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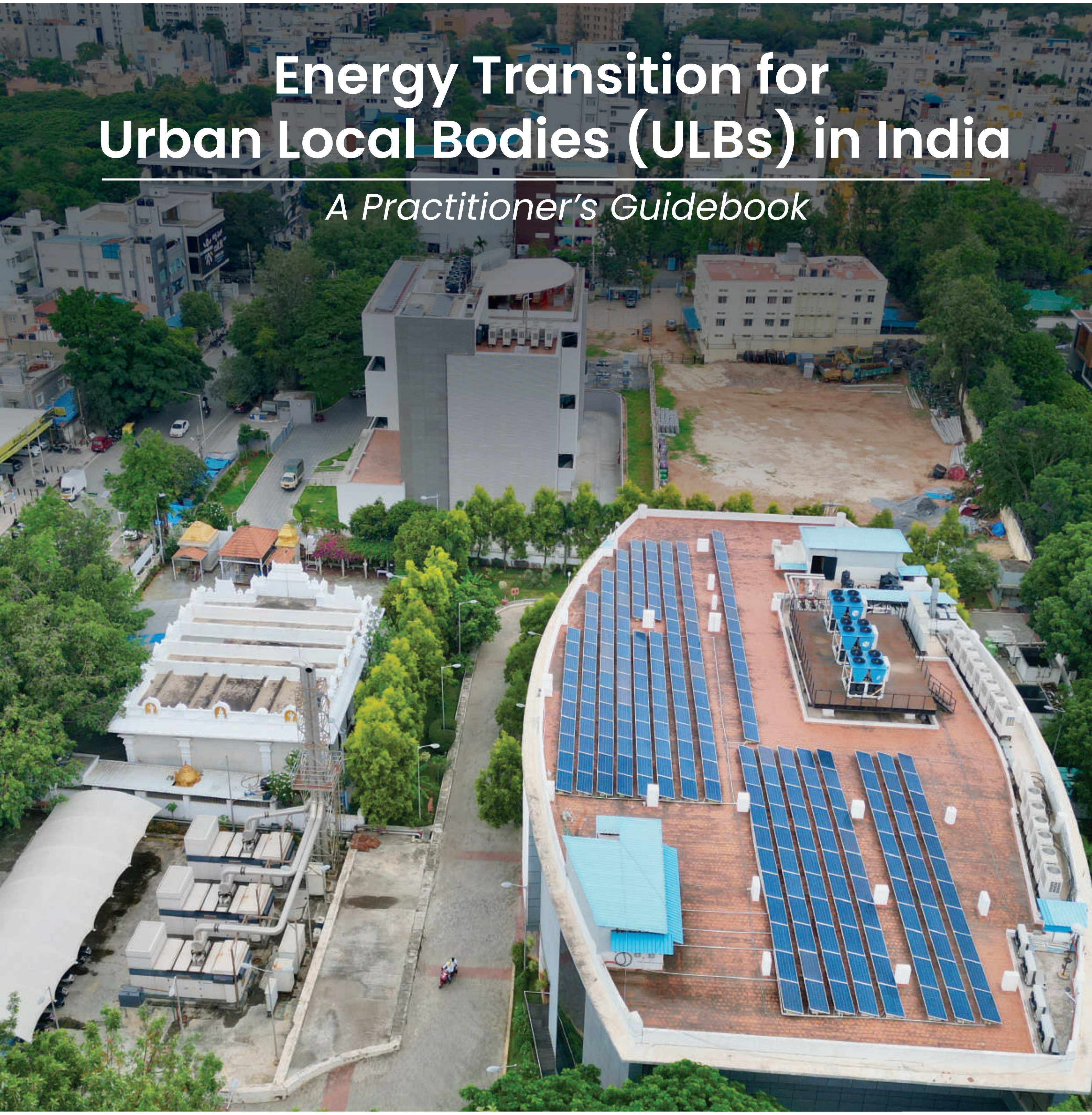
Energy Transition for Urban Local Bodies (ULBs) in India

A Practitioner's Guidebook



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Acknowledgement and Disclaimer

Prepared under:
This publication has been prepared with support from The Global Programme Climate Change and Environment (GPCCE) of the Federal Department of Foreign Affairs (FDFA) represented by the Swiss Agency for Development and Cooperation (SDC), prepared under the SDC funded "Capacity Building for Low-carbon and Climate Resilient City Development in India (CapaCITIES)" project.

Year of Publishing:
2026

Suggested Citation:
ICLEI South Asia (2026). Energy Transition for Urban Local Bodies (ULBs) in India: A Practitioner's Guidebook. Prepared under SDC supported "Capacity Building for Low-carbon and Climate Resilient City Development in India (CapaCITIES) project"

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Abbreviations

BESS	Battery Energy Storage System
CUF	Capacity Utilisation Factor
DG	Diesel Generators
DISCOM	Distribution Company (Electrical)
EC	Energy Conservation
EE	Energy Efficiency
EV	Electric Vehicle
GHG	Greenhouse Gases
MLD	Million Litres per Day
MRV	Monitoring, Reporting and Verification
O&M	Operations and Maintenance
PPA	Power Purchase Agreement
PV	Photovoltaics
RE	Renewable Energy
RTPV	Rooftop Solar Photovoltaic
SDG	Sustainable Development Goals
STP	Sewage Treatment Plant
SWM	Solid Waste Management
T&D	Transmission and Distribution
ULB	Urban Local Body
WDS	Water Distribution System
WtE	Waste-to-Energy
WTG	Wind Turbine Generator
WTP	Water Treatment Plant

Executive Summary

India's urban centres are emerging as the country's primary growth engines, contributing significantly to economic development, infrastructure expansion, and public service delivery. Rapid urbanisation has increased the demand for energy-intensive municipal operations such as water supply and distribution. India's ambitious long-term development and climate commitments, including the vision of Viksit Bharat 2047 and the transition to net-zero emissions by 2070, underscore the vital role of Urban Local Bodies (ULBs) in advancing sustainable, low-carbon development pathways. As major power consumers in urban areas, ULBs can drive the energy transition by implementing initiatives across municipal infrastructure and service delivery.

This guidebook can assist ULBs in planning, prioritising, financing, and implementing energy transition interventions across municipal service operations. It can help decision-makers identify suitable opportunities for energy conservation (EC), energy efficiency (EE), and renewable energy (RE) solutions, and assess various technology and integration options, regulatory considerations, financing strategies, and implementation planning. Recognising that cities differ significantly in infrastructure readiness, institutional capacities, and resource availability, the guidebook suggests a diverse range of approaches and strategic considerations rather than prescribing a singular implementation pathway.

The guidebook emphasises reducing energy demand as a cost-effective intervention compared to RE integration, highlighting the significance of EC and EE measures. It discusses the value of energy audits, electricity bill analysis, and energy data management for municipal operations. Interventions such as efficient pumping systems, LED street lighting, infrastructure improvements (EE retrofitting), and optimisation of municipal service operations can substantially reduce electricity consumption and operational costs.

Further, the guidebook presents various RE technologies suitable for municipal service operations in ULBs, such as rooftop solar, hybrid RE systems, bioenergy, and emerging technologies such as green hydrogen. It explains the different RE integration options, including on-site and off-site installations, and emerging innovative approaches. Also, considerations regarding regulatory charges, such as banking charges, in design and integration of RE projects are discussed to facilitate informed decision-making. Financing strategies and implementation models are vital for implementing energy transition initiatives, and this guidebook covers the various financing options, including municipal CapEx investments, grant funding, debt and market borrowings, hybrid finance, and innovative finance approaches. It also covers implementation models such as ESCO and RESCO arrangements, public-private partnerships (PPPs), and demand aggregation strategies that ULBs can choose to mobilise investments while managing financial risks, operational responsibilities, and project scalability.

The guidebook highlights key activities ULBs can undertake to ensure successful project delivery, focusing on quality assurance, prudent decision-making, monitoring, and institutional capacity building to achieve sustainable and scalable energy transition outcomes. For effective and successful implementation of energy transition initiatives, the guidebook concludes with a structured approach for municipal leadership and decision-makers that underscores the importance of prioritising proven, financially viable interventions, beginning with EC and EE measures, and then progressing to larger RE and advanced technological solutions.

01 Introduction

1.1 | Background

As India looks ahead to becoming a frontrunner in achieving net-zero and RE targets, cities will play a crucial role in this transition. India is the third-largest energy consumer in the world,[1] and the recent rapid growth in its power generation capacity is significantly driven by RE sources, particularly solar photovoltaics. As the country aims to become a developed nation by 2047, guided by its Viksit Bharat 2047 Vision, the next decade is critical to scale up its RE capacity, which has the potential to grow from a 43% share in 2025 to approximately 90% by 2050 under a net-zero pathway[2]

With more than 40 % of India's population expected to live in urban areas by 2030,[3] ULBs[4] will be driving this energy transition, serving as engines of development, innovation, and sustainability. Rapid urban population growth, ageing infrastructure, inefficient assets, and climate stresses are increasing energy demand and the costs of municipal services, such as water supply, drainage, waste management, street lighting, and public mobility. Thus, advancing the sustainable energy transition is essential for ULBs to enhance EE, improve energy access, optimise long-term expenditures, and support sustainable urban development.

ULBs face several challenges in advancing the sustainable energy transition, including fragmented decision-making, limited institutional and resource capacity, and frequent turnover among administrative officials and decision-makers. City officials also require technical capacity building on enabling policy frameworks, financing schemes, prioritisation of interventions, performance-driven procurement, data analytics and implementation models to support evidence-based solutions for low-carbon and energy-efficient municipal infrastructure and service delivery.

The ability of cities to plan and manage their sustainable energy transition will play a key role in determining India's sustainable growth trajectory over this period. This guidebook will help ULBs make informed and strategic decisions to advance the energy transition in municipal operations by strengthening their understanding of technical solutions, policy and regulatory frameworks, financing mechanisms, and implementation strategies for sustainable energy transition. It offers a strategic perspective on prioritising high-impact, short-term solutions that can yield immediate cost savings and deliver tangible energy-saving outcomes.

1 Stanford (2026). Understand energy in India. https://understand-energy.stanford.edu/news/understand-energy-india

2 NITI Aayog (2026). Scenarios towards Viksit Bharat and Net Zero - Sectoral Insights: Power. https://niti.gov.in/sites/default/files/2026-02/Scenarios-Towards-Viksit-Bharat-and-Net-Zero-Sectoral-Insights-Power.pdf

3 Economic Survey of Rural-Urban Population. [Press Release] https://www.pib.gov.in/PressReleaseIframePage.aspx?PRID=2042542®=3&lang=2

4 An Urban Local Body (ULB) is the governing administrative tier responsible for managing and developing cities and towns

1.2 | What does Energy Transition Mean for ULBs

ICLEI South Asia's analysis of 13 Indian cities revealed that the water supply sector contributes to more than half of municipal electricity consumption due to energy-intensive pumping operations. Wastewater management and water supply alone account for 74% of the municipal electricity consumption, requiring targeted interventions such as retrofitting or replacing inefficient pumps to reduce electrical consumption, lower peak demand, reduce monthly energy bills, and improve reliable service delivery, especially in water and wastewater facilities with high tension (HT) pumping loads. Streetlighting, municipal buildings, and other facilities such as municipal offices, hospitals, and community halls account for the remaining electricity consumption, as shown in Figure 1.

54% Water Supply and Distribution

20% Wastewater Management

20% Streetlights

6% Municipal Buildings and Others

Figure 1: Share of electricity consumption across municipal facilities[5]

Apart from electricity consumption, ULBs also use conventional fuels for various purposes, such as CNG (Compressed Natural Gas) for the municipal transport fleet. For ULBs, the sustainable energy transition is the shift from conventional, carbon-intensive energy systems to cleaner, sustainable, and energy-efficient systems. It is not only about reducing emissions but also about enhancing service delivery efficiency and lowering operational costs, which requires integrated planning, institutional coordination, and effective use of data and technology.

Sustainable energy transition for cities encompasses adoption of RE, improved EE, and sustainable urban infrastructure, as broadly highlighted in Figure 2. ULBs should enhance EE to reduce overall energy demand, which can lower operating costs and optimise the RE capacity required to meet the energy demand. This, in turn, leads to lower capital and operational expenditure for RE infrastructure investments.

Enhancing EE and adopting RE can also offer several other benefits for the local community, such as reduced local pollution, increased green local jobs, improved energy access and security, and greater availability of capital to improve service infrastructure and delivery. Lower municipal energy demand also reduces transmission and distribution (T&D) losses, reduces overall power procurement costs for DISCOMs, and improves the financial health of the power sector. Through local policies, procurement practices, and regulatory tools, ULBs can actively drive wider energy transition across the city and serve as an example for households, businesses, and institutions.

5 Based on ICLEI South Asia's analysis of data from 13 municipal corporations (mix of Tier I, II, III cities of India)

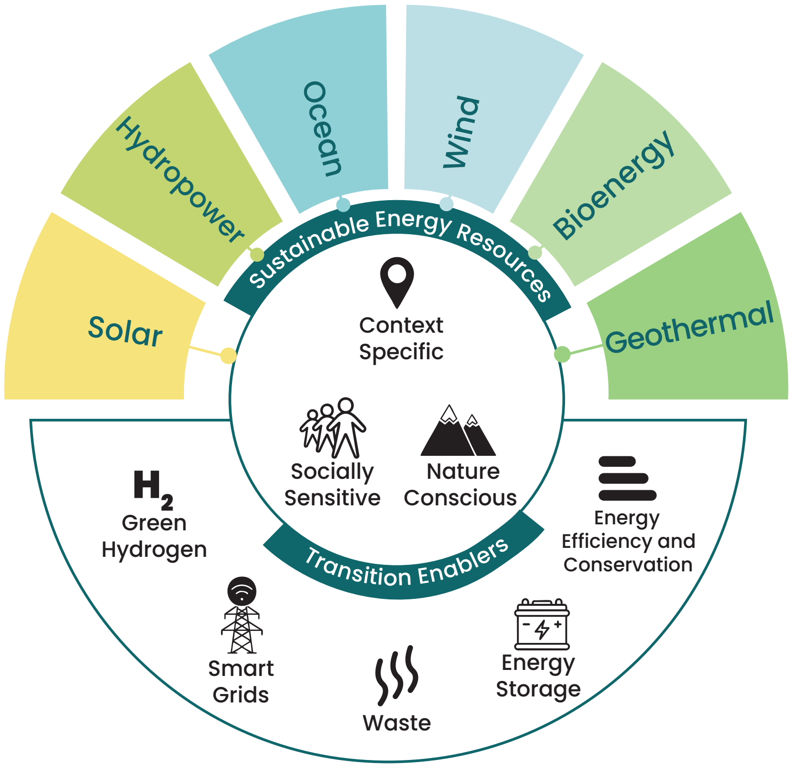

Figure 2 Energy Transition Wheel (Source: ICLEI World Secretariat)

1.3 | Policy, Regulatory, and Market Drivers for Clean Energy Transition

National and state-level regulatory frameworks, guidelines, policy initiatives, and financial support programmes have created an enabling environment for ULBs to adopt cleaner, more energy-efficient solutions. Examples include Eco-Niwas Samhita, Energy Conservation and Sustainable Building Code (ECSBC) 2024, AMRUT 2.0, PM E-drive Scheme, National Clean Air Programme (NCAP) and the Street Lighting National Programme, to name a few. These initiatives provide financial and technical support for interventions such as electrification of public transport and municipal fleet, waste-to-energy facilities, energy-efficient street lighting, and RE installations on public infrastructure, helping cities adopt low-carbon technologies while addressing urban service-delivery challenges.

Municipal energy transition must also account for tariff and operational instruments, such as banking provisions, deviation settlement mechanisms, TOD (time-of-day) tariffs, and other grid-management charges levied by electricity regulators and system operators as they affect project economics and operational feasibility. Further, the energy transition strategies must also consider the evolving policy and regulatory landscape driven by digitalisation and grid modernisation. Initiatives such as Advanced Metering Infrastructure (AMI), smart meters, and smart grid technologies are expected to improve demand side management, enable time-of-day tariffs, and enhance system transparency and efficiency.

02 Energy Conservation and Efficiency Strategies

Energy Conservation (EC) measures are interventions that reduce energy consumption without compromising processes or outputs, while EE refers to energy-efficient operations that result in output or performance improvements, energy, time, and cost savings, and lower maintenance requirements. ULBs can implement the following three key strategies to enhance EE in municipal operations.

2.1 | Optimising Energy Expenditure

Understanding the components of electricity billing is essential for ULBs to identify cost drivers and optimise energy expenditure. Table 1 outlines the key energy billing elements, their implications for municipal operations, and the actions ULBs can take to improve EE and reduce costs.

Table 1: Billing Elements and Optimising Strategies

Billing Component	Definition	Optimising Strategies
Demand Charges	Demand Charges refer to the charges levied by the DISCOM for the sanctioned load or Contract Demand (CD) (kW or KVa), approved for a particular municipal building or facility, based on the existing tariff order. Typically, demand charges are based on the actual maximum demand (MD), which is the maximum demand drawn by the consumer facility over 15-minute intervals. If MD>CD, consumers are charged based on MD. If MD<CD, the applicable charges typically range from 75% to 100% of the contract demand, depending on local laws.	Lowering the CD for a connection through detailed scrutiny of operating patterns and seasonal impact by analysing bills across 12 to 24 months can lead to cost savings in demand charges. This is a significant opportunity for ULBs to save upfront fixed electricity charges without CapEx interventions. However, reducing contract demand below average operational requirements will result in additional penalties or charges, ultimately leading to higher payments to DISCOMs. Therefore, the ULB should carefully analyse this to ensure that lowering CD accrues cost savings.
Power Factor (PF) Charges	PF Charges are levied by DISCOMS to ensure power quality and grid reliability. Lower power quality impacts DISCOMs by increasing wire heating, transformer overloading, and reducing grid reliability. Typically, if consumers maintain a Power Factor (PF) above a threshold, say 0.95, DISCOMs provide a rebate, while a deterioration in PF can result in penalties.	Several municipal operations of ULBs with energy-intensive loads, such as pumping stations, Heating, Ventilation and Air Conditioning (HVAC), and processing plants (compressors and induction motors), are heavily impacted by PF penalties. ULBs can invest in various measures to improve PF, such as capacitor banks or automatic power factor correction (APFC) panels near reactive loads, and receive rebates and lower electricity bills

Billing Component	Definition	Optimising Strategies
Time of Use (ToU) Charges	Time of Use (ToU) / Peak-demand Charges are typically applicable to High Tension (HT) facilities of the ULB, where additional charges (in addition to the normal tariff) are levied for drawing power during DISCOM's peak-demand hours, to prevent grid overload or network congestion. Some DISCOMs may also have provisions for off-peak charges (lower-than-normal tariffs), such as for consumption during solar generation hours.	These charges are unavoidable if ULB operations fall within the peak-demand hours defined by the DISCOM. However, careful planning by shifting non-critical loads to off-peak hours will result in financial savings to ULBs. For example, operating water storage pumps during off-peak hours can reduce time-of-use charges and maximum demand.
Night-time Concessional	Many state regulators offer concessions or rebates for electricity consumption during predefined night hours, especially for ULB operations. These rebates help DISCOMs reduce the daytime peak demand and improve grid management and reliability.	ULBs can reduce electricity costs by assessing and shifting the load of non-critical HT connections that qualify for night-time concession.
Delayed Payment Charges	This charge is a penalty levied by DISCOMs when a consumer does not pay their electricity bill by the due date. Usually, these penalties have a compounding effect and can also result in service disconnection when threshold durations are breached.	Ensuring financial and administrative discipline in budget allocation and in the timely approvals for energy bill payments can help ULBs avoid these penalties.

2.2 | Conducting Municipal Energy Audits

Undertaking energy audits at the municipal level will help identify inefficiencies, quantify energy savings, prioritise high-impact energy conservation and efficiency interventions with clear techno-commercial benefits, and enable facility-level energy benchmarking. Energy audits help ULBs establish the baselines required for verification and participation in market-based mechanisms such as Energy-Saving Certificates (ESCerts) and Carbon Credit Certificates (CCCs). ESCerts are tradable instruments issued against verified energy savings, while carbon markets (including India's new Carbon Credit Trading Scheme [CCTS]) enable the trading of verified emission reductions. Together, these mechanisms can support ULBs in generating additional revenue streams by monetising energy savings and accessing climate finance from development banks, philanthropies, and other sources.

Three types of energy audits can be conducted based on local needs, data availability, and institutional readiness of ULBs, as shown in Table 2, namely, walk-through, targeted or investment-grade energy audits. Walk-through audits are rapid assessments that identify quick EE gains with minimal effort. Targeted audits focus on performance improvements for high-energy systems, such as pumping or street lighting. Investment-grade audits include in-depth technical and financial analysis to support major capital investments. The guiding questions for conducting or reviewing municipal energy audits are given in Table 3.

Table 2: Type of energy audits (Reference: BEE[6])

Type of Energy Audit	Purpose	Expected Outcomes
Walk-through or Preliminary Energy Audit	Rapid, visual inspection to identify energy wastage and quick opportunities without detailed measurements.	Preliminary list of no / low-cost measures, rough savings estimates, and areas needing deeper analysis.
Targeted Energy Audit	In-depth assessment with data logging, measurements, and system performance analysis.	Accurate energy use baseline; quantified savings potential; technical recommendations; and cost-benefit analysis.
Investment-Grade Energy Audit OR Comprehensive Energy Audit	High-accuracy analysis to develop bankable projects, including financial modelling and risk assessment.	Detailed technical designs and savings estimate, financing plans, return-on-investment analysis and documentation

Table 3: Guiding Questions for Energy Audit

Audit Phase	Guiding Questions
Pre-Audit Phase	• What are the objectives of the energy audit? What are the outcomes of EE measures implemented by the ULB in the past, if any? • Which buildings and facilities have the highest energy consumption? Are building plans and electrical drawings available? • Are there any economic, legal, or financial constraints limiting the implementation of energy-saving measures? • What energy performance monitoring and data collection systems exist? • What permissions and safety standards are required for conducting energy audits?
Audit Phase	• What is the service life, condition, and maintenance history of major equipment? • Where do measurable energy losses occur, and does any system exist that can capture this data? • What opportunities exist for technological improvements to improve efficiency, reduce demand and shift loads? Are there procurement-related challenges in implementing these upgrades? • Which measures should be prioritised based on cost, savings potential, ease of implementation, payback period, risk and impacts on operational and service reliability?
Post-Audit Phase	• How will the impact of EE measures be monitored and verified (M&V)? • How can the capacities of management, department heads, and operating staff be strengthened to support implementation? • How can procurement processes be modified to enable energy-efficient equipment with timely implementation and competitive pricing? • What are the standard operating procedures (SOP) and mechanisms that will be established to sustain performance and meet energy benchmarking targets?

2.3 | Identifying and prioritising interventions

Based on energy audits, ULBs should identify EE interventions that can deliver tangible cost and energy savings across a range of municipal operations and facilities. Priority can be given to high-impact, no- or low-cost infrastructure measures and enabling actions such as creating awareness for behavioural change, developing supportive policies and institutionalising EE in municipal services through dedicated EE cells or officials in each department. Some of the common EE interventions relevant to municipal operations are presented in Table 4.

6 Bureau of Energy Efficiency (2015). General aspects of energy management and energy audit. Guidebook for National Certification Examination for Energy Managers and Energy Auditors

Table 4: Common energy efficiency interventions for ULB operations

Energy Efficiency (EE) intervention	Typical Energy Saving (%)	Typical Payback (years)	Potential intervention areas
Energy-efficient pumps (can be paired with variable frequency drives and SCADA-based monitoring)	20% to 50%	2 to 5	Municipal pumping facilities like water and sewage treatment plants, pumping and lifting stations
LED Lights (can be paired with automated timers or smart controls)	50% – 60%	1.5 to 2.5	Streetlights, office buildings, hospitals, and schools
EE equipment (such as BLDC fans), building envelope retrofits and	50% – 60%	2 to 3	Office buildings, hospitals, and schools
EE HVAC systems (equipment and behavioural changes)	10% - 25%	4 to 5	Office buildings, hospitals, community halls and indoor public facilities
Rooftop Solar PV systems (can be paired with net metering and battery storage)	30% – 50%	4 to 7	Office buildings, water treatment plants, schools, and hospitals
Building envelope improvements (cool roofs, insulation, efficient glazing)	10% - 25%	5 to 8	Office buildings, schools, hospitals, community halls, and affordable housing projects

ULBs can adopt a structured approach, such as the PDCA (Plan–Do–Check–Act) cycle, to plan and implement energy management interventions. Adopting such an approach enables systematic planning, implementation, performance monitoring, and corrective actions to enhance EE over time. Institutionalising the PDCA approach helps embed data-driven decision-making and accountability in municipal operations.[7] Table 5 outlines the purpose and key activities associated with each stage of the PDCA cycle for energy management.

Table 5: PDCA cycle for continuous energy management improvement

Plan	Do	Check	Act
Purpose Establish baselines, prioritise interventions and set goals and targets for energy savings	Implement energy-saving and operational improvement measures identified through the audit	Monitor, measure and verify (M&V) implemented energy-saving actions	Improve performance through corrective measures and refine interventions
Key Activities Defining scope, conducting energy audit, data collection and analysis, setting performance indicators and targets, and identifying and prioritising short-, medium-, and long-term energy-saving measures	Implementation of energy-saving measures and operational improvements across municipal operations and services	Monitoring and tracking energy savings through key performance indicators (KPIs), comparing energy consumption with respect to baseline, and identifying deviations	Implement corrective measures, standardise best practices and SOPs, and scale up successful Energy Efficiency (EE) measures

7 Guidelines for auditing management systems. (2018). [Book]. In ISO 19011 (Third edition). ISO. https://www.wyvernltd.com/wp-content/uploads/2022/11/ISO_19011_2018en.pdf

Case Example: Investment-grade energy audit for Kakinada's water pumping stations and municipal buildings

An investment-grade energy audit was conducted for Kakinada Municipal Corporation's (KMC) water pumps, along with an audit of KMC's main office, smart city office, and command and control centre. Key measures identified include replacing eight old pumps with energy-efficient pumps, which can save about 159,342 kWh of power and have a payback period of 2.21 years. For buildings, EE measures included BLDC fans, building envelope retrofits, and solar PV integration.

Case Example: Energy audit for Visakhapatnam's water and wastewater facilities

An investment-grade energy audit for Greater Visakhapatnam Municipal Corporation's water and wastewater facilities, supported by ICLEI South Asia and C40 Cities, identified potential for energy conservation, energy efficiency, and on-site renewable energy interventions. A total of 33 pumps, with capacities ranging from 30 to 500 kW, were identified for replacement at a cost of about INR 185 lakhs, with a simple payback period of one year. Improving the power factor (PF) up to 0.98 would require an investment of INR 20 lakhs, with a simple payback of 1.5 months.

Reference

03 Renewable Energy for Urban Local Bodies

Integrating RE into municipal operations is a key strategy for ULBs to reduce energy costs, lower carbon emissions, and strengthen long-term sustainability. However, the wide range of available technologies, financing structures, and regulatory provisions can often make decision-making complex and overwhelming. This section outlines the RE integration options relevant to municipal applications and provides guidance on how ULBs can strategically prioritise and maximise RE integration in line with their operational needs and local context.

3.1 | Technological Options for RE Integration

ULBs can choose from multiple technology options to integrate RE across municipal services and infrastructure. ULBs can deploy RE systems based on solar power (rooftop, ground-mounted, floating, canal-top, carport, solar thermal, and photovoltaic thermal [PVT] systems), wind energy (wind turbine generators and micro-wind turbines), hydropower, bioenergy, and hybrid renewable systems combining solar, wind, and battery energy storage systems (BESS). ULBs can also implement waste-to-energy plants, such as biomethanation and Bio-CNG plants, to manage waste while generating energy. Emerging technologies such as green hydrogen for power and clean transport applications, along with micro-hydro and geothermal systems, offer additional options for sustainable energy generation depending on local resource availability.

3.1.1 Solar Power

Rooftop Solar PV (RTPV): RTPV systems are a popular and scalable RE solution for ULBs, with relatively short development and implementation timelines, enabling ULBs to achieve early energy cost savings and visible progress in their energy transition efforts. Public buildings such as administrative offices, schools, hospitals, and community facilities are typically suitable for RTPV deployment, which can be chosen based on electricity demand, building age, structural suitability, shading conditions, and long-term facility usage. Furthermore, RTPV systems can be integrated into municipal utility infrastructure, including water treatment plants (WTPs), solid waste management (SWM) facilities, and bus depots that typically have stable daytime electricity demand, making them suitable for solar PV integration.

Ground-mounted Solar PV: Ground-mounted solar projects can be installed within or outside the premises of a ULB's municipal service facilities with HT connections, such as WTPs, SWM facilities, and buildings, based on long-term land availability, considering land requirements for infrastructure expansion over the next 20–25 years.

Floating Solar PV: Floating solar PV is an ideal option for ULBs with large water bodies within their jurisdiction or in the vicinity, such as lakes and reservoirs. However, feasibility analyses and due diligence, including bathymetry and hydrology surveys, environmental assessments, and techno-commercial viability assessments, must be conducted before selecting suitable sites. Essential safety protocols for project construction, operation, and maintenance must also be followed.

Case Example: Coimbatore's Floating Solar PV Plant at Periyakulam Lake

The Coimbatore City Municipal Corporation is the first urban local body in Tamil Nadu to install a floating solar power plant (FSPV) in a lake within the city. The 154 kWp capacity plant was deployed as a pilot project on Periyakulam Lake, which has the potential to support an 18-MWp floating solar PV plant.

The FSPV plant, costing INR 145 lakhs, was supported by equal contributions from the Tamil Nadu Govt's Namakku Naame Thittam (NNT) scheme and the CapaCITIES project, funded by the Swiss Agency for Development and Cooperation (SDC). The project is expected to generate 0.23 million kWh of electricity annually and, over its lifetime, will produce 5.7 million kWh.

Key Highlights:

- 280 units of 550 Wp Mono C-Si PERC solar panels
- 2 units of 75 kW string inverters
- 150 kVA (LV/11 kV) power transformer

Reference:

Canal-top Solar PV: Power generated from canal-top solar PV installed over suitable water canals, using specialised mounting structures, can be used to offset grid-based electricity consumption in ULB operations, such as irrigation or water-supply pumping. The projects can be implemented through joint partnerships with state government departments that typically manage irrigation canals under a captive or open-access model.

Car Pod / Parking Shade Arrangement: Solar PV can also be deployed at existing or upcoming car parking facilities with shadow-free space available. Solar power can be used for EV charging and other energy requirements within the parking premises.

Building Integrated Photovoltaics (BIPV): BIPV refers to solar installations integrated into building structures (typically vertical installations) where the solar PV panels also serve as tiles, windows, and other exterior building cladding. BIPV has high upfront costs and lower efficiency than conventional panels. However, it is ideal for high-rise buildings with limited roof space and can generate electricity while serving as part of the building envelope.

Solar Thermal: Solar thermal panels can be deployed where hot water or steam is required, such as hospitals, kitchens, guest houses and canteen facilities. Concentrated-type solar thermal panels use mirrors or lenses to focus solar radiation onto a surface, raising the heating medium to very high temperatures and are typically used for industrial or large-scale applications. On the other hand, non-concentrated solar thermal panels directly absorb solar radiation to heat water or other media and are suitable for commercial applications.

Photovoltaic Thermal (PVT): PVT systems are suitable for ULBs located in regions with lower atmospheric temperatures, such as hilly regions in the northern and north-eastern states of India. The panels can generate electricity and heat for operational needs and can be used for space heating, swimming pools, canteen facilities, and hospitals.

3.1.2 Wind Energy

Wind Turbine Generators (WTGs): ULBs can invest in installing wind turbine generators (WTGs) in high-wind resource areas to meet the electricity demand of energy-intensive facilities with HT loads, such as WTPs or STPs, under the open access model. WTG capacities typically range from 2 MW to 5 MW, depending on local wind resources, costs, and grid infrastructure availability, and can supply RE power during non-solar hours. While they offer higher generation per unit of installed capacity and require less space than solar, they entail higher upfront costs and greater generation variability.

Micro-Wind Turbines: Micro-wind turbines are small-scale wind electricity generation systems that typically range from a few watts to kilowatts in capacity and can be integrated into buildings, roads, or streetlight poles. They are suitable for coastal or high-altitude cities with steady wind flows and can be deployed as a hybrid system with solar PV and battery storage systems to enhance power generation and reliability.

3.1.3 Bioenergy

ULBs manage significant volumes of biodegradable waste, including food and garden waste, and animal residues. Energy generation from these waste streams through biomethanation can help cities reduce dependence on landfills, lower greenhouse gas emissions, and address waste management challenges. The resulting biogas can be purified to CNG standards (>96% purity), stored, bottled, and supplied to the market or used for power, heating, or cooling in municipal operations or as fuel for municipal transport fleets. Biomethanation / Bio-CNG facilities, when developed with careful project design, techno-commercial feasibility assessment, environmental safeguards, and regulatory compliance, can contribute to long-term sustainable waste management and energy transition efforts in cities.

Case Example: Udaipur's 20 TPD biomethanation plant

Udaipur city generates around 220 tonnes of waste per day (TPD), of which 68% is organic. As part of a sustainable waste management initiative, a 2-TPD biomethanation plant was developed under the CapaCITIES project, supported by the Swiss Agency for Development and Cooperation (SDC). The plant had the potential to reduce 1,437 tCO_2e at full capacity. This pilot effort led the city to develop a 20-TPD biomethanation plant under the Design, Build, Operate, and Transfer (DBOT) model. The plant, built and operated by Mahindra Waste to Energy Solutions Ltd (MWTESL), generates around 1600 m^3 of raw biogas per day, which is converted into around 600 kg of compressed biogas (CBG) per day, with a methane purity level of 93-96%. It has the potential to reduce CO_2e emissions by around 4,000 tonnes annually when operated at full capacity. The bottled CBG and biofertiliser from the plant are sold in the open market. Such waste-to-energy operations support the energy transition and add economic and sustainability value for city management.

Reference

3.1.4 Battery Energy Storage Systems (BESS)

BESS can enhance the reliability of RE power systems deployed by the ULBs by storing excess renewable generation and supplying power during periods of low generation or peak demand. BESS can be deployed on-site (e.g., integrated with rooftop solar installations) or off-site as part of larger solar, wind, or hybrid RE plants deployed off-site for captive use. BESS can also reduce reliance on diesel generators used for backup power when deployed alongside rooftop solar PV installations in municipal buildings and facilities. At larger scales, hybrid systems with storage can help manage generation variability, match supply with demand, and comply with local grid regulations.

3.1.5 Electric Vehicles Powered by Renewable Energy

Clean mobility is critical for ULBs to achieve their sustainable energy transition targets, reduce GHG emissions, and improve the local environment (air quality). Electric vehicles (EVs) may not be directly an RE technology or solution, but EVs powered by RE sources will assist ULBs in their energy transition journey while reducing the city's dependence on fossil fuels and operational costs.

ULBs can use EVs in municipal fleets and public transport, and wherever feasible, EV charging stations, transport hubs, bus stops, depots, and municipal parking facilities can be integrated with on-site rooftop solar systems. Larger bus depots can be integrated with off-site RE plants that will power their EV charging infrastructure. Solar-powered EV buses are typically deployed under Gross Cost Contract (GCC) arrangements, where the economics depend on the contracted per-kilometre rate, daily operating distance, and applicable government subsidies. These buses offer a daily range of about 220–330 km, with a typical payback period of 4 to 7 years.

Case Example: Ahmedabad's on-route EV charging station integrated with solar PV

Ahmedabad city adopted EV buses to drive the energy transition in its public transport and reduce emissions. The city implemented a pilot opportunity charging station for e-buses with a 120 kWp grid-connected rooftop solar system (comprising 550 Wp panels each), a robotic cleaning system, and a 240 kW EV bus charger (CCS II type with dual guns) in the existing Bus Rapid Transit System (BRTS) route managed by the Ahmedabad Municipal Corporation (AMC). The project was implemented in partnership with the CapaCITIES project, supported by the Swiss Agency for Development and Cooperation (SDC).

Key highlights include:

- Project cost: INR 15,700,000
- On-route charging for 40 to 45 electric buses
- Elimination of 120 hours of non-productive operations, and annual savings of INR 150 lakhs (by preventing dead running of EV buses to charging ports, charged at INR 55 per kilometre)
- The city is scaling up similar installations across the city for topping-up charging for EV buses, and preventing dead-running for charging needs

Reference

3.1.6 Hybrid Systems and Other Technologies

Hybrid Systems: Hybrid RE systems combine multiple technologies, such as solar, wind, and BESS to improve reliability, maximise RE utilisation, and reduce electricity costs in municipal operations. Large municipal facilities such as water and sewage treatment plants typically operate round the clock. Solar PV generation can offset daytime loads while wind power can complement energy supply during late evening and early morning hours.

Green Hydrogen: Green hydrogen, produced through electrolysis powered by RE, represents an emerging opportunity for the energy transition in municipal transport and as a clean fuel. Potential uses include integrating electrolysers with RE installations and utilising treated wastewater for electrolysis. The generated hydrogen can be used in fuel cells to generate electricity, in municipal public transport fleets, or blended into the local gas distribution network for residential and commercial applications. Hydrogen demand and supply, especially for the public transport sector, can be planned through medium- to long-term agreements with nearby private developers, industries, or suppliers.

Micro-hydro: ULBs located near rivers or natural streams can explore micro-hydropower for electricity generation. The generated power can be used to run nearby ULB facilities or integrated with the local grid. Before implementation, ULBs should assess seasonal water availability, flow consistency, environmental clearances, and integration with existing infrastructure to ensure technical and financial viability.

Geothermal: Geothermal energy is a highly site-specific renewable resource that can be explored by ULBs located near geothermal belts[8] (Himalayan belt, West Coast, Narmada-Tapi-Godavari-Mahanadi basins, and the Cambay region) or areas with favourable subsurface thermal gradients (i.e., areas with sufficient subsurface temperature difference). Where feasible, geothermal resources can be utilised for electricity generation, district heating or cooling, and efficient air-conditioning systems in municipal buildings. ULBs should conduct geological assessments and feasibility studies to evaluate resource availability, long-term sustainability, and integration with local energy infrastructure before considering deployment.

3.2 | Options for RE integration into municipal buildings and facilities

RE can be integrated into municipal operations through multiple approaches, depending on infrastructure availability, regulatory provisions, and the feasibility of projects for existing or upcoming facilities to meet part or all of the energy demand. ULBs may adopt on-site installations, such as rooftop solar on municipal buildings, or off-site RE procurement through grid-connected ground-mounted solar, wind, or hybrid projects. Innovative approaches may be considered where permitted under policy and regulatory provisions.

Different options of RE integration approaches for ULBs are shown in Table 6. The choice of approach should be guided by state energy policies and regulations, local DISCOM infrastructure readiness, and techno-commercial feasibility assessments to ensure reliable and cost-effective integration.

8 Chouhan et al, 2024. Assessment of the geothermal potential zone of India utilizing GIS-based multi-criteria decision analysis technique. Renewable Energy. https://doi.org/10.1016/j.renene.2024.120552

Table 6: Type of RE integration options for ULBs

Onsite	• Net metering • Gross metering • Net billing • Behind the Meter Storage
Offsite	• Open Access (Captive Consumption, Third Party Sale) • Group Net Metering
Innovative approaches	• Green Power Purchase from DISCOM • Virtual Power Purchase Agreement (VPPA) • Peer-to-Peer(P2P) Energy Trading • Ancillary Services

3.2.1 Onsite RE Integration

On-site RE integration involves connecting the RE source directly to the consumer's premises, before the utility's (or DISCOM's) meter. The most common example of on-site RE integration for a ULB is rooftop solar PV (RTPV) installations. Different RE setoff mechanisms for on-site RE integration are explained below, and a comparison is shown in Table 7.

Net Metering: This mechanism offsets RE against electricity consumed from the grid, whereby surplus energy can be reimbursed, and for deficit energy units, charges will be levied on the consumer as per state regulations.

Gross Metering: Under this mechanism, all solar power generated is exported to the grid at the fixed feed-in-tariff (FiT), and consumers purchase their electricity separately from the grid at the normal retail tariff.

Net Billing: This is a modified net metering provision under which the exported solar power is credited at a predefined tariff determined by local regulations and policies, while imported grid power is charged at the normal retail tariff.

Table 7: Comparison of on-site RE setoffs

	Net Metering	Net Billing	Gross Metering
Benefits to ULBs	Surplus generation can be exported to the grid and adjusted against consumption. This mechanism is often more economically beneficial to ULBs.	Promotes self-consumption of RE power, and surplus energy is sold at a fixed tariff. Offers better benefits than gross metering, particularly when self-consumption of all RE power is maximised.	Generation is sold at a fixed tariff. This is better suited for installations beyond permitted on-site solar capacities, as it provides predictable, regular cash flow.
Critical Considerations	Regulatory limits for maximum system capacity, along with settlement period and other charges.	Existing tariff rates and export tariffs must be evaluated. BESS can be explored when the price of exporting power is lower to maximise self-utilisation.	Since this is more beneficial to DISCOMs, ULBs can deploy RE plants if they are economically viable and secure a long-term agreement (at least 10 years) with the DISCOM.

ULBs can explore deploying behind-the-meter (BtM) energy storage systems such as BESS[9] along with RE deployment, as it will allow for maximising on-site RE use and reducing grid injection. Further, energy storage can assist ULBs in reducing maximum demand, charges, and peak demand charges (defined in later sections), and can also serve as an emergency backup system when deployed alongside on-site RE plants. Further, ULBs can replace existing DG sets with BESS, integrated with RE, as per the Electricity (Rights of Consumers) Amendment Rules, 2022.[10]

3.2.2 Offsite RE Integration

Offsite RE integration involves installing or procuring RE plants at a remote location, outside the consumer's facility, with energy consumption settled through the consumer's utility (or DISCOM) meter. This process is primarily governed by open access (OA) regulations in India. Since off-site integration is not limited by space constraints, the scale of off-site RE integration is typically larger than that of on-site RE integration. Such large-scale off-site RE installations help ULBs transition energy-intensive loads to RE power without practical constraints such as land availability. Some off-site RE integration options suitable for a ULB are explained below.

Open Access: Open access is a regulatory mechanism that allows eligible consumers to purchase or integrate RE directly from generating sites using existing grid infrastructure. This mechanism allows consumers the flexibility to procure power from sources other than local distribution companies. Based on local regulations, it is typically explored for RE power plants with capacities greater than or equal to 1 MWp, and contracts typically range from short-term (up to 1 year) and medium-term (1 to 5 years) to long-term (beyond 5 years). The intra-state operations of open access are typically managed by the State Load Dispatch Centre (SLDC), while interstate operations are coordinated by the Regional Load Dispatch Centre (RLDC). Broadly, two types of open access mechanisms are most suitable for ULBs to integrate RE, as described below.

- **Captive and Group Captive Open Access model:** Under the captive model, the ULB facilities must consume at least 51% of the RE electricity generated annually, with the ULB making at least a 26% equity investment in the RE generating plant. Group captive open access allows multiple ULB facilities to use the RE generated from a common RE project.

- **Third Party Sale:** ULBs with limited financial resources and capacity to implement RE plants under the captive open access model, due to high upfront investment costs and operational risks, may opt for a third-party sale mechanism. In this model, a private or independent power producer develops, finances, and operates the RE project and supplies electricity to the ULB under a medium- to long-term Power Purchase Agreement (PPA) at a mutually agreed tariff. This approach transfers investment, procurement, and O&M responsibilities to the developer, though electricity costs may be higher compared to captive or group captive models.

Group Net Metering: Group net metering allows electricity generated from a single RE installation to be distributed to multiple ULBs, typically connected with the same DISCOM. This mechanism is particularly useful for ULBs where several municipal buildings have limited rooftop space or are technically unsuitable for solar installations. The RE settlement shall be proportional to the share

9 BtM storage: This has a configuration of electrical storage (BESS) before the DISCOM meter (i.e., consumer side)
10 Electricity (Rights of Consumers) Amendment Rules, 2022, Ministry of Power, India (2022). [Press release] https://powermin.gov.in/sites/default/files/Electricity_Amendment_Rules_2022.pdf

ratio defined in the project development phase. Implementation, however, remains subject to state-specific regulations and DISCOM operational provisions.

3.2.3 Innovative RE integration approaches

Numerous emerging models are in the early or pilot stages, or have recently been introduced in India, and are gaining regulatory and commercial traction. These models are likely to become more relevant over the next five to ten years as grid modernisation and the energy transition accelerate.

Green Power Procurement from DISCOMs: Under the Green Energy Open Access Rules, 2022, consumers can procure renewable electricity directly from the DISCOM on request, at a regulator-approved premium green tariff. This green tariff includes the pooled cost of renewable power, cross-subsidy charges, and the service charges levied by DISCOMs. The option allows consumers to meet various sustainability and renewable purchase obligations while deferring upfront capital investment in RE projects. Thus, ULBs can opt for green power procurement while considering other commitments, sustainability branding and reporting requirements, and opportunities to access sustainability-linked finance.

Virtual Power Purchase Agreement (VPPA)[11]: A VPPA is a bilateral, non-transferable, and specific delivery contract between a consumer and RE-generating stations (REGS), under which the consumer guarantees payment of a mutually agreed-upon (strike) price to REGS for the duration of the contract. The REGS shall sell the electricity they generate on a power exchange at the prevailing settlement price, except for renewable purchase obligations and renewable consumption obligations. The difference between the strike price and the settlement price shall be settled bilaterally between the contracting parties with mutually agreed terms. It is important to understand that this mechanism does not involve physical delivery of electricity. However, the RECs are transferred to the consumer for RPO/RCO compliance. The mechanism is more of a price-hedging and sustainability-compliance instrument than a regular Power Purchase Agreement (PPA) and requires a minimum contract term of one year.

Peer-to-Peer (P2P) Energy Trading: P2P energy trading allows electricity consumers or prosumers to sell surplus RE directly to other consumers through a DISCOM-facilitated platform. Transactions are enabled through smart meters and digital settlement systems, with applicable network charges regulated by the utility. The Ministry of Power has recently initiated pilot frameworks to test this model in a few states,[12] which may inform broader adoption in the future.

Ancillary Service Markets: Ancillary service markets enable system operators to procure services such as frequency regulation, reserve capacity, and voltage support to maintain grid stability, primarily driven by the Ancillary Services Regulations, 2022.[13] Certain municipal assets, such as waste-to-energy plants, hybrid RE plants, EV charging depots, or flexible municipal

11 Central Electricity Regulatory Commission (CERC). (2025). Guidelines for virtual power purchase agreements. https://www.cercind.gov.in/regulations/Guidelines-VPPA.pdf

12 India Energy Stack Taskforce. (2026). India Energy Stack Taskforce Releases Version 0.3 strategy and architecture Documents. https://www.financialexpress.com/policy/economy/power-ministry-rolls-out-india-energy-stack-v0-3-framework/4134023/ , The Components of India Energy Stack. (n.d.).https://www.pib.gov.in/PressReleasePage.aspx?PRID=2236992®=3&lang=2

13 CERC. (n.d.). Central Electricity Regulatory Commission (Ancillary Services) Regulations, 2022. https://www.cercind.gov.in/Regulations/Ancillary-Service-Regulations-2022.pdf

loads (such as Water Distribution Stations), may participate by providing grid support services. As India's power markets evolve, such mechanisms could offer additional value streams for ULBs' infrastructure assets while supporting overall grid reliability.

The combination of various RE integration approaches (onsite, offsite, and other innovative approaches) will provide significant opportunities for ULBs to achieve their sustainable energy transition goals.

3.3 | Understanding Regulatory Charges in RE Integration

Before investing in RE power infrastructure, ULBs should review relevant policies and regulations to understand how energy accounting, grid access, charges, and losses impact project viability. These regulations differ by state and can greatly affect savings, cash flow, and contractual arrangements. Such charges are often subjective and vary depending on local policies, consumer categories, the size of connected RE capacity, and other factors. Assessing the various regulatory charges levied on an intended RE integration option will enable ULBs to optimise project design, maximise project viability, and enhance long-term gains, ensuring the project's success. The typical regulatory charges levied when ULBs integrate RE plants for captive use are explained below.

Banking Charges: Banking charges were introduced in India to address grid reliability challenges caused by increased RE integration, allowing DISCOMs to charge consumers for the utilisation of exported surplus solar power (or banked energy stored in the grid) during non-solar hours or within specified settlement windows (like 15-minute blocks). The banking charges vary from state to state and are levied based on per unit of electricity injected. Financial settlements are made for every billing cycle or annually, as required by local regulations. If these charges are applicable to the proposed RE project, ULBs must assess demand patterns against RE generation to optimise banking charges.

Wheeling charges: Wheeling Charges are paid to DISCOMs by open access consumers for using their grid infrastructure to transfer (or wheel) RE to the consumption facility. It is generally charged per unit of electricity transmitted (kWh) or per capacity (kVA).

Transmission Charges: Transmission Charges are paid to intra-state or inter-state transmission companies for use of their transmission grid infrastructure, levied on a per-unit basis for power transmitted through their grid network. When an open-access consumer uses both intra-state and inter-state transmission grid networks, the consumer pays charges to both the transmission operators as specified by the state and central regulatory commissions.

State Load Dispatch Centre (SLDC) Charges: SLDC charges are levied by the load dispatch centre of the state where the project is located, irrespective of where it is utilised. Within a state, the SLDC is responsible for coordinating power sector operations among generators, transmission system operators, and distribution companies. They collect these charges from open-access consumers for scheduling, monitoring, and coordinating the power transactions. These charges consist of a one-time registration fee for the project, and a recurring operational charge calculated based on the short, medium, or long-term contract duration.

Cross Subsidy Surcharge (CSS) and Additional Surcharge (AS): CSS and AS are levied on open-access consumers to prevent operational losses for DISCOMs when they facilitate consumers to source power independently. The CSS is levied to compensate for the loss of cross-subsidy recoveries that DISCOMs use to subsidise the cost of domestic and agricultural tariff rates. AS charges are imposed to recover the fixed costs of long-term power purchase agreements that the DISCOM has already signed as part of its long-term planning for power procurement and supply. Under prevailing regulations in many states, these charges do not apply to ULBs if RE power is procured under the captive or group captive model. However, these charges apply to procurements under the third-party sales model in open access.

Deviation Settlement Mechanism (DSM) Charges: DSM charges are levied by SLDC on the project developer or the open-access consumer, such as a ULB, to maintain grid operations. The charges are determined based on deviations from the scheduled power transaction, that is, under-drawl or over-drawl of power that can impact grid frequency. These charges are levied to penalise deviations that may destabilise grid frequency and incentivise adherence to the committed schedule.

Qualified Coordinating Agency (QCA) charges or fees: A QCA is an independent third-party agency that manages forecasting, scheduling, controlling, and coordinating with SLDCs for large RE projects (≥1 MWp) to support grid stability and reliability for grid operators. QCA charges are the direct service fees the QCA charges power producers for providing day-ahead/intra-day weather forecasting and grid schedules. As penalties and rewards are linked to RE power scheduling and actual performance, the QCA charges may vary based on the penalty risk shared with project developers or clients.

Standby Charges: These charges are levied by DISCOMs in a few states under the Green Energy Open Access (GEOA) rules for open-access consumers to compensate the DISCOM for maintaining and availing backup power if the RE generation source fails during scheduled generation or suffers an outage.

Table 8 provides an illustrative summary of typical on-site and off-site charges.

Table 8: Typical regulatory charges for RE installations

Typical Charges	On-site	Off-site
Banking Charges	Yes	Yes
Wheeling Charges	No	Yes
Transmission Charges	No	Yes
SLDC Charges	No	Yes
CSS & AS Charges	No	Yes
DSM / UI Charges	Yes	Yes
QCA Charges	Yes	Yes
Standby Charges	No	Yes

3.4 | Strategic Considerations for RE Integration

ULBs can choose from several RE solutions and technologies available for developing RE projects to meet their sustainable energy transition goals. Each RE solution can have multiple technical variants with varying performance characteristics that require careful evaluation. ULBs should assess different technology options based on cost, local resource availability, technical feasibility, O&M requirements, regulatory provisions, and associated risks. For example, when solar PV systems are considered for deployment, the PV module technologies such as bifacial, TOPCon (N-type or P-type), and HJT (Heterojunction Technology), along with configurations like multi-bypass junction designs, offer varying efficiencies, performance characteristics, and degradation rates that can impact lifetime generation of power and its levelised cost. High-efficiency PV modules can increase the capital procurement costs, but their higher energy yield makes them suitable for space-constrained sites available for RE deployment within a ULB's jurisdiction, including rooftop spaces that depend on building footprint, structural suitability and shading conditions.

A key performance indicator to consider while developing RE projects is the capacity utilisation factor (CUF), which represents the ratio of actual energy generated over a period to the maximum possible generation at the rated capacity. The CUF for solar and wind systems largely depends on site-specific resource availability (solar irradiance and wind speed), technology selection, system losses, and system degradation over the project lifecycle, all of which can influence overall project costs and returns on investment.

Levelised cost of electricity (LCOE) is a metric that can help ULBs to compare different RE technology options. LCOE is the average per-unit (INR/kWh) cost of generation over the full project lifecycle, considering total capital expenditure, financing costs, O&M expenses, and power generation. A technology with higher capital cost but higher CUF or lower system degradation rates will have higher energy yield per rated capacity and can deliver a lower LCOE, indicating a better long-term value compared to cheaper alternatives. On grid parity comparison based on ULB's prevailing grid tariff, LCOE indicates the savings potential of a given RE option.

Beyond LCOE, ULBs should also account for cost considerations that can significantly impact project economics, such as the financing structure and cost of capital, open-access and grid-integration charges, banking charges, O&M costs over the project lifecycle, and state-specific incentives and charges. ULBs should consider technical due diligence, estimated LCOE, financial requirements, expected payback periods, policy provisions, and long-term operational characteristics to identify the most suitable and sustainable RE solution and technology for implementation. Table 9 presents some RE technologies along with their indicative capital costs, typical CUF, and estimated payback periods.

Table 9: Comparative assessment of RE technologies for ULBs

Technological Solutions	Typical Technology Cost[14] (Reference Year 2025)	Technical Performance	Typical Payback (Years)
Rooftop Solar PV	~ INR 50,000 to 65,000/kWp	CUF: 17% to 20%	3 to 6
Ground-mounted Solar PV	~ INR 30 to 40 million/MWp	CUF: 19% to 22%	4 to 6
Floating and Canal Top Solar PV	~ INR 45 to 70 million/MWp	CUF: 19% to 23%	6 to 9
Wind Turbine Generator	~ INR 70 to 90 million/MWp	CUF: 25% to 35%	6 to 9
Hybrid RE (Solar/Wind + 4 Hours of BESS)	~ INR 100 to 120 million/MWp	CUF: 28% to 40%	8 to 12

Note: Costs and CUF values are indicative and can vary significantly depending on project scale, site conditions, technology, and market prices.

A significant challenge for ULBs in developing RE projects is space constraints. Rooftop and on-site ground-mounted installations are limited by available area, structural load-bearing capacity, and shading, while off-site deployment of large-scale ground-mounted solar PV or wind projects requires land that may not be available within municipal limits. ULBs should, therefore, adopt a combination of on-site and off-site RE deployment, integrated as required to meet their power demand and achieve the sustainable energy transition goals. On-site generation (behind-the-meter) avoids grid charges and transmission losses, while off-site open-access projects enable larger capacities and access to better resource sites, subject to applicable charges.

For RE projects where the power generation profile of the selected RE technology does not align with the municipal load profiles, energy banking allows surplus RE injected into the grid to be drawn later, effectively using the grid as a virtual store. However, banking terms vary considerably by state and can significantly impact project economics. ULBs should verify the prevailing banking charges, settlement cycle, and withdrawal restrictions in their state before finalising project sizing, as restrictive banking (or lapsing of unused energy) can make on-site consumption or co-located battery storage more economical than relying on the grid for time-shifting. It is also important for ULBs to consider T&D losses when designing RE projects. These losses must be factored into the energy injected at the RE generation source, as the losses at the T&D grid infrastructure are deducted from the energy set-off consideration at ULB's grid-connected facilities.

14 Considers only approximate technical cost and does not include any site development cost, land lease, and additional electrical infrastructure costs. 2025 is the reference year for the costs.

04 Financing Strategies and Business Models

4.1 | Financing Strategies for Municipal Energy Transition

Effective financial planning, budgeting, and resource allocation are essential for implementing energy transition interventions in ULB operations. ULBs can adopt a range of financing approaches depending on the project's scale, technology choice, local regulatory context, and risk considerations. Common options include municipal CapEx (equity) investments, grants and external financial assistance, debt financing and market borrowings, and hybrid financing structures that combine public and private capital. In addition, emerging and innovative financing mechanisms may also provide opportunities to mobilise resources for clean energy investments. Various mechanisms through which ULBs can finance their sustainable energy transition journey are shown in Figure 3.

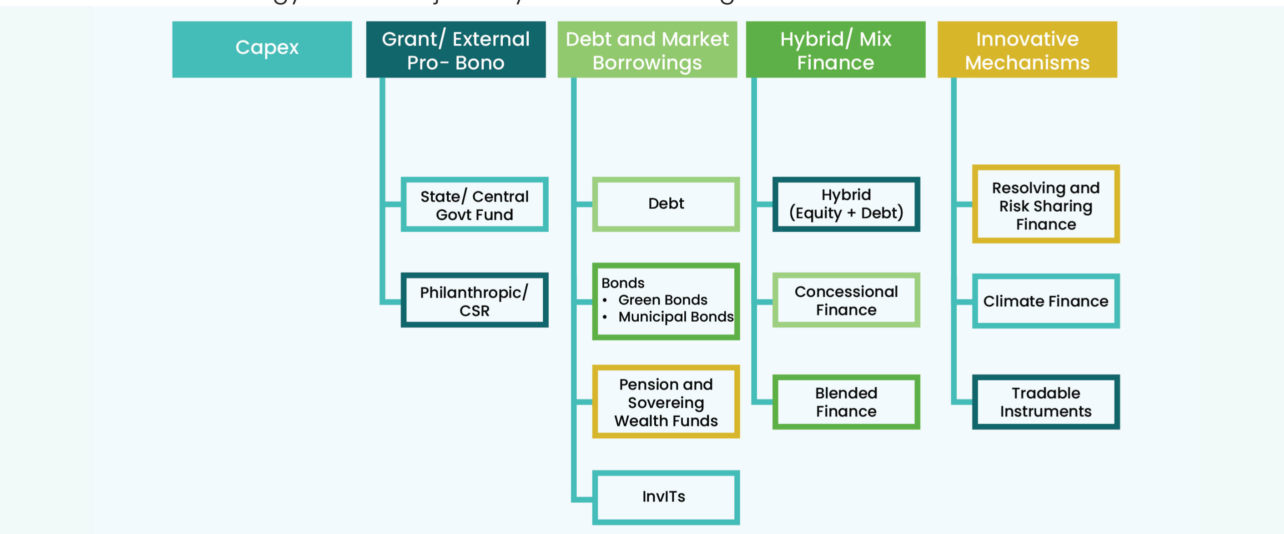

Figure 3: Financing options for municipal energy transition

While many energy transition interventions require upfront investment, they can deliver long-term benefits through reduced energy costs, improved service reliability, and lower environmental impact. Careful assessment of financial viability, institutional capacity, and implementation risks is therefore important when selecting suitable financing structures.

4.1.1 CapEx (Equity)

In the CapEx model, the ULB uses its own funds or capital resources to implement energy transition measures, including investments in RE infrastructure and services, based on its financial strength. However, ULBs may have to prioritise their own capital expenditure for key urban services and infrastructure such as water supply, road development, and sewage management. Each city can have its own considerations and expenditure limits, and budgetary provisions for CapEx investments in energy transition interventions will be assessed in accordance with local rules and evaluation criteria. CapEx investment by a ULB mainly depends on its own approval process and provides autonomy in project design and procurement evaluations within existing procedures. This makes it a preferred model for interventions with relatively lower capital costs such as rooftop solar PV deployments, and procurement of energy-efficient equipment to retrofit older or end-of-life equipment.

4.1.2 Grants / External Pro-bono Financial Support

Given the developmental responsibilities and public service mandate of ULBs, various national programmes, development partners, and philanthropic institutions provide grants or pro-bono financial assistance for infrastructure and sustainability initiatives. The use of these funds may be conditional or unconditional and is often intended to support climate resilience interventions. Such external financial support enhances the capital available to ULBs, helping reduce upfront investment barriers and enabling the implementation of energy transition projects with lower financial risk.

Raising funds from state and Central-assisted schemes or provisions: The Central government and various state governments provide financial grants to ULBs, both tied and untied, which can be utilised for energy transition initiatives. While some tied grants are conditional, based on the utilisation aspect, others may require a return in certain installments. ULBs must assess available grants when planning the energy transition projects. For example, Finance Commission grants and programmes such as CITIIS 2.0, AMRUT 2.0, Central Finance Assistance for waste-to-energy, Smart Cities Mission, and PM–eBus Sewa offer pro-bono grants, while schemes like State Energy Conservation Fund (SECF) and Municipal Demand Side Management (MuDSM) financial assistance require ULBs to return the financial assistance from the savings arising from energy transition initiatives.

Philanthropic and CSR Financing: Philanthropic foundations, corporate social responsibility (CSR) funds, and international institutions focused on climate and sustainability, such as multilateral development banks (MDBs), development finance institutions (DFIs), and climate funds, increasingly support energy transition initiatives. These sources can provide catalytic funding, technical assistance, or viability gap financing to help municipalities design and implement energy transition projects. Such support often helps mobilise larger pools of private capital and concessional financing from development banks by reducing early-stage risks and aligns municipal projects with broader climate action and the Sustainable Development Goals (SDGs).

4.1.3 Debt and Market Borrowings

Debt: Debt financing involves borrowing funds from lenders, with an obligation to repay the principal along with interest over a specified period. Such arrangements typically have fixed or predetermined repayment terms and are prioritised over equity in terms of repayment obligations. As a result, debt generally presents a lower risk profile for investors than equity financing, while offering relatively moderate returns. For ULBs, debt financing can support energy transition investments, which offer long-term, predictable returns.

Bonds: This is a popular and emerging debt-financing option, in which ULBs or state governments (on behalf of ULBs) issue bonds to raise capital from investors, with repayment over a fixed period through interest and principal payments. Although raising bonds requires initial due diligence, credit assessment, and compliance with accounting and reporting requirements, they provide ULBs with procurement flexibility comparable to that of equity investments.

Typically, bonds are issued by individual ULBs for specific projects and financial requirements. However, smaller ULBs often lack the scale, credit history, and financial expertise to access capital markets independently. To overcome this, states such as Tamil Nadu (Tamil Nadu's Water and

Sanitation Pooled Fund 2002)[15] and Karnataka pioneered a pooled finance mechanism, in which a state-level Special Purpose Vehicle (SPV) combines several smaller ULBs to raise a single bond. This achieves the scale needed to attract institutional investors, reduces per-ULB transaction costs, and shares risk.

The pooled finance mechanism is now being formalised at the regulatory level. In May 2026, the Securities and Exchange Board of India (SEBI) issued a consultation paper proposing a comprehensive overhaul of SEBI (Issue and Listing of Municipal Debt Securities) Regulations, 2015, including a dedicated disclosure framework for pooled-finance bond issuances, alongside provisions enabling sustainability-linked municipal bonds. Once finalised, these norms are expected to give institutional investors greater confidence in pooled structures, potentially reviving pooled finance as a route for smaller ULBs to fund infrastructure, including climate resilience and sustainability projects.

Green Bonds and Municipal Bonds are two types of bonds that can be considered by ULBs for financing energy transition projects, and are explained below:

- **Green Bonds:** Green bonds are municipal or corporate bonds specifically earmarked for environmentally sustainable projects. For ULBs, such bonds can support RE generation, EE improvements, and low-carbon infrastructure. They often attract climate-focused investors and can enhance the city's sustainability credentials while mobilising dedicated climate finance.

- **Municipal Bonds:** Municipal bonds are debt instruments issued by ULBs to raise capital from investors for infrastructure projects. They can finance energy transition investments such as energy-efficient street lighting, solar installations, and smart infrastructure upgrades. Their advantage is in providing access to large upfront capital at relatively lower borrowing costs and longer repayment periods. Municipal bonds are generally of two types: revenue-obligation bonds and general-obligation bonds. General-obligation bonds are repaid with the overall revenues of ULBs, whereas servicing revenue-obligation bonds is tied to the cash flows of specific projects.

Pension and sovereign wealth funds: The National Investment and Infrastructure Fund (NIIF) is India's quasi-sovereign infrastructure fund anchored by the Government of India. It is designed to attract sovereign wealth funds and global pension funds to infrastructure sectors, including energy and mobility. These projects can include city-level initiatives like e-bus fleets, EV charging infrastructure, distributed solar systems, and energy-efficient infrastructure.

Infrastructure Investment Trusts (InvITs): InvITs are SPV-based financing instruments that pool investor capital and require strong credit ratings, such as AAA, to attract institutional investors. ULBs can explore them for large-scale projects typically of INR 500 crore or more. Regulations require at least 80% of assets to be operational and revenue-generating, with a minimum offer size of INR 250 crore. The ULB acts as sponsor, transferring assets to a trust-held SPV, and must distribute at least 90% of net distributable cash flows to unitholders. InvITs help ULBs reduce debt-heavy structures, attract private equity into operational (brownfield) assets, and offload

15 World Bank. (2016). Case Studies in Blended Finance for Water and Sanitation: Pooled Municipal bond issuance in Tamil Nadu (India). In Water Global Practice [Report]. https://documents1.worldbank.org/curated/en/702211472040099035/pdf/107974-BRI-P159188-BlendedFinanceCasesIndia-PUBLIC.pdf

revenue risk, but they require high technical and legal capacity within the ULB for successful implementation, and require ULBs to appoint an investment manager. Investor returns are distributed as variable dividends based on revenue. Though InvITs are comparatively new and complex financing mechanisms, they can help ULBs restructure debt, optimise operational costs, reduce borrowing costs, and create additional large-scale infrastructure projects. 16

4.1.4 Hybrid (Equity + Debt + Grant) Project Finance

Hybrid (Equity and Debt) Finance: RE projects (especially large-scale projects like GM-Solar PV and wind energy) are typically implemented through a hybrid project finance mix of equity and debt (typically a ratio of 30:70). Such project finance reduces the upfront capital requirement for ULBs, but also reduces the risk, as such financing is primarily based on project cash flows, and not on the cash flows of the business unit. The lending rate depends on the credit rating of the ULBs, the type of RE technology, expected electricity generation based on local potential, prevailing regulations under which plants will be installed, and other project risks.

Concessional Finance: Concessional finance refers to funding provided at below-market interest rates and with longer repayment periods, typically by government programmes, development banks, or philanthropic institutions. Such financing helps ULBs implement high-impact energy transition projects by lowering capital costs and improving overall project viability. It is commonly extended through government assistance programmes (such as CITIIS 2.0), philanthropic grants, development finance institutions, and climate or sustainability funds supporting urban infrastructure and clean energy initiatives.

Blended Finance: Blended finance combines multiple sources of capital, such as ULB equity contributions, concessional finance from government or development institutions, grants, and private investment. This structure helps lower the overall cost of financing by mixing concessional funding with market-based capital. In many cases, concessional finance plays a catalytic role by reducing perceived risks and attracting private-sector participation, enabling ULBs to implement energy transition projects that might otherwise face financial or investment barriers. The key features of blended finance are shown in Figure 4.

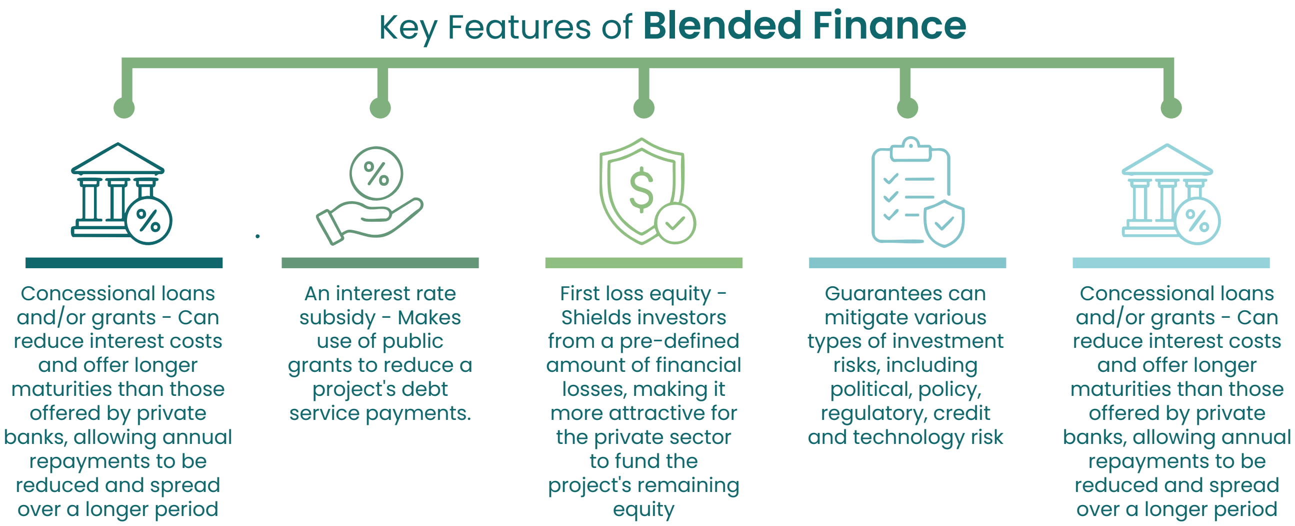

Figure 4: Key features of blended finance (Source: adapted form ICLEI World Secretariat)

16 Kachari et al (2025). India's municipal corporations exploring InvIT instruments for fund raise. Economic Times. ETInfra.com. https://shorturl.at/Xkv1A

4.1.5 Innovative Mechanisms

Revolving funds: Revolving funds are usually established by the government to support specific energy transition projects. This approach involves an upfront financial provision to drive the uptake of energy transition projects with specific purposes, and repayments from the project's energy and cost savings to ensure fund recovery, maintain a reserve, and support new projects. For example, the State Energy Conservation Fund (SECF) across states and UT administrations in India facilitates the implementation of EE projects, and a major part of the fund is disbursed under a revolving investment fund mechanism.

Risk-sharing Finance: Risk-sharing finance is a category of financing mechanisms that provides limited upfront grants but focuses on sharing financial risks to improve the bankability of energy transition projects. Partial risk guarantees and dedicated funds like the Partial Risk Guarantee Fund for Energy Efficiency (PRGFEE)17 and the Partial Risk Sharing Facility (PRSF)18 programmes help mitigate repayment and performance risks associated with energy transition projects undertaken by ULBs. By reducing perceived financial uncertainty, these mechanisms encourage lenders and private investors to finance municipal EE and clean energy projects.

Climate Finance: Climate finance can be mobilised by ULBs to fund energy transition projects, typically supported by development banks, climate funds, and international agencies. Most of the climate financing (~80%) is provided upfront before the project is operational, while Results-Based Climate Finance (RBCF) pays the project developer upon achievement of project results such as reductions in GHG emissions, MWh of energy generated, and number of EV buses deployed.

Tradable Instruments: Tradable environmental instruments allow ULBs to monetise the environmental attributes of their clean-energy and emission-reduction activities, generating a supplementary revenue stream that improves project viability and bankability. Unlike financing instruments, these instruments do not provide upfront capital, but reward verified renewable generation or emission reductions after an energy transition project is operational and can be sold to entities seeking them for regulatory compliance or voluntary sustainability commitments. The two most relevant instruments for ULBs are Renewable Energy Certificates (RECs) and carbon credits, and are explained below.

- **Renewable Energy Certificates (RECs):** RECs are tradable instruments, each representing 1 MWh of renewable electricity generation. Eligible RE projects must register under the REC mechanism to avoid double-counting of RE claims. In some cases, municipal RE projects (such as waste-to-energy projects) may sell electricity to the DISCOM under a conventional PPA while retaining the associated REC benefits, which can then be traded in the power exchange market. This mechanism is useful when renewable electricity generation is not fully utilised by the ULB, allowing the environmental value to be realised separately from the energy sale.

- **Carbon Credits:** Carbon credits are tradable instruments representing verified reduction

17 International Energy Agency. (2021). Partial Risk Guarantee Fund for Energy Efficiency (PRGFEE). https://www.iea.org/policies/6202-partial-risk-guarantee-fund-for-energy-efficiency-prgfee?__cf_chl_f_tk=oiB7PC3aAVsUKG86shJYlWCTeQtgl1tJSV2sjLU7tYQ-1782874426-1.0.1.1-1XSLz19yWLQhCyFXUK1.i3h8_jz4wBDS4xEMeinOu9c

18 World Bank Group. (2015) Government of India and World Bank sign agreement for $43 million Partial Risk Sharing Facility for Energy Efficiency Project. World Bank. https://shorturl.at/L1R7b

or removal of GHG emissions, each denominated as one tonne of CO_2 equivalent (tCO_2e), enabling entities to buy and sell them. Under India's Carbon Credit Trading Scheme (CCTS) administered by the Bureau of Energy Efficiency (BEE), carbon credits represent verified emission reductions achieved through activities such as RE adoption, EE improvements, or EV adoption.[19] The CCTS framework comprises two mechanisms: a compliance mechanism for designated energy-intensive industries and an offset mechanism through which non-obligated entities can register eligible projects for emission reductions, removals, or avoidance and receive Carbon Credit Certificates (CCCs). ULBs can potentially participate by generating credits from eligible projects such as RE adoption, EE improvements, landfill methane recovery, or clean transport, and trading them on power exchange markets, creating an additional revenue stream while supporting climate mitigation goals.

4.1.6 Financing Challenges

Energy transition financing presents challenges around project bankability, as many initiatives require stronger financial structuring to attract investors. Effectively managing risks and ensuring long-term operational success also demands robust planning and monitoring systems. ULBs often face capacity constraints in accessing external financial resources, technical expertise, and existing governance mechanisms (refer to Figure 5). However, these challenges also create opportunities to strengthen institutional capabilities, build skilled technical teams, and adopt more resilient governance frameworks. With the right support and partnerships, these barriers can be transformed into pathways for sustainable and scalable energy transition investments.

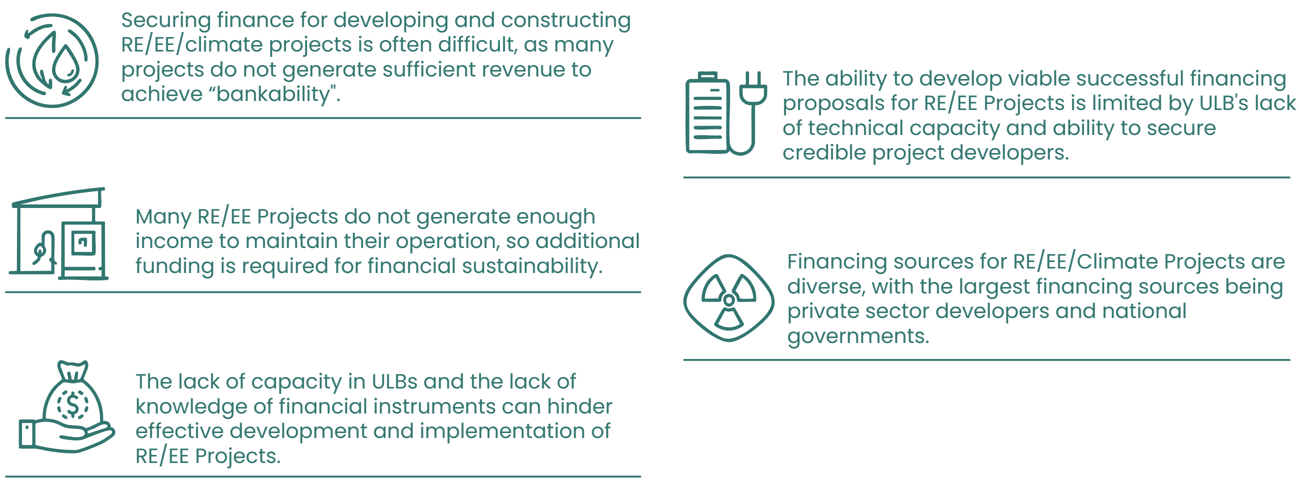

Figure 5: Energy transition financing constraints for ULBs
(Source: adapted form ICLEI World Secretariat)

4.1.7 Upscaling Energy Transition Finance for ULBs

Upscaling energy transition finance for ULBs is critical to achieving sustainable urban development. As cities increasingly adopt clean energy solutions, the need for structured, diversified financing approaches becomes increasingly important. ULBs can explore a range of financing optionsbased on the nature of energy transition projects, their bankability, and the availability of external resource mobilisation mechanisms. Careful evaluation of projects, such

19 Bureau of Energy Efficiency (2024). Approved sectors in offset mechanism under CCTS by Government of India. https://beeindia.gov.in/WriteReadData/RTF1984/RTF-PDF-4edb9be54a4b43e6_1776057028.pdf

as technical feasibility, financial viability, and risk profiles, helps identify the most suitable financing pathways. This section outlines a practical approach for assessing financial resources and success factors to strengthen project bankability.

ULBs can use the question-based approach described in Figure 6 to develop a structured assessment framework tailored to their local context to evaluate diverse financing options for energy transition projects. These questions are designed to support strategic, informed decision-making to identify suitable financing options and allocate appropriate financial resources.

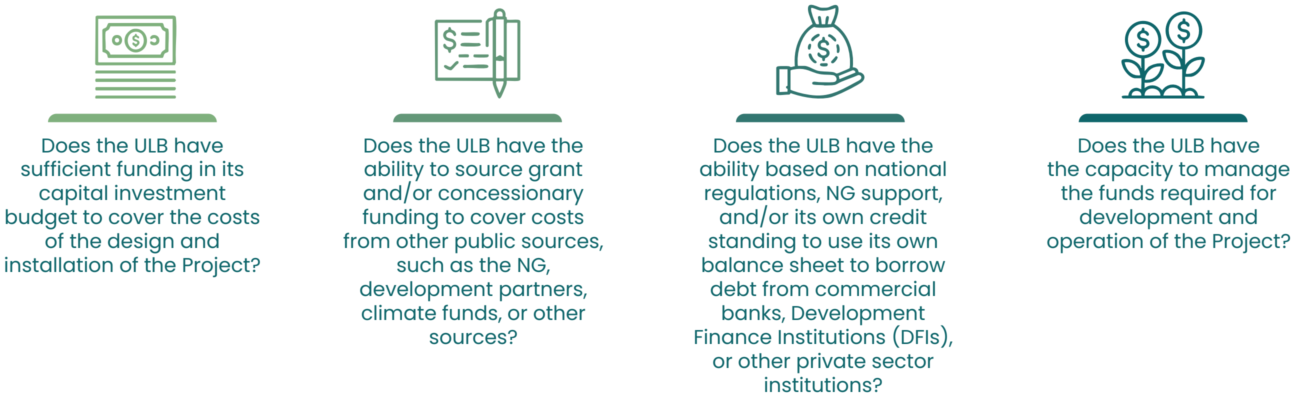

Figure 6: Approach to evaluate financing options for energy transition projects

The success factors that can enable financing for energy transition projects include strong institutional readiness, strengthened governance, transparent monitoring, and performance-based implementation arrangements (refer to Figure 7). A focus on enhancing project bankability, managing risks, and building technical and governance capacity is essential. These factors can collectively help attract and sustain diverse sources of financing for the successful implementation of energy transition projects.

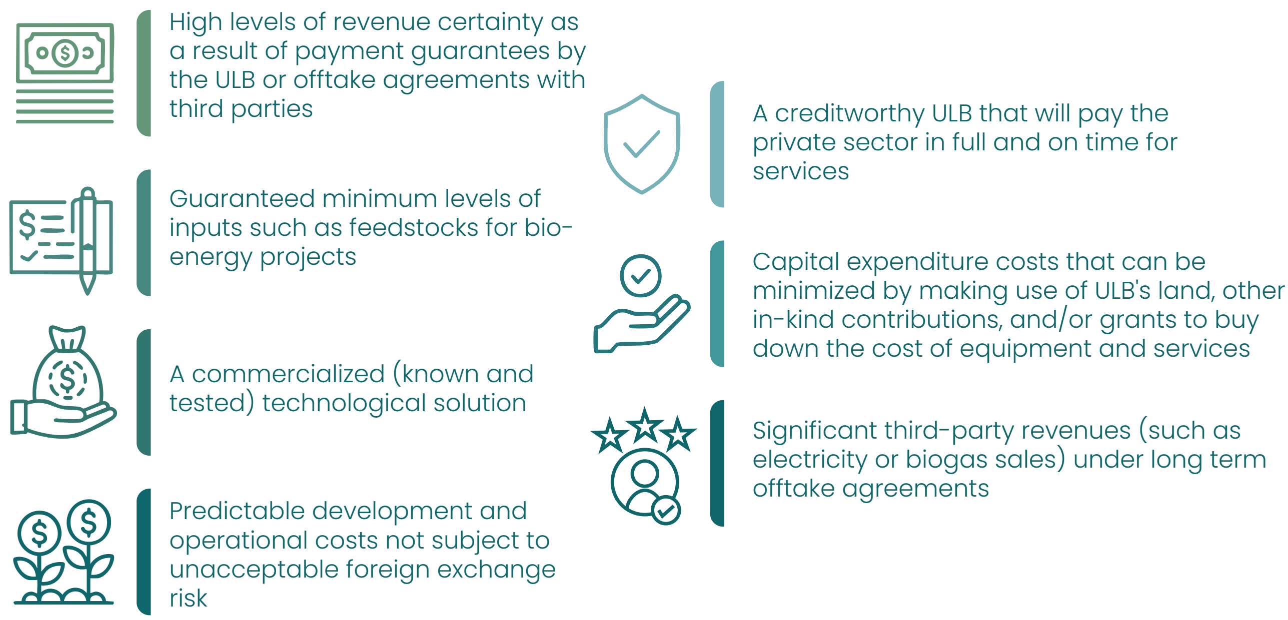

Figure 7: Success factors for financing energy transition projects for ULBs

(Source: adapted form ICLEI World Secretariat)

4.2 | Implementation Models

Independent ULB-led Implementation: This is the most common model, in which ULBs manage overall procurement and project implementation, drawing on various internal and external financial resources. Smaller, bankable projects can be funded by the ULBs through equity (CapEx) investments based on their financial capacity, while large-scale projects involve a combination of debt, grants, and other financial sources. This approach allows ULBs to maintain maximum control but demands greater institutional capacity for project development and execution.

RESCO / ESCO: Under the Renewable Energy Service Company (RESCO) or Energy Service Company (ESCO) model, a private developer finances, installs, and operates the energy system, while the ULB pays through energy savings or power purchase agreements. This model is commonly used for rooftop solar, street lighting, and other EE retrofits such as pump replacements, and it reduces the ULB's upfront investment requirement while transferring technical and performance risks to the service provider. However, an effective contract design with clear performance and evaluation criteria, is needed to avoid disputes with the developer. The energy transition project assets can be transferred to ULBs after the contract term, such as under the BOOT (Build, Own, Operate, Transfer) model.

Gross Cost Contract (GCC) Model for Clean Public Transport: This approach enables the city to minimise initial capital expenditure while paying a fixed per-unit fee based on the level of service provided. This model is commonly used in procuring public transportation services, including for EV buses, where ULBs pay a per-kilometre fee to the operators. This fee recovers the contractor's capital and operational costs. Such contracts should integrate RE-based charging to reduce transport and grid-electricity emissions.

Public Private Partnership (PPP): In this model, ULBs can partner with the private sector to design, finance, build, and operate infrastructure projects. They are especially suitable for technically complex, capital-intensive, and large projects such as waste-to-energy plants and large RE initiatives. An SPV is established to own a PPP project, with public and/or private shareholders, depending on the chosen model. PPPs can facilitate private sector technical and financial expertise, mobilise private capital, reduce capital expenditure, ease working capital pressures, and minimise disruption to other municipal services. PPPs require robust contractual and governance mechanisms to ensure effective project implementation and to avoid disputes over revenue-sharing arrangements.

Demand Aggregation: Under this model, ULBs can aggregate energy transition procurement across departments or across multiple ULBs, coordinated by a state-level governing body. Larger-scale procurement, supported by external procurement and technical experts, can reduce the cost of energy transition initiatives compared to an individual approach. Examples include the procurement of energy-efficient devices (such as air conditioners, streetlights, LED lights, and BLDC fans) and RE projects (such as large-scale captive ground-mounted solar PV projects).

Table 10: Comparison of Implementation Models

Implementation Model	Supportive Factors	Constraints
Independent ULB implementation	Full ULB control; well-defined procurement; quality checks on EPC/implementing agencies	ULB bears technical and financial risks; needs dedicated technical/O&M teams and management of equity contributions
RESCO / ESCO	Low upfront capital; leverages private-sector skills (design, O&M, M&V); performance risk transferred to developer	Long-term contracts bind both parties; requires robust M&V; contracts must address project variations (e.g., changing pump duty points)
Gross Cost Contract (GCC)	Upfront and project risks pass to developer; performance-linked payment ensures service quality	Long-term liabilities and cost exposure (e.g., growing city traffic, electricity rates); potentially higher lifetime cost
Public Private Partnership (PPP)	Private-sector technical know-how; mobilises project funding; reduces upfront capital	Processes can be onerous and time-consuming; private capital can be expensive
Demand Aggregation	Economies of scale; lower transaction costs; better quality and bankability	Complex coordination and data collection; needs robust O&M mechanisms for long-term functioning

05 Implementing Energy Transition Interventions

5.1 | Prioritisation of Interventions

Based on the technical, policy, and regulatory options discussed earlier, suitable energy transition technologies can be mapped across municipal sectors, as illustrated in Figure 8. This mapping helps ULBs identify sector-specific opportunities, enabling individual departments such as water, wastewater, street lighting, buildings, transport, and SWM to implement appropriate interventions within their operations. ULBs must prioritise relevant technologies for the municipal sector under consideration and then further narrow their focus to proven solutions with minimal upfront investment and quick results.

Firstly, ULBs should focus on energy conservation and efficiency measures, followed by rooftop solar installations at suitable municipal facilities. Subsequently, larger RE projects such as ground-mounted solar, wind, canal-top, or floating solar can be considered. Other interventions may include electric mobility for municipal transport, hybrid RE systems, bioenergy solutions, and, where feasible, emerging options such as green hydrogen.

Energy transition initiatives should follow a phased approach. Initial actions may include energy audits, operational improvements, and efficiency upgrades. Medium-term efforts can focus on RE deployment, infrastructure upgrades, and electrification of municipal fleets. In the long term, integrating digital monitoring systems, advanced energy management tools, and emerging technologies can strengthen sustainability outcomes. Cross-departmental coordination and pilot-based implementation for innovative technologies can further support learning and scalable adoption across municipal sectors.

Energy Transition Solutions	Sub-type Classification	Water (WTP, WDS)	Waste water	Street light	Buildings	Transport	SWM
EE & EC	Retrofit/ Replacement/ New	Yes	Yes	Yes	Yes	Yes	Yes
RTPV, Solar Carpod	Onsite	Yes	Yes	No	Yes	Yes	Yes
Ground Mount SPV	Onsite	Maybe	Maybe	No	Maybe	Maybe	No
	Offsite	Yes	Yes	Maybe	Maybe	Yes	Maybe
FSPV, Canal Top SPV	Offsite	Yes	Yes	Maybe	Maybe	Yes	Maybe
Solar Thermal, PVT	Onsite	Maybe	Maybe	No	Yes	No	No
Wind (WTG)	Offsite	Yes	Yes	Maybe	Maybe	Yes	Maybe
BESS	DG Replacement, Grid Support	Yes	Yes	No	Yes	Yes	No
Hybrid RE	Offsite	Yes	Yes	No	No	No	No
Bioenergy	Production/ Capture	No	Yes	No	No	No	Yes
Green Hydrogen	Production/ Consumption	Yes	Yes	No	Maybe	Yes	No

Color Legends: Yes | No | Maybe

Figure 8: Energy transition interventions and their suitability for municipal sectors

5.2 | Implementation Framework

The implementation framework presented in this section outlines the key measures required to ensure the successful execution of energy transition projects by ULBs. It describes the critical actions to be undertaken before, during, and after installation to support effective project delivery. The framework emphasises institutional ownership, strategic decision-making, transparent and efficient procurement and installation processes, and robust monitoring and accountability.

01 Pre Implementation

- Short-term implementation plan and strategy
- Focus pilot to scale-up
- Technical due diligence
- Governance and decision-making
- Efficient Procurement Management and Quality Control

02 During Installation and Commissioning

- Commissioning
- Quality Checks and Periodic Visits

03 Post Implementation

- Monitoring through KPIs
- Periodic reporting and review
- Training, awareness and communication

5.2.1 Before Implementation

Short-term implementation plan and strategy: The first step towards a sustainable energy transition for ULBs is to develop a time-bound implementation plan with short-term interventions to be implemented within three years and medium-term interventions targeted for implementation over the next 5-10 years. The plan should identify and prioritise energy transition interventions, goals, required investment, and strategic alignment with the city's development priorities and municipal capacities. Short project concept notes and white papers covering technical and financial aspects, as well as enabling policy measures, will support further evaluation and development of projects.

Focus pilot to scale-up: ULBs can pursue pilot demonstration projects for new and innovative technologies and approaches (such as green hydrogen and hybrid plants) to assess technical feasibility and operational requirements before considering larger deployments. Early pilot initiatives can help ULBs build institutional capacity as they prepare for hydrogen's broader role in India's evolving clean energy ecosystem. For proven technologies, scale can be increased based on requirements, prior learning, market factors, and other considerations.

Technical due diligence: A key step in implementing energy transition initiatives is carefully mapping suitable technologies across municipal sectors such as water supply and wastewater management. Site visits by relevant departments or designated energy officers help incorporate ground-level realities into project planning. During these assessments, local needs for EE, RE, and conservation measures can be identified, and demand patterns, electricity bills, grid constraints,

and structural or financial limitations can be evaluated.
For example, analysing load patterns can inform the viability of solar installations and potential banking implications, while billing assessments reveal applicable rebates, tariffs, and areas for cost savings. Similarly, shadow analysis assesses the potential for rooftop solar integration. Careful selection of facilities, deployment sites, appropriate technologies, and a robust procurement process are critical for effective project implementation.

Governance and decision-making: Based on the short- and medium-term energy transition strategies and interventions identified in the plan, the ULB should prioritise interventions for implementation. This should be followed by allocating the required technical and financial resources to the relevant departments, establishing accountability and delivery timelines, and developing technical and procurement documentation. Appointing a nodal department or officer, supported by nodal officers across participating departments, can facilitate cross-departmental collaboration for quicker resolutions and decision-making to effectively procure, implement, and monitor energy transition interventions.

Prudent financial management and phased implementation approaches for larger initiatives will help ensure timely execution. Decision-makers should assess the required equity exposures, potential external financing support from ongoing state and central government schemes, and assistance programmes, the possible impact of cost overruns due to implementation delays, and the necessary resolutions. The following guiding questions can support ULBs in prioritising interventions and ensuring smooth and effective implementation of energy transition initiatives:

- Where are execution risks lowest, and which energy transition projects align with current institutional readiness?
- Which interventions offer the highest impact in terms of energy savings, cost reduction, and bankability?
- What level of investment is required, and how does it align with available financial resources and funding options?
- Can solutions be piloted before scaling up to reduce risk and validate performance?
- Are relevant departments aligned and prepared for implementation and long-term operations?
- What monitoring, reporting, and verification (MRV) mechanisms are in place to track performance and outcomes?

To mitigate technical and financial risks, due diligence should prioritise proven, bankable technologies, and undertake risk assessments and sensitivity analyses for policy and regulatory changes and project cash-flow variabilities. It is also important to assess the institutional capacity, maintenance practices, staff skills, departmental coordination, reskilling needs, and the existing mechanisms for interdepartmental communication, coordination, and accountability.

Energy transition projects often span multiple years, extending beyond the tenure of Municipal Commissioners, Mayors, or elected councils. Changes in administrative leadership or political priorities can delay, dilute, or discontinue initiatives unless safeguards are built into project design and governance. Maintaining data records and long-term strategies ensures continuity, and nodal officers involved in the initiatives should brief incoming decision-makers on each project's benefits and rationale.

Efficient Procurement Management and Quality Control: Once technologies, sites, and implementation mechanisms are identified, a robust procurement and bid design process is essential, with procurement documents that clearly define performance requirements, quality standards, and technical specifications, including material inspection, commissioning criteria, expected performance levels, and degradation-permit clauses. It should also incorporate clear KPIs and MRV systems for accountability and performance tracking.

In addition, the procurement contracts must specify implementation timelines with penalty provisions for unjustified delays, emphasise digital performance monitoring, and define clear indicators, roles, and responsibilities to prevent disputes, particularly in ESCO/RESCO contracts. ULBs may include a five-year annual maintenance contract or comprehensive maintenance contract in the project scope, ensuring quality installations by holding developers liable for sustained performance and safeguarding investment recovery. Procurement should be performance-based and avoid redundant rate contracts or schedules of rates that may not reflect evolving technical and performance needs.

5.2.2 During Installation and Commissioning

Quality Checks and Periodic Visits: Throughout the project implementation, it is imperative to conduct critical material inspections at manufacturing facilities, such as solar PV modules for large-scale ground-mounted solar projects, and during plant construction to avert last-minute quality failures. A systematic approach to quality assurance will promote the project's success and ensure that performance outcomes meet expectations. When necessary, ULBs may engage third-party or external experts to oversee critical project sites, for instance, larger rooftop solar PV installations.

Commissioning: Upon final installation and project commencement, commissioning tests must be carried out in accordance with the procurement quality control criteria. During commissioning, performance shall be tested under various loading conditions or input levels, such as testing of pumps at various flow rates and input pressures, and the output of PV modules in solar PV installations. If substandard performance is found during such tests, it should be rectified by the developer, and necessary penalties may be imposed in accordance with the procurement contracts. This is essential for holding the developer accountable to ensure project success.

5.2.3 Post Implementation

Monitoring through KPIs: Monitoring is crucial for energy transition projects to ensure they achieve the intended technical performance, financial savings, and lower environmental impacts from municipal energy consumption. For all energy transition projects, ULBs can develop project-specific monitoring frameworks with defined KPIs and timelines. The frameworks can be as simple as spreadsheet tables or as complex as centralised reporting dashboards with project-specific indicators that need to be filled in by departmental nodal officers or project implementation agencies, depending on the implementation model.

ULBs should monitor actual performance against established performance standards, baselines, or benchmarks, and determine the actual energy and cost savings, and verify the results internally or through third-party agencies. Performance metrics against identified KPIs should be reported using standard templates, and any deviations must be addressed promptly or escalated to the appropriate authorities.

Periodic reporting and review: The monitoring reports from periodic performance assessments should be reviewed regularly, ideally first by the concerned nodal officer, and then presented to decision-makers, who can then use them to track project implementation, performance, critical operational challenges, and any technical or operational failures. Based on this review, the ULB leadership can issue directives to implement course corrections to address underperformance and ensure the project objectives are met. The decision-makers will also be better equipped to support scale-up, annual budgetary allocations, and raising finance for projects.

Periodic monitoring and reporting enable data-driven decision-making in practice by integrating details of the implemented energy transition projects with real-time or periodic KPIs, including demonstrated project performance, energy and cost savings, and environmental impacts. External debt or financial investment can be secured through transparent demonstrations of project performance, helping expand the scale and impact of energy transition interventions. Strong governance, leadership, and transparency will help raise external finance for citywide scale-up of energy transition initiatives.

Training, awareness and communication: During implementation, ULBs can engage their technical staff at different stages to deepen their exposure to and understanding of the energy transition, while drawing on their departmental and local experience for valuable input. For interested staff, ULBs can organise internal site visits or structured training to encourage them to propose and implement energy transition measures within their departments. ULBs must also train relevant staff in the O&M of energy transition projects, as sustained O&M ensures the consistent functioning and performance of EE equipment and RE installations. Further, the ULBs should communicate the project results, lessons learned, and scale-up activities internally and externally.

5.3 | Managing Risks for Energy Transition Projects

Identifying and effectively managing risks is essential to the successful implementation of energy transition projects, ensuring both project viability and financial sustainability. While multiple risk factors influence project outcomes, ULBs must prioritise the management of key risks and adopt comprehensive mitigation strategies to support resilient and efficient project execution.

- **Design risk:** The risk that a plant's design does not meet technical standards, policy and regulations, or legal and environmental standards; and the risk that faulty design results in operational issues.
- **Construction risk:** The risk that construction time exceeds the time projected, resulting in additional costs or loss of income.
- **Cost overruns:** The risk that budgeted costs for buying equipment and constructing infrastructure end up being much higher than estimated.

Proactive risk management by ULBs builds investor confidence. It also ensures smoother implementation by minimising disruptions and cost overruns. Ultimately, it supports long-term operational stability and sustainability of energy transition initiatives. Risk mitigation measures offer a structured way to identify, evaluate, and manage potential risks throughout the project lifecycle. The main steps to reduce risks for energy transition projects are shown in Figure

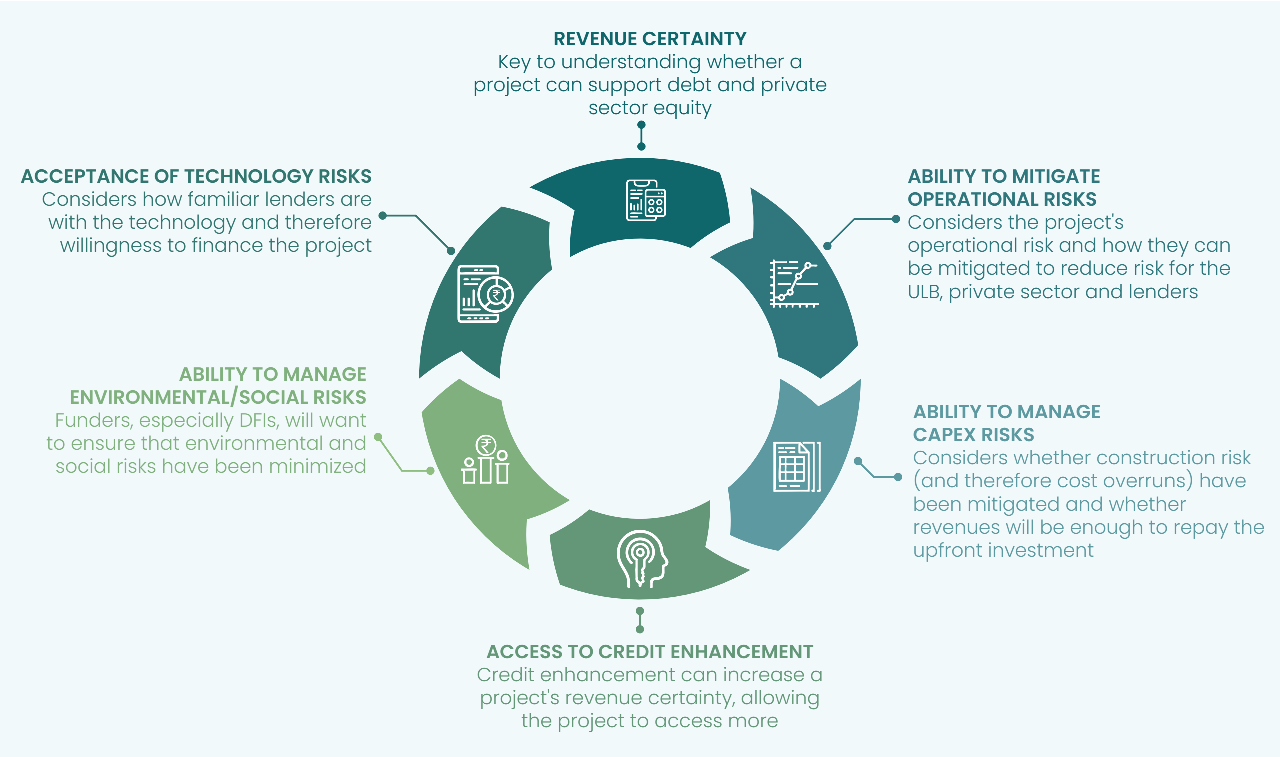

Figure 9: Risk mitigation approach for implementing energy transition projects (Source: adapted from ICLEI World Secretariat)

06 Way Forward for Municipal Energy Transition

Cities serve as major hubs of economic activity and energy consumption. ULBs are a crucial starting point for showcasing sustainable energy transition interventions and how these interventions enhance energy performance across their infrastructure and services. By adopting structured strategies focused on energy conservation, efficiency, and the integration of RE sources, cities can reduce operational costs and emissions while setting an example for other urban stakeholders.

The objective of this guidance document is to support municipal decision-makers in identifying practical pathways and making informed choices to advance the energy transition in their city's municipal operations. Further, it emphasises a better understanding of electricity tariffs, billing, policy, and regulatory frameworks for prioritised planning. A structured approach to planning and implementing energy transition initiatives supported by cross-departmental collaboration is needed, and periodic monitoring and review of progress by decision-makers will ensure that energy transition efforts remain aligned with broader urban development and sustainability goals. The ULBs can follow the approach suggested below:

Prioritise EE over RE Solutions: ULBs should prioritise EC and EE interventions to reduce the overall energy consumption and costs. This can include, but is not limited to, energy-efficient pumping systems, LED street lighting, energy audit of buildings and facilities, and optimisation of operational processes for better load management.

As the next step, ULBs should consider integrating RE solutions such as rooftop solar, bioenergy, wind, and hybrid systems to meet their energy needs. The selection of suitable RE solutions should be based on local resource availability, technical and economic feasibility, and the operational requirements of various ULB services.

Baseline Assessment and Energy Transition Planning: Prior to execution, ULBs should analyse the demand trends and load profiles to identify energy-intensive municipal buildings and facilities. They can conduct energy audits, site assessments, data analyses, and feasibility studies as necessary to understand the baseline scenario and identify priority interventions. Establishing an accurate baseline will support informed decision-making for energy transition planning, including setting evidence-based, ambitious yet achievable targets, and will enable monitoring of implementation progress.

ULBs should develop a comprehensive energy transition plan that outlines the findings of baseline assessments, identifies solutions, and prioritises interventions, targets, and suitable implementation models with associated cost implications. The ULB's sustainable energy transition goals should be aligned with the broader policy, regulatory, and market context, considering state- and national-level policies and regulations, grid constraints, and available incentives, to ensure that the RE projects deployed are both technically feasible and economically viable.

Implementation Models for Energy Transition: Considering policies, regulations, and space constraints within their local jurisdiction, ULBs should implement RE power plants on-site in their buildings and facilities, and as off-site projects, or procure RE power under innovative procurement models as suited to their municipal service requirements. The successful implementation of energy transition interventions depends on selecting appropriate financing and business models.

ULBs can leverage internal municipal resources, grants from state and national governments, climate finance, municipal bonds, green bonds, and private sector participation. Implementation can be carried out through various mechanisms such as CapEx, ESCO or RESCO models, PPPs, or other arrangements outlined in the report. Prioritisation of RE technologies for the energy transition should consider proven performance, capital requirements, anticipated savings, and long-term operational implications, ensuring that ULBs focus on solutions that provide reliable, measurable benefits.

Monitoring and Institutional Capacity Building: During implementation, robust procurement processes, technical due diligence, quality control, and performance monitoring systems are vital for guaranteeing reliable outcomes from energy transition efforts. Post-implementation, consistent monitoring of system performance, timely maintenance, and periodic reviews of results are essential to sustain energy savings and operational reliability. Monitoring the performance of EE measures and RE deployments, making necessary adjustments, and sharing lessons across departments can enhance future project outcomes, underscoring the crucial role of post-implementation learning in strengthening institutional capacity.

ULBs should develop a strong understanding of electricity tariffs, billing structure, associated charges and penalties, and the relevant regulatory frameworks to build institutional capacity to consciously manage loads considering peak demand, power factor, and tariff structures. Over time, building local technical and managerial capacity through project experience and targeted training will enable cities to expand their energy transition initiatives more effectively.

Overall, the approach outlined in this guidance document is structured to help ULBs advance the energy transition through systematic planning, implementation, and monitoring of these initiatives. By improving the operational efficiency of urban service sectors and enabling sustainable municipal operations, ULBs can demonstrate leadership in the urban sustainable energy transition. These efforts strengthen municipal governance, enhance the quality of urban service delivery, and help build a low-carbon, climate-resilient and sustainable urban future.

Energy Transition for Urban Local Bodies (ULBs) in India
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2026

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