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MINISTRY OF
**POWER**
सत्यमेव जयते

# INDIA ENERGY STACK:
## Strategy Document

VERSION 0.2
DECEMBER, 2025

**India Energy Stack**

The Ministry of Power is reimagining the digital backbone for India's Power sector by creating a Digital Public Infrastructure (DPI) for the Power sector through the India Energy Stack (IES). The IES is being advanced under a whole-of-ecosystem approach through a phased programme of design, pilot implementation, and national rollout.



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Note: The India Energy Stack documents are currently in draft form, going through various revisions, and will be released regularly as the idea evolves for public consultation and review. The contents of these documents should currently be seen purely as a draft.

**Glossary of Terms**

| Acronym | Expanded form | What it refers to in this context |
|---|---|---|
| **AGC** | Automatic Generation Control | Automated control of generator output to support frequency control |
| **AMI** | Advanced Metering Infrastructure | Smart metering system including meters, communications, and head-end |
| **AS** | Ancillary Services | Grid support services like reserves and frequency response |
| **ATC** | Available Transfer Capability | Transfer capacity available for transactions after reliability margins |
| **CIS** | Customer Information System | Utility customer and account management system |
| **CMMS** | Computerized Maintenance Management System | Maintenance planning and work order management tool |
| **CEMS** | Continuous Emissions Monitoring System | Continuous monitoring of emissions at generation units |
| **CPO** | Charge Point Operator | Entity that owns or operates EV charging stations |
| **CRM** | Customer Relationship Management | Customer engagement, complaints, and service management tool |
| **DEEP** | Discovery of Efficient Electricity Price | India's e-bidding and reverse auction procurement portal |
| **DER** | Distributed Energy Resource | Distributed generation/storage like rooftop solar and batteries |
| **DERMS** | Distributed Energy Resource Management System | System for monitoring and managing DERs and aggregations |
| **DISCOM** | Distribution Company | Electricity distribution utility |
| **DRMS** | Demand Response Management System | System to run demand response programs and event dispatch |
| **EAM** | Enterprise Asset Management | Asset lifecycle management system for utilities and grid owners |
| **EMS** | Energy Management System | Control-room system for monitoring and operating the grid |
| **ERP** | Enterprise Resource Planning | Enterprise finance, procurement, inventory, and operations system |
| **GENCO** | Generation Company | Power generation entity or utility |
| **GIS** | Geographic Information System | Spatial asset and network mapping system |
| **HVDC** | High Voltage Direct Current | DC transmission technology and associated corridor assets |

| | | |
|---|---|---|
| **IAM** | Identity and Access Management | Identity, authentication, authorisation, and access control tooling |
| **KPI** | Key Performance Indicator | Performance metric used for monitoring outcomes and compliance |
| **LiDAR** | Light Detection and Ranging | Remote sensing used for corridor and right-of-way monitoring |
| **MDMS** | Meter Data Management System | System that stores, validates, and provides meter data |
| **MERIT** | Merit Order Dispatch of Electricity for Rejuvenation of Income and Transparency | Public transparency portal for merit order and procurement insights |
| **MIS** | Management Information System | Reporting and compliance information system |
| **N-1 / N-2** | Contingency criteria | Planning/operational checks for one or two element outages |
| **NPP** | National Power Portal | National portal providing power sector data and dashboards |
| **OTC** | Over-the-Counter | Bilateral contracting outside an exchange platform |
| **PMU** | Phasor Measurement Unit | Synchrophasor device for wide-area monitoring and stability analysis |
| **REC** | Renewable Energy Certificate | Tradable certificate representing renewable generation attributes |
| **RPO** | Renewable Purchase Obligation | Regulatory requirement to procure a share of electricity from renewables |
| **SCADA** | Supervisory Control and Data Acquisition | Real-time monitoring and control system for grid assets |
| **SEM** | Special Energy Meter | High-accuracy meter used for settlement and energy accounting |
| **SIEM** | Security Information and Event Management | Central security monitoring, logging, and alerting system |
| **SOC** | Security Operations Center | Team and function monitoring and responding to cyber incidents |
| **TARANG** | Tarang portal (commonly referenced as a Ministry/NPP-linked dashboard for generation and projects) | Public dashboard for generation/project information in the Indian power sector |
| **TRANSCO** | Transmission Company | Entity owning or operating the transmission network |
| **TTC** | Total Transfer Capability | Maximum transfer capacity before applying reliability margins |

| | | |
|---|---|---|
| **UFLS** | Under Frequency Load Shedding | Automatic load shedding to arrest frequency decline |
| **UVLS** | Under Voltage Load Shedding | Automatic load shedding to arrest voltage collapse |
| **V2G** | Vehicle-to-Grid | EVs discharging power back to the grid as a flexibility service |
| **WAMS** | Wide Area Monitoring System | PMU-based monitoring for grid stability and oscillation detection |
| **WFM** | Workforce Management | Crew dispatch, work orders, and field operations management |

# 1. PREFACE

## 1.1 PURPOSE OF THIS DOCUMENT

The strategy document offers a comprehensive overview of how the India Energy Stack (IES) will be developed, implemented, and expanded within the power sector. It articulates the reasoning behind establishing a cohesive digital infrastructure, outlines the fundamental principles guiding the design, and sets clear expectations for stakeholders involved in its execution. The goal is to transition the sector toward interoperable, standards-based interactions that enhance reliability, transparency, and efficiency. Additionally, the document delineates the roadmap for rolling out the IES through the Architecture, Adoption, and Accelerator tracks, providing policymakers and technical bodies with a shared reference for informed decision-making.

## 1.2 IES AS PART OF INDIA'S DIGITAL PUBLIC INFRASTRUCTURE JOURNEY

India's Digital Public Infrastructure (DPI) journey has consistently focused on building population-scale public goods that establish shared digital frameworks for identity, payments, and data exchange. Examples such as Aadhaar, UPI, DigiLocker, eKYC and eSign have demonstrated how open standards and trusted governance can transform entire sectors. The India Energy Stack builds upon this concept within the power sector, where reliable, verifiable, and interoperable data flows are crucial for both operational stability and sector-wide innovation. Although the energy system is distinct from previous DPIs due to its nature as a cyber-physical network constrained by real-time demands, the core philosophy remains: establish open standards, foster trust and accountability, and allow a diverse ecosystem of public and private entities to engage on equal footing. The IES represents the next phase in this evolution, enabling the power sector to leverage digital public infrastructure while acknowledging its operational challenges.

# 2. VISION & MISSION

**Vision**: An interoperable power sector where data can be shared safely and consistently, so utilities, system operators, regulators, and service providers can coordinate better and empower consumers with increased reliability and affordability and enhanced choice.

**Mission**: To set common rules for how power sector systems identify actors and assets, exchange data, and verify transactions. IES will publish shared standards and interfaces, define a trust and assurance framework, provide sandbox environments for testing and scaling interoperable solutions and support phased adoption across institutions.

# 3. INDIA ENERGY STACK: A TRUST BRIDGE FOR THE POWER SECTOR

As India grows into a $5 trillion economy with an ambition to reach $30 trillion by 2047, the per capita energy consumption is set to increase manifold, while meeting the nation's Net Zero commitments by 2070 (MEA, 2024) (PIB, 2023) (PIB, 2018). Thus, our power sector needs to be able to ramp up to support this growth while maintaining the momentum for exponentially growing renewable generation. Over the next decade, the challenges in managing our generation mix and grid will become increasingly complex.

The growing adoption of renewable energy has led to the emergence of prosumers, households and businesses that both consume and produce electricity through rooftop solar installations, further exemplifying this transformation.

### 3.1 NEED FOR A DPI IN THE POWER SECTOR

Although India has invested heavily in operational technologies such as smart meters and SCADA, the sector lacks an integrated digital framework that connects these systems. Past programmes like RAPDRP created valuable digital assets but did so in pockets, reflecting the fragmented roles of GENCOs, TRANSCOs and DISCOMs across states. The result is a set of digital islands rather than a unified national ecosystem, limiting the sector's ability to manage rising demand and coordinate an increasingly diverse generation mix. This fragmentation creates significant operational challenges that impede the energy sector's ability to meet India's growing energy demands efficiently (Ravi Kumar, 2025). To address these systemic issues, it is essential to first understand the specific challenges currently plaguing the energy sector.

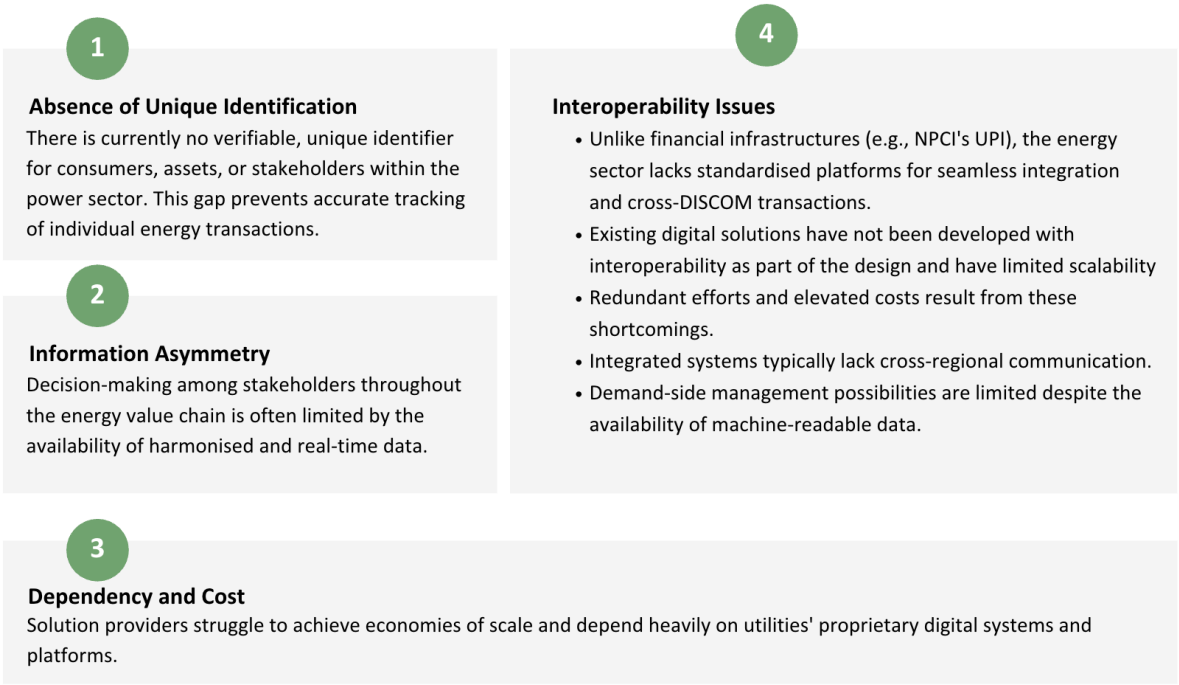


*Figure 1 Key Challenges in the Energy Sector (Ravi Kumar, 2025)*

These challenges collectively point to a fundamental need for a unified digital architecture that can serve as the backbone for India's energy transformation. The solution lies in adopting a Digital Public Infrastructure (DPI) approach, which has proven successful in other sectors of the Indian digital economy.

The power system is a complex network where digital data and the physical flow of electricity directly influence each other. This two-way coupling between digital data and physical processes, where each continuously affects the other, makes the design of Digital Public Infrastructure (DPI) challenging. In such a system, information from each stakeholder should be complete, consistent, and reliable to improve grid operations, market settlements, and overall system stability.

### 3.2 IES DEFINITION

India Energy Stack (IES) is a digital public infrastructure to identify and connect stakeholders and assets, thereby facilitating open data exchange in the power system through uniform specifications and standards, unlocking transparent, reliable, inclusive, efficient, and affordable access to energy.

### 3.3 SCOPE OF IES

IES is…

- **A set of protocols/specifications** that makes **interoperability** between grid entities/stakeholders **uniform, reliable, verifiable and trustworthy**. Essentially, IES defines how entities (DISCOM-Apps; DISCOM-GENCO; DISCOM-Transco; Genco-Transco; EV charger- Charger booking apps; consumer-producer etc.) interact with one another
- **A set of services** (API definitions and calls) **plus a data model/taxonomy** (how components are identified, organised and relate to each other, i.e., how the specified services are used together).

Therefore, IES is a **foundational digital layer** combining a common interaction framework, standardised **taxonomy/data models**, **assurance** mechanisms for **trust and validation**, and baseline technical standards. This enables the development of scalable solutions for the energy sector.

IES is NOT…

- A centralised database/data lake.
- **A centralised service** that pulls or receives data from various entities.
- A software package.
- **Dependent on a strict hierarchy.** It does not presume a hierarchical structure of the energy sector to function.
- A set of specifications and standards whose sole purpose is to integrate internal systems of any stakeholder/entity/utility.

## 3.4 HOW IES SERVES DIFFERENT STAKEHOLDERS IN THE ENERGY ECOSYSTEM

| Stakeholder | Core Problems | Possible IES Approach |
|---|---|---|
| **GENCOs** | Limited telemetry, no carbon tracking, no market visibility | Open telemetry APIs, digital maps, and carbon accounting APIs |
| **TRANSCOs** | Asset data silos, no DER integration, limited external data access | Open asset registries, infrastructure maps, grid-edge integration ssa |
| **DISCOMs** | Fragmented billing/data systems, vendor lock-in, poor demand visibility | Smart meter integration, unified registries, analytics, and openness KPIs |
| **Regulators** | Reliance on static reporting, low digital skills, unavailability of tools for policy making | Real-time dashboards, sandboxes to test new tariffs/market, automated compliance monitoring |
| **System Operators (SO/DSO)** | Disconnected grid levels, DER blind spots, no coordination framework | Shared nodal data views, DSO-TSO APIs, grid connectivity maps |
| **Market Operators (Exchanges, OTC platforms)** | Fragmented market data, no standard APIs, limited grid visibility for market operations | Standard APIs, real-time grid-linked market data, integrated participant registries, and a common carbon marketplace |
| **Consumers** | Limited real-time usage/ billing data, no carbon footprint visibility, Limited participation in energy markets | Consented data sharing, real-time dashboards, unified energy accounts, P2P exchange (trading) |
| **Startups/Tech Providers** | No sandbox, data access barriers, redundant integrations across utilities | Common registries, Open APIs , innovation sandboxes, Data marketplace (Open Datasets) |

*Figure 2 Benefits for different stakeholders*

### 3.5 HOW IES WORKS IN PRACTICE

IES defines the **rules for interaction** between federated systems, ensuring that whenever data is exchanged, it does so in a **secure, standardised, and verifiable** manner. IES does **not** enter or control the internal processes of the stakeholders' federated systems. Each utility, market operator, or participant continues to manage its own platforms.

A **federated system** is an independent IT/OT system that maintains its control over its local data and operations.

In any interaction, IES provides the **common information rails** that enable transparent, unified, and interoperable exchange among federated participants. It only defines the **specification for data exchange**, not the control logic itself. By standardising these interactions rather than internal systems, IES is reinforcing its role as a trust bridge across the energy ecosystem.

IES provides this data exchange specification for all kinds of digital transactions in the power sector. These transactions may also have an impact on the actual physical flow of energy.

To operationalise this, IES will function as a suite of protocols and standardised APIs that builds on the sector's existing technical foundations and introduces new specifications where necessary. Interactions can draw on established frameworks such as IEC 61850, ICCP, IEEE 1547 and IEEE 2030.5, OpenADR, Beckn, OCPI, . All of these sit on harmonised data models from IEC 61970, IEC 61968, IEC 62325, other existing core primitives and grid data models, creating a consistent and interoperable structure for every interaction.

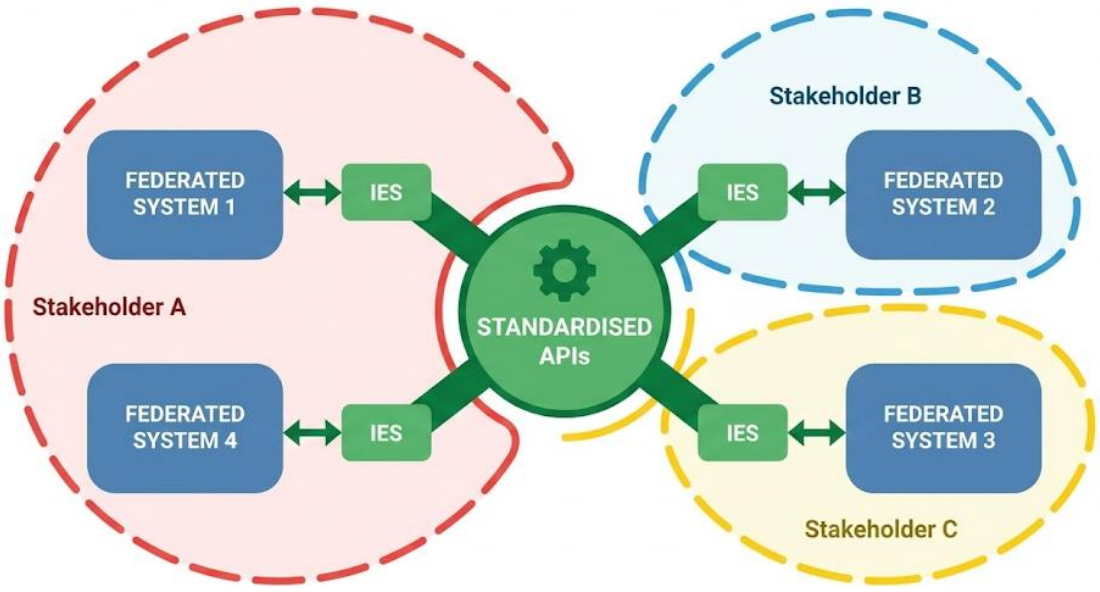


*Figure 3 IES Interactions across federated systems/stakeholders*

## 4. IES DELIVERABLES

IES will be rolled out through three tracks (AAA):

### 4.1 IES ARCHITECTURE

Defines the technical blueprint for the IES ecosystem. It sets the common rules that let different power-sector actors exchange data and execute digital interactions safely and consistently, including shared data models, identifiers, APIs, registries, and assurance requirements.

Refer to the IES Architecture Document and the IES GitHub Repository for more details

### 4.2 IES ADOPTION STRATEGY

Defines how the sector moves from the architecture to real implementation. It maps stakeholder readiness, identifies incentives and barriers to adoption, and outlines programs and policy or regulatory actions needed for uptake. It includes phased pathways, pilots, capacity building, integration with legacy systems, and practical compliance or certification approaches so organisations can become IES-ready and IES-compliant.

### 4.3 IES ACCELERATOR

Builds the practical enablers that speed up adoption of the architecture. It provides sandbox environments, testing tools, and reference solutions so utilities, system operators, market participants, and innovators can validate IES-aligned use cases under controlled conditions. The accelerator generates evidence on interoperability, performance, safety, and regulatory implications to inform scale-up, without compromising reliability, security, or consumer trust.

## 5. GUIDING PRINCIPLES

- Transparency & Efficiency - all transactions should be verifiable, tamper-evident, and machine-readable.
- Data Federation - data remains where it is generated; IES provides standardised interfaces for secure exchange.
- Interoperability - stakeholders should be able to join or exit with minimal friction, enabled by open APIs and specifications.
- Functional Scope - defines functions (standards, governance, services), not rigid technology forms.
- Scalability & Resilience - decentralised architecture (UPI-like) avoids central bottlenecks; systems must scale to population-level usage.
- Open Innovation - provides core data and services for private and public actors to build applications on top of them, including AI-readiness.
- Inclusivity & Accessibility - smaller stakeholders with limited capacity can use common shared infrastructure; larger ones may self-deploy.
- Privacy & Trust: Mandate secure data exchanges, privacy protection, and robust compliance frameworks.

- Cybersecurity by Design - ensure authenticated nodes, strong access controls, and continuous monitoring across all interactions.
- Deterministic Reliability - requires timing guarantees and full auditability for critical, cyber-physical interactions.
- Ecosystem Neutrality - maintain technology- and vendor-neutral standards that prevent lock-in and support open participation.
- Sovereignty & Regulatory Alignment - align with national priorities on data sovereignty, security, and compliance.
- Leveraging Existing Systems – build on current infrastructure, standards, and operational workflows to ensure seamless adoption and preserve sector investments.
- Minimalism – define the baseline set of standards, registries, and interfaces needed for interoperability and trust; avoid over-prescribing technology or data beyond what is necessary.

## 6. MAPPING OF EXISTING DIGITALISATION EFFORTS

The methodology for mapping existing digital efforts was initiated through primary consultations with key stakeholders to define priority areas for digitalization. These insights served as the directive for targeted secondary research, enabling a focused review of relevant documentation to identify and map the digital systems currently in operation. An exhaustive list of existing digital systems and initiatives can be found in Annexure 3.

## 7. DEVELOPING IES AAA FRAMEWORK – ONE USECASE AT A TIME

IES will be developed use case–by–use case to ensure that each specification is grounded in a real, end-to-end interaction and is accompanied by implementable artefacts for the ecosystem.

For every prioritised use case, we work across the three AAA tracks—Architecture, Accelerator, and Adoption Strategy—to deliver a complete “use case package”, not an isolated standard.

For each use case, the package is developed as follows:

• **Architecture:** Develop the end-to-end data flow and interaction blueprint (actors, identifiers, registries, shared data models, APIs, consent and assurance requirements), and define the required digital contracts and policy-as-code artefacts so the interaction is verifiable and enforceable.
• **Accelerator (pilot use cases):** If the use case is in the pilot portfolio, implement a sandbox with reference implementations, mock services, test data, and automated conformance checks so participants can build, test, and integrate quickly.
• **Adoption Strategy:** Translate the use case into rollout guidance for national adoption—policy and regulatory recommendations, governance and accountability model,

operational/process changes, capacity building, and the financial implications and incentives required for scaled uptake across states and institutions.

A master list of use cases is maintained in **Annexure 1**. Pilot use cases are selected from this master list and will be refined as consultations and learnings progress.

## 7.1 CRITERIA AND SCORING MATRIX FOR IES USE CASE SELECTION

As the India Energy Stack (IES) architecture progresses, selecting priority use cases is a design and governance decision—not a backlog exercise. In IES, early use cases act as reference patterns that validate and refine the stack's primitives (identity and addressability, registries and verifiable credentials, consent and secure data sharing, interoperable APIs, and digital energy contracts / policy-as-code). The initial portfolio should therefore maximize ecosystem value, remain implementable within Indian power-sector constraints, and generate high-quality learnings that generalize across states and institutions.
To make selection repeatable and defensible, IES uses a rubric-based prioritization method. Each candidate use case is scored across a small set of criteria. Scores and weights are judgment calls—grounded in evidence where available—but ultimately subjective. The process is designed to make those judgments explicit, comparable, and explainable.

### *7.1.1 Criteria for Use Case Ranking*

- **Value and market demand:** strength of stakeholder demand and clarity of the value pool / incentives.
- **End-consumer centricity:** how directly the use case improves consumer experience, choice, transparency, or outcomes.
- **System impact:** measurable impact on grid reliability, affordability, flexibility, loss reduction, planning, or operations.
- **Leverage on core IES building blocks:** extent to which the use case exercises IES primitives end-to-end.
- **Feasibility and time-to-value:** ability to deliver a credible sandbox demo / pilot quickly with bounded scope and realistic dependencies.
- **Institutional and implementation complexity:** number of actors and depth of IT/OT, process, and policy change; includes assurance requirements.
- **Data readiness and interoperability lift:** availability/quality of required data plus the degree to which IES can standardize and unlock reuse.
- **Impact of failure and learning value:** operational risk of piloting vs. the density of reusable learnings produced (governance, consent, DX, assurance).

### *7.1.2 Scoring Methodology*

Each use case is scored per criterion on a 0–10 scale using anchored rubrics (0 = very low/absent, 10 = very high/strong). Scoring is ideally done independently by at least two reviewers (e.g., a utility / power-systems reviewer and a DPI / architecture reviewer), followed by a short calibration discussion to reconcile differences. Both the scores and any

weights applied are inherently subjective and may vary by stakeholder role, geography, and institutional context. IES therefore converges on a pragmatic "midline" score per criterion for the sole purpose of ranking and shortlisting the top use cases—not to claim absolute precision. For transparency, record one or two evidence signals (or assumptions) that justify each score.

Weights are a program-level preference, not a scientific truth. They express what the current phase optimizes for—for example, near-term adoption and demonstrable value may be emphasized early, while later phases can tolerate higher complexity and longer time-to-value. Weights should be reviewed periodically as ecosystem maturity, policy direction, and implementation capacity evolve.

Finally, perform a light sensitivity check (e.g., small changes to a few scores or weights) to ensure the ranking is not driven by a single assumption.

### *7.1.3 Criterion Scoring Matrix*

The table below is an unweighted, easy-to-read reference for scoring. If weights are applied, they are layered on top of these scores in the spreadsheet model.

| # | Criterion | Operational meaning | What to look for (evidence signals) | 0 / 5 / 10 anchors |
|---|---|---|---|---|
| 1 | Value and market demand | Strength of real demand plus clarity of the value pool and aligned incentives. | Committed pilots/sponsors; multi-actor demand; clear beneficiaries; measurable savings/revenue/avoidance; regulatory/prior scheme alignment. | 0: no clear ask/value • 5: plausible but weak commitment • 10: strong demand + clear, measurable, aligned value |
| 2 | End-consumer centricity | How directly the use case improves the consumer's experience, choice, transparency, or grievance resolution. | Direct consumer-facing flow; reduces friction/errors; improves trust/visibility; supports consented sharing; clear UX journey. | 0: back-office only • 5: indirect consumer benefit • 10: direct, high-salience consumer journey + clear outcome metrics |
| 3 | System impact | Tangible impact on grid outcomes and | Reliability/flexibility gains; loss reduction; improved planning/forecasting; faster | 0: unclear/indirect • 5: moderate and |

| | | | | |
|---|---|---|---|---|
| | | sector performance. | clean-energy integration; measurable KPIs. | measurable • 10: high-impact with strong KPIs and operator relevance |
| 4 | Leverage on core IES building blocks | Extent to which IES primitives are exercised end-to-end (not a one-off integration). | Identity/addressability; registries; verifiable credentials; consent; interoperable APIs; contracts/policy-as-code; auditability. | 0: barely uses primitives • 5: uses 2–3 primitives • 10: multiple primitives end-to-end with audit-ready traces |
| 5 | Feasibility and time-to-value | Ability to deliver a credible sandbox demo / pilot quickly with bounded scope. | Well-bounded scope; implementer availability; sandbox friendliness; limited long-lead dependencies; clear demo artifacts. | 0: blocked/unclear scope • 5: doable with effort • 10: well-bounded, quick pilot + strong demonstrability |
| 6 | Institutional and implementation complexity | Depth of change across institutions, IT/OT systems, processes, and assurance requirements. | Actor count; integration points; workflow change; regulatory dependencies; need for strong security/privacy/non-repudiation; adapter feasibility. | 0: many actors, deep invasive change • 5: moderate complexity • 10: limited actors, mostly adapters + well-defined assurance controls |
| 7 | Data readiness and interoperability lift | Availability/quality of required data and the opportunity to standardize and unlock reuse | Existing data sources; access pathway; quality/completeness; mapping to shared schemas/taxonomies; interoperability pain addressed. | 0: data absent/blocked • 5: partial/uneven • 10: good data access + strong |

| | | | | |
|---|---|---|---|---|
| | | across the ecosystem. | | standardizatio n / reuse potential |
| 8 | Impact of failure and learning value | Operational risk of piloting versus the density of reusable learnings produced for IES. | Failure does not impact real-time ops; clear rollback; learnings on consent/governance/security/ DX; reference implementation value. | 0: high operational risk, low learning • 5: manageable risk, some learning • 10: safe to pilot + high learning density |

*Table 1: Scoring Matrix for Use cases*

Preliminary top use cases for different stakeholders based on the use case criterion for the list of master use cases from Annexure 1 are as follows. A detailed preliminary scoring exercise for all the use cases in Annexure 1 is provided in Annexure 4.

| | Stakeholder Category | Top Use Case |
|---|---|---|
| 1 | DISCOMs | Customer onboarding and service connection |
| 2 | DISCOMs | DER integration and prosumer settlement |
| 3 | Regulators | Time-of-use tariffs and dynamic pricing |
| 4 | System Operators | Asset registry and tagging |
| 5 | Aggregators | Demand response program delivery and settlement |
| 6 | System Operators | Generation forecasting |
| 7 | Market Operators | Renewable energy certificates trading and compliance |
| 8 | TRANSCOs | Network topology and boundary management |
| 9 | GENCOs | Plant performance monitoring |
| 10 | DISCOMs | Peer-to-peer and local prosumer trading pilots |

*Table 2: Top use cases based on scoring matrix*

## 8. CYBERSECURITY, PRIVACY, AND TRUST FRAMEWORK

The India Energy Stack aims to establish a robust cybersecurity and privacy framework that prioritises protecting sensitive energy data and fosters trust among all stakeholders. The approach embeds security and privacy by design, applying proven tools such as encrypted data exchange, consent-based sharing, and trusted digital identity frameworks. The architecture is modular and scalable, enabling large volumes of devices and data to interoperate securely through open, standardised APIs.

The framework will apply methods such as data encryption, secure data enclaves, and role-based access controls in line with national cybersecurity standards. It will evolve through

coordinated engagement with utilities, operators, regulators, and technology partners to strengthen threat detection and maintain resilience against emerging risks. By giving consumers control over how their data is used, the framework aims to establish trust as a core property of the digital energy ecosystem.

## 9. STAKEHOLDER ROLES & RESPONSIBILITIES

IES requires coordinated participation across institutions that shape policy, operate the grid, deliver services, innovate digitally, and ultimately engage as users. Mapping the stakeholder ecosystem clarifies who contributes to standards, adoption, governance, and service development. This section presents the key actors and their roles in enabling sector-wide interoperability and long-term adoption.

### Core IES Stakeholders

| Stakeholder | Role in IES |
|---|---|
| GENCOs | Participate in IES via platform integration, generation data sharing, forecasting, and market participation |
| TRANSCOs | Implement IES via platform integration, transmission network data sharing, asset registries, and grid visibility enhancement |
| DISCOMs | Implement IES via platform integration, data sharing, consumer service enhancement, and retail market enablement |
| System Operators (SO/DSO) | Coordinate grid operations, integrate real-time data flows, enable balancing and ancillary services through IES protocols |
| Market Operators | Facilitate market clearing, settlement, and trading platforms aligned with IES standards and APIs |
| Regulators (CERC, SERCs, etc.) | Frame regulatory guidance, support innovation, ensure frameworks enable IES adoption |
| Consumers (Residential, Commercial, Industrial) | Participate in IES-enabled services; benefit from transparency, improved access and empowerment |
| Startups/Tech Providers | Develop IT/OT solutions conforming to IES standards, ensure interoperability; build, pilot, and scale new solutions leveraging IES APIs; integrate and manage smart metering (AMISPs); access and disseminate data securely through IES-standard APIs |

### Supporting Ecosystem Stakeholders

| Stakeholder | Role in IES |
|---|---|
| Ministry of Power | Leads conceptualization, sets policy direction, conducts stakeholder engagement and ecosystem design |
| Banking Corporations (e.g., REC, PFC) | Provide financial support and credit enhancements for IES rollout and innovation projects. REC also serves as the nodal agency for the IES project |
| Standard Setting Bodies (e.g., BIS, IEC) | Define, publish, and maintain technical standards to promote uniformity, interoperability, and safety |

| Stakeholder | Role in IES |
|---|---|
| International Bodies (ISA, IEA, etc.) | Help replicate the IES model in other regions and provide guidance for global adoption |

## 10. SUCCESS METRICS & KPIS

The India Energy Stack will be evaluated on whether it becomes the shared digital foundation for the power sector and whether it delivers measurable improvements in system performance and consumer value. Progress will be tracked across the following dimensions.

| Dimension | KPI / Success Metric |
|---|---|
| **Adoption and Coverage** | % of utilities, system operators, market bodies, and providers aligned with IES specs |
| | % of sector interactions routed through IES-compliant interfaces |
| **Ecosystem Development & Consumer Value** | Number of 3rd-party apps/services leveraging IES |
| | Improved consumer access and choice (surveyed) |

*Table 3: Success Metrics*

## 11. NEED FOR A NATIONAL POWER SECTOR DATA POLICY

### 11.1 CONTEXT AND STRATEGIC IMPERATIVE

The Indian power sector is currently navigating a "Triple Transition" defined by decarbonization, decentralisation, and digitalisation. To meet the national target of 500 GW of non-fossil fuel capacity by 2030, the grid must manage high variability from renewable sources, requiring real-time visibility into data (Ministry of Power, 2023). Simultaneously, the Revamped Distribution Sector Scheme (RDSS) is driving a massive digital overhaul, with a target to install 250 million smart prepaid meters. As of December 2025, over 20 crore meters have been sanctioned, and approximately 4.76 crore have been installed (Ministry of Power, 2025).

However, the sector's financial viability remains precarious, with state-owned distribution companies (DISCOMs) accumulating losses of nearly ₹6.77 lakh crore by FY23 (Josey et al., 2024). While digitalisation offers a pathway to operational efficiency, the current data landscape is fragmented across state lines and proprietary silos. The absence of a unified governance framework risks turning these digital investments into "data swamps" rather than assets. The **National Power Sector Data Policy (NPSDP)** will serve as the governance "constitution" for the **India Energy Stack (IES)**, ensuring that data flows securely and interoperably to support grid stability and financial turnaround (Kumar, 2025).

## 11.2 THE POLICY FRAMEWORK: FOUR PILLARS

The proposed policy framework is designed to reconcile the conflicting demands of open innovation, consumer privacy, and critical infrastructure security. It rests on four conceptual pillars:

1. **Cyber-Physical Specificity:** Unlike purely digital sectors, data in the power grid often controls physical assets. The policy distinguishes between *Informational Data* (billing, commercial) and *Operational Data* (control commands). It mandates "Zero Trust" architectures and strict IT-OT segmentation for operational data to prevent cyber-threats from causing physical kinetic damage (Central Electricity Authority, 2021).
2. **Federation over Centralisation:** Recognising India's federal structure, the policy rejects a central data warehouse. Instead, it adopts a federated architecture where data remains with custodians (DISCOMs, SLDCs) but is accessible via unified APIs. This aligns with the India Energy Stack's vision of a decentralised, interoperable network (Mercom India, 2025).
3. **Taxonomy and Criticality:** The policy introduces a functional taxonomy (Operational, Asset, Market, Consumer, Planning) and overlays it with a criticality assessment. Non-critical, non-personal data is "presumed open" to foster innovation, while critical operational data is restricted. This classification supports the broader goals of the National Data Governance Framework Policy (MeitY, 2022).
4. **Role-Based Entitlements:** Access is democratised but governed. Entitlements are based on the entity's role (e.g., Regulator, Researcher, Market Participant) rather than commercial negotiation, ensuring a level playing field for startups and researchers.

## 11.3 ARCHITECTURAL DESIGN: THE INDIA ENERGY STACK (IES)

This policy puts the India Energy Stack into action as the sector's shared digital foundation. The IES architecture is organised into four building blocks. (Kumar, 2025):

- **Data Layer:** Distributed systems of record exposed via standard adapters.
- **Identity Layer:** Unique registries for assets (transformers, meters) and entities to enable seamless interoperability.
- **Exchange Layer:** Adoption of the Common Data Model to ensure semantic consistency across utilities.
- **Consent Layer:** A consent mechanism that lets consumers approve, limit, and revoke sharing of their smart meter data with specific third parties for specific purposes, with clear audit trails and legal compliance (NITI Aayog, 2020; Government of India, 2023).

The National Power Sector Data Policy is not merely a regulatory requirement but a prerequisite for India's energy transition. By standardising data governance, India can unlock the value of its physical infrastructure investments, ensuring a grid that is secure, financially viable, and ready for a decarbonised future.

A detailed zero-draft policy paper on the same will be presented alongside the IES Strategy Document V 0.3.

# 12. DISCUSSION ON USECASES

## 12.1 PEER-TO-PEER (P2P) TRANSACTIVE ENERGY AS AN IES USE CASE

### 12.1.1 Context and problem statement

Distributed Energy Resource (DER) participation in India is accelerating, presenting an opportunity to upgrade the sector's commercial and operational interfaces for high-frequency, small-value transactions. While the physical grid is adapting to absorb distributed generation and flexible demand, realising the full potential of these assets requires an evolution in settlement mechanisms and incentive structures. By future-proofing these frameworks, the power system can unlock value in three key areas: improving monetisation avenues for prosumers, enhancing trust in demand response programs, and streamlining the management of export limits and billing reconciliation (Ministry of Power, 2022).

### 12.1.2 Definitions and System boundary and operating model

A Workable Definition

In the context of the India Energy Stack (IES), P2P is defined as a digitally mediated transaction wherein a buyer and seller agree upon a price and quantity for a specific time block. Settlement is executed based on verified metering data and schedules compliant with grid regulations.

System Boundary: Physical layer versus financial layer

The operating model distinguishes between the physical and financial layers to ensure systemic stability.

- **Physical Layer:** Electricity flows adhere to network physics. System operators and DISCOM control rooms retain absolute authority over security, balancing, congestion, and restoration. Any P2P construct must accept override, curtailment, and emergency controls as non-negotiable operational boundaries.
- **Financial Layer:** P2P operates on the financial layer, managing contractual entitlements and settlement. The primary requirement is that financial settlement must be reconcilable with physical measurements and grid scheduling intervals.

Operating Principle

The design adheres to the maxim "settle what can be verified." Where verification capabilities are nascent, products must be constrained or risk-adjusted accordingly.

### 12.1.3 Current landscape (programs, pilots, institutional readiness)

**Status of Pilots and Regulatory Progress** Indian pilots have successfully demonstrated that transaction matching and digital contracts are technically feasible and align well with consumer preferences for choice. Notable examples include the blockchain-based solar trading pilots permitted under regulatory sandboxes in Uttar Pradesh and Delhi (India Smart Grid Forum [ISGF], 2021).

**Institutional Readiness and Key Regulatory Developments** Recent regulatory notifications indicate that the sector is moving from experimentation to formalisation. Specific provisions now emerging in state regulations include:

- **Delhi (DERC):** The *Peer to Peer Energy Transaction Guidelines, 2024* have formally defined P2P platforms as "Service Providers" or distribution licensees. These guidelines introduce specific operational constraints, such as capping transactions at 500% of the prosumer's sanctioned load and mandating that schedules be submitted "8 time blocks before commencement" to align with grid operations (Delhi Electricity Regulatory Commission [DERC], 2024).
- **Uttar Pradesh (UPERC):** The *CRE Regulations, 2024* and earlier amendments have established clear eligibility criteria for captive and renewable generating plants to engage in intra-state transactions, validating the "prosumer" status in regulation (Uttar Pradesh Electricity Regulatory Commission [UPERC], 2024).
- **Karnataka (KERC):** The draft regulations released in 2024 for blockchain-based P2P solar transactions emphasize the necessity of dynamic pricing frameworks and mandate the installation of smart meters for all participants (Karnataka Electricity Regulatory Commission [KERC], 2024).
- **Metering Standards:** The Central Electricity Authority (CEA) has reinforced the technical baseline through the *Functional Requirements for Advanced Metering Infrastructure (AMI)*, which mandates settlement-grade data granularity essential for reconciling these transactions (Central Electricity Authority [CEA], 2016; CEA, 2020).

These developments confirm that while the technology stack is mature, the regulatory focus is correctly shifting toward "Service Provider" definitions, scheduling discipline, and strict metering standards.

## 12.2 ACTOR MODEL AND ROLES

The P2P ecosystem comprises the following core actors:

- **Consumers and Prosumers:** End-users engaging in buying, selling, or flexibility provision, retaining explicit consent rights over their data.
- **DISCOMs:** Network operators and billing custodians; they serve as the default anchor for settlement reconciliation in early implementation phases.
- **SLDCs/System Operators:** Authorities responsible for scheduling, security, and validating operational data.
- **P2P Platforms:** Intermediaries facilitating discovery, matching, contracting, and transaction record-keeping.

- **Aggregators:** Entities pooling small assets to transact at scale and manage performance risks.

**Market Institutions:** Exchanges and registries where P2P interfaces with existing market rails.

### *12.2.1 Scope and End-to-end lifecycle (process steps and data flows)*

Exclusions (Scope)

To maintain regulatory clarity, it is crucial to define what P2P is not:

- It is not the physical routing of electrons between specific parties.
- It is not a mechanism to bypass DISCOM network obligations or consumer protection mandates.
- It is not a substitute for State Load Despatch Center (SLDC) scheduling, congestion management, or security operations.
- It is not inherently cross-border or inter-state; portability is a distinct design choice (Central Electricity Regulatory Commission [CERC], 2023).

End-to-end lifecycle

A credible P2P use case requires a defined lifecycle:

1. **Eligibility and Onboarding:** Issuance of unique IDs, verification of grid connections/meter types, and registration of aggregator roles.
2. **Discovery and Contracting:** Standardisation of products (energy blocks, flexibility baselines, attribute bundles) and transparent disclosure of risks and fees.
3. **Scheduling and Gate Closure:** Alignment of nomination deadlines with grid operations, including rules for post-gate modifications (settled as deviations).
4. **Delivery and Measurement:** Utilisation of interval metering with tamper detection; established methodologies for flexibility measurement and verification (M&V).
5. **Settlement and Reconciliation:** Netting rules between platform records and utility billing, application of loss factors, and dispute resolution logic.

### *12.2.2 Use-Case Variants and Product Definitions*

P2P can supports multiple product forms:

- **Retail Local Energy Exchange:** Prosumers selling surplus to local consumers within a DISCOM area, integrated with utility billing.
- **Flexibility and Demand Response:** Aggregators contracting demand reduction, selling verified flexibility to DISCOMs.
- **Virtual Power Plant (VPP) Aggregation:** Pooling small assets to provide predictable schedules and ancillary services.
- **Storage Arbitrage:** Behind-the-meter storage leveraging price differentials, subject to network constraints.
- **Attribute Trading:** Decoupling green attributes for voluntary compliance, ensuring no double-counting occurs.

## 12.3 DESIGN FACTORS

To ensure viability, the policy framework must address:

- **Data and Metering:** P2P requires settlement-grade metering. Policy must mandate minimum standards for interval granularity, latency, and tamper controls.
- **Operations (Hosting Capacity):** Retail P2P is constrained by feeder hosting capacity and voltage limits. Rules must necessitate pre-trade feasibility checks or transparent ex-post curtailment.
- **Security:** P2P introduces new digital endpoints. Strong authentication and role-based access are mandatory. Platforms must not issue operational control commands unless certified via approved interfaces.
- **Consumer Protection:** Safeguards regarding price transparency, data consent, and liability allocation are essential to prevent reputational risk.
- **Commercial Coherence:** P2P should be designed as a value-added service on the network—subject to explicit network service charges—rather than a "retail bypass" mechanism.

## 12.4 RISKS

The transition to a transactive energy framework introduces systemic exposures that extend beyond simple technical failures. By decentralising settlement and dispatch, P2P creates new vectors for financial imbalance, operational instability, and data fragmentation. If these risks are not preemptively managed through policy design, they manifest as hard constraints that prevent the ecosystem from scaling. The bottlenecks below are the most critical among these failure modes.

10.4.1 Bottlenecks and failure modes

Scaling P2P faces five specific bottlenecks:

1. **Operational Digitisation:** Manual scheduling prevents P2P from evolving beyond demonstration projects. Machine-readable interfaces are a prerequisite.
2. **Utility Capacity:** Utilities lack the capacity to reconcile high-volume micro-transactions without a standard interface layer.
3. **Regulatory Fragmentation:** Divergent State Electricity Regulatory Commission (SERC) rules on eligibility and charges impede interoperability.
4. **Charge and Subsidy Structure:** P2P cannot scale if it erodes cross-subsidy without compensation. Transparent network pricing is required.
5. **Data Access:** Lack of consent-based pathways for meter data access stifles value-added services.

## 12.5 POLICY AND REGULATORY RECOMMENDATIONS

National Level

- Issue a national P2P definition distinguishing retail P2P from Open Access portability.
- Adopt a model framework for platform registration and cybersecurity.
- Standardise IES-aligned interfaces for nominations and settlement reports.

State (SERC) Level

- Notify retail P2P frameworks defining eligibility and network charges.
- Permit aggregator-led flexibility programs with defined M&V requirements.

System Operations

- Define gate closure compatibility and permissible data flows between platforms and operational systems.

Strategic Insert: Delhi Pilot Design

- **Scope:** High-rooftop-density feeders within one DISCOM.
- **Anchor:** DISCOM acts as the reconciliation authority.
- **IES Link:** Implementation of IES-aligned APIs for interoperability testing.

### *12.5.1 Regulatory mapping*

A coherent interpretation of P2P versus Open Access is vital:

- **Open Access:** A legal construct for non-retail procurement, involving distinct approvals and transmission charges.
- **P2P:** A contracting interface. It becomes "Open Access" only when it crosses retail boundaries.

Mapping:

- *Intra P2P (Within License Area):* Regulated retail product; DISCOM anchors settlement.
- *Inter P2P (Cross-Area):* Layer over Open Access rails; requires charge coherence and scheduling digitisation.

Most retail electricity tariffs in India are bundled. When a consumer pays ₹ X/kWh, that single number covers three distinct things:

- **Energy:** The cost of the electrons (Generation).
- **Network:** The cost of wires, transformers, and staff (Distribution).
- **Policy/Subsidy:** Surcharges to subsidize poorer consumers (Cross-subsidy).

**Charge coherence** is the principle that P2P transactions must strictly **unbundle** the price of energy from the cost of the network. It ensures that while buyers and sellers trade power directly, they still explicitly pay the utility for wire usage and mandatory social subsidies. This prevents "retail bypass," guaranteeing that innovation reduces energy costs without bankrupting the grid operator.

## 12.6 IES LINKAGE

The India Energy Stack acts as the enabler for scale through:

- **Architecture Pointers:** Providing standard APIs for identity, consent, and transaction reporting.
- **Adoption Incentives:** Framing P2P as a cost-reduction tool for utilities (peak management) rather than a threat.
- **Accelerator Components:** Providing reference implementations for onboarding, settlement templates, and security certification checklists.

### *12.6.1 Roadmap and Sequencing*

- **Phase 1 (Retail P2P Pilots):** Focus on settlement discipline and consumer protection within single DISCOM areas. Output: Standardised APIs and reconciliation processes.
- **Phase 2 (Interoperability):** Testing identifiers and consent across heterogeneous utility systems. Output: Conformance certification.
- **Phase 3 (Portability):** Leveraging Open Access rails for broader contracting. Output: A coherent pathway respecting system operations.

### *12.6.2 Metrics and monitoring (infrastructure and sector outcomes)*

Infrastructure Metrics

- Percentage of transactions using IES-aligned identifiers.
- Coverage of settlement-grade metering.
- Transaction audit pass rates.

Sector Outcome Metrics

- Peak reduction verified by Measurement & Verification.
- Net consumer bill impacts.
- Reduction in billing disputes related to exports.

## 12.7 ANNEXES

Detailed technical specifications, including standard data schemas, API definitions for nomination and settlement, assurance tier checklists, and role-based obligation matrices, are specified in the **India Energy Stack Architecture Document**.

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Note: All annexures are populated based on ongoing discussions and, therefore, will be updated with every version.

## 13. ANNEXURE 1: IES POTENTIAL USE CASES – MASTER LIST

**Use Case Definition**: In the power sector, a use case is a specific operational, commercial, or regulatory task that grid actors and consumers need to complete by exchanging defined information through defined systems to deliver a measurable outcome.

The list generated below is based on various inputs from stakeholder consultations and expert working groups of IES.

Stakeholders: GENCOs, TRANSCOs, DISCOMs, Regulators, System Operators (SO/DSO), Market Operators, Consumers, Startups/Tech Providers

| S.No | Use Case | Relevant Stakeholders | Systems to Integrate | Description | Possible Outcomes |
|---|---|---|---|---|---|
| 1 | Sector participant onboarding and role registration | Regulators, System Operators, DISCOMs, Market Operators, Startups/Tech Providers | Participant registry, IAM, compliance systems | Register an entity, validate credentials, assign roles and permissions for market and operational participation | Faster onboarding, fewer access disputes, clearer accountability |
| 2 | Customer onboarding and service connection | Consumers, DISCOMs, Startups/Tech Providers | CIS/CRM, workflow, GIS, MDMS/AMI | Create or update a customer profile, map to premise and service point, assign meter, activate supply | Shorter connection timelines, reduced duplicate records, fewer billing errors |
| 3 | Consent-based data sharing | Consumers, DISCOMs, Startups/Tech Providers, Regulators | Consent manager, CIS, MDMS, API gateway | Capture consent with purpose and scope, grant time-bound access, maintain access records | Controlled portability, fewer privacy breaches, higher third-party innovation readiness |
| 4 | Asset registry and tagging | DISCOMs, TRANSCOs, GENCOs, | EAM, GIS, SCADA naming, CMMS | Create authoritative asset records, unique IDs, | Better maintenance planning, reduced asset |

| S.No | Use Case | Relevant Stakeholders | Systems to Integrate | Description | Possible Outcomes |
|---|---|---|---|---|---|
| | | Startups/Tech Providers | | lifecycle attributes, location binding | ambiguity, improved restoration accuracy |
| 5 | Network topology and boundary management | DISCOMs, TRANSCOs, System Operators | GIS, DMS/EMS, planning tools | Maintain connectivity model, hierarchies, boundary points, versioned snapshots | Consistent analytics, better loss accounting, fewer reconciliation disputes |
| 6 | Settlement-grade metering validation | Startups/Tech Providers, DISCOMs, GENCOs, System Operators, Market Operators | SEM/MDMS, validation engines, settlement systems | Validate metered data, flag gaps and anomalies, publish validated datasets for settlement | Fewer disputes, faster settlement cycles, improved data integrity |
| 7 | Cybersecurity access governance and audit | DISCOMs, TRANSCOs, GENCOs, System Operators, Market Operators | IAM, SIEM/SOC, API gateway, logging | Enforce access policies, log access, detect anomalies, support investigations | Reduced cyber risk, stronger compliance posture, faster incident response |
| 8 | Regulatory reporting and compliance submission | DISCOMs, TRANSCOs, GENCOs, System Operators, Regulators | MIS, reporting tools, document systems | Compile statutory reports from operational and commercial records and submit with traceability | Improved compliance, fewer manual errors, faster audits |
| 9 | Generation forecasting | GENCOs, Startups/Tech Providers, System Operators | Forecasting tools, plant historian, scheduling systems | Generate day-ahead and intraday forecasts for solar, wind, hydro and provide updates | Lower forecast error, reduced imbalance costs, better dispatch decisions |
| 10 | Plant performance monitoring | GENCOs, Startups/Tech | SCADA, historian, performance analytics | Track availability, heat rate, auxiliary | Higher availability, lower fuel cost, earlier fault detection |

| S.No | Use Case | Relevant Stakeholders | Systems to Integrate | Description | Possible Outcomes |
|---|---|---|---|---|---|
| | | Providers, System Operators | | consumption, ramp rates, alarms | |
| 11 | Maintenance and outage planning for plants | GENCOs, System Operators, TRANSCOs | CMMS/EAM, outage coordination tools | Plan maintenance windows, declare outages, coordinate approvals, manage revisions | Lower system risk, fewer forced outages, reduced congestion impacts |
| 12 | Condition-based maintenance for generation assets | GENCOs, Startups/Tech Providers | IoT platforms, vibration sensors, CMMS/EAM | Use sensor and vibration data to trigger maintenance based on health indicators | Lower unplanned downtime, reduced maintenance cost, longer asset life |
| 13 | Fuel supply chain tracking | GENCOs, Startups/Tech Providers | ERP, supply chain systems, inventory tools | Track deliveries, stock levels, fuel quality from source to plant | Reduced stockouts, fewer quality issues, improved cost control |
| 14 | Emissions monitoring and compliance reporting | GENCOs, Regulators | CEMS, compliance tools | Capture continuous emissions data and prepare compliance submissions | Fewer violations, better auditability, smoother inspections |
| 15 | Hybrid plant coordination | GENCOs, Startups/Tech Providers, System Operators | Site controller, EMS, scheduling tools | Coordinate solar, wind, storage, and thermal resources at a site to meet schedules | Improved dispatchability, reduced curtailment, higher revenue stability |
| 16 | Dispatch instruction receipt and acknowledgement | System Operators, GENCOs | Dispatch systems, plant control systems | Receive dispatch instructions, acknowledge, execute, and log compliance | Faster response, clearer accountability, fewer disputes |

| S.No | Use Case | Relevant Stakeholders | Systems to Integrate | Description | Possible Outcomes |
|---|---|---|---|---|---|
| 17 | Black start capability testing and readiness | System Operators, GENCOs, TRANSCOs | Restoration planning tools, plant logs | Maintain readiness records, conduct tests, report capability status | Faster restoration, improved resilience, reduced blackout duration risk |
| 18 | Renewable curtailment analysis | GENCOs, System Operators, TRANSCOs | SCADA/EMS, constraint systems, analytics | Identify curtailment events, link to constraints, outages, and operational decisions | Reduced curtailment, targeted upgrades, improved transparency |
| 19 | Transmission state estimation inputs | TRANSCOs, System Operators | EMS, SCADA, state estimation tools | Provide measurements and topology updates required for reliable state estimation | Better situational awareness, improved security assessment |
| 20 | Load flow and constraint monitoring | System Operators, TRANSCOs | EMS, analytics | Simulate and monitor power flows to detect overloads and voltage issues | Reduced overload risk, improved congestion visibility |
| 21 | Contingency analysis (N-1, N-2) | System Operators, TRANSCOs | EMS, contingency analysis tools | Evaluate credible contingencies and publish required operational actions | Higher reliability, fewer cascading failures, better preparedness |
| 22 | Transmission outage planning | TRANSCOs, System Operators, GENCOs, DISCOMs | Outage coordination systems | Coordinate planned outages for lines and substations, manage approvals and conflicts | Lower system risk, fewer curtailments, reduced congestion surprises |
| 23 | Dynamic line rating operations | TRANSCOs, System Operators | DLR systems, weather feeds, EMS | Update line capacity limits based on weather and conductor conditions | Higher transfer capability when safe, better congestion management |

| S.No | Use Case | Relevant Stakeholders | Systems to Integrate | Description | Possible Outcomes |
|---|---|---|---|---|---|
| 24 | Right-of-way and encroachment monitoring | TRANSCOs, Startups/Tech Providers | Drone/LiDAR systems, GIS, asset risk tools | Detect encroachments, vegetation risks, and compliance issues along corridors | Fewer faults, lower outage risk, improved safety compliance |
| 25 | Substation asset health monitoring | TRANSCOs, Startups/Tech Providers | Substation monitoring, IoT, EAM | Monitor transformer oil, breaker condition, partial discharge, alarms | Reduced failures, better spares planning, lower maintenance cost |
| 26 | HVDC corridor operations | TRANSCOs, System Operators | HVDC control systems, EMS | Monitor HVDC performance, manage setpoints, handle faults and isolations | Improved stability, reduced outage duration, clearer fault attribution |
| 27 | ATC/TTC and transfer margin publication | System Operators, Market Operators | Operator tools, portals | Calculate and publish transfer capacities and assumptions with revisions | Better market transparency, improved planning |
| 28 | Real-time SCADA/EMS monitoring | System Operators, TRANSCOs, DISCOMs | SCADA, EMS | Monitor grid state in real time and generate alarms and events | Improved situational awareness, faster response to incidents |
| 29 | AGC and load-frequency control operations | System Operators, GENCOs | AGC systems, EMS | Send control signals and monitor response to maintain frequency | Improved frequency compliance, reduced deviations, better reliability |
| 30 | Congestion management and redispatch | System Operators, GENCOs, DISCOMs, TRANSCOs | EMS, dispatch tools | Apply redispatch, curtailment, and network actions to relieve bottlenecks | Reduced overloads, lower curtailment cost, improved security |
| 31 | WAMS and PMU-based stability monitoring | System Operators, TRANSCOs | WAMS, PMU network, analytics | Use synchrophasors for oscillation detection and stability assessment | Earlier disturbance detection, improved stability control |

| S.No | Use Case | Relevant Stakeholders | Systems to Integrate | Description | Possible Outcomes |
|---|---|---|---|---|---|
| 32 | Event and disturbance analysis | System Operators, TRANSCOs, GENCOs | EMS, WAMS, disturbance recorders | Package and analyse post-fault data for root cause and corrective actions | Faster investigations, improved corrective actions |
| 33 | Islanding and restoration coordination | System Operators, DISCOMs, TRANSCOs, GENCOs | Restoration planning tools, control room logs | Manage island operation and coordinate restoration steps | Reduced outage duration, safer restoration, improved resilience |
| 34 | Emergency load shedding execution logging | System Operators, DISCOMs | Protection and control systems, logs | Record UFLS/UVLS actions, triggers, affected areas for audit and tuning | Better protection tuning, improved transparency |
| 35 | Day-ahead market clearing | Market Operators, GENCOs, DISCOMs, Startups/Tech Providers | Exchange platform, clearing engine, settlement | Collect bids and offers, clear market, publish schedules and prices | Efficient price discovery, reduced procurement cost |
| 36 | Real-time market clearing | Market Operators, GENCOs, DISCOMs, Startups/Tech Providers | Exchange platform, clearing engine, settlement | Close-to-delivery clearing for balancing and short-term trades | Better balancing, reduced deviations, improved liquidity |
| 37 | Bilateral and OTC contracting | DISCOMs, GENCOs, Market Operators | Contract management, scheduling tools | Negotiate contracts, manage nominations, confirmations, schedule linkage | Tailored risk management, improved procurement flexibility |
| 38 | Reverse auction and e-bidding procurement | DISCOMs, GENCOs, Startups/Tech Providers | DEEP or procurement portal, evaluation tools | Run competitive procurement with bids, awards, and contract artefacts | Lower purchase cost, improved transparency |

| S.No | Use Case | Relevant Stakeholders | Systems to Integrate | Description | Possible Outcomes |
|---|---|---|---|---|---|
| 39 | Ancillary services procurement | System Operators, GENCOs, Market Operators | AS platform, dispatch tools, settlement | Procure reserves and response services, activate, measure performance, settle | Improved reliability, fair compensation |
| 40 | Co-optimised energy and ancillary clearing | Market Operators, System Operators, GENCOs, DISCOMs | Clearing engine, settlement | Joint clearing of energy and ancillary services reflecting constraints | Lower system cost, clearer scarcity signals |
| 41 | Imbalance settlement and deviation charges | Market Operators, System Operators, GENCOs, DISCOMs | Settlement, metering validation, billing | Calculate deviations between schedule and actuals, apply charges, resolve disputes | Reduced gaming, faster dispute closure |
| 42 | Capacity and reliability procurement | Regulators, System Operators, GENCOs, DISCOMs | Market platform, qualification tools | Procure firm capacity obligations and track performance | Improved adequacy, clearer investment signals |
| 43 | Renewable energy certificates trading and compliance | Market Operators, GENCOs, DISCOMs, Regulators | REC registry, trading platform | Issue, transfer, retire certificates and track compliance | Improved RPO compliance, reduced double counting |
| 44 | Carbon credits and clean fuel certificates | Market Operators, GENCOs, Startups/Tech Providers | Carbon registry, verification systems | Register projects, issue credits, transfer and retire with verification | Credible claims, new revenue streams |
| 45 | Market monitoring and surveillance | Regulators, Market Operators | Surveillance tools, audit logs, analytics | Detect manipulation, unusual bidding, concentration risks, rule violations | Higher market integrity, stronger enforcement |
| 46 | Load forecasting and demand analytics | DISCOMs, Startups/Tech Providers | MDMS, DMS, analytics | Forecast feeder and system demand and | Lower peak procurement, improved reliability |

| S.No | Use Case | Relevant Stakeholders | Systems to Integrate | Description | Possible Outcomes |
|---|---|---|---|---|---|
| | | | | identify demand management levers | |
| 47 | Outage management for distribution | DISCOMs, Consumers, Startups/Tech Providers | OMS, DMS/SCADA, WFM | Detect faults, isolate, dispatch crews, track restoration, notify customers | Shorter outages, better SAIDI/SAIFI |
| 48 | Energy accounting and AT&C loss analysis | DISCOMs, Regulators | MDMS, billing, SCADA, analytics | Reconcile energy input with billed consumption across hierarchy | Reduced losses, higher revenue realisation |
| 49 | Revenue protection and theft detection | DISCOMs, Consumers | MDMS, billing, analytics | Detect anomalies and tamper events and initiate investigations | Reduced theft, improved collections |
| 50 | Network planning and investment prioritisation | DISCOMs, Regulators | GIS, planning tools, EAM | Identify reinforcement needs, hosting capacity, capex prioritisation | Better capex efficiency, fewer constraints |
| 51 | DER integration and prosumer settlement | DISCOMs, Consumers, Startups/Tech Providers | DER registry, billing, MDMS, DERMS | Register DER, measure exports, settle credits, manage operational impacts | Higher DER uptake, fewer settlement disputes |
| 52 | Time-of-use tariffs and dynamic pricing | DISCOMs, Consumers, Regulators | Billing, MDMS, customer apps | Apply interval tariffs, publish price signals, explain bills | Peak reduction, fairer cost allocation |
| 53 | Prepaid metering and recharge | DISCOMs, Consumers, Startups/Tech Providers | AMI, MDMS, billing, payment gateway | Enable prepaid balance management, top-ups, and service control policies | Reduced arrears, improved cash flow |

| S.No | Use Case | Relevant Stakeholders | Systems to Integrate | Description | Possible Outcomes |
|---|---|---|---|---|---|
| 54 | EV charging integration and managed charging | DISCOMs, Startups/Tech Providers, Consumers | Charger mgmt, billing, DRMS | Track sessions, apply tariffs, enable managed charging participation | Reduced local congestion, lower peak impact |
| 55 | Demand response program delivery and settlement | DISCOMs, Startups/Tech Providers, Consumers | DRMS, MDMS, billing | Enrol customers, dispatch events, measure response, pay incentives | Reduced peak, new flexibility resource |
| 56 | Customer energy advisory and alerts | Consumers, DISCOMs, Startups/Tech Providers | Customer apps, analytics, CIS | Provide insights, peak alerts, bill forecasts, savings recommendations | Lower consumption, higher satisfaction |
| 57 | Grievance and service request management | Consumers, DISCOMs | CRM, OMS, WFM | Log complaints, track SLAs, coordinate field visits, close with evidence | Faster resolution, improved accountability |
| 58 | Subsidy eligibility and benefit delivery | DISCOMs, Regulators, Consumers | CIS, billing, benefit platform | Determine eligibility, apply subsidy logic, reconcile benefit flows | Better targeting, reduced leakage |
| 59 | Renewable forecasting and scheduling services | Startups/Tech Providers, GENCOs, System Operators, Market Operators | Forecasting platforms, scheduling systems, settlement | Provide market-facing forecasts, intraday revisions, and accountability artefacts supporting scheduling and settlement | Better forecast discipline, lower imbalance exposure, clearer accountability |
| 60 | Demand response aggregation for market participation | Startups/Tech Providers, Consumers, DISCOMs, Market | DRMS, aggregator platforms, MDMS, settlement | Aggregate flexible loads, qualify portfolios, dispatch events, measure | New flexibility supply, reduced peak costs, improved reliability |

| S.No | Use Case | Relevant Stakeholders | Systems to Integrate | Description | Possible Outcomes |
|---|---|---|---|---|---|
| | | Operators, System Operators | | response, settle flexibility as a traded product | |
| 61 | Storage and energy shifting products | Startups/Tech Providers, DISCOMs, Market Operators | Storage management systems, market platform, settlement | Offer storage-backed blocks or shifting services, validate delivery performance, settle obligations | Better peak management, improved RE integration, new revenue streams |
| 62 | DISCOM procurement optimisation and schedule readiness | DISCOMs, Market Operators, System Operators | ERP or procurement tools, portfolio systems, scheduling tools | Translate demand forecasts and contract positions into procurement plans, nominations, schedules, and revisions | Lower procurement cost, fewer deviations, improved planning discipline |
| 63 | Transparency portals and public data publishing | DISCOMs, TRANSCOs, GENCOs, System Operators, Market Operators, Regulators, Consumers | DEEP, NPP, MERIT, TARANG-type portals, data pipelines | Publish standard datasets and indicators with definitions, revisions, and traceability | Improved transparency, better benchmarking, lower information asymmetry |

## 14. ANNEXURE 2: POWER SECTOR LIFECYCLE PAIN POINTS AND WHAT IES ENABLES

The list generated below is based on various inputs from stakeholder consultations and expert working groups of IES.

| Lifecycle stage | Critical pain points | What IES can enable |
|---|---|---|
| **Planning and investment** | Planning inputs are fragmented and lagged across utilities, SLDCs, generators, and regulators. Asset lists, demand baselines, losses, and constraints are inconsistent. Forecasts and studies are hard to reproduce because data and assumptions are not traceable. | Standard identifiers and registries for consumers, meters, feeders, substations, generators, and contracts. Common data models for topology, outages, metering, and forecasts. Provenance and audit trails so planning inputs are comparable and defensible. |
| **Build, commissioning, and onboarding** | Onboarding of new assets and connections is manual, duplicated across systems, and inconsistently named. Commissioning evidence and configuration metadata are missing or not linked. Field and enterprise records diverge over time. | Standard onboarding and registration workflows at the interface level. Consistent naming and metadata requirements. Ability to link commissioning evidence and configuration to an asset identity, improving downstream consistency across systems. |
| **Operations, control rooms, and reliability** | OT and IT systems exchange events inconsistently. Time alignment, latency, and data quality vary across vendors. Outage workflows and incident analysis face weak end-to-end traceability across systems. | Authenticated, auditable exchange patterns for operational interactions between systems and entities. Standard event definitions and time-stamping. End-to-end logging to support incident reconstruction and accountability without replacing control systems. |
| **Scheduling, dispatch, and renewables integration** | Forecast and telemetry exchanges are inconsistent. Baselines and time-series alignment differ across participants. Disputes persist because the data trail from inputs to outcomes is not consistently auditable. | Standard interfaces for forecast submission, telemetry exchange, and time alignment backed by verifiable credentials. Traceable provenance from input data to reported outcomes, improving |

| | | |
|---|---|---|
| | | transparency and reducing reconciliation friction. |
| **Metering, billing, and revenue assurance** | Meter data formats, event codes, and mapping between meter, consumer, and tariff context are inconsistent across AMI vendors and utility systems. Exception handling is weak and disputes rely on manual checks. | Common metering data models and event taxonomies. Strong linkage between consumer, meter, location, and tariff metadata. Assurance levels and audit trails that support automated validation, consistent exceptions, and evidence-based dispute handling. |
| **Consumer service and participation** | Consumer data is not portable and service channels are fragmented. Third-party services require bespoke integrations. Consent and purpose limitation are not consistently implemented across providers. | Standard consented data sharing with purpose limitation and audit logs. Predictable APIs that reduce bespoke integrations and allow consumer-authorised services to operate with consistent permissions and accountability. |
| **DER, EVs, and flexibility participation** | DER registration, measurement, and verification are inconsistent. Aggregation is constrained by unclear baselines and weak verification. Utilities and regulators lack a standard way to verify performance and compliance across providers. | Registries and identifiers for DER and flexibility providers. Standard measurement and verification data flows. Credentialed participation and auditable performance records that support scalable programs under regulatory oversight. |
| **Settlement, payments, and dispute resolution** | Settlement and reconciliation are slow because actors rely on different data versions and limited traceability from events to obligations. Disputes escalate due to weak evidence trails. | Contract reference resolution and provenance linking events, identities, and obligations across the transaction chain. Machine-readable, time-stamped audit trails that narrow disputes and reduce reconciliation overhead. |
| **Compliance, reporting, and governance** | Reporting is duplicative and inconsistent across institutions. Cyber, privacy, and access controls are unevenly implemented. Accountability for who accessed what data, for what purpose, is often weak. | Standard governance primitives for access control, purpose limitation, assurance tiers, and continuous auditability. A practical split between critical and non-critical exchanges, with consistent compliance evidence across actors. |

| | | |
|---|---|---|
| **Cross-cutting systemic issue** | Core coordination failure across actors due to missing identifiers, inconsistent definitions, and low-trust exchanges. High integration cost across legacy systems and vendors. | A shared sector trust layer that standardises identities, interfaces, data models, assurance, and audit. Lower coordination and integration cost without centralising all sector data or replacing existing systems. |

## 15. ANNEXURE 3: MAPPING EXISTING DIGITALISATION EFFORTS

Digital Systems in Indian Power Sector (The Tools)
Definition: The software, hardware, and platforms used for real-time operations, data collection, and transactions.

**A. Grid Operations & Planning Systems**

| Digital System | Description | Deployment Status |
|---|---|---|
| **SCADA/EMS** | **Supervisory Control and Data Acquisition**; the core software for real-time monitoring and control of the transmission grid. | Operational at NLDC, all 5 RLDCs, and 33 SLDCs; upgrades ongoing for RE integration. |
| **REMC** | **Renewable Energy Management Centres**; AI-driven forecasting and scheduling hubs co-located with LDCs to manage variable solar/wind power. | **11 Operational** (1 National, 3 Regional, 7 State) managing 55GW+ of RE. |
| **ADMS** | **Advanced Distribution Management System**; integrates SCADA, DMS, and OMS for holistic distribution network control. | Deployed by private DISCOMs (TPDDL, Adani); piloting in select public utilities. |
| **OMS** | **Outage Management System**; software to predict outages and coordinate faster restoration crews. | Integrated with ADMS in urban centers; standalone pilots in others. |
| **GIS** | **Geographic Information System**; spatial mapping of electrical assets (poles, transformers) and consumer indexing. | Widely deployed; essential for asset management and fault location. |
| **Digital Twin** | Virtual real-time replica of the physical grid for simulation and predictive analysis. | Pilots by Powergrid (transmission) and JVVNL Rajasthan (distribution). |

**B. Metering & Distributed Energy Systems**

| Digital System | Description | Deployment Status |
|---|---|---|

| | | |
|---|---|---|
| **AMI** | **Advanced Metering Infrastructure**; smart meters with 2-way communication for real-time billing and monitoring. | ~22.9 million installed; 222 million sanctioned under RDSS. |
| **MDMS** | **Meter Data Management System**; central software that validates, stores, and analyzes the massive data flow from smart meters. | Deployed alongside AMI projects. |
| **DERMS** | **Distributed Energy Resource Management System**; software to manage grid-edge assets like solar, storage, and EV chargers. | Early pilot stage (e.g., BRPL Delhi). |
| **UEI** | **Unified Energy Interface**; open network protocol (Beckn-based) for interoperable energy transactions (like UPI for energy). | Pilot stage (EV charging in Kochi/Delhi); UEI Alliance formed. |

**C. Market, Settlement & Scheduling Platforms**

| Digital System | Description | Deployment Status |
|---|---|---|
| **NOAR** | **National Open Access Registry**; centralized platform for short-term open access (STOA) to the interstate transmission system. | **Active**; reduced processing time from days to hours. |
| **SAMAST** | **Scheduling, Accounting, Metering & Settlement of Transactions**; state-level software for intra-state scheduling and billing. | Operational in MP, Delhi, Gujarat, Maharashtra; implementing in others. |
| **PUShP** | **High Price Day Ahead Market & Surplus Power Portal**; allows DISCOMs to display and trade surplus power capacity. | **Active**; launched March 2023. |
| **DEEP** | **Discovery of Efficient Electricity Price**; e-bidding portal for short/medium-term power procurement by DISCOMs. | **Mandatory** for transparent price discovery. |
| **PRAAPTI** | **Payment Ratification And Analysis in Power procurement**; portal tracking invoicing and payments between GENCOs and DISCOMs. | **Active**; brings transparency to sector overdues. |
| **LPSC Portal** | **Late Payment Surcharge** portal; tracks EMI payments for liquidating legacy dues under LPS Rules 2022. | **Active**; critical for financial discipline. |
| **MERIT** | **Merit Order Despatch**; portal displaying marginal costs and source-wise purchase to optimize procurement. | **Active**; helps states minimize power purchase costs. |
| **REC Registry** | **Renewable Energy Certificate Registry**; digital ledger for issuing and trading RECs. | **Active**; managed by GRID-INDIA. |

**D. Consumer, Solar & Transparency Portals**

| Digital System | Description | Deployment Status |
|---|---|---|
| **National Portal for** | Single-window digital interface for **PM Surya Ghar** scheme applications and subsidies. | **Active**; primary channel for residential solar. |

| | | |
|---|---|---|
| **Rooftop Solar** | | |
| **National Power Portal (NPP)** | Centralized database and dashboard for all power sector data (generation, transmission, distribution). | **Active**; the "Single Source of Truth" for sector data. |
| **Vidyut PRAVAH** | Real-time dashboard displaying power availability, demand, and market clearing prices. | **Active**; public transparency tool. |
| **TARANG** | **Transmission App for Real Time Monitoring**; tracks status of transmission projects and delays. | **Active**; project monitoring tool. |
| **Urja Mitra** | Outage notification platform sending SMS/email to consumers about scheduled outages. | **Active**; integrated with many DISCOMs. |
| **e-Amrit** | One-stop portal for Electric Vehicle information, charging, and investment policies. | **Active** (NITI Aayog initiative). |
| **ICED** | **India Climate & Energy Dashboard**; open-data platform for energy and climate statistics. | **Active** (NITI Aayog). |

Digital Initiatives in Indian Power Sector (The Drivers)
Definition: The schemes, policies, and missions that fund, mandate, or drive the adoption of the systems above.

| Digital Initiative | Objective | Status & Key Focus |
|---|---|---|
| **RDSS** | **Revamped Distribution Sector Scheme**; primary funding vehicle for grid modernization. | **Active**; funds AMI (250M meters) and IT/OT integration. |
| **PM-KUSUM** | Solarization of agriculture; **mandates digital adoption** via Remote Monitoring Systems (IoT) for pumps. | **Active**; created a massive distributed IoT network. |
| **SMNP** | **Smart Meter National Programme**; the specific target to replace 250M conventional meters. | **Active**; largely subsumed under RDSS implementation. |
| **NSGM** | **National Smart Grid Mission**; fosters pilots, standards, and capacity building for smart grids. | **Active**; completed 11 pilots; Knowledge Centre established. |
| **Green Energy Corridor (GEC)** | Transmission infrastructure for RE; includes **digital communication backbone** (OPGW) for telemetry. | **Active**; Phase-II ongoing (20GW integration). |
| **CSIRT-Power** | **Computer Security Incident Response Team**; institutional body for power sector cyber defense. | **Active**; established April 2023 at CEA. |

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| **AI/ML Mission** | Strategic initiative to adopt AI for load forecasting, predictive maintenance, and theft detection. | **Ongoing**; Centers of Excellence (CoE) at PSUs; regulatory sandbox discussions. |
| **FOLD** | **Forum of Load Despatchers**; institutional initiative for training operators in digital systems (SCADA/REMC). | **Active**; ensures workforce readiness for digital tools. |
| **CCTS** | **Carbon Credit Trading Scheme**; creating a domestic carbon market (requires a digital registry). | **Development**; BEE finalizing framework; Registry built by Grid-India. |
| **One Sun One World One Grid** | Transnational grid vision requiring complex **digital scheduling** across time zones. | **Concept**; technical studies on digital handshakes ongoing. |
| **UDAY** | **Ujwal DISCOM Assurance Yojana**; financial turnaround scheme that *first mandated* smart metering (Legacy). | **Closed**; set the foundation for current digital push. |

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## 16. ANNEXURE 4: PRELIMINARY USECASE RANKING EXERCISE

| Criterion Weightage | 20% | 20% | 20% | 10% | 8% | 8% | 5% | 9% | 100 % |
|---|---|---|---|---|---|---|---|---|---|
| Criterion Score 0-10 | Value and market demand | End-consumer centricity | System impact | Leverage on core IES building blocks | Feasibility and time-to-value | Institutional and implementation complexity | Data readiness and interoperability lift | Impact of failure and learning value | Total Score |
| Customer onboarding and service connection | 8 | 9 | 6 | 9 | 8 | 7 | 8 | 9 | 0.791 |
| Grievance and service request management | 8 | 9 | 6 | 8 | 8 | 6 | 6 | 7 | 0.745 |
| Subsidy eligibility and benefit delivery | 9 | 9 | 6 | 6 | 8 | 6 | 6 | 7 | 0.745 |
| Consent-based data sharing | 8 | 6 | 6 | 10 | 8 | 7 | 8 | 9 | 0.741 |

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|---|---|---|---|---|---|---|---|---|---|
| EV charging integration and managed charging | 8 | 9 | 6 | 8 | 8 | 4 | 6 | 7 | 0.729 |
| Customer energy advisory and alerts | 8 | 9 | 6 | 6 | 8 | 6 | 6 | 7 | 0.725 |
| Outage management for distribution | 8 | 9 | 6 | 6 | 8 | 6 | 6 | 7 | 0.725 |
| Time-of-use tariffs and dynamic pricing | 8 | 9 | 6 | 6 | 8 | 6 | 6 | 7 | 0.725 |
| Prepaid metering and recharge | 8 | 9 | 8 | 6 | 6 | 4 | 8 | 4 | 0.716 |
| Demand response program delivery and settlement | 9 | 7 | 8 | 8 | 6 | 4 | 6 | 4 | 0.706 |
| Asset registry and tagging | 7 | 3 | 6 | 9 | 8 | 7 | 8 | 9 | 0.651 |
| Sector participant onboarding and role registration | 7 | 3 | 6 | 9 | 8 | 7 | 8 | 9 | 0.651 |
| Transparency portals and public data publishing | 6 | 4 | 6 | 9 | 8 | 7 | 7 | 9 | 0.646 |
| Revenue protection and theft detection | 8 | 4 | 6 | 8 | 7 | 6 | 6 | 8 | 0.646 |
| Energy accounting and AT&C loss analysis | 7 | 4 | 8 | 6 | 7 | 6 | 6 | 8 | 0.646 |
| Renewable curtailment analysis | 7 | 4 | 8 | 6 | 7 | 6 | 6 | 8 | 0.646 |

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|---|---|---|---|---|---|---|---|---|---|
| Settlement-grade metering validation | 9 | 3 | 8 | 8 | 6 | 4 | 8 | 4 | 0.636 |
| Imbalance settlement and deviation charges | 9 | 3 | 8 | 8 | 6 | 4 | 6 | 4 | 0.626 |
| DER integration and prosumer settlement | 9 | 3 | 8 | 8 | 6 | 4 | 6 | 4 | 0.626 |
| Event and disturbance analysis | 7 | 4 | 6 | 8 | 7 | 6 | 6 | 8 | 0.626 |
| Demand response aggregation for market participation | 6 | 7 | 6 | 8 | 6 | 4 | 6 | 6 | 0.624 |
| Reverse auction and e-bidding procurement | 8 | 3 | 8 | 8 | 6 | 4 | 6 | 4 | 0.606 |
| Bilateral and OTC contracting | 8 | 3 | 8 | 8 | 6 | 4 | 6 | 4 | 0.606 |
| DISCOM procurement optimisation and schedule readiness | 8 | 3 | 8 | 8 | 6 | 4 | 6 | 4 | 0.606 |
| Renewable energy certificates trading and compliance | 8 | 3 | 8 | 8 | 6 | 4 | 6 | 4 | 0.606 |
| Day-ahead market clearing | 9 | 3 | 8 | 6 | 6 | 4 | 6 | 4 | 0.606 |
| Regulatory reporting and compliance submission | 7 | 4 | 6 | 6 | 7 | 6 | 6 | 8 | 0.606 |

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|---|---|---|---|---|---|---|---|---|---|
| Market monitoring and surveillance | 7 | 4 | 6 | 6 | 7 | 6 | 6 | 8 | 0.606 |
| Grid resilience analytics and extreme-weather risk planning | 7 | 4 | 8 | 6 | 4 | 4 | 6 | 8 | 0.606 |
| Plant performance monitoring | 7 | 4 | 6 | 6 | 7 | 6 | 6 | 8 | 0.606 |
| Maintenance and outage planning for plants | 7 | 4 | 6 | 6 | 7 | 6 | 6 | 8 | 0.606 |
| Right-of-way and encroachment monitoring | 7 | 4 | 6 | 6 | 7 | 6 | 6 | 8 | 0.606 |
| Substation asset health monitoring | 7 | 4 | 6 | 6 | 7 | 6 | 6 | 8 | 0.606 |
| Transmission outage planning | 7 | 4 | 6 | 6 | 7 | 6 | 6 | 8 | 0.606 |
| Condition-based maintenance for generation assets | 7 | 4 | 6 | 6 | 7 | 6 | 6 | 8 | 0.606 |
| Emissions monitoring and compliance reporting | 7 | 4 | 6 | 6 | 7 | 6 | 5 | 8 | 0.601 |
| ATC/TTC and transfer margin publication | 6 | 4 | 8 | 6 | 6 | 6 | 6 | 6 | 0.6 |
| Generation forecasting | 8 | 3 | 8 | 6 | 6 | 4 | 6 | 4 | 0.586 |
| Load forecasting | 8 | 3 | 8 | 6 | 6 | 4 | 6 | 4 | 0.586 |

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| and demand analytics | | | | | | | | | |
| Renewable forecasting and scheduling services | 8 | 3 | 8 | 6 | 6 | 4 | 6 | 4 | 0.586 |
| Peer-to-peer and local prosumer trading pilots | 6 | 3 | 8 | 8 | 6 | 4 | 4 | 7 | 0.583 |
| EV flexibility products and V2G participation | 4 | 7 | 6 | 8 | 6 | 4 | 4 | 7 | 0.583 |
| Ancillary services procurement | 8 | 3 | 8 | 8 | 4 | 3 | 6 | 4 | 0.582 |
| Capacity and reliability procurement | 8 | 3 | 8 | 8 | 4 | 3 | 6 | 4 | 0.582 |
| Cybersecurity access governance and audit | 7 | 2 | 6 | 9 | 7 | 5 | 7 | 6 | 0.575 |
| Carbon credits and clean fuel certificates | 6 | 4 | 6 | 8 | 6 | 6 | 5 | 6 | 0.575 |
| Network planning and investment prioritisation | 7 | 4 | 6 | 6 | 4 | 4 | 6 | 8 | 0.566 |
| Real-time market clearing | 9 | 3 | 8 | 6 | 4 | 3 | 6 | 2 | 0.564 |
| Hybrid plant coordination | 6 | 4 | 6 | 6 | 6 | 6 | 6 | 6 | 0.56 |
| Fuel supply chain tracking | 6 | 4 | 6 | 6 | 6 | 6 | 6 | 6 | 0.56 |
| Storage and energy shifting products | 6 | 4 | 6 | 6 | 6 | 6 | 6 | 6 | 0.56 |

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|---|---|---|---|---|---|---|---|---|---|
| Co-optimised energy and ancillary clearing | 8 | 3 | 8 | 6 | 4 | 3 | 6 | 2 | 0.544 |
| Dispatch instruction receipt and acknowledgement | 8 | 3 | 10 | 4 | 2 | 2 | 6 | 2 | 0.54 |
| Load flow and constraint monitoring | 6 | 1 | 10 | 6 | 2 | 2 | 6 | 2 | 0.48 |
| Contingency analysis (N-1, N-2) | 6 | 1 | 10 | 6 | 2 | 2 | 6 | 2 | 0.48 |
| WAMS and PMU-based stability monitoring | 6 | 1 | 10 | 6 | 2 | 2 | 6 | 2 | 0.48 |
| Emergency load shedding execution logging | 6 | 1 | 10 | 4 | 2 | 2 | 6 | 2 | 0.46 |
| Network topology and boundary management | 6 | 1 | 10 | 4 | 2 | 2 | 6 | 2 | 0.46 |
| Congestion management and redispatch | 6 | 1 | 10 | 4 | 2 | 2 | 6 | 2 | 0.46 |
| Transmission state estimation inputs | 6 | 1 | 10 | 4 | 2 | 2 | 6 | 2 | 0.46 |
| Black start capability testing and readiness | 6 | 1 | 10 | 4 | 2 | 2 | 6 | 2 | 0.46 |
| Islanding and restoration coordination | 6 | 1 | 10 | 4 | 2 | 2 | 6 | 2 | 0.46 |
| Dynamic line rating operations | 6 | 1 | 10 | 4 | 2 | 2 | 6 | 2 | 0.46 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Real-time SCADA/EMS monitoring | 6 | 1 | 10 | 3 | 2 | 1 | 6 | 1 | 0.433 |
| AGC and load-frequency control operations | 6 | 1 | 10 | 2 | 2 | 1 | 6 | 1 | 0.423 |
| HVDC corridor operations | 6 | 0 | 10 | 2 | 2 | 1 | 5 | 1 | 0.398 |


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