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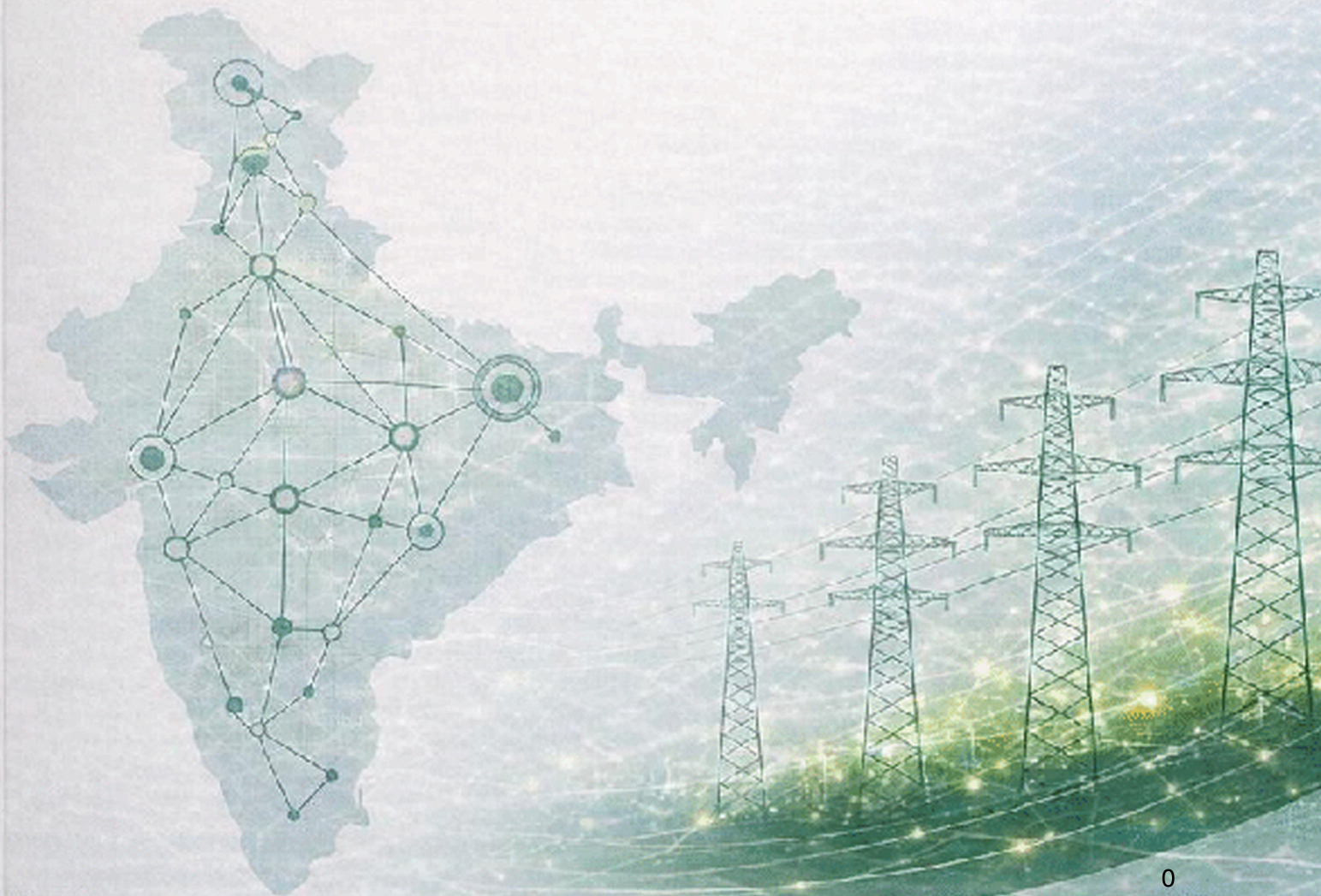
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4th DiSCOM Conclave 2026

Creating Next Generation DISCOMs

Financially Strong and Digitally Smart



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Executive Summary

India's power sector has grown significantly over the last decade. The country has added large amounts of generation capacity, expanded renewable energy, and reduced peak power shortages. However, the distribution segment (the DISCOMs) remains the most stressed part of the system. DISCOMs are responsible for delivering electricity to homes, industries, farmers, and businesses. If they are financially weak, the entire power sector becomes unstable.

Today, many DISCOMs are under financial pressure. Their total outstanding debt is above ₹7 lakh crore. Every year, state governments commit large subsidy amounts, but payments are often delayed. Most importantly, many DISCOMs still spend more money supplying electricity than they recover from consumers. This gap between the cost of supply and revenue collected continues to strain the system. Unless this structural gap is reduced, long-term stability will remain difficult.

A major reason for this stress is high technical and commercial losses. In several states, electricity is lost due to outdated infrastructure, theft, and billing inefficiencies. Reducing these losses is one of the fastest ways to improve financial health. Smart metering, feeder monitoring, better energy accounting, and strict enforcement can significantly improve revenue realization. However, installing technology alone is not enough. DISCOMs must actively use data to monitor performance and take corrective action.

India is rapidly increasing renewable energy capacity. Solar and wind power are expanding across the country. While this supports climate goals, it also makes distribution operations more complex. Renewable energy is variable. It requires better forecasting, grid upgrades, and BESS storage solutions. Distribution networks must be modernized so that they can handle two-way power flows, rooftop solar, and future demand from electric vehicles.

Digital transformation is therefore essential. DISCOMs need integrated systems for billing, outage management, load forecasting, and customer service, enabled through technologies such as AMI, artificial intelligence, digital twins, predictive analytics, and cyber-secure smart grids. Data must be accurate, secure, and actively used for decision-making, with strong cybersecurity becoming critical as operations become more digital. A modern DISCOM should operate using real-time data rather than manual processes.

Consumers are also changing. Rooftop solar adoption is rising. Electric vehicles are increasing. More consumers want reliable service, transparent billing, and digital

interaction. DISCOMs must become more customer focused. This includes easier rooftop solar approvals, better grievance systems, time-based tariffs, and improved communication.

Governance reform is equally important. Professional management, transparent reporting, timely subsidy payments, and stronger regulatory oversight are necessary for long-term credibility. Without institutional discipline, financial and operational reforms will not sustain.

Looking ahead, significant investment will be required. Smart meters, substation upgrades, digital systems, storage integration, and EV infrastructure will demand capital. Access to investment will depend on improving financial health and governance standards.

In summary, India's distribution sector is at a turning point. The challenges are serious but manageable. Financial discipline, loss reduction, digital modernization, renewable readiness, and better governance must move forward together. If implemented with consistency and accountability, these reforms can strengthen the foundation of India's energy transition and ensure reliable, affordable power for the future.

PRELIMINARIES & LEADERSHIP VISION



Mr. P R Kumar
Chairman,

Message from Chair, Power Committee, PHDCCI

I am glad to note that PHDCCI, which acts as the “Voice of Industry & Trade” is organizing 4th DISCOM Conclave 2026 on the theme – Creating Next Gen Discoms: Financially Strong & Digitally Smart on 24th February, 2026 and a Knowledge Report is being released on this occasion in collaboration with our Knowledge Partner – Fichtner Consulting Engineers (India) Pvt. Ltd.

The sector is entering a new phase defined by high renewable penetration, bidirectional power flows, electrification of transport, proliferation of prosumers, and real-time energy markets. Technologies such as advanced metering infrastructure (AMI), artificial intelligence, digital twins, predictive analytics, and cyber-secure smart grids are set to fundamentally redefine how distribution networks should be planned, operated, and financed. The transition to green, digital, and financially resilient DISCOMs is no longer a choice, rather a necessity. Future DISCOMs must move beyond traditional revenue models. Flexibility services, virtual power plants, battery energy storage, demand response, peer-to-peer trading, and monetization of data and ancillary services will play a key role. These innovations, however, must be backed by sound financial discipline, cost-reflective tariffs, intelligent power procurement, and bankable business models.

As the vital interface between power generation and consumption, DISCOMs play a decisive role in determining the quality, cost, and sustainability of electricity supply in India. Their effectiveness directly influences industrial growth, agricultural resilience, urban development, and the success of national priorities, including Make in India, Digital India, EV adoption, and large-scale renewable integration. In alignment with the Hon’ble Prime Minister’s vision of Viksit Bharat @ 2047, the power distribution sector must emerge as a foundation of India’s transformation into a developed, energy-secure, and technologically advanced nation. By 2047, India’s electricity demand is expected to multiply significantly, driven by industrial expansion, digital infrastructure and urbanization. DISCOMs will therefore need to evolve into intelligent energy service utilities to ensure reliable, affordable, and sustainable 24x7 power for all.

Our vision for the future of power distribution is anchored on three fundamental pillars: Digital Transformation, Green Energy Integration, and Financial Sustainability. I am sure that this Conclave organized by the Power Committee of PHDCCI will be a remarkable and impactful platform, fostering meaningful dialogue and actionable outcomes for the transformation of DISCOMs.

Jai Hind!!

**(Mr. P R
KUMAR)**



Dr Ranjeet Mehta
CEO & Secretary General

Message from CEO & Secretary General, PHDCCI

India's power distribution sector stands at a critical juncture. As the backbone of the electricity value chain, DISCOMs play a pivotal role in ensuring reliable, affordable, and sustainable power for all. However, persistent challenges related to integration of renewable energy, financial viability, operational inefficiencies, and technological gaps continue to impede their performance.

Our collective mission is to catalyze the transformation of India's power distribution sector by building financially resilient, digitally empowered, and consumer-centric Discoms that can reliably support India's economic growth and energy transition.

I am happy to note that the Power Committee of PHDCCI is organizing the 4th DISCOM Conclave on the theme – Creating Next Gen Discoms: Financially Strong & Digitally Smart on 24th February 2026 and a Knowledge Report is being released on this occasion in collaboration with our Partner – Fichtner Engineering & Consulting.

The Conclave will provide an excellent platform for stakeholders to deliberate on structural reforms, cost-reflective tariffs, and reduction of AT&C losses and improved governance frameworks.

This Report will serve as a meaningful reference for driving reforms and fostering financial stability across India's power distribution sector.

I look forward to the valuable insights and recommendations that will emerge from this Conclave

(Dr Ranjeet Mehta)

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NUCLEAR



1. Current state of Discoms in India

The power distribution sector of India is at a critical inflection point. An emerging trend in the sector has been observed - even as we adopt more efficient technologies, our resource consumption has been seen to increase. The fiscal year 2025-26 marked a landmark period for India's power sector, with historic advancements in energy generation, transmission, and distribution. From meeting peak power demand of 242.49 GW to reducing energy shortages at the national level to a mere 0.03% in FY 2025-26, the sector demonstrated resilience and commitment to sustainable growth.

In Financial Year 2025-26, Indian Distribution sector has pivoted from physical network expansion to commercial and digital optimization. As the sector prepares for FY 2026–27, the focus is shifting toward absolute financial solvency and the management of high-density renewable loads as demonstrated by the enforcement of Late Payment Surcharge (LPS) rules to eliminate legacy dues, the transition to Direct Benefit Transfer (DBT) for subsidy rationalization, the large-scale deployment of Smart Prepaid Meters under the RDSS, and the integration of Battery Energy Storage Systems (BESS) with solarized agricultural feeders. Sectoral Transformation & Profitability (FY 2025-26).

For the first time in a decade, the distribution sector has recorded a collective Profit After Tax (PAT) of ₹2,701 crore in FY 2024–25, marking a significant recovery from a loss of ₹25,553 crore in year FY 2023-24 and ₹67,962 crore in FY 2013-14.

This recovery can be attributed to a combination of sustained reform measures, including -

- Revamped Distribution Sector Scheme (RDSS): Enhancing financial viability through infrastructure modernization and accelerated smart metering.
- Additional Prudential Norms: Linking access to finance for Power sector Utilities to achievement against performance benchmarks to promote fiscal and operational discipline.
- Amendments to Electricity Rules: Enforcing timely cost adjustments, prudent tariff structures, and transparent subsidy accounting to ensure full cost recovery.
- Electricity Distribution (Accounts and Additional Disclosure) Rules, 2025: Introducing uniform accounting and enhanced transparency across Distribution utilities for improved financial governance.

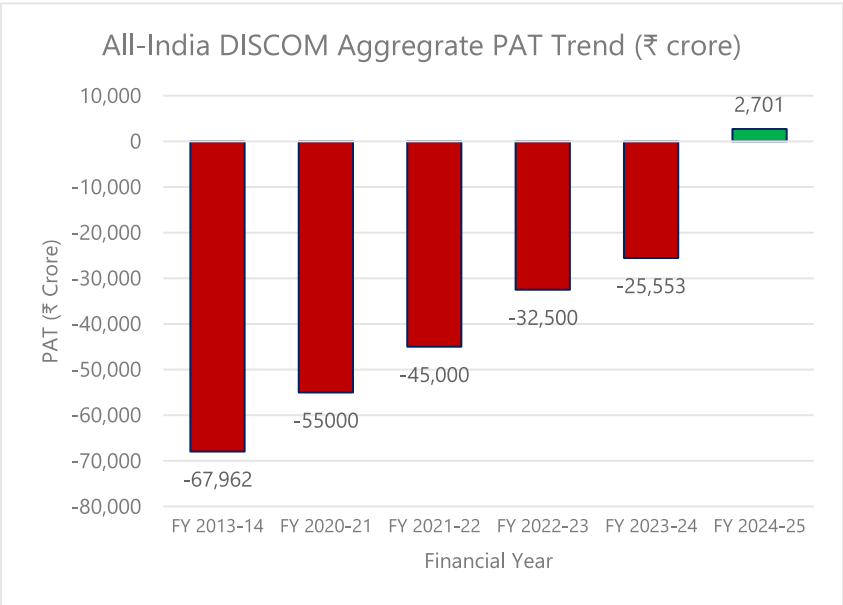


Figure 1 All-India DISCOM Aggregate PAT Trend

As per the Final Audited Aggregate reported by the Ministry of Power to the Parliament of India in the Winter Session of 2025 the results of these reforms are evidenced by the PAT posted by DISCOMs, as well as other performance indicators as listed below

- The Aggregate Technical & Commercial (AT&C) losses have reduced from 22.62% in FY 2013-14 to 15.04% in FY 2024-25.
- The improved cost recovery is signaled by the Average Cost of Supply–Average Revenue Realized (ACS–ARR) gap, which has narrowed from ₹0.78/kWh in FY 2013-14 to ₹0.06/kWh in FY 2024-25.

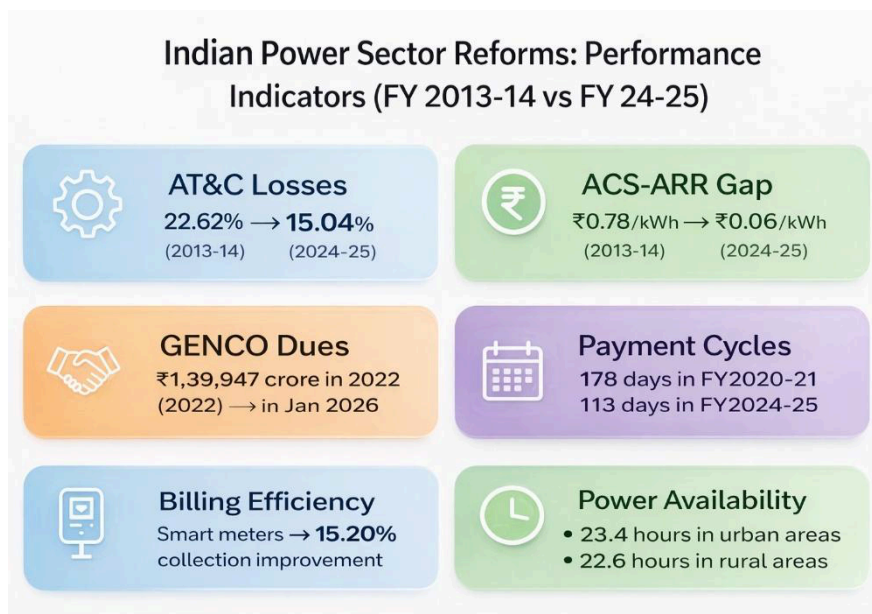


Figure 2 Performance indicators

- The Electricity (Late Payment Surcharge) Rules have led to a 96% reduction in outstanding dues to generating companies, from ₹1,39,947 crore in 2022 to ₹4,927 crore by January 2026.
- The Distribution utility payment cycles have also come down significantly from 178 days in FY 2020-21 to 113 days in FY 2024-25.
- Billing Efficiency: Smart meter deployment in India has significantly improved billing efficiency by automating meter readings, eliminating manual errors, and reducing estimated billing. This, combined with real-time consumption tracking and prepaid options, has increased revenue collection for utilities, reducing AT&C losses from 21.91% in FY21 to 16.12% in FY24, and reduced billing disputes for consumers.
- Forward Strategy (FY 27): The focus is moving beyond simple installation to data utilization, while leveraging AI-driven analytics for load forecasting and "Time-of-Day" (ToD) tariff implementation to manage the evening peak.
- Reliability Indices: Power availability has stabilized at 23.4 hours in urban areas and 22.6 hours in rural areas, marking a near-complete elimination of structural load-shedding.

Supply and Demand Dynamics

The sector is undergoing an unprecedented surge in demand while integrating a higher share of renewable energy.

- Demand Peaks: India met a record peak demand of 242.49 GW in June 2025, with the energy shortages at the national level reduced to a mere 0.3% in FY 2024–25.
- Consumption Patterns: Consumption is led by the industrial sector (41.8%), followed by households (24.3%), agriculture (17%), and commercial users (8.3%).
- Generation Mix: Total installed capacity reached 476 GW by June 2025. Renewables (excluding large hydro) accounted for almost 50% of the total installed capacity as of June 2025.

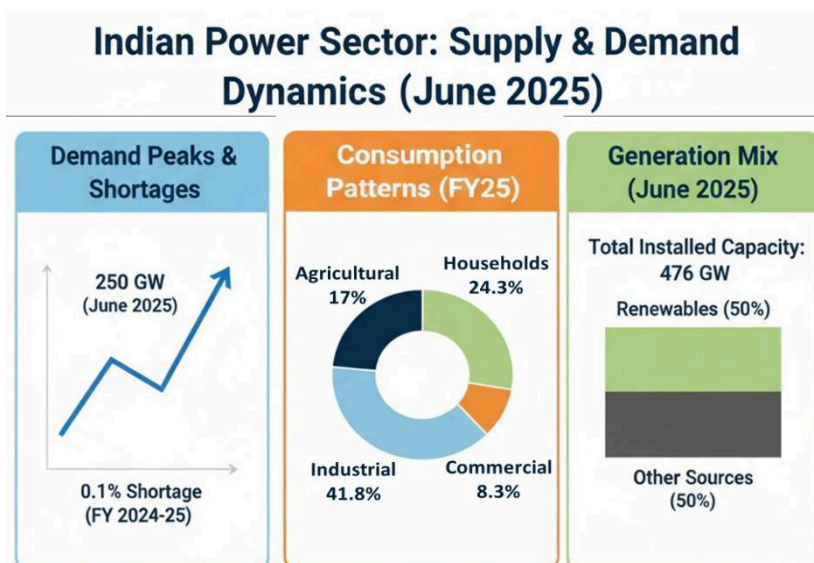


Figure 3 Indian power sector: Supply & Demand Dynamics

State-wise Performance (FY 2024)

There is wide variation in the performance of individual utilities:

- Top Performers: DGVCL (Gujarat) reported the lowest AT&C losses at 1.31%, followed by private utilities like TP Delhi (5.91%) and Adani Electricity Mumbai (6.12%).
- High-Loss Utilities: Nagaland (47.11%), Arunachal Pradesh (44.56%), and Jharkhand (31.17%) continue to report extreme AT&C losses.
- Debt Concentration: Six states (Tamil Nadu, Rajasthan, Uttar Pradesh, Madhya Pradesh, Telangana, and Maharashtra) account for approximately 75% of the total losses accumulated in the sector.



2. Benchmarking Strategy to Manage Discoms

The benchmarking strategy for India's power distribution utilities is primarily operationalized through a Results Evaluation Framework introduced under the Revamped Distribution Sector Scheme (RDSS). This strategy shifts the focus toward performance-linked financial assistance, requiring discoms to meet specific pre-qualifying criteria and clear minimum scoring thresholds to access government funding.

To bring forward "Next-Gen Discoms," the benchmarking strategy for the upcoming fiscal year needs to be recalibrated to shift from basic financial recovery to high-performance operational integration. These suggestions serve as suggestions for aligning state-level utility performance with national energy transition goals, specifically targeting the 500 GW non-fossil capacity milestone by 2030.

Performance-Linked Financial Architecture

The current strategy utilizes the Results Evaluation Framework to enforce fiscal discipline across the distribution sector. The deployment of ₹3.03 lakh crore RDSS outlay—originally sanctioned for the FY 2021–22 to FY 2025–26 period—is strictly contingent upon utilities meeting the following efficiency thresholds:

- **Cost-Reflective Tariff Compliance:** A non-negotiable benchmark is the elimination of new "Regulatory Assets." Utilities are evaluated on their ability to secure timely tariff orders from State Electricity Regulatory Commissions (SERCs). This

includes the mandatory implementation of automatic Fuel and Power Purchase Adjustment Surcharges (FPPAS) to insulate balance sheets from global commodity price volatility.

- **Subsidy Realization:** Benchmarking tracks the 100% implementation of Direct Benefit Transfer (DBT) for agricultural and domestic segments. This mechanism ensures that the projected ₹2.2 lakh crore subsidy requirement remains cash-neutral for DISCOMs by ensuring upfront liquidity.
- **Legacy Debt Restructuring:** Utilities are assessed on their progress in carving out ₹2.74 lakh crore in unsustainable debt identified by the national panel. The objective is the transition of these liabilities into state-backed instruments, thereby improving credit ratings to facilitate market-based borrowing

Technical Benchmarking Parameters



Figure 4 Technical Benchmarking Parameters

Operational Excellence & Technical Benchmarks

The technical benchmarking strategy has shifted from macro-level targets to feeder-level accountability.

- **AT&C Loss Compression:** The national benchmark for FY 2026–27 is set at 12%–15%. However, for Tier-1 urban utilities, the benchmark is being tightened to <10% to reflect the efficiency gains from full-scale smart meter integration.
- **Reliability Indices (SAIFI/SAIDI):** For the first time, rural reliability benchmarks are being aggressively aligned with urban standards, targeting 23.5+ hours of daily supply across all consumer categories.
- **Asset Management:** Benchmarking includes a mandatory reduction in Distribution Transformer (DT) failure rates to below 5%, supported by IoT-based remote monitoring systems.

Digital Maturity & Data-Driven Decision making

The benchmarking of "Digital Discoms" moves beyond hardware installation to data-driven outcomes.

- **Smart Metering Lifecycle:** Evaluation is based on the transition to 100% prepaid billing in high-loss clusters, which significantly de-risks the collection cycle.
- **Demand Forecasting Accuracy:** Discoms are benchmarked on the variance between their AI-driven day-ahead load forecasts and actual demand. Reducing this variance is critical to minimizing reliance on expensive, short-term power procurement.
- **Time-of-Day (ToD) Tariff Readiness:** Assessing the utility's capability to implement dynamic pricing, which is essential for shifting peak loads and optimizing the power purchase mix.

Implementation and Verification Strategy

To ensure the integrity of these benchmarks, the strategy employs a rigorous verification process:

- **Action Plans and DPRs:** Discoms must prepare detailed Draft Project Reports (DPRs) that analyze the root causes of their specific losses and propose a work plan for system strengthening,
- **Third-Party Evaluation:** The evaluation and verification of these targets are conducted by independent third parties on an annual basis to ensure objective assessment.

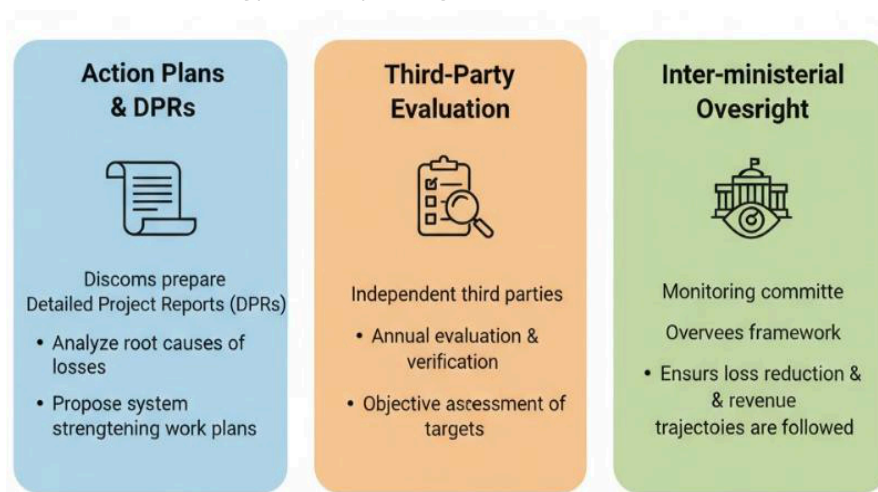


Figure 5 benchmarking strategy for Discoms

- **Inter-ministerial Oversight:** An inter-ministerial monitoring committee oversees the framework, ensuring that trajectories for loss reduction and revenue realization are strictly followed.

3. THE FOUR PILLARS: TECHNICAL DISCUSSIONS

The strategic roadmap for the Indian distribution sector is anchored by four foundational pillars designed to transition the industry toward a sustainable and digitally integrated future.

- **Pillar I** focuses on financial sustainability through debt restructuring, tariff rationalization, and the enforcement of commercial discipline.
- **Pillar II** targets the delivery of reliable and affordable power by leveraging real-time market trading and optimizing the renewable energy mix.
- **Pillar III** addresses sustainability and net-zero objectives by managing decentralized energy resources, such as rooftop solar and EV charging loads. Finally,
- **Pillar IV** utilizes digital disruption, incorporating AI-driven forecasting, IoT-enabled grids, and cybersecurity to enhance operational efficiency and network security.

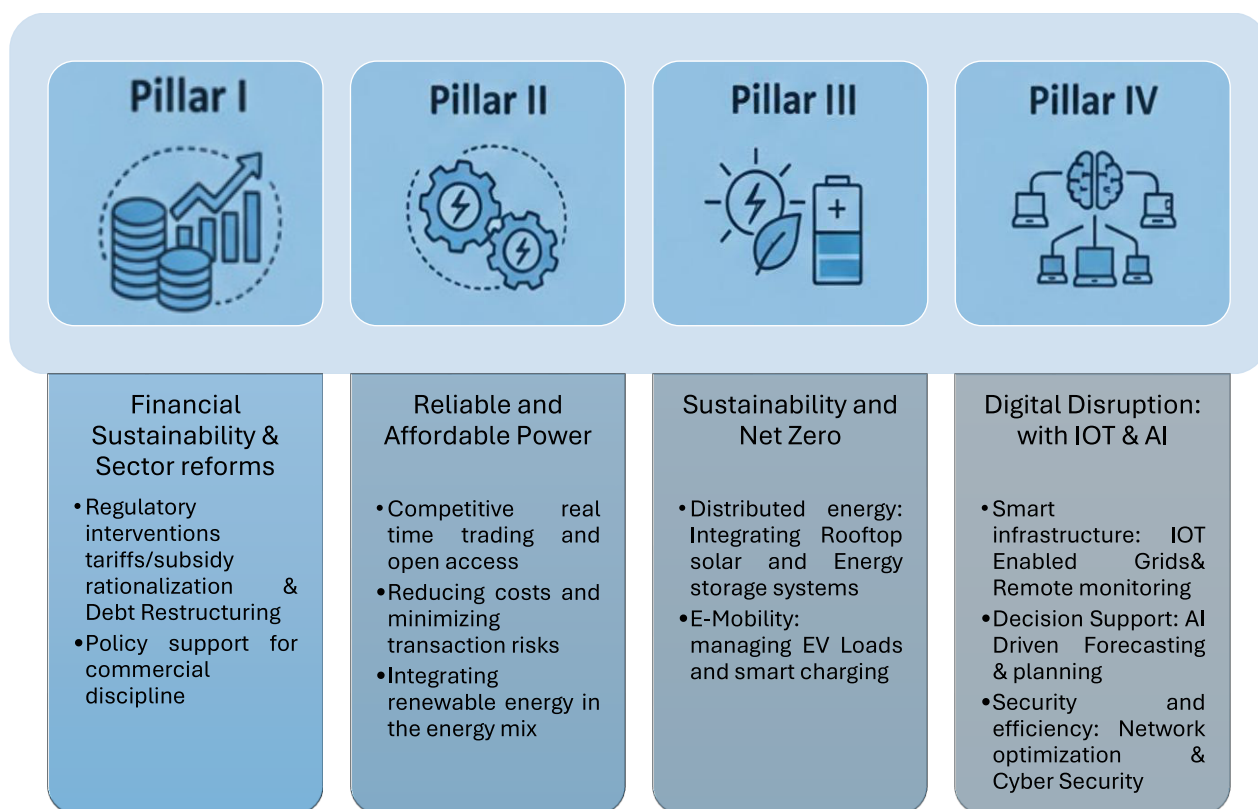


Figure 6 THE FOUR PILLARS

Lifeline of Delhi



Changing Lives
Watt by Watt

From homes to hospitals and
industries to institutions,
BSES powers 2/3 of Delhi
with unwavering reliability.

#RoshanHaiMeriDilli

3.1. Pillar I: Financial Sustainability & Sector Reform

The financial architecture of the Indian power distribution sector is undergoing a structural shift from a "liquidity-support" model to an "accrual-based sustainability" model. For the strategic period of FY 2026–27, the sector's financial health is defined by the legacy of accumulated debt, the persistence of the ACS-ARR gap, and an increasing reliance on state-funded subsidies.



Figure 7 Type of theft in the power sector

3.1.1. Financial Stress, Debt Challenges, and Revenue Gaps

The financial stability of India's distribution sector in the FY 2026–27 period is conditioned by the legacy of structural deficits and the emerging requirements of a high-RE (Renewable Energy) grid. While operational metrics have improved, the "stock" of debt and the "flow" of revenue remain misaligned in several key jurisdictions.

The financial standing of state-owned Discoms is determined by three primary variables: the accumulated debt stock, the operational gap (ACS-ARR), and the subsidy realization timeline.

I. Analysis of Accumulated Debt Stock

As of late 2025, the gross debt for state-owned DISCOMs is estimated at ₹7.18 lakh crore. This debt is not uniform in nature; it represents a combination of long-term capital liabilities and short-term liquidity bridges.

- **Composition of Debt:** Approximately 60% of this debt is held by state-owned power finance institutions (PFC and REC), with the remainder spread across commercial banks and bonds.
- **The "Unsustainable" Component:** A national-level assessment has identified ₹2.74 lakh crore as unsustainable debt. This category includes loans where interest obligations exceed the utility's operating margins, effectively creating a "debt trap" where fresh borrowings are utilized solely for debt servicing rather than asset creation.

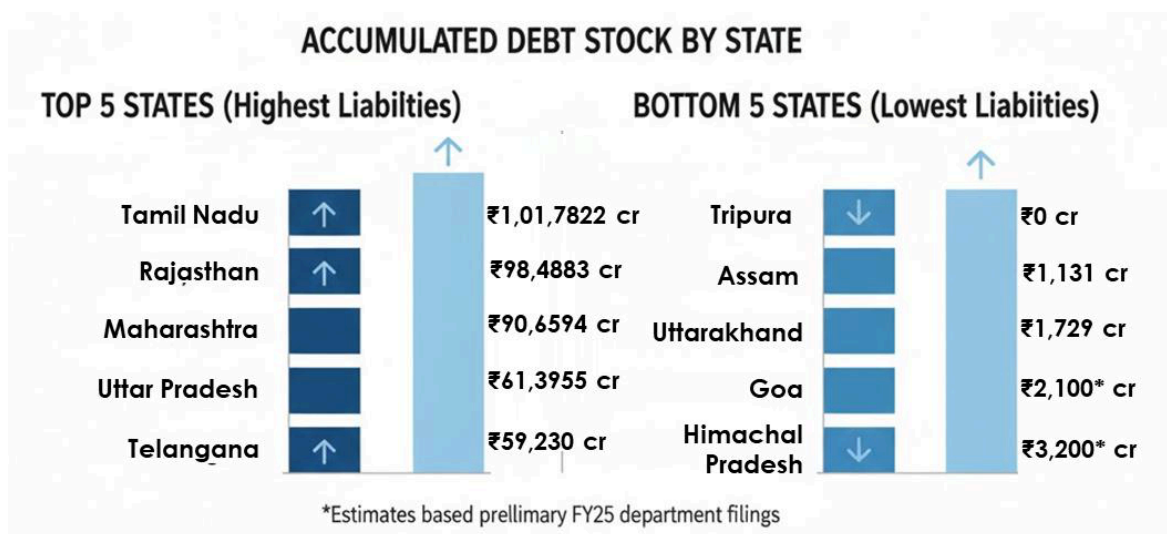


Figure 8 Accumulated Debt Stock by state

- **Interest Burden:** Interest expenses currently account for a significant portion of the Average Cost of Supply (ACS). In high-debt states, interest costs can range from ₹0.50 to ₹0.80 per unit, creating an inherent disadvantage in achieving revenue parity.

II. The ACS-ARR Gap: Mechanics of Revenue Shortfalls

The gap between the Average Cost of Supply (ACS) and Average Revenue Realized (ARR) serves as the primary indicator of financial distress.

- **Cost Drivers (ACS):** In FY 2026–27, the ACS is being pressured by rising power purchase costs due to the integration of Battery Energy Storage Systems (BESS) and the requirement for "Round-the-Clock" (RTC) renewable power. While RE generation costs are low, the associated balancing and firming costs are increasing the bulk supply tariff.
- **Realization Constraints (ARR):** Revenue realization is often hampered by:
 - **Non-Cost Reflective Tariffs:** Delays in passing through cost increases via annual tariff revisions.
 - **Cross-Subsidization:** High industrial tariffs (often 20-30% above ACS) lead to "Open Access" migration, where industrial consumers bypass the DISCOM, leaving the utility with a lower-paying consumer mix.
- **National Status:** The national ACS-ARR gap, which stood at 73 paise per unit in FY 2023, has seen a sharp compression to ₹0.06 per unit in the current fiscal year. However, the goal for FY 2026–27 is a "Negative Gap" or "Surplus" to allow for the internal accrual of capital.

III. Subsidy Dynamics and Fiscal Dependency

The distribution sector remains a primary vehicle for state-level social welfare, which manifests as a heavy reliance on subsidies.

- **Projected Subsidy Requirement:** For FY 2026–27, the estimated subsidy requirement is ₹2.2 lakh crore, primarily supporting agricultural pump-sets and low-income domestic consumers.

- Liquidity Strain: Even when subsidies are fully "booked," the delay in "cash realization" from state treasuries creates a working capital vacuum. This forces DISCOMs to take high-interest short-term loans, further inflating the ACS.
- State-wise Variation: States like Rajasthan, Uttar Pradesh, and Tamil Nadu exhibit the highest subsidy-to-revenue ratios, making their financial health highly sensitive to state budgetary allocations.

IV. Impact of Unrecognized Revenue (Regulatory Assets)

A critical but often invisible component of financial stress is the accumulation of Regulatory Assets. These are expenses that the regulator has acknowledged as "pass-through" but has deferred to future years to avoid "tariff shock" for consumers.

- The ₹3 Lakh crore Problem: Cumulative regulatory assets across India have reached approximately ₹3 lakh crore. These assets exist only as accounting entries and do not provide immediate cash flow.
- Financing Gap: Since DISCOMs must pay generators in real-time but only recover these costs from consumers over several years, they face a permanent financing gap that is typically filled by expensive short-term debt.

3.1.2. Advanced Metering Infrastructure (AMI), Feeder-Level Analytics, Theft Detection, and TOTEX-Based Performance Contracts

High AT&C losses represent one of the most significant structural barriers to financial sustainability and decarbonization in the Indian distribution sector. Every unit of electricity lost erodes revenue and represents avoidable generation, fuel consumption, and associated emissions, making loss reduction both a financial reform and a decarbonization strategy. The shift from reactive loss management to data-driven, performance-linked reduction requires deployment of advanced metering, digital analytics, targeted enforcement, and contracting models that align incentives with measurable outcomes; in this context, an integrated reform package comprising Advanced Metering Infrastructure (AMI), feeder-level analytics, technology-enabled theft detection, and TOTEX-based performance contracts can significantly strengthen a DISCOM's financial sustainability.

3.1.3. Regulatory Interventions: Subsidy Rationalization & Debt Restructuring

Regulatory interventions in the upcoming financial year can focus on institutionalizing cost-reflectivity and de-leveraging balance sheets. These interventions are designed to eliminate the

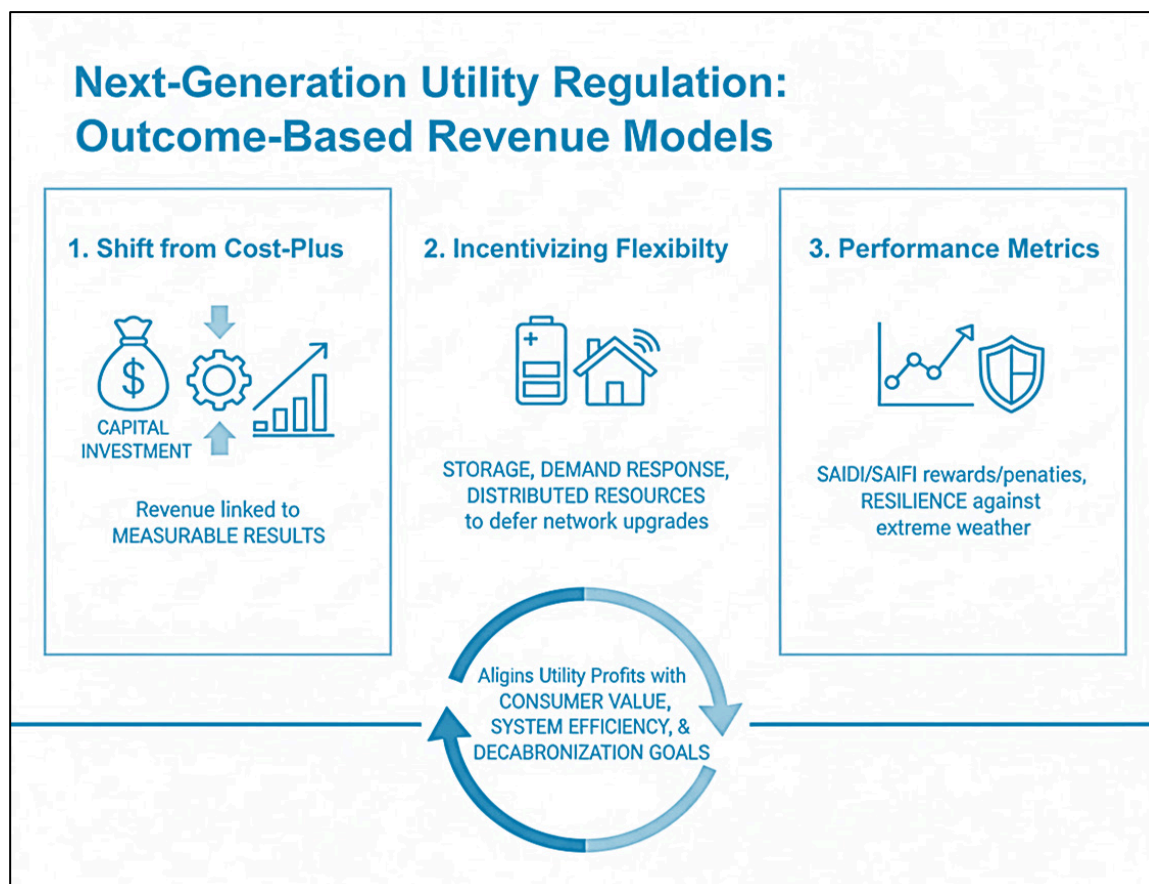


Figure 9 Outcome-based revenue models, Incentivizing flexibility and reliability

structural causes of "Regulatory Assets", i.e., revenue gaps that are recognized by regulators but have yet to recover through tariffs.

I. Subsidy Rationalization via DBT

The shift toward Direct Benefit Transfer (DBT) is the primary regulatory tool to decouple social welfare objectives from utility operations.

- **Payment Discipline:** States are required to provide 100% of the subsidy amount in advance to the Discom. Failure to do so results in a regulatory directive to bill consumers at the full, non-subsidized tariff.
- **Consumption Accuracy:** By linking subsidies to actual meter readings via smart meters, regulators are eliminating "ghost" consumption and inaccurate agricultural load estimations, which previously masked technical losses.
- **Projected Outlay:** For FY 2026–27, the all-India subsidy requirement is estimated at ₹2.2 lakh crore. DBT integration ensures this amount does not stay trapped in state treasuries, thereby reducing the Discom's working capital interest burden.

II. Strategic Debt Restructuring

To address the ₹7.18 lakh crore debt stock, a multi-agency approach is being utilized to ring-fence "unsustainable debt."

- **State-Backed Debt Takeover:** Following the framework of previous liquidity schemes, a portion of the ₹2.74 lakh crore unsustainable debt is being transitioned into State Government bonds. This reduces the interest rate from commercial bank levels (10–12%) to sovereign-backed levels (7–8%).
- **Interest Coverage Ratio (ICR) Benchmarking:** Financial institutions like PFC and REC have introduced strict ICR mandates. Discoms must demonstrate an ICR of > 1.25 to qualify for fresh capital expenditure (CAPEX) loans for grid modernization.
- **Restructuring of Trade Payables:** The Late Payment Surcharge (LPS) Rules effectively function as a debt restructuring tool by converting short-term trade payables (dues to Gencos) into long-term EMIs (Equated Monthly Installments), thus smoothing out the cash flow requirements over a 48-month horizon.

III. Strategic Focus of the Electricity Amendment Initiatives

The policy direction is centered on legislative and executive mandates that prioritize "Consumer-Centricity" and "Financial Realism."

- **Mandatory Fuel Cost Pass-Through:** Policy support has been extended to ensure that Fuel and Power Purchase Adjustment Surcharges (FPPAS) are not delayed by regulatory inertia. By ensuring regular pass-through, the policy prevents the "under-recovery" of power purchase costs, which was the primary driver of book losses in previous years.
- **Corporate Governance and Audit Standards:** Under the RDSS guidelines, Discoms are now required to adhere to strict timelines for the publication of audited annual accounts⁹. This transparency is a prerequisite for any central grant or debt-restructuring support.
- **Decoupling Subsidy from Operations:** The policy roadmap emphasizes the transition to Direct Benefit Transfer (DBT).

IV. Impact on Sectoral Credit Profile

The combination of LPS rules and the Electricity Amendment's focus on cost-reflectivity has stabilized the "Power Value Chain."

- **Reduction in Genco Receivables:** The reduction in overdue has significantly improved the liquidity of power generators, allowing them to service their own fuel supply and debt obligations.
- **Standardization of Performance:** The Results Evaluation Framework now benchmarks all utilities on their adherence to these commercial rules. In FY 2026–27, a utility's "Commercial Discipline Score" will be the primary determinant for its ability to raise capital for digital and green infrastructure.

3.2. Pillar II: Power Exchanges for Reliable & Affordable Power

In the context of consumer-led clean energy procurement, power exchanges are one of the four market instruments identified (along with green tariffs, open access, and distributed RE) through which consumers can access renewable energy.

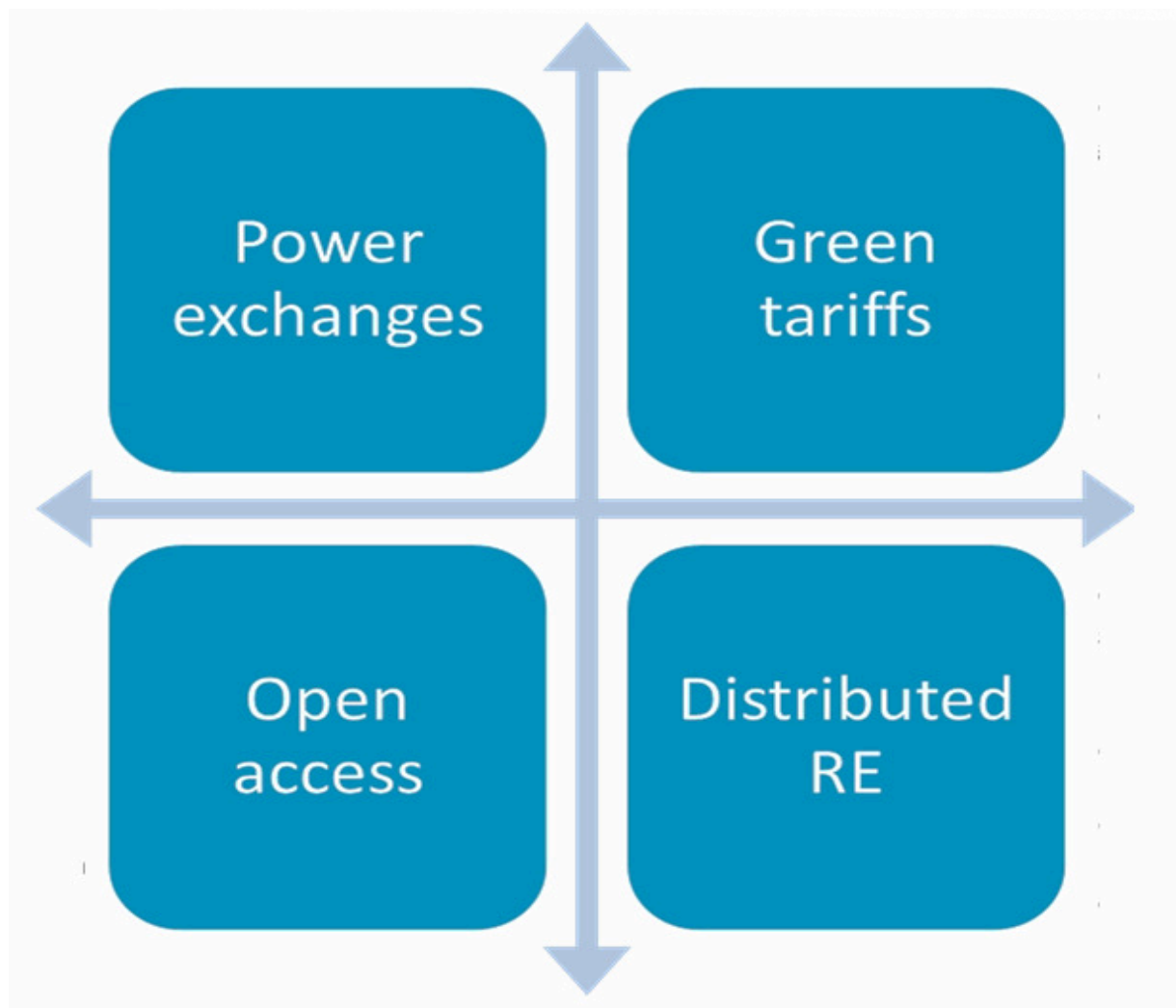


Figure 10 Instruments to access Renewable Energy

3.2.1. Market Dynamics: Competitive Real-Time Trading & Open Access

The strategic landscape for power procurement in FY 2026–27 is defined by a shift from rigid, long-term contracting to a dynamic, multi-platform market environment. This transition is essential for managing a high-renewable energy grid and ensuring that Discoms remain commercially competitive against alternative supply models.

I. High-Frequency Trading: The Real-Time Market (RTM)

The RTM has emerged as a critical operational tool for Discoms to manage the inherent intermittency of renewable generation and unpredictable demand spikes.

- Intra-Day Balancing: Utilities now utilize half-hourly trading windows to balance their portfolios just one hour before delivery. This reduces the reliance on expensive "spinning reserves" and minimizes deviation settlement charges.
- Economic Dispatch: By leveraging real-time price signals, Discoms can optimize their "merit order dispatch," choosing to buy cheaper market power during solar-peak hours and backing down high-cost thermal units.

II. Open Access Challenge and Competitive Retention

The expansion of Green Open Access and the liberalized market for Commercial & Industrial (C&I) consumers are reshaping Discom revenue models.

- Industrial Migration: Large consumers are increasingly procuring green power directly from exchanges to meet sustainability mandates and reduce energy costs.
- Cross-Subsidy Rationalization: To prevent the flight of high-paying consumers, regulators are benchmarking Discom tariffs to within $\pm 20\%$ of the Average Cost of Supply (ACS), forcing utilities to compete on price rather than relying solely on captive consumer bases.
- Retention Strategy: Discoms are evolving to offer "Green Power" as a premium service, utilizing the Green Day-Ahead Market (G-DAM) to procure and supply renewable energy to corporate clients, thereby retaining them within the utility network.

III. Market Participation and Liquidity Benchmarking

Access to these competitive markets is now strictly governed by financial discipline, as mandated under the Late Payment Surcharge (LPS) Rules.

- The Liquidity Filter: Only Discoms with zero current overdue to power generators are permitted to trade on the exchanges. This makes market participation a "liquidity prize," as access to the Day-Ahead and Real-Time markets typically allows for a 10–15% reduction in marginal power purchase costs.
- Volume Growth: As of late 2025, market-based trading accounts for an increasing share of total energy volume, as utilities move away from long-term PPAs that carry high fixed-cost burdens.

3.2.2. Price Discovery: Reducing Costs and Minimizing Transaction Risks

In the strategic framework for FY 2026–27, power exchanges serve as a critical instrument for financial de-risking. By shifting a portion of procurement from rigid long-term contracts to competitive spot markets, Discoms can mitigate the impact of rising bulk supply costs and enhance liquidity.

I. Market-Driven Cost Optimization

The utilization of power exchanges acts as a corrective mechanism for the rising Power Purchase Cost (PPC), which has seen a 5-year CAGR exceeding 5.0% in the period leading to FY2023¹.

- **Mitigating Variable Cost Inflation:** In FY2023 and FY2024, the surge in PPC was largely driven by a higher dependence on expensive imported coal and elevated short-term market tariffs. Exchange-based procurement allows Discoms to bypass expensive bilateral contracts in favor of competitive price discovery on the Day-Ahead Market (DAM).
- **Marginal Cost Reduction:** By utilizing market signals, utilities can "back down" inefficient legacy thermal plants with high variable costs and instead procure cheaper surplus power from the exchange, directly lowering the overall Average Cost of Supply (ACS).

II. Minimizing Transaction and Settlement Risks

Power exchanges provide a standardized and secure settlement environment that reduces the counterparty risks inherent in bilateral trades.

- **Elimination of Payment Delays:** Unlike traditional PPAs, which have historically suffered from payment backlogs, exchange transactions are cleared up on a "delivery-against-payment" basis. This ensures that generators receive timely payments, which in turn reduces the risk premium they build into their offer prices.
- **Regulatory Compliance and the LPS Filter:** Access to the lower prices on exchanges is now a statutory incentive for financial discipline. Under the Late Payment Surcharge (LPS) Rules, any utility that defaults on its payments to generators is restricted from the exchange. This debarment acts as a significant transaction risk, as it forces the utility to procure power from more expensive, unregulated sources.
- **Security Constrained Economic Dispatch (SCED) and Market-Based Economic Dispatch (MBED)** are national power-market reform mechanisms introduced by the Central Electricity Regulatory Commission (CERC) and implemented by POSOCO/Grid-India under the Electricity Act-2003 framework and Indian Electricity Grid Code (IEGC-2023 transition). SCED began as a POSOCO/CERC pilot for centralised optimisation of interstate generating stations, while MBED is the next-stage reform formally discussed in CERC consultation papers and the Ministry of Power's power-market reform roadmap to move India toward national merit-order dispatch across all generators. By 2026, these are recognised as core pillars of India's ongoing electricity market redesign aligned with the Electricity (Amendment) reform trajectory, real-time market expansion, and the transition toward a unified national power market.

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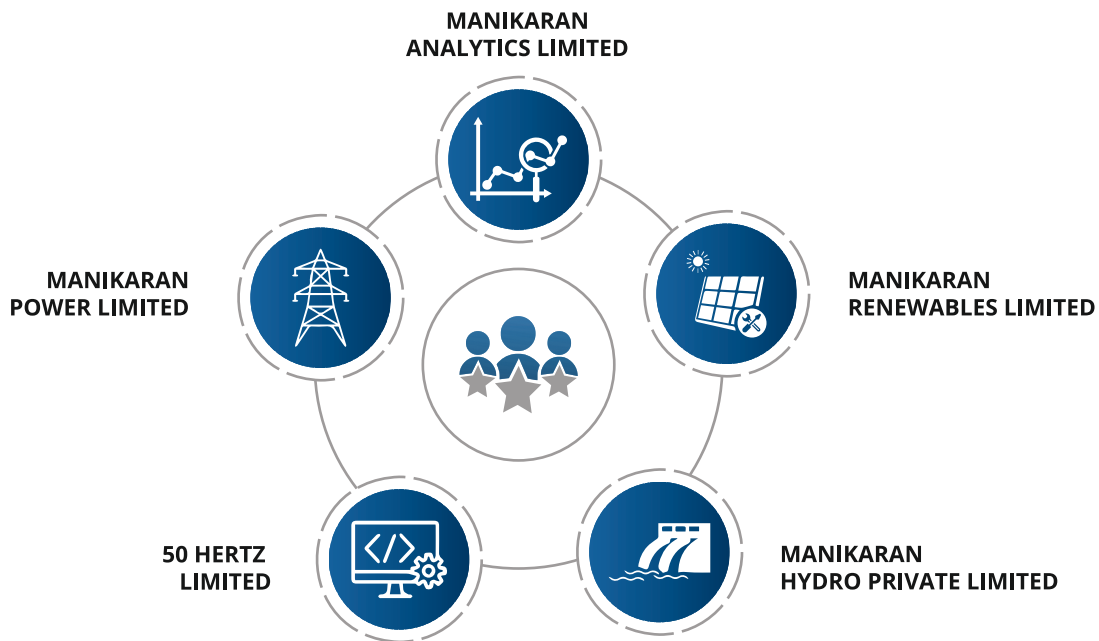
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3.3. Pillar III: Sustainability & Net-Zero: Integration of RE & BESS

The distribution sector is currently aligned with national targets of achieving 500 GW of renewable energy by 2030 and becoming Net Zero by 2070. This transformation requires a fundamental shift in how power distribution is approached, moving from traditional centralized models to decentralized, green, and digital solutions.

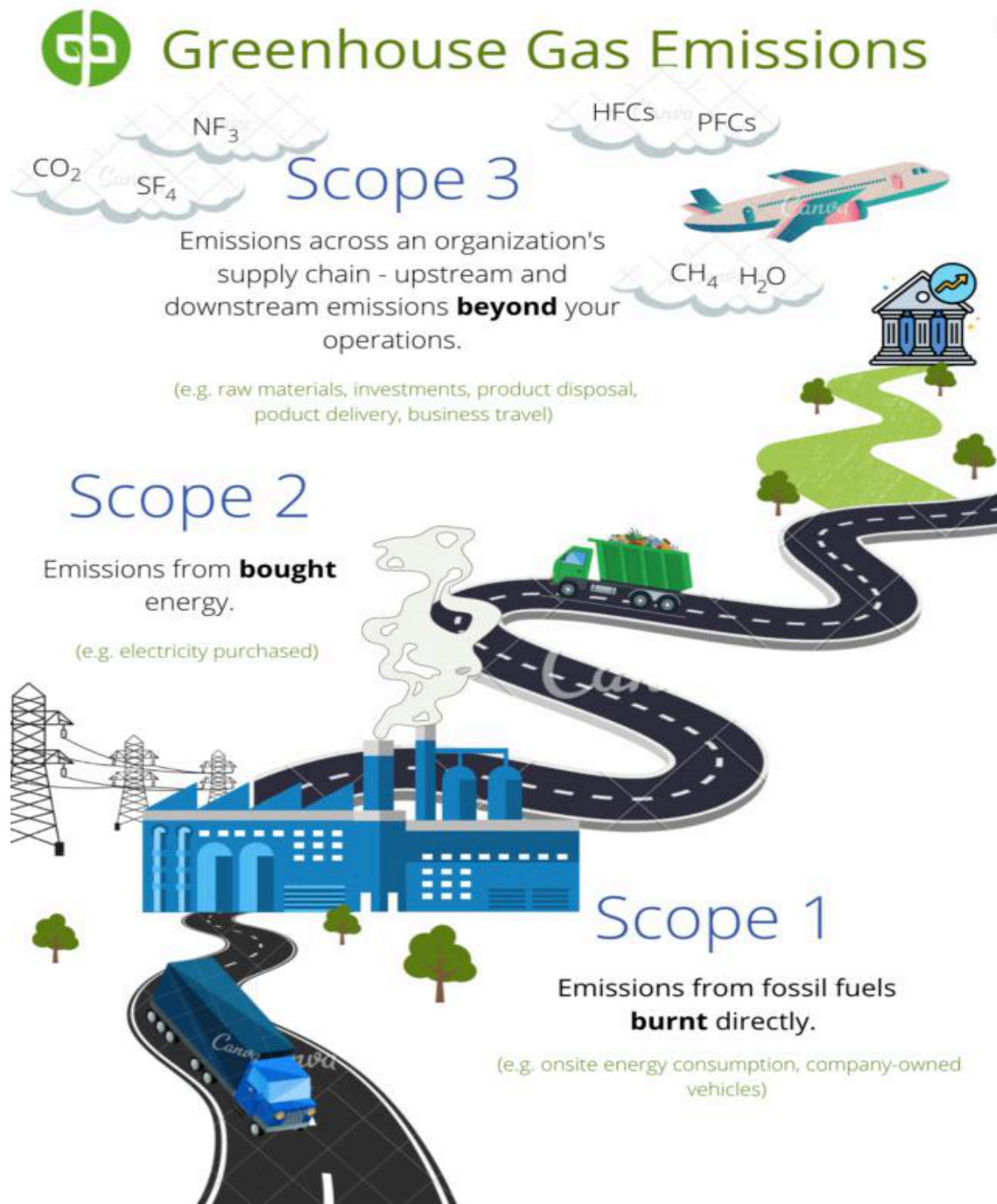


Figure 11 types of GHG emissions

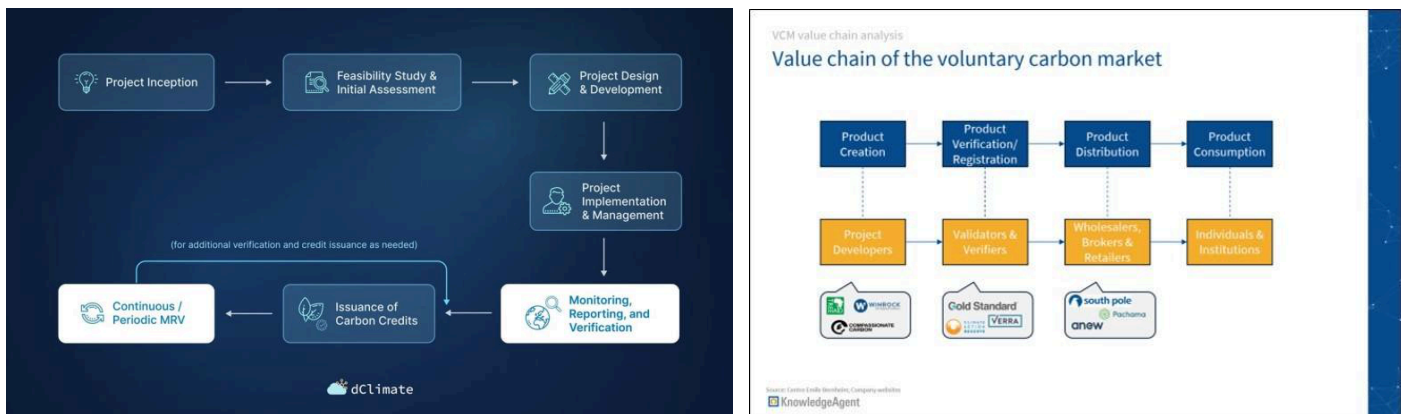


Figure 12 Carbon Monetization Flow for DISCOMs aligned with BEE and emerging carbon market frameworks.

3.3.1. Carbon Monetization: Turning Decarbonization into Financial Value

Carbon monetization is often misunderstood as a trading activity. For DISCOMs, it should instead be treated as a financial discipline that converts verified net-zero outcomes into tangible balance-sheet support.

3.3.2. High-Potential Carbon Asset Classes for DISCOMs

AT&C loss reduction and energy savings Avoided generation from reduced losses directly translates into avoided emissions, making this one of the most defensible carbon pathways.

India's commitment to achieve Net Zero by 2070, backed by ambitious interim targets for renewable energy expansion and emissions intensity reduction, places the power sector at the center of the national climate agenda. While generation-side decarbonization has progressed rapidly, the distribution segment remains the most complex and financially constrained part of the electricity value chain.

Distribution Companies (DISCOMs) sit at the critical interface between clean generation and end consumers. They are expected to integrate renewable energy, enable electric mobility, deploy smart meters, reduce losses, improve reliability, and manage increasingly volatile demand profiles—all while operating under persistent financial stress.

In this context, the net-zero transition for DISCOMs is not merely a technology challenge. it is also a funding, risk, and monetization challenge.

Without credible financing pathways, even the most advanced decarbonization plans remain aspirational.

3.3.3. The DISCOM Net-Zero Funding Stack

The Net Zero funding stack utilizes a layered investment model to transition the distribution sector toward sustainable operations.

At its base, the Catalytic Layer uses RDSS grants and state support to de-risk infrastructure projects. This is scaled by the Debt Layer through institutional lending from PFC, REC, and multilateral banks. Advanced funding is secured via the Capital Markets Layer through green and sustainability bonds. Finally, the Outcome Layer integrates carbon monetization and sustainability-linked loan benefits, which improve the credit profile of utilities and effectively lower the overall cost of capital.

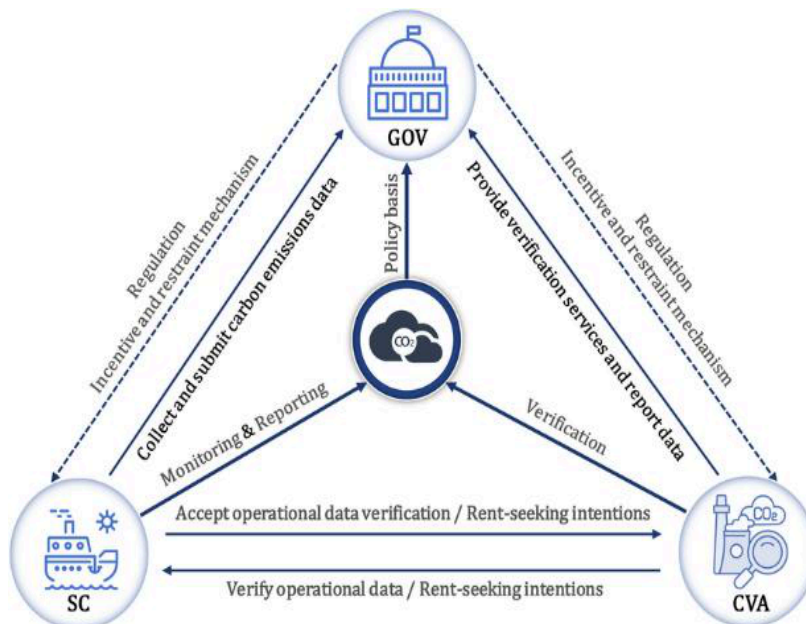


Figure 13 Carbon Monetization Stack – From Data to Finance

3.3.4. E-Mobility: Managing EV Loads and Smart Charging Infrastructure

The integration of Electric Vehicles (EVs) is being managed through a combination of infrastructure deployment and digital load management techniques to ensure grid stability and financial sustainability:

- **Infrastructure Deployment:** Utilities are actively facilitating the expansion of EV charging infrastructure under established Demand Side Management (DSM) schemes. This includes simplifying the process for setting up public and private charging stations to meet the rising demand.
- **Smart Load Management:** To mitigate the impact of high-power EV charging on the distribution network, DISCOMs are adopting smart charging infrastructure. This involves using digital tools to monitor and



Figure 14 EV Charging

schedule charging loads, preventing peak-time grid congestion and optimizing the use of existing network capacity.

- **Technological Integration:** The management of EV loads is increasingly integrated into the utility's broader digital ecosystem, utilizing SCADA and Advanced Distribution Management Systems (ADMS) for real-time visibility into feeder-level demand.
- **Sustainability Alignment:** E-mobility initiatives are paired with renewable energy integration, such as promoting rooftop solar through schemes like PM Suryaghar, to ensure that the power used for EV charging is increasingly derived from green sources.

3.3.5. *Distributed Energy: Integrated Rooftop Solar in the Distribution Mix*

Distributed energy systems (DES), or distributed energy resources (DER), are small-scale, decentralized power generation and storage technologies—such as rooftop solar, batteries, and wind turbines—located close to the point of consumption rather than at centralized power plants. They increase grid reliability, reduce transmission losses, and allow consumers to generate, store, and manage their own electricity.

3.3.6. *Grid Resilience: Role of Battery Energy Storage Systems (BESS),*

India's distribution networks face increasing stress due to rising peak demand, aging infrastructure, and high Aggregate Technical and Commercial (AT&C) losses, which climbed from 15.3% to 16.3% between 2023 and 2024. These losses highlight deeper structural issues such as outdated lines, poor billing systems, and inadequate investment in modern infrastructure. Strengthening grid resilience is therefore essential to maintain a reliable, stable supply while accommodating growing renewable energy penetration and economic expansion. Battery Energy Storage Systems (BESS) have emerged as an effective tool to stabilize distribution networks, offering peak reduction, improved reliability, and enhanced flexibility in system operations.

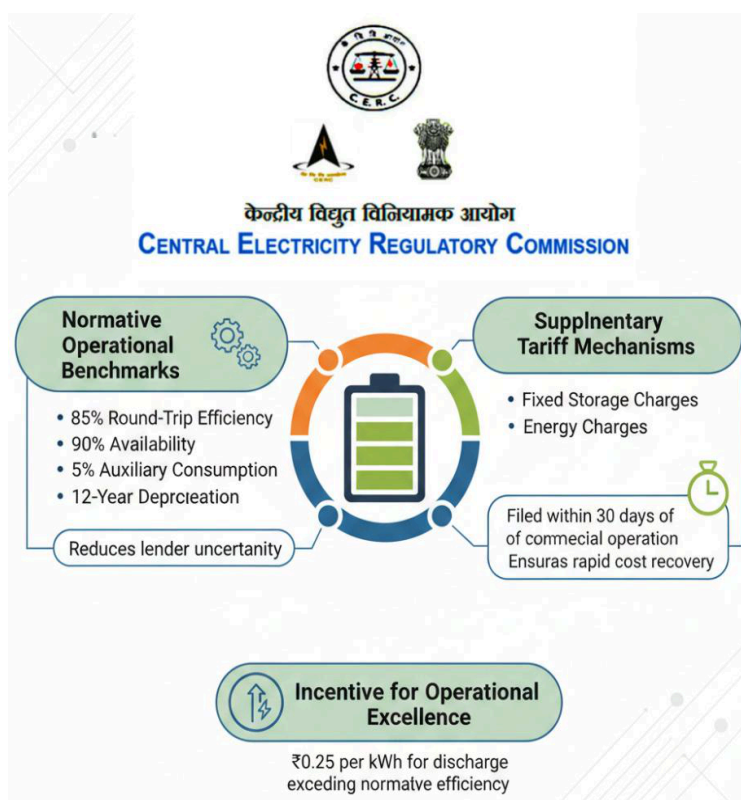


Figure 15 Government Policies supporting BESS in India

3.3.7. Integration: Managing Renewable Energy in the Energy Mix

As India advances toward its 500 GW non-fossil capacity target by 2030, the distribution sector is adopting advanced integration strategies to maintain grid stability and optimize procurement costs.

I. Optimizing the Energy Mix through Market Instruments

To manage the rising Power Purchase Cost (PPC), which has historically grown at a median 5-year CAGR of over 5.0%. Discoms are increasingly utilizing specialized market segments for RE procurement.

- Green Day-Ahead Market (G-DAM): This platform allows Discoms to procure renewable energy at market-clearing prices that are often more competitive than traditional long-term bilateral agreements⁴.
- Real-Time Market (RTM) for Balancing: Utilities are leveraging the RTM to manage the "duck curve" and RE intermittency, procuring power in half-hour windows to balance sudden fluctuations in solar or wind generation.
- Reducing Dependence on Costly Sources: A core benchmark for FY 2026–27 is the reduction of reliance on expensive short-term thermal PPA tariffs through the higher sourcing of "cheaper" renewable energy coupled with storage solutions.

II. Renewable Purchase Obligation (RPO) Compliance

Regulatory benchmarking places a critical emphasis on RPO fulfillment as a prerequisite for national performance ratings.

- REC Market Participation: Discoms utilize the Renewable Energy Certificate (REC) market to bridge gaps in physical RE procurement, ensuring they meet statutory green energy targets without incurring regulatory penalties.
- Strategic Procurement: By integrating REC trading with physical G-DAM purchases, utilities can achieve a "Green Portfolio" that supports both national environmental goals and local financial sustainability.

3.4. Pillar IV: Digital Disruption: Modernizing with IoT & AI

With large-scale rollout of smart meters, DISCOMs are becoming custodians of vast volumes of consumer and grid data, making data governance, privacy, and cybersecurity critical regulatory priorities. Future regulations will increasingly require clear rules on data ownership, secure storage, controlled sharing, and protection of consumer information. As AI and analytics are used for forecasting, billing, and theft detection, algorithm transparency, auditability, and cyber-resilience will become essential to maintain trust and regulatory compliance. Strong data governance frameworks will therefore be key to unlocking digital innovation while safeguarding consumers and critical infrastructure.



Figure 16 applications of IoT for Environmental Sustainability

3.4.1. Digital MRV Platforms Integrating AMI, SCADA, Analytics, and Audit-Ready Reporting

As DISCOMs move toward decarbonization and net-zero alignment, the availability of credible and verifiable operational data becomes essential not only for efficiency improvement but also for financing and carbon monetization. Lenders, multilaterals, and carbon markets increasingly require evidence-based performance measurement before capital deployment. In this context, Digital MRV (Monitoring, Reporting, and Verification) platforms emerge as critical enabling infrastructure.

Digital MRV converts fragmented operational data into structured financial and environmental intelligence, allowing DISCOMs to demonstrate measurable improvements in efficiency, emissions reduction, and system performance.

I. MRV as the Foundation of Bankable Decarbonization

Traditional DISCOM reporting has largely been periodic, and compliance driven. Net-zero financing, however, requires continuous measurement and verification of outcomes such as energy savings, loss reduction, renewable integration, and avoided emissions.

Digital MRV platforms enable DISCOMs to establish credible baselines, track performance improvements in near real time, and provide confidence to lenders, regulators, and carbon markets. From a financing perspective, MRV converts operational improvements into bankable metrics required for sustainability-linked loans, green bonds, and blended finance structures.

II. Integration of AMI, SCADA, and Operational Data Systems

The effectiveness of digital MRV lies in system integration rather than standalone technologies. A robust architecture combines AMI data for consumption and billing accuracy, SCADA systems for real-time grid monitoring, and analytics platforms that identify trends and operational inefficiencies.

Integration enables DISCOMs to move from static reporting to continuous operational intelligence, allowing reconciliation of energy input, delivery, and billing across the network.

III. Analytics-Driven Measurement of Decarbonization Outcomes

Digital MRV platforms allow DISCOMs to quantify outcomes that were previously difficult to measure, including avoided emissions from loss reduction, renewable energy absorption, demand response impacts, EV smart charging benefits, and efficiency gains from automation.

This capability is essential for carbon monetization, where verified avoided emissions form the basis of credit generation. Without data-backed analytics, carbon benefits remain unverifiable and financially unusable.

IV. Audit-Ready Reporting and Regulatory Transparency

Financing and carbon markets require audit-ready documentation and traceable data. Digital MRV platforms automate reporting through standardized performance reports, audit trails, and data consistency between operational and financial records, enabling third-party verification.

This improves transparency with regulators and investors while strengthening confidence in recognizing efficiency gains and decarbonization investments within regulatory frameworks.

V. MRV as Financial Infrastructure, Not IT Infrastructure

MRV should be viewed not as an IT upgrade but as financial infrastructure. Just as accounting systems establish financial credibility, MRV systems establish operational and environmental credibility.

For DISCOMs, this enables access to sustainability-linked finance, green bonds, and emerging carbon markets while improving lender risk perception. By reducing information asymmetry between utilities and financiers, digital MRV lowers perceived risk and helps unlock capital for net-zero investments.

VI. Strategic Insight

Digital MRV platforms integrating AMI, SCADA, analytics, and audit-ready reporting create the bridge between operational reform and financial transformation. By making efficiency and decarbonization outcomes measurable and verifiable, DISCOMs can convert technical

improvements into investable assets and enable sustained access to capital for long-term financial sustainability.

3.4.2. Decision Support: AI-Driven Forecasting and Planning

Utilities are increasingly integrating Artificial Intelligence (AI) and Machine Learning (ML) to transition from reactive to predictive operations, focusing on the following areas:

- **Load Forecasting and Demand Planning:** DISCOMs are utilizing AI-driven analytics to enhance the precision of demand forecasting. This enables more efficient power procurement planning, helping utilities manage peak demand and optimize their power purchase costs.
- **Predictive Maintenance:** By converging Information Technology (IT) and Operational Technology (OT), utilities are implementing pilot projects for the remote condition monitoring of Distribution Transformers. AI-driven systems analyze sensor data to detect potential faults before they occur, improving network reliability and reducing downtime.
- **Revenue Protection and Vigilance:** AI/ML-powered vigilance applications are being deployed to identify patterns indicative of electricity theft, such as meter bypassing or unauthorized connections. These systems provide priority "push notifications" to field teams, enabling targeted and data-driven anti-theft drives.
- **Customer Service Optimization:** AI-driven chatbots, such as "Elektra," and automated helpdesks are being used to handle consumer grievances 24/7. Some utilities have introduced AI-driven complaint prioritization to reduce resolution times and improve overall customer experience.
- **Billing Precision:** Advanced technologies, including OCR-based meter reading and automated anomaly detection, are utilized to enhance billing precision and reduce commercial losses.

3.4.3. Security & Efficiency: Network Optimization and Cybersecurity Protocols

The sector is undergoing a transition from traditional network management to data-driven, secure operations through several key initiatives:

- **Convergence of IT and OT:** Utilities are integrating Information Technology (IT) with Operational Technology (OT) to gain real-time visibility into the distribution network. This includes the deployment of SCADA, GIS mapping, and Advanced Distribution Management Systems (ADMS) to monitor feeder-level performance and improve grid reliability.
- **Grid Automation:** Advanced technical upgrades—such as automated reclosers and fault passage indicators—are being utilized to enable faster fault detection and restoration, minimizing downtime for consumers.
- **Smart Metering (AMI):** The rollout of Advanced Metering Infrastructure (AMI), specifically RF/GPRS-based smart meters, allows for automated energy accounting and remote operations. Under the RDSS, over 20.33 crore smart meters have been sanctioned to enhance billing accuracy and revenue realization.

- **Cybersecurity & Cloud Transformation:** To protect these expanding digital assets, DISCOMs are migrating legacy systems to secure cloud environments (e.g., MS Azure). These platforms provide built-in security protocols to safeguard sensitive utility data, consumer information, and critical grid infrastructure against cyber threats.
- **AI-Driven Diagnostics:** Pilot projects are utilizing AI-driven analytics for the remote condition monitoring of Distribution Transformers. These systems detect anomalies and potential failure points early, allowing for preventive maintenance and optimizing asset lifecycles.

This integrated approach ensures that as distribution networks become more "intelligent" and interconnected, they remain resilient against both technical failures and external security breaches.

3.4.4. Smart Infrastructure: IoT-Enabled Grids and Remote Asset Monitoring

Utilities are transitioning from legacy infrastructure to "intelligent" networks by integrating Information Technology (IT) with Operational Technology (OT). The key components of this smart infrastructure include:

- **Advanced Metering Infrastructure (AMI):** The rollout of RF/GPRS-based smart meters—with over 20.33 crore sanctioned and 5.28 crore installed nationwide—enables automated energy accounting, remote connection/disconnection, and real-time consumption monitoring.
- **Remote Condition Monitoring:** DISCOMs are implementing pilot projects for the remote monitoring of Distribution Transformers. These IoT-enabled systems utilize sensors to track asset health, allowing for preventive maintenance and reducing the risk of catastrophic failure.
- **Grid Automation & Visibility:** The convergence of SCADA (Supervisory Control and Data Acquisition), GIS (Geographic Information System) mapping, and ADMS (Advanced Distribution Management Systems) provides utilities with real-time, feeder-level visibility.
- **Rapid Fault Response:** Technical upgrades like automated reclosers and fault passage indicators are integrated into the grid to enable faster fault detection and restoration, significantly enhancing network reliability.
- **Digital Project Tracking:** Some utilities have developed specialized digital portals to monitor infrastructure projects through their entire lifecycle, from initial conception to final commissioning.

This transition to smart infrastructure allows utilities to move away from reactive maintenance toward data-driven, predictive operations, ultimately reducing technical losses and improving the quality of power supply.

4. Evolution of the Power Market in India

Authored by -

Mr. Harish Saran, Managing Director

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Introduction

The evolution of the power market in India represents one of the most significant structural transformations in the country's economic and infrastructure landscape. From a vertically integrated, state-dominated electricity system to a progressively competitive, market-oriented framework, India's power sector has undergone multiple phases of reform driven by rising demand, fiscal stress, technological advancement, and the imperative of energy security and sustainability. These abstract traces the historical development, institutional reforms, market mechanisms, and emerging trends shaping the Indian power market, highlighting both achievements and persistent challenges.

Pre-Reform Era: State Monopoly and Vertical Integration

At the time of Independence in 1947, India's power sector was small, fragmented, and underdeveloped, with electricity generation largely confined to urban centers and industrial hubs. Recognizing electricity as a public good essential for economic development, the government adopted a state-led model. The Electricity (Supply) Act, 1948 laid the foundation for the establishment of State Electricity Boards (SEBs), which were responsible for generation, transmission, and distribution within their respective states.

This vertically integrated monopoly structure aimed to ensure universal access and coordinated planning. Central Public Sector Undertakings (CPSUs) such as the National Thermal Power Corporation (now NTPC) and National Hydroelectric Power Corporation (NHPC) were later created to supplement state efforts, particularly for large thermal and hydro projects. While this model enabled rapid capacity addition during the early decades, it gradually became inefficient due to political interference in tariff setting, inadequate cost recovery, poor maintenance, and mounting financial losses. Electricity tariffs were often used as instruments of social policy, resulting in cross-subsidization and chronic underinvestment.

Drivers for Reform: Economic Liberalization and Sectoral Stress

By the late 1980s and early 1990s, the limitations of the state-dominated electricity model became evident. Demand for power grew rapidly with industrialization and urbanization, while supply lagged due to capital constraints and inefficiencies.

Transmission and distribution (TCD) losses were exceptionally high, often exceeding 30%, and SEBs accumulated unsustainable financial deficits.

The broader economic liberalization initiated in 1991 acted as a catalyst for power sector reform. The government recognized the need for private investment, improved operational efficiency, and market-based signals to guide capacity addition and consumption. Early attempts included opening generation to private participation and introducing independent power producers (IPPs). However, the absence of a comprehensive regulatory and market framework limited the success of these initiatives.

Institutional Reforms and the Electricity Act, 2003

A watershed moment in the evolution of the Indian power market was the enactment of the Electricity Act, 2003. This legislation consolidated earlier laws and fundamentally restructured the sector. Key provisions included the unbundling of SEBs into separate generation, transmission, and distribution entities; the introduction of open access in transmission and distribution; and the establishment of independent regulators at the central and state levels.

The Act empowered the Central Electricity Regulatory Commission (CERC) and State Electricity Regulatory Commissions (SERCs) to determine tariffs, regulate competition, and protect consumer interests. It also recognized electricity trading as a distinct licensed activity, laying the groundwork for organized power markets. The policy shift marked a transition from administrative allocation to market-oriented mechanisms, with competition envisioned as a driver of efficiency and innovation.

Emergence of Power Exchanges and Short-Term Markets

The mid-2000s witnessed the operationalization of power trading platforms, most notably the Power Exchange India Limited (PXIL) and the Indian Energy Exchange (IEX). These exchanges enabled transparent price discovery through day-ahead and intra-day markets, allowing generators, distribution companies (DISCOMs), and large consumers to buy and sell electricity based on demand-supply dynamics.

The growth of short-term markets reduced reliance on long-term power purchase agreements (PPAs) and improved system flexibility. Over time, additional market segments such as real-time markets, term-ahead markets, and ancillary services were introduced. These developments aligned India's power sector more closely with global best practices and enhanced grid stability, particularly in the context of increasing renewable energy penetration.

Renewable Energy and Market Transformation

The rapid expansion of renewable energy has been a defining feature of India's power market evolution over the past decade. Driven by climate commitments, declining technology costs, and supportive policies, India emerged as one of the world's largest

markets for solar and wind power. Competitive bidding mechanisms replaced feed-in tariffs, leading to significant cost reductions and improved efficiency.

Renewables introduced new challenges for market design due to their variable and intermittent

nature. This necessitated reforms in scheduling, forecasting, balancing, and ancillary services. The development of green term-ahead markets and renewable energy certificates (RECs) reflected efforts to integrate clean energy into market structures while maintaining grid reliability.

Distribution Sector Challenges and Financial Stress

Despite progress in generation and trading, the distribution segment remains the weakest link in the Indian power market. DISCOMs continue to face financial distress due to high aggregate technical and commercial (ATCC) losses, inadequate tariffs, delayed subsidy payments, and inefficiencies in billing and collection. Various reform schemes, including financial restructuring packages and performance-linked incentives, have been introduced to address these issues.

The sustainability of power markets ultimately depends on the creditworthiness of DISCOMs, as they are the primary buyers of electricity. Without financially viable distribution utilities, market signals remain distorted, and private investment is discouraged. Recent policy emphasis on smart metering, prepaid systems, and privatization in select regions aims to improve accountability and efficiency.

Market-Based Economic Dispatch and Future Reforms

A key ongoing reform is the proposal for Market-Based Economic Dispatch (MBED), which seeks to optimize generation dispatch across the country based on marginal costs rather than bilateral contracts. MBED has the potential to reduce overall power procurement costs, improve utilization of efficient plants, and lower emissions. Its implementation, however, requires resolution of concerns related to federalism, legacy contracts, and revenue allocation.

Looking ahead, the Indian power market is expected to evolve toward deeper competition, greater digitalization, and enhanced integration with emerging technologies such as energy storage, electric vehicles, and demand response. The convergence of power markets with environmental and carbon markets is also anticipated as India advances its energy transition goals.

Conclusion

The evolution of the power market in India reflects a gradual but decisive shift from state control to market orientation. While significant milestones have been achieved, particularly in generation capacity expansion, renewable integration, and price discovery, the journey remains incomplete. Structural challenges in distribution, regulatory consistency, and institutional coordination continue to constrain the full realization of market efficiency.

Nevertheless, India's experience demonstrates the complexity of power sector reform in a large, diverse, and rapidly growing economy. The continued evolution of market mechanisms, supported by sound regulation and financial discipline, will be critical in ensuring reliable, affordable, and sustainable electricity for the country's long-term

5. Smart Grids 2.0 and Digital Twins

Building Autonomous, Self-Optimizing Distribution Networks for India's Energy Transition

Authored by -

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The Next Phase of Distribution Transformation

India's electricity distribution sector is entering a period of structural transformation. Rapid renewable energy integration, electrification of mobility, growth of distributed energy resources (DERs), and rising consumer expectations are fundamentally changing the way distribution networks operate. Traditional grid architectures—designed for one-directional energy flow and predictable demand—are increasingly inadequate for managing dynamic, decentralized energy systems.

In this evolving landscape, DISCOMs are required to move beyond incremental digitalization toward intelligent, adaptive, and autonomous network operations. The next phase of grid evolution—often described as *Smart Grids 2.0*—is characterized by deep integration of IoT, artificial intelligence, edge computing, and digital twin technologies. These technologies collectively enable distribution networks to become self-aware, self-healing, and self-optimizing.

The transition is not merely technological. It represents a shift from reactive asset management to predictive and autonomous system operation, with significant implications for reliability, operational efficiency, asset life extension, and long-term financial sustainability.

From Smart Grids to Smart Grids 2.0

The Emergence of Autonomous Distribution Networks

The first generation of smart grids primarily focused on automation and visibility, smart meters, SCADA systems, and basic remote monitoring. While these improvements enhanced operational awareness, decision-making largely remained manual and reactive.

Smart Grids 2.0 represents the next evolution, where digital infrastructure enables real-time decision-making and automated response mechanisms within the network itself.

IoT-Enabled Distribution Infrastructure

The foundation of Smart Grids 2.0 lies in widespread deployment of IoT-enabled devices across substations, feeders, transformers, and switching points. Sensors continuously monitor

parameters such as load, voltage, temperature, equipment health, and power quality. This granular data provides the visibility required for advanced analytics and automated control.

Unlike traditional monitoring systems, IoT-based infrastructure enables continuous situational awareness across the distribution network, allowing utilities to detect anomalies before they evolve into outages or equipment failures.

Digital Substations and Edge Intelligence

Digital substations represent a significant shift from conventional substation architecture. By digitizing protection, control, and communication systems, substations become intelligent nodes capable of local decision-making.

Edge computing plays a critical role in this transformation. Instead of transmitting all operational data to central control centers, edge devices process data locally, enabling faster response times and reducing communication latency. This is particularly important for outage prevention, voltage regulation, and fault isolation, where milliseconds can determine system stability.

The combination of digital substations and edge intelligence reduces dependence on centralized intervention and supports the emergence of distributed operational intelligence within the grid.

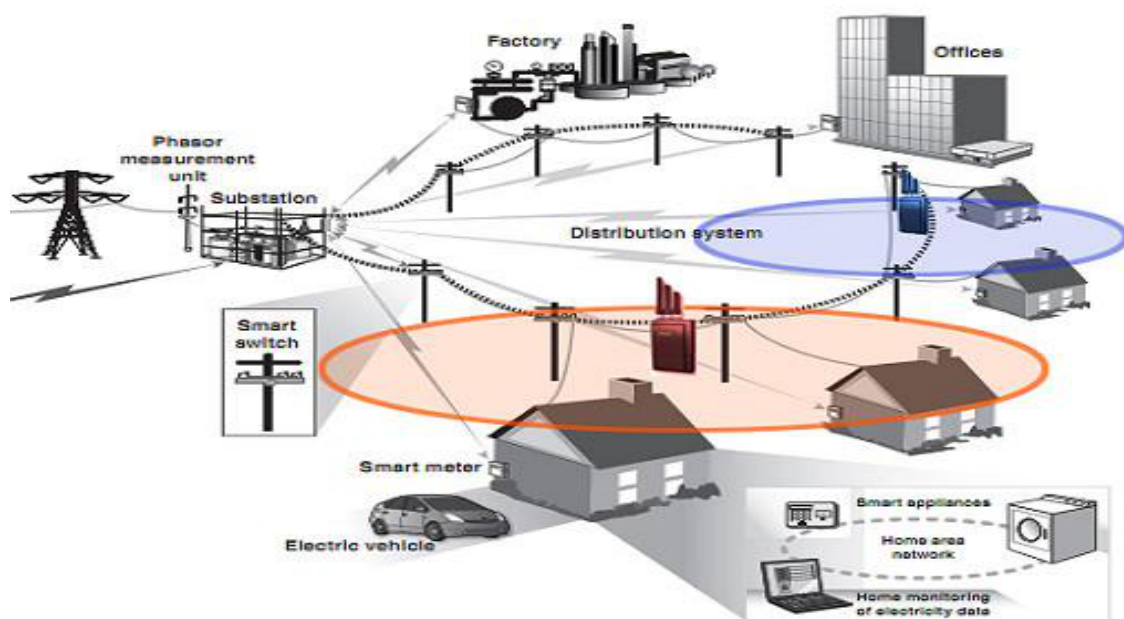


Figure 17 Smart Grid 2.0 – Self-Optimizing Distribution Network Architecture

AI-Driven Self-Healing and Autonomous Outage Management

One of the most visible outcomes of Smart Grids 2.0 is the development of self-healing networks. AI-driven systems analyse network conditions continuously and automatically initiate corrective actions such as load reconfiguration, fault isolation, or alternate supply routing.

Autonomous outage management systems integrate fault detection, predictive analytics, and switching automation to reduce outage duration and improve reliability indices such as SAIDI and SAIFI. Over time, the system learns from historical events, improving response accuracy and reducing human intervention.

This capability marks the transition toward what may be termed Self-Optimizing Grids—networks that continuously adjust operational parameters to maintain efficiency, reliability, and stability under changing conditions.

AI and Digital Twins: The Next Frontier in DISCOM Planning and Asset Management

While automation improves operational response, the next leap in distribution efficiency comes from the ability to simulate and predict system behavior before failures occur. This is where digital twin technology becomes transformative.

A digital twin is a dynamic, virtual replica of a physical asset or network that continuously receives operational data from the field. By combining engineering models with real-time data, digital twins allow utilities to analyse performance, predict failures, and optimize operations without interrupting physical systems.

Despite global adoption in manufacturing and aviation sectors, digital twin applications in distribution utilities remain relatively underexplored in India, making this an important area for future innovation.

Digital Twins of Feeders and Substations

Creating digital twins of feeders and substations enables DISCOMs to simulate load flows, voltage profiles, and asset stress conditions under different operating scenarios. Utilities can evaluate the impact of renewable integration, EV charging loads, or network reconfiguration before implementation. This capability significantly improves planning accuracy by replacing static

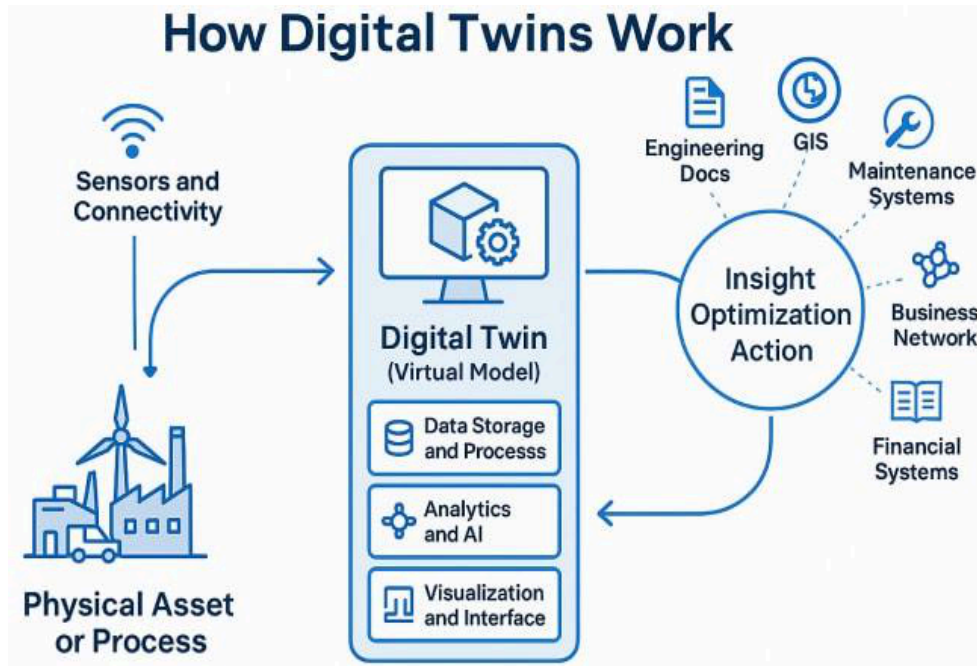


Figure 18 How Digital Twins Work

assumptions with data-driven simulations. It also allows planners to prioritize investments based on actual asset stress rather than age-based replacement cycles.

Predictive Maintenance and AI-Based Failure Prediction

Traditional maintenance strategies rely on periodic inspections or reactive repairs after failure. AI-driven predictive maintenance shifts this approach by analysing operational patterns to identify early signs of equipment degradation.

Machine learning models can detect anomalies in temperature, load variation, vibration, or switching behavior that precede failures. Early intervention prevents unplanned outages, reduces repair costs, and enhances system reliability.

For DISCOMs, predictive maintenance also reduces emergency capital expenditure and improves operational efficiency, both critical factors in improving financial sustainability.

Asset Life-Cycle Optimization

One of the most significant benefits of digital twin implementation is asset life-cycle optimization. Rather than replacing equipment based solely on age or conservative estimates, utilities can extend asset life safely based on actual performance data.

Optimized asset utilization reduces capital expenditure requirements while improving return on existing infrastructure investments. This is particularly relevant for financially constrained utilities where capital availability is limited.

Over time, digital twin-based planning enables a transition from asset replacement strategies to asset optimization strategies, improving long-term investment efficiency.

Financial and Operational Implications for DISCOMs

The adoption of Smart Grids 2.0 and digital twin technologies has implications beyond operational improvement. By improving measurement accuracy, reliability, and predictability, these technologies directly influence financing and investment decisions.

Autonomous outage reduction improves revenue continuity. Predictive maintenance reduces emergency expenditure. Optimized asset utilization lowers capital intensity. Together, these outcomes strengthen DISCOM financial profiles and improve access to performance-linked and sustainability-oriented financing.

Equally important, digitally measurable outcomes support emerging frameworks such as carbon monetization, where the avoided losses, improved efficiency, and optimized operations contribute to verifiable emissions reduction.

The Road Ahead: From Automation to Autonomous Utilities

The future distribution utility will operate as an intelligent, data-driven platform where operational, financial, and sustainability decisions are interconnected. Industry 5.0 principles emphasize the collaboration between human expertise and intelligent systems, allowing engineers and operators to focus on strategic decisions while routine optimization occurs autonomously.

Technology ecosystems emerging in this space increasingly focus on integrating engineering models, real-time operational data, and AI-driven analytics into unified platforms capable of supporting planning, operations, and sustainability objectives simultaneously.

For DISCOMs, the journey toward Smart Grids 2.0 is therefore not merely a technology upgrade—it is a transition toward resilient, adaptive, and financially sustainable distribution systems capable of supporting India's long-term energy transition.

India's energy transition demands distribution networks that are intelligent, flexible, and capable of operating under increasing complexity. Smart Grids 2.0 and digital twin technologies provide the foundation for this transformation by enabling autonomous operations, predictive asset management, and data-driven planning.

As DISCOMs evolve toward self-optimizing networks, the integration of AI, IoT, and digital twins will play a decisive role in improving reliability, extending asset life, and enabling financially viable decarbonization pathways.

The distribution network of the future will not simply deliver electricity, it will continuously learn, adapt, and optimize itself, forming the backbone of a sustainable and resilient energy ecosystem.

As distribution networks evolve in response to increasing renewable integration and changing demand patterns, the convergence of digital intelligence, engineering systems, and sustainability objectives will define the next phase of utility transformation. The transition toward self-optimizing grids and digital twin-enabled planning reflects a shift from reactive infrastructure management to continuous optimization, enabling improved reliability, operational efficiency, and financially sustainable decarbonization.

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Their contributions have significantly enhanced the analytical depth and practical relevance of this report.



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