption by approximately 14.5 MWh from the baseline. Replacing conventional ceiling fans with 5-star rated BEE 5-STAR fans shows a further possible reduction potential of ~15 MWh and replacing inefficient stock of ACs has substantial reduction potential of 108.8 MWh. Additional ECMs, including the installation of occupancy sensors and improved plug load management for computers in offices and laboratories, contribute to savings of 4.3 MWh, external window shading can save another 21.8 MWh and switching off computers (vs) leaving on standby reduces 6.3 MWh. Furthermore, installing rooftop solar PV systems utilizing 50% of the available roof area has potential to offset annual electricity consumption by 83.7 MWh. For remaining 164 MWh Achieving net-zero energy status for the municipal office building category, however, would require procuring additional renewable electricity through green tariff mechanisms offered by DISCOMs.

Energy Conservation Measures in Hospital Building Category

To identify the ECMs in the hospital category buildings, the walkthrough energy audit has been conducted in the Nair hospital and Kem hospital premises. The ECMs have been identified for main hospital buildings as well as the other typologies of buildings in the premises, e.g., staff quarters, hostels, etc. The impact of the identified ECMs in terms of energy savings, investment required for the identified ECMs and payback period of the investment have been presented in table below. The impact of the ECMs have been averaged out for the two hospital buildings and scaled up for the entire hospital building stock to analyse the impact of ECMs at stock level.

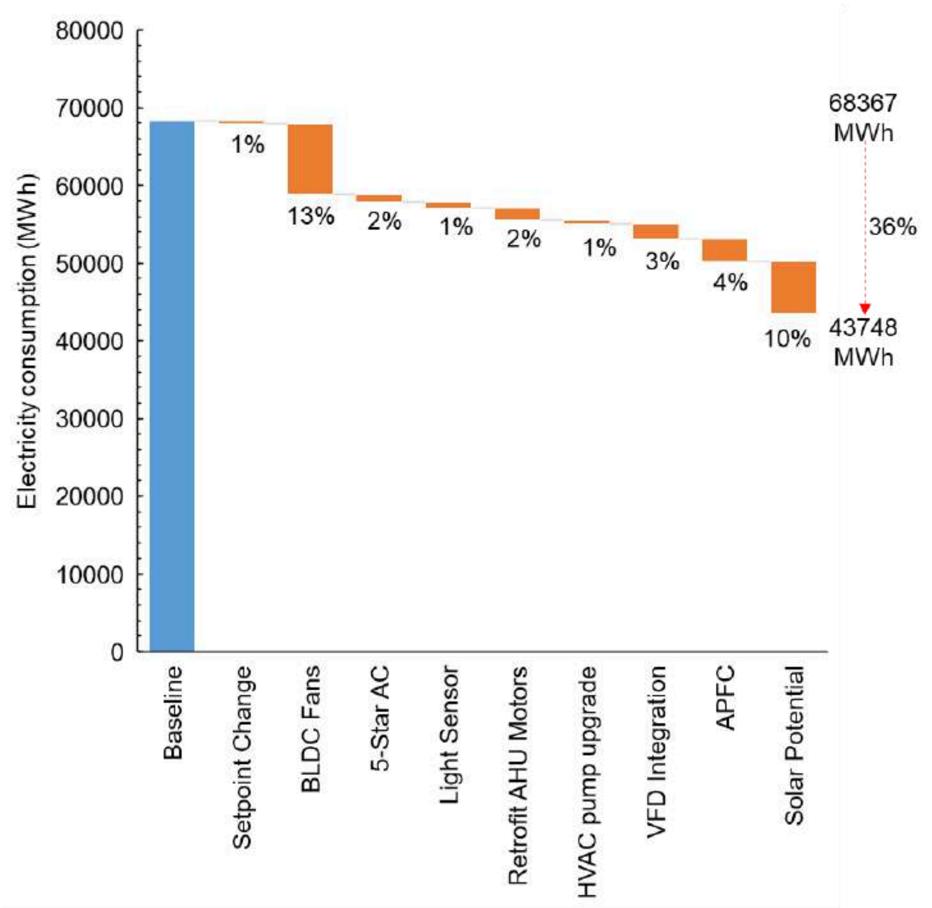


Figure 5: Impact of ECMs at stock level for municipal hospitals BMC

Source: authors

The stock-level impact analysis of ECMs for hospital buildings indicates that small behavioural changes, such as adjusting air-conditioning setpoint temperatures, can result in approximately **486 MWh** of energy savings. Medium-cost measures including the replacement of conventional ceiling fans with **BLDC fans**, substitution of old air-conditioning units with **5-star energy-efficient models**, installation of **lighting occupancy sensors**, retrofitting of inefficient **AHU motors with IE5 motors**, upgrading of **HVAC pumps**, integration of **variable frequency drives (VFDs)**, and installation of **automatic power factor correction (APFC) devices** collectively yield up to **17,599 MWh** of additional savings.

Utilizing **50% of the available roof area** for rooftop solar PV installation can further offset approximately **6,839 MWh** of annual electricity demand. The remaining grid dependence of around **43,433 MWh** can be addressed through **open-market procurement of renewable electricity via DISCOMs' green tariff mechanisms**, enabling large hospital buildings to achieve near **net-zero energy** status. Smaller hospital facilities can fully attain **net-zero energy status** by implementing the identified ECMs in combination with rooftop solar integration.

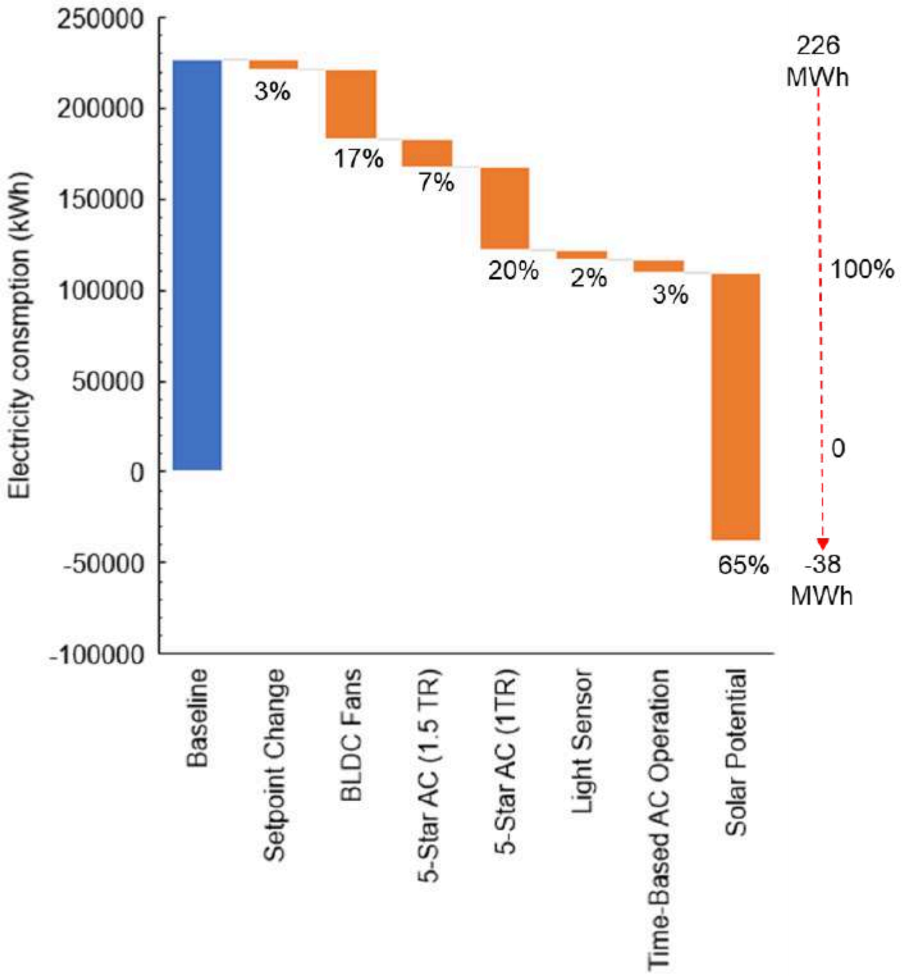


Figure 4: Impact of ECMs at stock level for Municipal hospital PMC

(Source: authors)

The stock-level impact analysis of ECMs for hospital buildings indicates that small behavioural changes, such as adjusting air-conditioning setpoint temperatures (24 to 26 °C), can result in approximately 5.7 MWh of energy savings. Medium-cost measures—including the replacement of conventional ceiling fans with BEE 5-STAR fans saves 37.8 MWh, substitution of old air-conditioning units with 5-star energy-efficient models 1.5 TR results in savings of 15.4 MWh), 1 TR saves 45.9 MWh, installation of lighting occupancy sensors saves 5.3 MWh, and time-based AC operation can yield 7.4 MWh of additional savings. Utilizing 50% of the available roof area for rooftop solar PV installation can further offset approximately 147.3 MWh of electricity demand.

Energy Conservation Measures in Auditorium Building Category

To identify the ECMs for auditorium category buildings, the walkthrough audit of the two auditorium buildings namely "Kalidas Natyagriha" and "Prabodhankar Natyagriha" have been conducted. The impact of the identified ECMs have been presented for both the auditorium buildings in the following table. Further, the impact of identified ECMs has been scaled up to all auditorium category buildings to analyse the impact of identified ECMs at the stock level.

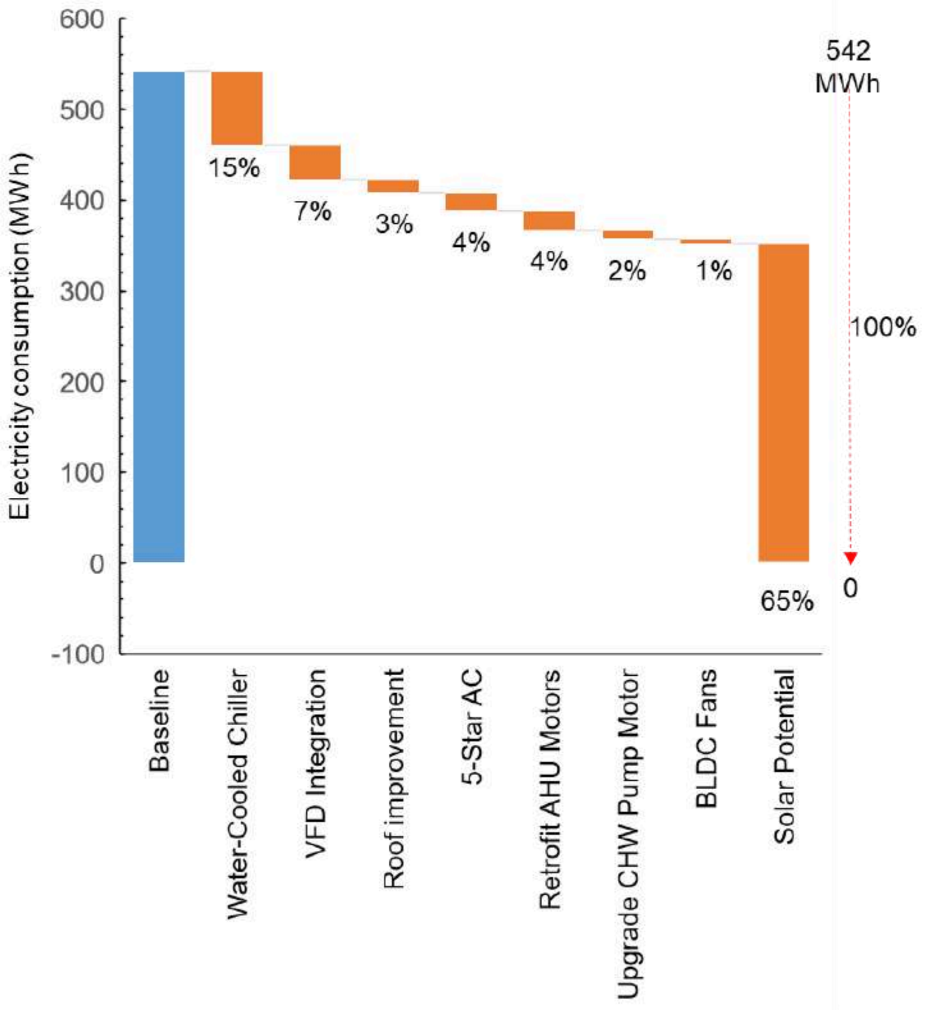


Figure 6: Impact of ECMs at stock level for municipal auditoriums BMC

Source: authors

The impact analysis of the identified ECMs for the auditorium building stock indicates that **passive measures**, such as installing roof insulation, can yield approximately **15 MWh** of energy savings. **Low-cost measures**, including the replacement of conventional ceiling fans with **energy-efficient BLDC fans**, contribute an additional **5 MWh** of savings. **Medium-cost interventions** such as replacing old inefficient air-conditioning units with **high-efficiency models**, retrofitting **AHU motors with IE5- rated motors**, and upgrading existing **pump motors** can collectively achieve savings of about **55 MWh**.

More **capital-intensive measures**, including the replacement of centralized **air-cooled chillers** with **water-cooled systems** and the **integration of variable frequency drives (VFDs)**, offer an additional reduction of approximately **120 MWh** from the baseline consumption at the stock level. Furthermore, utilizing **50% of the available roof area** for **rooftop solar PV installation** can offset around **351 MWh** of annual electricity consumption across the auditorium building stock.

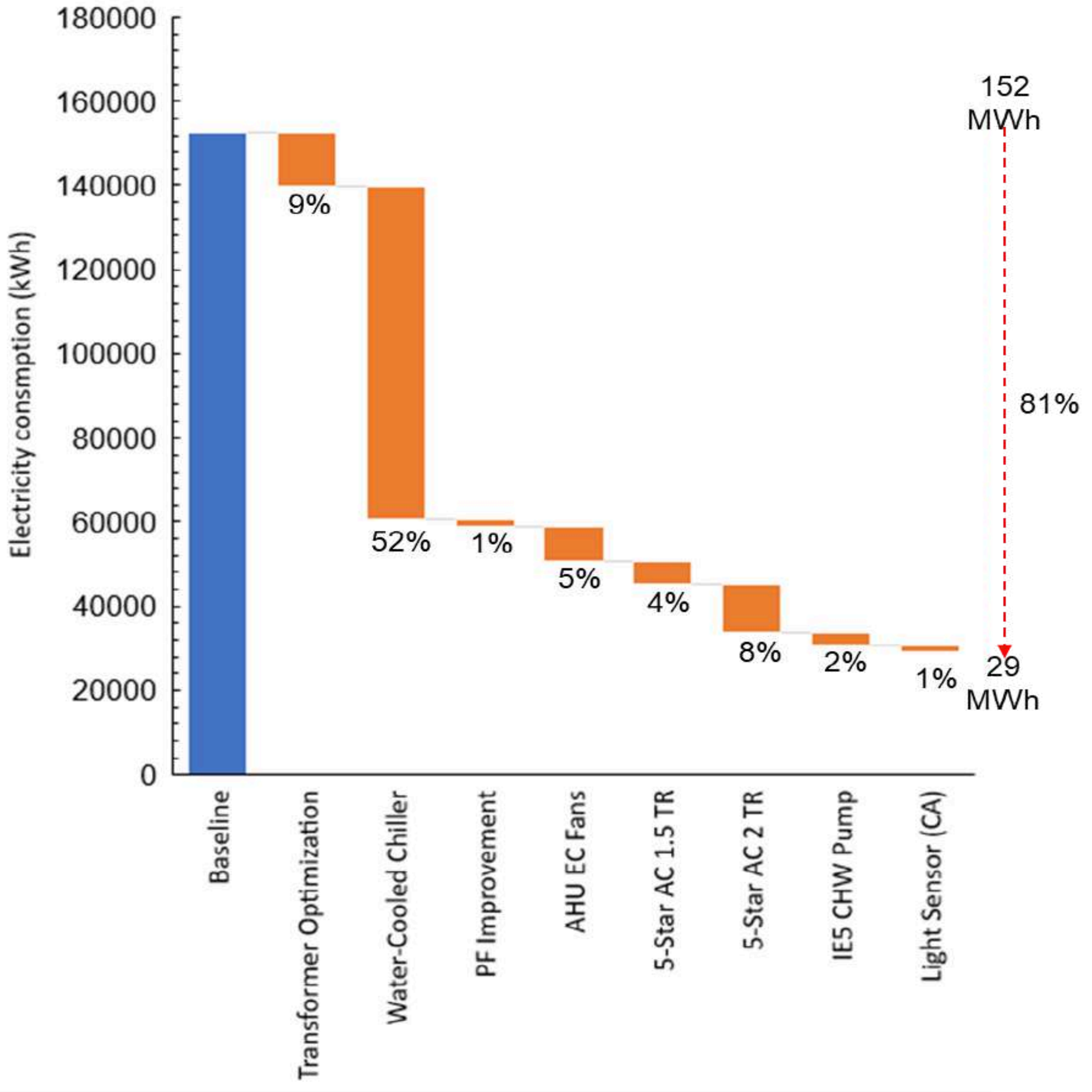


Figure 5: Impact of ECM at stock level for Municipal auditorium PMC

(Source: authors)

The impact analysis of the identified ECMs for the auditorium building stock indicates that transformer optimization can yield approximately 13.14 MWh of energy savings. Medium-cost interventions—such as replacing air-cooled chillers with high efficiency water-cooled chillers can help in substantial reduction of 78.8 MWh. AHU EC fans yield 8.3 MWh savings, replacing inefficient AC stock with 5-star (1.5 TR) result in 5.5 MWh savings and 5-satr (2 TR) results in savings of 11.6 MWh. Additionally, replacement of IE2 CHW pump motor with IE5 motor can help in reducing ~3 MWh and occupancy sensors can result in saving 1.3 MWh energy.

ECM Categorization by Cost-Effectiveness and Impact across Building Typologies

Based on the analysis of ECMs and their energy reduction potential across different categories of municipal buildings, this section summarizes the measures by grouping them into no-cost, low-cost, medium-cost, and cost-intensive categories along with their respective impacts.

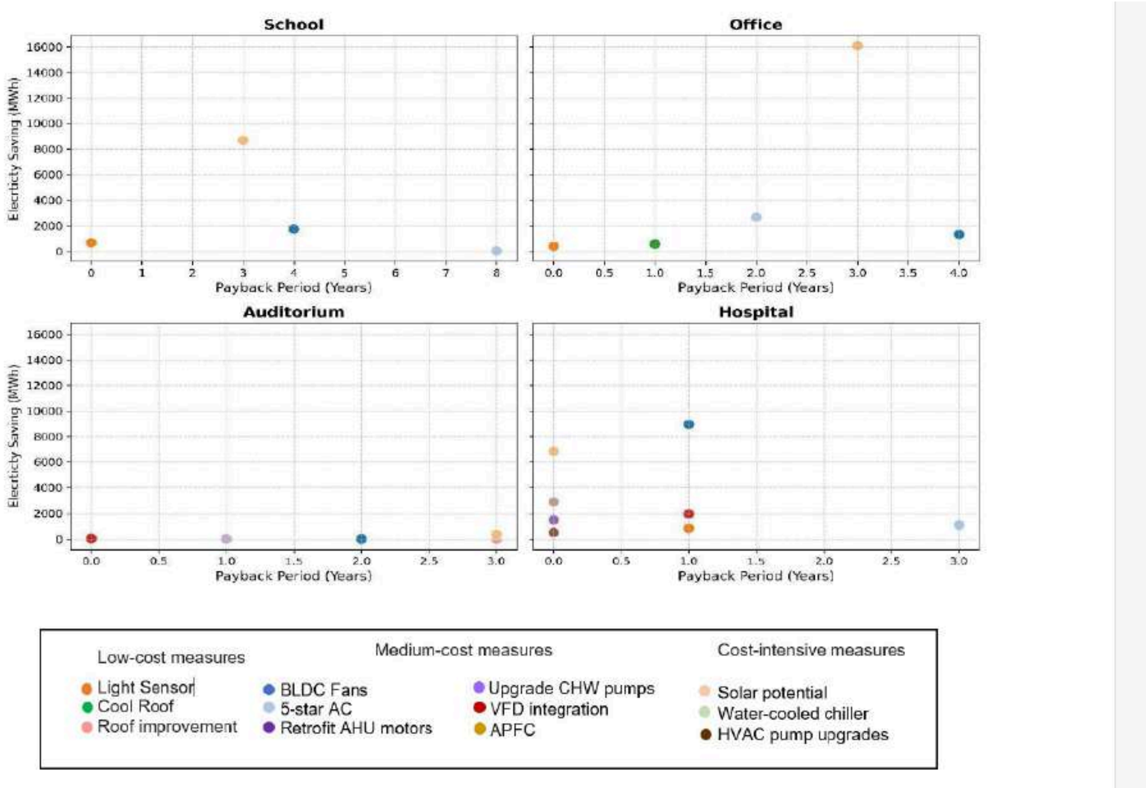


Figure 7: Payback periods and energy savings for different municipal buildings

Source: authors

Figure 7 shows the scatter plots showing the relationship between Simple Payback Period (Years) and Energy Saving (MWh) for various Energy Conservation Measures (ECMs) across different building types, here are the key insights:

Solar Potential is a High-Impact, Quick-Return Measure: Across all four building types (School, Office, Auditorium, and Hospital), «Solar Potential» consistently appears as a measure with significantly high energy savings (MWh) and a relatively low payback period (generally between ≤1 and 3 years). This indicates that investing in solar energy systems is a highly effective strategy for achieving net zero energy status and provides a quick return on investment regardless of the building type.

Variability in Performance for Common Measures: Measures like «BLDC Fans» and «5-Star AC» are common across multiple building types, but their performance (both MWh savings and payback period) varies. This suggests that the effectiveness of these measures can be influenced by the specific characteristics and energy usage patterns of each building type. For example, "BLDC Fans" show very high savings in Hospitals with a short payback, but lower savings in Auditoriums with a slightly longer payback.

Quick Payback for Certain Measures: Several measures consistently show a payback period of ≤1 year. These include "Light Sensor", "Cool Roof", "Water-Cooled Chiller", "VFD Integration", "Retrofit AHU Motors", "Upgrade CHW Pump Motor", "HVAC Pump upgrade", and "APFC". While the MWh savings for these measures might not always be the highest, their rapid payback makes them attractive options for quick wins in energy efficiency.

In summary, the analysis provides an overview of ECMs impact and cost effectiveness, enabling stakeholders to quickly identify high-potential measures and tailor energy efficiency strategies to the specific requirements of different building types.

Top 3 Measures Based on Energy Savings

Energy Conservation Measure (ECM)	Electricity Saving (MWh)
Solar Potential	31,956
BLDC Fans	12,005
5-star Air Conditioners	3,794

Strategies for Achieving Net-Zero Carbon Status for New Municipal Buildings

New municipal buildings offer the opportunity to minimize embodied carbon by adopting **low-carbon construction materials**. When combined with **energy-efficient design**, **passive architectural strategies**, **procurement and installation of high-efficiency systems**, and **on-site renewable energy generation** (such as rooftop solar PV), these measures can collectively enable the attainment of **net zero carbon** status.

The following section outlines the **proposed strategy** for achieving net zero carbon status for new municipal buildings.

The action plan for achieving net zero carbon status for new municipal buildings is based on **five key strategies - passive design measures, active design interventions, low-carbon material selection, integration of renewable energy, and clean energy procurement**.

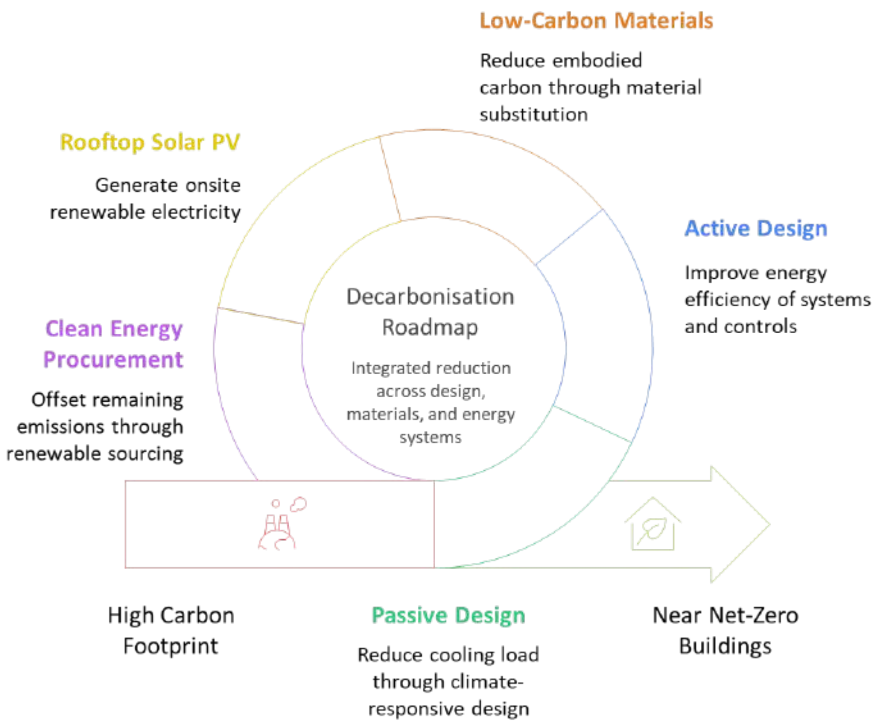


Figure 8: Strategic pillars of the decarbonisation roadmap for new municipal buildings

Source: authors

Passive Design Strategies

Passive design strategies are the foundation of a low-energy and low-carbon building, as they reduce the inherent demand for heating, cooling, and lighting by making use of natural climatic conditions. For new municipal buildings, incorporating passive measures from the earliest design stage ensures long-term energy savings, improves indoor comfort, and minimizes the scale of active systems required. The following key interventions have been identified for implementation to achieve net zero carbon status.

1. Building orientation and WWR optimization
2. Envelope design: The envelope design improvements are based on the MahaECBC[3] rules. For the basic improvement, Mahaurja 1-star envelope parameters are considered and subsequently 2-star and 3-star for further improvement.
   a) External walls
   b) Roof
   c) Windows

3. Window shadings

   a) Horizontal shading devices
   b) Vertical shading devices

[3]Industries, Energy, Labour and Mining Department (IELMD), Government of Maharashtra, Notification No. 155 (Mumbai, 2025).

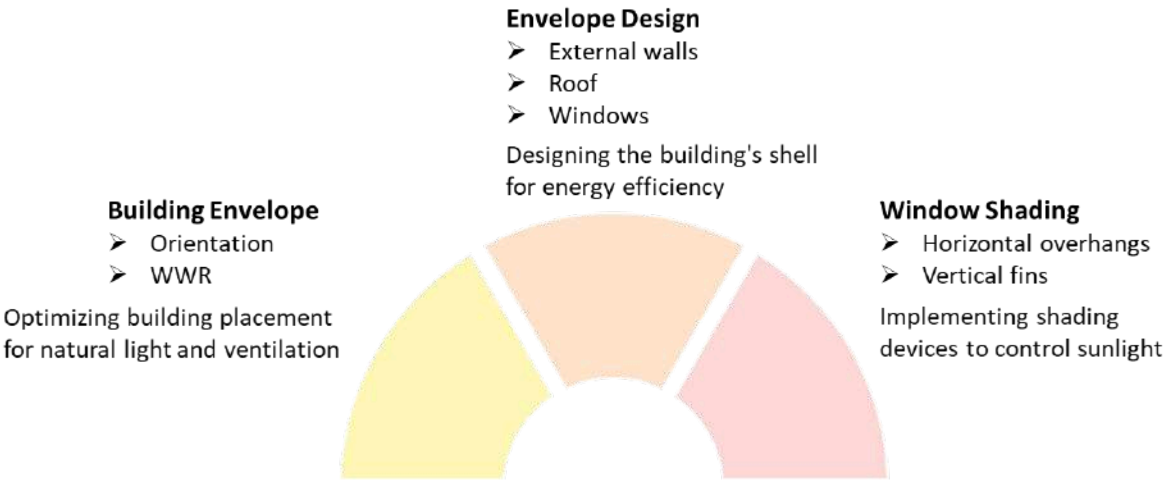


Figure 9: Passive design strategies to optimize orientation, envelope, and shading for reduced cooling demand

Source: authors

Building orientation

Optimizing the building orientation with respect to solar exposure and prevailing winds reduces cooling demand, enhances natural ventilation, and improves daylight utilization. Proper orientation is a **no-cost, high-impact passive strategy** that should be addressed early in the design stage.

Strategies

- Place longer façades along the north–south axis.
- Use shading from nearby trees, structures, or landscape features.
- Align orientation with prevailing wind direction to aid ventilation.
- Consider site-specific constraints in the early design stage.
- Conduct site-specific solar and wind analysis for optimal ventilation and daylighting.

Window-to-Wall ratio (WWR) optimization

Limiting the window-to-wall ratio balances daylight access with thermal gain, reducing artificial lighting demand while minimizing heat ingress. Proper WWR optimization complements shading and envelope strategies to achieve energy efficiency.

Strategies

- Limit WWR on east and west façades.
- Optimize north/south window sizes for daylight and ventilation.
- Balance WWR to meet daylight without increasing cooling loads.
- Follow ECBC/MahaECBC benchmarks for optimal ratios.
- Coordinate WWR adjustments with shading devices for maximum energy efficiency.

Envelope design improvements

The building envelope governs heat transfer between interior and exterior spaces. Enhancing envelope performance reduces heating and cooling loads, improves thermal comfort, and aligns with ECBC/MahaECBC incremental star-rated standards. Envelope measures can be applied to walls, roofs, and windows.

Strategies for walls

- Adopt low-conductivity materials like AAC or fly ash bricks.
- Use insulated or cavity wall assemblies.

- Upgrade to ECBC+ or Super ECBC compliant wall systems.
- Minimize thermal bridges at wall junctions.

Strategies for roof

- Add thermal insulation layers under the roof slab.
- Apply reflective or cool roof coatings.
- Use ventilated or double-skin roof systems.
- Explore green roofs for insulation and heat island reduction.
- Apply higher-performance insulation and reflective surfaces for 2-star and 3-star upgrades.

Strategies for windows

- Use double or low-E glazing.
- Adopt thermally broken window frames.
- Ensure optimized U-value and SHGC as per ECBC levels.
- Limit window size on heat-exposed façades.
- Combine glazing with external shading for maximum effect.

Window shading

Shading devices control solar heat gain while allowing natural daylight, reducing cooling loads and improving occupant comfort. Shading design should be coordinated with window placement, WWR, and building orientation.

Strategies for shading

- Use vertical fins on east and west façades; operable fins for flexible control.
- Provide horizontal overhangs on south façades.
- Install operable louvers for flexible control.
- Combine shading with daylight redirection elements (light shelves).
- Integrate shading design with façade aesthetics and ventilation.

Table 6 shows the indicative cooling load reductions and associated operational carbon reduction potential with different passive design strategies compared to respective base case building design.

Table 6: Passive design measures with strategy-wise cooling load and operational carbon

Passive design measure	Strategy	Indicative reduction potential – Cooling load (%)	Indicative reduction potential – Operational carbon (%)
Building orientation	Longer façade aligned East–West vs North–South	3–5	2–3
Window-to-wall ratio (WWR) optimization	Reduce WWR from 60% to 40%	18–20	9–12
	Reduce WWR from 60% to 30%	25–30	15–20
Envelope design – walls	1-star MahaECBC upgrade	3–5	2–4
	2-star MahaECBC upgrade	4–6	3–5
	3-star MahaECBC upgrade	6–8	4–6

Envelope design – roof	1-star MahaECBC upgrade	7–9	4–6
	2-star upgrade (reflective / ventilated roof)	11–14	9–12
	3-star upgrade (high-performance insulation + green/reflective roof)	14–17	11–14
Envelope design – windows	ECBC compliance	20–25	15–20
	ECBC+ compliance	22–27	15–20
	Super ECBC compliance	25–30	18–22
East–West window vertical shading devices	Shallow depth (0.5 m)	<1	<1
	Medium depth (0.75 m)	<1	<1
	Deep depth (1.0 m)	<1	<1
North–South window vertical shading devices	Shallow depth (0.5 m)	6–8	3–5
	Medium depth (0.75 m)	7–10	4–6
	Deep depth (1.0 m)	9–12	5–8

Note: *The indicative percentage reduction in operational carbon is associated with the reduction in cooling energy consumption.*

Active energy reduction strategies

Active energy reduction strategies are critical for new municipal buildings, complementing passive measures by improving the efficiency of municipal buildings and reducing operational energy demand. These interventions ensure that the building meets functional requirements while minimizing operational carbon emissions. By integrating energy-efficient lighting, fans, and HVAC systems from the design stage, new buildings can achieve significant energy savings and long-term decarbonisation targets. The following key interventions have been identified for inclusion in the decarbonisation roadmap.

1. Lighting and controls
2. BLDC fans
3. HVAC and controls

- Split AC upgrade pathway (2-star → 5-star → VRF (centralized system))
- Chiller upgrade pathway (air-cooled → water-cooled with 1-star, 2-star, 3-star efficiency levels + AHU fans and pumps upgrade)

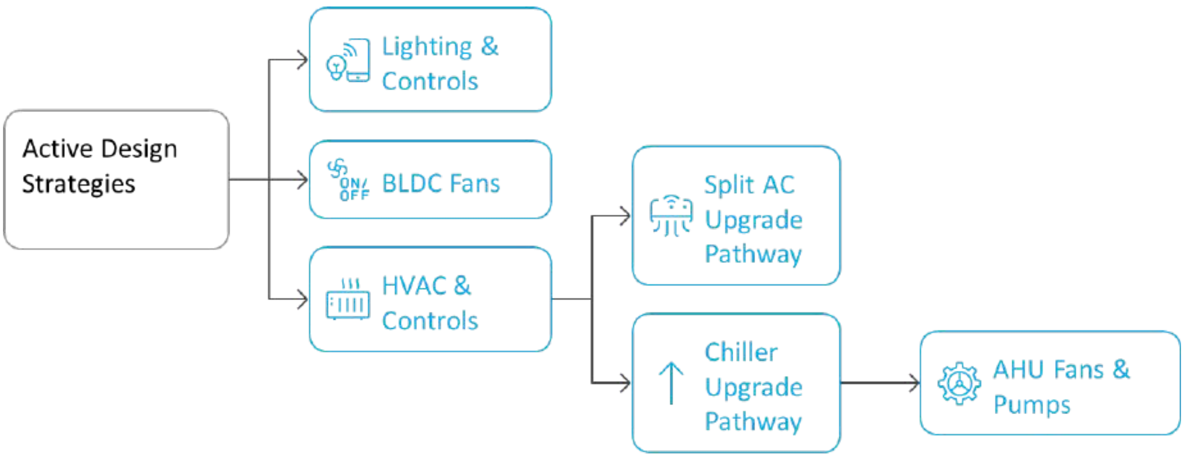


Figure 10: Active design strategies to enhance energy efficiency through lighting, HVAC, and controls

Source: authors

Lighting and controls

For new municipal buildings, designing lighting systems with energy-efficient fixtures and smart control strategies reduces electricity demand, improves visual comfort, and contributes to lower operational carbon. Early integration allows optimal layout, zoning, and coordination with daylighting strategies.

Implementation strategies

- Install high-efficacy LED luminaires throughout the building.
- Integrate daylight sensors in areas with sufficient natural light to minimize artificial lighting use.
- Use occupancy sensors in intermittently used spaces such as meeting rooms, corridors, and washrooms.
- Implement dimming controls for adaptable illumination levels.

BLDC fans

In new municipal buildings, replacing conventional fans with brushless DC (BLDC) fans reduces energy consumption and lowers internal heat gain, indirectly reducing cooling loads. Integration with controls allows flexible operation and part-load savings.

Implementation strategies

- Install BLDC ceiling fans in all occupied spaces.
- Integrate fan operation with smart controllers for speed and occupancy-based control.
- Ensure interoperability with building energy management systems.
- Standardize procurement for consistent efficiency across the building.

HVAC and controls

Split AC upgrade pathway

For new municipal buildings with split AC systems, adopting higher-efficiency units from the design stage reduces energy demand and operational carbon. Installing 5-star AC units or VRF systems allow alignment with ECBC star ratings and long-term energy targets.

Implementation strategies

- Specify 5-star BEE-rated split AC units instead of lower-efficiency units.
- Adopt VRF systems with COP improvements corresponding to BEE 2-star, and 3-star levels.
- Implement zoning and demand-based controls for part-load efficiency.
- Optimize system sizing through detailed load calculations.
- Include regular commissioning and maintenance protocols to maintain efficiency.

Chiller upgrade pathway

For new municipal buildings with centralised cooling, water-cooled chillers with high efficiency should be integrated from the outset. Alongside chiller selection, upgrading **AHU fans and chilled water pumps** ensures overall system efficiency and contributes to operational energy savings.

Implementation strategies

- Specify water-cooled chillers in place of air-cooled systems for new construction.
- Adopt 2-star, and 3-star ECBC-compliant chiller levels for energy efficiency.
- Use energy-efficient AHU fans with variable frequency drives (VFDs).
- Install high-efficiency chilled water and condenser water pumps with VFDs.

- Optimize condenser water temperature and flow rates.
- Integrate advanced building management systems for monitoring and control.

Table 7 presents the potential reduction in operational carbon emissions achieved through the use of energy-efficient active systems compared to conventional inefficient systems.

Table 7: Active design measures with strategy-wise operational carbon reduction

Active design measure	Strategy	Indicative operational carbon reduction (%)
Lighting and controls	LED upgrade with sensors	6–8
BLDC fans	Upgrade from conventional fans	60
HVAC – Split AC pathway (Baseline: 2-star split AC)	Upgrade from 2-star to 5-star	38–42
	Transition to VRF (ECSBC compliant)	42–47
	Transition to VRF (ECSBC+ compliant)	53–57
	Transition to VRF (Super ECSBC compliant)	58–62
HVAC – Centralised chiller pathway (Baseline: air-cooled chiller)	1-star air-cooled chiller	5–10
	2-star air-cooled chiller	10–15
	3-star air-cooled chiller	18–22
	4-star air-cooled chiller	23–28
	5-star air-cooled chiller	28–32
	1-star water-cooled chiller	43–45
	2-star water-cooled chiller	48–52
	3-star water-cooled chiller	54–58
	4-star water-cooled chiller	57–61
	5-star water-cooled chiller	60–65

Note: *The indicative percentage reduction in operational carbon is associated with the reduction in cooling energy consumption.*

Embodied carbon reduction through low-carbon materials

Embodied carbon emissions from material extraction, manufacturing, transport, and construction forms a major, front-loaded part of a building's total carbon footprint. For municipal projects, where material choices are shaped by scale and procurement norms, addressing embodied carbon is vital to align upfront emissions with long-term net-zero goals. While active energy reduction strategies reduce energy use and subsequently operational carbon over building lifecycle, early cuts in embodied carbon prevent irreversible "locked-in" emissions. Key strategies include adopting low-carbon and recycled materials, optimizing material efficiency, and integrating procurement policies that prioritize verified low-carbon products. The following subsections outline material-specific pathways and quantified reduction potentials for municipal buildings.

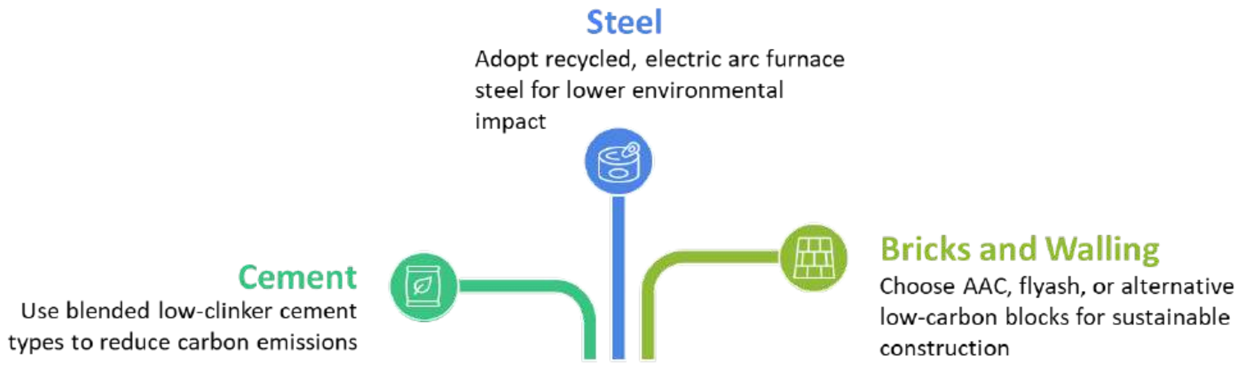


Figure 11: Low-carbon material strategies to reduce embodied emissions in construction

Source: authors

Cement

Concrete, primarily composed of cement, is a major contributor to embodied carbon in the building sector. Structural elements such as foundations, frames, and slabs account for significant cement consumption, making low-carbon alternatives a key lever for decarbonization.

Strategies

- **Prioritize lower-carbon cements:** Portland Slag Cement (PSC) and Portland Pozzolana Cement (PPC) for general construction; GGBS-rich mixes for structural concrete; pilot Limestone Calcined Clay Cement (LC3) in suitable applications.
- **Increase supplementary cementitious material (SCM) content:** Replace OPC clinker with GGBS, fly ash, or pozzolans.
- **Optimize mix design and detailing:** Reduce cement content through performance-based design, high-strength mixes, and durable detailing.
- **Ensure local sourcing and logistics:** Short transport distances and verified low-carbon production minimize embodied carbon.
- **Explore innovative binders:** Alkali-activated and low-clinker cements can provide additional reductions where standards and durability allow.

Table 8: Emission factors and reduction potential of cements

Source: authors

Cement type	Emission factor ($kgCO_2e/kg$)	% reduction vs OPC
Ordinary Portland Cement (OPC)	0.996	Baseline (0%)
Portland Pozzolana Cement (PPC)	0.710	~29%
Portland Slag Cement (PSC)	0.487	~51%
Portland Composite Cement (PCC)	0.541	~46%
GGBS-based cement	0.490	~51%
Limestone Calcined Clay Cement (LC3)	Varies by mix	Up to ~40%

Steel

Steel is extensively used in reinforcement, structural frames, roofing, façades, and building services. Its production is highly energy-intensive, making it a major embodied carbon hotspot in municipal buildings.

Strategies

- **Maximize recycled content:** Maximize use of high-recycled-content steel (e.g., Electric Arc Furnace steel) wherever structurally feasible.
- **Procure green-rated steel:** Adopt the Ministry of Steel's green steel classifications (three- to five-star ratings).
- **Material efficiency:** Optimize structural design, use high-strength sections, and reduce waste through prefabrication.
- **Use GFRP rebar for non-critical components:** Replace conventional steel reinforcement with Glass Fiber Reinforced Polymer (GFRP) bars where structural demands permit.

The above measures can lower embodied carbon from steel by **40–80%**, depending on sourcing strategy and rating compliance.

Table 9: Emission factors and reduction potential of steel

Source: authors

Steel type	Emission factor (tCO_2e/t)	% reduction vs conventional steel	Reference
Conventional (Virgin) steel – BF–BOF route	2.6	Baseline (0%)	IFC[4]
Recycled steel – EAF route	0.52	~80%	Lodha study[5]
Green steel (3-star)	2.0 – 2.2	~15–23%	Ministry of Steel[6]
Green steel (4-star)	~1.6 – 1.8	~30–38%	
Green steel (5-star)	≤1.2	≥50%	

Bricks

Bricks are a predominant walling material in buildings and contribute significantly to embodied carbon, particularly conventional fired clay bricks.

Strategies

- **Replace conventional fired clay bricks with low-carbon alternatives:** Fly ash bricks, Autoclaved Aerated Concrete (AAC) blocks and Agrocrete[7]..
- **Improve fired brick production efficiency:** Encourage procurement of bricks manufactured using the zig-zag kiln process to reduce emissions.
- **Explore emerging materials:** Agrocrete and hempcrete blocks for infill walls.

Table 10: Emission factors and reduction potential of brick technology and alternative walling materials

Source: authors

Walling / brick type	Indicative emission factor ($kgCO_2e/m^3$)	% reduction vs conventional burnt clay bricks
Burnt clay bricks	240–250	Baseline (0%)
Fly ash bricks	120–140	~40–50%
AAC blocks	90–110	~55–65%
Hollow concrete blocks	110–130	~45–55%
Agrocrete / alternative bio-based blocks	60–80	~65–75%

[4] International Finance Corporation (IFC). IFC India Construction Materials Database: Methodology Report. Washington, DC: International Finance Corporation, 2022.
[5] Lodha Group. "Building India's Future with Lower Carbon Emissions: The Untapped Potential of Recycled Steel." Lodha Group Blog, n.d. Accessed January 27, 2026.
[6] Ministry of Steel, Government of India. Taxonomy Brochure. New Delhi: Ministry of Steel, 2025.
[7] Global Housing Technology Challenge–India (GHTC-India). Agrocrete, Solid & Hollow Concrete Blocks and Binder. Ministry of Housing and Urban Affairs, Government of India.

Rooftop solar integration

Rooftop solar photovoltaic (PV) systems are most essential to achieve net zero carbon status for upcoming municipal buildings. By generating clean, renewable electricity onsite, PV integration offsets grid-based fossil fuel consumption, lowers operational carbon emissions, and enhances energy resilience. In new buildings, PV integration should be considered from the early design stage to ensure adequate structural provisions, optimal orientation, and seamless integration with electrical systems.

Figure 12 illustrates the strategies for integrating rooftop solar systems with municipal buildings, mapped in terms of **implementation complexity** and **energy generation potential**. Strategies positioned in the **lower-left quadrant** represent options that are easier to implement but yield relatively low energy generation. Those in the **lower-right quadrant** involve higher installation complexity yet offer limited generation potential. The **upper-left quadrant** includes strategies that are more complex to install but deliver higher energy generation, while the **upper-right quadrant** represents the most complex strategies, offering the **highest potential for energy generation**.

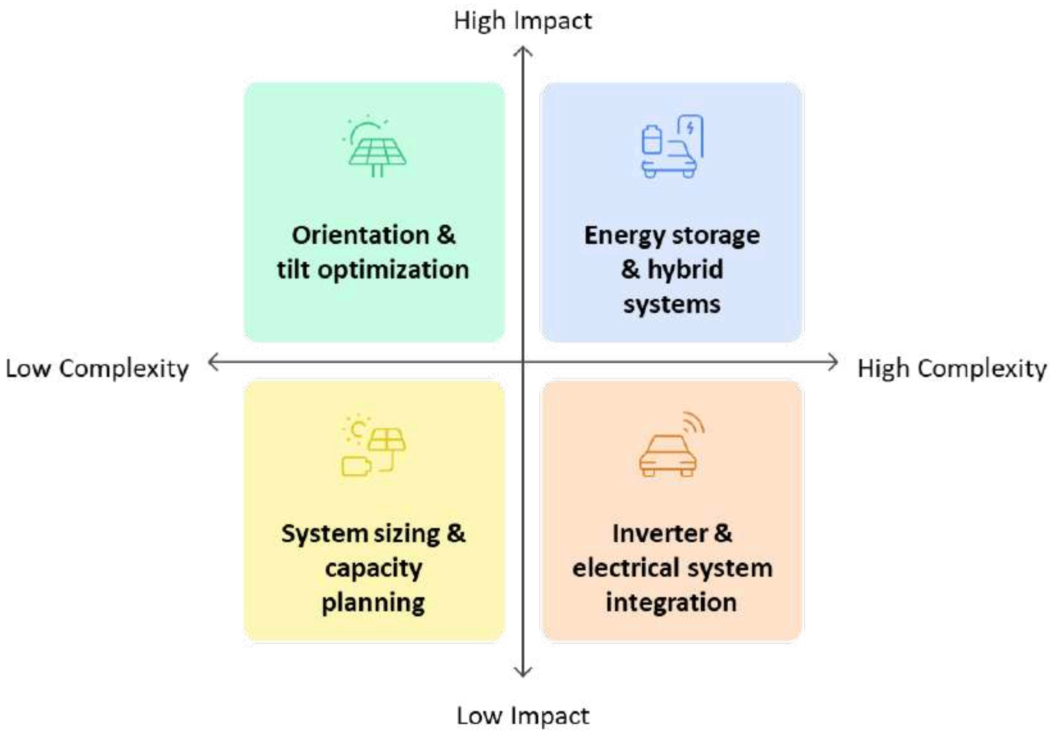


Figure 12: Rooftop solar PV integration to maximize onsite renewable energy generation

Source: authors

System sizing and capacity planning

Proper system sizing ensures that rooftop PV installations meet building energy demand efficiently without overloading the roof structure. Accurate capacity planning balances available roof area, projected energy consumption, and long-term expansion potential, ensuring alignment with state level renewable targets.

Implementation strategies

- Include structural provisions for rooftop load and maintenance access.
- Integrate PV sizing with energy efficiency measures to minimize oversizing.
- Conduct detailed building energy demand assessment.
- Size PV system according to available roof area and ECBC compliance level.

- Plan for modular capacity addition for future expansion.

Orientation and tilt optimization

Optimizing the orientation and tilt of PV panels maximizes annual energy generation and system efficiency. Careful design minimizes shading losses, enhances yield, and allows seamless integration with the building form, including the use of building-integrated PV where roof area is limited.

Implementation strategies

- Orient PV panels south-facing in the Indian context for maximum yield.
- Optimized tilt angle is typically 15°, balances performance across different seasons for Mumbai and Panvel.

Inverter and electrical system integration

Efficient inverters and smart electrical integration ensure reliable power conversion, maximize PV utilization, and enable grid connectivity. Integration with building energy management systems allows real-time monitoring, fault detection, and performance optimization.

Implementation strategies

- Select high-efficiency string or central inverters with MPPT (Maximum Power Point Tracking).
- Connect PV output to the building energy management system (BEMS).
- Incorporate smart inverter features for grid support and reactive power control.
- Enable real-time monitoring of generation and consumption for performance optimization.

Energy storage and hybrid systems

Pairing PV with energy storage enhances renewable energy utilization and ensures continuous power supply during grid interruptions. Storage solutions support peak load management, improve energy resilience, and help municipal buildings achieve higher levels of operational carbon reduction.

Implementation strategies

- Integrate battery systems for partial storage, smooth intermittent solar supply.
- Enable peak shaving and demand response integration.

Table 11: Rooftop solar PV measures

Source: authors

MahaECBC level	Roof area utilized for PV (%)	Orientation & tilt	Typical solar yield ($kWh/m^2·year$)
1-star MahaECBC compliant	50	True South, fixed tilt ~15°	250–300
2-star MahaECBC compliant	60	True South, tilt 15–20° (seasonal adjustment optional)	350–400
3-star MahaECBC compliant	70	True South, adjustable tilt 10–25° for seasonal optimization	450–500

Net-zero	>70	True South, adjustable tilt 10–30°, optimized shading	450–500

2.7.5 Clean energy procurement / open-source renewable energy

After implementing passive and active efficiency measures and integrating onsite renewable generation through rooftop PV, the remaining grid dependency can be further offset through clean power procurement. This includes participation in open-access renewable energy programs, purchase of Renewable Energy Certificates (RECs), or entering Power Purchase Agreements (PPAs) with renewable energy producers. BMC can leverage the *Green Tariff Policy* introduced by the Maharashtra Electricity Regulatory Commission (MERC), which enables institutional and bulk consumers to procure renewable energy from distribution licensees (DISCOMs) at a regulated "green tariff." The process allows municipal consumers to source their electricity entirely or partially from renewable energy without developing captive systems or entering into direct Power Purchase Agreements (PPAs) with generators.

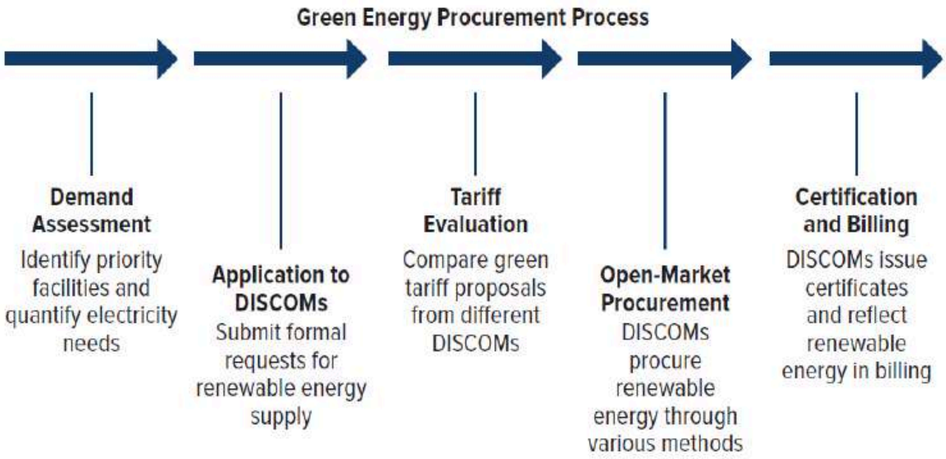
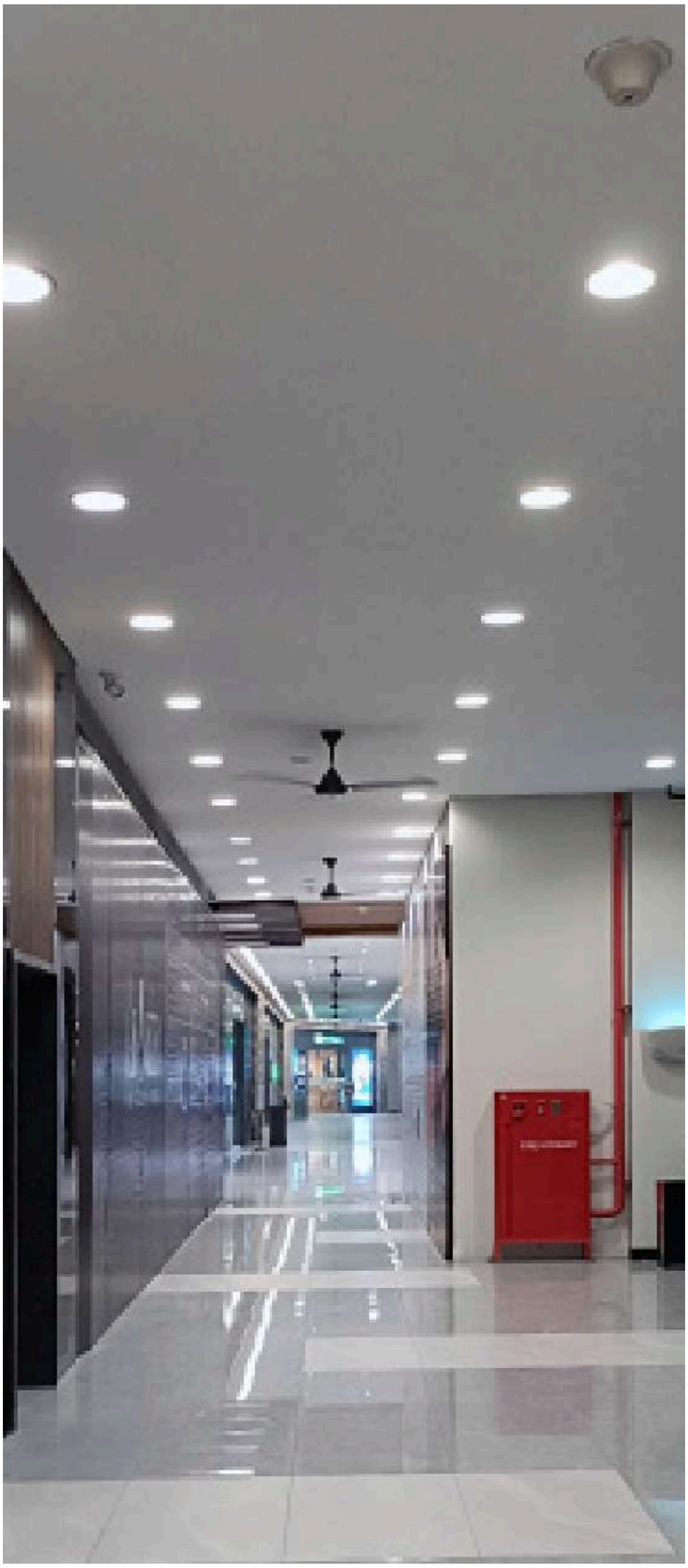


Figure 13: Steps for BMC to procure renewable energy through open market through green tariff

Source: authors

To minimize the cost of renewable energy procurement, BMC can adopt a strategic approach that combines long-term contracting with optimized demand management. By entering into 10–25-year Power Purchase Agreements (PPAs) with DISCOMs through open-market competitive bidding, BMC can secure lower tariffs by leveraging economies of scale and benefiting from the continued decline in renewable energy costs. Further, by aggregating electricity demand across its municipal facilities into a single procurement block, BMC can achieve larger contract volumes, leading to improved price discovery and more favourable terms. After implementing energy efficiency measures across its buildings, the corporation should align the contracted renewable energy capacity with the reduced post-efficiency base load to avoid over-procurement and ensure optimal utilization of renewable supply. Through this integrated approach combining demand-side efficiency with long-term renewable energy procurement BMC can achieve cost-effective decarbonization, lower its dependence on conventional grid power, and make significant progress toward its municipal Net Zero targets.

03 Implementation Mechanism



Municipal corporations face major financial barriers to scaling energy-efficiency measures due to:

- **Tight budgets:** Most funds are tied to essential operations, leaving little for capital-intensive upgrades.
- **High upfront costs:** Projects like solar or retrofits need large initial investment with long payback periods and uncertain savings.
- **Limited financing options:** Weak credit profiles and lack of tailored instruments (e.g., performance contracts, shared-savings models) restrict access to loans or private capital.
- **Regulatory bottlenecks:** Ambiguous policies and absence of guaranteed savings deter financiers.
- **Low prioritization:** Energy efficiency often takes a backseat to immediate service needs like water, sanitation, and roads.

Many city and state climate plans recognise both the opportunity and the financing barrier: Mumbai's Climate Action Plan[8] highlights energy and buildings as priority sectors but flags implementation and financing challenges for large-scale retrofits; Ahmedabad's Climate Resilient City Action Plan[9] and Pune's district Climate Action Plan[10] similarly call for greener, energy-efficient buildings while stressing the need for innovative financing and capacity building at the municipal level. State Energy Efficiency Action Plans (for example Karnataka[11] and Maharashtra[12]) set out programmes and demonstration projects for public buildings and recommend financial mechanisms and performance-based models (such as ESCOs, revolving funds, and state-supported incentives) to bridge the upfront funding gap yet they also note that limited municipal creditworthiness and weak baseline data reduce bankability and slow uptake. Strengthening municipal balance sheets, de-risking projects through state or national credit enhancements, and scaling performance contracting with robust measurement & verification are recurring policy recommendations across these plans to unlock municipal investments in energy efficiency.

Finance mechanisms

Self-implementation through internal/public budgetary resources

In FY 2024–25, the **Brihanmumbai Municipal Corporation (BMC)** allocated **32.18% of its total capital budget** to climate-relevant activities. Of this, **0.1% (~`32.5 crore)** was earmarked specifically for the **energy and buildings** sector supporting measures such as **LED retrofits** and **rooftop solar installations.**

Several low-cost **Energy Conservation Measures (ECMs)** with strong returns on investment can be implemented directly through BMC's **municipal or climate budget**. These include:

- Replacing inefficient lighting systems with LEDs
- Upgrading conventional ceiling fans to BLDC fans
- Replacing outdated air-conditioning units with energy-efficient models
- Utilizing green cess revenues to fund small-scale interventions

Implementation Strategy of Low Cost ECMs – Example of Fan Replacement

Walkthrough energy audits of BMC buildings indicate heavy reliance on **conventional ceiling fans**, which consume significantly more electricity than newer models.

- **BLDC fans** consume **30–40% less electricity**, resulting in **5–10% overall energy savings** at the building level.
- Large-scale replacements are needed across **municipal offices, hospitals, schools, and auditoriums**.

3.1.1 Phased replacement approach

- Target fans **6–10 years old** in the first phase.
- Replace fans **under 5 years old** in subsequent phases.

Procurement strategy:

[8] Brihanmumbai Municipal Corporation (BMC). Mumbai Climate Action Plan (MCAP). Mumbai: Brihanmumbai Municipal Corporation, 2022.
[9] Ahmedabad Municipal Corporation (AMC). Ahmedabad Climate Resilient City Action Plan (CRCAP). Ahmedabad: Ahmedabad Municipal Corporation, 2021.
[10] Pune Municipal Corporation (PMC). Pune Climate Action Plan / Climate Change and Environment Action Plan (CCEAP). Pune: Pune Municipal Corporation, 2022.
[11] Government of Karnataka. State Energy Efficiency Action Plan (SEEAP) and Karnataka State Action Plan on Climate Change. Bengaluru: Government of Karnataka.
[12] Government of Maharashtra. State Energy Efficiency Action Plan and Maharashtra State Adaptation Action Plan on Climate Change. Mumbai: Government of Maharashtra.

- Implement **bulk procurement** to leverage economies of scale and reduce per-unit costs.
- The unit cost of BLDC fans declines significantly with higher procurement volumes.
- The following figure illustrates how the **unit cost decreases** as the procurement volume increases.

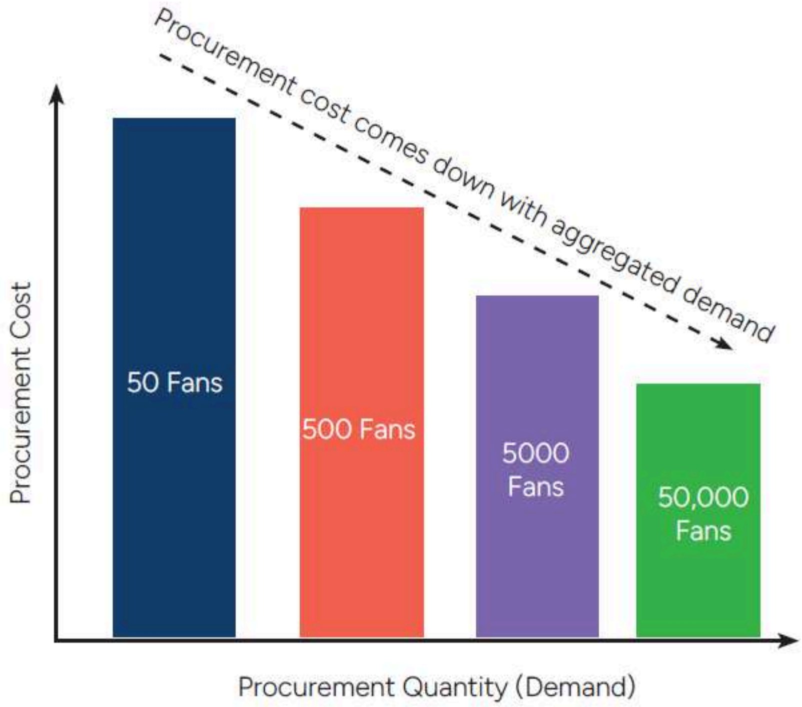


Figure 14: Decrease in unit cost during bulk procurement

**Numbers used are for creative visualisation purposes only*

In addition, other low-cost measures such as applying cool roof strategies and high-SRI (Solar Reflective Index) paints to selected municipal building typologies offer short payback periods and can also be implemented through BMC's dedicated climate budget resources.

The table below presents various financing mechanisms that BMC can use to implement low-cost energy efficiency measures through a self-financing approach.

Table 12: Approaches for self-financing

Mechanism	How it works	Municipal examples
Energy savings reinvestment (Revolving Fund)	Use the municipal climate or energy budget to implement initial low-cost ECMs (such as LEDs, BLDC fans, and occupancy sensors). Verified electricity bill savings are then reinvested into a revolving fund to finance subsequent energy efficiency upgrades.	Ahmedabad Municipal Corporation (AMC) established an Energy Efficiency Cell to monitor and reinvest savings; Nagpur Municipal Corporation (NMC) expanded LED streetlighting using internally generated savings.
Dedicated climate / energy budget earmarking	Allocate a fixed share of the municipal budget exclusively for energy efficiency measures (e.g., LED lighting, replacement of ceiling fans). Reduced	Brihanmumbai Municipal Corporation (BMC) earmarked 0.10% of its FY 2024–25 capital budget for energy and buildings; Pimpri-Chinchwad Municipal

	operational energy costs generate savings that self-finance further interventions.	Corporation (PCMC) under its Green City Action Plan and Delhi MCD implemented LED and solar projects using municipal budget allocations.
On-bill financing via utility partnership	The electricity utility finances energy efficiency upgrades upfront. The investment is recovered through a share of reduced electricity bills over an agreed period, while the municipality still benefits from net savings.	Odisha municipal corporations implemented LED streetlighting projects financed through on-bill savings recovery mechanisms.

Another approach to finance low-cost ECMs involves **demand aggregation** and **targeted low-interest loans**:

- BMC could **aggregate demand** for high-efficiency equipment (e.g., BLDC fans, efficient ACs) across all municipal facilities.
- This consolidated demand can be used to obtain a **concessional loan** from the **Maharashtra Energy Development Agency (MEDA)**, potentially supported by the **state's climate action budget**.
- **Loan repayments** (principal and interest) can be serviced through **energy cost savings**, creating a **self-sustaining financing model**.

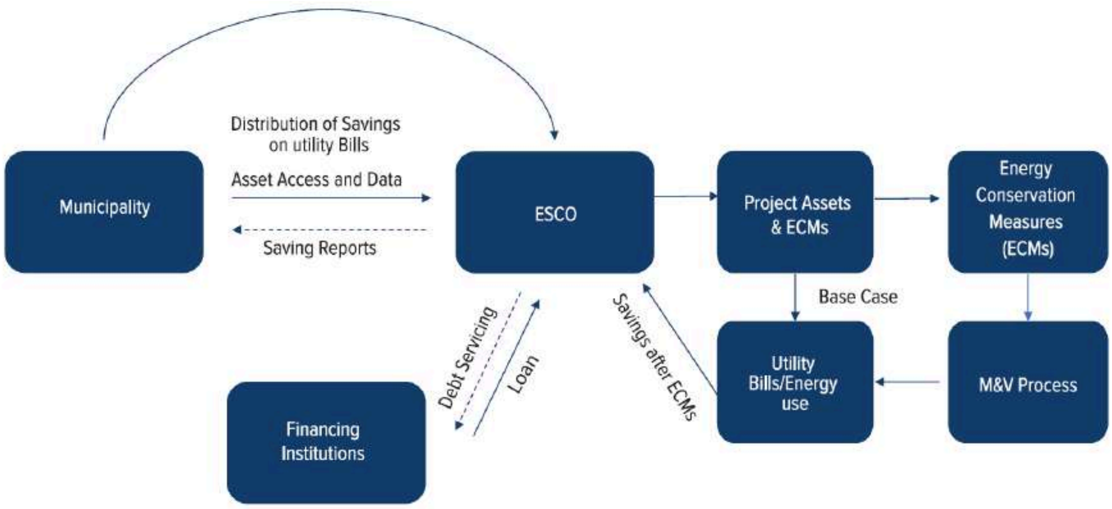
3.1.2 Third-Party and Performance Based Financing

ESCO-based implementation

Energy conservation measures of the nature of medium to high cost with near to long term payback period can be implemented through ESCO based financing mechanism. In this financing mechanism, BMC can establish a performance contract for energy savings with an ESCO which could be a company with technical expertise that enters into a **performance contract** with the municipality to implement energy efficiency measures that optimize energy usage and reduce expenditure in a technically or commercially viable manner. The EPC can be established for commercially feasible energy efficiency measures that offer attractive returns in the form of reduced operating costs due to optimized energy usage and reduced energy expenditure and improved delivery of services. BMC can establish multiple types of performance-based contracts with ESCOs depending on the nature of the energy efficiency project and investment required. These EPCs are described below:

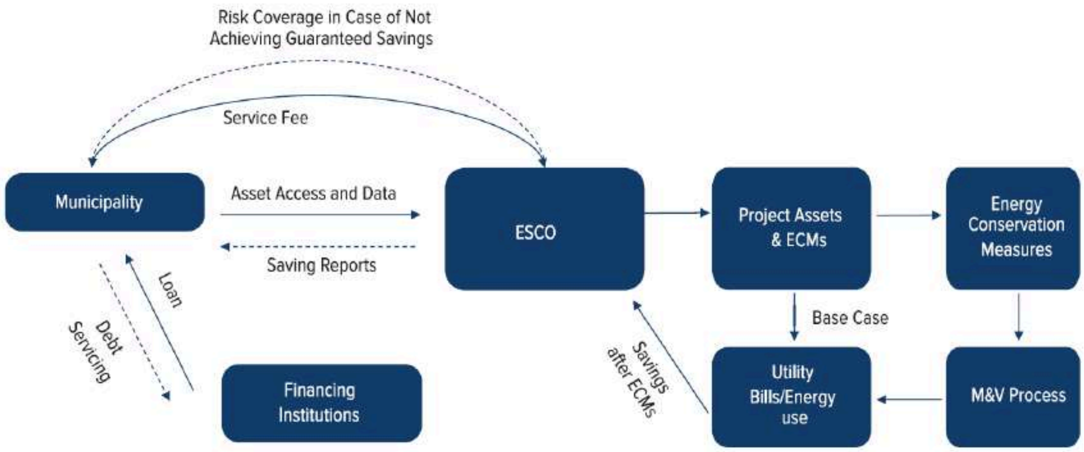
Shared Savings

Under this model, the ESCO finances the project either through its own funds or by borrowing from a third party. The ESCO takes on the performance risk of the project. The cost savings are divided between the ESCO and customer at a prearranged percentage for an agreed length of time. Under this mechanism, BMC can do the demand aggregation at the municipal building portfolio level for ECMs such as replacement of inefficient ceiling fans with energy efficient BLDC fans in all municipal buildings and appoint ESCOs (e.g., MahaPreit or private players) based on the pre-agreed EPCs terms. ESCO would bring the investment to deploy the energy efficient ceiling fan in all municipal buildings and savings from the electricity bill can be aggregated into an ESCROW account and shared between BMC and ESCOs.



Guaranteed Savings

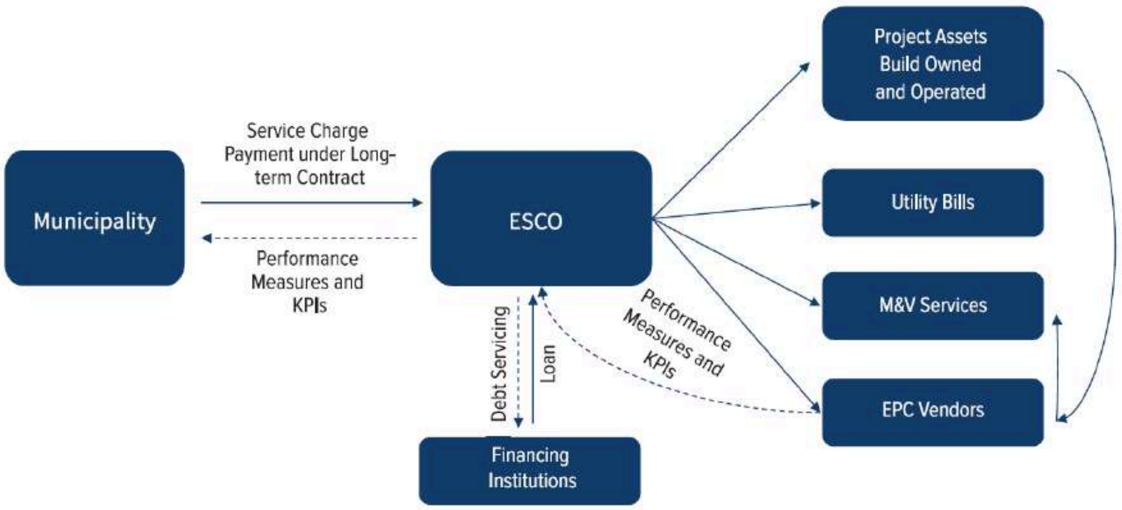
In this case, the customer finances the design and installation of the project by borrowing funds from a third party such as a bank or through leasing the equipment. The ESCO has no contractual arrangement with the bank but does assume the project risk and guarantees the energy savings made. If the savings do not reach agreed minimums the ESCO covers the difference; if they are exceeded then the customer agrees to share the savings with the ESCO.



Build Operate and Own (BOO) Model

In this model, a private organization builds, owns, and operates the energy-efficient facility. The government does not provide direct funding but may offer financial incentives, such as tax exemptions.

This financing mechanism is particularly suitable for **Cooling-as-a-Service (CaaS)**. For example, a private entity can upgrade existing cooling systems in selected municipal buildings and provide cooling services under pre-agreed terms, with municipalities paying based on actual usage.



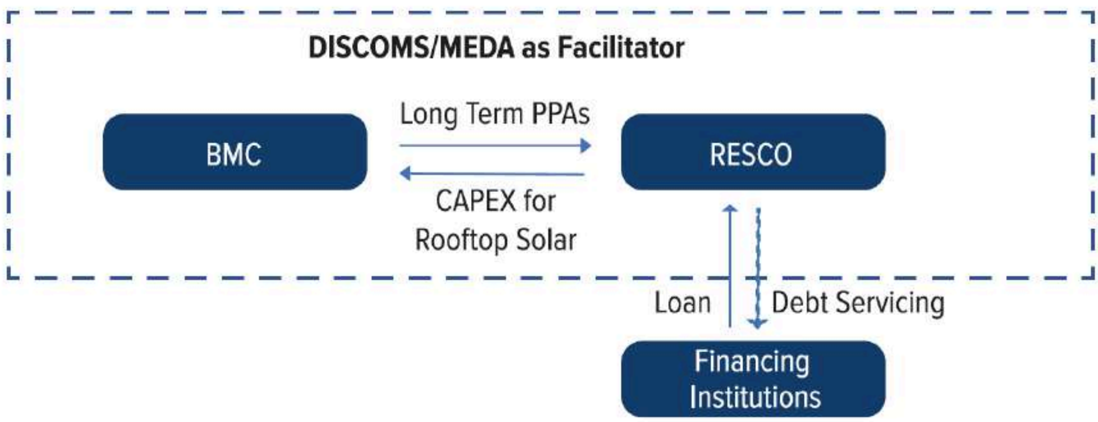
**A draft tender document for energy efficiency related project implementation under ESCO route has been provided in the appendix A which can be used by BMC to implement the identified ECMS in one of the identified municipal building categories on pilot basis.*

Renewable Energy Service Company (RESCO) Models for Renewable Energy

Under this model, a third party installs, owns, and operates renewable systems (e.g., rooftop solar) and sells electricity to municipalities under a long-term Power Purchase Agreement (PPA). Municipalities pay only for energy consumed at an agreed tariff often below grid rates avoiding RESCO would convert capital cost into operating expenditure, enabling large-scale deployment without straining municipal budgets. The RESCO entity would raise equity and debt against PPA-backed cash flows, while municipalities would benefit from immediate tariff savings and faster decarbonization of public assets.

Financing Route under RESCO Model

For the rooftop solar potential identified through the baseline assessment of municipal offices, hospitals, schools, and auditoriums, financing can be enabled through the RESCO model. Under this arrangement, BMC enters into a long-term PPA with a RESCO developer, facilitated by the DISCOM or MEDA. BMC pays for the electricity generated as per the agreed PPA tariff, ensuring timely and secure payments to the RESCO.



3.1.3 Financing through Specialized Institutional Debt

BMC can also attempt alternate sources of financing to provide funding for initiatives with a range of risks, rewards, and investment tenures. These consist of, among other things CSR funds (through partnership), municipal bonds, green bonds, carbon credits, and public-private partnerships. For example, PCMC successfully issues a 200 crore green municipal bond to fund sustainable urban mobility projects with 5.13 times subscription which is the first in Maharashtra[13].

Municipal bonds are now becoming an alluring source of funding. An estimate by ICRA shows that municipal bond issuances to raise over `1500 crore in FY 2025-26 primarily driven by the Government's push[14]. Reporting and compliance obligations for municipal bond issues are similar to those for corporate bond issues. These bonds provide investors with a fixed or variable rate of interest and have a minimum term of three years. India has so far issued medium-term, fixed-interest municipal bonds with maturities of five or ten years.

To raise a municipal bond, the corporation should have an operating surplus in the last three fiscal years and should not have a history of defaulting at repayment of loans or debt instruments acquired from financial institutions in the last one year. Municipal corporation can achieve a lower coupon rate if the municipal bonds that raise funds are used for green initiatives. Additionally, it is preferred that the issuing body has a minimum investment grade credit rating AA or more from one of the top credit rating agencies.

Table 13 classifies the ECMs by investment level low, medium, and high and identifies corresponding financing options for their implementation.

Table 13: ECM examples with possible financing mechanisms: summary

Low-cost (Near term- by 2030)	Measures: LED lights and occupancy sensors, Conventional fan replacement with BLDC fans, External window shading, Cool roofs/ceiling innovations Priority: Immediately (1-year timeline) replace all inefficient lighting system with efficient LED lighting fixtures. Fan replacement can be done in phases. e.g. Phase 1: Replace the most inefficient stock first, i.e. 6-10+ years old, Phase 2: Less than 5 years old. Possible Financing Mechanism: Aggregate demand and use bulk procurement through Internal/Public Budgetary Resources such as Municipal Budgets, Revolving Investment Funds (RIFs) such as from State Energy Conservation Fund, Revenue from earmarked Funds (Green Cess), ESCROW account through O & M budget and refinancing through savings. Implementation through DISCOM-led on-bill financing mechanism.
Medium cost (Mid-term – by 2040)	**Measures:** Replacement of inefficient old split AC with efficient one **Priority: Replacement can be done in phases based on star-ratings, e.g.** Phase 1- Replace all 1-star (most inefficient stock) ACs with 5-star Phase 2- Replace 2-star ACs with 5-star

[13] ET Government. "Pimpri-Chinchwad Makes History with India's First Green Municipal Bond." ET Government, June 13, 2024.

[14] Business World. "Municipal Bond Issuances to Raise over Rs 1,500 Cr in FY25–26: Report." Business World, n.d. Accessed January 27, 2026.

	Phase 3- Replace 3-star ACs with 5-star **Possible Financing Mechanism:** Demand Side Management activities by DISCOMs (BEST- Brihanmumbai Electricity Supply and Support replaced old air conditioners with energy efficient air conditioners[15]) through on-bill financing Implementation through ESCOs under EPC models (shared-savings/ guaranteed-savings)
Cost-intensive (Long term – by 2050)	**Measures:** Rooftop Solar, replacement of centralized air-cooled chillers with water cooled systems and integration of variable frequency drives (VFDs), Replacement of old centralized HVAC system with efficient one. **Priority:** **Phase-wise Implementation of Rooftop Solar:** **Phase 1:** Prioritize installation in municipal schools and auditoriums with large, structurally suitable roof areas offering high solar potential. **Phase 2:** Extend implementation to hospitals and municipal offices. Phased Replacement of Inefficient HVAC Systems: **Phase 1:** Replace old, inefficient centralized HVAC systems in buildings with high EPI values corresponding to BEE's **1-star** ratings. **Phase 2:** Upgrade HVAC systems in buildings with BEE's **2-star and 3-star** EPI ratings to further enhance overall portfolio efficiency. Possible Financing Mechanism: **Rooftop Solar Installation:** Implement through **Renewable Energy Service Company (RESCO)** or **Energy-as-a-Service (EaaS)** models, supplemented by **municipal bond financing** to enable capital-free deployment and long-term energy cost savings. **Replacement of Inefficient HVAC Systems:** Adopt a **Cooling-as-a-Service (CaaS)** model implemented via qualified **Energy Service Companies (ESCOs)** under performance-based contracting frameworks to ensure efficiency gains and measurable energy savings. **Measures:** Offsite RE procurement Financing Mechanism: Open market procurement through DISCOMs under MH's green tariff policy

Achieving the proposed energy efficiency targets for the municipal building stock necessitates coordinated commitments across multiple departments of the BMC, including Engineering, Mechanical and Electrical (M&E), Environmental, and Procurement divisions. These departments must collaborate to establish baselines, assess potential energy efficiency measures and their impacts, and develop key performance indicators (KPIs) to monitor progress. Furthermore, comprehensive financial planning is required to explore self-financing, co-financing, and external financing mechanisms for energy efficiency projects. For medium-depth retrofits, ESCOs with EPC models is essential, particularly where payback periods align with contractual terms. At a portfolio level, BMC should prepare aggregated tenders to reduce transaction costs and enhance scalability. For deep retrofitting initiatives, innovative financing approaches such as the issuance of green or municipal bonds, or the mobilization of external capital through public–private partnerships (PPPs), will be critical to ensuring long-term financial viability and sustained impact.

[15] Bureau of Energy Efficiency. "Sustainable and Accelerated Adoption of Energy Government of India", Ministry of Power.

Governance and Roles

BMC has several departments like- Engineering Services Department (M&E, School infrastructure Cell), Education and Health department, Disaster Management Cell, and general administration (e.g. IT, Accounts) etc. Mechanical & Electrical(M&E) Department currently oversee some functions and activities that fall under the proposed Energy Conservation Measures for Municipal buildings. For instance, the department has installed solar panel installations at a number of hospitals, and is taking actions to replace inefficient AC stock in municipal office and hospital buildings with efficient ones. Additionally, it has installed an IoT-enabled automated distribution system at the BMC Head Office with the goal of improving electrical safety and energy efficiency[16]. This department can continue as earlier and take up additional measures like replacement of old conventional fans with new BLDC fans in municipal buildings, retrofitting AHU motors and HVAC optimization. The Education department and Health department look after all programs within municipal schools and hospitals, which related to purchase of equipment like CCTV cameras, machines, or awareness regarding judicious use of resources. These departments can coordinate with M&E department for installation of energy-efficient appliances.

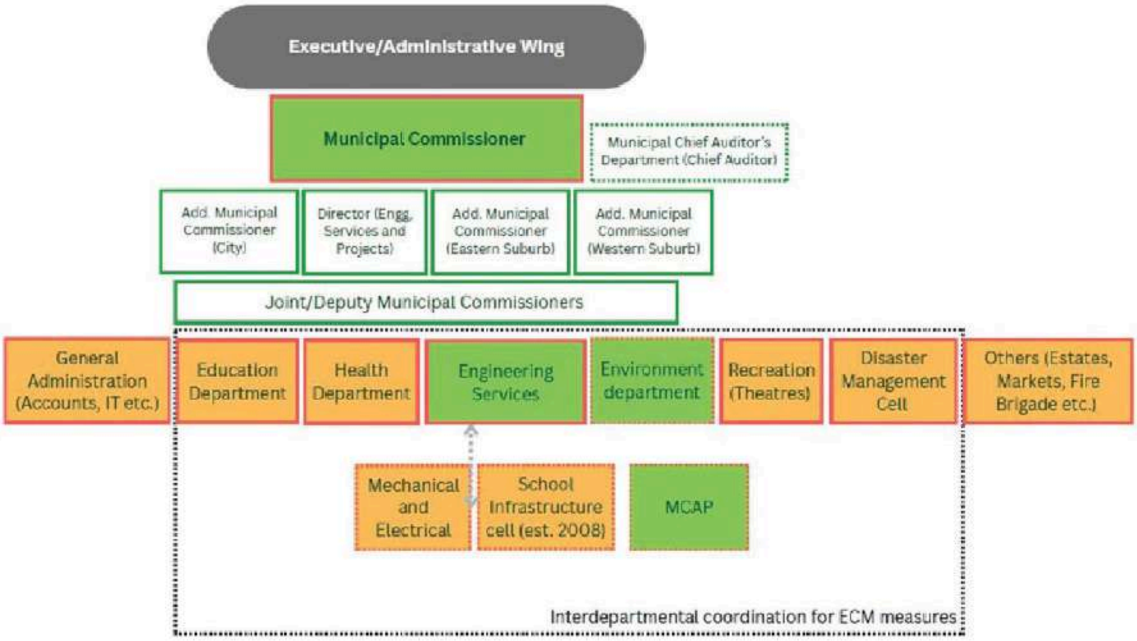


Figure 15: Existing institutional structure of departments relevant for Energy and Buildings in BMC[17]

A 'School Infrastructure Cell' was established here in the year 2008 within Engineering Services department to oversee- repair, upgradation, reconstruction and new Construction of BM. school buildings[18]. This department can continue with all coordination for municipal schools like envelope retrofitting and installation of rooftop solar in municipal schools. The Recreation Department looks at auditoriums and therefore could coordinate with other departments to implement energy-conservation measures in those buildings. The Disaster Management Cell also exists within the corporation which could dedicatedly take up heat-resilience measures like application of SRI paints on roofs of municipal buildings.

[16] Brihanmumbai Municipal Corporation (BMC). Climate Budget Report 2024–25. Mumbai: Brihanmumbai Municipal Corporation, 2024.

[17] Brihanmumbai Municipal Corporation (BMC). Document Repository. Mumbai: Brihanmumbai Municipal Corporation.

[18] Brihanmumbai Municipal Corporation (BMC). Year Book 2025. Mumbai: Brihanmumbai Municipal Corporation, 2025.

As per MCAP, the Environment Department is expected to take all necessary steps towards driving transition to net-zero. Therefore, this department could be appointed as the key nodal agency to monitor targets and activities taken up by others. Since no energy cell currently exists, MCAP proposed a department 'Buildings and Mobility' within the Environment Cell which co-ordinates with state level agencies like MEDA, MSEDCL, others (refer figure 16 taken from MCAP).

Figure 16: Proposed Buildings and Mobility cell under MCAP[19]

Roles and Responsibilities

Table 14: RACI for government departments

Roles	Municipal Departments	MEDA/ DISCOMS	ESCOs (Government/ Private)	Financial Institutions
Baselining of Municipal Buildings Energy Consumption and Benchmarking				
Enact energy performance standards for existing municipal buildings	Environment Department M&E Department			
Baseline assessment and energy benchmarking	Environment Department M&E Department			

[19] Brihanmumbai Municipal Corporation (BMC). Mumbai Climate Action Plan (MCAP) Portal. Mumbai: Brihanmumbai Municipal Corporation.

Energy audit of municipal buildings	Environment Department M&E Department			
Identification of ECMs for municipal building categories	Environment Department M&E Department			
Aggregation of ECMs for different municipal building typologies	Environment Department M&E Department			
Financial Planning under Climate Budget for Self-Financing and Concessional Loans				
Allocating budget for energy efficiency projects under climate budget	Environment Department M&E Department Finance Department	MEDA		
Application of concessional loan for EE projects to MEDA	Environment Department M&E Department	MEDA		
of repayment mechanisms	Environment Department M&E Department Finance Department			
Financial planning under ESCO mode for EE projects				
Preparing the tendering and procurement process	Environment Department M&E Department	MEDA/ DISCOMs	MahaPreit	
Developing the M&V protocols	Environment Department M&E Department	MEDA/ DISCOMs	MahaPreit	
Verification of M&V reporting	Environment Department M&E Department	MEDA/ DISCOMs	MahaPreit	
Structuring the repayment mechanism to ESCOs	Environment Department M&E Department	MEDA/ DISCOMs	MahaPreit	

	Finance Department			
Prepare tripartite agreement for large scale and cost intensive EE upgrades	Environment Department M&E Department	MEDA/ DISCOMs	MahaPreit	
Ensuring regulatory and code compliances	Environment Department M&E Department			

Standardization of the Procurement Process

Standardized procurement processes would help in the repeatable process of bringing energy efficiency projects to market. By using standardized requests for proposals with common scope of work, defined baselines, clear measurement & verification requirements and evaluation criteria – BMC can ensure that every bid they receive is evaluated consistently. This reduces ambiguity for vendors, speeds up the approval process (rapid awards), and makes it easier to compare results across projects. Importantly, aligning these criteria with *climate budget methods* ensures that project outcomes can be reliably quantified for Monitoring, Evaluation, and Reporting (MER) against climate and energy targets. Instead of taking up energy efficiency related projects in individual municipal buildings, portfolio aggregation bundles project together by municipal building typologies (e.g., schools, hospitals, offices). This has several advantages:

- **Reduced transaction costs**: Fewer procurement cycles, shared administrative costs, and standardized contracts.
- **Risk diversification**: Performance risks are spread across multiple buildings rather than concentrated in one.
- **Comparability of outcomes**: Since similar building types are grouped, results are easier to benchmark and integrate into climate budget reporting tables and sectoral action tracks. This allows municipalities to track not only project-level savings but also sector-wide progress in a structured way.

Measurement Reporting and Verification (MRV) Framework

The effective implementation of energy efficiency measures, whether through a self-financing mechanism or the ESCO route, requires a robust MRV framework. Figure illustrates the suggested MRV steps that the BMC can adopt for implementing energy efficiency related projects. As a first step, BMC should compile 12–24 months of historical electricity consumption data for the identified municipal building categories to establish a reliable baseline, followed by post-implementation data collection after the execution of ECMs. To enhance accuracy, BMC should also aim to capture data at the appliance or system level through sub-metering. Based on this measured data, suitable performance indicators such as energy use intensity (kWh/m^2) or energy consumption per appliance unit should be developed to compare pre and post ECM implementation performance. Once the performance results are analysed, BMC should engage an accredited third-party verifier to validate and certify the actual energy savings achieved. The verification process should adhere to standardized protocols such as those outlined in the International Performance Measurement and Verification Protocol (IPMVP) to ensure consistency and accuracy. Finally, if the ECMs are implemented under the ESCO route, BMC can link verified savings to payment terms, thereby ensuring performance-based accountability and transparency in project delivery.

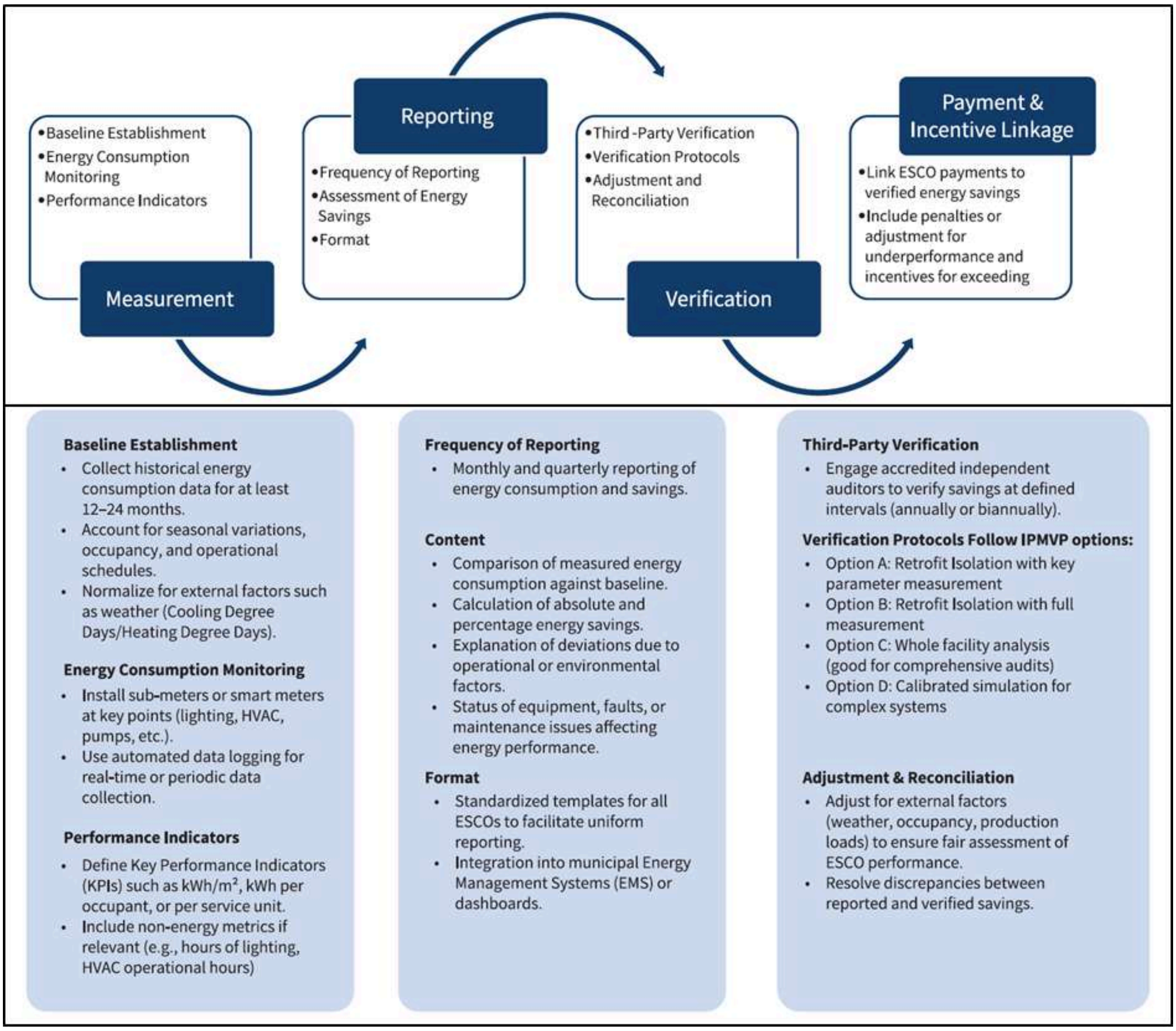


Figure 17: Measurement reporting and verification (MRV) framework

Figure below shows the near-term strategy for resource planning for taking up the energy efficiency projects in municipal buildings.

Figure 18: Near term year-wise resource planning

Source: authors

Risk Assessment and Resilience

Risk assessment is a fundamental component of performance-based contracts involving ESCOs, such as Energy Savings Performance Contracts (ESPCs) and Utility Energy Service Contracts (UESCs). In these agreements, a third-party contractor (the ESCO or utility provider) implements ECMs and guarantees a specified level of facility performance and cost savings.

The goal of risk assessment and management in this context is twofold: **to allocate project risks and responsibilities between the ESCO and the municipal corporation**, and **to use Measurement and Verification (M&V) to reduce the risk of non-performance to an acceptable level**

Key Tool for Risk Assessment: The RRP Matrix

The primary tool used for structured risk assessment and allocation is the **Risk, Responsibility, and Performance Matrix (RRP Matrix)**.

- **Purpose:** The RRP Matrix summarizes risks, responsibilities, and verification requirements that must be considered when developing performance contracts. It helps identify critical project risks, assess their potential implications, and clarify which party is responsible for managing them.
- **Process:** Early in project development, the ESCO (contractor) and the municipal corporation review the RRP Matrix to evaluate how key responsibilities will be allocated. This allocation drives the M&V strategy. The final agreed-upon RRP Matrix significantly influences the M&V approaches chosen for the project.

Categories of Project Risk: The RRP Matrix typically addresses three main categories of risk that influence performance contracts:

Table 15: Responsibility and performance matrix

Risk Category	Description and Scope	ESCO/Contractor Responsibility
Financial Risk	Risks related to savings shortfalls, unforeseen changes during implementation of ECMs, future facility changes, and energy prices (including annual escalation rates).	The ESCO is responsible for determining implementation costs and generally assumes responsibility for cost overruns in a fixed-price contract (unless the customer causes delays). Falling energy prices place the ESCO at risk of failing to meet guaranteed cost savings.
Operational Risk (Usage Risk)	Risks resulting from factors generally outside the ESCO's control that affect energy use and savings, such as facility operating hours, equipment loads, and weather.	Because ESCOs often cannot control usage factors, the customer generally assumes usage risk. This risk transfer is often achieved through stipulations (agreed-upon fixed values for parameters, regardless of actual behaviour).
Performance Risk	Uncertainty associated with an ECM's ability to achieve savings and meet contractual conditions (e.g., temperature setpoints or lighting levels). Performance risks are directly related to equipment efficiency and availability.	The ESCO assumes responsibility for the selection, application, design, installation, commissioning, and long-term performance of the equipment. The ESCO also bears the ultimate risk for guaranteed savings tied to operations, preventive maintenance, repair, and replacement, regardless of which party performs the physical activity.

M&V and Risk Management

M&V is integral to managing risk by balancing the cost of M&V activities with the value of increased certainty in the cost savings.

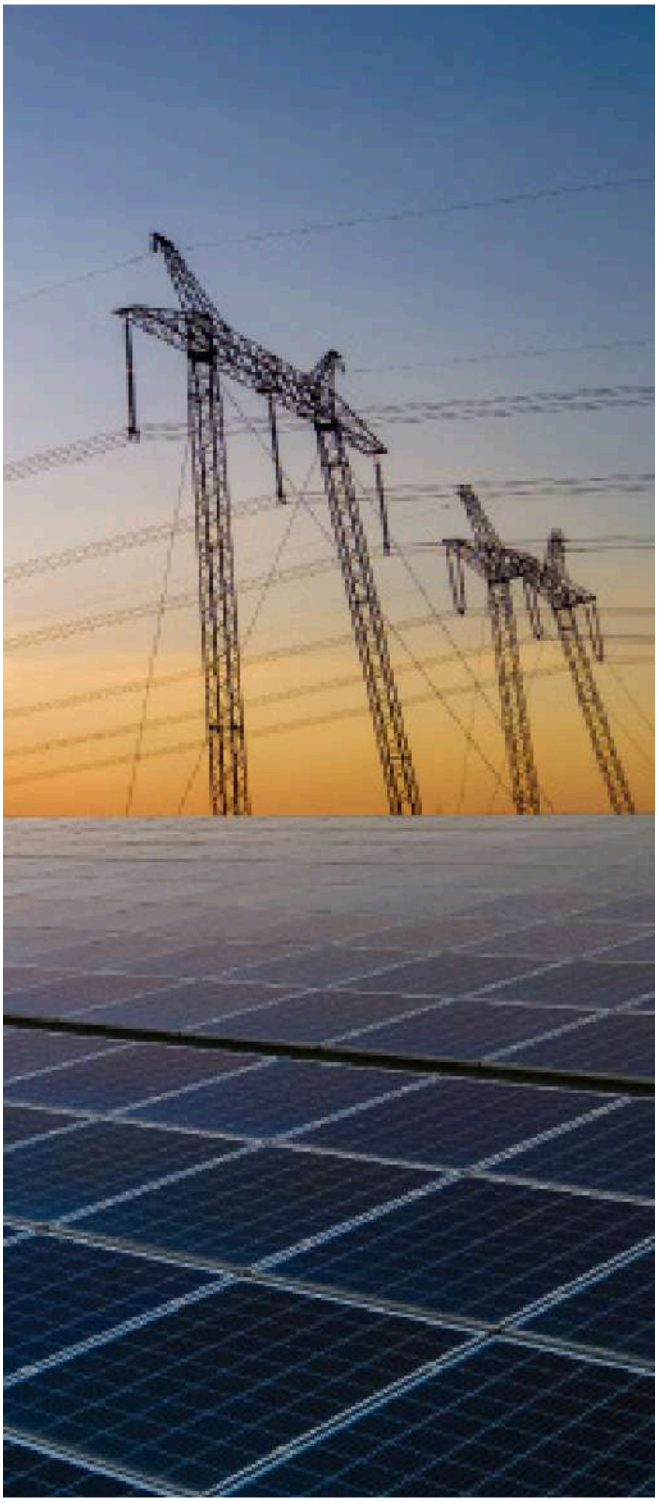
- **Risk of Achieving Savings:** The perceived risk associated with achieving the expected energy or cost savings determines the necessary **rigor** of the M&V

approach. ECMs with high estimated savings uncertainty may warrant greater attention.

- **M&V Option Selection:** The selection of an M&V option depends partly on the **risk of achieving savings** and the **complexity of the ECM**. For example, simple ECMs with low risk may use "Retrofit Isolation with Key Parameter(s) Measurement", while complex, interrelated ECMs with higher risks may require "Whole Facility Measurement" or "Calibrated Simulation".

- **Using Stipulations:** Stipulating certain fixed parameters in the M&V plan is a practical, cost-effective way to reduce M&V costs and allocate risks, particularly operational risks that neither party can fully control (e.g., equipment operating hours). Stipulation, however, is acceptable only for individual parameters and is prohibited for the total savings associated with an entire ECM.
- **Cost vs. Rigor:** The M&V effort must be scaled appropriately to the value of the project to ensure M&V costs are reasonable. Historically, overall annual M&V costs are often estimated at **1.5% to 3% of typical annual guaranteed cost savings**. Increasing M&V rigor increases cost but decreases the uncertainty in savings calculations, following a "law of diminishing returns.

04 From Roadmap to Action Plan



This section gives an overview of targets, finance strategy and timeline (discussed in previous chapters) in the form of a comprehensive roadmap followed by action plan for two identified buildings for pilots. It also provides a decision matrix for choosing financial strategy for interventions and finally a figure showcasing roles and responsibilities of various departments for seamless coordination.

Roadmap: Targets, timeline and strategy

The provided figure illustrates a comprehensive **Roadmap** detailing targets and finance strategies for municipal buildings across various timeframes, from 2025 to the year 2050 with the aim of reviewing actions at every 5-year interval. The plan addresses both **Existing Buildings**, prioritizing actions like energy audits, behavioural changes (e.g., AC temperature settings), and phased equipment replacement (fans and air conditioners) based on inefficiency, alongside **New Buildings**, where the focus is on developing sustainable procurement guidelines, utilizing low-carbon materials, and implementing passive design principles. A significant recurring goal throughout the decades is the installation of **Rooftop Solar** on municipal buildings, culminating in a target of all existing buildings becoming net-zero energy and all new buildings being net-zero carbon by 2050. To fund these transitions, a variety of **Finance Mechanisms** are proposed, including internal budgets, concessional loans, revolving funds, and innovative models such as On-bill.

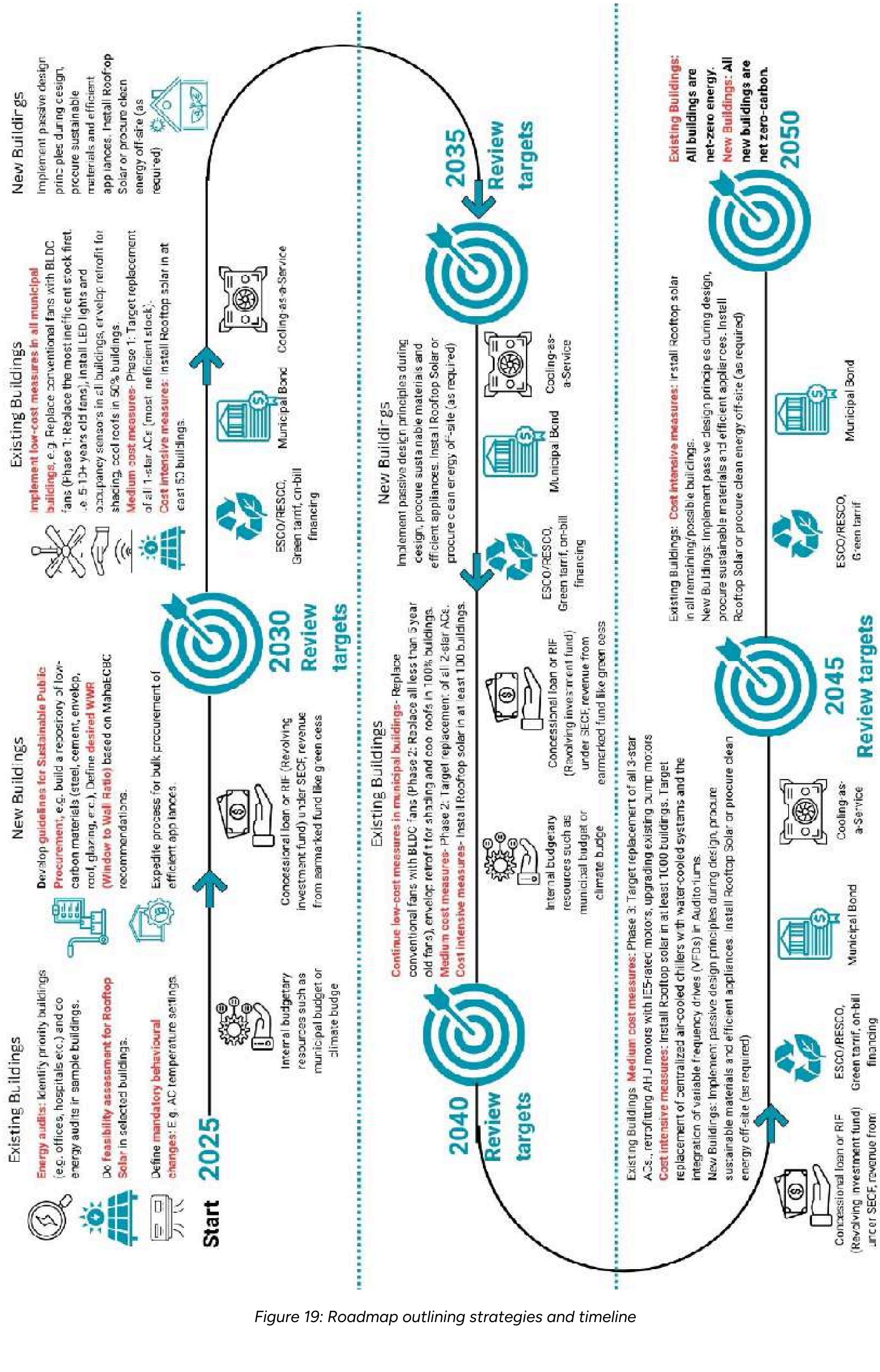


Figure 19: Roadmap outlining strategies and timeline

Action Plan: Pilots BMC

The baseline assessment of municipal buildings under BMC's jurisdiction (refer Chapter 1) showed that hospitals, municipal offices, school buildings and auditoriums are the largest energy consumers and therefore should be prioritized for action. Further, the walkthrough energy audit of the sample buildings under the identified municipal building categories helped to identify the ECMs and their impact on energy consumption reduction potential. The analysis showed that the scale of **impact of the identified ECMs is larger for the municipal offices and hospital category buildings compared to schools and auditoriums**. Therefore, two buildings- one from municipal offices and one from the hospital category buildings have been selected and action plans are illustrated. The RC Ward municipal office building has been selected under office category buildings and Nair Hospital premises has been selected under hospital category. The identified ECMs for both categories of municipal buildings has been categorized into five major strategies which are envelope and roof retrofitting, behavioural changes, appliances retrofitting, rooftop solar installation and offsetting the remaining grid dependency through open market procurement of RE through green tariff policy.

Draft templates for ESCO-based contracting for implementing the identified ECMs and for Measurement & Verification (M&V) have been provided in **Appendices A and B**, respectively. These templates can be utilized by the Municipal Corporation while issuing tenders.

The impact of the ECMs in terms of energy saving potential and annual monetary savings, investment required for the identified ECMs, payback period for that investment and financing mechanism for implementation is presented in figure 21 and 22 for RC ward municipal office and Nair hospital building respectively.

RC Ward Municipal Office Building

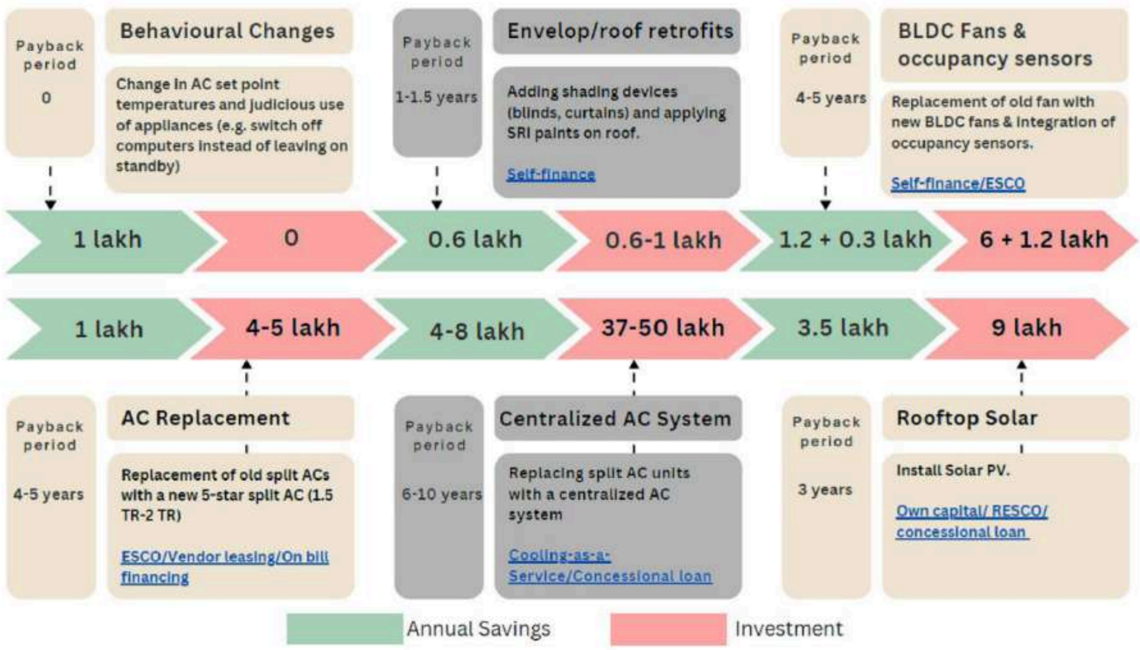


Figure 20: Action plan for RC ward municipal office building

Source: authors

Nair Hospital Building

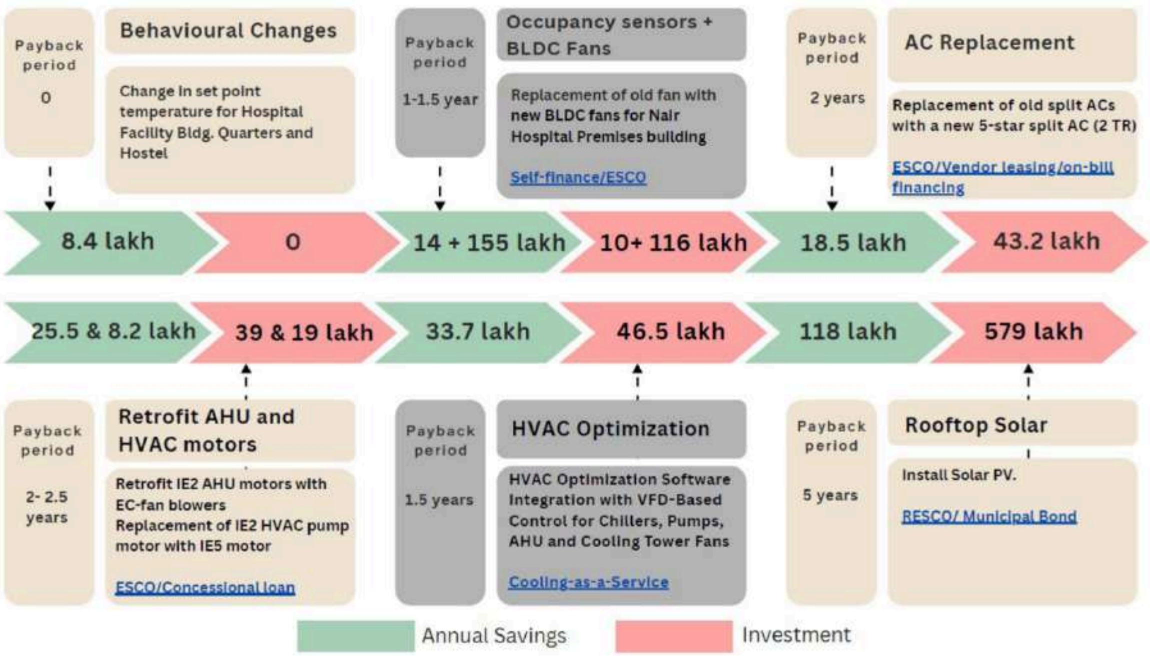


Figure 21: Action Plan for Nair hospital
Source: authors

Action Plan: Pilots PMC

The baseline assessment of municipal buildings under PMC's jurisdiction (refer Chapter 1) showed that municipal offices, hospitals, school buildings and auditoriums are the largest energy consumers and therefore should be prioritized for action. Further, the walkthrough energy audit of the sample buildings under the identified municipal building categories helped to identify the ECMs and their impact on energy consumption reduction potential. The analysis indicates that the identified ECMs have a greater impact potential in the auditorium building, whereas the school buildings are more likely to achieve net-zero status with relatively less effort and low-cost measures. Accordingly, the Adya Krantiveer Vasudev Balwant Phadke Auditorium and the D.B. Patil School have been selected for Net Zero Action Plan implementation. The identified ECMs for both categories of municipal buildings has been categorized into five major strategies which are envelope and roof retrofitting, behavioural changes, appliances retrofitting, rooftop solar installation and offsetting the remaining grid dependency through open market procurement of RE through green tariff policy.

Draft templates for ESCO-based contracting for implementing the identified ECMs and for Measurement & Verification (M&V) have been provided in Appendices A and B, respectively. These templates can be utilized by the Municipal Corporation while issuing tenders.

The impact of the ECMs in terms of energy saving potential and annual monetary savings, investment required for the identified ECMs, payback period for that investment and financing mechanism for implementation is presented in figure 21 and 22 for D. B. Patil School Building and Adya Krantiveer Vasudev Balwant Phadke Auditorium Building, respectively.

D. B. Patil School Building

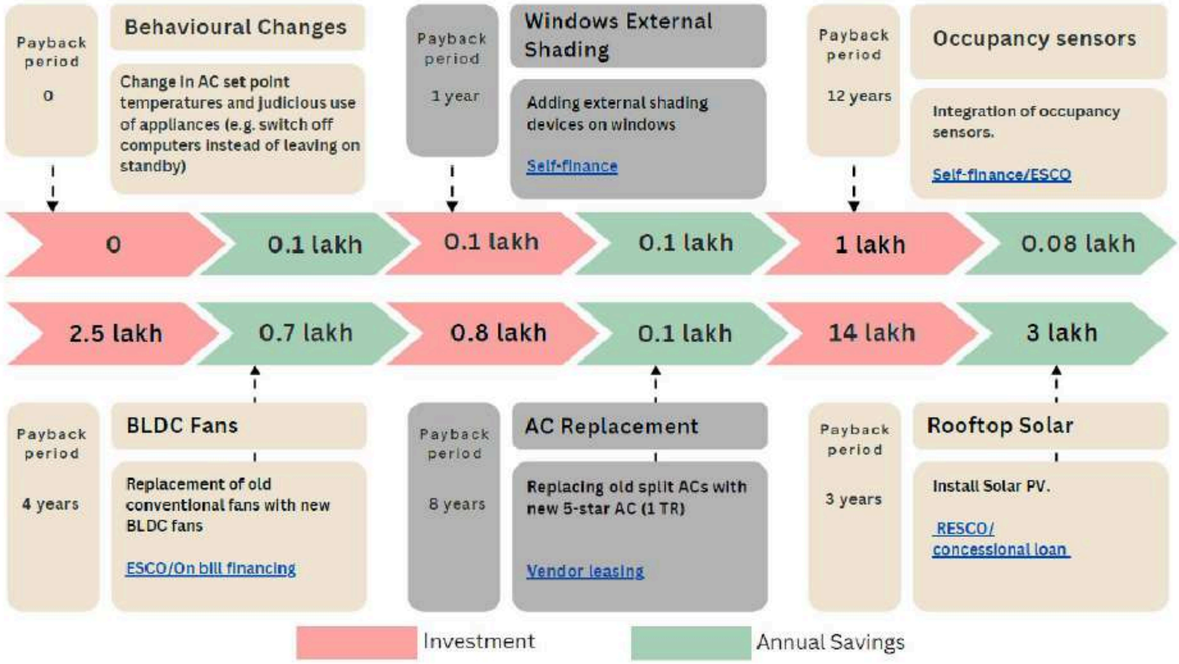


Figure 18: Action plan for D. B. Patil Municipal school building

(Source: authors)

Adya Krantiveer Vasudev Balwant Phadke Auditorium Building

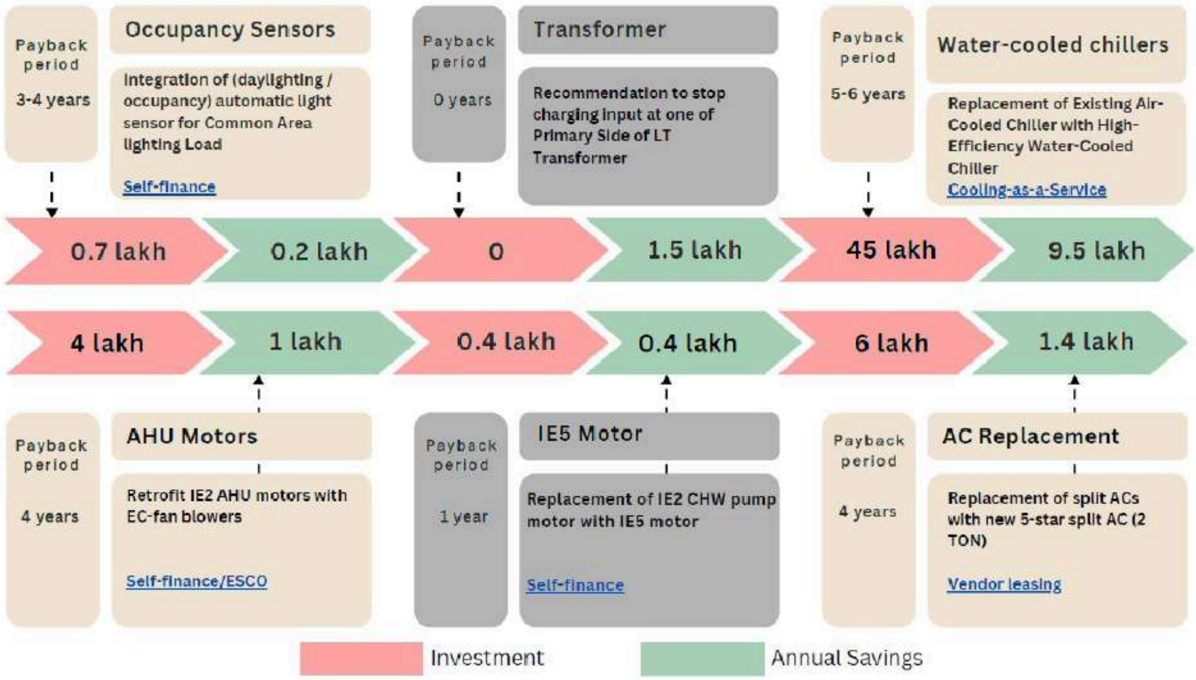


Figure 19: Action plan for Adya Krantiveer Vasudev Balwant Phadke Municipal auditorium building

Decision Matrix

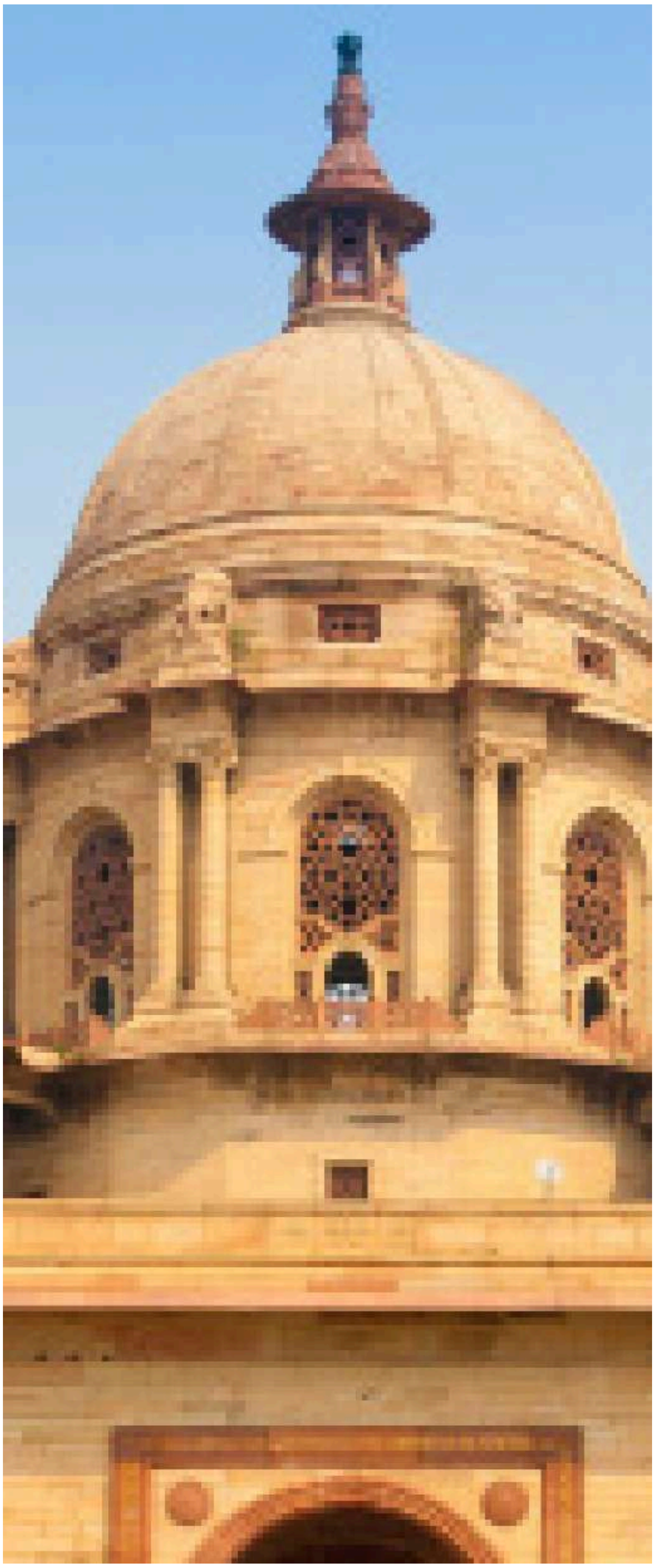
The decision matrix provided can assist municipal corporations in picking suitable financing mechanisms for various interventions through a sequence of questions about funding sources starting with internal budgets and progressing through state government funds, ESCOs, utility-based financing, CSR grants, leasing/vendor financing, and municipal bonds. Finally, to achieve seamless coordination a chart illustrating roles and responsibilities is provided.

Table 16: Decisions matrix for financing strategies

Building Identification and ECM Selection			
Target buildings based on baseline assessment and benchmarking	Categorise buildings based on BEE's star level benchmarking and target efficiency measures implementation in phased manner Phase 1 – Target buildings under 1-star category Phase 2 – Target buildings under 2-star category Phase 3 – Target building under 3-star category		
Identification of ECMs	Conduct ASHRAE investment grade Energy Audit to identify ECMs		
Categorization of ECMs	Low cost	Medium cost	Cost intensive
Decision questions to implement the identified ECMs	**Decision**	**Action**	**Financing Mechanism**
Does the municipal corporation have sufficient sources to fund the project itself?	If Yes → / If No ↓	Prepare application	Internal Budget/ Sources
Are funds available from state government bodies (e.g. State Energy Conservation Fund – SECF)?	If Yes → / If No ↓	Prepare application for the state-government	State public budgetary resources
Is utility on-bill financing possible?	If Yes → / If No ↓	Form partnership with a utility provider to fund and administer	Investment by utilities and repayment through bill
Are leasing or vendor financing programs available?	If Yes → / If No ↓	Check terms of leasing or vendor financing agreement	Specialized Institutional Debt and Leasing
Are grants or CSR funding available?	If Yes → / If No ↓	Partner with a CSR-registered	External funding mechanisms

		implementing agency	
Is financing through public or super ESCO possible?	If Yes → If No ↓	Develop EPC (Energy Performance Contract)	Investment by ESCOs, repayment based on EPC
Is the municipal corporation eligible to raise a municipal bond?	If Yes → If No ↓	Check eligibility and prepare application	Specialized Institutional Debt and Leasing

05 Conclusion



The Net Zero Municipal Buildings Action Plan marks a pivotal step in BMC's transition toward a climate-resilient and energy-efficient future. It sets a clear and actionable pathway for the BMC to decarbonize its building portfolio by 2050 anchored in evidence-based strategies, governance structure, scalable pilot projects, and innovative financing mechanisms. By addressing both existing and new buildings, the plan emphasizes the dual priorities of improving operational efficiency and reducing embodied emissions through low-carbon materials, passive design, and renewable energy integration.

The roadmap outlines a phased transition implementing all no-cost and low-cost measures by 2030, achieving 50% portfolio coverage under net-zero energy by 2040, and realizing full net-zero energy and carbon goals by 2050. Through institutional reforms such as establishing a Climate Budget Steering Cell, strengthening measurement, reporting, and verification (MRV) systems, and promoting cross-departmental coordination, BMC can embed sustainability within its core governance framework. Realizing this vision will require sustained commitment, capacity building, and partnerships across government, private sector, and civil society. By leveraging models like ESCO, RESCO, Energy-as-a- Service and Cooling-as-a-Service, along with municipal climate budgets and concessional financing, Mumbai can overcome fiscal barriers and unlock long-term energy and cost savings. As one of India's largest and most influential urban local bodies, BMC's leadership in implementing this Municipal Building Net Zero Action Plan will set a precedent for other municipal corporations across

Maharashtra and the country. By demonstrating that municipal buildings can lead the way to net-zero, BMC not only advances Mumbai Climate Action Plan and Maharashtra Decarbonization Roadmap commitments but also inspires a broader shift toward sustainable, low-carbon urban development.

Roadmap for Accelerating Rooftop Solar Deployment in Nashik City

Technical Partner:

1. Executive Summary

Under the **Maharashtra City Decarbonization Roadmap – Building and Energy Sectors**[1], Nashik has identified Rooftop Solar (RTS) as an highly actionable and scalable strategy for cities to decarbonise building energy sectors. With an estimated **RTS technical potential** of **1,448.3 MW**[2], the **city currently has the capacity to decarbonise its electricity grid and achieve the target of sourcing 36% of its energy from solar**. However, with only **15% of this potential currently realised**, there is an urgent need to accelerate deployment in order to achieve the targets of sourcing **40% of electricity from solar by 2040** and **60% by 2050** as outlined in its Climate Action Plan (CAP)[3].

The **Roadmap for Accelerating Rooftop Solar Deployment in Nashik City** outlines pathways with actionable strategies to scale RTS adoption across the city. The development of the roadmap follows an iterative and collaborative process, engaging officials from Nashik Municipal Corporation (NMC), Maharashtra State Electricity Distribution Company Limited (MSEDCL), the Nashik Municipal Smart City Development Corporation Limited (NMSCDCL), rooftop solar developers, technology providers, architects, builders, consumer representatives from different building typologies, and financial institutions. This approach (Figure 1) included data collection (on-ground surveys, interviews and site visits), landscape assessments covering technical, economic, and market; and stakeholder consultations to ensure that the strategic pathways developed are contextually relevant and actionable for Nashik.

The Roadmap outlines four strategic pathways supported by a phased implementation plan, a policy and incentive mandate roadmap, defined roles and responsibilities for key stakeholders, and a comprehensive Monitoring, Evaluation, and Reporting (MER) framework to guide city-wide RTS deployment. Additionally, it presents a detailed action plan for the NMC to implement RTS for its public buildings, along with technical guidelines for integrating RTS in both existing and new buildings, and recommendations for developing a municipal solar procurement policy.

Figure 1 Approach to Developing Roadmap to Accelerate Rooftop Solar Deployment in Nashik

[1] MVA, SED, C40 Cities, EDS 2023, Maharashtra - City Decarbonisation Roadmap : Energy and Building Sectors
[2] Based on MSEDCL data, 2024
[3] Nashik Climate Action Plan

Strategic Pathways to Accelerate Rooftop Solar Deployment in Nashik

The four strategic pathways to accelerate rooftop solar (RTS) deployment in Nashik have been developed to address key barriers identified through the landscape assessment studies. (Figure 2) below illustrates these pathways and their corresponding actions.

Figure 2 Pathways to accelerate RTS in Nashik

Pathway 1: Accelerate Adoption in High-Impact Areas

With over 65% of Nashik's buildings classified as permanent ("pakka")[4] with a substantial rooftop area of approximately 2,979,252 m² available, the city has the technical potential to accelerate RTS adoption. However, limited granular, ward-level data on parameters such as building-level techno-economic feasibility, grid readiness, and prevailing market conditions has slowed RTS implementation. This pathway proposes the identification and mapping of solar priority zones at the granular ward-level considering - solar potential, economic viability, and ease of implementation.

Pathway 2: Strengthen and Localize Regulatory Mechanisms

At the state level, regulatory mechanisms support the adoption of RTS. MSEDCL, in line with directives from the Maharashtra Electricity Regulatory Commission (MERC),[5] has enabled the adoption of net-metering to facilitate grid-connected RTS systems across the state. Additionally, the Unified Development Control and Promotion Regulations (UDCPR)[6] have mandated RTS installation for all buildings

[4] Pakka structure refers to built forms that are designed to be solid and permanent. This term is applied to buildings in South Asia built of substantial material such as stone, brick, cement, concrete, or timber.

[5] Maharashtra Electricity Regulatory Commission (Grid Interactive Rooftop Renewable Energy Generating Systems) Regulations, 2019

[6] Unified Development Control and Promotion Regulations (UDCPR)

with a plot area exceeding 4,000 sqm. However, on-ground implementation in Nashik remains limited. Consumers face delays of 2–12 months between net-metering approval and billing activation. The current UDCPR threshold excludes many smaller yet solar-ready buildings. This pathway focuses on strengthening and localizing regulatory mechanisms by improving transparency and coordination in the net-metering process and introducing a phased, city-wide RTS mandate for all building typologies.

Pathway 3: Facilitate Consumer Awareness and Participation
Limited consumer awareness of RTS benefits, financial incentives, and installation processes has been a major barrier to widespread RTS adoption in Nashik. This pathway focuses on enhancing consumer awareness by developing regional communication tools and cost–benefit calculators that simplifies information on RTS benefits and feasibility.

Pathway 4: Build Municipal Systems to Enable Business Models and Ensure Technology Resilience
While RTS deployment in Nashik is expanding, adoption remains limited among low-income households, group housing societies, and small commercial users due to lack of suitable business models and financing options. In addition, isolated incidents of poor installation practices and inadequate maintenance have affected system performance, underscoring the need for stronger quality assurance mechanisms. This pathway focuses on building municipal systems that enable diverse innovative business models and ensure long-term technology resilience.

Roadmap Implementation

a. Roadmap and Phased Mandates Plan: The roadmap considers a phased implementation approach for the four pathways spanning from 2025 to 2050, categorized into short-, medium-, and long-term actions. In addition, a Phased Mandates Plan has been developed to guide the adoption of mandates for residential, commercial, industrial, and municipal building typologies.

b. Roles and Responsibility: The document outlines roles and responsibilities for key stakeholders such as government and regulatory bodies, implementation agencies, research institutions, financial institutions for an effective implementation of the roadmap.

c. Monitoring, Evaluation and Reporting (MER) Framework: The MER framework includes key performance indicators (KPIs), evaluation metrics, and reporting mechanisms for each action under the pathways. This enables all stakeholders to track implementation progress, assess impact, and make data-driven decisions through access to dashboards, public reports, and annual evaluations.

d. Action Plan for NMC buildings: An action plan has been developed to transition all NMC buildings to RTS solar through context-specific technical guidelines, business models and financing mechanisms, and solar procurement guidelines.

Projected Impact
By 2050, Nashik's annual electricity consumption is projected to reach 13,065.7 GWh. Implementation of the Rooftop Solar Roadmap will enable Nashik to meet 60% of its electricity demand through RTS generating 7,838.84 GWh annually through installation of 5,965.63 MW, potentially avoiding 5.6 million tonnes of CO_2 emissions, and creating over 431.4 job-years in total. The successful implementation of the RTS roadmap will position Nashik as a model solar city, demonstrating accelerated RTS deployment aligned with its climate and decarbonisation goal.

2. Context

Nashik is the fourth-largest urban area in Maharashtra, with a total area of 259.13 sq. km. The city is located in the northwestern region of Maharashtra between 19°55′–20°05′N latitude and 73°42′–73°55′E longitude, lies approximately 180 km north of Mumbai and 220 km north of Pune. Geographically, the city is situated at an elevation of around 700 meters above mean sea level, with the Godavari River dividing it into Northern and Southern Nashik. As per the Energy Conservation and Sustainable Building Code (ECSBC), Nashik falls under the Hot and Dry climate zone. The city receives an average daily global horizontal radiation of 5,000–5,500 Wh/m²[7] per day, indicating consistent year-round potential for RTS deployment.

According to the Draft Revised Development Plan 2016, approximately 43.75% of the city's area is developed. Within this, the residential typology covers (52.5%), followed by industrial (14%), public and semi-public (7.5%), and commercial (2%) uses. Electricity consumption patterns in Nashik vary across building typologies, with the industrial sector exhibiting consistently high consumption, averaging around 230 MWh per month throughout the year. Public buildings maintain stable energy use, ranging between 5.3–6.4 MWh per month, while the commercial sector shows moderate fluctuations between 23–30 MWh monthly. In contrast, the residential sector experiences distinct seasonal variation, with consumption peaking during the summer months, 84.25 MWh in June and 77.02 MWh in May. In terms of contribution towards greenhouse gas (GHG) emissions based on MSEDCL,2024, the industrial sector contributes the highest share (70%), followed by residential (20%), commercial (8%), and public buildings (2%).

Electricity from solar currently meets 18% of total consumption in residential buildings and 14% in public buildings, while commercial and industrial sectors source 9% and 4% of their electricity from solar, respectively, as per MSEDCL (2024). With 19,488 net meters currently installed, the city has installed a total RTS capacity of 225MW.

NMC offers a 5% property tax rebate for projects with RTS PV systems since 2023. In addition to the UDCPR mandating RTS installation for all buildings with a plot area exceeding 4,000 sqm, NMC has encouraged new special developments and buildings taller than 24 meters to install RTS systems. All RTS installations currently follow the MSEDCL Grid-Interactive Rooftop Renewable Energy Generating Systems Regulations, 2019 and all RTS technicians currently follow the Standard Operating Procedures (SOPs) issued by MSEDCL and comply with all specified installation requirements established by the Ministry of New and Renewable Energy (MNRE).

Rooftop Solar (RTS) Potential in Nashik

A landscape assessment study was conducted to determine the RTS potential of Nashik. This study considered technical, economic, and market assessments to determine the city's overall RTS opportunity. (Table 1 summarizes the potential)

Table 1 Summary of rooftop solar potential by building typologies

Categories	Technical Potential (MW)	Economic Potential (MW)	Market Potential (MW)
Residential	879.50	703.60	598.06
Commercial (includes mixed use)	283.58	283.58	170.15
Institutional	48.62	48.62	29.17

[7] Calculated using climate consultant software

Categories	Technical Potential (MW)	Economic Potential (MW)	Market Potential (MW)
Public (includes govt. buildings, railways)	51.84	51.84	43.55
Industrial	184.77	184.77	155.21
Total	1448.32	1272.42	996.14

Considering currently installed capacity as per MSEDCL, 2024, the Table 2 below outlines the RTS to be installed for each building typology

Table 2 RTS progress and required installations across building typologies in Nashik

Category	Installed Capacity (MW)[8] (A)	Market Potential (MW) (B)	RTS to be Installed (MW)[9] (C = B-A)
Residential	69.7	598.06	528.36
Commercial and Institutional	25.8	199.32	173.52
Industrial	116.3	155.21	38.91
Public	13.2	43.55	30.35
Total	225.18	996.14	771.14

Nashik has a **technical potential of 1448.32 MW**; however, considering the economic viability and market studies, the **realisable market potential of the city is 996.14 MW**. Based on the current installed 225MW RTS capacity, the city has potential to install additional 771.14MW. The **Total Annual Electricity Consumption (GWh) for FY (2023-24) is 3,980.71 GWh** of which based on technical potential, **36%** of electricity demand can be met through RTS. In Nashik, **smart meter penetration** across electricity feeders currently ranges from as low as **2%** to a maximum of **36%**, highlighting potential for net-metering integration across feeders.

Insights from the consultations guiding roadmap development

a) Government incentives and rising electricity costs were cited as the primary drivers for RTS uptake, while high upfront investment, limited financing options, space constraints, and procedural delays (e.g., net-metering approvals, billing activation and subsidy disbursement) were common barriers.
b) Among residents surveyed, 20% utilized the PM Surya Ghar: Muft Bijli Yojana subsidy, 20% relied on solar loans, and the remainder self-financed their systems, often experiencing 2–12 month delays in billing activation.
c) Commercial establishments faced capital limitations and PPA restrictions (for capacity < 500KW), with many unable to claim depreciation benefits due to irregular tax filings.
d) Institutions noted the absence of targeted incentives and deferred RTS installation due to future vertical expansion plans
e) Hospitals highlighted uncertainties regarding upfront costs, payback periods, maintenance costs, and lack of concessional financing as major barriers.

The main objective of the roadmap is to provide a phased and actionable approach to scale RTS adoption across the different building typologies, taking cognisance of the on-ground barriers and challenges raised by stakeholders.

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[8] Source: MSEDCL 2024

[9] RTS requirement to be installed is calculated as a difference based on existing RTS capacity and the market RTS potential and the existing RTS capacity.

3. Approach to Development of the Roadmap

Transitioning the city of Nashik's 60% electricity demand to be met by rooftop solar by 2050 requires an approach that integrates policy, technology innovation, financial instruments, and community engagement. This roadmap has been developed through an iterative and collaborative process, engaging government officials, rooftop solar technology providers and experts, architects, consumers and financial institutions. This multi-stakeholder approach ensures the strategies identified for accelerating RTS deployment in Nashik are both contextually relevant and technically robust. The overall approach has been provided below (Figure 3)

Figure 3 Approach to Developing Roadmap to Accelerate Rooftop Solar Deployment in Nashik

Approach to Determining Rooftop Solar Potential

A comprehensive landscape assessment was conducted to determine the city's overall RTS opportunity.

a) **Technical potential** was determined using Geographic Information Systems (GIS). The existing building footprint layer of the city was used to determine the usable rooftop area. The solar analysis tool in GIS simulated the incident solar mean radiance (Mean) ($Wh/m^2/day$) on usable roof area for each building typology. The RTS generation potential (MW) was calculated using the formulae below:
   - Energy Output (MWh/day) = Usable Roof Area (m^2) × Mean Radiance ($Wh/m^2/day$) × 0.18 × 0.80 / 1,000,000 [10]
   - Solar Capacity (MW) to be installed = Energy Output (MWh/day) / Available Solar Hours

b) **Economic potential** was assessed by evaluating installation costs, available subsidies (such as the PM Surya Ghar: Muft Bijli Yojana), and MSEDCL electricity tariffs for FY 2025–26[11], along with applicable depreciation and commercial tax rates. These parameters were used to calculate the payback period and net present value (NPV) for rooftop solar (RTS) systems across different capacities (1kW–50kW), thereby determining the economically viable potential for RTS deployment. Considering lower financial returns and longer payback periods (> 5years) for residential societies,

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[10] Assumptions : Solar Panel Average Efficiency 18%, Performance Ratio 0.8%, Usable roof area : 50% of available roof area ((excluding obstructed, inaccessible portions and shaded portions of the rooftop)

[11] MSEDCL 2025-26 Tariff for LT categories: Residential (10.88), Non-residential (11.5), Public (9.1), Industry (7.2)

the technical potential in this segment was reduced by 20% to estimate the economic potential (MW).

c) **Market potential** was assessed using an adoption factor that accounted for parameters such as willingness to install, rooftop ownership and control, capital availability, dependence on subsidies, and awareness and trust in RTS systems. The adoption factor was derived from interactions with RTS vendors and existing and potential consumers, and subsequently applied to the technical potential of each building typology to estimate the market potential (MW).

Consultations were held with NMC, MSEDCL, rooftop solar vendors, and consumers across different building typologies to collect data, identify barriers and opportunities for scaling RTS. The data received from surveys and interviews conducted, contributed towards the city's realisable rooftop solar potential. Insights from the interaction further supported the development of the roadmap.

Development of the Roadmap

The development of the roadmap comprised of the following steps:

1. **Identification of Pathways to Overcome Key Barriers**
   Pathways to address the key barriers to accelerate RTS deployment were developed based on insights from stakeholder consultations, walkthrough assessments, and on-ground surveys, complemented by secondary research on successful approaches adopted in other Indian cities.

2. **Study of Cases to Inform Actions and Mandates**
   This includes study of actions and mandates adopted by cities (nationally and globally) to address similar challenges.

3. **Defining Timelines, Targets for Actions and Mandates**
   Each action has been categorized as short-term, medium-term, and long-term, prioritizing ease of adoption, potential impact and readiness for implementation.

4. **Identification of Roles and Responsibilities**
   For every pathway and action, corresponding roles and responsibilities are mapped across relevant departments, agencies, and stakeholders to ensure accountability and streamlined implementation.

5. **Integration of Monitoring, Risk Mitigation, and Financing Frameworks**
   Monitoring systems, risk management measures, and financing mechanisms were integrated into the roadmap to enable progress tracking, mitigate implementation risks, and support resource mobilization through appropriate business models.

4. Strategic Pathways to Accelerate Rooftop Solar Adoption

This section outlines four major strategic pathways to enable city-wide deployment of rooftop solar (RTS) in the city of Nashik: **accelerating adoption of RTS in high impact areas, strengthening regulatory mechanisms, enhancing consumer awareness and participation, and building resilient market systems for scaling emerging technologies and innovative business models**. Each strategic pathway responds to core barriers identified through policy reviews, stakeholder consultations, and on-ground assessments. Each pathway is supported by targeted actions, backed by case studies to demonstrate feasibility and implementation potential.

Pathway 1: Accelerate adoption of RTS in High Impact Areas

In Nashik, RTS is being installed at multiple locations – municipal, residential, commercial, industrial and institutional buildings, with total installed capacity amounting to 225MW. However, issues such as lack of technical feasibility, economic viability, fragmented roof ownership, and low awareness have hindered the large-scale acceleration of RTS. Identification of high impact sites for RTS installation will enable targeted efforts for accelerating RTS deployment.

Action 1.1 Identify and Map Solar Priority Zones

To identify where RTS installations can achieve highest impact with minimum efforts, NMC in collaboration with Maharashtra Energy Development Agency (MEDA) and the Maharashtra State Electricity Distribution Company Limited (MSEDCL), can undertake a detailed mapping and prioritization study. This initiative would require the integration of Geographic Information System (GIS) solar analysis with ward-wise energy consumption data and socio-economic feasibility studies as per parameters identified below:

a. Solar potential (based on roof orientation, slope and shading analysis)
b. Electricity demand ward level consumption data
c. Population growth estimated
d. Building typologies
e. Grid capacity and connection readiness
f. Socio-economic parameters

These datasets can be analysed to define 'High Solar Impact Zones', to guide NMC in prioritizing interventions for accelerating RTS. The following examples highlight how other cities and institutions have successfully identified and mapped solar priority zones for RTS planning and policy actions:

a. Chennai[12,13]: Conducted rooftop solar potential mapping using GIS to understand the technical potential of the city. The needs assessment combined the feeder capacity of wards and supported the city in taking actions to accelerate the RTS adoption. Additionally, CSTEP's Rooftop Evaluation

[12] Rooftop Solar _Chennai C40 Cities
[13] Center for Study of Science, Technology and Policy (CSTEP)

for Solar Tool (CREST), was developed to identify precise locations for installing rooftop photovoltaic (RTPV) systems on buildings.

b. **Singapore**[14]: Developing an Urban Digital Twin to mitigate operational greenhouse gas emissions in residential buildings through a potential intervention map (for setting emission targets, and undertaking decarbonisation actions such as energy-efficiency retrofits, RTS installation) through a multi-scenario planning tool (emissions data, energy use and policy strategies).

Pathway 2: Strengthen and Localize Regulatory Mechanisms for scaling RTS

At the state level, key regulatory mechanisms have been introduced to support the adoption of RTS. The Maharashtra State Electricity Distribution Company Limited (MSEDCL), in line with directives from the Maharashtra Electricity Regulatory Commission (MERC),[15] has enabled the adoption of net-metering to facilitate grid-connected RTS systems across the state. Additionally, the Unified Development Control and Promotion Regulations (UDCPR)[16] have mandated RTS installation for all buildings with a plot area exceeding 4,000 sqm. While these state-level provisions have been adopted in the city of Nashik, on-ground assessments reveal that regulatory and procedural challenges limiting consumer uptake of RTS are:

a. **Delays in net-meter activation** primarily due to coordination gaps between third-party vendor[17] responsible for installing Advanced Metering Systems (AMS) vendors and delaying updating installation data on the MSEDCL portal.
b. **Limited applicability of the 4,000 sqm mandate,** as only a small proportion of buildings in Nashik meet this threshold.

To address these challenges, the strategic pathway proposes 2 actions to enhance policy and regulatory mechanisms for RTS deployment.

Action 2.1 Develop a Real-time Net-Metering Status Platform

MahaDISCOM operates a dedicated net-metering portal that allows end-users to track the status of their RTS applications[18]. Although the net-metering process is officially expected to take around 45 working days, insights from on-ground surveys indicate that the actual timelines often range from 2 to 12 months with users reporting difficulty in tracking application progress and frequent delays in information updates. To improve accountability among stakeholders involved in net-metering installation and billing activation, there is a need to develop an institution-wide real-time dashboard. Such a platform would enable access for the NMC, MSEDCL divisions, and state-level agencies a consolidated view of RTS application statuses, installation progress, activation timelines, and system-wide bottlenecks across the city.

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[14] Understanding Household Carbon Emissions in Singapore
[15] Maharashtra Electricity Regulatory Commission (Grid Interactive Rooftop Renewable Energy Generating Systems) Regulations, 2019
[16] Unified Development Control and Promotion Regulations (UDCPR)
[17] ADANI - MSEDCL netmetering third party vendor contract
[18] MSEDCL - RTS application portal

RTS adoption in Maharashtra's cities, where stakeholders emphasized the importance of process visibility across institutions. They recommended the development of a publicly accessible dashboard to monitor city-wide RTS adoption trends and application progress drawing inspiration from platforms like EESL's UJALA portal[19], which enables transparent, multi-level monitoring. An example of such a platform is shown in figure 4.

The following examples (Table 3) highlight how other Indian states have developed portals/dashboards to improve transparency in net metering installation and activation :

Table 3 Precedent for Public Dashboards and Streamlined Net-Metering Process

Agency	State / UT	Intervention	Relevance
Uttar Haryana Bijli Vitran Nigam (UHBVN)	Haryana	Solar Rooftop Dashboard (Figure 4)	Tracks real-time status of applications, approvals, commissioning; activation, consumer grievances
Uttar Pradesh New and Renewable Energy Development Agency (UPNEDA)	Uttar Pradesh	Integrated RTS Portal[20]	Connects DISCOMs, vendors, and consumers to monitor all stages of the RTS process. Varanasi[21] has set up a control room for weekly monitoring of target achievement
BSES Rajdhani Power Limited (BRPL)	Delhi	Solar Application Portal[22]	Provides stage-wise updates with clear timelines, enabling consumers to track delays.

Figure 4 Module developed by Uttar Haryana Bijli Vitran Nigam (Source)

[19] UJALA - State Dashboard
[20] UPNEDA - Solar Rooftop Portal
[21] RMI- Rooftop solar for Indian Cities
[22] BSES - Delhi Solar Portal

Action 2.2 Develop and Implement Specific Mandates for Different Building Typologies

Nashik's built-up area is dominated by the residential sector (52.5%), followed by industrial (14%), public and semi-public (7.5%), and commercial (2%) across varying plot sizes. To incentivise consumers to adopt RTS at all building typologies, NMC is currently providing 5% property tax rebates and additional encouragement is extended to buildings exceeding 24 meters in height. The Town Planning Department is also considering mandating RTS installation in housing societies to meet the electricity demand of common amenities.

In residential buildings especially societies, financial constraints, shared rooftops and joint decision-making have slowed RTS uptake. Commercial buildings often face issues with ownership of rooftops and lack of suitable PPAs (below 500kW). Schools and hospitals need financing support to install RTS. On the other hand, public and industrial buildings with larger rooftops and clearer ownership have started installing RTS widely.

To accelerate city-wide RTS adoption, Nashik must transition from broad-based incentives to either by making additional provisions to the building bye-laws or developing a solar policy. This approach should prioritise building types and areas with higher implementation feasibility such as public buildings, industrial establishments, and large commercial plots. Subsequently, this can expand to other typologies (residential and institutional), where uptake may require greater coordination and financial support. Table 4 presents case city studies where adoption of phased mandate strategies have been adopted to accelerate RTS.

Table 4 Precedents of Phased Mandate RTS Adoption

City	Mandate
Delhi Solar Policy[23]	2016: • Mandated RTS for state government buildings with rooftop area of 500 sq.m. or above, • All new residential, institutional, government, commercial, group housing and industrial buildings are mandated to install RTS systems subject to the minimum area requirement (Unified Building Bye Laws (UBBL) for Delhi, 2016), • Central government subsidy only, strict minimum generation thresholds for generation-based incentives (GBI) 2023: • Rolled-out state-level subsidy, introduced GBI for <3kW and 3-10KW and for C&I consumers with no minimum generation condition
Chandigarh[24],[25]	2024: Achieved 100% rooftop solar installations on government buildings 2025: Looking at mandating RTS on all buildings (existing and new) • Plot size (100-500sq yards): Option to install 1kW Solar Plant or 100 litre solar heating system • Plot size (500-1000 sq. yards) : 1kW RTS • Plot size (1000-3000sq.yards): 2kW RTS • Plot size (above 3000 sq, yards): 3kW RTS
Green Gujarat Industrial	Targeting 100% industrial sector electricity demand through renewables by 2030

[23] Delhi Solar Energy Policy
[24] Chandigarh Mandate for RTS at buildings occupying plots larger than 100 square yards
[25] PIB - PM Surya Ghar Yojana

City	Mandate
Development Corporation (GIDC)[26]	
Gujarat Government[27]	Accelerate Rooftop Solar in MSME's through collateral free loans
California's Solar Roof Mandate for New Buildings (USA)[28]	2020: Solar energy a standard feature of new single-family homes and low-rise apartments 2023: Solar energy mandate expanded to cover many new commercial buildings and high-rise residential projects
Germany Baden-Württemberg[29]	2022: Owners of newly built non-residential buildings and residential buildings to cover roofs with solar 2023: Solar PV mandated for roof renovations of existing buildings in the state

Pathway 3: Facilitate Consumer Awareness and Participation

MSEDCL website[30] provides comprehensive information on the RTS installation process, including application procedures for net-metering and availing subsidies. It also offers access to tools such as the MNRE solar calculator, a list of empanelled vendors, and general FAQs to guide consumers. However, on-ground surveys in Nashik have revealed that consumers have limited awareness of the cost-benefits of RTS installation, as well as have insufficient update on city-wide RTS programs and local vendor details. This knowledge gap is visible across residential houses, societies, commercial establishments, and industrial buildings. Bridging this gap requires a proactive, city-level consumer engagement strategy that translates technical information into locally relevant, easy-to-understand guidance and support.

Action 3.1. Develop a Cost-Benefit Calculator

Existing national calculators on MSEDCL website rely on broad assumptions for tariffs, solar potential, and financing, not aligned with Nashik's context. Frequent changes in ToD tariffs, vendor pricing, net-metering benefits, and loan schemes make static tools quickly outdated, reducing user trust and slowing RTS adoption.

To address this, a dynamic, Nashik-specific calculator should be developed in collaboration with MSEDCL, RESCOs, financial institutions, and vendors. It could provide real-time estimates of ROI, payback, and savings using localized inputs such as electricity bills, usage patterns, and applicable subsidies. This will support informed decision-making across consumer segments and build confidence in RTS investments. Below are examples of location-specific calculators developed to simplify user decision-making and encourage financial investment for RTS installation.

[26] Green Industrial Revolution - Gujarat
[27] Gujarat Government Schmes for MSMEs
[28] California: Government Policies for Solar Panel adoption in new builds 2025
[29] Germany: Mandatory RTS installations
[30] Empanelled Agency List_PM Surya Ghar Muft Bijli Yojana

Case Studies:

a. **Solsavi: Your Rooftop Solar Guide, India**[31]: The calculator incorporates the latest state-specific tariffs, net metering mechanisms, and local policies to deliver accurate ROI, payback period, and savings estimates based on the user's location, electricity consumption, and consumer category

b. **Solar Cost Calculator, USA**[32]: Integrates Google Project Sunroof data and real-time utility rates to provide granular, address-specific financial analysis and ROI for rooftop solar in the United States, with regularly refreshed incentive and utility data

c. **SolarQuotes Solar & Battery Calculator, Australia**[33]: Delivers clear payback and savings projections for rooftop and battery setups, tailored for residential and small business users, reflecting current tariffs and market prices

Action 3.2 Create Communication and Awareness Channels

Currently in Nashik, RTS awareness is largely informal, spreading through word-of-mouth via neighbours or local vendors. There is no formal, city-led communication strategy. Although MSEDCL hosts an FAQ on its website, most prospective users interact directly with known vendors, often missing out on credible and updated information about regulations, net-metering, subsidies, municipal tax rebates, technologies and vendor profiles.

To improve awareness among consumers, NMC could initiate targeted outreach programs, public-facing communication materials, and RTS awareness campaigns. City-level platforms or RTS helpdesks can improve access to credible information, streamline decision-making, and reduce misinformation. Table 5 presents more information on how other cities are utilizing communication and awareness channels to build public trust, increase consumer participation, and accelerate RTS adoption.

Table 5 Case studies of RTS communication channels and awareness drives

City	Description
Surat, India	**#SuratSolar**[34] - Surat Municipal Corporation (SMC) launched this branded program in 2016 using e-media, newspapers, and solar camps to build public engagement. SMC became the nodal agency for GEDA to receive applications for grid-connected rooftop solar in Surat. Of the 418 MW potential estimated by TERI, DGVCL and Torrent Power have installed 40 MW, largely in the residential sector, driven by strong consumer-awareness efforts. Effective coordination among SMC, the DISCOMs, GEDA, and other stakeholders was central to the programme's success.
BSES Rajdhani (Delhi), India	**Utility-Anchored Rooftop Programme**[35] combines DISCOM-driven RTS promotion with consumer-facing communications and engagement.

[31] Solasvi: Rooftop Solar Guide calculator
[32] Solar Cost Calculator, USA
[33] Solar Quotes & Battery Calculator
[34] Solar Rooftop: Perspective of DISCOMS
[35] Solar Rooftop: Perspective of DISCOMS

Thiruvananthapuram, India	**ANERT**[36] regularly organizes public expos and awareness events like the Sooryakanthi RE & EV Expo to educate citizens about emerging technologies, financing options, inverter types, battery systems, subsidies, and installation basics.
Sydney, Australia	**Renewable Energy Help Centre**[37] A city-led platform offering renewable energy guidance and FAQs for residents to enhance awareness and informed decision-making.

Pathway 4: Build Municipal Systems to Enable Business Models and Ensure Technology Resilience

In Nashik, RTS installation in the residential sector is largely driven by capital expenditure (CAPEX). While the subsidies through PM Surya Ghar Muft Bijli Yojana have accelerated uptake in individual homes, adoption remains limited in group housing societies, where collective financing is a challenge and among low-income households with limited financial capacity. In the commercial sector, both CAPEX and Power Purchase Agreement (PPA) models are in use. However, barriers such as small energy requirements of MSMEs (often below 500 kW) hinder PPAs. To create an inclusive and equitable RTS ecosystem, there is a need to introduce innovative business models tailored to all user groups.

In Nashik, isolated incidents of module failures, such as dislodgement during high winds due to poor installation practices, lack of timely maintenance leading to poor performance have undermined confidence in RTS systems. To build a resilient market, NMC must institutionalize systems for incident reporting, promote certified high-quality RTS components, and strengthen technical standards and vendor accountability.

Action 4.1 Develop and Implement Diverse and Innovative Business Models

On-ground consultations in Nashik reveal that small-scale consumers such as residential housing societies, small commercial enterprises, schools, and hospitals lack the upfront capital or financial capacity to invest in RTS. Currently, large-scale investors and developers are hesitant to enter the Nashik market due to lack of demand aggregation, absence of standardized contracts, and limited municipal facilitation. To enable wider adoption, Nashik must build institutional support that de-risks investment and fosters a predictable, investment-friendly environment for emerging RTS business models.

The development and implementation of innovative business models will involve (illustrative list)

a) research on innovative models adopted by cities across India and globally,
b) determining application to Nashik's context
c) determining the value-proposition
d) development of model contracts
e) aggregation of demand across building typologies
f) implementation and M&V

[36] Anert Sooryakanthi RE & EV Expo
[37] Renewable Energy Help Centre, Sydney

The following examples highlight how Indian states and global cities have adopted diverse business models to expand rooftop solar deployment by addressing user barriers.

Examples of RTS Business Models adopted by cities

a. **Odisha, India[38]:** Through its nodal agency OREDA and Department of Energy, Odisha is experimenting with new business models such as solar partners and peer-to-peer trading to encourage uptake, along with demand aggregation efforts

b. **Gujarat, India**[39]: Enabled innovative models like the "rent-a-roof" program in 2010, with public-private partnerships allowing companies to lease rooftops for solar installations, selling power to the grid under incentivized feed-in tariffs

c. **Mumbai (Adani)** [40] :Mumbai's electricity providers have started transitioning the consumer base to renewable energy through fixed increments in bill amount.

d. **Karnataka, India**[41]
Karnataka Solar Policy permits:
    a. Consumer owned Model (Utility as aggregator)
    b. Consumer Owned Model (Utility as aggregator and EPC)
    c. Utility owned Model (Utility as aggregator and investor)
    d. Third party owned Model (Utility acts as an aggregator and trader)

e. **Kerala, India**[42]: Three business models were designed for Kerala State Electricity Board (KSEB) to invest as per the requirements of prosumers with interest to install RTS

f. **Chandigarh, India**[43]: CREST introduced a RESCO with BOT scheme for residential consumers

g. **Delhi**[44]: DERC is developing regulations for Hybrid RESCO Model where a tripartite agreement is signed between the consumer, the Discom, and the RESCO developer, community solar and peer-to-peer trading

h. **Copenhagen, Denmark**[45] : Under its 2025 Climate Plan, Copenhagen is leveraging public-private partnerships to scale rooftop solar by enabling third-party developers, citizen cooperatives, and building owners to co-invest in solar installations on both public and private rooftops.

i. **Cape Town, South Africa**[46]: Offers reverse feed-in tariff mechanisms for small-scale embedded generation (SSEG), enabling commercial and residential users to get paid for exporting solar energy to the grid.

Table 6 Summary of Business models adopted by cities/states

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[38] Tata Power Unveils Affordable Rooftop Solar Plan For Odisha
[39] Gujarat: IFC Solar PPP
[40] Adani Electricity: Green Tariff
[41] KERC - RTS Regulations
[42] KSEBL Renewable Energy (Solar) - success stories
[43] Scheme for Implementation of Phase-II Grid Connected Rooftop Solar Programme for achieving cumulative capacity of 12MW from Rooftop Solar (RTS) projects in Chandigarh for the current year 2020-21 through Renewable Energy Service Company (RESCO) in BOT model by CREST, Chandigarh.
[44] Delhi Solar Policy: Pathways to install RTS
[45] City of Copenhagen - Climate Action Plan 2025
[46] Cape Town: Cash for Power programme

Business Model	Definition	Cities / States
Consumer-Owned (CAPEX)	A model in which the consumer fully invests in and owns the rooftop solar system, assuming responsibility for all capital, operations, and maintenance costs, while retaining the complete benefit of electricity cost savings.	Karnataka, Kerala (Model 3)
RESCO / OPEX (Third-Party/Utility)	A model where a Renewable Energy Service Company (RESCO) or third-party entity owns and operates the rooftop solar system, with the consumer paying for electricity consumed, typically with minimal or no upfront investment.	Chandigarh, Delhi, Kerala (Model 2), Copenhagen
Utility-Owned / Aggregator-Led	A model in which the utility or aggregator installs, owns, and maintains rooftop solar systems, supplying electricity to consumers at preferential rates without transferring ownership.	Karnataka, Kerala (Model 1)
PPP / Lease / Rent - a - roof	A model where private or public-private partnership entities lease rooftop space to deploy and operate solar systems, providing the building owner with rental income or other financial incentives.	Gujarat, Copenhagen, Kerala (Model 1)
Peer-to-Peer / Community Solar	A model in which solar systems are collectively developed and shared within a community, enabling participants to access renewable electricity without individual ownership of the infrastructure.	Odisha, Delhi
Feed-in Tariff / Green Tariff	A model where consumers install rooftop solar systems and sell the generated electricity to the grid under a fixed tariff or green pricing mechanism, thereby generating revenue while supporting renewable energy adoption.	Gujarat, Cape Town, Mumbai

Example of Business Model Contracts

a. MNRE-Bidding document[47] template can be utilised by NMC to select RESCOs for implementing RTS projects on multiple rooftops under an aggregated capacity approach.

Examples of aggregating demand across building clusters or typologies

a. **I-Smart Program**[48]: The Indian Solar Market Aggregation for Rooftops to be implemented in Gujarat, Uttarakhand, Himachal Pradesh, and Jammu & Kashmir along with two Union Territories – Daman and Diu; and Dadra and Nagar Haveli.

b. **Delhi**[49]: Aggregated 40MW under RESCO model for consumers from residential, hospitals and municipal segments

c. **Pune**[50]: Aggregated demand on 34 municipal properties to implement a RESCO model

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[47] MNRE Knowledge Centre: Rooftop Solar

[48] i-Smart The Indian Solar Market Aggregation For Rooftops

[49] Delhi to launch RTS Demand Aggregation Model for Residential Consumers

[50] PMC Gets Rooftop Solar Power Setup on 34 Buildings

d. **Singapore SolarNova Program**[51]: Rooftop spaces of public housing estates (HDB blocks) and government buildings were aggregated and leased to private solar developers via competitive tenders.

For all rooftop solar business models [Consumer-Owned (CAPEX), RESCO/OPEX, Utility-Owned/Aggregator-Led, PPP/Lease, Peer-to-Peer/Community Solar, and Feed-in/Green Tariff]; NMC could play the following facilitation role:

a. Coordination and Facilitation
   i. Act as a bridge between utilities, consumers, developers, and regulators to streamline project approvals and implementation.
   ii. Facilitate access to municipal rooftops for solar projects (public buildings, schools, community centers).

b. Policy and Regulatory Support
   i. Support the programs through city-level policies, regulations, and guidelines, ensuring transparency, compliance, and faster adoption.
   ii. Align municipal-level approvals (structural safety, building permits, zoning) with state and national renewable energy regulations.

c. Site Identification and Feasibility
   i. Provide targets to local vendors to identify high-potential rooftops and aggregate project sites for RTS deployment under various business models.
   ii. Conduct or facilitate preliminary feasibility assessments

d. Financial Risk Mitigation
   i. Provide support to reduce financial or operational risks for utilities, RESCOs, and consumers through facilitation of incentives, subsidies, or partnerships.

e. Citizen Engagement and Awareness
   i. Promote adoption through local awareness campaigns, workshops, and outreach programs targeting households, commercial establishments, and RWAs.
   ii. Mobilize citizens for participation in community solar or peer-to-peer programs.

f. Monitoring and Reporting
   i. Track progress of RTS implementation across all models.
   ii. Provide data and insights to state agencies and regulators for planning, policy refinement, and reporting purposes.

Action 4.2 Establish Institutional Systems for Improving Technology Resilience

While MSEDCL- certified vendors operate in Nashik and MNRE- enforced technical standards are followed for RTS installations, the city currently lacks a formal central mechanism to monitor technology failures, track installation quality, or assess system performance over time. Users have also reported limited access to structured maintenance and service support systems throughout the RTS life cycle, such as timely inspection, cleaning, component replacement, and post-installation troubleshooting. As Nashik scales up

[51] SolarNova Rooftop Solar Program, Singapore

RTS adoption, it must move beyond one-time installations to build a robust and resilient market ecosystem. This requires establishing the following systems:

- Central performance monitoring and incident reporting mechanisms
- Mandatory O&M contracts to ensure long-term system reliability and vendor accountability

Case studies:

a. **National-Level Centralized Monitoring Centre**[52]: MNRE, in 2018 through the National Institute of Solar Energy (NISE) and USAID's Partnership to Advance Clean Energy–Deployment (PACE-D) program, issued a tender to establish a **centralized monitoring centre** for real-time performance tracking of solar PV systems across 40 pilot sites.

b. **Operational and Maintenance Guidelines**[53]: MNRE has introduced **Operational and Maintenance Guidelines** for Solar PV systems, outlining vendor responsibilities for periodic inspection, preventive maintenance, and complaint resolution to ensure long-term system performance

c. **Latest technical guidance and resources**[54]: MNRE - National Portal for Rooftop Solar site provides **capacity-building modules and training material** for DISCOM engineers, rooftop solar vendors.

[52] NISE - Request for Proposal on National Level Centralized Monitoring Centre
[53] Operation and Maintenance Guidelines of Grid Connected PV Plants
[54] MNRE Knowledge Centre: Rooftop Solar

5. Roadmap

Based on the pathways identified in Chapter 4, the roadmap (Figure 5) details actions to accelerate RTS in Nashik, accompanied with an mandates action plan (Figure 6) to adopt RTS across all building typologies.

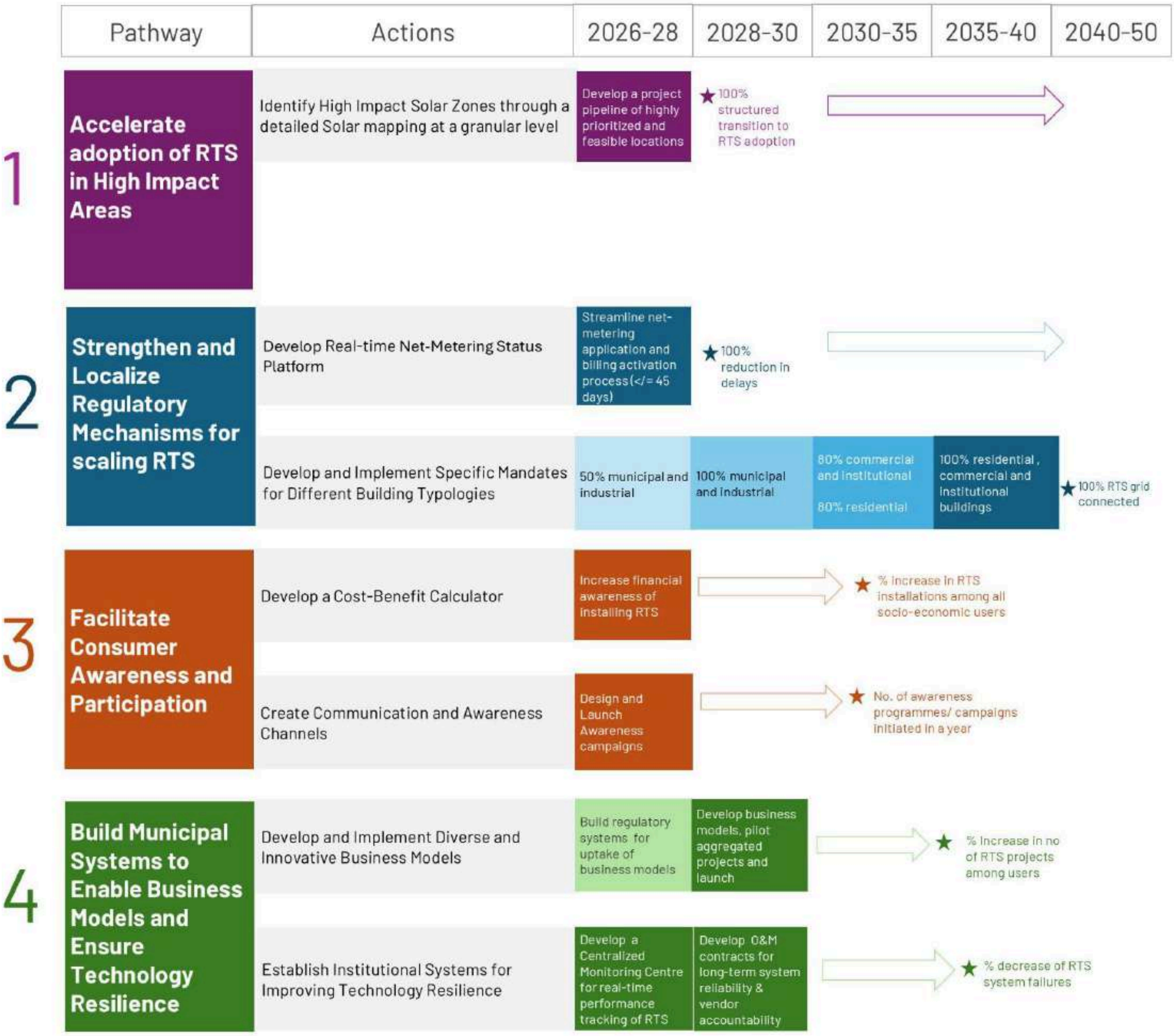

Figure 5 Roadmap for Accelerating RTS Deployment in Nashik

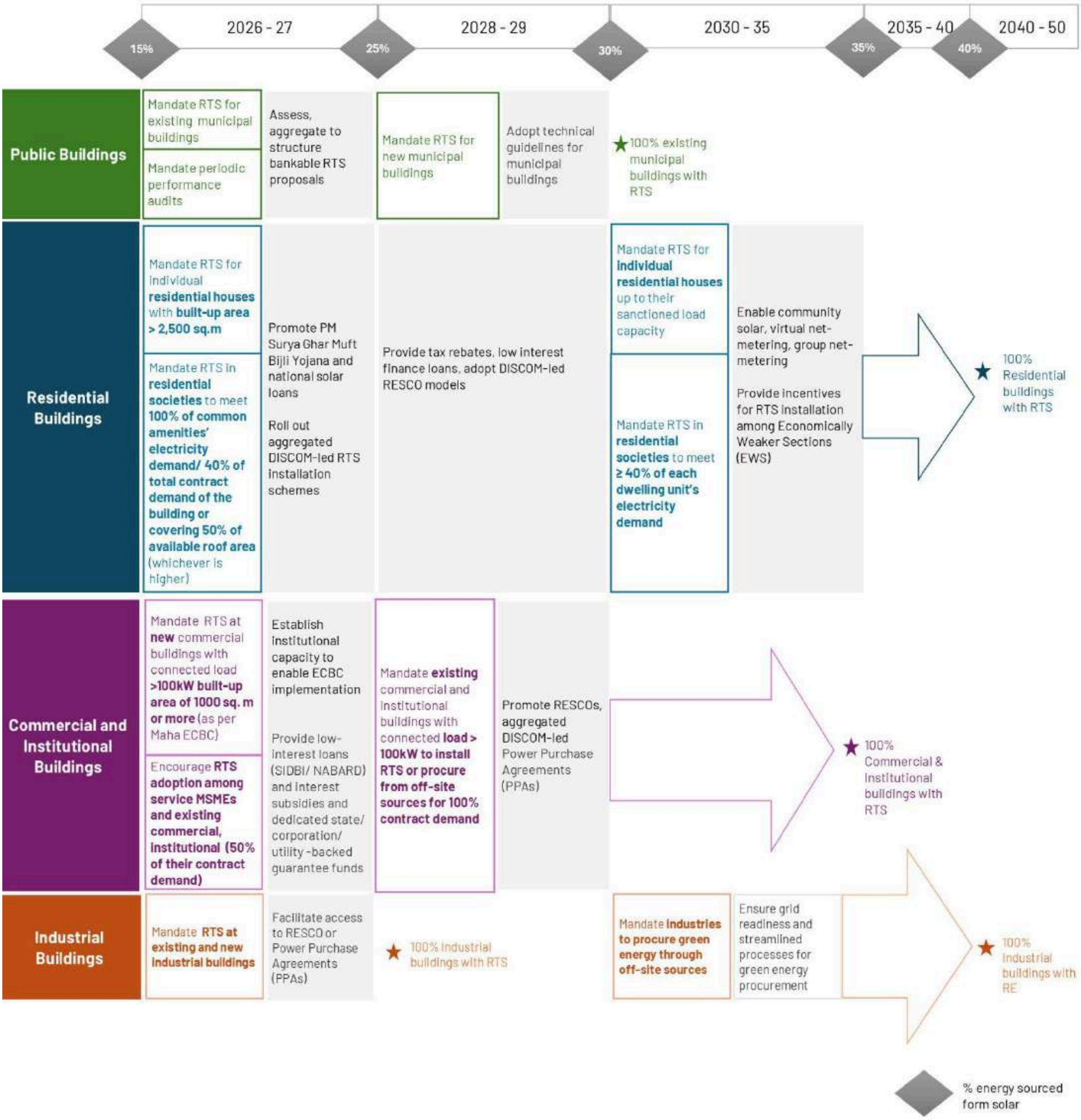

Figure 6 Phased-wise RTS mandate roadmap

6. Projected Impact of Roadmap Implementation by 2050

The implementation of the Rooftop Solar Roadmap for Nashik is expected to yield substantial environmental, economic, and social benefits by 2050. This section presents the projected impacts in terms of electricity demand met through rooftop solar, greenhouse gas (GHG) emission reduction, installed capacity requirements, and potential job creation. These projections are based on the city's estimated electricity demand growth, rooftop solar potential, and the policy and regulatory actions proposed within the roadmap.

- **Projected Electricity Demand (2050)** and RTS contribution to the energy mix: By 2050, Nashik's annual electricity consumption is projected to reach 13,065.73 GWh. The Nashik Climate Action Plan, targets 60% of the annual electricity consumption (7,838.8 GWh) to be met through RTS.
- **GHG Emission Reduction Potential**:The generation of 7,838.8 GWh from rooftop solar could avoid approximately 5.6 million tonnes of CO_2 emissions.[55]
- **Installed Capacity Requirement**: 5,965. 63 MW required to meet 60% of Nashik city's annual electricity consumption.
- **Job Generation Potential**: Considering an employment factor of 13.84 job-years per MW[56] for the construction and commissioning phase: The deployment of 5,965. 63 MW rooftop solar capacity would generate approximately 431 job-years[57] in total.

[55] CEA weighted average grid emission factor (2023-24)
[56] CEEW Report: Greening India Workforce
[57] 1 Job Year: 1 person employed full-time for 1 year

7. Implementation of Roadmap

Implementation of the road map requires coordinated efforts by multiple stakeholders at the city, state and national level. A RTS Cell (or a city climate action cell) is recommended at the city level that can be within the electrical/ environmental department of NMC to coordinate the multiple efforts between stakeholders.

The implementation framework is organized under three core components:

- Stakeholder Mapping
- Risk Identification and Mitigation
- Roles and Responsibilities

7.1 Stakeholder Mapping

Stakeholder identification and mapping play a crucial role in implementing the RTS Roadmap in Nashik. The matrix below (Figure 7) presents a visual mapping of key stakeholders based on their level of influence over and interest in the implementation of the RTS Roadmap. (Table 7) details Stakeholder Roles and (Table 8) identifies key risks and mitigation measures for RTS implementation.

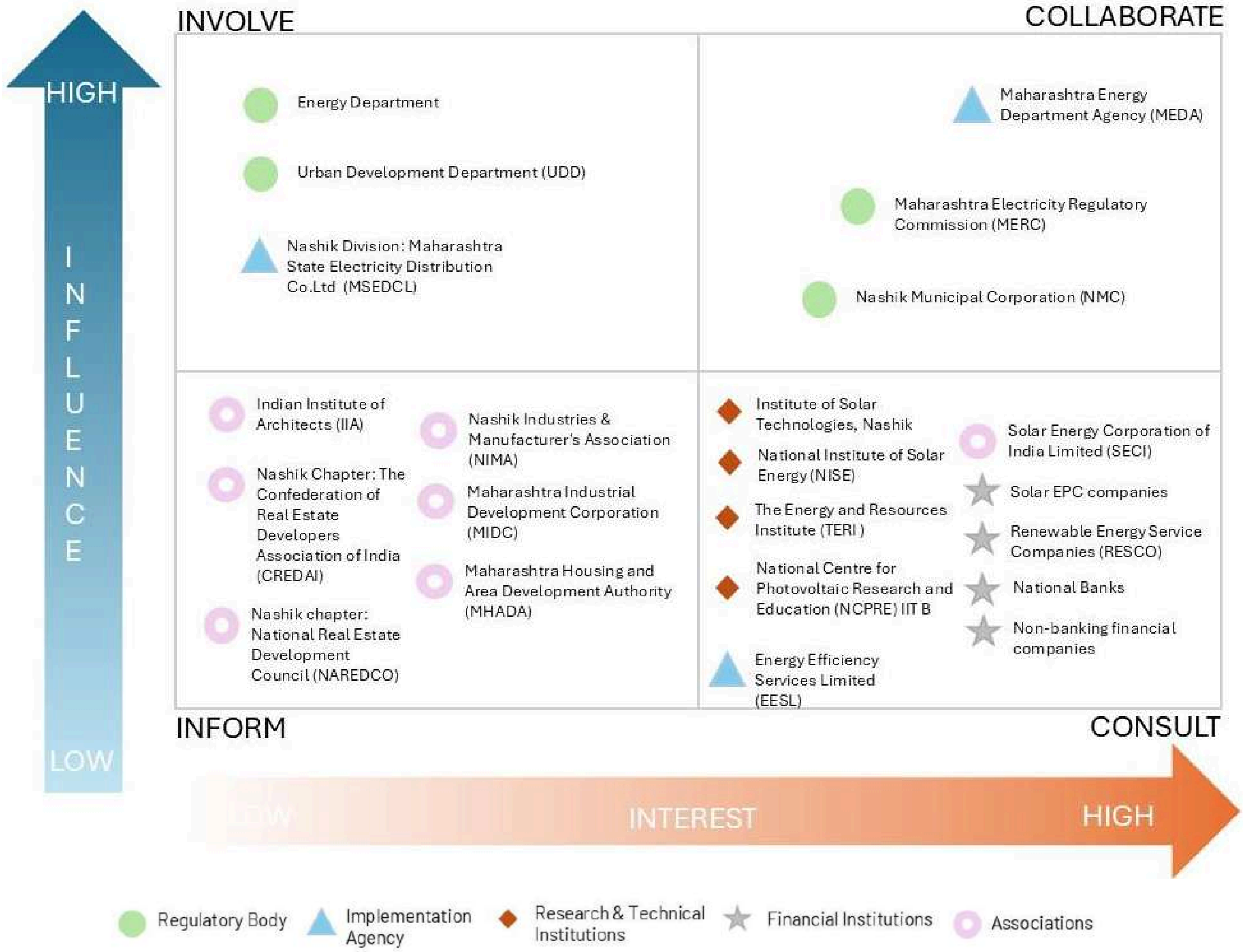

Figure 7 Stakeholder Roles

Table 7 Stakeholder Roles

Stakeholder Category	Organization	Role
Regulatory Body	Energy Department, Government of Maharashtra	Facilitating and promoting generation of electricity through renewable energy
	Urban Development Department (UDD)	Integrates rooftop solar mandates and provisions into building byelaws
	Maharashtra Electricity Regulatory Commission (MERC)	Promotes RTS through setting tariffs, regulations to enhance net metering, and grid integration
	Nashik Municipal Corporation (NMC)	Offers property tax rebates and incentives to encourage RTS installation
Implementation Agency	Maharashtra State Electricity Distribution Co. Ltd. (MSEDCL) – Nashik Division	Facilitates RTS applications, provides connections with net-meters and ensures systems are connected to the grid. Facilitates disbursement of subsidies and handles buy and sell of excess power generated
	Maharashtra Energy Development Agency (MEDA):	Adopts technical standards set at the central level, develops policies to encourage adoption, issues tenders, provides financial incentives
Research and Technical Institutions	Institute of Solar Technology (IST)	Provides hands-on training and certification programs to build a skilled workforce for rooftop solar installation
	National Institute of Solar Energy (NISE)	Offers technical guidance, standards, and quality assurance support for rooftop solar systems and components
	The Energy and Resources Institute (TERI)	Supports policy research, techno-economic analysis
	National Centre for Photovoltaic Research and Education (NCPRE)	Advances research, testing, and innovation in solar PV technologies to enhance system performance
Financial institutions	Solar EPC Companies	Handles the entire process of a rooftop solar installation, from initial design to final commissioning and operation
	Renewable Energy Service Companies (RESCOs)	Facilitates rooftop solar by investing in, installing, and maintaining the system on a client's roof
	National Banks	Provides financial mechanisms at concessional rates and offers direct loans
	Non-Banking Financial Companies (NBFCs)	Provides specialized solar loans for individuals and businesses, making the initial investment more accessible and affordable
Associations	Indian Institute of Architects	Influences rooftop solar adoption by educating its members and showcasing exemplary projects that incorporate solar technology.
	Confederation of Real Estate Developers' Associations of India (CREDAI)	Acts as an intermediary between developers and the government, raising issues and suggesting policy changes related to areas like rooftop solar
	National Real Estate Development Council (NAREDCO)	Acts as a bridge between the real estate industry and the government

Stakeholder Category	Organization	Role
	Nashik Industries & Manufacturers' Association (NIMA)	Mobilizes industrial consumers to implement rooftop solar systems and provides on-ground feedback on market and regulatory barriers.
	Maharashtra Industrial Development Corporation (MIDC)	Supports rooftop solar by promoting it within its industrial parks and incorporating it into the development control rules for new buildings
	Maharashtra Housing and Area Development Authority (MHADA)	Assists in the broader state government efforts to promote rooftop solar in Maharashtra

7.2 Risk Identification and Mitigation Framework

Table 8 Risk and Mitigation Measures

Risks	Mitigation Measures
Limited coordination between NMC, DISCOM, and private developers leading to delays in project approvals and execution.	Establish a dedicated RTS cell (Climate Action Cell) within the Electrical/ Environmental Department, NMC for coordination; hold quarterly joint review meetings with DISCOM and project developers.
Conflicts or overlaps between municipal bylaws and state RTS policies slowing implementation.	Review and issue clear municipal-level guidelines for faster approvals.
Limited awareness of on-ground challenges in mandate implementation.	Set up a continuous feedback mechanism with consumers, installers, and DISCOM; conduct periodic reviews to resolve operational issues.
Discontinuation of initiatives due to leadership change or shifting priorities.	Institutionalize rooftop solar initiatives within NMC's annual energy action plan; secure multi-year budget allocations and state support.
Low citizen interest or lack of awareness about RTS benefits and business models.	Conduct citywide campaigns, RWA-level workshops, and demonstration projects on municipal buildings to build public trust and visibility.
Inaccurate or delayed data reporting from installations at private buildings.	Develop an operational mandate requiring periodic submission of installation and performance data to a central monitoring system.
Risk from MSEDCL perspective: Poor quality or incomplete data from third-party net metering installers.	Develop a standard operating procedure (SOP) specifying data formats, fields, and submission timelines; conduct periodic training for installers.
Risk from MSEDCL perspective: Limited grid readiness for high RTS penetration (voltage fluctuations, reverse flow issues, lack of smart grid systems).	Implement phased grid upgrades; install voltage regulation and protection equipment; integrate smart grid and metering technologies.

7.3 Roles and Responsibilities

Successful implementation of the rooftop solar roadmap requires coordinated action from multiple stakeholders. The (Table 9) below outlines the primary stakeholders (responsible for initiating and leading actions) and secondary stakeholders (supporting, facilitating, or providing oversight) for the strategic actions proposed under this roadmap.

Table 9 Roles and responsibilities of stakeholders

Action	Primary Stakeholder	Responsibility	Secondary Stakeholder	Responsibility
Identify High Impact Solar Zones through a detailed Solar mapping at a granular level	**Nashik Municipal Corporation, MSEDCL**	• Provide access to GIS map with latest urban building footprint • Provide access to ward-wise electricity consumption data	Developers associations (CREDAI, NAREDCO) GIS technical assessors, community volunteer groups	• Conduct the technical mapping of feasible buildings at the granular ward and building level using GIS analysis • Assist in ground validation of solar mapping data, collection of socio-economic parameters
Develop Real-time Net-Metering Status Platform	MSEDCL	• Develop real-time public dashboard to track net-metering • Establish a coordinated task force for overseeing progress and resolving issues	Third-party vendors, IT department	• Share information of installed net-meters
Develop and Implement Specific Mandates for Different Building Typologies	**Nashik Municipal Corporation**	• Implement mandates for all building typologies, • Build internal capacity • Coordinate with UDD, MSEDCL, Banks, Associations (CREDAI, NAREDCO, NIMA, MIDC)	MSEDCL, UDD, Developers associations (CREDAI, NAREDCO)	• Implement pilot projects for (community solar, VNM, GNM) • Develop DISCOM-led RESCO aggregated projects, • Develop PPA aggregated projects
Develop a Cost-Benefit Calculator	**Nashik Division - MSEDCL, Nashik Municipal Corporation - Tax Department**	• Develop an Interactive Cost-Benefit Calculator by integrating financing information from banks, tax rebates, subsidies	Financial Institutions (Banks), Developer Associations (CREDAI, NAREDCO)	• Coordinate between stakeholders (MSEDCL, Property Tax Dept, Banks, etc) • Launch the calculator on the NMC website • Lead awareness campaigns to promote usage of the calculator and

Action	Primary Stakeholder	Responsibility	Secondary Stakeholder	Responsibility
				educate the public about RTS benefits.
Create Communication and Awareness Channels	**Nashik Municipal Corporation,** MSEDCL	• Develop a strategic communication plan to promote the benefits of Rooftop Solar • Organize workshops, exhibitions, and solar fairs in public spaces and institutions • Publish RTS updates and subsidy alerts on the official NMC website and social media handles	Community groups (NGOs, Youth Groups)	• Conduct door-to-door campaigns in clusters. • Mobilize local influencers, environmental clubs to spread RTS adoption stories.
Develop and Implement Diverse Innovative Business Models	**Nashik Municipal Corporation**, SECI	• Formulate clear regulations to support innovative rooftop solar business models • Develop investor-friendly policies to attract private and cooperative sector participation • Engage with financial institutions, industry associations (CREDAI, NAREDCO, MIDC, NIMA)	MSEDCL, NISE	• Develop and pilot business models • Document learnings from pilots for scale-up and regulatory refinement
Establish Institutional Systems for Improving Technology Resilience	**Nashik Municipal Corporation**, MSEDCL	• Develop a Centralized Monitoring Centre (CMC) for real-time performance tracking of RTS systems • Coordinate with third-party solar vendors, consumers, and municipal bodies for seamless data sharing and responsive system management	National institute of Solar Energy	• Provide technical assistance in system design, integration of monitoring technologies, and analytics frameworks. • Offer training programs, workshops, and knowledge transfer to municipal and DISCOM staff managing the CMC

8. Monitoring, Evaluation and Reporting Framework

A robust Monitoring, Evaluation and Reporting (MER) framework is essential to ensure acceleration of RTS in Nashik. The framework (Table 10) provides NMC and stakeholders with the indicators to track progress, measure outcomes, ensure transparency throughout the deployment process.

Table 10 Monitoring, Evaluation and Reporting Framework

Action	Monitoring (Key Performance Indicators)	Evaluation Indicators	Reporting
Identify High Impact Solar Zones through a detailed Solar mapping at a granular level	• Number of wards assessed for granular level RTS feasibility • Number of buildings identified per ward for potential RTS installation • Number of stakeholder consultations conducted to validate outputs	➔ % increase in feasible wards and suitable rooftops for RTS installation ➔ Total number of aggregated rooftop solar (RTS) installation projects	1. Annual report summarizing mapping results and successful RTS projects
Develop Real-time Net-Metering Status Platform	• Number of net-metering applications received in the month • Number of applications approved in the month • Number of net-meters installed in the month • Number of net-meters activated in the month • Average processing time : Application → Approval • Average processing time :Approval → Installation • Average processing time: Installation → Activation • % of applications processed within regulatory timeline (ie:45 days) • Number of applications with real-time status available on public portal/dashboard	➔ Average time taken from approval-to-activation ➔ % of users satisfied with the transparency of net-metering timelines	1. Quarterly public dashboard: bottleneck summary 2. Annual evaluation brief
Develop and Implement Specific	• % of existing buildings (by typology) complying with RTS mandate	➔ Total electricity demand in % met by RTS (by typology)	1. Annual public report: Typology-wise

Action	Monitoring (Key Performance Indicators)	Evaluation Indicators	Reporting
Mandates for Different Building Typologies	• Total RTS capacity installed (by sector)	→ Document challenges in adoption	compliance, total RTS capacity installed by typology, overall GHG reductions
Develop a Cost-Benefit Calculator	• Number of people using the cost-benefit calculator • % of users proceeding to install RTS post using the calculator	→ Percentage of users who report improved understanding of payback period, ROI, and savings	1. Summary of cost-benefit awareness improvement trends 2. Case studies of users who installed RTS after using the tool
Create Communication and Awareness Channels	• Number of awareness campaigns conducted • Number of participants • Number of promotional materials distributed • Number of media features/mentions (press, TV, social media) • Number of Website visits for RTS cost-benefit resources and other RTS schemes	→ % of surveyed target audience expressing intent to install RTS → % of participants citing campaign channels as their primary source of RTS information	1. Annual public report: Awareness survey results, success stories
Develop and Implement Diverse Innovative Business Models	• Number of projects implemented under each business model • Total installed capacity (kW) under each model. • Number of participating vendors, financiers, users in each model	→ Market share of innovative models within total RTS installations → % increase in user RTS adoption based on financial viability	1. Annual report summarizing total RTS capacity installed under innovative business models
Establish Institutional Systems for Improving Technology Resilience	• % of RTS systems connected to the Centralized Monitoring Centre • Average RTS system performance ratio	→ % increase in performance ratio due to CMC → Number of policy updates or interventions based on CMC data	1. Annual RTS operational and maintenance log reports

9. Action Plan for NMC Buildings

NMC has been actively installing RTS across its buildings.(Table 11) provides a summary of the total existing municipal buildings with existing RTS capacity and identifies additional buildings in the pipeline for future deployment. The total roof area of public buildings is 10,54, 700sq.m with total electricity consumption for 2023-24 is 111.89 GWh. (Figure 8) provides a Phased-wise RTS action plan for Municipal Buildings

Table 11 Pipeline of Municipal Buildings for RTS Installation

Municipal Buildings (by Typology)	Total	Buildings with RTS Installed	RTS Capacity Installed
Govt offices	46	4	306.99
School	114		
Hospitals & Nursing Homes	24	3	124.40
Fire Brigade House	6	1	13.20
Municipal Commissioner Bungalow	1	1	7.26
Library	119		
Exercise school	227		
Shopping centre	36		
Vegetable Market	19		
Truck terminus	3		
Auditorium	6	2	121.83
Swimming pool	6	2	
Planetarium	1		
Crematorium	49		
Stadium	3		
Workers House	21		
Toilets	495	87	87.00

As per MSEDCL (2024), 13.2 MW of rooftop solar capacity has been installed on public buildings, against a total technical potential of 51.84 MW. To support NMC in achieving the untapped potential and transitioning its municipal buildings to 100% solar energy, the following action plan outlines the key steps to be undertaken.

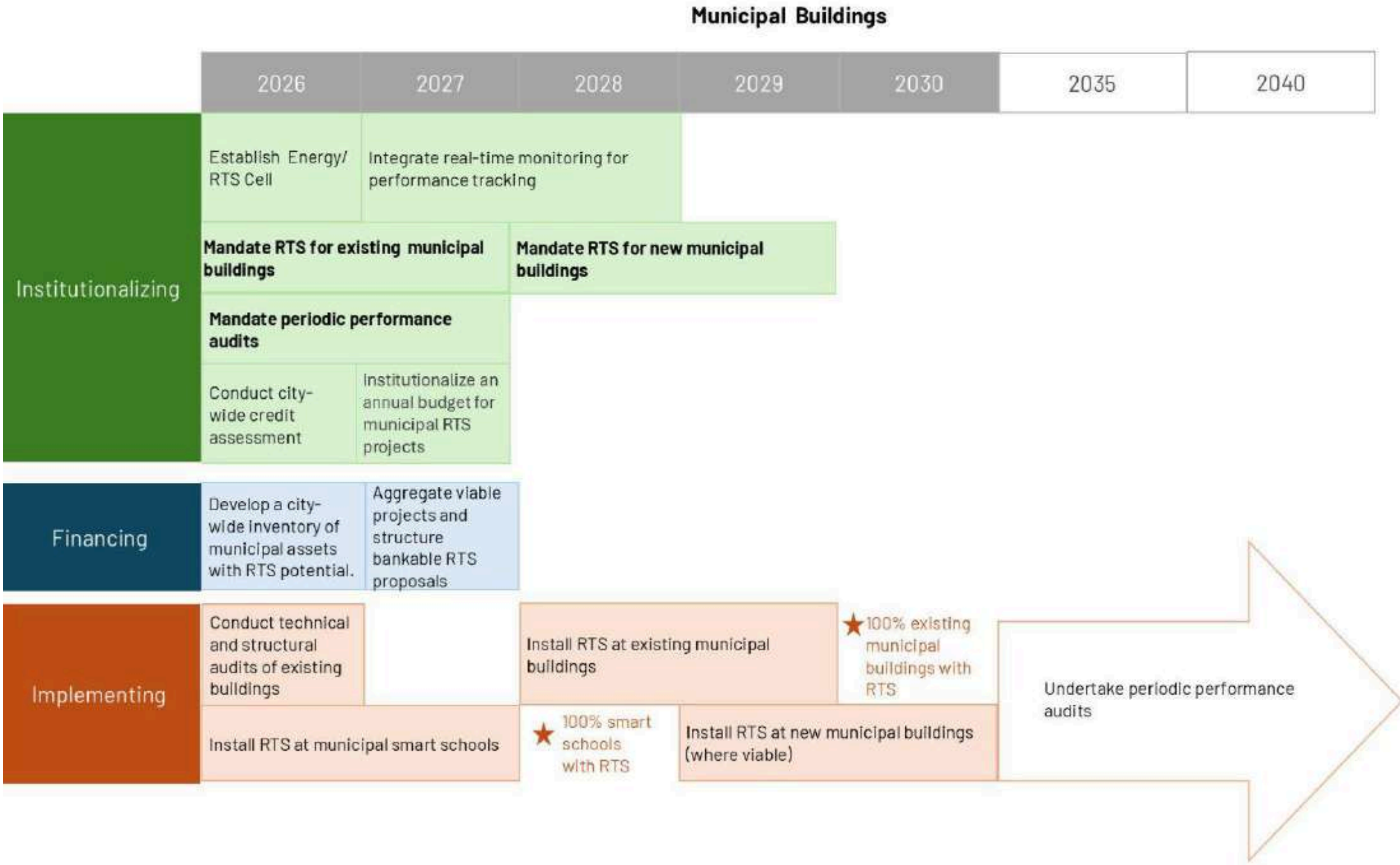

Figure 8 Phased-wise RTS action plan for Municipal Buildings

9.1 Guidelines for Retrofitting Municipal Buildings

To enable effective integration of RTS systems on existing buildings under the Nashik Municipal Corporation (NMC), the following step-by-step action plan to be followed during the implementation phase.

1. **Rooftop Space Assessment**
    a. Conduct rooftop inspections during peak sunlight hours (11 AM–4 PM) to identify shading from tanks, parapets, trees, nearby buildings, or other obstructions.
    b. Record and mark the location, size, and orientation of shaded areas and fixed structures on the roof layout.
    c. Document roof condition with photographs and measurements.
    d. Calculate the net usable roof area for solar PV installation by excluding shaded and obstructed zones.
    Note: As per MNRE, ~12 sq. m. of rooftop space is required per 1 kWp of installed solar capacity[58]

2. **Structural Assessment**
    a. Visually inspect the roof for damage such as cracks, seepage, or corrosion
    b. Engage a certified structural engineer to verify the roof's ability to bear the additional load of the RTS.

[58] Solar Energy Corporation of India_FAQ

c. Rectify deficiencies before installation, including waterproofing, reinforcement of beams/slabs, or other structural repairs.

3. **Estimation of Solar Capacity**
   a. Determine the building's average monthly electricity consumption (kWh)
   b. Estimate system size considering 1 kWp of solar PV generates ~1,400–1,600 kWh annually (~4 kWh/day).[59]

4. **Technical Standards & Design Considerations**

   Modules & Certification[60]
   a. Use only MNRE Approved List of Models and Manufacturers (ALMM)-compliant modules.
   b. Modules must be warranted for ≥90% of rated output at 10 years and ≥80% at 15 years.
   c. Comply with to the latest edition of IEC standards or equivalent BIS standards, i.e. IEC 61215/IS14286, IEC 61853-Part I/IS 16170-Part I, IEC 61730 Part-1 & Part 2 and IEC 62804 (PID). For the PV modules to be used in a highly corrosive atmosphere throughout their lifetime, they must qualify to IEC 61701/IS 61701.
   d. Ensure modules carry RFID tagging and labelling for traceability.

   System Design Parameters[61]
   a. Mount modules on south-facing frames, tilted 10 - 15° depending on site.
   b. Total system weight ≤ 30 kg/m²; for non-anchored Module Mounting Structures (MMS), use ballast (e.g., bricks) against wind uplift/drag.
   c. Design mounting structures for wind loads as per IS: 875 (Part 3)–1987.

   Material & Durability[62]
   a. Use galvanized iron (GI) or aluminium for MMS; ensure galvanization quality supports 25+ years of service.
   b. Prefer stainless steel fasteners; GI fasteners may be used as an alternative.
   c. Ensure all materials withstand humidity up to 100%, temperatures –40°C to +85°C, and wind gusts up to 160 km/h.

   Compliance[63]
   a. Adhere to MSEDCL technical specifications aligned with MNRE safety and performance standards.

5. **Contracting Process**
   a. Prepare a Scope of Work covering supply, installation, testing, commissioning, and O&M.
   b. Define performance benchmarks (efficiency, generation, maintenance response).
   c. Specify bidder eligibility: relevant technical experience, certifications, and financial qualifications.
   d. Include monitoring requirements, approvals, and provisions for post-installation training.

6. Award of Contract

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[59] Power Output of Roof Top Solar
[60] MSEDCL - RTS Technical specifications
[61] MNRE - BEST PRACTICES MANUAL FOR IMPLEMENTATION OF STATE-LEVEL ROOFTOP SOLAR PHOTOVOLTAIC PROGRAMMES IN INDIA
[62] MNRE - BEST PRACTICES MANUAL FOR IMPLEMENTATION OF STATE-LEVEL ROOFTOP SOLAR PHOTOVOLTAIC PROGRAMMES IN INDIA
[63] MSEDCL - RTS Technical specifications

a. Evaluate bids using techno-commercial criteria (system design quality, equipment standards, cost, warranties, O&M support, vendor track record).
b. Ensure installation is completed within a stipulated time period (post sanction).
c. Mandate strict adherence to MSEDCL Standard Operating Procedure (SOP)[64].

7. Metering & Grid Integration[65][66]

a. Coordinate with MSEDCL for net metering, subject to MERC regulations (2023), minimum installation of 1 KW
b. Procure and test Generation and Net Meters as per MERC standards at MSEDCL-approved labs.
c. Upload tested meter details on MSEDCL portal during commissioning.

8. Testing & Commissioning [67]

a. Sub-Divisional Officer (SDO) and Testing Engineer to verify compliance, approve commissioning, and record initial meter readings.
b. Field officer to update meter assignment details in the Net Connectivity Portal.

9. Post-Installation Documentation & Handover[68]

a. Consumers must upload commissioning documents on the MSEDCL portal before sanction validity, including:
    - Annexure I of MSEDCL SOP with system technical details.
    - Self-certification of safety along with Licensed Electrical Contractor's test report.
    - Photographs of the commissioned system.

10. Operation and Maintenance

a. Follow best practices in operation and maintenance[69]
b. Carry out regular cleaning of PV modules, continuous performance monitoring, and preventive maintenance of inverters and mounting structures. Cleaning and maintenance should be scheduled before 11:00 A.M. or after 5:00 P.M. The PV module surfaces should be cleaned with water at least once every six months and dust on panels to be removed once every 2-3 months.

9.2 Guidelines for New Municipal Buildings

To ensure that all future municipal buildings under Nashik Municipal Corporation (NMC) are designed to be capable of accommodating rooftop solar (RTS) systems, the following guidelines to be adopted

1. Rooftop Design Provisions

a. Design flat or gently sloped roofs (south facing preferably) with unobstructed areas for future PV installations.
b. Position water tanks, HVAC equipment, and parapet walls so they do not obstruct solar exposure.

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[64] MSEDCL- Standard operating procedures for installing and commissioning of RTS
[65] Maharashtra Electricity Regulatory Commission (Grid Interactive Rooftop Renewable Energy Generating Systems) Regulations, 2019
[66] MahaDISCOM- iSMART
[67] MSEDCL- Standard operating procedures for installing and commissioning of RTS
[68] MahaDISCOM- iSMART
[69] Best Practices in OPERATION AND MAINTENANCE of Rooftop Solar PV Systems in India

c. Provide safe roof access (stairs/ladders), railings, and designated walkways for operation and maintenance.
d. Allocate minimum ~12 sq. m per 1 kWp (MNRE benchmark) based on estimated building energy needs.
e. Ensure the design allows for module placement facing south with tilt between 10°– 15° (site-specific)

2. **Structural & Electrical Provisions**
   a. Design to withstand the additional weight of RTS systems (≤30 kg/m²).
   b. Design to comply with IS 875 (Part 3)–1987 for wind loads and site-specific conditions.
   c. Provide space for inverters, junction boxes, and cable trays within the building design.
   d. Include pre-laid conduits and electrical wiring pathways from roof to main electrical room.
   e. Integrate adequate grounding and protection measures as per MNRE/BIS standards.

3. **Implementation, Standards, and Operations**
   For all other technical standards, contracting procedures, metering, testing/commissioning, post-installation documentation, and O&M, new municipal buildings shall adhere to the same requirements specified under Section 7.1, Points 4 to 10.

10. Business Models and Financing Mechanisms for Municipal Buildings

This chapter outlines business models that have been adopted by Indian states and cities to accelerate RTS deployment at municipal buildings, along with the financial mechanisms that support their implementation. These models provide replicable approaches for Nashik Municipal Corporation to accelerate RTS at municipal buildings, depending on building typology and availability of financial resources.

10.1 Business Models

a) **EPC + O&M Contract**

In an EPC + O&M model, the municipal corporation pays an Engineering, Procurement, and Construction (EPC) contractor to design, supply, and install the solar system. Alongside installation, the contractor provides operations and maintenance services for an agreed period, usually five years. This ensures performance guarantees but requires the municipal corporation to bear upfront capital costs and long-term ownership responsibilities.

Case Study:

- Indore Municipal Corporation (IMC)[70][71] undertook an EPC project for design, supply, installation, testing and commissioning of a 60MW solar power project at Samraj and Ashukhedi villages in Madhya Pradesh with O&M for 10 years. The project cost is estimated to be Rs 2.87 billion. The solar plant is expected to generate electricity to help the IMC save approximately Rs 4 crore per month on electricity bills.

  Tender clauses[72]
  - The tender requires a Performance Guarantee Report ("PR value (PV Syst Report)") to be submitted at the time of bid submission.
  - For every 1% shortfall in PR below the committed PR value (committed at the time of bid submission), a penalty of 1% of the total Contract Value (i.e., total sum of all the Supply, Service and amount of O & M Contract) shall be levied.
  - Subject to Force Majeure Clause, if the Contractor fails to comply with the Time for Completion /successful commissioning or any extension thereof of Plant facilities in accordance with timelines as mentioned, then the Contractor shall pay to the Owner a sum equivalent to half percent (0.5%) per week of the Contract Price for the whole of the facilities as liquidated damages for such default

- Pune Municipal Corporation[73][74] has established 31 projects under the EPC mode using funds from the prize money received under the Majhi Vasundhara scheme generating approximately 16,69,594 units of electricity till date.

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[70] MP: EPC tender for 60MW solar project

[71] Indore: Request for Proposal for selection of EPC Contractor for Design, Supply, Installation, Testing & Commissioning including 10 years Comprehensive O&M of 60 MW (AC) Solar PV Project in Madhya Pradesh, India

[72] SELECTION OF EPC CONTRACTOR FOR DESIGN, SUPPLY, INSTALLATION, TESTING & COMMISSIONING INCLUDING 10 YEARS COMPREHENSIVE O&M OF 60 MW (AC) SOLAR PV PROJECT AT VILLAGE SAMRAJ & ASHUKHEDI IN MADHYA PRADESH, INDIA

[73] Pune: Solar Energy projects

[74] Pune: Solar Energy projects

b) RESCO – Lease Agreement

Under a RESCO lease model, a Renewable Energy Service Company (RESCO) installs and owns the solar system while leasing it to the client, (a municipal body),. with time period ranging between 10-25 years typically.The client pays fixed periodic lease charges, often linked to system output, without incurring upfront capital costs. Ownership may transfer to the client at the end of the lease term. This approach shifts technical risks to the RESCO, while the municipality commits to payment obligations.

Case Study:

- Brihanmumbai Electric Supply and Transport (BEST)[75] is adopting a RESCO leasing model through a Wet-Lease Agreement for installing rooftop solar systems at its bus depots. Under the model, a third-party installer/financier will design, finance, install, and operate the systems for a fixed 10-year lease term. BEST will make periodic lease payments, after which system ownership will transfer to BEST at a pre-agreed price. All power generated during the lease period will belong to BEST, eliminating the need for a separate power purchase agreement.

c) RESCO – Power Purchase Agreement (PPA)

In the RESCO PPA model, the RESCO finances, installs, and operates the solar system and client pays only for the electricity consumed on a per-kWh basis (typically ₹3.50 – ₹4.50 per kWh)[76]. The client avoids capital investment, while the RESCO recovers costs through long-term energy sales. Technical and generation risks rest with the RESCO, making it attractive for clients with budget constraints but stable demand for renewable energy.

Case Study:

- Maharashtra Energy Department Agency (MEDA) has installed 10MW grid-connected rooftop solar PV on state government buildings under the RESCO model with 25 years of O&M[77]
- Madhya Pradesh has implemented 26MW of Rooftop Solar Programs largely at government buildings via RESCOs using state and central subsidies. The electricity generated is supplied to beneficiaries under long-term Power Purchase Agreements (PPAs) with the developers.[78]
- Pune Municipal corporation has installed 9 RTS projects under the RESCO model generating approximately 25,25,077 units of electricity to date[79]

d) PPP – BOO model

In a PPP–Build, Own, Operate (BOO) model, the private developer is responsible for financing, installing, and operating the project, while accessing ownership through rooftop leasing. The public authority facilitates the arrangement by providing approvals, access to land or rooftops, and ensuring service offtake, such as purchasing electricity through a Power Purchase Agreement (PPA).

Case study:

- Gandhinagar[80] implemented a Public-Private Partnership (PPP) model for RTS deployment on government and residential buildings, with technical and financial advisory support from

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[75] Powering Mumbai's electric fleet with solar energy
[76] Key insights into solar PPAs complete guide
[77] MEDA issues 10MW RTS PV tender
[78] MP implements 26MW RTS programs via RESCOs
[79] Pune: Solar Energy projects
[80] Gujarat Solar Rooftop Program

IFC under the World Bank's ESMAP program. Through competitive bidding, Azure Power and SunEdison were selected to develop 2.5 MW each (total 5 MW) of rooftop solar capacity.The project involved an investment of USD 10–12 million (₹45–55 crore), covering system design, installation, and 25-year O&M by the developers. Under this model, developers leased rooftops from government and private owners to install and operate grid-interactive solar PV systems, requiring no capital cost from the rooftop owners.Electricity generated was fed into the grid through gross metering, with Gujarat Urja Vikas Nigam Limited (GUVNL) purchasing power at ₹11.21/kWh under a 25-year PPA. To encourage participation, rooftop owners earned a "Green Incentive" of ₹3/kWh, paid by developers based on actual generation serving as a performance-linked rental rather than a fixed lease payment.

- Bhubaneswar and Cuttack[81] implemented rooftop solar projects on 200 government and public sector buildings. IFC recommended a 25-year Build-Own-Operate (BOO) contractual agreement under which the winning bidder would install solar panels ensuring a minimum installed capacity of 4 MW. The Odisha project, estimated at USD 5 million, was financed entirely by the developer, with 30% reimbursed through central government grants, reducing upfront risks and ensuring financial viability.

e) PPP – Joint Venture (SPV Model)

In a Joint Venture PPP, a new Special Purpose Vehicle (SPV) is created as a joint-stock company with shared ownership between the municipality and a private partner, often a utility or developer. Both parties contribute equity and share risks, responsibilities, and returns. The SPV installs, operates, and manages the solar (or hybrid) plant, typically over a long concession term of 20–30 years

Case study:

- In Vadodara, a 5 MW rooftop solar project was set up with support from the International Finance Corporation (IFC). A private company, WAA Solar, created a SPV Madhav Solar Vadodara Rooftop Private Limited) to install solar panels on hundreds of rooftops across homes, businesses, and industries. Rooftop owners earn rent for providing their space, while all the electricity generated is supplied to the city's power utility (Madhya Gujarat Vij Company Limited), at a tariff set through a competitive bidding process under a 25-year agreement.[82]

Table 12 Business Models for RTS deployment at Municipal Buildings

Model	Owner	Payment Type	Risk	Projects Preference
EPC + O&M	Municipality	Upfront CAPEX + O&M fee	Municipality	**Large municipal-owned assets** (e.g., water pumping stations, sewage treatment plants, street lighting depots) where upfront capital funds are available (from grants, schemes, or bonds).
RESCO – Lease	RESCO → Municipality	Fixed lease/rental	RESCO (technical), Municipality (payment)	**Medium-sized public facilities** (e.g., bus depots, hospitals, schools, offices) where municipalities want solar without upfront costs but prefer eventual ownership.

[81] Odisha Rooftop Solar PPP
[82] Public-Private Partnerships: Lessons from Gujarat Solar

Model	Owner	Payment Type	Risk	Projects Preference
RESCO – PPA	RESCO	Pay per unit (₹/kWh)	RESCO (technical + generation)	**Public and institutional buildings** with steady daytime demand (e.g., government offices, universities, markets) and no capital allocation.
PPP – BOO	Private → Municipality	Revenue share or tariff	Shared	**Aggregated rooftop clusters** (e.g., residential colonies, mixed-use commercial zones, industrial estates) where private developers rent rooftops and sell power to the grid/utility
PPP – Joint Venture (SPV)	Shared (Municipality + Private)	Equity-based returns / dividends	Shared	**City-scale or multi-utility projects** (e.g., city-wide distributed solar, hybrid solar + storage parks, industrial clusters) where risks/returns are shared over long concession periods

10.2 Financial Mechanisms

a. **Smart City Mission**[83]
With 100 cities driving the initiative, the Smart Cities Mission has achieved substantial progress over the past decade and has now completed its 10-year tenure. Smart City Funds have emerged as an important source of financing for rooftop solar projects in India.Several cities such as Nashik, Bhopal, Indore, Dharamshala have successfully tapped these funds to deploy solar PV on municipal buildings, streetlighting, and public facilities, often through EPC or RESCO models.

b. **Municipal Solar Bonds (MSBs)**[84]
Municipal solar bonds are debt instruments issued by city governments or municipal authorities to raise capital dedicated to solar energy projects such as rooftop solar, solar parks, or hybrid renewable systems. They allow municipalities to leverage contributions from both public and private investors, providing upfront financing without straining city budgets. The SMBMSB model often functions as a public–private partnership at the city level, where the municipality issues the bonds and channels the proceeds to private rooftop solar developers through Special Purpose Vehicles (SPVs). The revenues generated from the solar projects are then used to repay investors, making MSBs a sustainable and transparent financing mechanism. The SMB model has shown considerable promise through its application in Surat, where the Surat Municipal Corporation (SMC) issued a Municipal Green Bond in October 2025. The ₹200 crore, AA+ rated bond was issued under SEBI's regulatory framework with a 10-year tenure and an annual interest rate of approximately 8.25%. It is designed to finance a 10 MW solar power project at SMC's Simada sewage treatment plant. The proceeds were channelled through a municipal SPV for project execution and repayment management, setting a precedent for climate-aligned municipal financing in India.

c. **SECI's Direct Investments**[85]
The Solar Energy Corporation of India (SECI) has been the implementing agency for national

[83] SmartNet RfPs for RTS
[84] Solar Municipal Bonds: Unlocking India's Energy Potential
[85] Scaling up Rooftop Solar Power in India: The Potential of Municipal Solar Bonds

rooftop solar schemes under the Ministry of New and Renewable Energy (MNRE). They have invited bids for the selection and empanelment of solar power developers for setting up grid-connected rooftop solar PV projects on government buildings across the country under the RESCO model through tariff-based competitive bidding.This mechanism has enabled the aggregation of rooftop solar demand across multiple government and institutional buildings, helping standardize procurement, reduce tariffs, and accelerate rooftop solar deployment nationwide

d. SECI's Payment Security Fund (PSF) [86]

To mitigate financial risks for private developers, SECI operates a Payment Security Fund (PSF). This fund ensures that developers receive timely payments even in cases where power distribution companies (DISCOMs) delay or default on their obligations. By guaranteeing payment flows, the PSF improves the bankability and financial stability of solar projects, encouraging private investment and smoother project execution.

e. Blended finance

Blended finance combines concessional capital (from donors, multilaterals, or government subsidies) with commercial capital (from banks or private investors) to reduce risks and make renewable projects more attractive. Tools such as first-loss guarantees, concessional debt, or interest subvention schemes can unlock private sector participation in projects that might otherwise fall short of investor risk–return expectations. In India, IFC applied this approach in several projects, e.g.: rooftop solar projects in Gandhinagar, Vadodara, (other cities of Gujarat), Bhubaneswar, and Cuttack, part-investment for Brookfield's Bikaner Solar Power Project helping to de-risk investments for private developers and ensuring their long-term financial viability.

f. Majhi Vasundhara Funds

A state-level environmental initiative in Maharashtra to promote actions to conserve the "Panchamahabhuta" (five elements). Prizes and funding are awarded to top-performing local self-government bodies (like municipal corporations and gram panchayats) that successfully implement environmental conservation initiatives. Cities can use these funds for their environmental and development needs.

g. CSR funds

With renewable energy and environmental sustainability as eligible activities under Schedule VII of the Companies Act, many companies are using their CSR budgets to finance solar installations in government schools, hospitals, anganwadis, training centres, and other public facilities. CSR-funded rooftop solar projects typically follow a no-capex or co-funding model, allowing public institutions to adopt clean energy without financial burden while enabling corporates to meet their ESG objectives.

[86] Scaling up Rooftop Solar Power in India: The Potential of Municipal Solar Bonds

11. Solar Procurement Policy for Municipal Buildings

A solar procurement policy can provide Nashik Municipal Corporation (NMC) with a standardized, transparent, and replicable framework for the installation of RTS across municipal buildings. By establishing clear procedures, such a policy would guide NMC in procuring RTS systems helping ensure competitive tariffs, financial prudence, and long-term performance.

In framing the Solar Procurement Policy, NMC to include the following essential components

1. **Procurement Models:**
   The policy to outline multiple procurement approaches, allowing flexibility based on building typology and financial feasibility:
   a. CAPEX/EPC Model (where NMC finances the installation and owns the asset)
   b. RESCO/PPA Model (where Developer invests; NMC purchases power at a fixed tariff)
   c. Lease/BOO Model (where developer builds, owns, operates system, and NMC pays a monthly fee until contract term).

2. **Bidding and Tendering Rules**
   To ensure transparency and competitiveness, the policy to define:
   a. Guidelines for Open Competitive Bidding
   b. Pre-Qualification criteria:
      - Minimum technical capacity installed (e.g.,1000 kWp cumulative).
      - Financial net worth threshold. (eg: average annual turnover of Rs.5,00,00,000 for past 3 financial years)
      - Experience in O&M for minimum 5 years.
   c. Bid Evaluation methodology:
      - EPC – lowest project cost
      - RESCO – lowest tariff
   d. Standard Tender Document
   e. Performance Guarantee Clauses

3. **Contracting Mechanisms**
   To ensure accountability and performance, the policy to define:
   a. Minimum Capacity Utilization Factor (CUF)
   b. Performance guarantees and bank guarantees
   c. Operation and maintenance responsibilities
   d. Penalty for underperformance/delayed commissioning
   e. Termination clauses and dispute resolution mechanisms

4. **Compliance Frameworks**
   To ensure effective monitoring and enforcement, the policy to include:
   a. Regulatory Alignment: Consistency with MERC net-metering regulations and MNRE subsidy frameworks.
   b. Monitoring Mechanisms: Smart meters with remote monitoring access for NMC.

c. Third-Party Verification: Periodic independent audits of performance and financial compliance.
d. Payment Protocols: Defined timelines for payments to developers/EPCs to reduce risk.
e. Institutional Oversight: Establishment of a Solar Procurement Committee (SPC) within NMC for procurement and monitoring.
f. Annual Performance Review: Yearly audits of installed projects against expected generation.
g. Transparency: Public disclosure of RTS adoption progress.

12. Project Profiles

The Nashik Municipal Corporation has been actively installing RTS systems across its municipal buildings. As per MSEDCL (2024), 13.2 MW of RTS capacity has already been installed, against a total technical potential of 51.84 MW identified across the municipal building's portfolio. The total roof area available on municipal buildings is estimated at 1,054,700 sq.m, with an overall electricity consumption of 111.89 GWh recorded in 2023–24.

To accelerate RTS adoption, as per consultations with NMC, key municipal buildings were identified such as:

a. NMC School 20 and 35
b. NMC School 27 and 28
c. Sadubhau Bhore Natyagruh
d. Atal Divyang Bhawan
e. Vilhodi Water Treatment Plant

These assessments[87] were conducted with the objective to evaluate the technical and structural feasibility for rooftop solar installations.

Based on the walk-through assessments, detailed project profiles were prepared for each of the five shortlisted buildings. These profiles capture the technical and structural conditions, rooftop solar potential, and investment and financial viability (including payback period and return on investment). These profiles present a comprehensive understanding of both the technical feasibility and the financial viability of scaling RTS across diverse municipal building typologies.

12.1 Typology: School

1.1.1 School 20 and 35

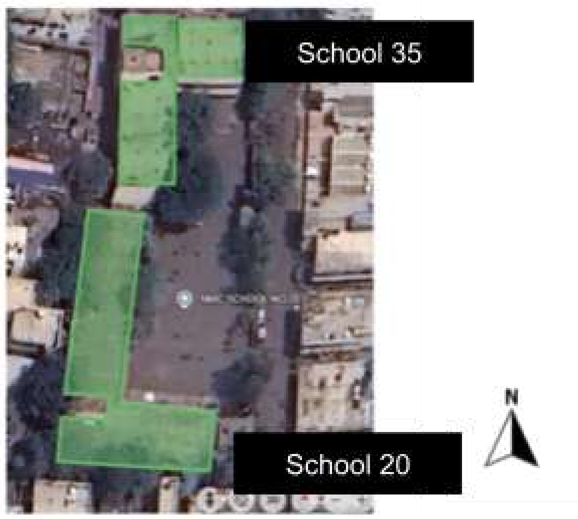

Figure 9 School 20 and 35 : Top View

[87] Sample form attached in Annexure A

Location	Shivaji Nagar, Satpur Colony, Nashik
Construction Year	School 20 (2007–2008), School 35 (2002)
Floors	School 20 (G), School 35 (G+1)
Occupancy	~1100 students
Operational Hours and Days	7:10 am – 5:35 pm, Monday–Saturday (~295 days/year)
Amenities on roof	School 20 (none), School 35 (concrete columns 12 nos)

Technical Assessment

a. Phase: Single-phase supply; request placed for three-phase to meet Smart TV and ICT load.
b. Metering: Single-phase digital meter in use; no smart Building management System (BMS) installed.
c. Major Electrical Equipment: 25 Computers, 4 Printers, 17 Smart TVs, 1 AC (2 Ton), 38 Fans, 57 Tube lights
d. Total connected load: 20 - 22kW
e. Backup: No DG sets; UPS installed.
f. Condition: Electrical wiring upgraded last year, safe and functional.

Structural Assessment

a. Roof Type: RCC flat roof
b. Roof Area: 12,094 sq. ft (combined)
c. Amenities on roof: None
d. Roof orientation: North, South and West
e. Shading:
    - School 20: ~15% shaded by trees (can be trimmed)
    - School 35: ~5% shaded by trees (can be trimmed)
f. Condition:
    - Minor hairline cracks, seepage and surface degradation in some areas,
    - No severe deterioration, sagging, or corrosion observed.
    - No past roof/ceiling repairs.
g. Access: Permanent staircase available, safe for installation and maintenance.
h. Future Expansions: None planned

Rooftop Solar Potential

a. Total roof area = 12,094 sq.ft (1,123.5 sq.m)
b. Effective usable area (considering shading from trees, columns on terrace, technical deductions) = **900sq.m**
c. The roof can install solar capacity of **75 kWp** (As per MNRE, ~12 sq. m. of rooftop space is required per 1 kWp of installed solar capacity)
d. Annual energy consumption: **15424 kWh/year**
e. RTS Capacity Requirement: (Annual energy generation/ Annual Solar Generation per kW (1KW of solar generates 1314 kWh annually)) = 15,424 kWh/ 1314 kWh = **12 kWp**

Findings

The usable roof area can meet **100%** of the building's RTS requirement, with additional capacity available for exporting surplus electricity to the grid.
However, structural strengthening and waterproofing treatment of the roof will be required prior to installation

Return of Investment and Payback period

a. Total investment to install 12kW = 12 x 55,000 = **Rs 6,60,000**[88]
b. Payback Period = Total Investment/ Annual Solar Electricity Savings = 6,60,000 / 1,29,298[89] = **5 years**
c. Return of Investment = (Annual Solar Electricity Savings / Total investment) *100 = (1,29,298 /6,60,000) *100 = **20%**
d. Annual Solar Electricity Generation for 12 kW = 12 x 1314 = **15,768 kWh/year**
e. Annual GHG Emissions = 15,768 X 0.727[90] = **11,463 kgC02/year (~11 tC02/year)**

Site Images

Figure 10 School 20 and 35 : Courtyard

Figure 11 School 35 : Terrace

Figure 12 School 20 : Terrace

[88] As per renewable energy expert guidance, the installation cost of a 1 kW rooftop solar system in India ranges between ₹55,000 and ₹90,000, depending on factors such as the type of solar panels, inverter technology, mounting structure, quality of components, battery back-up
[89] As per MSEDCL tariff rates
[90] CEA weighted average grid emission factor (2023-24)

1.1.2 School 27 and 28

Figure 13 School 27 and 28 : Top View

Name	School 27 (Ground Floor) & School 28 (1st Floor)
Location	MHB Colony, Satpur Colony, Nashik
Construction Year	1989
Floors	G+1
Occupancy	~1,200 students
Operational Hours and Days	7:00 am – 12:30 pm & 12:30 pm – 5:30 pm (Monday –Saturday) (~320 days/year)
Amenities on roof	None

Technical Assessment

a. Phase: Single-phase supply; request placed for three-phase to meet Smart TV and ICT load.
b. Metering: Single-phase digital meter in use; no smart BMS installed.
c. Major Electrical Equipment: 40 Computers, 3 Printers, 4 Projectors, 1 pump (2 HP), 32 Smart TVs, 136 Tube Lights, 74 Fans.
d. Total connected load: 20-22kW
e. Backup: UPS in classrooms & inverter in computer room; no DG sets.
f. Condition: Electrical wiring upgraded last year, safe and functional.

Structural Assessment

a. Roof type: RCC flat roof
b. Roof area : 13,507 sq.ft
c. Amenities on roof: Concrete columns at regular intervals (total 40 nos) and some cycles/benches stored.
d. Roof orientation: North, South, East, West
e. Shading: ~10–15% from trees (can be trimmed).
f. Condition:
   - Minor hairline cracks/seepage; some surface degradation.
   - No severe deterioration, sagging, or corrosion observed.
   - No past roof/ceiling repairs.
g. Access: Permanent staircase available.

h. Future Expansions: None planned

Rooftop Solar Potential

a. Total roof area = 13,507 sq.ft (1,254.5 sq.m)
b. Effective usable area (excluding east roof, concrete columns, considering shading from trees and technical deductions) = **738.86 sq.m**
c. The roof can install solar capacity of **61.6 kWp** (As per MNRE, ~12 sq. m. of rooftop space is required per 1 kWp of installed solar capacity)
d. Annual energy consumption: **15,424 kWh/year**
e. RTS Capacity Requirement: (Annual energy generation/ Annual Solar Generation per kW (1KW of solar generates 1314 kWh annually)) = kWh/ 1314 kWh = **11.7 kWp**

Findings

The usable roof area can meet **100%** of the building's RTS requirement, with additional capacity available for exporting surplus electricity to the grid. However, structural strengthening and waterproofing treatment of the roof will be required prior to installation.

Return of Investment and Payback period

a. Total investment to install 12kW = 12 x 55,000 = **Rs 6,60,000**
b. Payback Period = Total Investment/ Annual Solar Electricity Savings = 6,60,000 / 1,29,298= **5 years**
c. Return of Investment = (Annual Solar Electricity Savings / Total investment) *100 = (1,29,298 /6,60,000) *100 = **20%**
d. Annual Solar Electricity Generation for 12 kW = 12 x 1314 = **15,768 kWh/year**
e. Annual GHG Emissions = 15,768 X 0.727= **11,463 kgC02/year (~11 tC02/year)**

Site Images

Figure 14 School 27 and 28 : Courtyard

Figure 15 School 27 and 28 : Terrace (1)

Figure 16 School 27 and 28 : Terrace (2)

Figure 17 School 27 and 28 : Terrace (3)

12.2 Typology: Auditorium

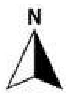

Figure 18 Sadubhau Bhore Natyagrug : Top View

Name	Sadubhau Bhore Natyagruh
Location	Hirawadi, Panchvati, Nashik
Construction Year	2023
Floors	G +2
Occupancy	230 seats (~ 20 support staff)
Operational Hours and Days	8 hours (currently not operational/ unspecified days)
Amenities on roof	None

Technical Assessment

a. Phase: Cubical HT (three phase)
b. Metering: Digital meter
c. Major Electrical Equipment: extensive lighting (many LED fittings), pumps, motors, ACs, parcan/spot/flood lights, fans, TVs, sound/CCTV/PA etc. (list attached in annexure C)
d. Total connected load: 252.34 kW
e. Backup: 320 kVA DG
f. Condition: Good (Recently completed construction)

Structural Assessment

a. Roof type: RCC flat roof, main auditorium roof is PUF sheet (slightly angled).
b. Roof area: 11,698 sq.ft (out of which 7,823 sq. ft is the PUF roof area)
c. Amenities on roof: None
d. Roof orientation: Longer (N-S)
e. Shading: None
f. Condition: New construction, no defects, no visible cracks on ceiling of the top floor
g. Access: Permanent staircase for terraces; temporary staircase required for PUF area installation
h. Future Expansions: None planned

Rooftop Solar Potential

a. Total roof area = 11,698 sq.ft (1086.7 sq.m)
b. Effective usable area = **869.36 sq.m** (deducting self-shading roofs and technical considerations)
c. The roof can install solar capacity of **72.44 kWp** (As per MNRE, ~12 sq. m. of rooftop space is required per 1 kWp of installed solar capacity)
d. Annual energy consumption[91]: (Connected load x Daily operating hours x Operating Days in a year) = 252.34 x 8 x 365 = **7,36,832.8 kWh/year**
e. RTS Capacity Requirement: (Annual energy generation/ Annual Solar Generation per kW (1KW of solar generates 1314 kWh annually) = kWh/ 1314 kWh = **560.7 kWp**

Findings

The usable roof area can meet **13%** of the building's RTS requirement. The main auditorium is covered with PUF (Polyurethane Foam) sheet roofing, which unlike conventional concrete roofs cannot directly support the weight of PV modules and mounting structures. Hence, specialized strategies such as elevated mounting frames, non-penetrative support systems, or lightweight ballasted structures will be required to ensure both the stability of the panels and the integrity of the roof.

Investment and Payback

a. Total investment = 72.44 x 55, 000 = **Rs 39,84,200**
b. Payback Period = Total Investment/ Annual Solar Electricity Savings = 39,84,200 / 10,75,604= **4 years**
c. Return of Investment = (Total Annual Savings / Total investment) *100 = (10,75,604/ 39,84,200) *100 = **27%**
d. Annual Solar Electricity Generation for 72.44 kW = 72.44 x 1314 = **95,186.16 kWh/year**
e. Annual GHG Emissions = 95,186.16 X 0.727 = **69,200.34 kgC02/year (~69.20 tC02/year)**

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[91] Unit rate as per MSEDCL tariff rates inclusive taxes (As the building is currently non-operational, electricity bills are not available. Therefore, the annual electricity consumption has been manually calculated.)

Site Images

Figure 19 Sadubhau Bhore Natyagrug : Roof view

Figure 20 Sadubhau Bhore Natyagrug : North Facade

Figure 21 Sadubhau Bhore Natyagrug : West Facade

Figure 22 Sadubhau Bhore Natyagrug : South Facade

12.3 Typology: Hospital/ Treatment Centre

Figure 23 Atal Divyang Bhavan - Top view

Name	Atal Divyang Bhawan
Location	Mumbai Naka, Vinay Nagar, Nashik
Construction Year	2023
Floors	G +4
Operational Hours and Days	8 hours (currently not operational/ unspecified days)
Amenities on roof	None

Technical Assessment

a. Phase: Cubical HT (three phase)
b. Metering: Digital meter
c. Major Electrical Equipment: LED lights, Ceiling Fans, Exhaust Fans, Water Heater, Water Cooler, Water Purifier, LCD Projector, AC, Borewell Pump, Filtration Plant, Lift, LED TV, PA System, Miscellaneous (list attached in Annexure C)
d. Total connected load: 121.82 kW
e. Backup: 125 kVA DG
f. Condition: Recently completed construction

Structural Assessment

a. Roof type: RCC flat roof, central part has corrugated tin roof supported by trusses
b. Roof area: 6,883 sq.ft
c. Amenities on roof: None
d. Roof orientation: Southwest, Southeast, North
e. Shading: None
f. Condition: New construction, no defects, no visible cracks on ceiling of the top floor
g. Access: Permanent staircase for terrace
h. Future Expansions: None planned

Rooftop Solar Potential

a. Total roof area = 6,883 sq.ft (639.4 sq.m)
b. Effective usable area = **511.52 sq.m** (considering technical deduction)
c. The roof can install solar capacity of **42.6 kWp** (As per MNRE, ~12 sq. m. of rooftop space is required per 1 kWp of installed solar capacity)
d. Annual energy consumption: **10,767 kWh/year**
e. RTS Capacity Requirement: (Annual energy generation/ Annual Solar Generation per kW (1KW of solar generates 1314 kWh annually)) = kWh/ 1314 kWh = **8.19 kWp**

Findings

The usable roof area can meet **100%** of the building's RTS requirement, with additional capacity available for exporting surplus electricity to the grid.

Investment and Payback

a. Total investment = 42.6 x 55, 000 = **Rs 23,43,000**
b. Payback Period = Total Investment/ Annual Solar Electricity Savings = 23,43,000 / 6,32,533= **4 years**
c. Return of Investment = (Annual Solar Electricity Savings / Total investment) *100 = (6,32,533/ 23,43,000) *100 = **27%**
d. Annual Solar Electricity Generation for 42.6 kW = 42.6 x 1314 = **55,976 kWh/year**
e. Annual GHG Emissions = 55,976 X 0.727 = **40,695 kgC02/year (~41 tC02/year)**

Site Images

Figure 24 Atal Divyang Bhavan - Entrance

Figure 25 Atal Divyang Bhavan - East Facade

Figure 26 Atal Divyang Bhavan - Terrace (1)

Figure 27 Atal Divyang Bhavan - Terrace (2)

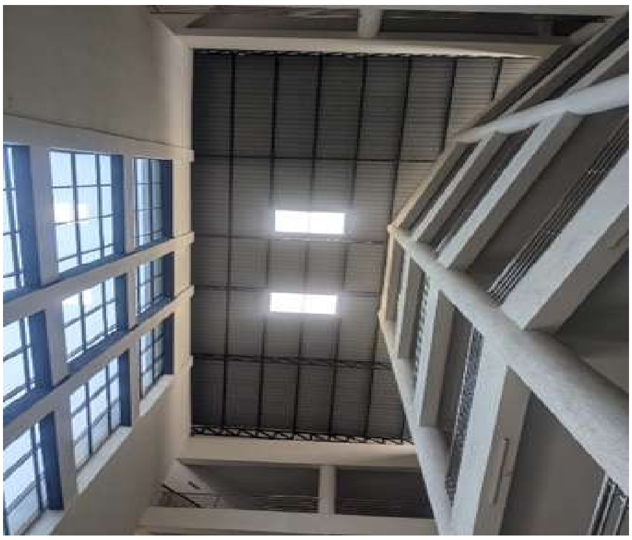

Figure 28 Atal Divyang Bhavan - corrugated tin roof

12.4 Typology: Water Treatment Plant

1. Clear Water tank
2. Admin Building
3. Annex Building
4. Filterbed – overhead tank
5. Chemical plant
6. Centrifugal Plant
7. Exland Building
8. Staff quarters

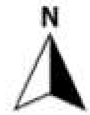

Figure 29 Vilhodi Water Treatment Plant: Site Map

Name	Vilhodi Water Treatment Plant
Location	Vilhodi, Nashik
Construction Year	2018
Floors	11 blocks, mix of G, G+1
Operational Hours and Days	24 hours, 357 days
Amenities on roof	Vents, mumty areas, mostly clear

Technical Assessment

a. <u>Phase:</u> Cubical HT (three phase)
b. <u>Metering:</u> Digital meter
c. <u>Major Electrical Equipment:</u> Pumps, Transformers, Agitators, Blowers, Ac, Fridge, Oven, Computers, UPS, Smart TV, LED lights
d. <u>Total connected load:</u> 6.9MW
e. <u>Backup:</u> 250 kVA DG
f. <u>Condition:</u> All electrical equipment in good condition, all properly enclosed wires

Structural Assessment

a. <u>Roof type:</u> RCC flat roof
b. <u>Roof area:</u> 40,353 sq.ft (8 feasible buildings)
c. <u>Amenities on roof:</u> Scattered vents on Clear Water Tank, Mumty area on Staff building, Trees on Exland building (to be cleared).
d. <u>Roof orientation:</u> Southwest, Southeast,
e. <u>Shading:</u> None, except for Exland building (due to existing trees)
f. <u>Condition:</u> No defects, no visible cracks on ceiling of the top floor
g. <u>Access:</u> Permanent staircase for terrace, except for the Filter Bed overhead tank terrace
h. <u>Future Expansions:</u> None planned

Rooftop Solar Potential

a. Total roof area = 40,353 sq.ft (3,749.2 sq.m)
b. Effective usable area = **2,624 sq.m** (considering vents, mumty areas and technical deduction)
c. The roof can install solar capacity of **218.6 kWp** (As per MNRE, ~12 sq. m. of rooftop space is required per 1 kWp of installed solar capacity)
d. Annual energy consumption: **7,17,245 kWh/year**
e. RTS Capacity Requirement: (Annual energy generation/ Annual Solar Generation per kW (1KW of solar generates 1314 kWh annually)) = kWh/ 1314 kWh = **545.8 kWp**

Findings

The usable roof area can meet **40%** of the building's RTS requirement.

Investment and payback

a. Total investment = 218.6 x 55,000 = **Rs 1,20,23,000**
b. Payback Period = Total Cost/ Annual Solar Electricity Savings =1,20,23,000/ 32,45,817= **4 years**
c. Return of Investment = (Total Annual Solar Electricity Savings / Total investment) *100 = (32,45,817/1,20,23,000) *100 = **27%**
d. Annual Solar Electricity Generation = 218.6 x 1314 = **2,87,240.4 kWh/year**
e. Annual GHG Emissions = 2,87,240.4 X 0.727 = **2,08,823 kgC02/year (~209 tC02/year)**

Site Images

Figure 30 Clear Water Tank

Figure 31 Administration Building

Figure 32 Annex Building

Figure 33 Centrifugal and Staff Building

Figure 34 Exland Building

Figure 35 Vilhodi Water Treatment Plant: Site Model

12.5 Project Profile Impact and Recommendations

The Table 13 below outlines the projected solar energy generation potential across four municipal building typologies and quantifies the associated greenhouse gas (GHG) emissions reduction achievable through their RTS deployment.

Table 13 Project Profile Impact for Building Typologies

Municipal Buildings (by Typology)	Total number	Buildings with RTS Installed	RTS Capacity Installed (kW)	Technical RTS potential per building (kW)	Aggregated RTS technical potential (kW)	Annual Solar Energy Generation (kWh)	GHG Emissions reduction potential (tC02/year)
Smart schools	88			12	1056	13,87,584	1,008.77
Hospitals & Nursing Homes	24	3	124.40	42.60	894.60	13,38,966	973.43
Auditorium	6	2	121.83	72.44	289.76	5,40,829	393.18
Water Treatment Plant	1			218.60	218.60	2,87,240	208.82
Total	**119**	**5**	**246.23**	**345.64**	**2458.96**	**35,54,620**	**2,584.21**

Recommendations

Typology: Schools

- Schools have the potential to meet 100% of their electricity requirements through RTS and export surplus to the grid. However, prior to installation, the school terraces need to undergo structural strengthening and waterproofing. Additionally, the existing single-phase meter needs to be replaced with a three-phase meter along with a net meter to facilitate smooth RTS integration.

- It is recommended to adopt an aggregated Public-private partnership: Build-Own-Operate (PPP-BOO) model, wherein a private developer finances, installs, and operates the solar system, retaining ownership through rooftop leasing, while the schools procure electricity via a Power Purchase Agreement (PPA).

Typology: Auditorium

- The auditorium assessed can utilize RTS to meet 13% of its electricity requirements; however, the main PUF sheet roof cannot directly support conventional PV modules. Prior to installation, it is recommended to deploy specialized elevated or ballasted mounting structures to protect roof integrity and ensure panel stability

- Based on the available capital, NMC can opt for either an Engineering, procurement and construction (EPC) model, where the municipality finances and owns the system, or a RESCO lease model, where a private developer finances, installs, and operates the rooftop solar system, and the auditorium procures electricity via a PPA.

Typology: Hospital/ Treatment Centre

- The building assessed has the potential to meet 100% of its electricity requirements through rooftop solar and export surplus to the grid. The RCC flat roof, along with the centrally located corrugated tin roof supported by trusses, is structurally sound, allowing direct installation of PV modules using standard mounting structures.

- Based on the capital available, NMC can choose an EPC model, where the municipality finances and owns the system, or a RESCO lease model, where a private developer finances, installs, and operates the rooftop solar system, and the building procures electricity through a Power Purchase Agreement (PPA).

Typology: Water Treatment Plant

- The Water Treatment Plant can utilize rooftop solar to meet approximately 40% of its electricity requirements. The RCC flat roofs across the eight feasible buildings are structurally sound and suitable for standard PV module mounting; minor obstructions such as vents, mumty areas, and trees (on the Exland building) need to be carefully considered while planning to maximize the usable rooftop area for RTS installation.

- Given the scale of the installation and available capital, NMC can consider an EPC model, where the municipality finances and owns the system, or a RESCO lease model, where a private developer finances, installs, and operates the system while the plant procures electricity through a PPA. Implementing robust O&M protocols, including preventive maintenance and continuous performance monitoring, will ensure optimal system efficiency and longevity.

Way Forward

The High-Impact Action Roadmaps presented in this compilation demonstrate that Maharashtra's cities are increasingly well positioned to move from climate ambition to implementation. Across diverse urban contexts—ranging from large metropolitan regions to rapidly growing secondary cities—the roadmaps show that targeted interventions in the energy and buildings sector can deliver significant emissions reductions while also improving thermal comfort, reducing operating costs, and strengthening urban resilience.

Collectively, the roadmaps highlight the importance of prioritising actions that are technically feasible, financially viable, and institutionally deliverable within existing governance frameworks. By focusing on high-impact levers such as energy efficiency in municipal and residential buildings, rooftop solar deployment, cool and green roofs, and decentralised renewable energy systems, the roadmaps establish clear pathways for near- and medium-term implementation. Importantly, they embed considerations of financing, stakeholder coordination, and monitoring from the outset—ensuring that climate action planning is grounded in delivery realities.

The findings also underscore the value of a state-enabled, city-led approach to decarbonisation. The Maharashtra City Decarbonisation Roadmap has provided a common framework that allows cities to tailor solutions to local needs while maintaining alignment with state and national climate priorities. This balance between standardisation and flexibility will be critical for scaling impact across the remaining cities in Maharashtra and beyond.

As cities transition into the next phase of implementation, sustained institutional support, capacity building, and access to finance will be essential. The roadmaps developed under this phase offer a strong foundation for this next step—signalling readiness for deeper investment, partnerships, and action. Together, they represent a practical and replicable model for accelerating clean energy and low-carbon buildings in Indian cities, contributing meaningfully to India's broader climate and development goals.