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BY INDIA SMART GRID FORUM AND LATIN AMERICAN SMART GRID FORUM

Advanced Metering Infrastructure (AMI):

Enabling the Next-Generation Power Systems



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Joint White Paper by

India Smart Grid Forum and Latin American Smart Grid Forum

Advanced Metering Infrastructure:

Enabling the Next-Generation Power Systems

Abstract

Advanced Metering Infrastructure (AMI) is becoming strategic digital infrastructure for next-generation electricity distribution. Its value extends far beyond remote meter reading: when combined with communications, data governance, cybersecurity and integration with utility IT and OT systems, AMI can improve operational visibility, automate meter-to-cash processes, support new tariffs and services, strengthen consumer participation and enable the coordination of distributed energy resources. This joint white paper by the India Smart Grid Forum (ISGF) and the Latin American Smart Grid Forum (LATAM SGF) brings together two complementary perspectives. India contributes the experience of one of the world's largest smart-metering programmes, including standardization, large-scale implementation and service-based commercial models under RDSS. Brazil provides a rapidly evolving market and regulatory context in which AMI is becoming increasingly connected to renewed distribution concessions, retail-market opening, resilience, smart tariffs, distributed generation, storage, flexibility and data-driven grid operation. The paper uses these experiences to identify principles relevant to India, Brazil and other Latin American and Caribbean markets: define use cases and measurable outcomes first; preserve technology neutrality; require interoperability and lifecycle cybersecurity; integrate AMI with enterprise and operational platforms; align commercial models with verifiable service levels; and engage consumers from the outset. Looking forward, AMI 2.0 can evolve into a secure digital platform supporting AI/ML analytics, outage and asset management, low-voltage visibility, demand response, DER coordination, managed EV charging and selected multi-utility applications. The central conclusion is not that one region should copy another, but that large-scale deployment experience and market-modernization experience can inform each other in building scalable, interoperable and future-ready distribution systems.

Joint Publication Disclaimer

This white paper has been jointly prepared by the India Smart Grid Forum (ISGF) and the Latin American Smart Grid Forum (LATAM SGF) to support technical and policy dialogue on AMI and grid modernization. Its analysis reflects the contributors' best understanding at the time of publication and may evolve with technology, regulation and market conditions. Reasonable efforts have been made to use reliable information, but neither organization warrants completeness or error-free content. References to technologies or commercial models are illustrative and do not imply endorsement. The document is not legal, regulatory, financial or investment advice.

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About India Smart Grid Forum

The India Smart Grid Forum (ISGF) is a Think-Tank of global repute on Smart Energy, Electric Mobility, Grid Modernization and Energy Transition. ISGF, established as a Public Private Partnership (PPP) initiative of Government of India in 2011, is spearheading the mission to accelerate electric grid modernization and energy transition in India. ISGF is registered as a Not-for-Profit Society under Indian Societies Act and has its head office at CBIP Building, Malcha Marg, Chanakyapuri, New Delhi 110021.

About Latin American Smart Grid Forum

The Latin American Smart Grid Forum (LATAM SGF), based in Brazil, is an independent regional platform dedicated to the modernization, digitalization and transformation of electricity networks. It convenes utilities, regulators, system and market institutions, technology providers, research organizations, investors and specialists from Brazil, Latin America and other regions to exchange experience and accelerate practical solutions for smarter, more resilient and consumer-centric power systems. Its agenda connects advanced metering, grid automation, telecommunications, data and cybersecurity with distributed energy resources, flexibility, storage, electric mobility, market modernization, regulation and new business models. The annual Smart Grid Forum in São Paulo is a principal meeting point for this community and, in 2026, reaches its 18th edition.

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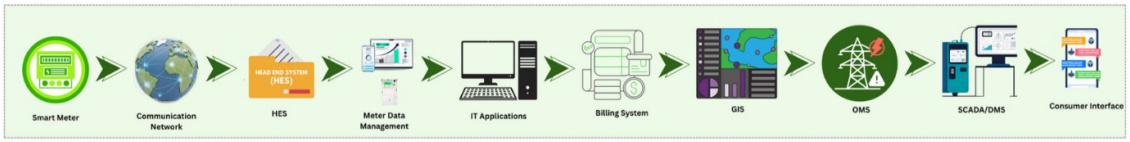
INTRODUCTION

Electricity distribution is entering a period in which metering, communications, data and grid operation can no longer be planned as separate domains. Advanced Metering Infrastructure (AMI) sits at the intersection of these functions and is therefore becoming strategic digital infrastructure for the next generation of power systems. This joint white paper by the India Smart Grid Forum (ISGF) and the Latin American Smart Grid Forum (LATAM SGF) examines AMI through complementary Indian and Latin American perspectives. India offers lessons from the evolution from electromechanical meters and AMR to one of the world's largest two-way AMI programmes, including standardization, interoperability, service-based procurement and the operational challenges of deployment at scale. Brazil illustrates a different but increasingly relevant transition: AMI is becoming part of a broader transformation involving renewed distribution concessions, low-voltage retail-market opening, resilience, smart tariffs, DER coordination, flexibility and the evolution of distribution companies toward data-driven, active-network operation. Together, these experiences reinforce a common principle: AMI should not be designed as a meter-replacement programme. It should be conceived as an integrated ecosystem of smart meters, communications, HES, MDMS, NMS,

SMOC, cybersecurity, data governance and interfaces with enterprise and operational systems. The appropriate architecture and commercial model will vary by market, but the design principles are shared: measurable outcomes, technology neutrality, interoperability, lifecycle resilience and security, consumer engagement and the ability to evolve toward AMI 2.0 applications.

Smart Metering – Beyond Just "Smart Meters"

In essence, smart metering is not simply about replacing old devices with digital ones. It is an integrated system that connects meters, communication networks, Utilities IT and OT platforms, and customer interfaces into a seamless ecosystem.



The goal is to capture, validate and analyse data at the frequency required by each use case and make it actionable for consumers and utilities. For customers, this can provide greater visibility and control over electricity use, enable time-of-use tariffs and prepaid services, and improve service restoration. For utilities, AMI data can support billing, load forecasting, loss analysis, outage management and asset optimisation. Smart meters typically incorporate a communications module or Network Interface Card (NIC) that exchanges data and commands with utility systems. Communications are therefore a mission-critical subsystem, but AMI performance should be assessed end-to-end rather than by radio technology alone. Coverage, latency, read success, command success, outage behaviour, cybersecurity, lifecycle support and total cost all matter. Utilities and service providers may use public telecom networks, utility-owned RF mesh or PLC, fibre/microwave backhaul, or hybrid architectures according to local conditions. Data is collected by HES platforms and processed by MDMS platforms for integration with billing, GIS, OMS, CRM and other utility applications.

The importance of AMI in India's power sector cannot be overstated. Distribution Companies (DISCOMs) continue to face mounting financial stress, driven by high aggregate technical and commercial (AT&C) losses, low billing efficiency, and weak collection rates. The time stamped interval readings (15 mins/30 mins) from the smart meters could provide visibility of power flows in the distribution network more granularly which will help in plugging the losses as well as improving billing and collection efficiency. In fact, recent data suggests that billing efficiency in Indian DISCOMs was about 86.91% and collection efficiency was about 96.51% in FY 2023-24. The total accumulated losses of DISCOMs stood at INR 6.92 lakh crore at the end of FY 2024. These numbers highlight why AMI is not simply a technological upgrade but a necessity for financial stabilization. By reducing losses, improving revenue assurance, and creating the basis for advanced tariff structures such as time-of-use tariff, AMI offers a direct pathway towards more sustainable finances for utilities. At the same time, it provides the intelligence required to integrate intermittent renewable energy sources, manage growing electricity demand, and align consumption with generation.

Key Components of AMI System

- **Smart Meters:** Responsible for measuring and recording data; and it typically comprises of a Communication Module or Network Interface Card (NIC) which can have different communication technologies - Cellular, RF Mesh or PLC. Smart meter also have a Built-in Connect/Disconnect Switch for remote disconnection and reconnection. Smart meters can be configured for Metering mode, Payment mode, Data capture period, Prepayment (Credit balance, last top up etc); and Over the Air Firmware upgrade; Activity Calendar (TOU, Bill Dates); and Key Change. Ideally, the meters should be sourced from multiple meter manufacturers to ensure that there is no vendor lock-in.
- **Communication Network:** Responsible for two-way communication and moving data and commands between the meter and the central server. Communication network could comprise of different networks - last mile/field area network (FAN), wide area network (WAN) and home area network (HAN) etc.
- **Head-End System (HES):** The software tool responsible for fetching the meter data from the meter to the central server. Key functions of HES are Device Management, Data Collection, Manage and Control Actions to be done by Field Devices, Store Data, Push Data to Upstream Applications, Maintain Integrity of Devices and Data. Other functions of HES are Configuration of Devices and Ability to Communicate with devices (Meters and DCUs), Update Current Status of Communications, Manage Data Flow/Connectivity Path, Over the Air Upgrade of Firmware, and Inventory Management.
- **Meter Data Management System (MDMS):** This is the heart of an AMI system which organizes and integrates the meter data with utility applications as well as providing useful insights and sending alerts and commands to the meter and other stakeholders. The key features of MDMS are Validation, Estimation and Editing Engine (VEE), Data Storage, Analytics, Reporting Module, Interfacing with Upstream Applications (Billing, CRM, Consumer Portal, ERP, GIS, OMS, etc).
- **Network Management System (NMS):** The software tool that monitors the AMI network in real-time and identify faults and intrusions. Initial AMI systems had NMS functionalities as part of HES.
- **Smart Meter Operations Centre (SMOC):** Modern AMI systems have SMOCs which help in smart meter rollouts and also help monitor and manage the AMI system. SMOC has several applications, advanced analytics and dashboards to manage the entire system. In AMI systems with SMOC, NMS is often part of the SMOC suite. Typical architecture and applications of SMOC is given at the Appendix.

Communication Solutions for AMI

The first and largest smart metering initiative in the world was by Enel, Italy which comprised of over 32 million meters in the early years of this century. Enel chose narrow band power line communication (PLC) technology for last mile connectivity. The smart meters were connected through PLC to a data concentrator unit (DCU) and most DCUs were connected to Utility Data Centre through GPRS network of the public telecom company. Some DCUs were connected through fibre optic cables of the utility wherever such options were available. The communication architecture of ENEL's AMI system is depicted below.

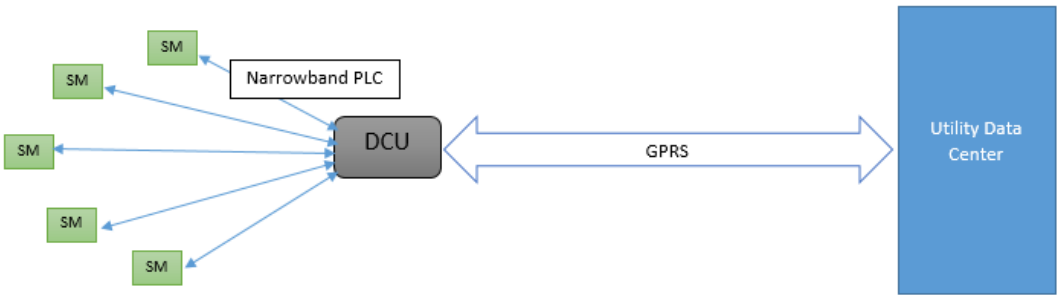


Figure 1: Communication Architecture of the first largest AMI implemented by Enel, Italy

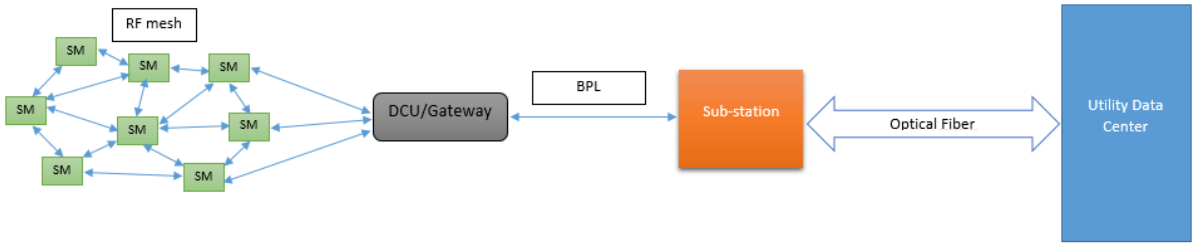


Figure 2: Communication Architecture of the AMI Project in Centre Point Energy, Houston

During 2005-2008, Centre Point Energy in Houston, Texas embarked on their smart metering journey. They chose RF Mesh for the last mile communication between the smart meters and the data concentrators; and deployed broadband over power line (BPL) technology on medium voltage (15 kV and 35 kV) lines for communication between the DCU and their substations which have fibre optic connectivity with the data centre. This network was completely built and managed by the utility and was not dependent on any public telecom operators. BPL technology was emerging those days but did not become a choice of the industry owing to high initial cost, proprietary standards as well as requirement of constant engineering support in the field.

During the same time period when Centre Point Energy was building their own communication system supported AMI network, in California Pacific Gas and Electric (PG&E) and Southern California Edison (SCE) were implementing their AMI systems with combination of communication solutions.

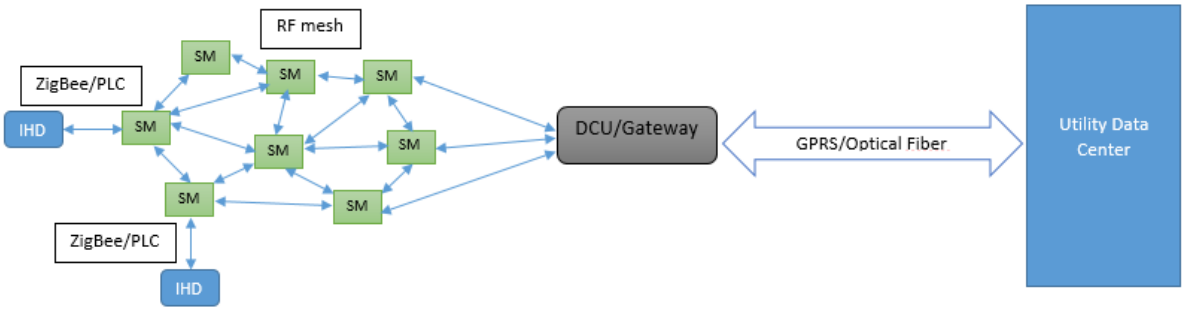


Figure 3: Communication Architecture of the AMI Project in Southern California Edison (SCE)

SCE chose RF Mesh for last mile connectivity and for DCUs to connect with the utility server, they chose GPRS and Fiber wherever feasible. They also promoted In-home Display Units (IHD) through PLC and Zigbee.

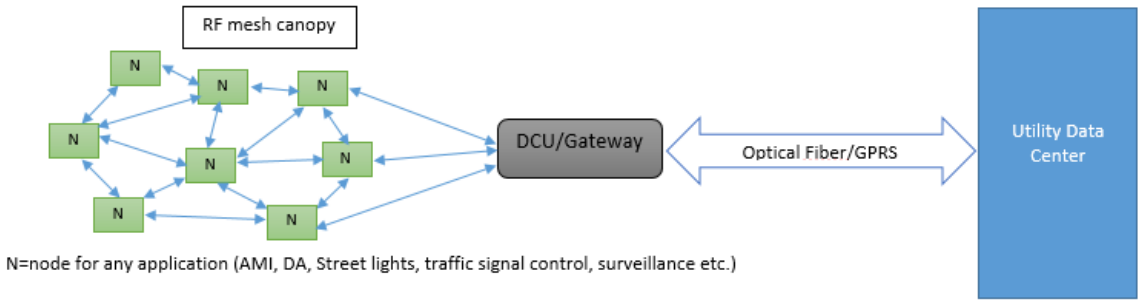


Figure 4: Communication Architecture of the AMI Project that can be extended to Smart City Applications

The above architecture of RF Mesh canopy was experimented at few places where the electric utility invested in building a city-wide RF mesh canopy that can be extended to other domains such as distribution automation (DA), streetlight controls, smart gas meters, smart water meters, traffic signals and other smart city applications. However, owing to higher capex, these systems did not scale up.

Following table gives a comparison of various communication technologies for smart metering.

Table 1: Comparison of Various Communication Technologies for Smart Metering

Technology	Home Area Network	Last Mile	Wide Area Network
Wireless	• RF Mesh • 6LowPAN • ZigBee • Wi-Fi • Bluetooth • Z-Wave • NFC	• RF Mesh • ZigBee • Wi-Fi • Millimeter Wave Technology • Bluetooth Low Energy (BLE) and BLE 5 • LoRA • NB IoT	• Cellular • Satellite • LPWAN • Long Wave Radio • TV White Space • Private Microwave Radio
Wired	• PLC • Ethernet	• PLC (narrow band) • Broadband on Power Line (BPL) • Ethernet • Control Area Network (CAN)	• Telecom Cables, Fiber Optic Cables • Power Line Carrier Communication (PLCC)

Table 2: Engineering Characteristics of AMI Communication Technologies

Characteristic	RF Mesh	Public Cellular	Private / Utility Cellular	PLC	LoRaWAN
Infrastructure ownership	Utility / AMISP	Mobile network operator (MNO)	Utility / private operator	Utility / AMISP	Utility / private operator / network provider
Spectrum	Typically licence-exempt	Licensed	Licensed / shared, depending on market	Power line	Typically licence-exempt
Topology	Mesh	Point-to-point via mobile network	Point-to-point via private network	Tree / star, depending on design	Star-of-stars
Resilience mechanisms	Alternate mesh paths; engineered gateways	Multi-operator / multi-SIM possible; coverage-dependent	Network engineered for utility requirements	Alternate paths may be limited; depends on grid topology	Gateway diversity; backhaul design
Best-fit conditions	Dense meter populations	Broad existing operator coverage	Strategic / private networks	Suitable power-line conditions	Low-data IoT use cases, subject to capacity and duty-cycle constraints
Key lifecycle dependency	RF planning, density and gateway/backhaul maintenance	MNO coverage, service continuity and commercial terms	Spectrum rights and network ownership/operations	Grid topology, electrical noise and coupling	Gateway density, duty cycle and operator/network support

No communications technology is intrinsically superior across all AMI environments; architecture should be selected against measurable end-to-end requirements. Latency, availability, redundancy and data capacity depend on network design, spectrum, topology, operator coverage, backhaul, device density and operating practices. Procurement should define measurable end-to-end SLAs—including scheduled and on-demand read success, command success, latency,

outage recovery, firmware-upgrade success, security controls and availability—and allow the AMISP to engineer a technology-neutral, potentially hybrid or multi-bearer architecture.

Interoperability Requirements

At Device Level:

- Meters from different manufacturers capable of interacting with DCU
- DCUs of different manufacturers capable of interacting with the HES

At Network Level:

- DCU capable of interacting with meters over different communication networks
- HES capable of interacting with DCU over different communication networks

At Application Level:

- DLMS specified at the application layer in India

At System Level:

- One MDMS for many HES
- Interoperability should extend beyond basic protocol compliance. Utilities should require conformance-tested DLMS/COSEM object models and security suites, well-defined HES-to-MDMS and enterprise APIs, portable device identities and keys, and documented data semantics. The objective is substitutability: meters, communications, HES and analytics components should be replaceable or expandable without forcing a wholesale redesign of the AMI estate.

AMI Design Principles

The key design principles of an AMI system are listed below.

1. **Scalability:** The AMI system should be scalable to several million meters.
2. **Performance and Reliability:** The AMI system should meet the defined and mutually agreed service level agreements (SLAs) on performance and reliability - typically above 99%.
3. **Modularity:** The AMI system should be modular for implementation in phases.
4. Cloud Readiness: The AMI system should be designed to be hosted on secured public cloud environments.
5. **Integration with Utility's IT and OT Systems:** The AMI (MDMS) should be integrated with utility's existing IT applications such as Billing and Payment Collection, Customer Information System (CIS), ERP, Outage Management System (OMS), Mobile Crew Management Systems and OT applications such as GIS, SCADA/DMS, DERMs etc.
6. **Interoperability**: Overall, the AMI system should be interoperable with different makes of meters and data concentrator units (DCU) in case of RF Mesh communication, different communication technologies such as RF Mesh, Cellular or PLC; and different Head End Systems (HES).
7. **Service Oriented Architecture (SOA):** SOA is a matured IT architecture where different applications are built as a loosely coupled services; and all services could access the same data which are stored in data historians or middleware applications. SOA help improve scalability, flexibility and interoperability.
8. **Business Continuity (BC) and Disaster Resiliency (DR):** All IT systems should be designed to ensure business continuity and disaster resilience, particularly large AMI systems that are critical to utility's revenues.
9. **Cyber Security:** Cyber security measures should be built into the design of the AMI system. Several important points on cyber security are described in the Standard Bidding Document (SBD) of the Revamped Distribution Sector Scheme (RDSS) program under which 250 million smart meters are being rolled out in India presently.
10. Technology Neutrality and Hybrid Communications: Procurement should specify outcomes and SLAs rather than mandate one communications technology across heterogeneous service territories. The architecture should permit RF mesh, cellular, PLC and other suitable technologies to coexist behind common HES/MDMS interfaces, with hybrid or multi-bearer designs used where they improve resilience or economics. 11. Observability and Lifecycle Management: AMI should provide continuous visibility of communications quality, device health, firmware versions, certificates/keys and SLA performance. Secure remote configuration and over-the-air upgrades are essential over a 10-15 year asset lifecycle. 12. Security by Design and Zero-Trust

Principles: Device identity, secure boot/root of trust where appropriate, mutual authentication, least-privilege access, encryption, key rotation, signed firmware and auditable software/firmware supply chains should be considered from design through decommissioning.

Benefits of AMI

The deployment of AMI is not merely a technological upgrade; it is a fundamental reform that generates substantial and quantifiable value for the entire power sector. The benefits extend across all stakeholders, from utilities to the end consumers. Early adopter utilities are already witnessing significant positive impacts such as the average revenue growth after AMI implementation was estimated to be above INR 200 per month per customer, while the monthly instalment to the AMISP was well below INR 100 per meter per month.

Table 3: Benefits of AMI to Utilities, Customers and Society

SI No	Benefits	Financial Impact	Dependence on Communication Technology
A. BENEFITS TO DISCOMs			
1	**Reduced meter reading and data entry cost:** Without smart meters, utilities must send personnel to customer premises to manually read the meter. Implementation of AMI enables remote meter reading both regularly and on demand. Data entry and processing is performed automatically. Overall, AMI should deliver greater convenience at reduced cost relative to traditional meter reading.	Medium	Low
2	**Reduction in time taken for meter reading and bill generation as well as reduction in errors:** There are always chances of human errors when meters are read manually or even via automatic hand-held devices. In addition, the process is time consuming. By delivering meter data automatically over communication networks, AMI eliminates human error from the meter reading process as well as make the entire process faster.	Medium	Medium
3	**Reduction in cost of disconnection and re-connection** as it can be managed through remote operation of the AMI system.	Medium	Medium
4	**Faster detection of dead meters** and hence enhanced revenue protection.	High	Medium
5	**Enhanced Revenue per Month:** Large share of meters existing in DISCOMs are old and hence the readings are not very reliable. With new smart meters, the accurate energy consumption can be captured which will enhance the monthly revenue considerably. It is expected that the monthly payment to AMI Service Provider (AMISP) can be met from the increased revenue.	High	Low
6	**Reduction in Aggregate Technical & Commercial (AT&C) losses:** AMI can remotely detect meter tampering and enable real time energy accounting. This reduces theft through by-passing the meter, thereby substantially reducing aggregate technical and commercial (AT&C) losses. AMI will also streamline the billing, or meter-to-cash process considerably by reducing the human errors in meter reading and billing.	High	Medium
7	**Enabling faster outage detection and service restoration after faults:** Traditionally utilities know about an outage only when they receive complaints from affected customers. Service restoration requires utility crews to identify the area and rectify the fault - a time consuming and expensive process. Smart meters conforming to IS 16444 are capable of sending 'last gasp' and 'first breath' messages, which informs the utilities when power has failed or resumed. This will reduce outage restoration times leading to financial savings and improved customer satisfaction.	High	High
8	**Better load research and demand forecasting** from the granular consumption data from AMI can reduce power purchase cost.	High	High
9	**Power quality measurement and management:** Smart meters are capable of measuring specific aspects in near real-time, such as power factor, over or under voltage, and over current. This helps utilities to enhance power quality in conjunction with power quality data from other sources. Improved power quality also leads to lower power losses. Also, avoid costs associated with investigation of voltage complaints.	Medium	Low

10	**Asset optimization:** AMI data supports granular monitoring of power flows on the distribution network which can help utilities to identify segments of over- and under-loading. This is valuable information for system planning and optimizing network upgrades. AMI data can also help balance load, which reduces power losses. Better visibility of loading on the power system will help faster/delayed capacity enhancement and prevention of failure/under-utilization of equipment. Furthermore, network monitoring can decrease equipment failure rate by identifying phase imbalances and over loading in advance which can be corrected.	High	High
11	**Ability to operate in pre-paid and post-paid modes.**	Medium	High
12	**Remote operations:** Smart meters typically include remote switching, which allows utilities to remotely disconnect or reconnect where necessary, such as when load is exceeded, for predetermined events, in the case of non-payment, or when a customer moves. Additionally, utilities can monitor the health of the meter and dispatch maintenance crew only where necessary.	Medium	High
13	**Improvement in reliability indices and its accurate measurement:** Enhanced monitoring of the distribution network operations would significantly improve the reliability indices like CAIFI/CAIDI, SAIFI/SAIDI as well as help measure these indices accurately.	Medium	Medium
14	**Real time energy auditing** and accurate energy accounting from time-stamped meter data.	High	High
15	**Reduced load on call centres**, customer care centres and billing centres.	Medium	Low
16	**Smart meters act as feedback points** for understanding the behavioural interpretations of energy demand as consumption which can be modified.	Low	Low
B. BENEFITS TO GENERATION AND TRANSMISSION COMPANIES			
1	Deferred or avoided transmission capacity investments.	High	Medium
2	Deferred or avoided generation capacity investments on peak load plants and spinning reserves.	High	Medium
C. BENEFITS TO CUSTOMERS			
1	Error-free bills and no need for visiting billing centres.	Medium	Low
2	Innovative tariff schemes.	Medium	Medium
3	Faster restoration in case of outages.	High	High
4	Remote control of loads in customer premises.	High	High
5	Ability to remotely manage and control appliances.	Medium	Medium
6	Potential to save money.	Medium	Medium
D. BENEFITS TO SOCIETY			
1	Reduction in carbon footprint owing to avoided travel by utility personnel for meter reading, disconnection, and reconnection.	Medium	Medium
2	Better customer engagement on energy conservation and demand side management initiatives.	Medium	Medium
3	Enhanced customer satisfaction.	Medium	Medium
4	Energy efficiency and energy conservation.	Medium	Medium

Source: ISGF White Paper on Smart Metering Program in India - A Critical Assessment, August 2023

SMART METERING JOURNEY OF ELECTRIC UTILITIES IN INDIA

In the 1990s, Indian utilities started replacing electromechanical meters with electronic meters. These meters were imported, and each make, and each model had different firmware and as result the data from different sets of meters came in different formats. In 2002, Delhi Vidyut Board (DVB) was unbundled, and three new distribution utilities (DISCOMs) were created in public-private-partnership (PPP) mode. Delhi Government retained 49% ownership, and 51% equity and independent management responsibility were given to the new DISCOMs – Tata Power Delhi Distribution Ltd (TPDDL), BESES Rajdhani Power Ltd (BRPL) and BSES Yamuna Power Ltd (BYPL). These new DISCOMs initiated installation of electronic meters, that were capable of Automatic Meter Reading (AMR) achieved through dialup network or data downloaded with handheld device (HHD). However, the data brought to the DISCOMs servers by AMR and through HHDs had different data formats for the data from different make and models of meters. This created huge problems for the utilities in billing. Central Power Research Institute (CPRI) also sensitized this issue and established a laboratory in 2002 to test the electronic meter's compliance with IEC 62056 standard that defines the data communication protocols – Device Level Messaging Specifications (DLMS) and its Companion Specification for Energy Metering (COSEM) protocol - a global standard for smart energy meter communication, data exchange, and management.

Under APDRP in 2003, the data collection was not successful because of the different data formats adopted by the meter manufacturers. Bureau of Indian Standards (BIS) initiated the work of formulating standards on Data Exchange for Electricity Metering Equipment in 2006; and finally recommended to Ministry of Power (MoP) in April 2008 to adopt IEC 62056 standards for all new programs involving metering. In 2009, when specifications for Restructured Accelerated Power Distribution Reforms Program (R-APDRP) were finalized, MOP adopted IEC 62056 (DLMS/COSEM) as the data format for all electricity meters to be installed under the program. This important step made the Indian meter manufacturers to adopt IEC 62056 as data standard for electricity meters in India. In 2011, BIS adopted DLMS standards as IS 15959. The electronic meter standard was also revised and issued by BIS as IS 13779. With this the output from all electronic meters followed same formats which ensured interoperability. By then smart metering had taken off in a big way in USA and Europe. The prices of smart meters were several hundred dollars which Indian utilities found unaffordable. MOP tasked Central Electricity Authority (CEA) to prepare the specifications of smart meters in 2012. The first version of the smart meter specifications was published in 2013; and was adopted for the 14 smart grid pilot projects allotted to utilities in different states under the R-APDRP. MOP advised CEA and BIS to convert the smart meter specifications into a national standard. Accordingly, BIS with inputs from the industry and other stakeholders, published IS 16444 – 2015 in August 2015; and issued the updated IS 15959 – Part 2 in 2016. These standards laid the essential groundwork for a harmonized, nationwide rollout of smart meters. All DISCOMs were advised to abide by these latest Indian Standards. IS 16444 is applicable to smart meters (Single and Three phase meters) for different types as below:

- Part 1 applies to AC static direct connected watt-hour smart meters (Class 1 and 2)
- Part 2 covers AC static transformer operated watt-hour and VAR-hour smart meters (Class 0.2S, 0.5S, and 1.0S). The standard is crucial for ensuring meters meet the requirements for accuracy, reliability, data security, and communication for integration into smart grids

IS 16444 does not specify any standard for communications (as it was felt not prudent to specify any single communication technology for the entire country) and each utility can choose the appropriate communication technologies in their service area.

The 14 smart grid pilot projects allotted to state utilities had smart metering as the main feature. Size of these projects varied from 8,000 to 20,000 customers (except for one project in Himachal Pradesh with 1,800 customers). Out of the 14 projects allotted, only 11 could be completed. Most of them took more than 5 years and delivered only smart metering functionality. ISGF had witnessed the struggles each utility and their vendors were going through with these small size of smart metering projects for years and realized that the capacity of the DISCOMs in India will not improve anytime soon to design a suitable smart metering project, award it through their regular bidding process to a capable contractor, commission the project, take over and maintain it for ten years or more. With this background ISGF published a White Paper titled "Metering as a Service" in September 2016. The paper proposed utilities to engage Metering Services Agencies (MSA) to install smart meters and maintain them for ten years against a monthly fee per meter based on mutually agreed service level agreements (SLAs). No upfront money to be invested by the DISCOMs; and leave the technology selection and implementation methodology to the MSA. ISGF had done extensive modelling studies and

proposed USD 1.00 per meter per month for 120 months for project sizes above 1 million meters. US Dollar was about 69 Indian rupees those days. This business model as well as the prices indicated came under huge criticism by the metering industry. BNEF studied this disruptive report and partnered with ISGF and published a finetuned version of that White Paper in March 2017 as a joint report of ISGF and BNEF. This report also maintained the one dollar per meter per month for 120 months. Towards end of 2017, Energy Efficiency Services Limited (EESL) was mandated by MOP to try out this model for 4 million meters in Uttar Pradesh (UP) and 1 million meters in Haryana. In 2018, EESL signed up with DISCOMs in UP and Haryana and began rollout of smart meters. These contracts were for little over Rs 100 per meter per month. Under this program about 2 million meters were installed (in UP + Haryana) before Covid-19 hit in 2020.

This is the same business model adopted for the ongoing 250 million smart metering program under Revamped Distribution Sector Scheme (RDSS). Out of 250 million, contracts for about 145 million have been awarded, and about 44 million have been installed so far.

250 Million Smart Metering Program under RDSS

India Leading the Global Smart Metering Revolution

India is spearheading a smart metering revolution with the deployment of 250 million smart meters under the Revamped Distribution Sector Scheme (RDSS) launched in 2021. Per latest estimates by CEA there are 320 million consumer meters in India; and this will exceed 350 million by 2030. This landmark initiative represents a strategic shift from the conventional capex model to a forward-looking "Leasing and Services Model" originally mooted by ISGF. RDSS offers a grant form Government of India (GOI) to the tune of 15% of the project cost (subject to a maximum of INR 900 per meter) to the implementing agency. The rest 85% of the project cost (plus financing cost) will be paid by the DISCOMs in 93 monthly instalments per meter based on the SLAs. This model of part Capex (15%) and part OPEX (85%) is called the TOTEX (Total Expenditure) Model, which integrates both capital and operational expenses. For smart metering projects, MOP has appointed REC Ltd and PFC Ltd as nodal agencies; and REC issued a model Standard Bidding Document (SBD) which is applicable all across the country. Since the technical and commercial conditions in the SBD are followed by all DISCOMs in India, the prices of meters and other equipment have come down considerably. REC has also empaneled 65 agencies eligible as Advanced Metering Infrastructure Service Providers (AMISPs) to bid for AMI projects under RDSS. DISCOMs should appoint AMSPs for the AMI projects through competitive bidding. AMISPs manage the complete end-to-end metering program from design and installation to maintenance for 93 months after commissioning. The 145 million meters awarded so far have prices around USD 1 per meter per month (1 USD is presently INR 88) which vindicates ISGF's forecast in 2016. The 250 million smart meter program is not merely an equipment replacement exercise; it is the foundation of a modern, data-driven, and resilient power grid. This transformation will empower consumers, help restore the financial vitality of DISCOMs, and pave the way for a clean and sustainable energy future.

Self-Reliant Indian Ecosystem

India's smart metering program has catalyzed the development of a formidable domestic ecosystem. In a short period, despite the global disruptions caused by the COVID-19 pandemic, the country has successfully cultivated a self-reliant manufacturing and service industry for smart metering.

- **Manufacturing Process:** There are currently 87 BIS-certified smart meter manufacturing units in India, with a cumulative annual production capacity of over 100 million smart meters. This capacity is not static; new companies are entering the market while existing players are augmenting their facilities, ensuring that the availability of meters will not be a constraint for the AMI rollout.
- **Integrated Capabilities:** A robust ecosystem of Original Equipment Manufacturers (OEMs), System Integrators, and AMISPs has emerged. This has been supported by a government policy that bans the import of smart meters from countries sharing a land border with India to preclude Chinese firms and boosting domestic production.

LEAPFROGGING TO AMI 2.0 AND FUTURE POTENTIAL

With nationwide rollout underway, the next step should be framed not simply as adding more applications to AMI, but as evolving AMI into a secure, observable and interoperable digital platform for the distribution grid. AMI 2.0 combines

granular meter data with device lifecycle management, communications telemetry, analytics and integration with operational systems. This allows utilities to identify stressed assets, voltage issues and anomalous consumption; support bidirectional flows from rooftop solar and storage; and create a trusted data layer for demand response, managed EV charging and distribution automation. Where technically and economically justified, the communications infrastructure can also support other utility or municipal endpoints. The value therefore shifts from “reading meters remotely” to continuously sensing, analyzing and acting across the low-voltage network.

AMI 2.0 networks can serve as a communication canopy for a multitude of smart grid and smart city applications as listed below:

- **Advanced Analytics:** The time stamped electricity consumption data captured from smart meters can be analyzed in real time using AI and ML tools to identify overloaded/stressed assets, replace transformers with higher capacity, correct phase imbalance issues, detect meter tampering, thefts and unmetered loads.
- Edge Intelligence and Event Prioritization: As meter populations scale, not every event needs to be transported and processed identically. Local filtering, event prioritization and edge analytics can reduce unnecessary traffic, improve response times for critical events and make communications resources more efficient, while preserving central governance and auditability. Digital Network Model and Low-Voltage Visibility: Combining AMI data with GIS, transformer/feeder topology and operational data can create a continuously improving digital representation of the low-voltage network. This supports phase identification, transformer-to-consumer mapping, voltage optimization, outage localization and more targeted capital planning.
- **Enhanced Grid Management:** The AMI network can support other intelligent devices on the distribution grid, such as reclosers, automated switches, line sensors, smart inverters and fault passage indicators. The voltage sensing capabilities of smart meters also provide operators with an unprecedented level of real-time visibility into grid health.
- **Transformer Monitoring:** The AMI system can be leveraged to implement transformer monitoring systems and get the near-real-time data of transformer performance to the DISCOM control room. The alerts of over voltage/temperature could trigger advance action before the transformer burnouts.
- **Demand Side Management:** AMI 2.0 could include a home automation functionality through wireless communication (ZigBee, Wi-Fi or similar technologies) with smart appliances in the home/building. These radios help enable demand response (DR) programs by creating connections to in-premise displays, smart thermostats and other smart appliances. When paired with time of use (ToU) tariffs, the smart devices may be programmed to react to price signals or curtailments to help manage energy consumption during peak periods.
- **Distributed Generation:** Modern smart meters can record multi-channel data, which is essential for managing bidirectional power flows from distributed energy resources like rooftop solar and for integrating battery energy storage systems.
- **Smart EV Charging:** AMI system could support smart charging of EVs which can control the power flow to the chargers during peak-hours.
- **Smart City Integration:** The AMI communication infrastructure can be leveraged to support a host of smart city applications, including smart street lighting controls, water and gas metering, smart parking systems, asset tracking, and environmental sensor monitoring, creating additional revenue streams and societal benefits.

BRAZIL: FROM SMART-GRID PILOTS TO MARKET, REGULATORY AND OPERATIONAL SCALE

Brazil has reached an inflection point in power-sector modernization. Several transformations are converging at the same time: renewal of distribution concessions with stronger performance and resilience requirements; planned opening of the low-voltage retail market; increasing digitalization and use of AMI; rapid growth of distributed and variable renewable generation; and the need to value flexibility as an operational resource. In this environment, smart grids are moving beyond a standalone technology agenda and becoming infrastructure that connects market reform, resilience, digitalization and consumer participation.

A highly renewable system with a more complex operating challenge

Brazil starts from a power system with a strong presence of hydro, wind, solar and bioenergy. This is a structural advantage for decarbonization, but accelerated expansion of variable renewables and distributed generation is increasing the complexity of planning and real-time operation. Curtailment, reverse power flows, local over-generation and voltage management are therefore becoming increasingly relevant. The challenge is no longer only to add renewable capacity, but to integrate it intelligently and economically through visibility, coordination, storage, demand response and active network management.

Renewed distribution concessions: performance, resilience and digital capabilities

The new distribution-concession cycle raises expectations for measurable service quality, continuity and resilience. Automation, telecommunications, asset management and digital operating capabilities become increasingly important to achieving outcomes perceived by consumers. This shifts the regulatory and investment discussion from the amount of CAPEX alone toward measurable performance, reliability and service quality.

Opening the low-voltage market: data and metering become critical

Brazil is preparing to extend retail-market opening from larger users toward mass-market consumers, with the current reform agenda indicating November 2027 for low-voltage commercial and industrial consumers and November 2028 for the remaining low-voltage market. Competition for customer relationships introduces new suppliers and digital agents and makes metering, data governance, billing processes and consumer protection central components of market architecture. Distribution companies consequently assume a broader systemic role: maintaining a neutral, reliable and increasing digital network platform while multiple agents interact with consumers and distributed resources.

Regulation is moving from principles to implementation

Recent regulatory consultations illustrate this transition from broad reform principles to detailed market rules, incentives and operating requirements. The 2026 agenda discussed in Brazil includes MME Public Consultations 227, 228 and 229 and ANEEL Public Consultation 33/2026. Together, they address economic regulation of commercialization, the architecture of a more open retail market, capacity and flexibility signals, and the connection and coordination of distributed energy resources.

MME CP 227 addresses the regulatory and inspection framework applicable to electricity traders, including the basis and procedures associated with the inspection fee.

MME CP 228 addresses a broad package for market architecture, including commercialization rules, AMI, settlement, storage, Supplier of Last Resort/default-supplier arrangements, migration between regulated and free markets and transition issues.

MME CP 229 introduces a stronger economic signal for system-critical periods, increasing the relevance of demand response, batteries, managed charging and other forms of flexibility.

ANEEL CP 33/2026 revisits connection and operation requirements for distributed generation, storage, electric vehicles, microgrids and controllable loads, with greater emphasis on observability, operability, controllability, interoperability, communications, protection and power quality.

Taken together, these initiatives point toward a new reference scenario in which energy, capacity, flexibility, data and coordination are increasingly interdependent. They also create a direct link between regulatory reform and the need for digital distribution infrastructure.

AMI and digitalization as enabling infrastructure

In Brazil, AMI is increasingly relevant not only for remote meter reading but also as a platform for new services, tariffs, granular data and automation. The key challenge is therefore not simply installing smart meters. It is building the surrounding operating platform: telecommunications, data governance, cybersecurity, integration with enterprise and operational systems, analytics and new utility processes. The target architecture increasingly combines AMI, sensors and telecom with ADMS/DERMS, automation, AI and OT/IT integration to make the grid observable, connected, controllable and cybersecure in near real time.

Smart tariffs, flexibility and active consumers

Tariff design is also evolving as a tool for aligning consumer behaviour with system needs. Time-of-use structures and more sophisticated hourly, capacity and dynamic signals can create economic value for load shifting, storage, electric vehicles and controllable demand. In parallel, flexibility is emerging as a system resource: storage, demand response, EVs, distributed energy resources and virtual power plants can help balance a renewable system and defer inefficient network expansion. Regulatory sandboxes provide a pathway to test these solutions before broader adoption.

From radial network operator to orchestrator of distributed resources

The distribution operating model is consequently changing. A network designed primarily for one-way energy delivery must evolve toward active management of bidirectional flows and distributed resources. ADMS, DERMS, AI, sensors, telecom, cybersecurity and integrated OT/IT environments provide the technology base for greater observability, coordination and near-real-time control. This evolution also changes the business model: value increasingly comes from services, data, flexibility, coordination and reliability, while investment decisions become more closely linked to outcomes and performance.

Implications for AMI strategy in Brazil

These developments reinforce the central thesis of this white paper. Brazil should avoid treating AMI as an isolated metering procurement. AMI should be designed as part of the future distribution architecture, with clear use cases linked to market opening, consumer services, smart tariffs, outage and asset management, DER coordination, flexibility and resilience. This makes interoperability, scalable communications, cybersecurity, data governance and integration with ADMS/DERMS strategic requirements rather than optional enhancements.

The Brazilian case also broadens the India-Latin America comparison. India contributes the experience of very large-scale AMI deployment and service-based commercial models; Brazil contributes a market in which AMI is becoming intertwined with retail competition, high penetration of renewables and distributed resources, performance-oriented concession regulation, flexibility and the evolution of the distribution company into a digital platform operator. The two experiences are therefore complementary and provide a useful basis for South-South cooperation on next-generation distribution systems.

LATIN AMERICA AND THE CARIBBEAN: ADAPT, DO NOT SIMPLY COPY

- Latin America and the Caribbean should not be treated as a single homogeneous AMI market. Utility structures, regulation, loss levels, telecom coverage, geography, tariff design and distributed-energy penetration vary substantially across countries and even within service territories. The Brazilian experience discussed in this paper illustrates how AMI can become intertwined with market opening, resilience, smart tariffs, DER coordination and active distribution operation; other countries will combine these drivers differently. The transferable lesson from India is therefore not a particular radio technology or contract template, but a set of principles: establish the use cases and measurable outcomes first; conduct whole-life cost-benefit analysis; standardize interfaces and security requirements; preserve technology neutrality; align payment with verified service levels; and build customer engagement and institutional capability from the beginning. Conversely, Latin American experience can contribute to the international AMI debate through its growing exposure to distributed generation, variable renewables, resilience requirements and evolving retail-market structures. The objective should be mutual learning and country-specific roadmaps, not replication of a single regional model. Future editions of this joint paper can deepen this comparative approach with additional cases from Mexico, Colombia, Chile, Costa Rica and other participating markets.

BUSINESS MODELS FOR SCALING AMI IN INDIA

India's experience demonstrates that the commercial model is as important as the technology for successful AMI deployment. The earlier small-scale smart-grid pilots faced difficulties because utilities had to design, procure, implement and subsequently operate the systems themselves. This experience led ISGF to propose the **Metering-as-a-Service model**, under which a service provider finances, deploys, operates and maintains smart meters against a monthly fee linked to defined SLAs. The model was subsequently demonstrated by EESL in Uttar Pradesh and Haryana and became the basis for the service-oriented AMI model adopted under RDSS.

The following business models can be considered for India and, with suitable adaptation, for Latin American utilities:

Table 4: Summary of Business Models for Scaling AMI in India

Sl No	Business Model	How it Works	Revenue / Payment Mechanism	Suitability
1	Metering-as-a-Service (MaaS)	AMISP finances, installs, operates and maintains smart meters and AMI infrastructure	Fixed monthly payment per meter linked to SLAs/KPIs	Proven in India
2	TOTEX / Leasing Model	Combination of limited upfront support and long-term service payments	Monthly per-meter payment over the contract period	Proven at national scale under RDSS
3	Performance-Based AMI Model	Service provider's remuneration is partly linked to measurable outcomes such as loss reduction, billing efficiency and revenue improvement	Base fee + performance incentive	Suitable for **high-loss DISCOMs**
4	AMI-as-a-Platform / SMOC-as-a-Service	Shared platform provides AMI monitoring, analytics, asset management, SLA management and customer analytics	Subscription/platform fee paid by utility	Emerging **AMI 2.0 opportunity**
5	Analytics-as-a-Service	AI/ML analyses AMI data for theft detection, transformer loading, power-quality issues, forecasting and revenue protection	Annual subscription or outcome-based fee	High potential
6	Demand Response / Flexibility Model	AMI enables identification and aggregation of flexible loads and participation in demand-response programmes	Shared savings / capacity or performance payments	Future opportunity
7	Smart EV Charging Model	AMI data and communication infrastructure support managed EV charging and peak-load optimization	Charging service fee + flexibility/revenue-sharing	Emerging
8	Multi-Utility Communication Canopy	AMI communication infrastructure is extended to street lighting, water, gas and other smart-city applications	Multiple users share infrastructure/platform costs	Long-term opportunity

Commercial-model implications for India and Latin America:

Illustrative evolution of commercial models: **Traditional CAPEX → Metering-as-a-Service / TOTEX → performance-linked services → AMI platform and analytics services → AMI 2.0 multi-service capabilities.** This should not be read as a mandatory sequence: the appropriate model depends on utility creditworthiness, regulatory treatment, market maturity, risk allocation and the ability to measure outcomes.

The **MaaS/TOTEX model should be presented as the most proven Indian model**, while performance-based contracts, SMOC-as-a-Service, analytics services, demand response, smart EV charging and multi-utility infrastructure sharing should be presented as **next-generation opportunities**. This distinction is important because the white paper currently

establishes strong evidence for MaaS/TOTEX, whereas the latter models are opportunities enabled by AMI 2.0 rather than already demonstrated at comparable national scale in the document.

CHALLENGES AND WAY FORWARD FOR SUCCESSFUL AMI ROLLOUT

States like UP, Haryana, MP and Assam implemented smart metering projects before launch of RDSS which were fairly successful. Under the RDSS, Assam and Bihar were the first states to commence large smart metering projects. Utilities in all these states have reported improvements in billing accuracy, better visibility into consumption patterns, and enhanced detection of meter tampering and theft. The introduction of prepaid meters has given consumers more flexibility while also ensuring that DISCOMs secure payments in advance. Yet, the rollout has not been without hurdles. In some regions, installation has been hampered by supply chain delays and poor meter testing results.

Technical challenges persist, particularly in rural and remote areas where reliable communication networks are harder to establish. Data management is another major issue - the sheer volume of information generated by millions of meters requires sophisticated storage, validation, and analytics tools which are missing in DISCOMs. Cyber security is an ever-present concern, given that each connected device is a potential entry gate for malicious activities. Equally significant are institutional challenges. Many DISCOMs lack the trained manpower and organizational structures needed to implement and operate AMI effectively. The frequent changes in utility leadership adversely affect continuity. Consumer acceptance has also emerged as a decisive factor. In some states, public protests against smart meter installations have forced utilities to slowdown or modify their rollouts.

It is sad to note that DISCOMs in South India (except Andhra Pradesh) are going very slow on smart metering program. Karnataka and Telangana have not initiated smart metering at all while Kerala is pursuing a pilot project with 200,000 meters. In Tamil Nadu the tendering process for about 30 million meters is lingering for several years. Andhra Pradesh has awarded contracts for all 5.7 million meters and installed about 1.8 million by August 2025. Government of India needs to take up this matter seriously with respective state governments in South India to accelerate their smart metering and digitalization journey.

Common Challenges of DISCOMs and AMISPs

Although 65 AMISPs have been empaneled for smart metering projects under RDSS, there are only about a dozen AMISPs are actively involved in the rollout so far. Most of these AMISPs are facing challenges with respect to approvals and payments from DISCOMs. Following are some of the common challenges expressed by AMISPs:

- The absence of a well-structured customer awareness campaign at national and state levels has limited the public awareness and acceptance of smart meters, despite smart meters' role in improving efficiency, reducing losses, and supporting renewable energy integration. There is policy ambiguity regarding AMISPs' role in customer engagement. While the RFP assign this responsibility to AMISPs, their limited influence compared to DISCOMs, and governments has led to communication gaps. Customer engagement should ideally start right from the beginning of the AMI project (to avoid pitfalls) which is not happening yet in India. In many countries AMI rollouts were suspended mid-way and engaged in long consultations with customer groups for their buy-in. In USA, 15 states had to include OPT-OUT options in their AMI programs because of customer objections.
- Inordinate delays in achieving Site Acceptance Test (SAT) milestone remain a serious concern for AMISPs and their ecosystem partners. Delays in achieving the SAT, extending from 7 to 13 months, have disrupted revenue flow, strained AMISPs financially, and weakened lender confidence. Deviations from the recommended installation strategy, legacy billing issues, and communication gaps have further slowed progress. Streamlined SAT timelines, and clear accountability frameworks are crucial for the program's success.
- Although MOP prescribed Direct Debit Facility (DDF) with First Right to DDF in the SBD for AMI projects, this has not been operationalized in any of the DISCOMs so far. All AMI projects are funded by investors because of this payment guarantee assured by MOP through the DDF. Otherwise AMISPs would not have been able to raise debt financing for these large AMI projects owing to the very poor credit ratings of DISCOMs. However, non-compliance of this clause is adversely affecting Investor confidence in the entire program.

- Absence of skilled manpower in DISCOMs who understands (a) Telecommunications, Metering and IT; and (b) Basic knowledge of System Integration, Site Acceptance Test (SAT) and User Acceptance Test (UAT) are adversely affecting the progress of the rollouts.
- Training programs and dedicated teams are missing in many DISCOMs
- Several DISCOMs do not have one single utility-wide Billing System which is a pre-requisite for successful AMI deployment
- Customer indexing on GIS maps is not being updated in most DISCOMs
- The integration of AMI system with outdated billing systems in some of the DISCOMs is creating significant challenges. The scope of the smart metering program is to transfer data from meters to the Meter Data Management System (MDMS) and integrate the MDMS with the Billing System and other utility applications; but not to overhaul existing billing systems. With each meter generating around 100+ data sets daily, legacy billing systems struggle to handle this volume efficiently, causing delays in the project. In such DISCOMs the billing systems may be replaced ASAP.
- The transition from postpaid to prepaid metering has created confusion, particularly in managing subsidies. A phased approach, starting with postpaid metering and gradually shifting to prepaid, has been suggested to mitigate this issue.
- While utilities possess significant expertise in power supply management, their IT capabilities have often lagged behind. This has presented a major hurdle in adopting smart metering systems, particularly when handling large volumes of data and integrating new technologies. The lack of sufficient IT personnel and expertise is contributing to delays and operational issues. Utilities need to prioritize IT capacity building to support the data-intensive nature of smart meter infrastructure effectively.
- Integrating smart meters with existing IT systems has emerged as a persistent challenge. Utilities reported frequent issues such as bidirectional meter errors, negative meter readings, and inflated billing values. Addressing these integration gaps through improved testing, data validation, and streamlined system architecture is crucial for ensuring the smooth operation of AMI systems.

In November 2023, ISGF issued a White Paper "**Smart Metering Program in India - A Critical Assessment**" which highlighted the major issues impacting the 250 million smart metering programs; and suggested several remedial measures. Only few states adopted some of those recommendations.

ISGF reiterates the following important issues that DISCOMs should consider for the success of the ongoing AMI projects:

- Life of the smart meters may be mandated to be 10 years or more (in Europe it is 15 to 20 years); and this reduces the tariff impact on customers.
- One DISCOM should have **ONLY ONE BILLING SYSTEM and ONE MDM** - there can be many makers of Meters and Head-Ends Systems (HES) in a utility, but MDM and Billing System should be only one each for ideal results. AMI will not yield true benefits in states with home-grown billing systems which cannot be integrated with any standard MDM – several DISCOMs have homegrown billing systems.
- MDM, BILLING SYSTEM and ERP should be COTS Applications for which trained personnel are easily available in the market
- Selection of Communication Technology may be left to the AMISP who should be contractually committed to the SLAs; DISCOMs should specify SLAs and Quality of Service (QoS) including Cyber Security
- Communication technology should not be prescribed solely by geography or technology label. Cellular, RF mesh, PLC and hybrid architectures can each deliver strong AMI outcomes when properly engineered. Utilities should define end-to-end SLA and QoS requirements—including scheduled and on-demand read success, command success, latency, outage recovery, cybersecurity, upgradeability and lifecycle support—while allowing the AMISP to select and optimize the communications mix. In heterogeneous territories, hybrid RF-mesh/cellular or other multi-bearer approaches may improve coverage, resilience and total lifecycle economics.
- AMI workloads may be hosted in appropriately secured public cloud, private cloud or utility data-center environments, subject to applicable regulation, data-residency requirements, risk assessment and business-continuity objectives. Cloud deployment can reduce hardware obsolescence risk and improve scalability, but it

does not by itself reduce cyber risk; security depends on architecture, identity and access management, configuration, monitoring, incident response and shared-responsibility controls.

- Smart Meter Operation Center (SMOC) should be part of the AMI system
- Explore the use of AI and ML tools for optimized energy management leveraging the time-stamped consumption data from smart meters
- For successful AMI rollout and customer's participation in leveraging the full benefits of the AMI systems, it is essential to have customer engagement by DISCOMs in the program right from the beginning with a proper awareness campaign and periodical surveys.
- For robust smart-grid security, utilities should establish a verifiable chain of trust from device identity through firmware and communications to backend applications. A hardware root of trust can strengthen this architecture by supporting secure boot, protected key storage, device authentication and signed firmware validation. It should be combined with certificate/key lifecycle management, least-privilege access, encryption in transit and at rest, vulnerability management, software/firmware provenance and monitored incident response. Security should be treated as a lifecycle discipline rather than a single device feature.

Ultimately, AMI is not just about smarter meters; it is about creating a smarter distribution system. It can become the digital backbone of a power system that is more observable, flexible, resilient and consumer-centric. India's experience shows the opportunities and difficulties of deploying AMI at very large scale: standardisation, service-based implementation, institutional capacity, interoperability, customer engagement and disciplined programme governance all matter as much as the meter itself. Brazil's current transition highlights a complementary dimension: granular data and two-way communications are increasingly linked to retail competition, smart tariffs, DER integration, flexibility, resilience and active network operation. Across both contexts, the integration of distributed generation, electric vehicles, demand response and storage will depend on secure data, reliable communications and increasingly coordinated grid operation. The path forward requires sustained investment in people and processes, regulatory oversight that protects consumers and rewards performance, and architectures that can evolve as technologies and market roles change. AMI should therefore be understood not as a single technology project, but as a long-lived digital capability whose value depends on how effectively it is integrated into the wider electricity system.

INDIA–BRAZIL: COMPLEMENTARY LESSONS FOR AMI 2.0

INDIA — DEPLOYMENT AT SCALE **Standardisation • MaaS / TOTEX • SLA-based deployment**	**BRAZIL — SYSTEM TRANSFORMATION** **Market reform • DER and flexibility • Active networks • Digital DSO**
NEXT-GENERATION AMI **Interoperable • Technology-neutral • Cybersecure • Data-driven • Multi-bearer • Consumer-centric**	**THE SHARED TRANSITION** **From metering infrastructure to a secure digital operating platform**
AMI 1.0: METER → READ → BILL ↓ AMI 2.0: SENSE → COMMUNICATE → ANALYSE → DECIDE → ACT	

CONCLUSION

Advanced Metering Infrastructure (AMI) is emerging as a foundational component of electricity distribution, moving utilities beyond conventional meter reading toward a data-driven, flexible and consumer-centric grid. The joint India-Latin America perspective developed in this paper shows that AMI creates value through two mutually reinforcing dimensions: deployment at scale and integration into a changing electricity-system architecture. India's experience demonstrates how standardization, service-based implementation and large-scale programme governance can accelerate deployment, while also revealing the importance of timely approvals, efficient acceptance processes, utility capabilities, customer engagement and clear accountability. Brazil's current transition shows how AMI can become integral to market opening, new consumer relationships, smart tariffs, resilience, DER coordination and increasingly active distribution-system operation.

Across both contexts, the central lesson is that AMI should be designed as an integrated ecosystem rather than a meter-replacement programme. Interoperability, scalable architecture, outcome-based communications, unified data governance, integration with IT/OT systems, business continuity and cybersecurity should be embedded from the outset. Communications procurement should be technology-neutral and SLA-driven, allowing cellular, RF mesh, PLC and hybrid designs to be optimized for local conditions. Commercial models should likewise be selected according to regulatory treatment, utility capability, risk allocation, lifecycle economics and the ability to verify outcomes. India's Maas/TOTEX experience provides an important reference for service-based deployment, but it should be adapted rather than replicated mechanically in other markets.

The strategic opportunity now is to move from AMI as billing infrastructure to AMI as a secure digital operating platform for distribution. AMI 2.0 can support advanced analytics, device lifecycle management, low-voltage grid visibility, transformer monitoring, demand response, distributed generation, storage, managed EV charging and selected multi-utility applications. In architectural terms, AMI 2.0 should be bearer-agnostic at the application layer and capable of intelligently using multiple communications bearers where this improves performance, resilience or lifecycle economics. Utilities should procure measurable outcomes rather than a preferred radio technology. India and Latin America bring different strengths to this transition: India offers the experience of extraordinary deployment scale and an expanding implementation ecosystem; Brazil and the wider region offer increasingly relevant experience with renewable integration, distributed resources, market reform, resilience and new distribution roles. The most useful path is therefore reciprocal learning, not one-way technology transfer. Architecture, regulation and business models must remain market-specific, while common principles - interoperability, measurable performance, cybersecurity, consumer protection, data governance and future-ready integration - provide the foundation for cooperation. In this sense, AMI is not the destination. It is a critical enabling layer for the next generation of intelligent, resilient and flexible power systems.

APPENDIX: Smart Meter Operations Centre (SMOC)

For large scale AMI rollouts, it is essential to have a Smart Meter Operations Centre (SMOC) that can manage meter rollouts, data collection, data integration, data provisioning and also data analytics. SMOC typically is responsible for:

- Centralized Project Management
- Platform for Business Intelligence
- AMI Events Management
- Enterprise Asset Management and Monitoring
- Consumer and Consumption Analytics
- AMI ROI Matrix Tracking (eg: revenue protection, load planning etc)
- Consumer Engagement Modelling
- SLA Management
- Service Ticket Management for Helpdesk
- Training Simulator

SMOC Analytics integrated with Customer Portal could provide real time visibility to customers on:

- Customer Billing and Energy Profile Information
- Prepayment Information
- Customer Centric Analytics
- Alerts on Account Information Updates
- Home Energy Profiles
- Customer Self Service
- Cost Saving Tips
- Customized Communication, Utility-branding, Customer Service and Feedback

By integrating SMOC Analytics with consumer portals, utilities can provide real-time billing information, personalized energy usage insights, and even cost-saving tips. This not only improves customer satisfaction but also builds the trust needed for large-scale rollouts. The financial model for AMI implementation also needs careful design. India has

adopted a total expenditure (TOTEX) model under its RDSS program, where service providers install, operate, and maintain the AMI systems for a decade, while utilities pay a per-meter monthly fee. This approach reduces upfront costs for utilities but requires rigorous monitoring to ensure that contracted service levels are met.

SMOC is now becoming an integral part of AMI 2.0. There are limited use cases of successful SMOCs as of now. There are no standards or globally accepted design and architecture of SMOCs. SMOC architecture is bespoken in most utilities based on their existing IT and OT systems.

A typical SMOC solution architecture is given at the diagram below.

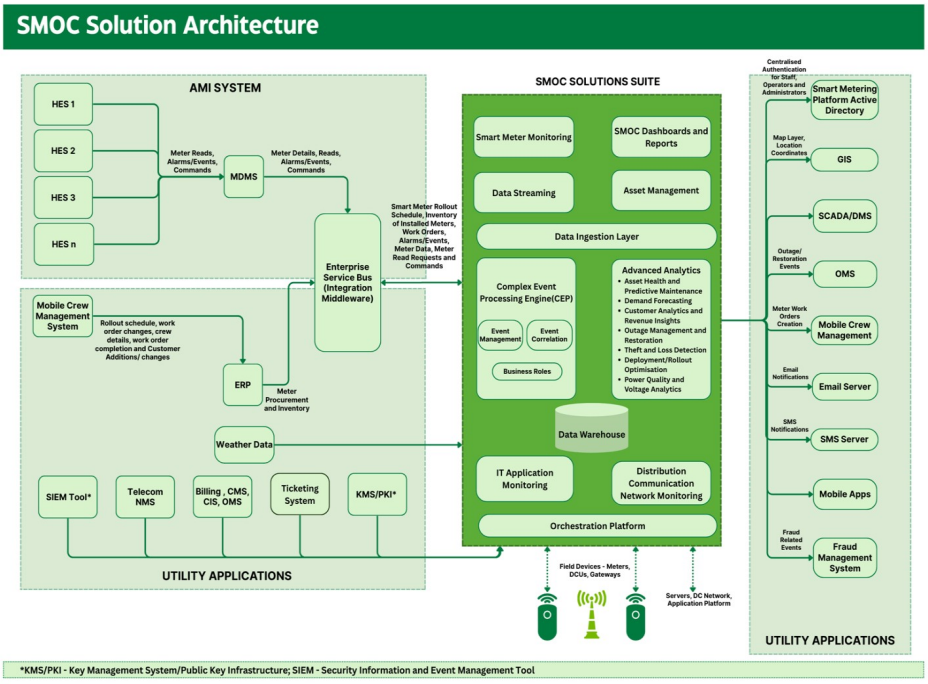


Figure 5: SMOC Solution Architecture

Typically, the outputs of the SMOCs are in dashboards style. It may be designed and built as dashboards that can be downloaded or saved as PDF, CSV or other file formats. The SMOC can be divided into 3 modules: Pre-Deployment Module, Deployment/O&M Module and Advanced Analytics Module. The functionalities in each of these modules are described below.

A. Pre-Deployment Module focusses on activities prior to field deployment such as:

- Appointment planning with customers for field installation (meters/gateways/data concentrators etc)
- Inventory and procurement management
- Field resource planning
- Telecom network assessment
- Civil work management

B. Deployment / O&M Module focuses on performance of day-to-day operations such as:

- Field deployment (actual versus planned versus ramp up)

- Meters installed versus commissioned versus reads collected (and break up of gaps / issues)
- Remote connection and disconnection statuses
- Events and alarm management
- Ticket management
- Release management - Device Firmware Upgrade, Device Configuration Upgrade and Application Software Upgrade
- Service Level Agreements (SLA) / Key Performance Indicator (KPI) including customer complaints
- Cyber security incidents management

C. Advanced Analytics Module focusses on analytics aspects for assisting the utility in taking informed decisions regarding losses, revenue management such as:

- AT&C loss reduction, for example, using complex event processing such as alarms and consumption co-relation
- Low power factor analysis providing revenue loss (such as <0.9) or revenue gain (such as >0.9) insights and provide inputs to SCADA/DMS team for corrective actions
- Low voltage detection for inputs to SCADA/DMS teams for correction
- Outage analytics using last gasp and first-breath notifications to OMS to understand the location and extent of the outage
- Distribution Transformer and Low Voltage Feeder loading analytics to prevent overloading in advance
- Detection of maximum demand violations by consumers
- Consumer analytics include abnormally low consumption, high bill alerts, low bill alerts etc.
- Device asset analytics including meters, gateways/data concentrators, distribution transformers etc
- Value added services for revenue enhancement including load disaggregation, energy saving tips via load profile analysis, consumer peer comparison, bill projection etc
- Revenue protection including potential payment defaulters, revenue forecasting in coming months using AMI consumption data etc
- Revenue analysis including revenue collection and arrear collection and trend analysis, maximum demand penalty collection etc
- Cost benefit analysis and cashflow analysis
- Utility / Department / Team level KPIs - Weekly, Monthly, Quarterly, Yearly etc

SMOC can support the utility to manage demand response (DR) programs. Since SMOC already has the granular consumption data, it could identify consumers with interruptible loads for participation in DR programs and schedule ideal time slots for DR events. While designing the SMOC, this aspect may be considered.