

An initiative supported by



Enable an Electric Utility to Leverage
Advanced Metering Infrastructure (AMI)
Roll-Out to Reduce
**Aggregate Technical & Commercial
(AT&C) Losses**



Submitted by



Submitted to





P Rajendra Cholan, IAS
Managing Director

Message from MD BESCOM

I am pleased to note that India Smart Grid Forum (ISGF) supported by Shakti Sustainable Energy Foundation (SSEF) has completed a detailed study on Enable an Electric Utility to Leverage Advanced Metering Infrastructure (AMI) Rollout to Reduce Aggregate Technical & Commercial (AT&C) Losses.

Bangalore Electric Supply Company Limited (BESCOM) is one amongst the progressive electricity distribution companies in India and always has been a front-runner in implementing new technologies. BESCOM distributes electricity to over 12 million customers in Bengaluru City and adjacent districts of Kolar, Tumakur, Ramanagara, Chikkaballapur, Chitradurga and Davanagere covering an area of 41,092 sq km. BESCOM has taken initiatives to ensure that all Bengaluru households get smart meters by March 2025. BESCOM is the State Nodal Agency for setting up EV charging infrastructure in Karnataka.

BESCOM has implemented pre-paid meters using keypad technology along with the vending system for temporary installations in BESCOM (other than Indiranagar Divisions) on Design Build Finance Operate and Transfer (DBFOT) basis for 5 years for a total quantity of 80,000. BESCOM has submitted the proposal to install 8.234 million smart meters through Revamped Distribution Sector Scheme including consumer as well as system meter.

I congratulate ISGF for this work and wish them success in their future endeavours.


P Rajendra Cholan, IAS
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India has embarked on an ambitious journey to install smart meters for 250 million+ electricity customers nationwide in next 4-5 years, out of which about 100 million are targeted to be completed by end of 2023. The availability of smart meters domestically is not considered to be a major challenge; however, the procurement of the best suited smart metering system is a challenge that needs to be tackled.

Metering is a key component of several government programmes in distribution companies (DISCOMs) including the Smart Metering National Programme (SMNP), the Ujwal Discom Assurance Yojana (UDAY), the Integrated Power Development Scheme (IPDS) and the National Smart Grid Mission (NSGM). These schemes are actively promoting smart metering to improve the billing and collection efficiency of discoms. This study entitled “Enable an Electric Utility to Leverage Advanced Metering Infrastructure (AMI) Rollout to Reduce Aggregate Technical & Commercial (AT&C) Losses” by the India Smart Grid Forum with support from Shakti Sustainable Energy Foundation will provide DISCOMs and other stakeholders with a roadmap to aid the smooth rollout of smart meters.

Shakti Sustainable Energy Foundation is engaging with DISCOMs and policymakers at the national and state level to create enabling policies mandates for accelerating Advanced Metering Infrastructure (AMI) in India. A key interest area is to develop interventions and business models for DISCOMs to implement smart metering within their jurisdictions. We are pleased to know that the technical support provided to the Bangalore Electricity Supply Company Limited (BESCOM) via the India Smart Grid Forum (ISGF) under a Shakti-funded initiative has contributed to the AMI rollout to reduce AT&C losses.

We anticipate that this work will set a precedence for distribution utilities across the country to plan for the AMI rollout.

Dr. Anshu Bharadwaj

Chief Executive Officer, Shakti Sustainable Energy Foundation



Preface



Reji Kumar Pillai

President – India Smart Grid Forum

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High levels of aggregate technical and commercial (AT&C) losses, increased energy theft, poor customer service and operational transparency, inefficient load management, and intermittent power supply are all challenges faced by electricity distribution companies in India. A series of schemes was launched by Government of India (GoI), to upgrade the distribution infrastructure and help the discoms improve their efficiency and revenues. Under the latest program the Revamped Distribution Sector Scheme (RDSS) launched by Government of India in July, 2021, provisions have been made to install 250 million smart meters across the country by March, 2025. Advanced Metering Infrastructure (AMI) or smart metering system eliminate the need for physical meter reading by the utility's personnel visiting the customer premises which most customers would detest in the post pandemic scenario. The implementation of smart meters technology in India gives discoms the ability to gather real-time information on the demand for residential electricity and make informed decisions to handle it.

ISGF with support from Shakti Sustainable Energy Foundation embarked on the project “Enable an Electric Utility to Leverage Advanced Metering Infrastructure (AMI) Rollout to Reduce Aggregate Technical and Commercial Losses (AT&C)”, a first of its kind study with Bangalore Electricity Supply Company (BESCOM). This study examined the AMI hardware/software technologies and various communication infrastructures, system integrations and Smart Meter Operations Centre (SMOC) which provides dashboards and reports to facilitate the communication and data exchange between two or more entities to ensure successful rollout of AMI. As part of this project ISGF evaluated the current business models of different stakeholders across India. This study also recommends the way forward for BESCOM, taking into account the various technology selection guidelines, system integration framework, customer engagement strategies and outreach mechanisms required for successful implementation of AMI.

Although the report is for BESCOM, the Smart Meter Operations Centre (SMOC) and other recommendations are relevant for other DISCOMs in Karnataka and other states as well. We hope this report will accelerate the AMI rollout in the country.

Reji Kumar Pillai



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implementation of policies in the following areas: clean power, energy efficiency, sustainable urban transport, climate change mitigation, and clean energy finance. We wish to thank Dr. Anshu Bharadwaj, CEO; Mr. Manu Maudgal, Director - Clean Power Programme and Siddharth Arora, Associate Director (Clean Power) for providing all the necessary guidance and support for this project.

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We would like to thank Mr. P. Rajendra Cholan, Managing Director and Mr. CK Sreenath, Deputy General Manager (Smart Grids and Electric Vehicles), Bangalore Electricity Supply Company Limited and the teams for providing all the necessary data required for this project.



Shakti Sustainable Energy Foundation seeks to facilitate India's transition to a sustainable energy future by aiding the design and implementation of policies in the following areas: clean power, energy efficiency, sustainable urban transport, climate change mitigation, and clean energy finance.



India Smart Grid Forum is a Public-Private Partnership initiative of Ministry of Power (MoP), Government of India for accelerated development of smart grid technologies in the Indian power sector. The mandate of ISGF is to advise Government on policies and programs for the promotion of Smart Grids in India, work with national and international agencies in standards development, and help utilities, regulators and the Industry in technology selection, training and capacity building.

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Abbreviations

ADR	Automated Demand Response
AMI	Advanced Metering Infrastructure
AMR	Automatic Meter Reading
AMRUT	Atal Mission for Rejuvenation and Urban Transformation
AT&C	Aggregate Technical & Commercial
BESCOM	Bangalore Electricity Supply Company Limited
BIS	Bureau of Indian Standards
CEA	Central Electricity Authority
CIS	Customer Information System
DAS	Distribution Automation System
DBFOT	Design Build Finance Operate and Transfer
DCU	Data Concentrator Unit
DISCOM	Distribution Company
DMS	Distribution Management System
EAI	Enterprise Application Integration
EESL	Energy Efficiency Services Limited
ETD	Electro Technical Division
FAN	Field Area Network
GIS	Geographical Information System
GoI	Government of India
GoK	Government of Karnataka
GVP	Gram Vidyuth Prathinidhi
HAN	Home Area Network
HES	Head End System
IPDS	Integrated Power Development Scheme
ISGF	India Smart Grid Forum
LAN	Local Area Network
MDAS	Meter Data Acquisition System
MDMS	Meter Data Management System



MoP	Ministry of Power
MWM	Mobile Workforce Management
NAN	Neighbourhood Area Network
NIC	Network Interface Card
NIIF	National Investment and Infrastructure Fund
NSGM	National Smart Grid Mission
NTP	National Tariff Policy
OMS	Outage Management System
RDSS	Revamped Distribution Sector Scheme
RPO	Recovery Point Objective
RTO	Recovery Time Objective
SEB	State Electricity Board
SLA	Service Level Agreement
SMNP	Smart Meter National Programme
SMOC	Smart Meter Operations Center
SOA	Service Oriented Architecture
SSEF	Shakti Sustainable Energy Foundation
ToU	Time of Use
TRM	Total Revenue Management
UDAY	Ujwal Discom Assurance Yojana
WAN	Wide Area Network



Executive Summary

The metering industry has taken rapid strides in the recent years from automated meter reading (AMR) to Advance Metering Infrastructure or smart metering, using bi-directional communication, thereby enabling greater benefits to electricity distribution companies (DISCOMs), customers and society. Advanced Metering Infrastructure (AMI) is an integrated system of smart meters, communication networks, and data management systems that enables utilities to offer new time-based tariff and incentives that encourage customers to reduce peak demand and manage energy consumption and their bills. Government of India (GoI) launched its first smart metering initiatives in 2013 through 11 smart grid pilot projects across India, followed by various programs and initiatives for reform programs such as Integrated Power Development Scheme (IPDS), Ujwal Discom Assurance Yojana (UDAY), National Smart Grid Mission (NSGM) and Smart Meter National Programme (SMNP). GoI has provided funds to the state governments for implementation of smart metering under NSGM and IPDS. As of May 2022, a total of 11.24 million smart meters have been sanctioned under these schemes, of which 4.42 million have been deployed across the various states in India.

To give a further push to reform the distribution sector, GoI announced Revamped Distribution Sector Scheme (RDSS) in July 2021 with an outlay of INR 303,758 crore over a period of five years from FY 2021-22 to FY 2025-26 with the objective to improve the quality, reliability and affordability of power supply to consumers through a financially sustainable and operationally efficient distribution sector. The scheme aims to reduce the AT&C losses across pan India level to 12-15% by 2024-25 by improving the operational efficiencies and financial sustainability of all state owned DISCOMs and Power Departments excluding private sector DISCOMs.

Karnataka is the seventh largest state in India in terms of power generation capacity with a total installed capacity of 30.68 GW, as of May 2022. The state has a high renewable energy potential of about 30 GW. Karnataka is among the few states where installation of prepaid electricity meters at public facilities has started under UDAY. Bangalore Electricity Supply Company Limited (BESCOM) has taken initiatives to ensure that all Bengaluru households get smart meters by March 2025. BESCOM distributes electricity to over 12 million customers in Bengaluru City and adjacent districts of Kolar, Tumakur, Ramanagara, Chikkaballapur, Chitradurga and Davanagere covering an area of 41,092 sq km. BESCOM is owned by the GoK and is one of the advanced DISCOMs in India and has always been a front runner in implementing new technologies. BESCOM is the State Nodal Agency for setting up EV charging infrastructure in Karnataka.

ISGF prepared a detailed Smart Grid Roadmap for BESCOM in 2020. Building on the earlier initiatives ISGF and BESCOM decided to mutually undertake an evaluative study on the AMI Rollout for the DISCOMs. The primary key findings of the study are as follows:

- AMI is more than a strategy to increase the meter-to-cash process; it is also a driver for major changes in DISCOM operations technology
- Large-scale AMI deployments will differ from previous utility-managed investment programmes. To design a technology-enabled management framework for project governance and AMI implementation, they will need to come up with new ideas
- The most common meter-level communication technologies are radio frequency (RF) mesh and cellular, which helps to optimise asset management and reduce AT&C losses
- Usage of innovative tools and techniques facilitates customer more control over their electricity consumption



- Life of the smart meter may be mandated to be minimum 10 years to reduce the tariff impact on customers

Layout of this Report: The report comprises of following chapters:

Chapter 1 lays out the foundation of the study and provides background of AMI, communication technologies, smart metering architectures, benefits and key challenges sophisticated in the AMI rollout. It also elaborates the study scope, objectives and methodology for the study. **Chapter 2** gives the review of AMI projects in India in terms of AMI initiatives, smart grid pilot projects sanctioned under R-APDRP/IPDS. In addition, some case studies – the ongoing and completed AMI projects in India are covered. It also covers the global smart metering standards and standards used in India required for AMI rollout. **Chapter 3** presents the ground work by DISCOMs for AMI and which provides technical and managerial capabilities to implement AMI eco system at DISCOM level. **Chapter 4** describes the existing metering scenario in Karnataka State DISCOMs covering all facets of the metering, billing, collection, energy accounting, AT&C losses, IT/OT systems and communication infrastructure. Karnataka was the India's first state use alternating energy, and to establish a professionally managed power corporation to plan, construct, operate and maintain power generation projects across the state. With this, BESCOM has taken initiatives to ensure that all Bengaluru households get smart metres by March 2025.

Chapter 5 presents the AMI hardware/software technologies and various communication infrastructures, system integrations and Smart Meter Operations Centre (SMOC) which provides dashboards and reports to facilitate the communication and data exchange between two or more entities to ensure successful rollout of AMI. **Chapter 6** evaluates the current business models of EESL and other utilities across India. **Chapter 7** recommends the way forward for DISCOMs, taking into account the various technology selection guidelines, system integration framework, customer engagement strategies and outreach mechanisms required for implementation of AMI. Finally **Chapter 8** gives the advanced analytics for AMI data using tools like Artificial Intelligence (AI) and Machine Learning (ML). It describes about various business cases implemented across utilities.



01 Introduction

1.1 Background

Electricity distribution companies (DISCOMs) are the critical element of the electricity chain, but they are often considered the weakest link. Created as part of electricity reforms beginning in the late 1990s, these were part of the unbundling of the former State Electricity Boards (SEBs), which were the vertically integrated utilities. Most DISCOMs remain 100% state owned, but buy or procure power from a variety of generators comprising state owned, central and private. Electricity DISCOMs in India face the daunting task of meeting the increasing demand for electricity by providing reliable electricity services while at the same time making efforts to recover operational costs and constantly allocating capital to invest in upgrading the electricity infrastructure. Continuously increasing residential demand, which accounts for a fourth of the country's electricity consumption, adds up to the DISCOM challenges. However, DISCOMs lack an appropriate understanding of household level electricity usage trends and their temporal and seasonal variance. The limited information about electricity use from conventional meters at a low frequency (once a month) does not render it suitable for demand analysis.

The main emphasis was on reducing DISCOMs operating losses, calculated by aggregate technical and commercial (AT&C) losses. A number of central government schemes are aimed to get AT&C losses below 15%. Decades of energy policy based on redistribution of social services have culminated not only in productivity but also contradictions with important consequences for the future of DISCOMs. Income from DISCOMs was not matched with their cost structures but held afloat through a blend of subsidies and cross-subsidies. Commercial and Industrial consumers overpaid to partly cover tariffs set well below residential and agricultural prices. The ostensibly independent electricity regulatory commissions routinely depended on a second layer of cross-subsidy in customer groups, with telescopic slabs or graded levels of progressive pricing.

The implementation of smart meters technology in India gives DISCOMs the ability to gather real-time information on the demand for residential electricity and make informed decisions to handle it. Government of India (GoI) launched its first smart metering initiatives in 2012 through 11 smart grid pilot projects across India. DISCOMs who invested in smart meters are reaping rich benefits presently and have ensured business continuity and resiliency.

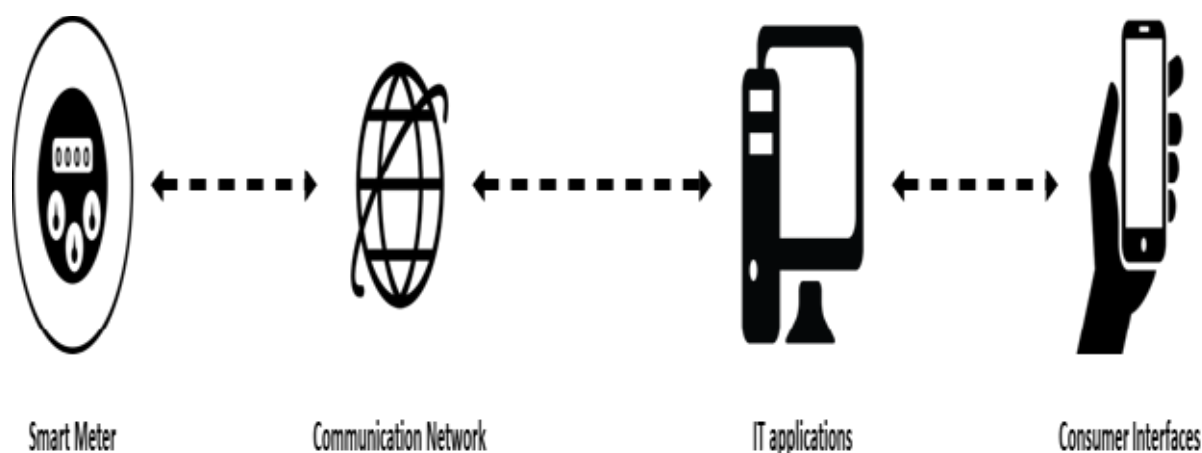


Figure 1-1: Smart meter network

Advanced Metering Infrastructure (AMI) or smart metering system eliminate the need for physical meter reading by the utility's personnel visiting the customer premises which most customers would detest in the present scenario. Ministry of Power (MoP), GoI was planning to install 250 million smart meters across India in next 4-5 years. Smart metering is expected to provide benefits for all stakeholders; however, its technical and business implications need to be articulated for each DISCOM considering the existing systems in order to plan successful rollout and design the IT architecture and system integration to derive maximum benefits to all stakeholders.

1.2 Advanced Metering Infrastructure (AMI)

Electric utility metering has been making gradual progress since 1970s when South Africa introduced prepaid metering system in certain localities where it was difficult to collect money. Later in the 1980s some utilities in USA tried with automatic meter reading (AMR) to read meters installed in hazardous or in-accessible locations. While prepaid meters progressed from keypad operated meters to two-way smart card operated pre-payment system in the 1990s, the AMR technology progressed rapidly from walk-by AMR (standing near a meter and down loading the readings with a hand held unit) to drive by AMR to fixed line AMR. Both these systems (prepaid meters and AMR) are still in use in different geographies to address specific business needs of DISCOMs.



Figure 1-2: AMR and prepaid meters

AMI is a new metering technology started development in early 21st century. The key difference between AMR and AMI is that AMR require only one way communication (meter to utility's computer), AMI require two-way communication between the meter and the utility's computer. With AMI, a meter can be programmed as prepaid or post-paid, the firmware inside the meter can be upgraded; and the meter can be disconnected and connected back remotely. AMI also deploy advanced software solutions such as meter data management system (MDMS) that can facilitate a whole new set of new services for the utility.

AMI comprises of smart meters, Data Concentrator Units (DCUs)/gateways/routers/access points, Head End System (HES), Meter Data Management System (MDMS) communicating over bi-directional Wide Area Network (WAN), Neighbourhood Area Network (NAN)/Field Area Network (FAN) and Home Area Network (HAN). Multiple smart meters can connect to a DCU/gateway/router/access point which in turn send aggregated data to the HES. The smart meter can also directly communicate with the HES using appropriate WAN technologies (for example GPRS sim cards in the smart meters can directly send data to the HES on servers in the control room). The MDMS collects data from the HES and processes it before sharing with billing system and other IT applications. Appliances such as TV, refrigerator, air conditioners, washing machines and water heaters etc. can be part of the HAN. At the heart of AMI, is the smart meter. The key features that make a meter smart are the addition of a communication module capable of two-way Machine to Machine (M2M) communications and a remote connect/disconnect switch.

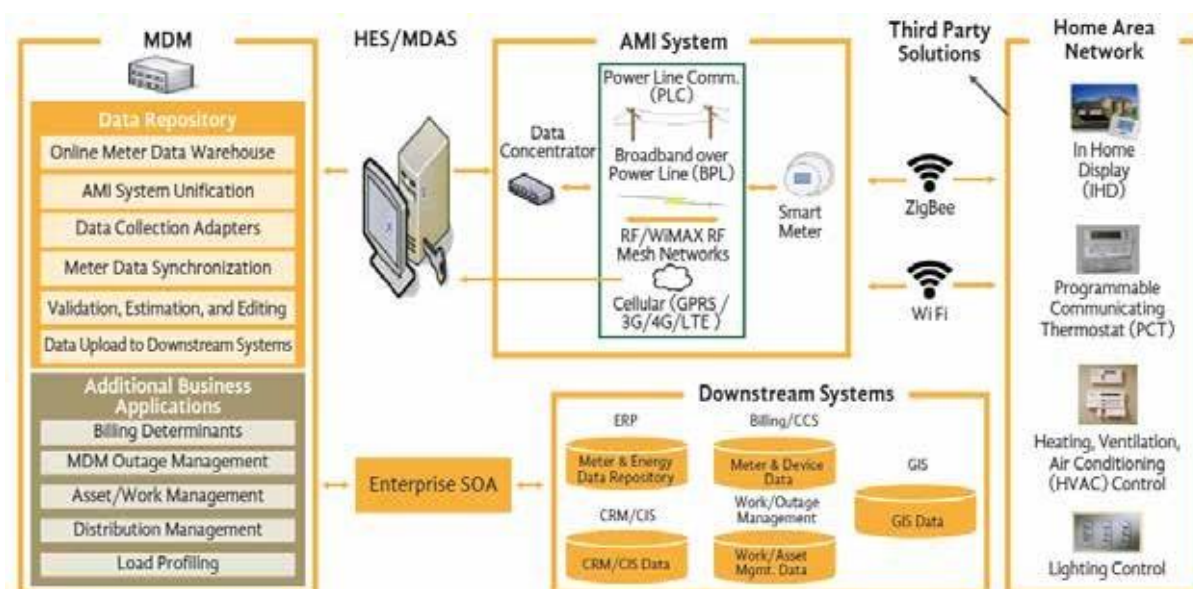


Figure 1-3: Typical architecture of AMI

Source: World Bank

In Home Display (IHD) is a device kept in the customer's premises that could display meter data and get confirmation from the consumer regarding his/her participation in a demand response program. Hence consumers will become informed and conscious. However, with the rise of the smart phone applications or 'apps', customers would not require IHDs at their homes. A smart phone can work as an IHD and hence the DISCOM or consumers need not invest in IHDs.



1.2.1 Communication Technologies for AMI

The below Table depicts some of the available choices for communication technologies for AMI deployment.

Table 1-1: Communication technologies for AMI

Technology/Protocol	Last Mile/NAN/FAN	Home Area Network (HAN)	Backhaul/WAN and Backbone
Wireless	6LoWPAN based RF mesh, ZigBee, Wi-Fi and Millimetre Wave Technology	6LoWPAN based RF mesh, ZigBee, Wi-Fi, Bluetooth, Z-Wave and NFC	Cellular, Satellite, LPWA, Long Wave Radio, TVWS and Private Microwave Radio Links (P2P and P2MP)
Wired	PLC, Ethernet, Serial Interfaces (RS-232, RS-422, RS-485) and DSL	PLC, Ethernet, Serial Interfaces (RS-232, RS-422 and RS-485)	Optical Fiber, Ethernet, PLC and DSL

Source: ISGF

1.2.2 Smart Metering Architectures

In the present scenario of smart metering, DCU aggregators and gateways are key elements. These devices not only decrease the total cost of ownership, but also offer reliable, scalable and interoperable last mile connectivity. Experiences from around the world shows that none of the solutions offer 100% reliable connectivity all the time. The best range often heard is between 95-98%; and in many cases it is well below 90%, some of the popular communication architectures deployed for AMI worldwide are mentioned below.

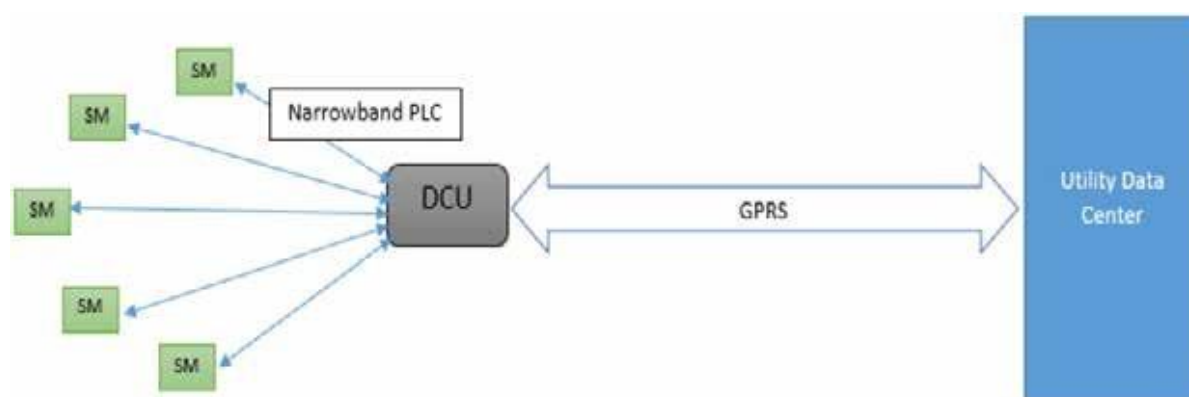


Figure 1-4: AMI architecture deployed by Enel (Italy)

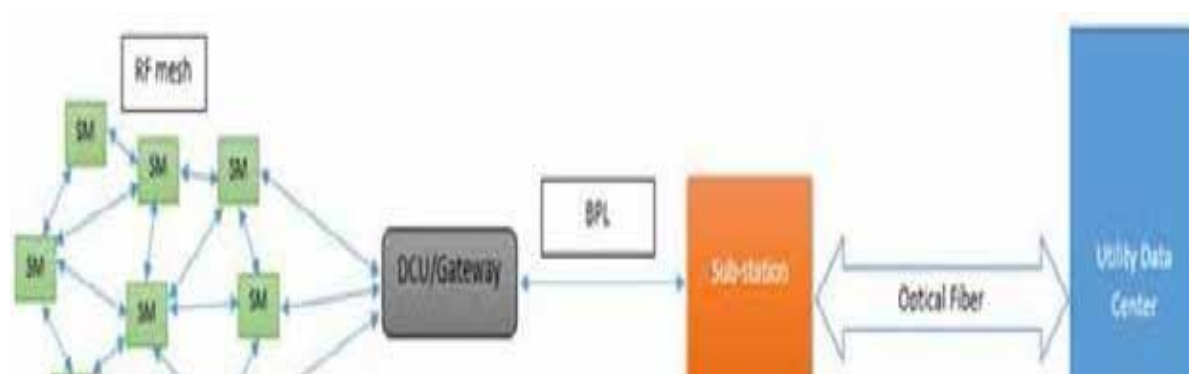


Figure 1-5: AMI architecture deployed by center point energy (USA)

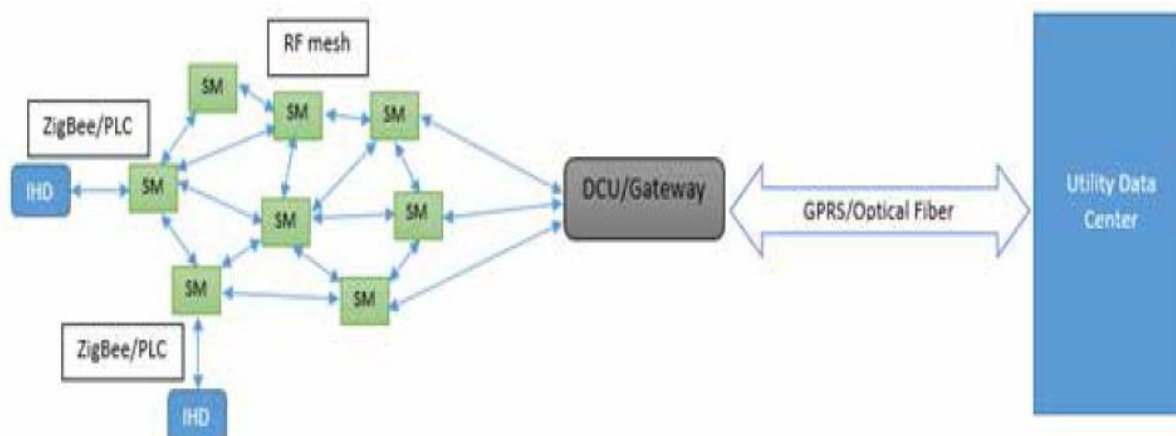


Figure 1-6: AMI architecture with RF mesh as last mile

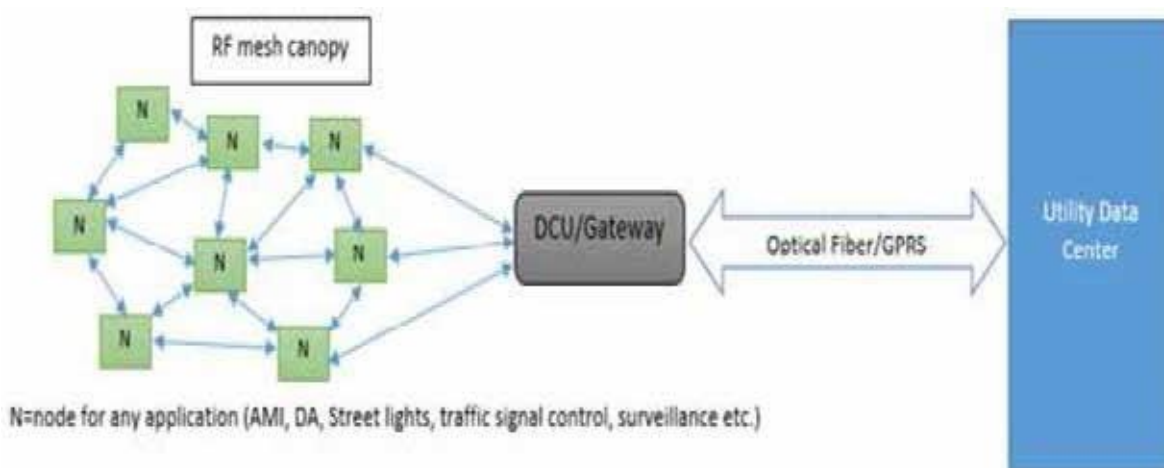


Figure 1-7: Emerging architecture for smart grid and smart city

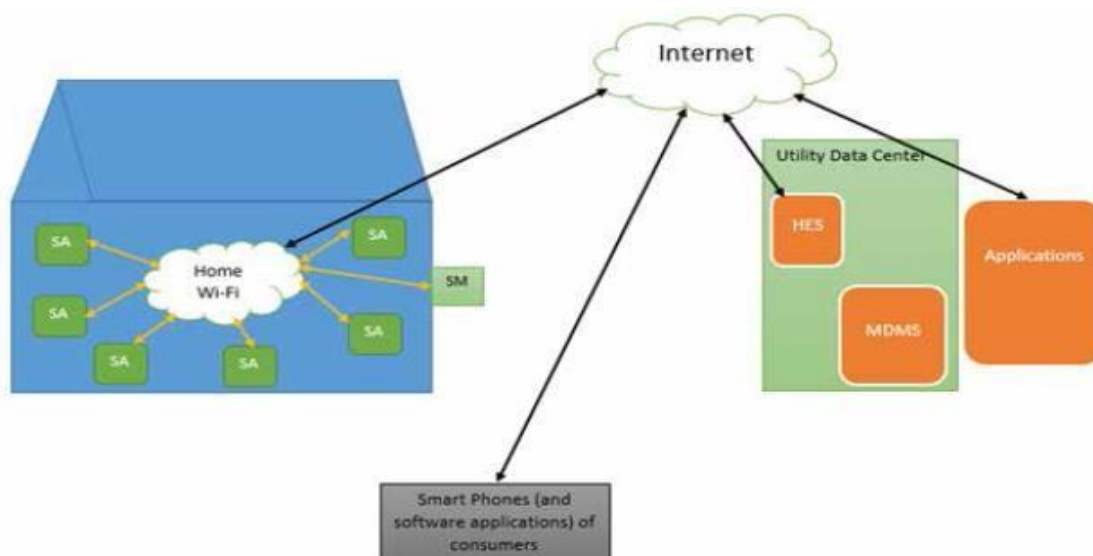


Figure 1-8: Communication architecture for next generation smart metering – IP metering

Source: ISGF



1.2.3 Key Challenges

The following are the key challenges to rollout of smart meters:

- **Consumer indexing** poses a challenge in maintaining the system since whenever consumer is tagged to a new DT discrepancy in billing is observed
- **Regulatory challenges** for implementation of PLM, connect/disconnect etc.
- **Integration of smart grid system** with existing Restructured Accelerated Power Development and Reforms (R-APDRP) system and/or legacy MBC systems
- **No smart meter standard was available at the initiation of deployment** however, some of the utilities have deployed IS 16444 compliant meters, while one of the DISCOMs had gone ahead with certification of IS 16444 which has slowed down the rate of deployment
- **High capital costs:** A full scale deployment of AMI requires expenditures on all hardware and software components, including meters, network infrastructure and network management software, along with cost associated with the installation and maintenance of meters and information technology systems.
- **Integration:** AMI is a complex system of technologies that must be integrated with DISCOMs information and operation technology systems including Customer Information Systems (CIS), Geographical Information Systems (GIS), Outage Management Systems (OMS), Work Management Systems (WMS), Mobile Workforce Management (MWM), SCADA/DMS, Distribution Automation System (DAS), etc.
- **Choice of communication** is limited due to geography and service providers availability and non-competitive rates
- **Capacity building and training challenges** are seen challenge as smart grid is a new concept for the DISCOM officials and skill set enhancement is needed for the systems deployed
- **Consumer resistance** was observed with some of the consumers reported increase in billing and also sought political intervention
- **Non flexibility of communication module** as they are integrated with smart meter of particular vendor and it is lock in case of interoperability

1.2.4 AMI Benefits to DISCOMs and Other Stakeholders

Besides, automating the metering and billing systems without human interventions and eliminating errors, there are several other benefits from AMI for a DISCOM which are explained in detail below. There are also benefits to generation and transmission utilities which are also captured in this section.

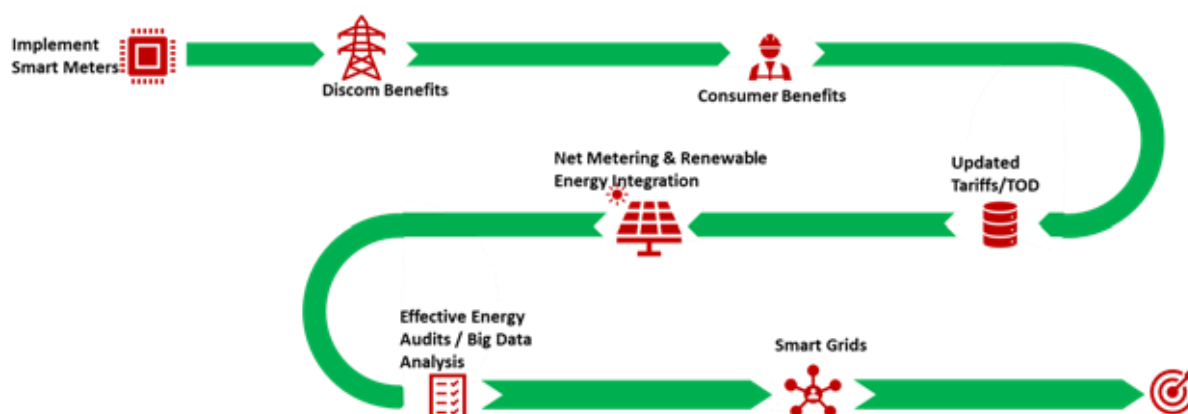


Figure 1-9: AMI benefits



1.2.4.1 Benefits for DISCOMs

Various benefits that will accrue to the DISCOMs from AMI implementation are mentioned below:

- **Reduced meter reading and data entry cost:** Without smart meters, DISCOMs must send their 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.
- **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.
- Reduction in cost of disconnection and re-connection as it can be managed through remote operation of the AMI system
- Faster detection of dead meters and hence enhanced revenue protection
- Real time energy auditing and accurate energy accounting from time stamped meter data
- **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 AMISP can be met from the increased revenue. This has been the experience in DISCOMs where AMI has been implemented (e.g.: Mysore, Indore, Gujarat, NDMC etc.)
- **Reduction in AT&C losses:** AMI can remotely detect meter tampering and enable near real time energy accounting. This reduces theft through by passing the meter, thereby substantially reducing 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.
- **Enabling faster outage detection and service restoration after faults:** Traditionally, the DISCOM know about an outage 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. The smart meter standards in India (IS: 16444) mandates all smart meters to be capable of sending 'last gasp' and 'first breath' messages, which informs the DISCOM when power has failed or resumed. This will reduce outage restoration times leading to financial savings and improved customer satisfaction.
- **Better load research and demand forecasting from AMI data can reduce power purchase cost:** With meter data time stamped at 15 minute intervals, AMI enables near real-time estimation of customer demand and understand customer's power consumption in granular detail. This improves DISCOMs load forecasting accuracy and enhances the ability to procure the right volumes of power. DISCOMs can also implement time of use (ToU) tariffs for different categories of customers and encourage load shifting with demand response programs. These measures could reduce peak load and hence reduce purchase of expensive power during the peak hours.
- **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 DISCOMs to enhance system power quality in conjunction with power quality data from other sources. Improved power quality also leads to lower power losses. Also, avoided costs associated with investigation of voltage complaints.
- **Asset optimization:** AMI data supports granular monitoring of power flows on the distribution network which can help DISCOMs 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.

- Ability to operate in prepaid and post-paid modes with smart meters
- **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 move. Additionally, DISCOMs can monitor the health of the meter and dispatch maintenance only where necessary.
- **Improvement in reliability indices and its accurate measurement:** Enhanced monitoring of the distribution network operations would significantly improve the reliability indices like CAIDI/CAIFI, SAIDI/SAIFI as well as help measure these indices accurately.
- Reduced load on call centers, customer care centers and billing centers
- Smart meters act as feedback points for understanding the behavioural interpretations of energy demand as consumption that can be modified

The quantum of these benefits differs for different utilities and need to be evaluated in detail.

1.2.4.2 Benefits to Generation and Transmission Utilities

Various benefits of AMI implementation for the Gencos and Transco's are mentioned below:

- Deferred or avoided generation capacity investments on peak load plants and spinning reserves resulting from accurate demand forecast
- Deferred or avoided transmission capacity investments due to asset remuneration and asset amortization resulting from accurate demand forecast

1.2.4.3 Benefits for Consumers

AMI implementation will also bring several benefits to consumers which are as follows:

- Error-free bills and no need for visiting billing centers
- **Innovative tariff schemes:** With AMI system, ToU or real time tariff and other innovative tariff schemes (e.g.: Tariffs based on actual capacity, tariffs based on agreed capacity, critical peak pricing, critical peak rebates and block pricing) can be offered to customers which will reduce peak load on the grid and help customers save on electricity bills
- Faster restoration in case of outages
- Ability to remotely manage and control appliances at home/office/factory (with additional home/building automation tools)

1.2.4.4 Benefits for Society

AMI implementation will also bring several benefits to society at large such as:

- **Reduction in carbon footprint:** Reduced patrolling for outage detection, meter reading, disconnection and reconnection etc.
- **Better customer engagement on energy conservation and demand side management initiatives:** Smart meters are supposed to cover several trans-disciplinary areas, including security of supply, accurate energy bills, promoting awareness of energy consumption, leading to increased



awareness of the cost of energy use, promoting energy efficiency behaviours and simplifying the transition from pre-paid to post-paid and vice- versa.

- Enhanced customer satisfaction
- **Energy efficiency and energy conservation:** Meta-analysis from the AMI programs in European countries indicate that on an average, consumers who actively use a smart meter can reduce their consumption of electricity by 5 to 8%.

1.3 Study Scope and Objectives

India Smart Grid Forum (ISGF) with support from Shakti Sustainable Energy Foundation (SSEF) undertook a detailed evaluation of the DISCOMs in the state of Karnataka and preparing a qualitative and quantitative framework to assist the DISCOMs for successful rollout of AMI in the state. The scope of the study covered:

- Detailed assessment of the current scenario in the DISCOMs with respect to metering, billing and collections; energy accounting and AT&C losses
- Assessment of DISCOMs preparedness in terms of technical and managerial capabilities, and enabling ecosystem to derive full benefits of AMI and other challenges
- Technology selection guidelines
- System integration framework
- Evaluation of business models to finance the AMI project
- Customer engagement strategies and outreach mechanisms
- Risk mitigation mechanisms for all stakeholders

1.4 Study Methodologies

A well-designed research methodology was adopted for this project as outlined below:

Step 1: Review of AMI implementation progress in Indian utilities

Thorough review of the AMI projects implemented (and ongoing) by DISCOMs in India undertaken including the failed projects. This will help map the key success factors and potential risks. Also, this will help to understand the effectiveness of different technologies as well as capabilities of key players in the market.

Step 2: Data collection from different stakeholders

Consultations with various stakeholders - central/state government departments, state utilities, meter manufacturers, meter service providers, telecoms, regulators and respective ministries conducted at various stages of the study. This will cover issues such as: smart meter functionalities including billing, field area and home area communication networks (FAN/HAN) support, real time events/alarms etc. can pose challenges to different stakeholders. Without a proper meter replacement/installation plan (considerations: meter age, site conditions, operation and customer engagement, efficiency etc.) problems could arise in smart meter installation. Some major challenges can also arise in FAN coverage and interference, data communication engineering and architecture (pertaining to data traffic handling), firmware management (security and upgrades), cyber security (end to end), scale up considerations (technical factors for implementation of a full-scale AMI project).



Other challenges may include: low smart meters availability and inventory logistics, potential network bottlenecks, backend system scale up, new firmware deployment etc.

Step 3: Analysis and recommendations

The key recommendations would cover: a) Cost-benefit analysis; b) Technology selection guidelines; c) System integration framework; d) Evaluation of business models to finance the AMI project; e) Customer engagement strategies and outreach mechanisms; and f) Risk mitigation mechanisms for all stakeholders



02 Review of AMI Projects in India

2.1 AMI Initiatives in India

In recent years, the metering industry has improving, transitioning from automated meter reading (AMR) to smart metering, which uses bidirectional communication to provide greater benefits to electricity distribution companies (DISCOMs), and consumers. With this, Government of India (GoI) has launched various programs and initiatives for reforming the power sector in India. These include Integrated Power Development Scheme (IPDS), Ujwal Discom Assurance Yojana (UDAY), National Smart Grid Mission (NSGM), Smart Meter National Programme (SMNP) and Revamped Distribution Sector Scheme (RDSS). GoI has provided funds to the state governments for implementation of smart metering under NSGM and IPDS. Priority would be given to the following:

- All electricity divisions of 500 Atal Mission for Rejuvenation and Urban Transformation (AMRUT) cities, with AT&C losses >15%
- All Union Territories
- Ministry of Micro, Small and Medium Enterprises (MSMEs) and all other industrial and commercial consumers
- All government offices at block level and above and
- Other areas with high losses for installation by December 2023

2.1.1 Integrated Power Development Scheme (IPDS)

The IPDS was notified by the Ministry of Power (MoP) on December, 2014 for strengthening of sub-transmission, distribution networks and metering of distribution transformers/feeders/consumers in the urban areas. IPDS had an outlay of INR 32,612 crore which includes a budgetary support of INR 25,354 crore from GoI. As of May 2022, for smart metering, the total approved project cost and project management agency (PMA) cost are around INR 228.55 crore and the total government grant approved is INR 144.37 crore of which INR 81.24 crore has been released¹. The smart grid pilot projects under IPDS sanctioned by MoP which are completed are as follows:

Table 2-1: Smart grid pilot projects under IPDS

Sl No	Project Area	Description (As of May 2022)
1	IIT Kanpur Smart City Pilot	• Project completed • Area – Smart City Pilot in IITK campus • Project cost: INR 11.394 crore, GoI support: INR 5.697 crore
2	Chamundeshwari Electricity Supply Corporation (CESC), Mysore	• Project completed • Functionalities: AMI, OMS, PLM and MG/DG • Consumers: 21,824 • Area: V V Mohalla, Mysore • SGIA: M/s Enzen • Project cost: INR 32.56 crore, GoI support: INR 16.28 crore
3	Uttar Haryana Bijli Vitran Nigam (UHBVN), Haryana	• Project completed • Functionalities: AMI, PLM and OMS

¹ IPDS: <https://bit.ly/3FijC4k>



		- Consumers – 10,188 - Area: Panipat City Sub Division - Project implemented under grant from NEDO (Japan)
4	Smart Grid Knowledge Center, Manesar	- Project completed - Functionalities: AMI, OMS, MG/DG, EVCI, HEMS, Cyber Security and Training Infrastructure - Area: POWERGRID complex, Manesar - SGIA: M/s Genus - Project cost: INR 5.96 crore, GoI support: INR 5.96 crore
5	Himachal Pradesh State Electricity Board (HPSEB), Himachal Pradesh	- Project completed - Functionalities: AMI, OMS and PLM - Consumers: 1,335 - Area – Kala Amb Industrial Area - SGIA: M/s GE T&D - Project cost: INR 19.45 crore, GoI support: INR 9.73 crore
6	Uttar Gujarat Vij Company Ltd (UGVCL), Gujarat	- Project completed - Functionalities: AMI, OMS, PLM and PQ - Consumers: 22,230 - Area: Naroda - SGIA: M/s Genus - Project cost: INR 23.18 crore, GoI support: INR 11.59 crore
7	Electricity Department of Government of Puducherry (PED), Puducherry	- Project completed - Functionalities: AMI - Consumers: 33,499 - Area: Division 1 of Puducherry - SGIA: M/s DFE, China - Project cost: INR 35.43 crore, GoI support: INR 17.72 crore
8	West Bengal State Electricity Distribution Company Limited (WBSEDCL), West Bengal	- Project completed - Functionalities: AMI and PLM - Consumers: 5,265 - Area: Siliguri Town - SGIA: M/s Chemtrols - Project cost: INR 6.955 crore, GoI support: INR 3.48 crore
9	Assam Power Distribution Company Limited (APDCL), Assam	- Project completed - Functionalities: AMI and PLM - Consumers: 14,519 - Area: Guwahati Division - SGIA: M/s Fluentgrid - Project cost: INR 19.56 crore, GoI support: INR 9.58 crore
10	Tripura State Electricity Corporation Limited (TSECL), Tripura	- Functionalities: AMI and PLM - Consumers: 45,290 - Area: Electrical Division No.1, Agartala - SGIA: M/s Wipro - Project cost: INR 63.43 crore, GoI support: INR 31.72 crore - TSECL to complete Smart Grid Pilot at Agartala from own resources. No further funding under IPDS
11	Southern Power Distribution Company of Telangana Limited (TSSPDCL), Telangana	- Project completed. Final claim with closure report submitted to MoP - Functionalities: AMI, PLM, OMS and PQ - Consumers: 11,906 - Area: Jeedimetla Industrial Area - SGIA: M/s ECIL - Project cost: INR 34.93 crore, GoI support: INR 17.47 crore

Source: NSGM

2.1.2 Ujwal Discom Assurance Yojana (UDAY)

UDAY, launched in September 2015, and the National Tariff Policy (NTP), amended in January 2016, mandate the deployment of smart meters for all consumers with a consumption above 200 kWh. As of May, 2022, 9 percent of the planned 5.73 million smart meters had been installed for consumers with electricity consumption above 500 kWh, and 11 percent of the planned 18.43 million smart meters had been installed, for consumers with electricity consumption of 200 kWh to 500 kWh².

2.1.3 National Smart Grid Mission (NSGM)

NSGM has been established by GoI, aims to accelerate the deployment of smart grids and smart meters in India. The programme has been in operation since January 2016, and as of May 2022, 1,35,757 smart meters had been installed out of the 3,63,433 sanctioned. Three smart grid projects have been sanctioned under this program and are at various stages of development as mentioned in below Table:

Table 2-2: Smart grid pilot projects under NSGM

SI No	Project Area	Description (As of May 2022)
1	Chandigarh Engineering Department (CED), Chandigarh (Sub Div-5)	- Till date, 24,149 smart meters installed in field - Functionalities: AMI, DTMU and SCADA - Consumers: 29,433 - Area: Sub Division 5 of Chandigarh - SGIA: M/s Analogics, M/s Synergy - PMA: M/s RECPDCL - Project cost: INR 28.58 crore, GoI support: INR 8.57 crore
2	Jaipur Vidyut Vitaran Nigam Ltd (JVVNL), Rajasthan (6 Urban Towns)	- Till date, 1,11,608 smart meters installed in field - Functionalities: AMI - Consumers: 1.5 lakh - Areas: Baran, Bharatpur, Bundi, Dholpur, Jhalawar, Karauli - Project cost: INR 87.43 crore, GoI support: INR 26.23 crore
3	CED, Chandigarh (Complete City Excl. SD-5)	- Revised sanction for AMI / Smart Metering with MBC and additional service cables issued on 9th Dec 202 - Functionalities: AMI - Consumers: 1.84 lakh - Area: Complete Chandigarh City (excl. SD5) - Project cost: INR 119.58 crore, GoI support: INR 35.87 crore

Source: NSGM

2.1.4 Revamped Distribution Sector Scheme

The Revamped Distribution Sector Scheme (RDSS) was launched by Government of India on July, 2021, provisions have been made to install 250 million prepaid smart meters across the country by March, 2025. A Reforms based and results linked scheme with an outlay of INR 303,758 crore over a period of five years from FY 2021-22 to FY 2025-26 with the objective to improve the quality, reliability and affordability of power supply to consumers through a financially sustainable and operationally efficient distribution sector. The scheme aims to reduce the AT&C losses to pan India levels of 12-15% by 2024-25 by improving the operational efficiencies and financial sustainability of all DISCOMs/Power departments excluding private sector DISCOMs. DISCOMs/Power departments would be able to

² UDAY: <https://bit.ly/3zrWs01>



access funds under the scheme for pre-paid smart metering, system metering and distribution infrastructure works for loss reduction and modernisation.

2.2 On-Going AMI Projects in India

As of May, 2022, a total of 10.52 million smart meters have been sanctioned under these schemes, of which 3.69 million have been deployed and 6.82 million are in the pipeline. Among agencies, Energy Efficiency Services Limited (EESL) has installed 2.64 million smart meters and REC Power Development and Consultancy Limited has installed 1 million smart meters. Power utilities have cumulatively installed 1.55 million smart meters. The ongoing AMI projects in India state-wise as mentioned in below Table.

Table 2-3: Ongoing AMI projects in India

SI No	State/UT	Utility	Sanctioned Smart Meters	Installation Status (As May, 2022)
1	Andaman	EDANI	103302	75200
2	Assam	APDCL	888100	190091
3	Bihar	NBPDCL	1030000	331920
4		SBPDCL	1360500	481579
5	Chandigarh	CED	213433	24149
6	Delhi	NDMC	64713	63692
7	Haryana	DHBVN	500000	181061
8		UHBVN	500000	251244
9	Himachal Pradesh	HPSEB	76028	60168
10	Jammu & Kashmir	JKPDD	115500	76050
11	Jharkhand	JBVNL	360000	0
12	Madhya Pradesh	MP-West	350000	124477
13	Punjab	PSPCL	96000	88107
14	Rajasthan	JaVVNL	431800	355428
15		AVVNL	190822	68673
16		JdVVNL	102182	56027
17	Tamil Nadu	TANGEDCO	141000	117527
18	Uttar Pradesh	MVVNL	905769	378862
19		PVVNL	1164138	198726
20		DVVNL	628686	147991
21		PuVVNL	1147102	321433
22		KESCO	156532	107318
Total			10525607	3699723

Source: NSGM

2.2.1 Completed Smart Metering Projects in India

As of May, 2022, a total of 0.72 million smart meters have been sanctioned under these schemes, of which 0.72 million have been deployed across the various states as mentioned in below Table.

Table 2-4: Completed smart metering projects in India

SI No	State/UT	Utility	Sanctioned Smart Meters	Installed Smart Meters
1	Andhra Pradesh	APEPDCL	2000	2000
2	Assam	APDCL	84259	84259
3	Bihar	IPCL	17100	17100
4		BEDCPL	1000	1000
2	Delhi	TPDDL	195000	195000



3	Gujarat	UGVCL	23760	23760
4	Haryana	UHBVN	10188	10188
5		POWERGRID	10	10
6	Himachal Pradesh	HPSEB	77047	77047
7	Karnataka	CESCOM	20916	20916
8	Kerala	CPT	805	805
9	Madhya Pradesh	MP-West	118836	118836
10	Odisha	OPTCL	4000	4000
		PPT	500	500
11	Puducherry	PED	30568	30568
12	Rajasthan	AVVNL	1000	1000
13		JaVVNL	70000	70000
14	Tripura	TSECL	43081	43081
15	Telangana	TSSPDCL	8882	8882
16	Uttar Pradesh	IITK	28	28
17	West Bengal	WBSEDCL	5164	5164
18		CESC	10000	10000
Total			724144	724144

Source: NSGM

The full details of ongoing and completed projects are given in Appendix I.

2.2.2 EESL/IntelliSmart Projects

2.2.2.1 EESL - Smart Meter National Programme (SMNP)

SMNP aims to replace 250 million conventional meters with smart meters in India. Smart meters are connected through a web based monitoring system which will help to reduce commercial losses of Discoms, enhance revenues and serve as an important tool in power sector reforms. Energy Efficiency Services Limited (EESL) business model to rollout smart meters is

Key Highlights:

- **AT & C loss reduction:** 11%-36%
- **Billing efficiency:** Increased by 21%
- **Increased revenues:** INR 264 Crore per annum (11 lakh meters)
- **Pre-Paid meters:** 140-150% of increased revenues in Bihar

revamping the current manual system of revenue collection which leads to low billing and poor collection efficiencies. This programme is being implemented under the BOOT model on cost plus approach, which means all Capex/Opex is done by EESL and the states/DISCOMs are not required to invest upfront. As of May, 2022 EESL has installed 2.64 million smart meters across the states Uttar Pradesh, Haryana, Bihar, NDMC-Delhi, Rajasthan, Assam and Andaman & Nicobar.

2.2.2.2 IntelliSmart Projects

To give a fillip to the vision of converting all the conventional electricity meters to smart meters in the next few years, EESL along with National Investment and Infrastructure Fund (NIIF), has formed a JV company – IntelliSmart Infrastructure Private Limited or “IntelliSmart” in 2019. The focus of IntelliSmart would be to drive efficiencies for DISCOMs, improve revenue management, and increase billing efficiency and consumer satisfaction. As of May 2022, 2.64 million smart meters installed across the various states in India as mentioned in below Table.



Table 2-5: IntelliSmart smart metering projects in India

SI No	State/UT	Installed Smart Meters (As of May 2022)
1	Andaman & Nicobar Islands	74209
2	Assam	962
2	Bihar	795875
3	Delhi	63705
4	Haryana	434346
5	Rajasthan	124700
6	Uttar Pradesh	1154330
Total		2648127

Source: IntelliSmart

To expand its fast-growing presence across the country, IntelliSmart is looking at penetrating states such as Jharkhand, West Bengal, Andhra Pradesh, Telangana and Gujarat, to implement digital solutions like smart metering. “IntelliSmart has secured its first order to install more than 6 lakh pre-paid smart meters in 19 circles of Assam. This becomes countries first ever competitively bid smart metering project by any State on TOTEX mode (Capex + Opex).

2.2.3 TPDDL AMI Project

In 2003, Tata Power Delhi Distribution Limited (TPDDL) developed and implemented its in-house AMR system with MDM and MDAS for 75,000 consumers having a connected load of 10 kW and above. In 2014, TPDDL became the first Indian power utility to launch an Automated Demand Response (ADR) project with smart meters.

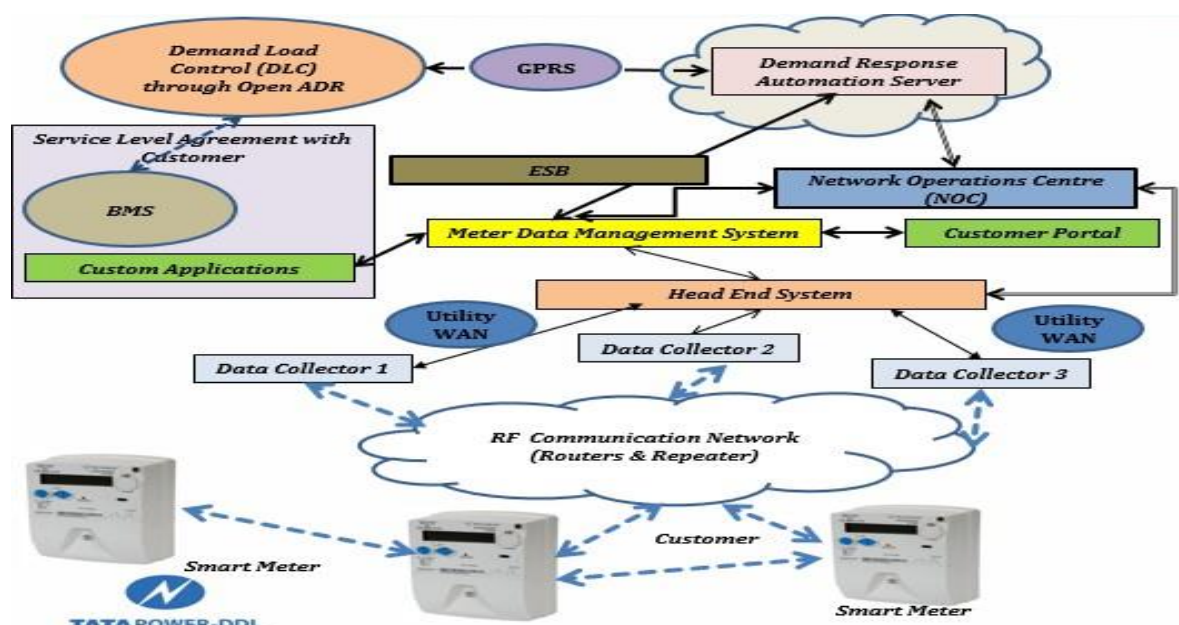


Figure 2-1: ADR with smart meter architecture

This pilot project was implemented in partnership with IBM, Honeywell, and Landis+Gyr and with the participation of select industrial and commercial consumers. Subsequent to ADR implementation, TPDDL has planned to implement smart meters for all consumers, in a phase wise manner. As of May, 2022, a total of 0.8 million smart meters have been planned, of which 0.24 million have been installed using RF-Mesh with OFC and Cellular Backhaul NBIoT.

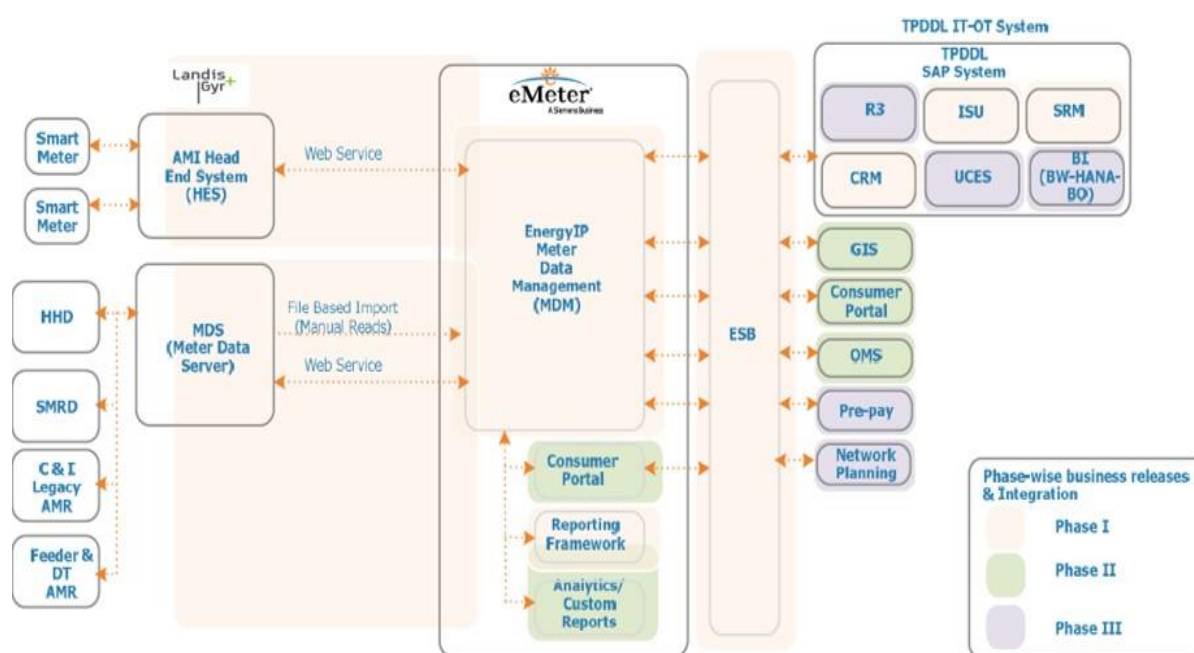


Figure 2-2: Overall architecture of AMI at TPDDL

Table 2-6: TPDDL AMI project

Customers	1.8 million
License Area	North and North West Delhi (510 sq. km)
Total Number of Smart Meters Installed	0.24 million
Technology	RF-MESH with OFC & Cellular Backhaul NBIoT RF Mesh: 865-67 MHz, RF (P2MP), RF Mesh: 2.4 GHz and 5.8 GH, PLC (3G,Prime), Cellular (2G,2.5G,3G,4G,LTE)
Smart Meter	Landis+Gyr, HPL, L & T
Modules Developed	- Billing (NET/Post/Pre-Paid) - Revenue Protection - Connect/Disconnect - Dashboard and Analysis modules
Billing Efficiency	98%
Enabled Features	Remote and on-demand reading, Remote firmware upgrade, Net metering, Time-of-Day (TOD) pricing and Prepaid metering, Power Quality Meter (PQM)/pulse-frequency modulation (PFM)
AMI Integrated with	MDAS and MDMS, MBC system, OMS, Mobile and web applications/self-service portal and CRM systems

2.3 Smart Metering Standards

The MoP mandated Central Electricity Authority (CEA) to prepare the functional requirements and technical specifications for indigenous smart meters. CEA released the first edition of the smart meter specifications in June 2013. MoP has requested the Bureau of Indian Standards (BIS) for formulating a national standard for smart meters. Subsequently, BIS assigned this task to the Technical Committee under Electro Technical Division (ETD) 13 to prepare the standards for smart meters. In August 2015, BIS published the new smart meter standard, IS 16444: AC static direct connected watthour smart meter, class 1 and 2 specification covering single phase energy meters, three phase energy meters with net metering facility. Another standard IS 15959: data exchange for electricity meter reading,



tariff and load control, companion specification has been revised and published as IS 15959: Part 2 Smart Meter in March 2016.

2.3.1 Smart Metering Standards in India

In June 2016, CEA issued the specifications of single phase and three phase smart meters, and functional requirements of AMI in India. All DISCOMs have been advised to abide by these specifications and minimum functional requirements and mandated all meters to be conforming to latest Indian Standards as listed below:

A. Standards for smart meters and associated data protocol

- BIS standard for smart meters (IS 16444) published in August 2015
- BIS standard on data protocol (IS 15959 Part 2) published in March 2016
- No standard required for communications, each utility to decide the suitable/appropriate communication technology (It is not prudent to specify any single communication technology for the entire country)

B. BIS Standard on Smart Meters (IS 16444) applies to:

- Single phase electricity meters
- Three phase electricity meters
- Single phase electricity meters with net metering facility
- Three phase electricity meters with net metering facility

These meters can be operated as both pre-paid and post-paid electricity meters. There is no need for another standard for pre-paid electricity meters.

2.3.2 Global Standards in Smart Metering

Table 2-7: Global standards in smart metering

Standard Body	Reference	Title
IEC	IEC 61968-9	Application integration at electric utilities - System interfaces for distribution management
IEC	IEC/TS 62351	Power systems management and associated information exchange - Data and communications security
IEC	IEC 62052 -11	Electricity metering equipment (AC) - General requirements, particular requirements, tests and test conditions
IEC	IEC 62056 – 21,42,46,47,53,61,62	Electricity metering - Data exchange for meter reading, tariff and load control
IEC	IEC 62058	Electricity metering equipment (AC) - Acceptance inspection
NEMA	SG-AMI 1-2009	NEMA Smart Grid standards Publication SG-AMI 1-2009 – Requirements for Smart Meter Upgradeability
EN	EN 13321 Series	Open data communication in building automation, controls and building management — Home and building electronic system
EN	EN 13757 -1,2,3,4,5	For utility metering using M-bus and other media
EN	EN 14908 series	Information Technology – Control Network Protocol
EN	EN 50065-1	Signalling on low-voltage electrical installations in the frequency range 3kHz to 1485 kHz – General Requirements, frequency bands and electromagnetic disturbances
EN	EN 50090 -3-1,2,3	Home and Building Electronic Systems (HBES)
EN	EN 50090 -4-1,2,3	Home and Building Electronic Systems (HBES)



EN	EN 50090 -7-1	Home and Building Electronic Systems (HBES)
EN	EN 61334-4-32	Distribution Automation Using Distribution Line Carrier Systems – Data Communications Protocols
IEC	EN 61334-4-511	Distribution Automation Using Distribution Line Carrier Systems – Data Communications Protocols – Systems Management – CIASE Protocol
IEC	IEC 61334-4-512	Distribution Automation Using Distribution Line Carrier Systems – Data Communications Protocols – System Management using profile 61334-5-1 – Management Information Base
IEC	IEC 62051-1	Electricity Metering – Data Exchange for Meter Reading, Tariff and Control – Glossary of Terms
IEC	IEC 62351 (all parts)	Power Systems Management and Associated Information Exchange – Data and Communications Security
EN	EN 62056-31,42,46,47,53,61,62	Electricity Meter Data Exchange
IEEE	IEEE 1377	Utility Industry Metering Communication Protocol Application Layer (End Device Data Table)
IETF	RFC 3394	Advanced Encryption Standard (AES) key wrap algorithm (Informative)
ANSI	ANSI C12.19	Utility Industry End Device Data Tables
ANSI	ANSI C12.22	Protocol Specification for Interfacing to Data Communication Networks



03 Ground Work by DISCOMs for AMI

3.1 Basic Preparedness

For a smooth AMI implementation, it is very important to have the basic preparedness of DISCOM in place. AMI implementation and the rollout would require a well-defined and proactive strategy and good understanding of the existing IT and automation system in the DISCOM. The following readiness should be ensured beforehand.

- The available technical capability of DISCOMs for AMI implementation
- Managerial capabilities of DISCOMs for AMI implementation
- Enabling eco system for the implementation of AMI
- Challenges envisaged in the AMI implementation

3.2 The Key Issues to be Addressed

3.2.1 Technical Capabilities

1. The interoperability should be established among different make of meters and communication system deployed.
2. A meter installation agency should be hired or a dedicated team for smart meter installation should be formed within the DISCOM and trained.
3. Different smart meters communication technologies should be tested for different field conditions.
 - RF mesh network
 - PLC
 - Cellular network
 - A combination of these
4. Meter data reading frequency for different types of consumers should be framed differently to serve the purpose.
5. Topology of meter communication should be established depending upon the field condition and suitability of technology.
6. Security of the communication network should be maintained.
7. The functioning of existing applications/systems ex. billing, customer care, GIS, analytics, reporting, load analysis, load forecasting, and OMS should be ensured before integrating it to AMI.
8. MDM should support asset management functionalities.
9. The billing system should support AMI Meter Data Management system and existing MDAS for the billing of different type of customers until the rollout gets completed.
10. The billing system should provide revenue protection support.
11. MDM should provide demand control/demand response support.
12. Integration of existing system like Interactive Voice Response System, Billing and collection software, GIS mapping, Consumer indexing, new connection and disconnections, Analytics,



Outage Management System among each other should not be compromised while integrating with AMI.

13. Appropriate security measure should be taken to prevent unauthorized access in AMI.

3.2.2 Managerial Capabilities

1. Adequate resource pool for AMI implementation should be planned and trained before starting the project.
2. The project team structure as listed below should be defined for AMI implementation.
 - Project Manager
 - System Integration Specialist
 - Cyber Security Specialist
 - Communication Technology Specialist
 - Other Resources
3. A governance Framework for AMI implementation shall be defined.
4. Required training on different subjects/components shall be provided to the resources involved in the project.
 - Hardware and Software including database, report, and analytic building course
 - Software application
 - Operator training
 - Network and cyber security training

3.2.3 Enabling Ecosystem

1. Smart Meter Operations Centre (SMOP) should be planned beforehand
2. Smart meters vendor pool must be identified and empanelled
3. Challenges in mass meter replacement shall be identified and addressed
4. Online data exposed to consumers, through web application or mobile app should be well protected
5. Response from different type of customers should be captured based on their ability to communicate
6. Provision for remote load connection/disconnection with appropriate safety measures should be tested for AMI
7. AMI implementation risk should be identified and mitigation measures should be taken
8. The business model for AMI implementation should be well planned and it should be in sync with the DISCOM's digital transformation roadmap
9. The methodology for AMI implementation and should be planned and communicated to relevant stakeholders

3.3 Other Important Measures

1. Advance Metering Infrastructure Service Providers (AMISP) bidders should have one project partner who are experienced System Integrators (SI) and have successfully implemented end-to-end integration (Meter-HES-MDM-Billing System) of an AMI project involving >1 million meters anywhere in the world. Tender evaluation committee should visit/interact with the SI and the Utility to understand the performance rather than going by the certificate from the client submitted by the bidders. Additionally experienced consultants may be insisted upon as part of the AMISP team.



2. All AMI projects should have a pilot demonstration phase involving 3-4 full feeders (about 5000 meters) which should be completed with full end-to-end integration within 9 months of placement of LoI.
3. Till the first awarded project's pilot demo phase is not completed, the same AMISP and the SI may not be awarded another project in any other DISCOMs.
4. DISCOMs must have ONLY ONE Billing System – this must be done on top priority. The legacy billing system must be available for integration with industry standard MDMs available in the market.
5. DISCOMs should share their process and context diagrams, IT architecture with interface details of all their legacy IT systems. DISCOMs may be advised to start this process on fast track as most of them do not have such clear architecture and documentation.
6. After successful completion of the pilot demonstration, the DISCOM should establish a Smart Meter Operations Centre (SMOC) which will be a control centre to monitor and manage the larger rollout smoothly.
7. Every DISCOM should first award a project involving 500K to 1 million meters in one city/town; out of which phase-1 should be the pilot demonstration of end-to-end integration with prepayment functionalities within 6-9 months. Thereafter, that AMISP can continue with rollout of that package in full.
8. After the pilot phase of the first project is successfully completed, the DISCOM can issue multiple tender packages for entire service area and engage different AMISPs for different areas. Each of such projects should be maximum of 1 million meters – not larger. The new AMISPs should integrate their HES with MDM in collaboration with the SI of the first AMISP who conducted the solution demonstration.
9. Telecom service providers should be mandated to commit SLAs for their services for AMI projects

3.4 Possible Challenges

India faces a number of challenges with respect to deployment of AMI:

3.4.1 Absence of Skilled Manpower

AMI is a new concept that involves in-depth knowledge of three distinct domains: metrology, telecommunications and IT. The DISCOMs are well versed with the electrical technologies of the electricity grid, but when it comes to telecommunications and IT, their expertise is limited. Furthermore, the fact that AMI is an evolving technology adds to the challenge.

3.4.2 Limited Awareness

As AMI is new in India, DISCOMs are still trying to understand its nuances. As a result, DISCOMs often find it hard to justify investments in AMI. Also, limited availability of information on successes in AMI deployments leads to an unclear picture for the decision makers.

3.4.3 Weak Procurement Framework

In most government tenders in India, the lowest bidder is awarded the contract. This often leads to the deployment of unproven technologies and systems by inexperienced parties. Often the lifecycle cost of such systems comes out to be much higher than the anticipated cost.



3.4.4 Customer Engagement

Many potential benefits of an AMI project rely on robust customer engagement. In India, this is an overlooked aspect by most DISCOMs. Customers will take part in AMI and demand response initiatives only when they understand the importance and benefits to them.

3.4.5 Implementation of AMI

AMI integration with the legacy systems in the DISCOMs brings technical challenges including the standardization of data formats to optimize interoperability across components, management of large volumes of electricity consumption data.

**04**

Assessment of the Current Metering Scenario in DISCOMs in Karnataka

4.1 Introduction

Government of Karnataka (GoK) has been making efforts in areas like grid modernization, smart metering, promoting electric vehicles and energy storage, enhancing capacity in renewable energy and developing microgrids. The KERC Smart Grid Regulation 2015 aims to integrate all smart grid technologies and measures to bring energy efficiency and operational improvement in generation, transmission and distribution and also promotes network security, renewable energy integration into the grid and microgrids.

To improve the operational and revenue realisation of the DISCOMs and to provide better value added services to consumers, power distribution sector state wide is rapidly adopting the smart metering technology. The futuristic technology helps DISCOMs in effective distribution operations as well as help utilities in managing dynamic and disruptive changes happening in the grids due to solar energy infusion, home automation, electric vehicles, energy storage, etc. Karnataka is among the few states where installation of prepaid electricity meters at public facilities has started under Ujwal Discom Assurance Yojana (UDAY). Several measures have been taken to reduce the AT&C losses of DISCOMs by improving billing and collection through removal of manual intervention and reducing meter tampering by consumers. Karnataka is fast moving towards creating an efficient smart energy ecosystem in the state. The state has been implementing reforms for reducing electricity prices and making retail tariffs cost reflective which would help make power for all a reality in Karnataka.

BESCOM has taken many initiatives to ensure that the Bengaluru households get smart meters by March 2025. The smart meters will be installed in two stages. The first phase will have 17-17.5 lakhs smart meters installed at government buildings, commercial enterprises, industries, and similar organizations by December 2023; whereas the second phase will have 55 lakhs smart meters installed covering all residential buildings within Bengaluru City by March 2025.

Chamundeshwari Electricity Supply Corporation has successfully completed a smart metering pilot project which was undertaken in one of the subdivisions in Mysore in 2013. The project involves installation of smart meters for 21,824 consumers (10% of total consumers in Mysore city), with a good mix of residential, commercial, industrial and agricultural consumers, including 512 irrigation pump sets. It covers over 14 feeders and 473 distribution transformers, and accounting for input energy of 151.89 MU. Functionalities of peak load management and outage management have been achieved by implementing AMI for residential consumers and industrial consumers, besides integration of distributed generation/micro-grid integration. CESC is planning to implement smart meters for other areas based on the results of implementation of this pilot project.

4.2 Metering, Billing and Collection System

Metering is the first step in measuring power consumption and presenting the consumers their usage to charge them corresponding to the service delivered. At present, a meter reader approaches each individual consumer with the bill for the revenue realization. The consumers are provided various options to pay their electricity bills at circle, zonal and subdivision offices through cash, cheque and Demand Draft (DD) etc. On successful transaction, receipt is furnished to the consumers. In order to

facilitate easy payment of bills, the DISCOMs also has made a Mobile App for consumers. The Mobile App offers following features for both consumers as well as its employees.

- Generic information about DISCOMs (Tariff, policies, schemes and offices etc.)
- Consumption, billing and payment history
- Online payment
- Consumer specific services (Integration of analytics)
- Display RR no. wise list of payment dues
- Scheduled and un-scheduled power outage information

Meter reader's handle a host of data every day, the data entry is done manually which is prone to human error. DISCOMs has initiated the Automatic Meter Reading (AMR) technology, is used for collecting consumption, diagnostic, and status data from energy metering devices and transferring that data to a central database for billing, and analysing. It saves the cost of periodic trips to each physical location to read a meter. Another advantage is that billing can be based on near real-time consumption rather than on estimates based on past or predicted consumption. This timely information coupled with analysis can help both utility providers and consumer's better control the use and production of electric energy consumption.

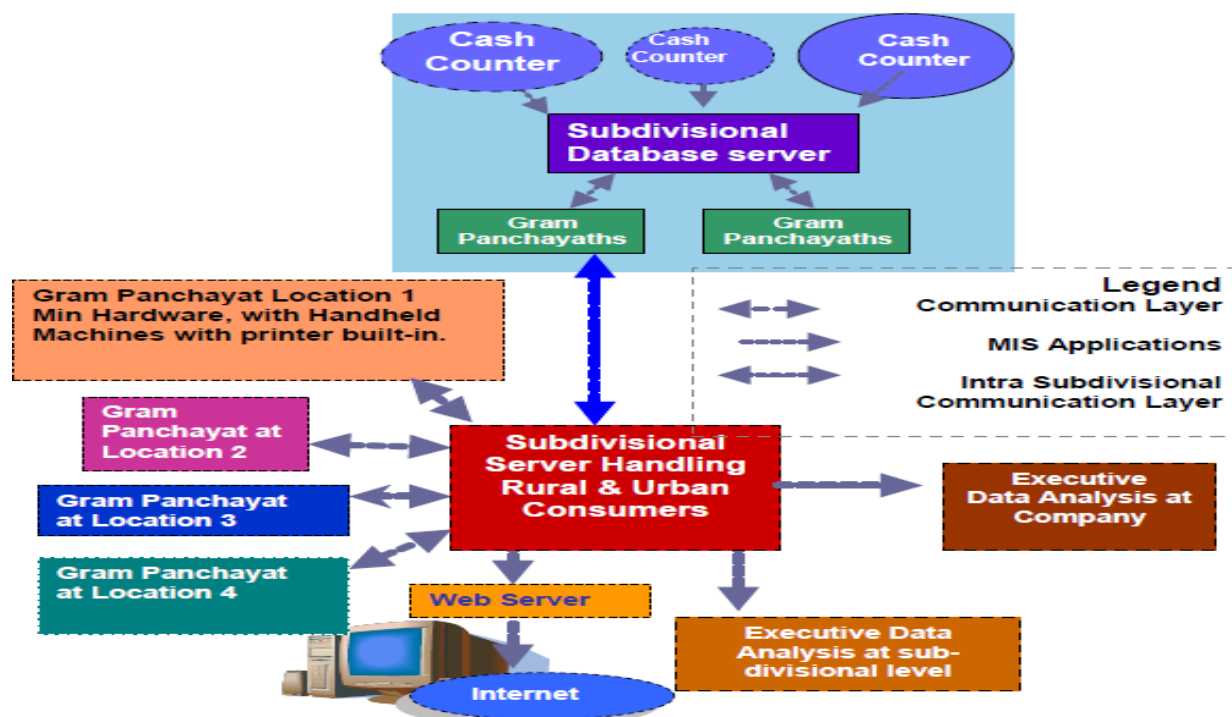


Figure 4-1: Schematic for billing and MIS at subdivision level

The AMR mechanism of BESCOM at DTC Metering and consumer level as mentioned below.

AMR at DTC level:

BESCOM has installed 50,872 modems to DTCs in R-APDRP towns. The DTC meter data is communicated to Meter Data Acquisition System (MDAS) through GPRS modems. The Energy Audit reports were made available in R-APDRP portal.

In Non-RAPDRP area, BESCOM has installed 45,000 DTCs metered with inbuilt modems in the areas of Bengaluru Rural, Ramanagar, Tumkur and Davangere O&M Circles to enable AMR. The DTC meters



communicate with Meter Data Acquisition System and the MDAS is integrated with Total Revenue Management (TRM), which is a billing software for non-RAPDRP areas of BESCOM provided by Nsoft, Bangalore. The DTC wise energy audit reports are available in Nsoft portal.

AMR at Consumer Level:

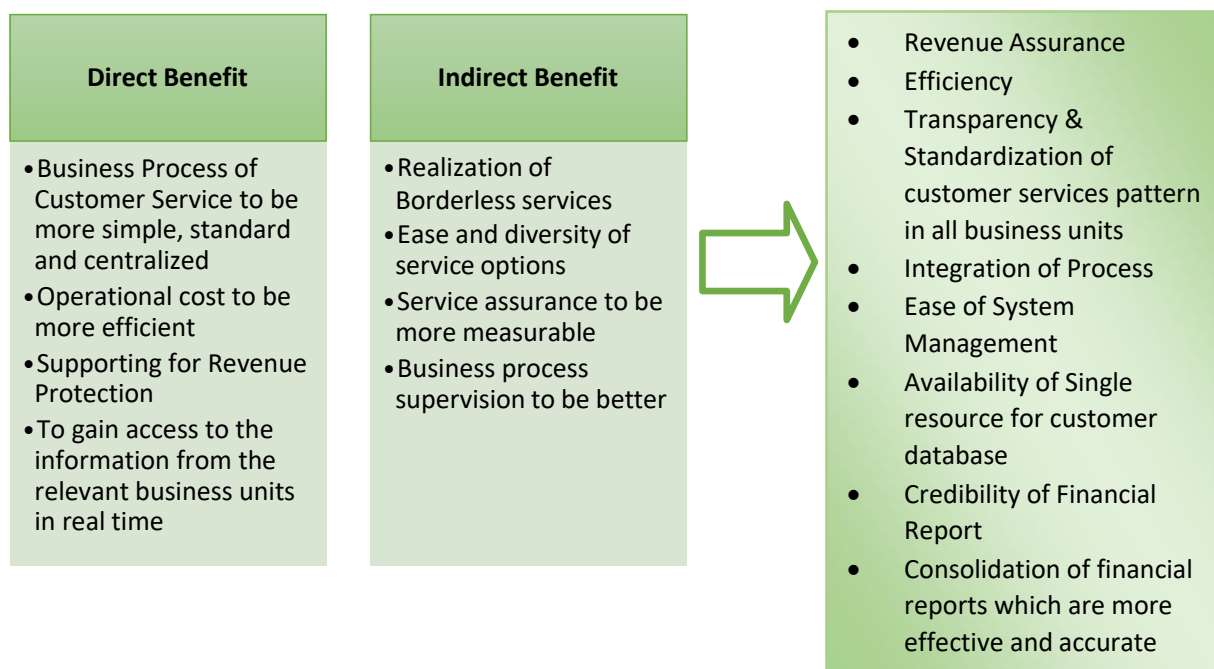
DDUGJY: BESCOM has taken up HT metering work along with AMR under DDUGJY a GoI initiative program. Fixing of modems to the existing HT installations. Configuration of modems and pushing the data from meter to existing server of BESCOM (Nsoft server). As on January 2021, approximately around 260 Nos. of modems were communicating with MDAS; on the first day of every month data is pushed to Nsoft server.

IPDS: BESCOM has taken up following metering works along with AMR under IPDS a GoI initiative program. Modems for 40 HP and above LT3 and LT5 installations in IPDS towns of BESCOM pushes the data to the existing MDAS with GPRS enabled data communication. The work of supply and commissioning of modems has been completed whereas the work of integration is under progress. As on January, 2021 approximately around 7,482 Nos. of modems are communicating to MDAS and 4,871 Nos to MDM.

Pre-paid Meters:

A pilot project was taken up by installing prepaid meters with smart card technology to temporary installations in Indiranagar division, based on its experience it is being rolled out in entire BESCOM jurisdiction for temporary connections. BESCOM has implemented pre-paid meters using keypad technology along with the vending system for temporary installations in BESCOM (other than Indiranagar Divisions) on Design Build Finance Operate and Transfer (DBFOT) basis for 5 years for a total quantity of 80,000 nos.

Benefits of Standard Billing System



4.3 Energy Accounting

The GoK has made it mandatory for DISCOMs to undertake energy accounting periodically. The energy accounting will provide detailed information regarding electricity consumption by the different consumers and the transmission and distribution losses in various areas. It will also identify losses and theft and enable actions by fixing the responsibility of the officers. The data will enable the DISCOMs to take appropriate measure for reducing their electricity losses. The DISCOMs will be able to plan for suitable infrastructure up-gradation as well as demand side management efforts in an effective manner.

Energy accounting will contribute towards the climate actions of India in meeting the goal of the Paris Agreement. Energy accounting will account for energy inflows at several voltage stages in the distribution network, such as RE generation, open access consumers, and energy consumption by the end consumers. Energy accounting with an annual energy audit would help to identify losses and pilferages and focus on taking appropriate measures. The initiative will also identify electricity leakage, theft, wastage or insufficient use of electricity and enable the DISCOMs to take appropriate measures to reduce transmission and distribution (T&D) losses.

At present DISCOMs operating Town-wise, Feeder-wise, DTC-wise, administrative hierarchy wise energy accounting/auditing and reporting is provisioned under R-APDRP system.

4.4 AT&C Losses

The advantage of this indicator is that it provides a realistic picture of energy and revenue loss situation. The AT&C losses comprise of technical losses and commercial losses. Technical losses occur naturally and consists mainly of power dissipation in electricity system components such as lines, transformers and other equipment's but the non-technical losses are caused by action of external to the power system such as electricity theft, non-payment by customers, errors in accounting and record keeping. The technical and commercial losses bear effect on the operational performance of DISCOMs and revenue. It also indicates the billing, vigilance and health of the distribution systems. As a result, one of the most significant features of AT&C losses must be maintained to a minimum in order to ensure the DISCOMs technical and financial viability. The AT&C losses of Karnataka stands at 14%. The DISCOM wise AT&C losses of Karnataka state as mentioned in below Table.

Table 4-1: DISCOM wise AT& C loss trajectory up to 2021-22

SI No	Year	BESCOM	CHESCOM	GESCOM	HESCOM	MESCOM	Karnataka Total
1	2017-18	13.37	14.27	23.41	18.99	11.65	16.29
2	2018-19	12.72	13.59	22.84	18.56	11.28	15.72
3	2019-20	11.87	12.99	22.44	17.96	10.79	15.15
4	2020-21	11.51	12.51	21.72	17.43	9.92	14.57
5	2021-22	10.91	12.19	21.01	17.00	9.32	14.00

Source: IPDS

Karnataka's distribution sector has the following opportunities that could help DISCOMs to reduce their AT&C losses.

- Most of the DTs and consumers are metered
- Most categories of consumers pay their bills promptly
- Very few instances of theft take place
- A system is in place to compile data on energy input and energy consumed



With a few additional improvements in the system, Karnataka could achieve AT&C losses of less than 10% at the DISCOM level in the future. Integration of technology to reduce manual interventions and a more stringent administrative control could help in enhancing the DISCOMs performance by reducing the AT&C losses. The following implementable measures are suggested for reducing losses within a comparatively short period of time.

- Feeder wise revenue accounting and monitoring of energy sales
- Computing accurate IP set consumption through agricultural feeder mapping
- GIS-based energy audit
- Closer verification of Gram Vidyuth Prathinidhis (GVPs) billing

4.5 IT and OT Systems

BESCOM IT infrastructure and communication network is the backbone of enterprise IT system for the organization, which provides computing facility for automation of business functions. The main data center facilities of BESCOM are hosted at M/s SIFY's Data Center in Bangalore.

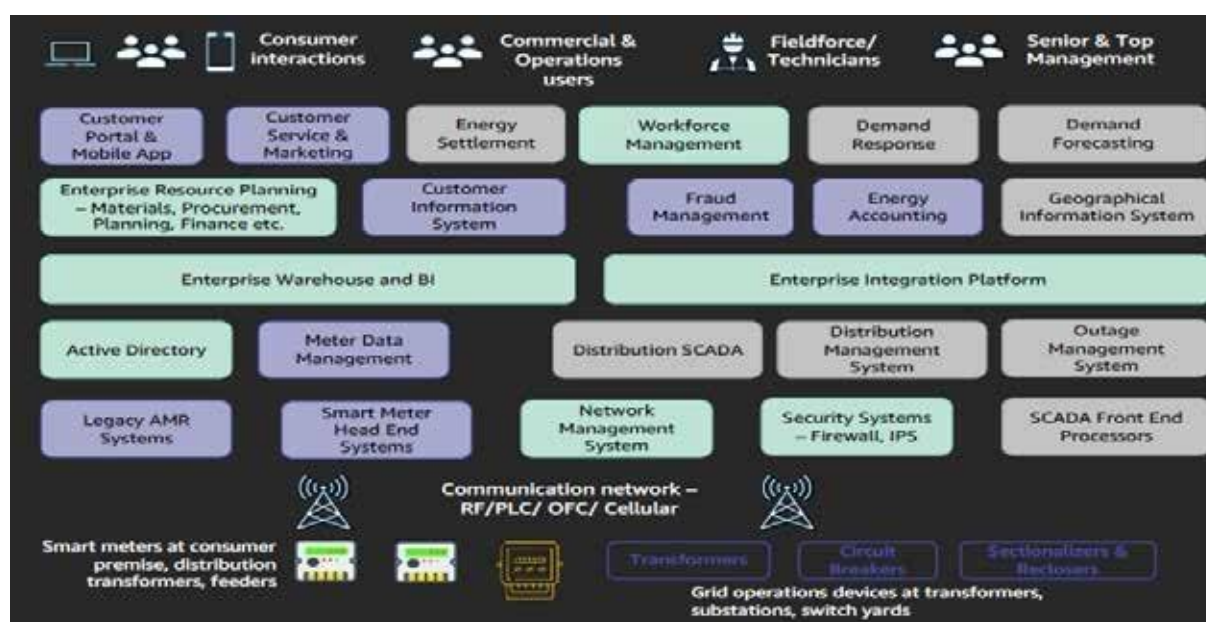


Figure 4-2: IT and OT systems

The end user computing facilities comprise of computers and accessories at different functional departments located at various offices spread across the area of jurisdiction under BESCOM. Separate local area networks (LANs) have been established at respective premises of different offices for users in various departments. Wide area network (WAN) has been established for interconnecting all the offices.

Table 4-2: IT and OT systems

Sl No	Systems	Application	Platform	Database	Integration with Destination System	Integration Through	Frequency
1	IT Systems	CC&B (New Connection, CRM, Metering,	Oracle	Oracle	WAMS, GIS, MDM, MIS/BIP, WSS		



		Billing, Collection and Disconnection					
2		WSS	Java	Oracle	CCB, External Systems (KUM/Seva Sindhu/E-Sign/SAKALA)		
3	OT Systems	GIS Web Solution	ESRI, ArcFM, .Net	Oracle - 11g	Within RAPDRP system - WAMS, NA, MDM, EA Outside RAPDRP system - DAS	Web services DAS- Proxy server	on real time basis DAS- on monthly basis
4		MDA-MDM Solution	Analogics and AmiTech	MS-SQL	CC&B, WAMS, MIS	P2P	15 Mins
5		Identity Access Management & System Security	IBM Tivoli identity management	MS-SQL			

Source: BESCOM

4.5.1 IT and OT Applications

BESCOM has progressively deployed different independent software applications on as and when required basis which comprise a number of legacy systems. The applications have been developed by different agencies on various platforms using a variety of database technologies. These applications are suitable for specific business functions and used by different users of BESCOM. The detailed list of IT and OT applications is given in below Table:

Table 4-3: IT and OT applications

Sl No	Name of Application	Status
IT Applications		
1	Outage Management System (OMS)	Implemented by integrating with existing PGRS (Third party system) of BESCOM
2	Field Force Automation (FFA) Solution	Functions limited to crew management is built into OMS and implemented. The available facilities are sparingly used.
3	Integrated Billing and Collection Systems	Billing and Collection both are handled in single application (CCB)
4	Cyber Security for OT Systems	The required Cyber security controls for the existing system are as per NERC-CIP standards but external security audit is to be carried out and the same is under discussion.
OT Applications		
1	SCADA/DMS	- KPTCL's current SCADA system is integrated to push the 11kV feeder data to R-APDRP system - SCADA DMS functionalities implemented and in commercial operation



2	Geographical Information Systems (GIS)	GIS is currently implemented for 25 towns of R-APDRP wherein data is updated regularly with respect to asset mapping and consumer indexing. GIS is also going to be further extended to 20 IPDS towns in BESCOM
3	Distribution Automation (DA) and Substation Automation	Limited to Bangalore City jurisdiction, DA is implemented. Substation automation not in the scope of BESCOM
4	Distribution System Planning and Modelling Tools	Planning of distribution system limited to identification of automation points for SCADA operations.

4.6 Present Baseline Parameters/KPIs

Every customer in a DISCOM is connected to a feeder. A feeder is the connection from a sub-station through wires, transformers etc. to a customer. It is fairly common practice in the electric utility industry to use the standard IEEE reliability indices like SAIFI, SAIDI, CAIDI and MAIFI to track and benchmark reliability performance.

Table 4-4: KPI parameters

Parameters	Feeder Level Value	Optional/Mandatory
SAIFI	20.21	Mandatory
SAIDI	16.76	Mandatory
ASAI		Optional
CAIDI	0.79	Mandatory
CTADI		Optional
CAIFI		Mandatory
ASIDI		Optional
ASUI		Optional
MAIFI	12.8	Optional

05 AMI Implementation Strategy

For large AMI rollout BESCOM would need a Smart Meter Operations Center (SMOC). As part of the smart meter rollout there are around 250 million smart meters to be installed across India by 2025 with communication network, Head End, Meter Data Management System, Workforce Management system etc.

The diagram below shows an overview of the solution components that should be covered in this solution blueprint (Highlighted as SMOC applications suite):

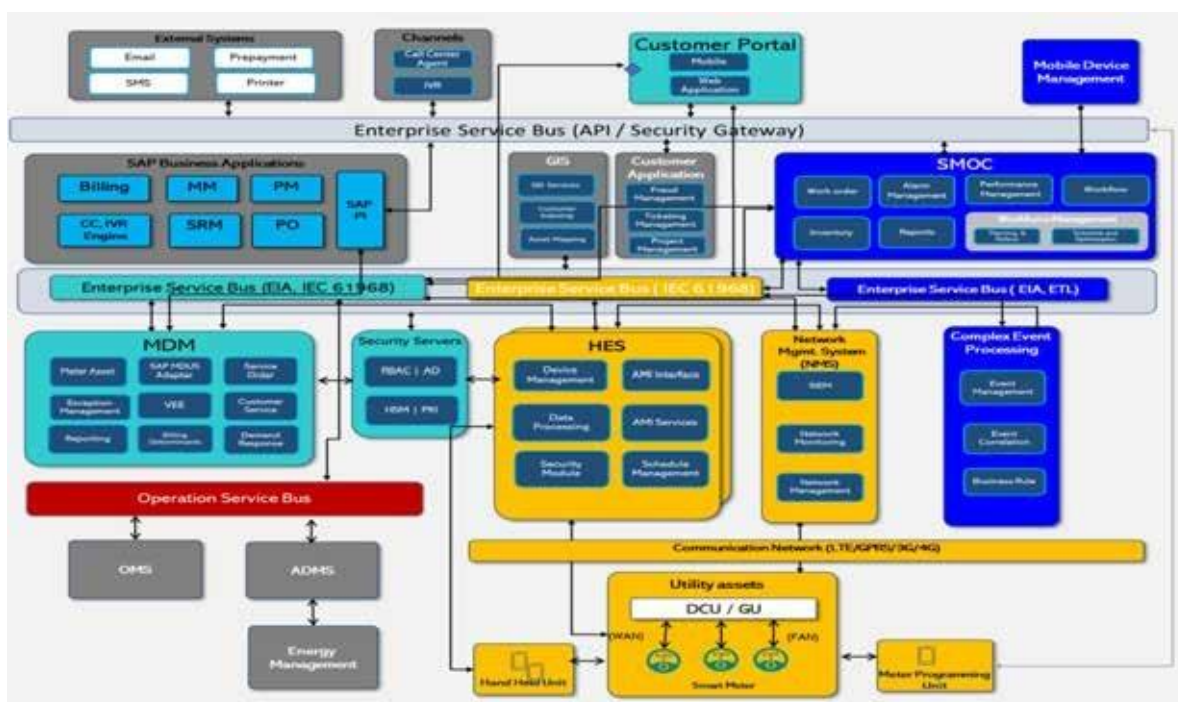


Figure 5-1: AMI solution components

The AMI ecosystem should not only address basic functionalities of the smart metering system defined by CEA, but also capable of integrating with AMI functions such as AMI Field Services, AMI meter Management System, AMI Network Management System etc. The integration with other systems like Distribution Automation System (DAS), Outage Management System (OMS), Customer Information System (CIS), Material Management/Warehouse Management System (WMS) etc. for current and future use cases. The AMI system helps utilities to manage their resource and business process efficiently, it shall support the following minimum functionalities:

- Remote meter data reading at configurable intervals (Push/Pull)
- Time of day (ToD)/Time of Use (ToU) metering
- Prepaid/Post-paid functionality
- Net metering
- Alarm/Event detection
- Remote load limiter and connection/disconnection at defined/on demand conditions
- Remote firmware upgrade



- Integration with other existing systems like call centre, billing and collection software, GIS maps, consumer indexing, new connection and disconnection, analytics, Outage Management System, field force management etc.
- Import of legacy data from existing modules/MDAS of R-APDRP wherever possible
- Security features to prevent unauthorized access to the AMI including smart meter and meter data etc. and to ensure authentication of all AMI elements by third party

5.1 Necessary Hardware/Software Technologies and Services

The below diagram shows the necessary hardware/software technologies and services.

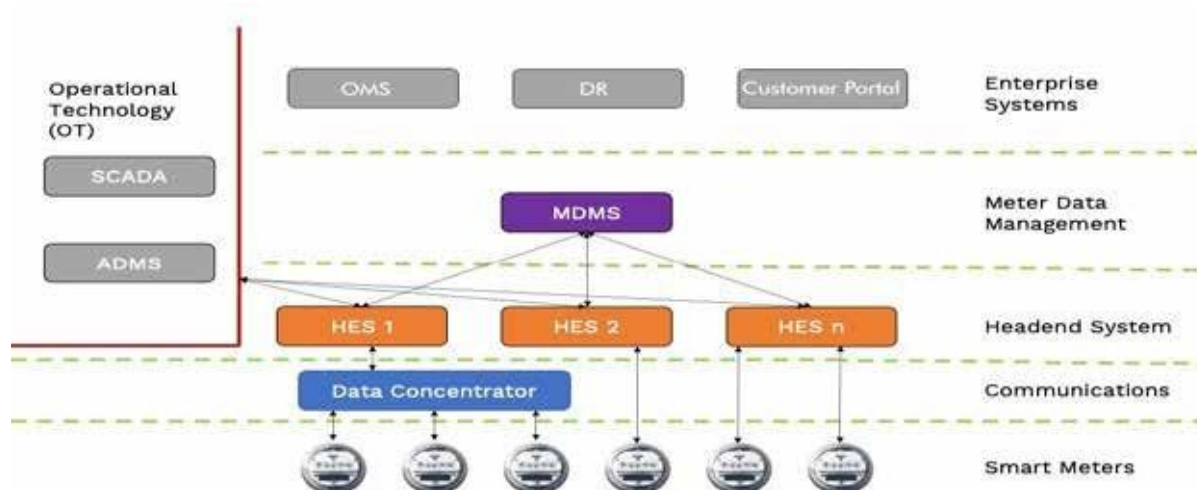


Figure 5-2: Hardware/Software technologies and services

5.1.1 Smart Meters

Smart meters should comply with the utility smart meter technical specification for single phase, three phase whole current and CT operated meter. The smart meter specification should be in lined with DISCOM purchase policy and AMI rollout plan. The interoperability between different devices and relevant applications (Meter/Repeater/DCU/HES/MDM) shall be ensured while going ahead with single vendor/multi-vendor purchase. It should be ensured that the meters have valid BIS certification.



Figure 5-3: Smart meters



The smart meter installation shall be done by either trained DISCOM meter installers or by the AMI implementing agency as per the practices of DISCOM. There are software application available to support end-to-end meter installation process, DISCOM should take help of such applications for the meter installations, if the decide to install the meters by their own workforce. It should be decided beforehand that, where the remote connect and disconnect switches will be fixed (Inside meter/outside meter) looking into the trade-off of metre tampering and switch maintenance.

After meter installation, required parameters shall be updated in DCU/HES/MDM, the information should also be available on portal/app for providing information to consumers. All meters falling under one DCU shall be commissioned and checked for proper communications in presence of utility in-charge.

5.1.2 Communication Infrastructure

The communication infrastructure planning should be done on the basis of individual area and the suitable communication technology for the same. Radio frequency communication/RF mesh network/ PLC or cellular network or a combination of these can be an option based on technical feasibility. The communication network shall comply with suitable standards from ITU/IEC/IEEE/CEN/CENELEC/ETSI for HAN, NAN and WAN network. Communication network shall ensure reliable two-way communication between various nodes (Smart meter/DCU/Repeater/Modem) and HES. Smart meter/DCU should must support over the air firmware up-gradation for better maintenance of the communication network. In case of RF based network license free frequency band should be adopted. Though the engagement of cellular operator falls in the scope of AMI implementing agency, a thorough check for network availability of different service provider shall be done by DISCOM to ensure the required performance level.

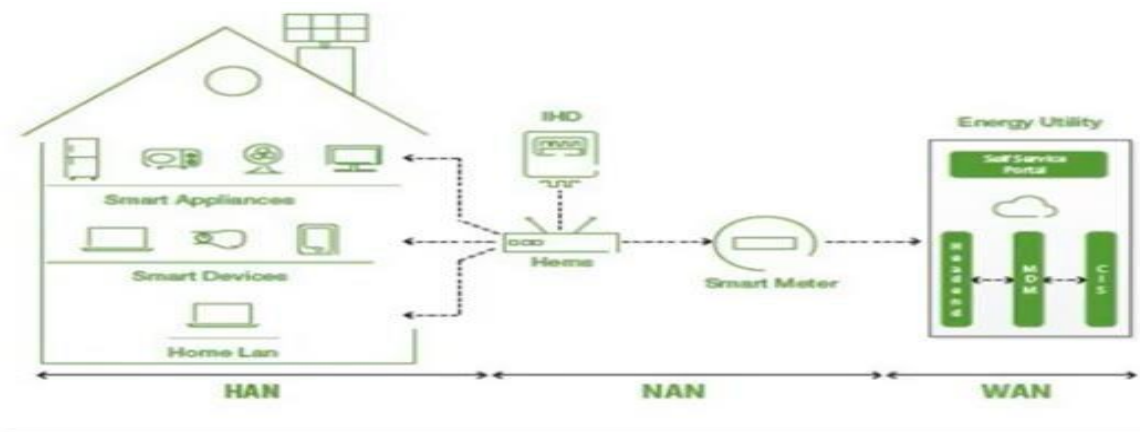


Figure 5-4: Communication infrastructure

5.1.3 Head End System

The HES acquires meter data through a communication channel without any human intervention and monitor the same. HES should support the collection and storage of data with adequate scalability in line with DISCOMs future planning. It should perform all the requisite functions with the help of the requisite software and hardware to achieve the defined service level agreement (SLA) of AMI. HES shall ensure data integrity and be developed on open platform based on distributed architecture for scalability without compromising the performance of the system it shall support storage of raw meter data, alarms and alerts with optimum data security.



HES should manage data from a multitude of field devices and applications. It shall support integration through web services/APIs to exchange data with other systems like third party MDMs, billing, GIS, OMS, streetlight management system, and SCADA etc. The solution/system shall be Service Oriented Architecture (SOA) enabled. It shall be able to integrate with telecom service providers' M2M platforms for deriving status of cellular SIM cards of gateways, DMS nodes, Network Interface Card (NIC). This should interface with MDMS over SOA/Web services, and the data exchange models and interfaces shall comply with CIM/XML/IEC 61968/62056.

It shall provide real time information about the network and its associated systems like AMI field service, work force management system. The various functions shall include:

- Two way communication with meter/repeater/DCU
- Maintain time sync with DCU/meter
- Encryption of data for secure communication
- Signals for meter connect and disconnect
- Acquisition of meter data in push and pull mode (On periodic interval and on demand)
- Store raw data for defined duration
- Audit trail and event and alarm logging
- Handling of control signals/event messages on priority
- Setting of smart meter configurable parameters
- Communication device status and history
- Network information in case more than one technology is deployed in field between the two devices
- Critical and non-critical reporting functionality
- Alarms and event log for meter events like tamper/power failures etc.
 - If data is not received from DCU/Meter
 - If relay does not operate for connect/disconnect or there is communication link failure with DCU/Meter or network failure while non-critical events may be retry attempts on communication failure
 - Periodic reading missing and failure to connect etc.

5.1.4 Meter Data Management System (MDMS)

The MDMS shall support storage, archiving, retrieval and analysis of meter data and various other MIS along with validation and verification algorithms. It shall act as a central data repository and have ability to import raw or validated data in pre-defined formats and export the processed and validated data to various other systems and services in the required format. It shall provide validated data for upstream systems such as billing, customer care, analytics, reporting, and load analysis, load forecasting, PLM and OMS etc. MDM should also support the future requirement of DISCOM and should facilitate the integration of other smart grid functionalities like distribution transformer health monitoring system, self-healing system etc. as required by the DISCOM. MDM should provide revenue protection support as well as demand control/demand response support.

MDM must integrate with modern service oriented architectures in order to manage the data across the many systems, applications and processes that run the business. It must seamlessly integrate with various applications, and all Business Intelligence (BI) systems, designed to bring the right information in the right form to the right person at the right time.

It helps to run the operation more effectively and ensures better decisions making. In addition to supporting and augmenting SOA and BI systems, the MDM applications must support data governance



for defining the data definitions, standards, access rights and quality rules. MDM executes these rules. MDM enables strong data controls across the enterprise. The MDM applications must have the following characteristics:

- A data quality function that can find and eliminate duplicate data while insuring correct data attribute survivorship
- A data quality interface to assist with preventing new errors from entering the system even when data entry is outside the MDM application itself
- A continuing data cleansing function to keep the data up to date
- An internal triggering mechanism to create and deploy change information to all connected systems
- A user interface to support casual users and data stewards
- A data migration management capability to insure consistency as data moves across the real time enterprise
- A business intelligence structure to support profiling, compliance, and business performance indicators
- A single platform to manage data objects in order to prevent the proliferation of information on top of the existing fragmentation problem
- An analytical foundation for directly analysing master data
- A highly available and scalable platform for mission critical data access under heavy mixed workloads
- A comprehensive data security system to control and monitor data access, update rights, and maintain change history

The DISCOM should specify the performance level for the defined number of smart meters with facility of scalability. It should have the ability to selectively choose data to be maintained or to be archived as per requirement.

5.1.5 Customer Engagement Platform (CEP)

CEP offers a comprehensive web portal plus a mobile interface built as a progressive web app to enhance the utility customer experience with online account management, bills and payments, usage tracking, and virtual agents for customer's service. The utility companies can improve their Meter-to-cash performance by integrating with Demand Side Management systems to create individual offers and services to various customer segments.

- Customer Relationship Management:
 - Enhanced customer experience and reduced service costs with Chatbots
 - LiveChat
 - Service Management
 - Self-help
 - Online Account Management
- Outage Alerts:
 - Specifying the outage alerts to the customer
- Utility's Analytics:
 - It provides the analytics solutions to the customer which provides different consumption graph
 - Reductions graphs and many more
- Customizable communication preferences:



- Meter-to-cash performance improvement with integration with Demand Side Management systems
- Create individual offers and services
- Display existing tariff and incentives rates, participation options in alternate plan

5.1.6 Outage Management System

An outage management system (OMS) predicts and tracks resolution of power outages and other similar events (e.g., unsafe conditions such as wires down) in a utility's electric distribution system. An OMS is important on blue sky days, but it becomes the centre of the utility's universe during major weather events and facilitates various services.

- Outage prediction:
 - The OMS uses outage information from all sources in combination with the connectivity information of the electric distribution model to predict the most likely source(s) of the problem(s):
 - Service outage isolated to a single customer or to a group of customers
 - Transformer outage
 - Outage at a higher-level device on the feeder (fuse, recloser, etc.)
 - Entire feeder is out
- Calculate Estimated Time of Restoration (ETR):
 - Throughout the outage event, an estimated time of restoration (ETR) is calculated and updated based on the latest information. The customer may be given a default ETR (e.g., "2 hours") until more information is known about the fault and restoration job status
 - The OMS may calculate an ETR for the job based on the total number of events outstanding, priority of the job, number of crews available, etc.
 - The crew may give an updated ETR once they have assessed the situation onsite
- Confirm restoration, detect nested outages:
 - OMS allows to detect the nested outages as well
- Outage correction:
 - An outage correction switch plan may be used after-the-fact to represent exactly what switching actions happened at exactly what time in order to better represent how long each impacted customer was out—this results in more accurate outage metrics
- Planned outages and switching: The OMS can also keep track of planned outages.
 - The group needing the outage submits a request
 - A switching plan and steps are created (minimizing the number of customers out and the duration of their outage when possible), checked and approved
 - The outage is scheduled—any impacted customers are notified
 - The planned outage steps are executed

5.1.7 Demand Response System

MDMS is capable to integrate with existing Demand Response (DR) system(s) to receive the DR program events, analyse, process, and store these events and can further be integrated with mobile app/portals to send the notifications to the participating customers.

- DR Event Notification



- MDM can receive the DR event notifications from other external systems
- Analysis of DR Event
 - MDM can perform different analysis based on the DR program such as calculating the baselines
 - Load reductions and preliminary baselines
 - Sending notification to the customers through different modes such as email
 - Mobile and other mobile apps
- Incentive / Penalty Calculation
 - MDMS can do the incentive penalty calculations for the DR program
- Generation of Load Report
 - MDMS allows to integrate with different external systems which allows to meet the reporting requirements of the customer

5.2 Smart Meter Operations Centre (SMOC)

Field deployment of smart meters is one the biggest challenges that DISCOMs face in their smart metering programmes. A dedicated Smart Meter Operations Centre (SMOC) can overcome the obstacles and significantly reduce rollout risk. It will help in taking accountability for the overall field deployment and coordination across all business functions. The right approach to field deployment can result in a saving of 20% -30% in rollout's final operational costs.



Figure 5-5: Smart meter operations centre

Smart Meter Operations Centre (SMOC) facilitates:

- Platform for business intelligence
- AMI events management
- Centralized project management office
- Enterprise asset management and monitoring
- Consumer and consumption analytics
- Smart metering RoI matrix tracking (e.g. revenue protection and load planning etc.)
- Consumer engagement modelling
- SLA management
- Service ticket management for helpdesk
- Training simulator

SMOC provide following real time visibility to end consumers:

- Consumer billing and energy profile information



- Prepayment information
- Consumer centric analytics
- Alerts on account information updates
- Home energy profiles
- Consumer self service
- Cost saving tips
- Customized communication, DISCOM branding, customer service and feedback

The diagram shown below depicts the external systems as BESCOM existing systems and the SMOC solution components. BESCOM existing solutions, SMOC and other packages are represented by different colours in system diagram. The same color legend has been used in other relevant diagrams also. The system diagram gives an overview of the different systems involved for SMOC solution implementation and a high level view of information flow between systems.



5.2.1 SMOC Systems and Resources

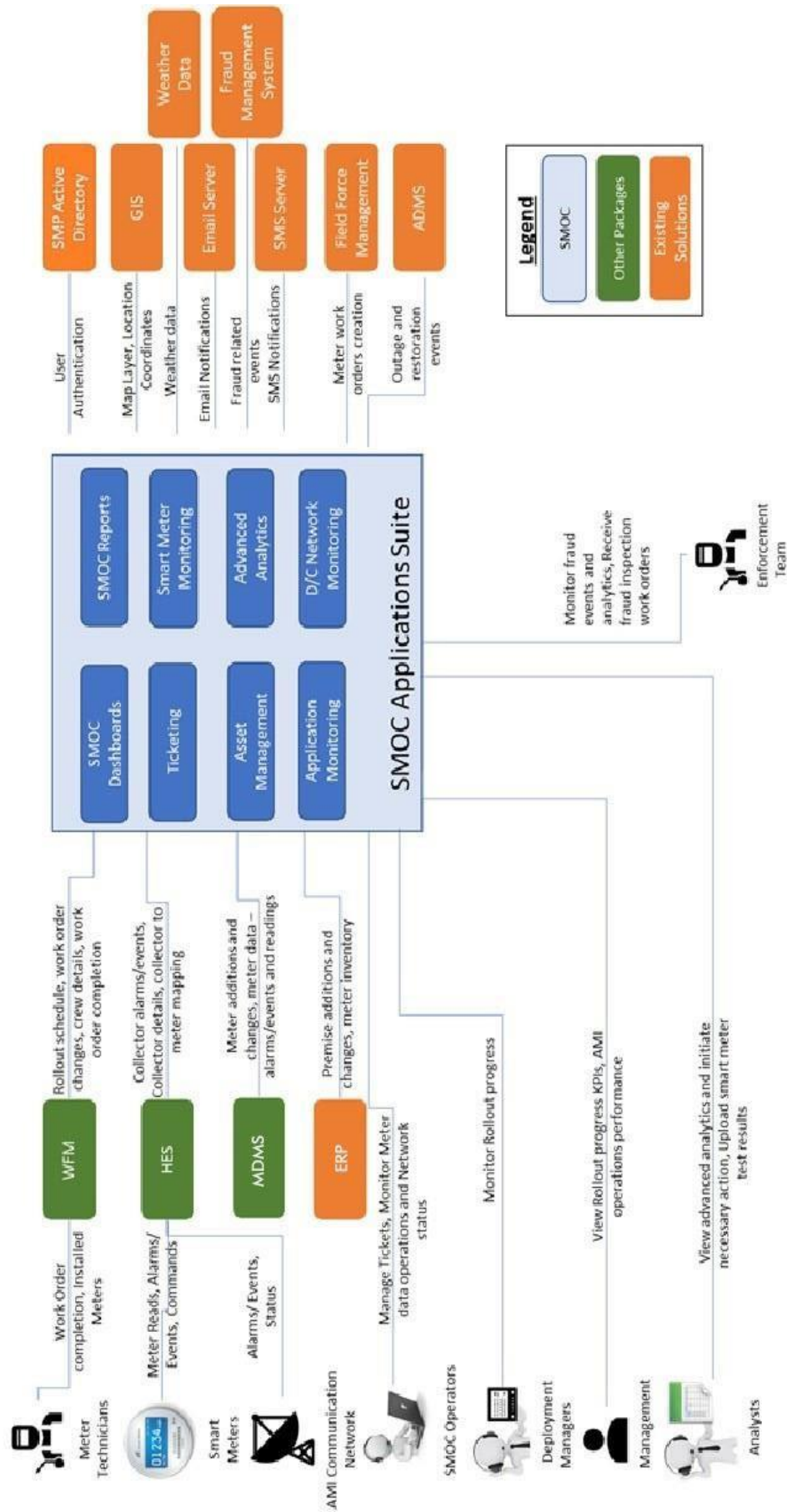


Figure 5-6: SMOC system and resources



The details of different systems involved and resources required for SMOC are as follows:

5.2.2 SMOC Application Suite

SMOC dashboards and reports: SMOC dashboards and reports should be implemented using best of breed analytics solution to show KPIs related to meter rollout, meter operations, and select transaction reports. Data required for dashboards will be sources from external systems and SMOC systems.

Ticketing: Ticketing system will be part of SMOC solution and will be responsible to store ticket details related to SMOC operations. Users can login and create/update tickets related. In some use cases, tickets are also automatically created by other SMOC solution components using APIs.

Smart meter monitoring: The smart meter monitoring solution would be responsible for receiving the alarms and event generated by smart meters. This would be used for the identification, classification and collation of events to flag potential theft, fraud and faults.

Asset management solution: The asset management would be the single point for the aggregation of the meter asset information, along with associated required customer details using additional fields. This information is maintained via integration from an external system through the API. The repository would itself not be the master of the information, rather they would reflect the status as propagated by the system that own the data.

Advanced analytics: This component is responsible for building models using Artificial Intelligence and Machine Learning algorithms to do predictive analytics for fraud, faults and theft. The product that would provide the functionality is python.

IT application monitoring and DC network monitoring: This component provides monitoring of the IT/networking devices in the production zone for SMOC, monitoring of the important virtual machines in the production zone SMOC, monitoring the key parameters for critical application in the production zone for SMOC.

5.2.3 Existing Applications

Active directory: Active directory will store the username and passwords for all applications in smart metering program.

Geographical Information System (GIS): GIS will store the location details of all smart metering assets smart meters and AMI communication network devices. GIS is based on ESRI ArcGIS platform.

Email server: Email server will be responsible to send emails to users for predefined notification rules. SMOC solution will integrate with server to send email notifications.

SMS server: SMS server will be responsible to send SMS to users for predefined notification rules. SMOC solution will integrate with SMS server to SMS notifications.

Field Force Management (FFM): Field force management handles work orders to be executed by staff. SMOC solution will integrate with FFM to create work orders related to smart meter installation, inspection (meter faulty and fraud), replacement and removal. Work orders will be created in FFM for use cases meter related activity is to be performed by staff.

Advanced Distribution Management System (ADMS): ADMS include systems to monitor and control the electricity distribution network for activities like fault location, isolation, outage identification,



restoration etc. ADMS typically includes SCADA, DMS, OMS and field equipment like feeders, transformers, sensors, circuit breakers etc. As part of smart metering implementation, ADMS will be receiving outage and restoration events from smart meter to manage outages.

Fraud Management System: Fraud management system will be responsible to handle fraud related cases. As part of smart metering implementation, fraud management system will be receiving the fraud events captured by smart meters and triggering predefined business process.

5.2.4 Other Applications and Resources

Workforce Management System (WFM): WFM is the tool used to create and manage work orders related to smart meter deployment. These work orders also capture the smart meter details that are installed and non-smart meter details which are removed from site. WFM provides smart meter deployment work orders created, status updates to smart meter deployment work orders and details of smart meters installed.

Head End System (HES): HES is the system which will be the gateway between smart meters and the enterprise application layer. HES has capabilities to enable smart meter registration/activation into BESCOMs AMI network followed by activities like remote meter reading, firmware/configuration updates and command execution.

Meter Data Management System (MDMS): MDMS is responsible to receive data from multiple HES, run validation and exception rules. MDMS acts as the primary source of meter data for all other external systems. For SMOC solution, MDMS is expected to be one of the major sources of data.

SAP: SAP is the customer information system used in BESCOM and has details of all electricity consumers in BESCOM area. SAP will be providing all premise details covered in smart meter deployment schedule, and the inventory details of smart meters.

Meter Technicians: Meter installers are responsible to replace the non-smart meters to smart meters or all activities related to smart meter management e.g. smart meter installation, inspection, removal.

Smart Meters: Smart meters are communication enabled electricity meters along with other features like relay for supply disconnection, local storage for different types of meter reads and events, capability to accept commands remotely from Head End systems etc.

AMI Communication Network: AMI communication network is the network back bone through which smart meters send meter data to Head End systems. AMI communication network will consist of different network devices.

SMOC Operators: SMOC operators will be responsible to monitor the smart meter rollout progress and operations using SMOC and non SMOC solutions. During the monitoring process, SMOC operators will initiate actions through systems or offline methods to resolve issues remotely or through technician's onsite.

BESCOM Deployment Managers: BESCOM deployment managers are responsible to monitor the rollout progress of smart meter replacement and work with installation companies to plan and resolve issues if any.

BESCOM Management: BESCOM management team will be viewing the KPIs related to smart meter rollout and operations using SMOC dashboards.



BESCOM Analysts: BESCOM analysts will be viewing the output of SMOC advanced analytics and initiating necessary action either through systems or offline.

BESCOM Enforcement Team: BESCOM enforcement team is responsible to monitor fraud related alarms/events from smart meters and take necessary action. BESCOM Enforcement team will also receive work orders for potential fraud based on which site inspection is done by them.

5.2.5 Key Architectural Design Principles

Following architectural decisions have been considered in the SMOC solution.



Figure 5-7: Key architecture design principles

Scalability:

- **Infrastructure scalability:** The infrastructure should be scalable to meet the varying demands, website traffic, application development or production needs, new applications, load tests etc.
- **Data scalability:** Support scale of input sources both in terms of number of source systems and transaction/event volume of each source system. Solution should contain capabilities to scale horizontally without disturbing the base architecture.
- **Application scalability:** i) Design ensure that new applications can be added without major impact on overall system; ii) Should ensure it can be scaled easily for new capacity augmentation (like increase in number of application user).

Performance:

- Design should consider, various workloads and data access patterns and have clear logical boundaries to perform storage, compute and balanced workloads
- Design should ensure that the query response time(s)/time(s) for analysis/transformation does not get negatively impacted with scale

Modularity: Architecture should be modular and component based to allow the existing components to be used to design new functionality or to interface other solutions.

Cloud: Application should be ready to run on cloud computing infrastructure. Cloud native means the software was designed and built using cloud principles.



Integration: The solution should have ability to integrate and interoperate with other applications using open standards and integration methods, be it Legacy systems or other future data and analytics applications/platforms.

Reliability:

- It is achieved by tools that can notify, alert and if possible, predict node, disk or application failure. Failure of node, disk or any network component should not affect the overall functionality
- The solution should be designed in such way that it will serve users even when confronted with node failures or network partitions

Interoperability: The proposed solution must have open and industry standards for interoperability and the solution components shall be standard based and adopt an open approach rather than support a specific technology.

Service Oriented Architecture (SOA): AMI solution components must follow SOA principles to provide specific services using well defined interfaces and service driven architecture at the core of it. AMI system features can be accessed via any user interface (Internal or third party applications) which shall work on top of these services. Adoption of open standards are of paramount importance for the robust and scalable AMI system.

Business Continuity and Disaster Recovery: Disaster recovery services to ensure continuity of operations in the event of failure of primary data center meet the Recovery Point Objective (RPO), Recovery Time Objective (RTO) and failover requirements.

Cyber Security: It's becoming clear that there's a need to implement better security for critical infrastructure. Of even more pressing need is the transition from old, serial based networks to more modern IP based infrastructure. This move requires the incorporation of corporate network security controls into critical infrastructure networks.

Micro Services: Micro services is a popular, modern practice; with the help of Micro services different component of AMI can be segregated in different small services which can be deployed and operated independently for each other.

5.3 SMOC Enterprise Architecture

The architecture overview gives an overview of the SMOC solution and its components, and the external systems sending or receiving data from SMOC.

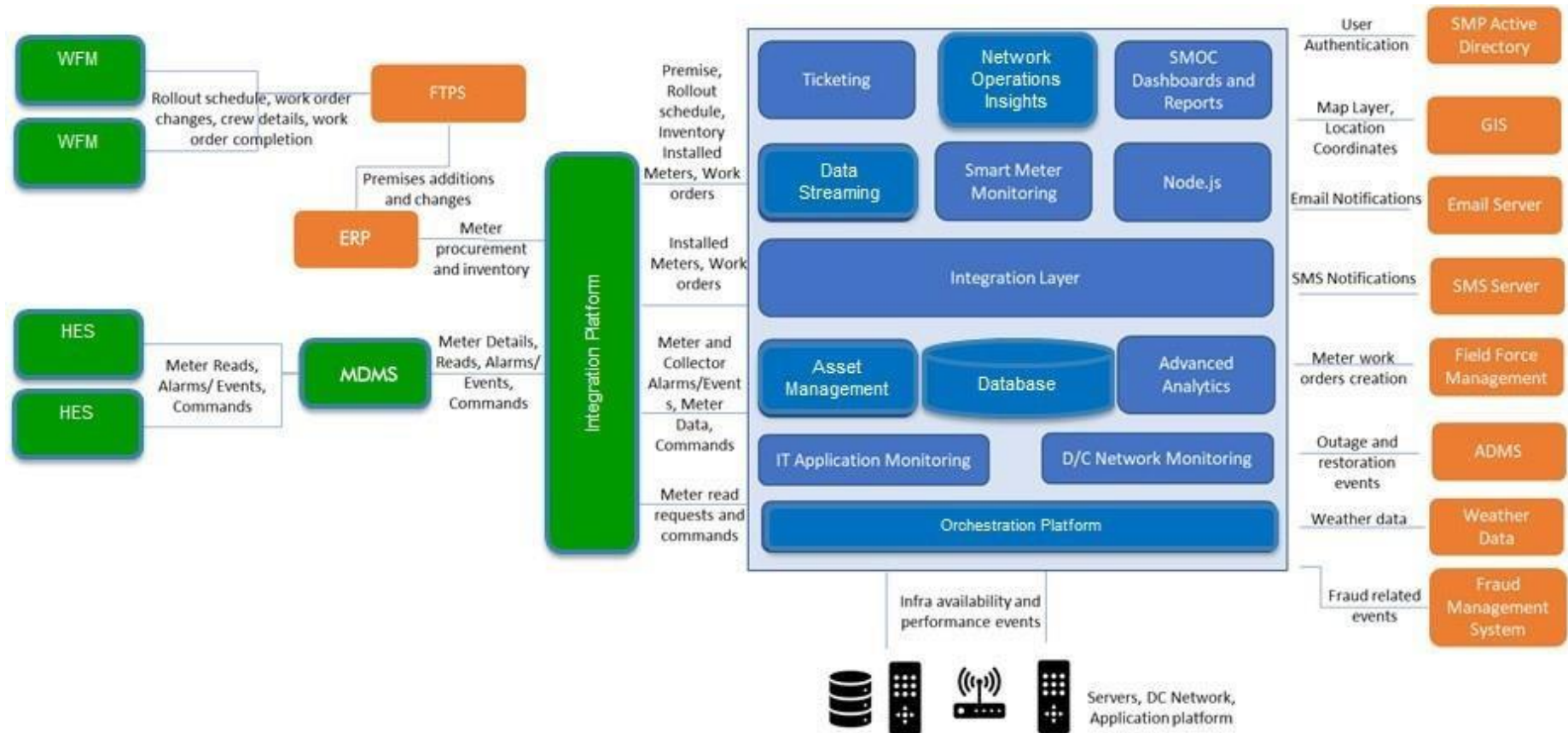


Figure 5-8: SMOC solution architecture



There SMOC is shown as a system and different resources/actors participation in the system. Here the application suite has been elaborated and the overall architecture of the solution is shown, several subsystems architecture has been shown in subsequent pages where talking about specific functionalities.

FTPS server: The File Transfer Protocol on SSL (FTPS) server will be holding all the CSV file extract provided by source systems.

Integration platform: Integration platform is the enterprise service bus/middleware which will push data to SMOC solution or receive requests from SMOC depending for various use cases. Integration platform will be responsible to integrate with downstream and upstream applications and BESCOM systems and provide required data to SMOC.

SMOC integration layer: This layer will be used to integrate SMOC with external systems in this project.

Scalable, distributed and high performance data streaming platform: This platform will be used to implement SMOC where near real time alarms shall be analysed.

In large scale smart meter rollouts establishing the SMOC is very essential to manage data collection, data integration, data provisioning and data analytics.



Figure 5-9: AMI data processing

5.3.1 SMOC Asset Management

Best of breed asset management solution should be implemented to meet the asset management requirements of smart meter program. It will maintain consumer premises, smart meter assets and collector assets. The asset management would be the single point for the aggregation of the meter asset information, along with associated required customer details using additional fields. This

information is maintained via integration from an external system through the API. The repository would itself not be the master of the information; rather they would reflect the status as propagated by the system that own the data. Following modules will be implemented:

- **Service address:** A premise is a physical location where smart meter has to be installed (The existing one has to be removed and smart meter has to be installed). The physical location of AMI communication devices (Collectors) will also be stored in service address application.
- **Work order:** Work order tracking application will be used to create and update work orders for smart meter assets and premises where smart meters are installed.
- **Assets:** The assets application will be storing details of smart meters assets and the AMI communication network device assets.
- **Labour:** The Labour application will be storing details of labour working on maintaining smart meter assets and AMI communication network devices.

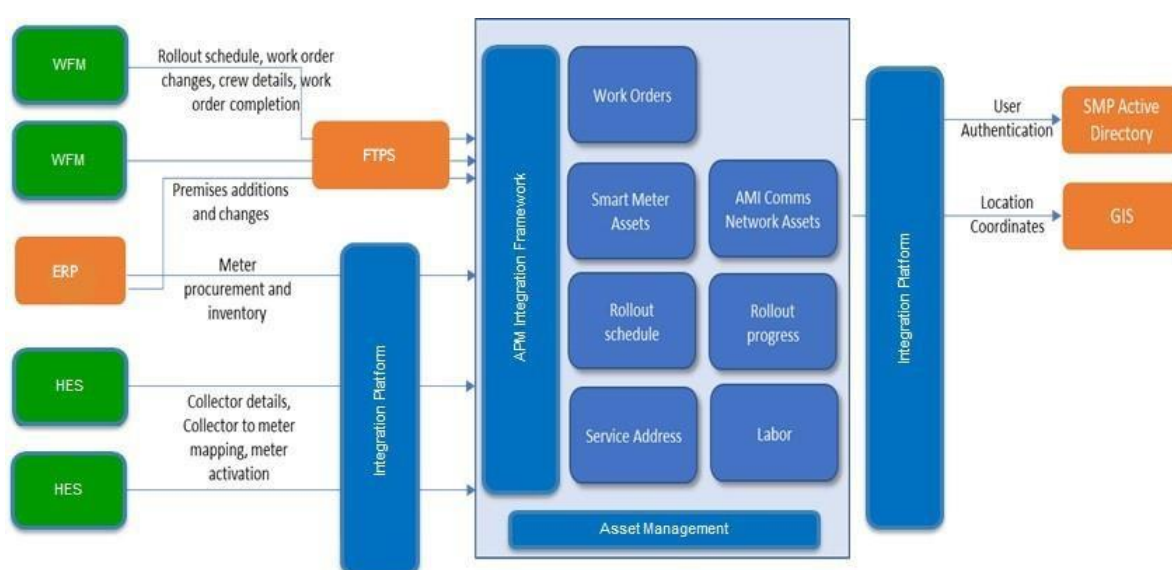


Figure 5-10: SMOC asset management

5.3.2 SMOC Dashboards and Reports

The dashboards will provide various graphical and tabular views along with KPIs related to smart meter rollout and meter data operations. These views will be provided by sourcing data from multiple SMOC and non SMOC systems and presented in visualization layer.



Figure 5-11: SMOC dashboard and reports

5.3.3 Smart Meter Monitoring

The smart meter monitoring solution would be responsible for receiving the alarms and events generated by smart meters and AMI communication network devices (Collectors). This would be used for the identification, classification and collation of events to flag potential theft, fraud and faults.

Following modules will be configured in smart meter monitoring:

- **Operations Management (Alarm Management):** This module will receive alarms and events from smart meters and collectors from MDMS (smart meter alarms and events) and HES (collector alarms and events). The events and alarms will be grouped logically for those with similar names.
- **Alarm views:** This module will provide dashboard views of the alarms and events coming from smart meters, collectors and DC network devices. In these views, users can acknowledge, escalate, prioritize events and also initiate new tickets in ticketing system.

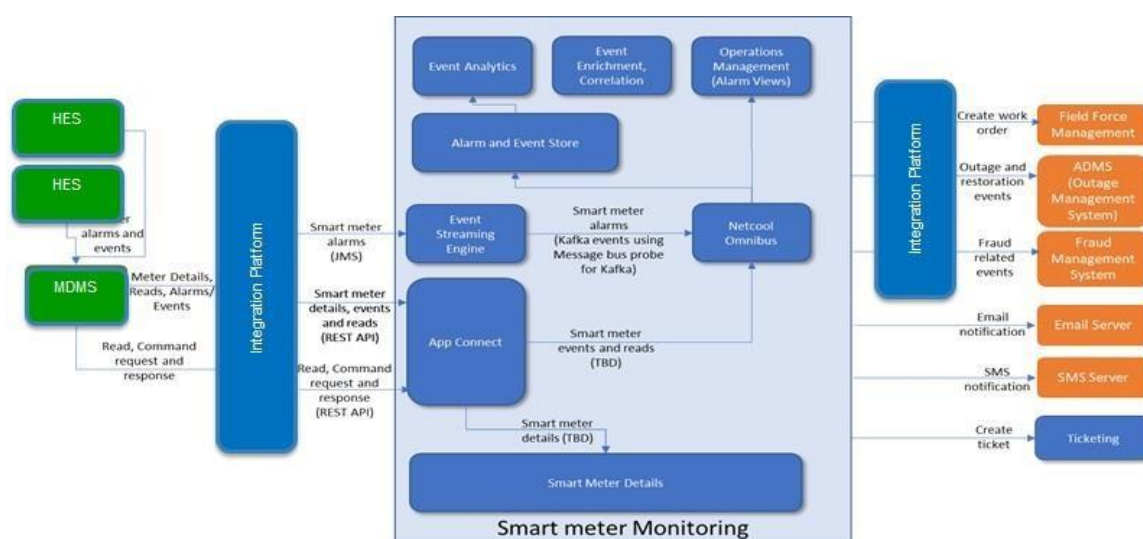


Figure 5-12: Smart meter monitoring

5.3.4 Ticket Management using Control Desk

Control desk will provide functionalities for creation and lifecycle management of the ticket either manually or through automated process on identification of a problem in the smart meter events or IT events or via manual observation on the SMOC dashboard.

Following functionalities will be configured in control desk:

- **Incident management:** This module will provide interface for raising and managing all the real time incidents by users and also provides additional interface for automations to raise incidents in real time.
- **Problem management:** This module will provide interface for raising and managing all the problem cases by users and also provides track of problem resolutions.
- **Workflows:** This module will provide automations for creating automatic workflow management for incident and problem cases.

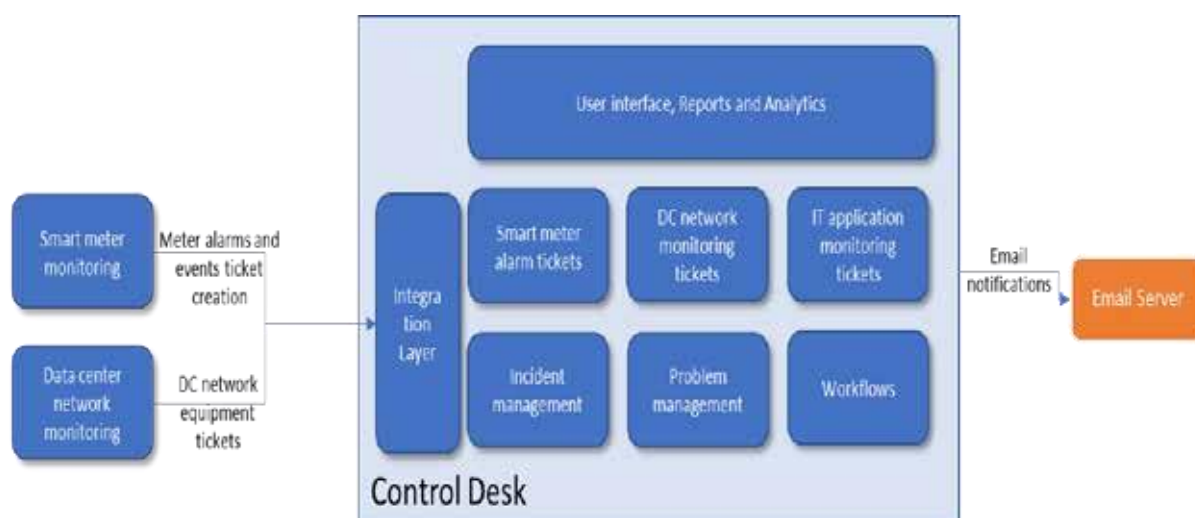


Figure 5-13: Ticket management using control desk

5.3.5 IT Application Monitoring

IT Application monitoring will provide monitoring of IT/networking devices, virtual machines infrastructure monitoring and application performance parameters.

- Monitoring of the IT/networking devices in the production zone for SMOC
- Monitoring of the important virtual machines in the production zone SMOC
- Monitoring the key parameters for critical application in the production zone for SMOC

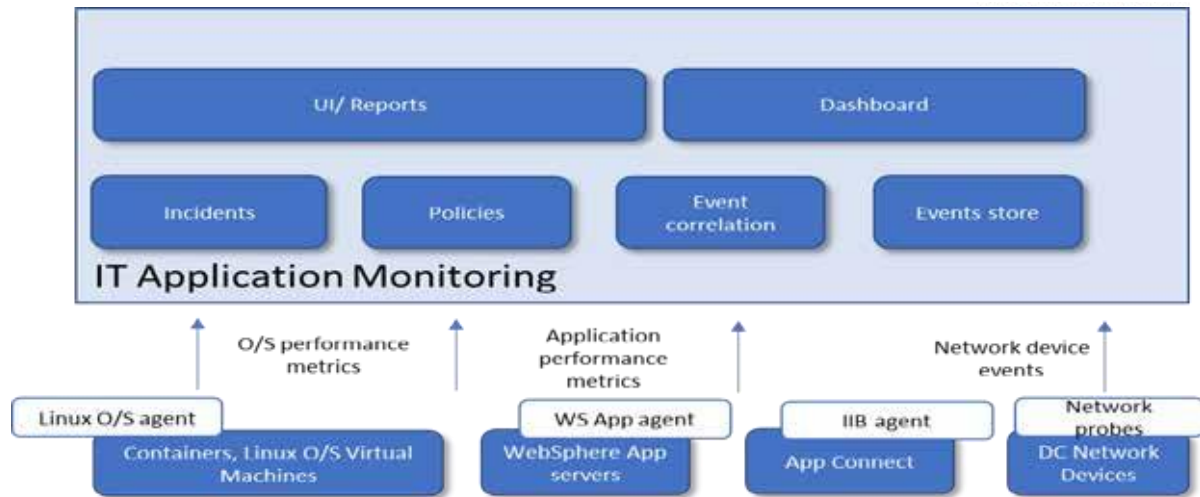


Figure 5-14: IT application monitoring

5.4 System Integration Framework

SMOC integration involves integration of SMOC components with external applications and BESCOM existing systems. SMOC integration also includes integration between SMOC applications. The interfaces between the MDMS and other DISCOM systems should be done in way so that it provides efficient processing and minimises processing time and it must ensure sufficient flexibility to accommodate future system change.

- **Use SOA:** A SOA enables to reduce the cost of development and enhancing flexibility to accommodate continuing advances in AMI technologies.
- **Flexibility and data reuse:** Enterprise Application Integration (EAI) service buses can be leveraged as the preferred interface both between the AMR systems and the MDMS and between the MDMS and backend applications.



5.5 KPI Targets of AMI System

AMI system performance largely depends upon network service provider and AMI implementing agency. The desired performance level of the system is as follows:

Table 5-1: Key performance indicators

SI No	Requirement	Performance Level
1	Collection of daily meter readings (as per IS 16444/15959 part 2)	1. All interval data from 95% of meters within 8 hours after midnight 2. All interval data from 99.9% of meters within 24 hours after midnight
2	Remote reads of individual meters if data is not received on daily basis.	1. Action performed at 90% of meters within 1 Hour 2. Action performed at 99% of meters within 2 hours 3. Action performed at 99.9% of meters within 6 hours
3	Remote load control commands for selected consumers	1. Action performed at 95% of meters within 5 minutes 2. Action performed at 99% of meters within 10 minutes
4	Remote connect/disconnect for selected consumers	1. Action performed at 90% of meters within 10 minutes 2. Action performed at 99% of meters within 1 hour 3. Action performed 99.9% of meters within 2 hours
5	Meter loss of supply and outage detection	1. Alarms to be received within 5 minutes for 90% of meters
6	Remotely altering settings in meter/ firmware upgrade	1. Action performed at 99% of meters within 24 hour 2. Action performed at 99.9% of meters within 36 hours
7	Remotely read events logs	1. Action performed at 90% of meters within 30 minutes 2. Action performed at 99% of meters within 1 hour 3. Action performed at 99.9% of meters within 6 hours
8	Reading the event logs pertaining to all meters	1. The data pertaining to 99.5% of meters with in 1 day
9	Updating of data on consumer portal/app. The performance level of updating of individual consumer data on portal/app after receiving the data in MDM.	1. Action performed for 90% of consumers within 1 hour after receiving the data in MDM 2. Action performed at 99.5% of meters within 6 hour after receiving the data in MDM
Performance Requirement for User Interface		
10	Any real time display and application display on workstation console along with data values shall appear on screen.	1. Within 2 sec
11	Manual data entry of the new value appears on screen	1. Within 2 sec
12	Display update rate	1. 2 sec for 4 displays together
13	Response time for display of alarm and event after receipt in system	1. Within 1 sec of receipt in system
14	Requests for printing of displays (To be acknowledged with an indication of request is being processed).	1. Within 2 sec

15	Requests for generation of reports (to be acknowledged with an indication of request is being processed).	1. Within 2 sec
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Note: * The performance level for generation of bills would be as per requirement of the utility.

*The performance levels are average performance levels over the period of a year and exclude force majeure events.

5.6 Pay-for-Performance Program

Pay-for-Performance (P4P) model for the implementation of smart metering or AMI programs is an innovative business model proposed by ISGF way back in 2016 in a White Paper³. Based on the experience of Indian DISCOMs in implementation of Automated Meter Reading (AMR) for feeder meters as part of the R-APDRP projects in various states during 2009-2015 period, ISGF proposed this new model of engaging a Metering Services Agency (MSA) who will be responsible for selection of appropriate technologies for the AMI system, select project partners and OEMs, implement the entire AMI system and maintain it for ten years. The DISCOMs will specify the SLAs and based on the performance will pay a monthly fee per meter for ten years. In this scenario, there is no risk of wrong technologies and non-performing assets accumulated by DISCOMs.

This model was first adopted in a partial manner by EESL under the Smart Meter National Programme (SMNP) in Uttar Pradesh and other states. EESL has already implemented 1.6 million smart meters in this model where DISCOMs have not made any upfront payment to EESL; instead paying INR 87-110 per meter per month.

Based on the success and acceptability of the EESL projects in UP and Bihar, Ministry of Power has adopted the P4P model in a TOTEX form (15% upfront payment and rest on monthly payments per meter for 84 months) in the Standard Bidding Documents (SBD) for rollout of 250 million smart meters under the RDSS program.

5.7 KPIs and SLAs

The AMI implementation agency shall be measured on certain KPIs and SLAs during the Built-up & Deployment, Implementation & Go live and O&M phase. The AMI implementation agency shall only get compensated if their work meets the basic parameters in KPI and SLA as mentioned below. The agency shall provide daily/monthly reports for these parameters. (e.g. total number of instances of portal being down in a month, latency of UI, availability etc.).

Table 5-2: Performance criteria with penalties

Data Type	Performance Requirement (averaged over a month)	Penalty
1. Scheduled Tasks		
1.1 Scheduled Interval data readings		
Periodic collection of the interval (Assuming 30 minutes interval, may be changed based on the	From 95% of meters within 8 hours	Deduction of 0.2% of Monthly Fee for every 1% or part there of capped at 1% penalty

³ Give the link of ISGF White Paper: https://indiasmartgrid.org/report_register.php?report_id=73



specific AMI cluster requirement) load profile data for the day		
1.2 Scheduled Interval data readings		
Periodic collection of the interval (Assuming 30 minutes interval, may be changed based on the specific AMI cluster requirement) load profile data for the day	From 98% of meters within 12 hours	Deduction of 0.2% of Monthly Fee for every 1% or part there of capped at 1% penalty
1.3. Scheduled daily meter readings		
Previous days (All previous days from the last billing cycle) interval energy and total accumulated energy	From 99.5% of meters within 24 hours after midnight	Deduction of 0.2% of Monthly Fee for every 1% or part there of capped at 2% penalty
1.4. Scheduled billing profile data for the bill period		
Collection of billing data for the bill period	From 99.5% of meters before the next periodic collection is scheduled.	Deduction of 0.5% of Monthly Fee for every 0.5% or part there of capped at 3% penalty
2. Remote Actions / tasks performed by AMI System		
2.1 For remote connect/disconnect with acknowledgement/ response for selected meters		
Remote connect / disconnect of the AMI meters	Action performed at 90% of meters within 15 minutes	Deduction of 0.5% of Monthly Fee for every 0.5% or part there of capped at 2.0% penalty
2.2 For remote connect/disconnect with acknowledgement/ response for selected meters		
Remote connect / disconnect of the AMI meters	Action performed 99.5% of meters within 6 hours	Deduction of 0.25% of Monthly Fee for every 0.5% or part there of capped at 1.0% penalty

Source: REC

The HES implementing agency shall be measured on certain KPIs and SLAs during the Implementation and O&M phase. They shall only get compensated if their work is of high quality and bears maximum efficiency. The basic parameters in KPI and SLA are mentioned below. HES implementing agency shall provide daily/monthly reports for these parameters. (e.g. total number of instances of portal/CMS/mobile application being down in a month). The table below shows the performance criteria and service level agreements along with penalties for HES Specific service levels.

Table 5-3: Service levels for HES specific services

SI No	Parameter	Service Level
1	Offline actions between HES and MDMS	80% completed in 7 seconds and 99% within 30 seconds
2	On demand actions carried out on High Priority	1) Action performed at 90% of meters within 1 Hour (2) Action performed at 99% of meters within 2 hours; and (3) Action performed at 99.9% of meters within 6 hours.
3	On demand actions carried out at Low Priority	95% completed within 24 hours and 99% within 72 hours



4	Actions carried out on predefined Schedule date and time	90% completed within 1 hr. of scheduled date and time and 99.9% within 24 hrs. of scheduled date and time
5	Recurring data delivery actions	95% completed within 8 hours after midnight and 99.9 % within 24 hrs. after midnight.
6	Alerts and notifications	95% submitted to HES in 5 minutes of occurrence and 99.9% within 24 hours
7	7A: Actions related to Firmware5 upgrade or rollback activity for asset population < 10,000	95% of individual assets to be modified (updated or rollback) within 3 working days of scheduled date (update) or requested date (rollback) and 99% of individual assets to be (updated or rollback) within 5 working days of scheduled date (update) or requested date (rollback)
	7B: Actions related to Firmware5 upgrade or rollback activity for asset population > 10,000 and <50,000	95% of individual assets to be modified (updated or rollback) within 10 working days of scheduled date (update) or requested date (rollback) and 99% of individual assets to be (updated or rollback) within 15 working days of scheduled date (update) or requested date (rollback)
	7C: Actions related to Firmware5 upgrade or rollback activity for asset population > 50,000	95% of individual assets to be modified (updated or rollback) within 30 working days of scheduled date (update) or requested date (rollback) and 99% of individual assets to be (updated or rollback) within 90 working days of scheduled date (update) or requested date (rollback)
8	Performance level for remote load control commands for selected consumers	(1) Action performed at 95% of meters within 5 minutes;
		(2) Action performed at 99% of meters within 10 Minutes
9	Performance level for remote connect / disconnect for selected consumers	(1) Action performed at 90% of meters within 10 minutes;
		(2) Action performed at 99% of meters within 1 hour; and
		(3) Action performed 99.9% of meters within 2hours.

Source: Intellismart

The urgency is classified in four categories:

- Critical: If not dealt with immediately the service will escalate many times over within a short time-period or Incident has Tax, Legal or Statutory impact
- High: If not dealt with in the very near future (within the half day) the service will escalate severely till solved
- Medium: If not dealt with in the near future (within 2 days) it will impede business/ IT processes
- Low: All others



Table 5-4: Severity levels (P1/P2/P3/P4)

Severity Levels (P1/P2/P3/P4) are decided based on these two dimensions through the following grid				
Urgency	Extensive	Significant	Moderate	Minor
Critical	P1	P1	P2	P1
High	P1	P2	P2	P2
Medium	P2	P2	P3	P4
Low	P3	P3	P3	P4

Table 5-5: Penalty applicable for different severity level

Applications support	Expected	Minimum	Penalty (% of monthly O&M charges)
Incident Response Time	99.00%	95.00%	0.50%
P1 Severity Level Incidents Responded within 15 mins	99.00%	95.00%	0.50%
P2 Severity Level Incidents Responded within 30 mins	99.00%	95.00%	0.50%
P3 Severity Level Incidents Responded within 90 mins	99.00%	95.00%	0.50%
P4 Severity Level Incidents Responded within 120 mins	99.00%	95.00%	0.50%
Incident resolution time			
P1 Severity Level Incidents Resolved as agreed	2 Hours	2 Hours	1% (for every P1 incidents breaching SLA) beyond which 0.1% per hour per incident
P2 Severity Level Incidents Resolved as agreed	8 Hours	8 Hours	1% (for three P2 incidents breaching SLA) beyond which 0.05% per hour per incident
P3 Severity Level Incidents Resolved as agreed	16 Hours	16 Hours	0.5% (for five P3 incidents in a month) beyond which 0.02% per hour per incident
P4 Severity Level Incidents Resolved as agreed	32 Hours	32 Hours	0.5% (for ten P4 incidents in a month) beyond which 0.02% per hour per incident

EESL has signed MoUs for smart meters with Andhra Pradesh, Uttar Pradesh, Haryana, Bihar, NDMC-Delhi, Rajasthan, and Telangana and for prepaid meters with the states of Uttar Pradesh and Tripura.

Table 5-6: IRR calculation for smart meters

Year	@25% S/W Cost	@ 40% S/W Cost	@ 50% S/W Cost	
2022	-3629	-4536	-5444	Smart Meter Cost 4536 Hardware 2722 Software 1814
2023	1031.4	1031.4	1031.4	
2024	1031.4	1031.4	1031.4	
2025	1031.4	1031.4	1031.4	



2026	1031.4	1031.4	1031.4	
2027	1031.4	1031.4	1031.4	Software Cost @ 25% 907 @ 40% 1814 @ 50% 2722
2028	1031.4	1031.4	1031.4	
2029	1031.4	1031.4	1031.4	
IRR	21%	13%	8%	

UPPCL being the Nodal Agency for Smart Meter Rollout in Uttar Pradesh is paying 85.95 INR per month for 7 years to EESL. The revenue generated by the meter is INR 1031.40 (85.95X12) per annum. The Internal Rate of Return can be calculated with the help of below mentioned three scenarios. It is assumed that the software cost of the meter can vary from 25 % to 50%, whereas with 40% software cost the IRR is 13% as shown in the table above.



06 Business Models

6.1 Cost Estimates and Cost-Benefit Analysis of AMI

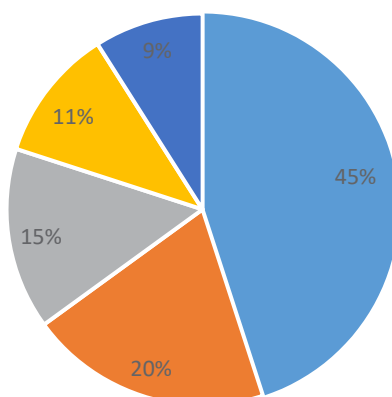
6.1.1 AMI - Drivers and Stakeholders

- **Government Regulations:** Through regulations, tax structures, cost recovery mechanisms, and financing, governments can play an essential role in stimulating the implementation of AMI. The rules that ensure interoperability, define the scope of data privacy, and set long-term cost-benefit criteria. The GoI is assisting DISCOMs by enacting various schemes and regulations to help them strengthen their power sectors. The government is taking AMI deployment on a larger scale and at a faster speed more seriously. The GoI has recently made a determined effort to promote smart meter deployment under the SMNP, which intends to replace 250 million traditional meters in India with smart meters.
- **Cost Savings:** Meter readers do not need to physically access smart metres to take a reading since they are fully digitized. This results in significant cost savings for DISCOMs, as these employees may be utilized for other activities, reducing the need for new hires. Smart meters can also help DISCOMs to save money by maximizing the use of existing resources. Smart meters communicate real-time data to DISCOMs, allowing them to make fully informed decisions about where to deploy assets, especially when distributed energy resources are involved. Increased load does not always necessitate increased infrastructure, and smart meters can assist DISCOMs to determine when this is the case. DISCOMs can use AMI data to enhance billing accuracy, reduce consumer complaints, and resolve billing disputes faster. AMI allows DISCOMs to discover and notify customers of unexpected usage trends ahead of time, before bills are sent out. Pre-pay billing services, which help customers avoid defaulting on payments, can also help DISCOMs to increase revenue collection and cost recovery. Apart from that, enhanced tamper and theft detection capabilities provided by AMI deployments improve revenue collection and reduce costs.
- **Ability to offer new rates and services:** Many attempts have been made to enhance the progressive billing mechanism of the electricity rate, and ToU pricing is emerging as a viable option, that refers to the segregation of energy rates based on the time in which the energy is being consumed. ToU is a way in which DISCOM providers attempt to alleviate demand during peak periods by enforcing a tariff structure that charges an increased rate within the typical peak. AMI is capable of introducing a variable dynamic pricing mechanisms into the system, as well as a variety of services related to E-mobility, particularly for EV charging.

Apart from these, many technical parameters act as a driver for AMI deployment considering reliability, managing distributed energy resources, and positive environmental impact.

6.1.2 AMI System Costs

The total capital costs of deploying AMI include the hardware and software costs (meter modules, network infrastructure, and network management software for the AMI system), as well as installation costs, meter data management, project management, and information technology integration costs.



■ Endpoint Hardware ■ Network Hardware ■ Installation ■ Project Management ■ IT

Figure 6-1: AMI costs

6.1.3 Cost Benefit/Cost Value Analysis Fundamentals

- Costs: Total Costs for a program
- Benefits: All the benefits (avoided costs, deferred costs, intangibles and value adds)
- Interest rate, discount rate, minimum attractive rate of return (MARR)—all mean the interest rate to use in the calculation
- Rate of return, return on investment, and internal rate of return—all mean the “interest rate where the present worth of the investment equals the present worth of the savings.”
- Simple Payback (SPB) is the number of years before the savings “payback” the investment
 - $SPB = \text{Investment} / \text{Net Annual Savings}$
- Salvage Value is the value of the equipment at the end of the project life. Sometimes salvage value is positive and sometimes it is negative
- Rate of Return and Payback
- Net Present Value – Time Value of Money

6.1.4 Case Studies

The following case studies reflect the experience of numerous international electrical utilities with the rollout of AMI. Where possible, information was gathered from representatives of each utility who were directly involved in the implementation effort. Within the context of these case studies, a full implementation represents 100% completion within the scope of each utility’s project.

ONCOR: ONCOR is an electric utility based in the southern region of the United States, which operates the largest distribution and transmission system within the state of Texas. The utility supplies power to about 7 million consumers, covering an area of over 120,000 miles of distribution and 14,000 miles of transmission lines. The utility’s AMI deployments started in 2008 and they have since completed a rollout of about 3.5 million smart meters to date. ONCOR employs a two way communications network, using a 900 MHz RF mesh network with smart meters that utilize large capacitor packages.

AMI Cost Savings: Since the AMI rollout, ONCOR has remotely completed almost 17 million service orders, eliminating the need to drive over 114 million miles, resulting in savings of up to 9.5 million gallons of fuel.



ONCOR AMI Deployment: The average new meter installations per day was about 3,500. Supporting the smart meter rollout, ONCOR also launched an extensive consumer education campaign, teaching their customers the benefits of smart meters. The smart meters record consumption every 15 minutes and ONCOR has established a Smart Meter Web Portal allowing consumers to access and review their electricity consumption.

Southern California Edison (SCE): SCE, the largest subsidiary of Edison International, is the primary electricity supply company for much of Southern California, United States. It provides 5 million customers with electricity across a service territory of approximately 50,000 square miles.

AMI System and Communications: The communication system is composed of three infrastructure subsystems: WAN, FAN and LAN. For instance, the WAN infrastructure subsystem may include high-speed fiber; 4G cellular; 5G cellular; and dedicated, utility owned, cellular point to multipoint or point-to-point systems.

Table 6-1: SCE smart connect costs and benefits

USD Millions, Nominal		Deployment Costs	Post Deployment Costs	Deployment Benefit	Post Deployment Benefit
Operations	Capital	1187.9	410.2	86.5	341.6
	O&M	258.3	823.1	170.7	3704.4341.6
	Total	1446.2	1233.3	25701	3704.4
Demand Response	Capital	38.8	16.3	70.3	4046.0
	O&M	148.5	332.6	110.2	161.8
	Total	187.3	348.8	180.5	2792.0
Total (Operations and Demand Response)	Capital	1266.7	426.4	156.8	2953.8
	O&M	406.8	1155.7	280.8	503.4
	Total	1633.5	1582.1	437.6	6496.3
Total		3215.6		7437.3	6999.7

SCE AMI Deployment: As the largest rollout of smart meter technology ever undertaken in the United States, SCE's Smart Connect project demanded a comprehensive, multi-layered solution – one that could define new business and technical processes before addressing the myriad logistical issues associated with implementation.

Phase I: Project planning for business process design, initial systems integration work, development of a test plan, and development of a policies and procedures manual.

Phase II: Pilot installation and testing of systems integration work and execution of the test plan, including the installation of approximately 10,000 meters.

Phases III and IV: Full meter deployment of approximately 5.2 million meters. The main contractor, CORIX, was responsible for residential installation, including all personnel, AMI inventory, equipment, warehouse and office space, software, and work management tools. Teams from SCE conducted the equivalent implementation for commercial customers. Meter deployment was conducted as a geographical rollout with each sector installed and tested across the state.

Utility Case Study – AMI Cost Benefit Analysis

Table 6-2: AMI cost calculations

AMI Cost Calculations		
Number Customers		579393
	Capital (USD)	Annual O&M
Software Implementation		
Application specific software cost	2800000	560000
Application hardware cost	1300000	260000
Software integration cost	852431	35508
Customer web portal development	NA	NA
Total software cost	4952431	855508
Meters and Installation		
Average material cost per meter	119.5	
Installation labour cost per meter	24.8	
Vendor project management cost per meter	10.76	
Percent damaged meter base repair cost	0.2%	
Average damaged meter base repair cost	900	
Total hardware cost	102338272	
Metering Communication		
Fixed network (Cost per meter)	1.8	
Installation cost for network per meter	0.77	
Vendor project management network cost per meter	3.46	
Total communication cost	3939192	1900000
Project Management		
FTEs required	16	1
Annual cost per FTE	210000	250000
Total project management	3380000	260000
Training		
Customer training		
Employee training	400000	50000
Business process changes	554000	55400
Total training cost	954000	106400
Total initial cost	116643896	3110908
Annual Ongoing Capital Cost		
Annual meter replacement cost	1143402	

Table 6-3: AMI benefit calculations

AMI Benefit Calculations	
Meter Reading Savings	
Normal read – Total cost to read per month	963993
Number of meters per month	579393
Average cost to read per meter	1.66
Special read – Average percent of meter per month	3.2%
Special read – Average number of meters per month	18541
Special read – Cost to read per meter	3.58
Special read – Total cost to read per month	66375
Monthly meter reading cost	1030368
Workforce reduction – Percentage	95%
Adjusted monthly manual meter reading cost	978850
Total annual savings	11746198
Customer requested – Connect/Disconnect	
No. of Meters per month	11588
Average cost to connect/disconnect per meter	19.78
Total manual connect/disconnect	458416
Field collection for Non-pay	



Number of field site visit per months	1333
Percent disconnect (Repeat visit required for reconnect)	45%
Average cost for field site visit	20
Total Non-Pay field collection	38667
Workforce reduction - Percentage	85%
Adjusted monthly manual meter reading cost	422520
Total annual savings	5070241

Table 6-4: Cost benefit analysis for AMI

Cost Benefit Analysis for AMI		
Item	Base Case 5-year Deployment	Base Case 10-year Deployment
Costs (Cumulative 20 years)		
O&M expenses for AMI system	665	653
New capital investment for AMI system	996	1031
Sub Total	1661	1684
B. Operational Benefits and Delivery Service Revenues (Cumulative 20 years)		
Operational efficiencies and Cost reductions	1625	1539
Avoidance of capital expenditure	3	3
Collection of delivery service revenues due to reduction in UFE and CIM	564	531
Sub total	2192	2073
C. Additional Benefits (Energy, Transmission and Other Rider Cost Reductions and Revenues) (Cumulative 20 Years)		
Reduction in energy purchased power costs due to reduction in UFE and CIM	708	667
Collection of energy and other revenues due to reduction in UFE and CIM	1051	991
Reduction in bad debt expenses	791	745
Sub Total	2550	2403
D. Total (Cumulative 20 years)		
Benefits less costs	3081	2795
E. Net Customer Impact		
Net Present Value (NPV)	1296	1152
Discounted payback period (Customer perspective)	8 years	9 years

6.2 Business Models

6.2.1 Drivers of AMI Business Case

The total cost of AMI deployment and the payback period differed significantly from utility to utility, revealing the plethora of elements which go into determining a utility's unique business case. The total cost of the AMI procurement and installation included not only the meter, but also a variety of non-meter fixed costs, including communications equipment upgrades and data management systems. Software and licensing fees, installation labour, information technology testing and requirements gathering, project management, software integration, and staff training were among the non-hardware costs.

Total implementation cost and the rate of return on AMI investments are determined by multiple factors:

- **Full scale implementations** generally has a lower total cost per meter because AMI



communications network upgrades, data management system integration, and other fixed installation costs make up more than half of the total cost per meter on average. The meter device cost represented only about 47% of the total cost per meter on average. The total cost per meter reported by the pilot scale projects skews the distribution, because the integration of communications equipment and information systems is a fixed cost that is allocated across a relatively smaller numbers of meters. Once the communication networks and data management systems are in place, the incremental cost per additional meter typically drops.

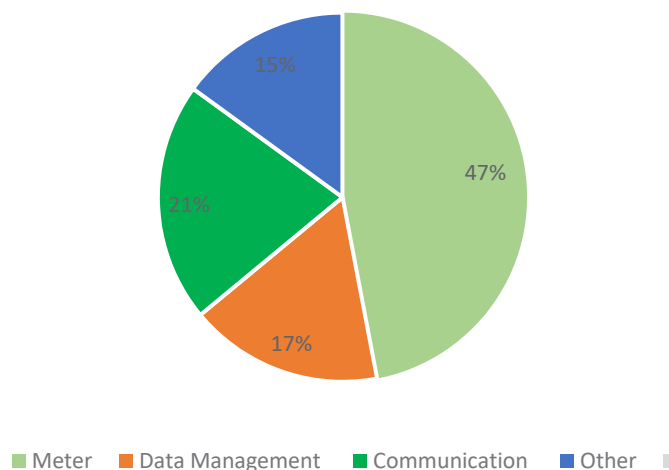


Figure 6-2: Average installation cost per meter breakdown in USA
(refer **Appendix III** for Smart Meter Status in USA)

- Enabling smart meter features and integrating AMI with a larger number of utility systems can raise the total AMI implementation cost, but also increase the value of benefits to support the business case. Additional functions enhanced revenue recovery from tamper detection, reduced outage management costs, enhanced voltage monitoring, and reduced peak demand from AMI enabled DSM programs.

Customer outreach and education contribute to overall cost, and vary by project. Some utilities may experience push back from customers who are concerned about the perceived risks of smart meter health effects and data privacy intrusions. Smart meter opt-out provisions are offered to address these concerns.

Table 6-5: AMI business models

Business Model	Model Description	Considerations
Capex Model	- A part of the payment made on the supply of material - Remaining amount structure over the project deployment and operations, generally in equal monthly instalments	- Payment terms linked to implementation milestone and predefined Service Level Agreements (SLAs) - Detailed Bills of Quantity (BOQ) to be determined at tender stage
Savings Model	- Minimal/ Zero upfront payment by utility - Payment based on realization of benefits (Recovery capped at return expectations of the funding agency)	- Payment terms linked to meeting agreed project saving KPIs - Requires creation of utility governance structure with nominated officials for decision making and monitoring of project



		• Payment terms to consider timely installation • Should have clearly defined and agreed baseline and M&V methodology
Lease Model	• Payment over a specified tenure on a per consumer per month basis • Features of the lease model can also be structure with capex, and/or saving models to bring elements of other models also. As an example, for the recent Smart Meter procurement by EESL, its investment recovery from utilities in UP and Haryana is in form of lease payments over the project lifecycle (10 years)	• Payment terms to consider timely installation and meeting of defined equipment SLAs • Detailed BOQ may not be required for tendering however need to be specified for reference and use

Utilities may decide to adopt aforementioned models on the basis of their own unique characteristics, financial and risk appetite. They approach asset ownership through one of two models: the managed service provider model and the utility owned model. The choice is driven largely by the type of regulatory environment within the region, but security often plays a role as well.

6.2.2 Utility Owned Model

The assets are owned and operated by the utility. This model's main attributes are as follows:

- The utility is responsible for procurement, finance, implementation and upgrades
- The utility must anticipate formal IT teams and processes for scheduled upgrades
- There is potential to participate in bulk purchasing
- The potential for stranded assets is high

The utility owned model is the most common approach. The prevalent regulatory paradigms are to accountable for this. Despite a recent shift toward utilities contracting AMI as a managed service, the complexity of integration and limited cost recovery alternatives have resulted in the majority of existing large deployments being done by utilities.

Since each utility's value streams provide a unique set of advantages, the AMI business case differs from utility to utility. The procurement, installation, and integration of smart meters, communications equipment, and data management systems, as well as organizational costs, are all included in the AMI business case. As a result, the following must also be included: Fees for software and license, labour for installation, information technology testing and requirements gathering, project management, software integration, and employee training.

6.2.3 Managed Service Provider Model

In the managed service provider model, the assets are owned and operated by a service provider. The main attributes of such an arrangement are as follows:

- Hosted/SaaS/lease model approach
- Vendor manages installation, upgrade
- Vendor owns performance service-level agreements
- Operational cost model, with minimal capital costs
- Telecommunications and security are critical

- Change management is the responsibility of the service provider

There are several managed service providers of Field Area Network (FAN) communications, AMI headend, and backhaul communications that have deployed their offerings worldwide. Quite often, the AMI head end is provided as a hosted solution on the utility's data centers.

6.2.4 Finance Build Own Operate Transfer (BOOT) Approaches

The Smart Metering programme implemented by EESL in various states, has a unique characteristic of seeking no upfront capex requirements from DISCOMs or state governments wherein all investments for installing and operating the meters over the years, along with complete digital backend IT systems for remote operations, is being undertaken by IntelliSmart. IntelliSmart implements the Smart Metering (AMI) solution under BOOT Model. The DISCOMs are required to pay the monthly lease rentals only and that too out of the savings they make due to smart meters, over the operations period. This model would work on the lines of Pay as you Save (PAYS) approach.

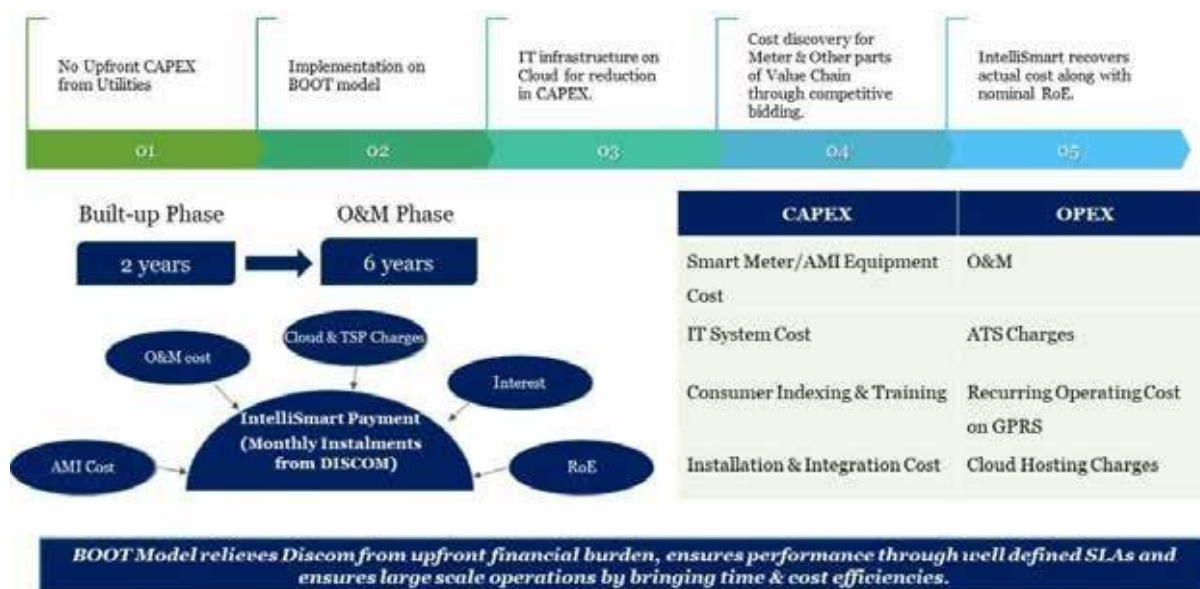


Figure 6-3: IntelliSmart business model

Key Component costs:

- Cost incurred for AMI components. (Project CAPEX)
- OPEX (O&M/FMS Expenses, Cloud Hosting Charges, ATS/AMC and GPRS charges) during the project period
- Project Management Cost (PMC)
- Interest and financing charges
- Return on Equity
- All the cost components shall be excluding GST and other applicable statutory taxes and shall be charged extra as per actual

6.2.5 Other Innovative Business Model

Innovative business models may be explored to eliminate the technology risk for the DISCOMs. Also business models that reduce the capex and requirement of technical manpower to maintain the AMI system at the DISCOM may be considered favourable. One such business model where in AMI is



provided as a service for a monthly fee per customer is described in Appendix II. In this model, a financial intermediary such as a bank or any other financial institution will procure the smart meters and lease them to the utility against a monthly rent for a period of ten years. Since AMI involves expertise in three distinct domains, namely, metering, telecommunication and information technology (including both software and hardware), and experience from around the world shows that no one agency could master these distinct components of AMI, it is proposed to appoint a Metering Services Agency (MSA) who will be responsible (along with their sub-contractors and associates) for a variety of functions related to implementation of AMI and its maintenance.

6.2.6 Cost Recovery

Across utilities and geographies, a variety of cost recovery mechanisms are in use. Localized regulatory models by country, state, or province drive these. The cost recovery models can be divided into several categories:

- **Regulated rate increases:** The DSO negotiates with the regulators on the costs and rate of return for the AMI deployment. This model is used in North America.
- **Market based rate increases:** The charges are passed on to ratepayers based on market principles and regulatory guidance on cost-benefit analyses at the utility or DSO level. This is the European Union's model.
- **Rate of return model:** In this approach, regulators create detailed definitions of expenses, interest rates, and other critical characteristics in order to calculate a rate of return that includes an inflation adjustment. In Australia, this model is used.
- **Cost per meter benchmark:** For cost recovery purposes, the regulators evaluate the nominal cost of adopting AMI in terms of a "per meter" benchmark. This was popular in Australia, but it is no longer in use. The Australian Energy Regulator (AER) established a "Revised Order" that became the key tool for determining metering service pricing. The new Order outlined a fundamentally different approach to pricing: a cost pass-through model in which rollout budgets are defined in advance and annual charges are calculated based on actual expenditure. The final report from AER, which included a computation of the Weighted Average Cost of Capital (WACC), established a return for costs linked to AMI adoption while establishing minimal performance standards.
- **One time incentives with a time window:** The DSO pays for AMI deployment with a onetime incentive (tax write-offs or subsidies). These are frequently used in conjunction with other models to strengthen the business case, as well as a stand-alone cost recovery model.
- **Proportional or annual penalty levies:** If the DSO fails to deploy AMI and smart meters within a mutually agreed-upon time range, penalties will be applied. Several EU countries, notably Germany, utilize this form of penalty.

6.3 Evaluation of Business Models to Finance the AMI Project

DISCOM should take a rigorous approach to identify costs and benefits in order to appropriately decide which AMI programs to pursue and when. The business cases can be decided on the basis of following factors:

- The cost assumptions should be both holistic (all-inclusive) and conservative (no overlapping benefits) in order to appropriately account for all program benefits



- It is common for a project lifecycle to be considered over a 20 year period to align with most vendor warranty periods. Alternative scenarios can consider the effects of different deployment paces and timing of expected benefits
- The most robust financial models will allow a utility to compare several scenarios with a simple toggle to turn the programs on or off and automatically recalculate the financial metrics
- The industry trends seem to indicate that most utilities are moving towards a preference for hosted/SaaS solutions. Ultimately, the decision process should consider IT strategic plans, budget and resource availability at the utility



07 AMI Rollout Recommendations

7.1 Technology Selection Guidelines

The DISCOMs may priorities the customers and locations for deployment of AMI according to feeders having majority of customers with high monthly consumption (>1000 units, >500 units, >200 units), feeders with high AT&C loss (>15% feeders) and feeders with high annual energy sales. AMI rollout may be undertaken for all feeders that will enable online energy auditing. All new meters to be purchased from July 2016 to be smart meters conforming to the latest amendments of IS 16444 and IS 15959. Selecting a smart meter involves considerations across four domains: features, technology, applications envisioned, and vendor. Based on study analysis, DISCOMs prioritized different domains when selecting a smart meter.

Table 7-1: Smart meter technology selection guidelines

Features	Technology	Applications	India and Global Vendors
• Instantaneous voltage and current • Peak voltage and current • System frequency • RMS voltage and current • Power Factor • Instantaneous Apparent and Real power • Capacitor for events and alerts • Network interface cards	• Single, Three phase metering • Firmware • Meter settings/configuration • Point to Point (Cellular/SIM cards) • Mesh	• Interval consumption measurements • Register reads • Meter health/status • Voltage sags and swells • Temperature sensor alerts • Tampering alerts	• L&T • Landis+Gyr • Genus • GE • Trilliant • Secure • Sensus • Aclara • Bosch • Fluent grid • Gram power • EDF • NEDO • Synergy SS • Enzen Global • Nsoft India Service • Dongfang Electronics • Wipro • ECIL • Chemtrols • Schneider Electric • Techno Electric

Source: NSGM



7.2 System Integration Framework

To ensure that the overall metering services are efficient and accurate, all the components must be integrated so, they work together as one system. The process of system integration involves integrating AMI, MDMS, CIS and billing systems with each other. Additionally, depending on the DISCOMs capabilities, OMS, DMS, and other Distribution Automation (DA) systems can be integrated as well, increasing the benefits of the smart grid technology. Although system integration can involve many technical challenges, it should be one of the first factors a DISCOM addresses when planning a smart metre rollout. Typically, services from vendors are procured to assist in this process if it cannot be handled in-house. Software often requires additional development to allow for the integration of these systems.

Additional systems that DISCOMs are now starting to integrate web portals, time-based rates, incentive programs, and customer devices. Information system integration is typically an ongoing process within DISCOMs; however, when done correctly, it can provide diversity of new functions that can improve the efficiency of operation. AMI can be used to integrate a wide range of applications.

- Customer Relationship Management (CRM)
- Enterprise Resource Planning (ERP)
- Work Order Management
- Accounting
- Asset management
- Customer service

Putting all of the data collected by the smart devices together and understanding of it is essential for DISCOMs taking full advantage of AMI. Integrated applications can improve the efficiency, reliability, and customer service. Smart meter analytics is a fast expanding area in which DISCOMs can collect, analyse, and evaluate the data in order to make better business approach to increasing revenue. In developed countries, DISCOMs have attempted for using AMI data to:

- Allow for meter-to-cash applications
- Improve operational efficiency
- Improve outage management
- Enhance situational awareness through advanced data analytics
- Serve as a precursor to distribution automation etc.

7.3 Customer Engagement Strategies and Outreach Mechanisms

While operational and economic benefits can be achieved by DISCOMs that follow best practice, for customers to share in the gains requires widespread consumer awareness of the technology. International experience has demonstrated that when DISCOMs do not actively engage with consumers before installing smart meters, there is frequently widespread pushback. This leads to cost overruns, delays and general declines in customer satisfaction. For a successful large-scale implementation, there has to be well planned consumer interaction and so that they conceive it as positive change and support the rollout. The National Smart Grid Mission has allocated INR 2 million for each of the 60 state-owned DISCOMs to implement customer engagement programs. Utilities should take this opportunity to ensure their metering rollouts are inclusive of, and beneficial to, all customer groups.

Customers' needs to be educated on the benefits of smart meters and society at large. Consumer engagement and education program to be conducted well in advance of smart meter installation. To



design an effective consumer education program, it's important to understand the consumer profile and consumer touch points.

Table 7-2: Understanding consumer profile

Type of Usage	Education Level	Income Level	Consumption Level	Employment Level
- Residential - Commercial - Industrial - Agricultural	- Uneducated - School/College going/passed - Professional degrees	- Poor Class - Medium Class - Upper Class	- Low - Medium - High	- Working Class - Unemployed - Retired

Consumer Touch Points:

- Customer care centre for new connection, queries and complaints
- Meter reader
- Electricity bills – Printed, SMS, E-mails
- Utility portal, Chatbots, Voicebots, social media
- Community meetings, information booths
- Shopping malls, cinema halls, TV, Radio

Proposed executive plan:



Consumer Education and Engagement Tools:

Table 7-3: Consumer education and engagement tools

Printed Ads	Educational Videos	Face-to-Face Meetings and Workshops	Street Plays and Workshops	Social Media/Web
- Local Newspapers - Flyers - Banners - Posters and - Wall Painting	- Association Meetings - Cinema Halls - Cable TV and Radio	- Residential Welfare Associations - Market Committees - Industry Associations - Retired Persons - Local Clubs - Schools - Colleges - Gram Panchayats etc.	- Schools - Colleges - Shopping Malls - Rural Consumers	- Mass-mail - Facebook - Twitter - Online public forums - Blogs - Utility website - Online discussion groups and YouTube

Case study TPDDL:



Figure 7-1: TPDDL customer engagement programs

7.4 Risk Mitigation Mechanisms

The AMI rollout process requires an effective system implementation and integration process. This is due to the complexity of AMI's technology as well as the multiple integration points with other enterprise IT systems. Risk awareness and preparation are important aspects for DISCOMs throughout the rollout and operational eco system. This section will focus on two kinds of risks: these are associated with cyber security, AMI system's implementation and operations.

7.4.1 Cyber Security

As discussed in Chapter 1 AMI technology brings many benefits for DISCOMs, customers and society. The underlying technology that enables these improvements, however, has significant IT and process implications for DISCOMs. It can be difficult to overcome the cyber-risk concerns which come with by using AMI technology to safely enable systems, monitor operations, and respond to threats.

The early adopters of AMI technology did not have access to the technology options available today, such as standardized interconnection protocols, cellular based connectivity models, and mature security event monitoring tools. Planning a balanced approach that appropriately matches the investment in safeguards with the risk profile of the various components of the AMI system can help maximize the Return on Investment (RoI) for cyber-risk protection. DISCOMs have taken different approaches to accomplishing this task, often based on financial, business, technology, or schedule drivers. Once adopted, AMI technology introduces the following risk domains:



- **Safety:** Manipulation/attacks on AMI system can lead to voltage surges that risk the health and safety of DISCOM personnel and customers.
- **Customer equipment:** Using AMI solution communication mechanisms to attack customer's residential or industrial networks and equipment.
- **Service delivery:** Attacks on the AMI solution that can potentially subject electricity service delivery to prolonged, multi-year disruptions.
- **Brand and reputation:** Attacks against the AMI solution for political purposes, reducing trust in the DISCOM brand among customers and governmental entities.
- **Revenue loss:** Attacks with the objective of energy or financial theft.
- **Data privacy:** Breaches of customer data privacy with brand and potential compliance impacts.

In order to address these risk categories, protections must be included across the AMI system, including edge devices, business systems, operational systems, supporting processes, corporate infrastructure, communication networks, and third-party vendors. A targeted approach to developing these safeguards can significantly improve the AMI system's security. The technologies and processes involved in securely enabling AMI are described in the Table below.

Table 7-4: Technologies and process to securely enable AMI

DISCOM Office	• Security information and event management logging • Domain, certificate authority and network segmentation • Directory service managed system and user accounts • System hardening guidelines • Robust vulnerability management • Incident response playbook • Threat intelligence integration • MDAS meter turn off application controls
Cellular	• Cellular meter authentication • Prohibited meter to meter communication • Non-Routable cellular network • Cellular event log monitoring • Integrated key management landscape
RF Mesh and Cellular	• Unique meter cryptographic keys • Over the air firmware support



	• Standards based protocols • Meter integration testing
HAN/Customer Presentment	• Latest HAN protocol specifications • Web application secure development standards • Customer multi factor based authentication • Customer password complexity enforcement • Web integration testing

It can be challenging, however, for a DISCOMs business units to manage and mitigate risks during a largescale AMI implementation. Risks related to AMI implementation and operations can be broadly classified as follows:

Technology risk: DISCOMs are exposed to technology risk because they invest heavily in information technology. DISCOMs can protect their interests by implementing cutting-edge technologies that meet industry standards and are unlikely to become redundant in the near future. Pilot projects are useful for validating the cost-benefit analysis and technical feasibility of smart metering technologies.

Integration risk: AMI programs generally enable the integration of numerous vendor solutions. DISCOMs must evaluate which integration tasks they are able to implement in-house, outsource, the number of prime contractors and vendors.

Implementation risk: The implementation of an AMI can be more difficult than simply selecting and implementing new technologies. AMI project, requirement, test, and change management processes which are well specified can be essential key steps to a successful AMI implementation.

Financial risk: For the AMI implementation initiatives, DISCOMs payable huge capital investments and pay large upfront expenditures, and there is always the risk of not achieving the program's targeted financial objectives. It's quite likely that the project's cost and schedule will exceed expectations. Pilot projects, phasing AMI implementation, using managed services, as well as using incentives can all help DISCOMs avoid this risk.

7.5 Impact on Customers and DISCOMs

To fully take benefits of introducing AMI, the DISCOM typically orders it from the backend, which includes setting up an MDMS to accept interval reads and making adjustments to the CIS to account for new billing characteristics. Some DISCOMs have delayed this change in favour of creating billing determinants (i.e., customer usage data needed to generate the bill) that approximate regular monthly consumption reads. The field has the most significant impact on the DISCOM. Models for deployment have often followed a similar pattern, which includes the following:

- Identification of appropriate meters for residential and commercial customers including field deployment tests to account for territory issues, number of channels, battery life, registers, volume of data retained on the meter, and ability to upgrade the meter as needed. Also critical for deployment issues such as warranty, and support for specific requirements such as HAN, ZigBee, single phase, three phase, and integration with the selected head end system
- Identification of field area network (typically cellular or mesh)
- Selection of meter installation vendor
- Planning of a zone-based approach for replacing existing meters
- Scheduling of meter deployments
- Meter deployments and shutting down of manual reads for the route, requiring:
 - Coordination of field area networks within the deployment area



- Coordination of wide area networks into the area for backhaul
- Data from smart meters may be used to track electricity consumption at the household level and identify consumers who are accountable for peak demand. This can aid DISCOMs in planning load curve flattening measures and lowering the cost of additional generation now necessary to meet peak demand
- Smart meters may be used by DISCOMs to improve service delivery, load control, and facilitate India's low-carbon transition

7.5.1 Resources and Change Management

The resources of an organization consist of people, materials, equipment, knowledge and time. Because most organisations have limited resources, every AMI implementation project must make trade-offs about how and when project resources are used. Similarly, change management is a framework for addressing the impact of new business processes, organisational structure changes, and social trends within an organisation. To evaluate the level of impact, AMI implementation starts with a review of current business processes and stakeholder organisations.

The DISCOMs interviewed for this study found that the implementation of AMI required some resource realignment and change management on both a technical and organisational level. The effect area and types of impacts identified with the installation of AMI across the DISCOMs questioned for this study are included in the table below.

Table 7-5: Resource and change impact of AMI implementation

Department	Component	Impact
Field Operations/ Meter Reader	Meter	● Reduced need for meter readers ● Retraining requirement as staff transferred from meter reading and field technical support to network, RF and other technical support roles ● Reduced truck rolls (i.e., travel) to/from reported outages, with impacts on fleet mileage and maintenance
Field Operations	Head-End System (HES)	● Exponential increase in volume of meter-read information ● Ability to locate meter when multiple head end systems are in use
Network Operations	Field area network (FAN)	● Significant implementation staffing needs to cover AMI meter communications ● Specialist skills needed for RF analysis and troubleshooting
Network Operations	Wide area network (WAN)	● Increased communications capability for managing backhaul communications ● Redundant network capability needed to offset potential bandwidth issues ● Network traffic prioritization needed for shared networks – i.e., outage management prioritized over other traffic ● Typically, the establishment or reinforcement of a Network Operations
Customer Service	Meter Data Management System (MDMS)	● Volume of data increase in the form of more granular interval data ● Ability to perform VEE (validate, estimate and edit) function to adjust for missed reads through interpolation techniques ● Ability to identify potential fraud through use of flags on read ● Potential increase in size of customer service team to handle additional customer interaction
Customer Service	Consumer Information System (CIS)	● Based upon tariff: ○ Interval billing ○ Net billing for solar Photo Voltaic (PV) customers ○ Pre-pay ○ Enhanced time-of-use (TOU) billing ○ Quicker move-in/move-out ○ Turn-off/turn-on



Operations	Outage Management System (OMS)/ Advanced Distribution Management System (ADMS)	• Ability to leverage momentary voltage fluctuations to determine future network issues • Ability to detect phase to support corrections to GIS systems • Ability to leverage Fault Location, Isolation, and Service Restoration (FLISR) and other advanced analytics tools
Engineering	All	• Enhanced ability to perform transformer load analysis and other network assessments • Enhancement to new construction planning
IT	All	• Requirements for new integration between typically segregated systems (e.g., CIS to GIS) • Additional field cyber security considerations/implementations • Typically, the establishment of a Smart Meter Operations Center (SMOC) • Greater storage requirements to support higher volume of interval reads
Other	Utility oversight	• Broader efforts may include the state utility commissions and filings by the individual utility to gain approval of the inherent changes brought about by the introduction of AMI
Other	Customer communications	• Stakeholder education on benefits of smart meter technology, how to read and interpret new and more-detailed information regarding electrical usage • Customers occasionally unwilling to accept an AMI meter due to concerns over privacy or related to radio frequency emissions • Establishing a specialized communications team during the implementation project and subsequent adoption period was a consensus recommendation from the utilities interviewed for this study

7.6 Recommendations

AMI/MDM systems must be integrated with ERP and billing and customer care systems; also, with GIS and Outage Management Systems (OMS), Mobile Crew Management Systems and SCADA/DMS and Distribution Automation Systems where every such applications are implemented successfully. The secure, end-to-end integration of Head-End System (HES) and Meter Data Management System (MDMS) is critical for successful AMI operations. AMI will not yield true benefits in DISCOM with home-grown billing systems which cannot be integrated with any standard MDM. Several states Maharashtra, Gujarat, Tamil Nadu, Kerala, HP, Rajasthan etc. are facing the same challenge. One DISCOM should have only one billing system and one MDM. There can be many makes of Meters and Head-Ends. Ideally the data centre may be on any secure public cloud – reduced cyber threat and risk from obsolescence of hardware and operating systems.

AMI functionalities and technologies have significantly matured and become standardized. Radio Frequency (RF) mesh and cellular have emerged as the most prevalent meter-level communication technologies. Most utilities that have implemented large AMI programs have made use of “hybrid” communications technologies that include both RF mesh and cellular networks. Utilities’ choice of communications technologies should be based on their specific requirements and the current state of product evolution and market dynamics. It is very important to test and select the suitable communication technology for AMI pilot and its rollout. It should not be left on the AMI service provider who is contractually committed to the SLAs; DISCOMs should specify SLAs and Quality of Service (QoS) including Security. AMI specifications and design should be aimed at a future state of operations to maximize benefits over the project lifetime and minimize the risk of obsolescence.



08 Advanced Analytics

The use of data driven decision making processes will be strengthened in DISCOMs that will boost operational efficiency. DISCOMs are data powerhouses generating data on energy use, financial transactions, and customer initiated interactions (complaints, feedback, etc.). Due to their limited scope and inflexible modelling capabilities, existing rule based analytics tools, which are commonly used by utilities, provide limited benefits. Advanced analytics solution in SMOC will help achieve functionalities of event correlation and Machine Learning. Advanced analytics will support customer business and grid management in real-time, supported by exponential technologies like AI, edge computing and 5G. Smart meters continuously measure profile data about consumption, generation, voltage, current, frequency, events and power quality data (PQD). Overtime a growing AMI data corpus will be formed to be used to model forecasts and to detect anomalies.

In recent years, utilities have turned their attention to automation and the closely connected digitalization. As a result, there has been a push to create a digital replica of every business operation, assuming that efficiency gains are realized. DISCOMs across India are making concerted efforts towards achievement of these priorities by adopting innovative approaches around data-driven decision making, which can be supported by the integration of Advanced Analytics Artificial Intelligence (AI), Machine Learning (ML), and Data Science.

AI and ML are widely recognized as the most significant advancements in terms of simulation of human intellect through computer programmes or machines. While many business processes have already been integrated with digital technologies, AI and ML technologies can go much further by bringing automated decision-making and self-learning capabilities. These technologies have risen to unparalleled prominence internationally in recent years, while NITI Aayog and other ministries in India have already adopted several ground breaking initiatives. In the last few years, the Indian electricity sector has undergone significant transformations, largely targeted at improving the efficiency and long-term viability of the distribution sector.

The AT&C losses in India is around 16.95 % (As of May 2022) and maximum contribution for commercial loss is attributed to electricity theft owing to a variety of reasons. Therefore it is required by the utilities to reduce such theft cases and identify defaulters so, that proper measures can be taken to ensure all the units supplied to every customers are accurately billed.

Similarly, with penetration of more and more distributed energy resources like rooftop solar PV (SRTPV), energy storage systems, electric vehicles etc. and introduction of new market instruments (Real Time Market, Green Day Ahead Market, and Green Term Ahead Market etc.), accurate load forecasting has assumed highest priority for efficient operation of the distribution grid. Time-stamped consumption data from smart meters can help forecast feeder-wise demand in different time slots of the day accurately. Improved load forecasting accuracy will also facilitate the utilities in optimizing power procurement cost, asset investment, and optimal utilization of distributed energy resources etc. which will not only help in improvement of operational efficiency but will also help in increasing the utility's revenue.

8.1 Benefits of Advance Analytics

8.1.1 For Customers

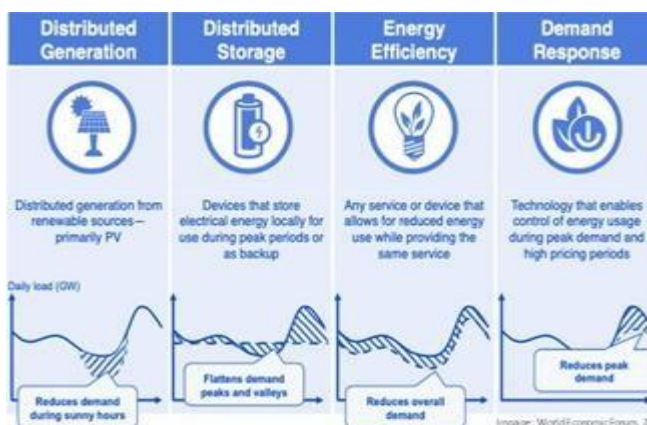
- Implementation of Time of Use (ToU) tariff
- Energy savings alerts to customers
- Different tariff plans to customers enabling savings on energy cost
- Excess usage identification
- Direct link to outage information
- Remote turn on/off service
- Identify and rectify phase imbalance in distribution transformers
- Disaggregation (e.g. behind home energy management systems) to identify faulty technical equipment or energy wasters
- Load disaggregation to implement EV programs



8.1.2 For Grid Optimization and DER Integration

- Improve grid stability and utilisation
- Optimise operational energy flow with predictive analytics
- Intelligent voltage monitoring
- Active transformer load management
- High impedance detection
- Detect broken neutral or imbalances in loads
- Outage detection
- Cable failure analysis
- Wire down analysis
- Active demand response
- Distributed generation detection

Data Analytics will provides decision support to optimize operational energy flow with predictive analytics which will help to balance supply and demand in real time. The analytics will provide the control over the following functionalities using predictive analytics and by calculate maintenance requirements for grid components.



8.2 Applications of Data Analytics

Data analytics will help utilities to perform on line energy audit to calculate losses in real time or near real time. The analytics will also help utilities to extract and use the information embedded in meter data which can provide information such as:

- Meter data validation
- Tamper and missing information due to communication failure, meter fault etc.
- Energy audit and accounting of DTs



- Peak demand identification
- Consumer profile analysis
- Forecast and build predictive models for demand response program planning
- Consumer abnormal pattern analysis

Following analytics are carried out with meter data as described below:

8.2.1 Data Validation

Data validation identifies parameters that can go wrong at the meter/recorder and cause the data collected not to reflect actual usage. These rules applied to kWh, kVARh, voltage, current, and PF data. It evaluates the quality of the data and generates estimate where errors, overlaps, redundancies and gaps exist. It estimates interval data based on meter readings by filling and correcting the missing gaps and errors on particular day.

Meter Id	00hr	01hr	02hr	03hr	04hr	05hr	06hr
137	-	-	F	-	-	-	-
171	F	F	-	-	-	-	-
208	-	-	-	-	-	-	F
306	-	-	F	-	F	-	-
307	F	-	-	-	-	-	-
329	-	F	-	-	-	-	-
334	-	-	-	F	-	-	-
339	-	-	-	-	F	-	-

F : value missing\ not obtained correctly

Figure 8-1: Missed read of some of the meters

8.2.2 Tamper and Missing Information

Meter events and usage information can help in understanding an overall picture of what's happening with a consumer's energy usage over time. This unified view enables to detect energy theft, meter tampering or equipment problems that may be affecting service levels. As availability of supply at consumer end is very crucial, total power off hours during a day and long outage events cab be analysed to find out time taken to attend the events or working efficiency of maintenance crew. These analytics will help utilities to calculate various reliability indices of distribution system such as SAIFI, and SAIDI etc.



Figure 8-2: Outage duration

8.2.3 Energy Audit and Accounting

The efficiency of a power system is determined by the losses involved in the system. All the technical losses and commercial losses includes AT&C losses, energy theft etc. which needs to be effectively reduced. To calculate loss at the feeder level or DT level energy audit analysis at daily, weekly, monthly can be carried out mentioned in below Figure. To understand the consumption pattern and to analyze the abnormal consumption of energy by individual consumers various analysis like average percentage loss, maximum, minimum demand of day in DT can be carried out. These essential details revealed the nature of load and also helped in forecasting of load.

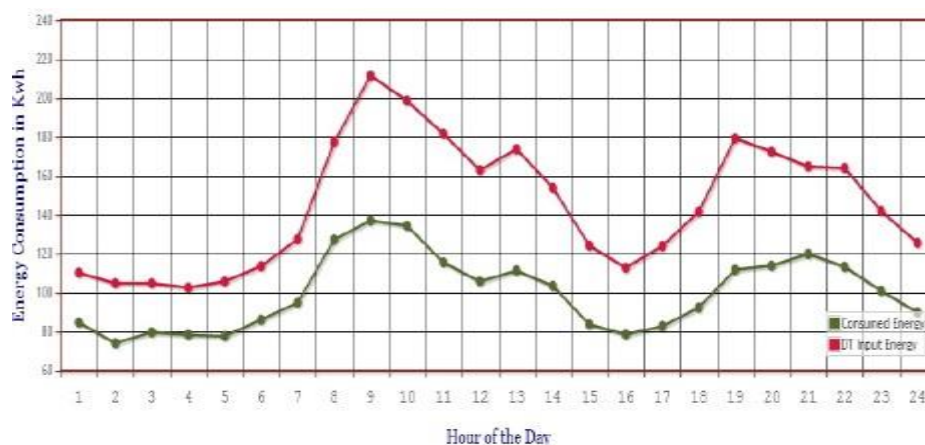


Figure 8-3: Typical Energy Audit (Intra-Day)

8.2.4 Peak Demand

For electricity grid, the critical requirement is to flatten the load curve by peak clipping and valley filling through tariff incentive/disincentive or through demand side management. The advantages of flattening the load curves are cost saving on account of additional infrastructure, energy savings due to reduce grid losses etc. Aggregate hourly load profiles of any DT reveal load peaks and valleys in a day. Aggregated meter reading of individual consumer under the same distribution transformer gives the information of consumer contributing in peak and valley. The minimum, maximum, standard deviation will help utilities to identify the consumers who are drawing more or less during peak hours.

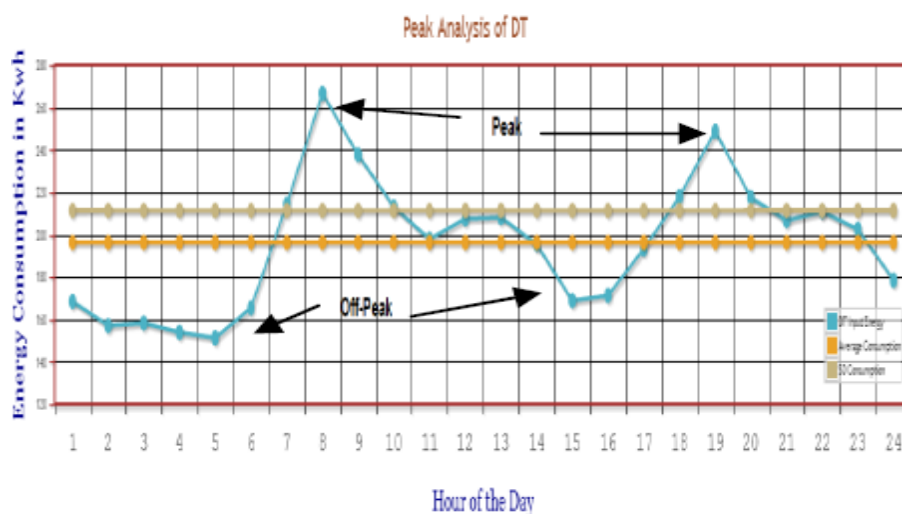


Figure 8-4: Peak and Off-Peak patterns



8.2.5 Consumer Profile Analytics

Daily energy consumption pattern yields information such as minimum, average and maximum energy consumption as well as change in daily energy usage. These information will help consumers in better energy management. A typical consumption pattern of a consumer on a particular day collected through smart meter is shown in below Figure.



Figure 8-5: Consumer profile on a particular day

Further, weekly and monthly analysis of consumer consumption behavior will help utilities to identify the consumption pattern in working days and holidays and accordingly plan energy requirement for working days and holidays.

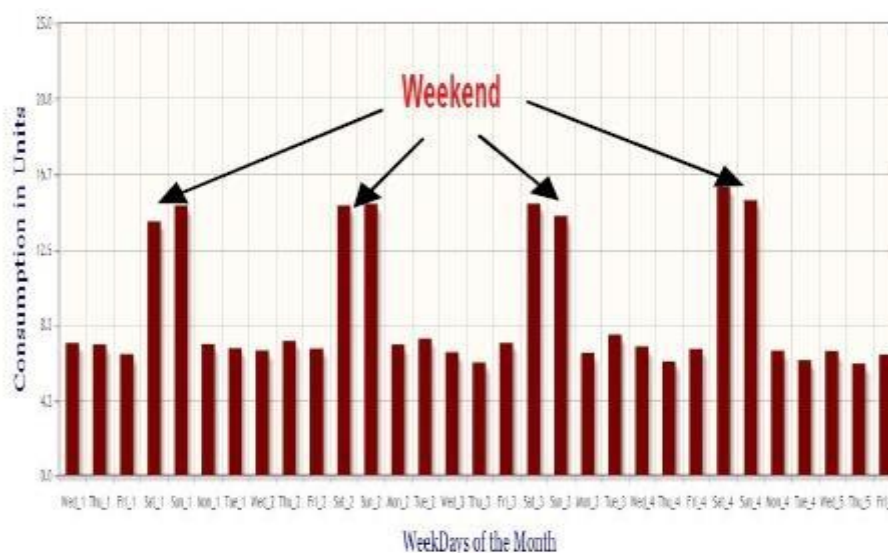


Figure 8-6: Consumption pattern during weekends

8.2.6 Load Forecasting

Load forecasting is essential for defining the requirements of the distribution network capacity, scheduling, and approximating AT&C losses, estimating the existing networks capability to transfer increasing loads and create effective demand response programs. On the basis of previous energy pattern of usage, newly pattern can be identified.

8.2.7 Abnormal Behavior Identification

By analysing consumption pattern of consumers, utilities are able to distinguish between a normal daily consumption patterns from an abnormal one. Based on historical data of consumer, the utility can identify irregular consumption and detect potential issues. Therefore, daily energy consumption patterns can be an important variable to monitor and trigger consumer action.



Figure 8-7: Consumer profile of particular day

8.3 Select Use Cases of Advanced Analytics with AMI

8.3.1 Electricity Theft Detection using AI Driven Smart Meter Data Analytics

In developing countries, non-technical losses are a significant and growing financial concern for electricity distribution companies. Workforce intensive inspections and account auditing is expensive, while enforcement is always challenging. Some utilities rely on smart meter tamper events, which don't necessarily reflect theft. Moreover, utilities haven't been able to completely decode the correlation between consumption patterns, electrical data and smart meter tamper events. Instead, advancement in data driven methodologies for electricity theft detection have gained attention from researchers worldwide. Recorded user electricity consumption data is dependent on multiple factors such as weather, occupancy, presence of HVAC systems, etc. which entails the need to identify exclusive patterns of theft.

AI based data analytics for smart meters, a technology can identify appliance signatures from 15/30 minute interval consumption data (kWh) captured and transmitted by smart meter, without using any other hardware.

Advantages:

The AI based algorithms recognize the consumer behaviour pattern in terms of appliance usage across different times of the day, and days of the year. It also recognizes the effect of weather conditions – such as temperature and humidity on consumer behaviour on specific appliance usage. The novelty of algorithm of energy theft AI framework lies in the fact that:

- **Awareness of appliance usage at a given time of day:** Advantage of access to appliance disaggregation information coming out of our patented set of disaggregation algorithms.

- **High hit rate:** The AI engine processes the electrical data from the meter download and analyses it in terms of tamper events, voltage and current profiles, phase association etc. Disaggregation information along with behavior modelling and correlation among energy consumption, current, voltage and meter events creates a powerful tool for identifying various kinds of theft with a very high degree of accuracy. The algorithms for theft detection have been built, customized and fine-tuned on the basis of data from a number of Indian utilities and lacs of customers over the last 15 months.
- **Actionable categories:** The AI framework is designed to provide action oriented results to the utility by: i) Classifying theft into different actionable categories by directionally indicating towards the reason/type of theft, and ii) Calculating likely the probability of theft and thereby eliminating a lot of false positive cases. The utility can then prioritize on-ground work to maximize revenue impact.
- **Fast classification:** Ability to label homes across actionable categories within seconds while handling all home data input from smart meters.
- **Super scalable:** The framework is easily scalable to the entire population and gives output in the form of an easy to handle tabular format containing theft categories and rankings.

8.3.2 Accurate Demand and RE Forecasting

Renewable energy, including DERs such as rooftop solar, EVs, energy storage and demand response systems are expected to grow in the coming years. An AI powered smart meter can prove to be the best solution for effective renewable energy management, as it performs two essential functions: creation through data analysis and utilisation through optimal demand supply matching. It consists of two AI applications: energy forecasting and grid balancing. Demand, RE generation, and market price forecasting's are all improved by using AI based tools.

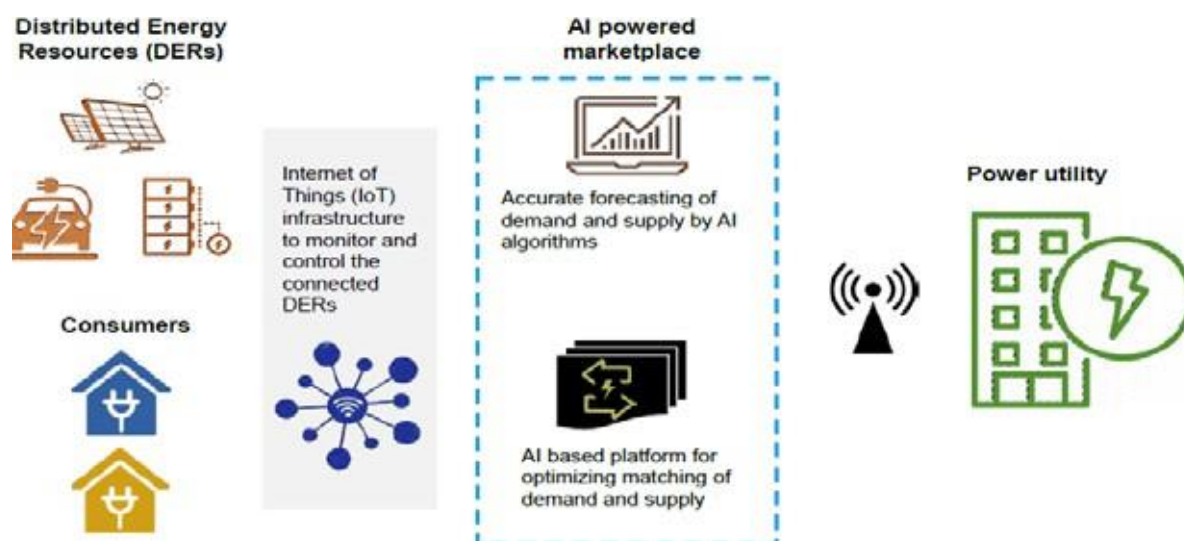


Figure 8-8: AI based demand and RE forecasting

8.3.3 Using Machine Learning and Deep Learning for Energy Forecasting

Grid analytics can cover wide varieties of data, for monitoring assets and power system events using Smart Meter data. For asset management signal processing and AI techniques to monitor asset health

is being used with the development of predictive maintenance and remaining useful life (RUL) algorithms.

Online Detection of Power System Events

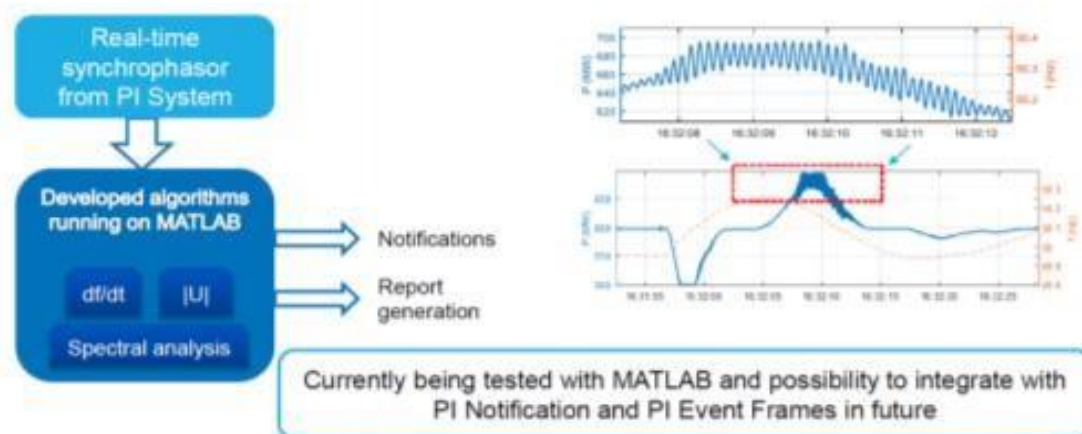


Figure 8-9: Online detection of power system events

Energy price forecasting can be achieved by:

- Use AI to forecast load, generation and prices at multiple nodes
- Integrate forecast models with grid simulation to improve system reliability

8.3.4 Applying Artificial Intelligence for Metering, Billing and Collection

The utilities revenue was hard hit as meter reader were not allowed inside premises for capturing meter reading and self-billing application had its own challenges in delayed billing and payment. CLK2PAY innovated during the COVID times is an advanced AI intervention to enable (a) Quickly pull meter reading on the already clicked images (b) Metering, Billing, Collection (MBC) in less than a minute. The innovation has been adopted to solve pain areas of utilities, APC used data science expertise and applied deep learning technology to solve this problem with innovation. CLK2PAY not only enhanced the efficiency towards the revenue recognition for utilities, but also enabled the process efficiency. APC team conducted an online survey during COVID time, wherein the inputs on delay in existing process were encouraging to create CLK2PAY. The solution has two variant i.e. (Phase I) pulling information from images captured by meter reader or customer through self-billing existing utility application as photo audit which was earlier a manual or time consuming process and delay of 4-7 days has been brought down to less than one day (Phase II) provide mobile solution to customer to capture meter reading in real time and process to billing and payment. This will not only fasten the revenue recognition process, but also add to the operation efficacy and reduction to the cost in serving the customer. The normal cost of (a) Meter reading (b) Send of bill (c) Follow up on payment (d) Defaulter or debtors' pursuit is INR 15 to 20 per person per month. CLK2PAY, is just enables this is one fourth of the cost.

Mobile based "apk" uses deep Learning based OCR as AI engine. The deep leaning framework "YOLO" has been customized along with RCNN/CNN model to get the meter reading.



Figure 8-10: Smart meter dashboard

8.3.5 Cash Flow Improvement and Revenue Recognition Application Platform

Utilities tend to realize only 60-70% of the revenue before or on the due date. With at least 2-5% consumers being chronic in nature for the remaining consumer's revenue collection has DSO spread over a month. Any solution in this regard is a welcomed as the billing collection is always a pain for utility. Smart meter powered by AI based solution is helping Delhi based utility to predict the customer payment behaviour and apply the business decision to target the customer in phased manner to get the revenue earlier.



Figure 8-11: Defaulter prediction AI application in use at utilities of NCR Delhi and Ahmedabad

Also, utility can plan for better mechanism to reduce the burden to decrease the operation cost like reducing the no of cash collection centre by shifting customer from cash to online mode. Utility also interested to know the seasonal and event impact to manage the defaulter in a better way. The solution uses defaulter prediction along with consumption forecasting model and then applying ML model to cluster into “Critical”, “Severe” and “Mild” category.

Problem areas are defaulter prediction model, seasonal/event analysis and payment mode prediction model and campaign management solution. Advanced ML model has been applied viz. logistic regression, Bayesian algorithm, xGboost, and ensemble modelling for defaulter prediction for next months based on historical data (At least for 12 months data).



Actual_Default_Oct	31554
Predicted_Default_Oct	23175
Accuracy	~73%
Total Value(Actual)	~11 Cr
Total Value (Predicted)	~9 Cr (~81%)
Actual_Default_Nov	33915
Predicted_Default_Nov	20280
Accuracy	~60%
Total Value(Actual)	~12 Cr
Total Value (Predicted)	~7.5 Cr (~61%)

Figure 8-12: Smart meter dashboard – Actual and predicted data

Cluster modeling has been applied on top of defaulter model outcome along with consumption data to get the category of customer as “Critical”, “Severe” and “Mild”.

Campaign solution is applied at two levels:

- Level 1: To target defaulter model outcome to get early revenue using email, SMS and WhatsApp campaign along with IVR. For defaulter field can connect with customer based on amount and history of the customer directly
- Level 2: To target “Critical”, “Severe” and “Mild” customer using email, SMS, WhatsApp campaign along with IVR

Below data points have been used in the technology:

- Payment data
- Subsidy data
- Consumption data
- MRD files
- Campaign data

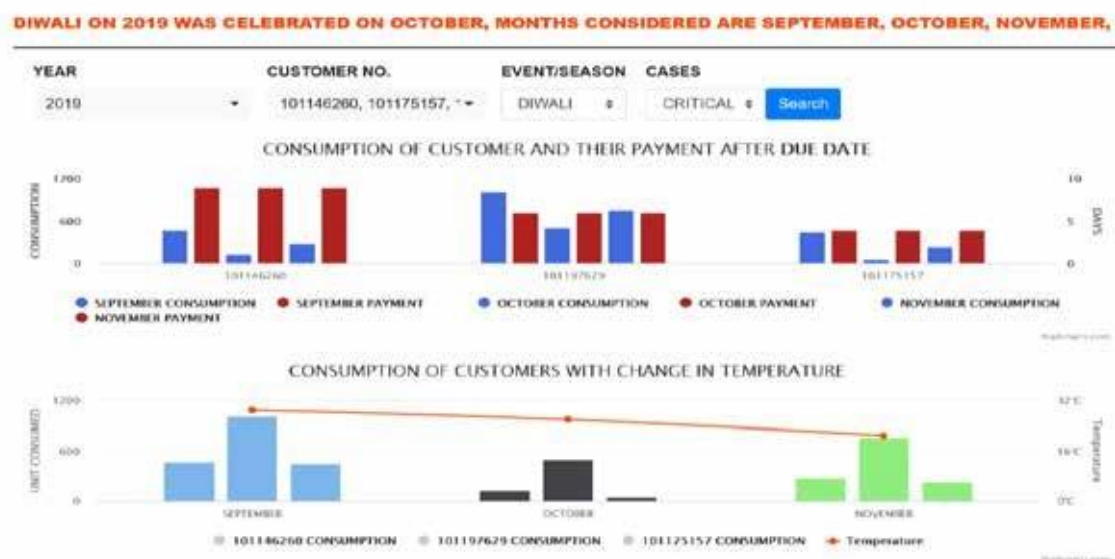


Figure 8-13: Consumption of customer payments

8.3.6 Outage Management Digitalization

At the utility TPDDL had identified few basic problems need resolution:

- What will be demand of electricity at different hours of the day
- What will be the load growth at the distribution transformer and feeder level



- Identify which consumer is likely to default this month
- How many customers will come to the customer care today
- How many customers may call at the call centre at certain hour
- Which 11 kV feeder is likely to trip this month
- Which employee may resign
- Can we project cash flow on different days to handle operating cash flow better
- Can we reduce or optimize the cost of inventory

TPDDL could create models for all the above and with acceptable level of accuracy, sensitivity. TPDDL are working on increasing the sensitivity of prediction of customer theft model which is highly skewed data by nature. The business needed the next level i.e. what to do with these predictions, what action to be taken. Using smart power powered by advanced analytics are the best possible solution for addressing the above mentioned issues. Like segregation of customers for different type of follow up actions to get the payment. Creation of service order depending upon the load growth or feeder tripping likelihood. Optimizing cash collection agent or call centre agent and in which way.

TPDDL has reached very high level of accuracy for load matching, inventory optimization, commercial meter forecast, cash flow prediction as well as defaulter's predictions.

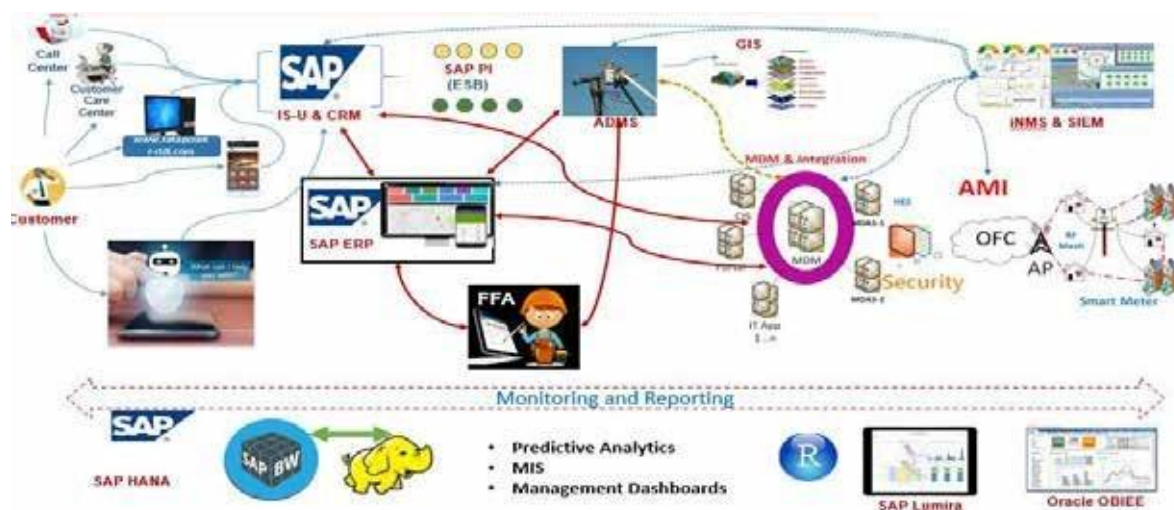


Figure 8-14: Outage management digitalisation

Appendix I Smart Metering Implementation Status in India

Table 0-1: Smart metering implementation status in India

Sl No	State	Utility	Sanctioned Smart Meters	Business Model	Scheme	Installed Smart Meters (As of May 2022)
1	Andaman	EDANI	64,102	Opex	IPDS	36,800
2			39,200		DDUGJY	38,400
3	Assam	APDCL	70,000	Capex	Utility Owned	70,000
4			1,34,000	Capex	Utility Owned	1,20,427
5			1,34,000	Capex	Utility Owned	69,038
6			3,63,500	Opex/Hybrid	Utility Owned	0
7			2,56,600	Opex/Hybrid	Utility Owned	0
8			14,259	Capex	SG Pilot	14,259
9	Andhra Pradesh	APEPDCL	2,000	Capex	Utility Owned	2,000
10	Bihar	NBPDCL	10,30,000	Opex	Utility Owned	3,31,920
12		SBDCL	13,20,000	Opex	Utility Owned	451079
14		IPCL	40,500	Opex	Utility Owned	30,500
15			17,100	Capex	Utility Owned	17,100
16		BEDCPL	1,000	Capex	Utility Owned	1,000
17	Chandigarh	CED	29,433	Capex	NSGM	24,149
18			1,84,000	Capex	NSGM	0
19	Delhi	NDMC	64,713	Opex	Utility Owned	63,692
20		TPDDL	1,95,000	Capex	Utility Owned	1,95,000
21	Gujarat	UGVCL	23,760	Capex	SG Pilot	23,760
22	Haryana	UHBVN	10,188	Capex	SG Pilot	10,188
23			5,00,000	Opex	Utility Owned	2,51,244
24		DHBVN	5,00,000	Opex	Utility Owned	1,81,061
25		POWERGRID	10	Capex	SG Pilot	10
26	Himachal Pradesh	HPSEB	1,335	Capex	SG Pilot	1,335
27			75,712	Capex	IPDS	75,712
28			76,028	Capex	Utility Owned	60,168
29	Jammu and Kashmir	JKPDD	1,15,500	Capex	PMDP	76,050
30	Jharkhand	JBVNL	3,60,000	Capex	NSGM	0
31	Karnataka	CESCOM	20,916	Capex	SG Pilot	20,916
32	Kerala	Cochin Port	805	Capex	IPDS	805
33	Madhya Pradesh	MP-West	3,45,463	Capex+Opex	IPDS	1,24,477
34			4,537	Capex+Opex	Utility Owned	0
35			1,18,836	Capex	IPDS	1,18,836
36	Odisha	OPTCL	4,000	BOOT	Utility Owned	4,000
37		Paradip Port	500	Capex	Utility Owned	500
38	Puducherry	PED	28,910	Capex	SG Pilot	28,910



39			1,658	Capex	Utility Owned	1,658
40	Punjab	PSPCL	88,100	Capex	IPDS	88,107
41			7,900	Capex	Utility Owned	0
42	Rajasthan	JaVVNL	2,81,782	Capex	IPDS	2,40,820
43			18	Capex	Utility Owned	0
44			1,50,000	Hybrid	NSGM	1,14,608
45			70,000	Capex	Utility Owned	70,000
46		AVVNL	1,88,860	Opex	IPDS	68,673
47			1,962	Opex	Utility Owned	0
48			1,000	Capex	Utility Owned	1,000
49		JdVVNL	97,158	Opex	IPDS	56,027
50		JdVVNL	5,024	Opex	Utility Owned	5,024
51	Tamil Nadu	TANGEDCO	1,41,000	Capex	Utility Owned	1,17,527
52	Tripura	TSECL	43,081	Capex	SG Pilot	43,081
53	Telangana	TSSPDCL	8,882	Capex	SG Pilot	8,882
54	Uttar Pradesh	IITK	28	Capex	SG Pilot	28
55		MVVNL	9,05,769	Opex	Utility Owned	3,78,862
56		PVVNL	11,64,138	Opex	Utility Owned	1,98,726
57		DVVNL	6,28,686	Opex	Utility Owned	1,47,991
58		PuVVNL	11,47,102	Opex	Utility Owned	3,21,433
59		KESCO	1,56,532	Opex	Utility Owned	1,07,318
60	West Bengal	WBSEDCL	5,164	Capex	SG Pilot	5,164
61		CESC	10,000	Capex	Utility Owned	10,000
62	Total		1,12,49,751	Total		44,23,867



Appendix II Framework for Smart Meter Rollout Based on Leasing and Services Model

In April 2016, ISGF released a Paper on 'AMI Rollout Strategy for India' that described a framework based on a 'Leasing and Services' model. The premise of this Paper was built on the present situation of electricity distribution companies in India wherein they neither have technical capability to buy the best technology and maintain it in-house nor have the finances for upfront capital investment for AMI deployment.

As per this model, manufacturers with BIS certified smart meters may be empanelled with rates of meter and different communication devices which the DISCOMs can choose based on their unique requirement. The cost of the smart meters and cost of the communication devices/Network Interface Cards (NIC) to be specified separately. A financial intermediary such as a bank or any other financial institution will procure the smart meters and lease them to the utility against a monthly rent for a period of ten years. Since AMI involves expertise in three distinct domains, namely, metering, telecommunication and information technology (including both software and hardware), and experience from around the world shows that no one agency could master these distinct components of AMI, it is proposed to appoint a Metering Services Agency (MSA) who will be responsible (along with their sub-contractors and associates) for a variety of functions related to implementation of AMI and its maintenance. Typical scope of services of a MSA would include:

- i. Testing and certification of the meter and communication devices to be procured by the DISCOM for the defined scope of AMI in a given area/town with chosen communication technology/technologies
- ii. Taking delivery of meters and communication devices from the DISCOM and installing them at customer premise; and return of old meter to the DISCOM
- iii. Establishing and maintaining the last mile communication connectivity for smart meters for a period of at least 10 years
- iv. Selecting the appropriate communication technology for providing a Wide Area Network (WAN)/backhaul network
- v. Leasing of bandwidth (wherever required) and maintaining for 10 years
- vi. Sizing of software and hardware of HES, MDMS and associated IT systems, and providing O&M services for at least 10 years. The MDMS, HES and associated IT systems to be housed at DISCOM premises or hosted in a sovereign public cloud
- vii. Integrating, testing and commissioning of the entire AMI system
- viii. Creation of middleware (if required) and integration of MDMS with middleware
- ix. Integration of MDMS with other systems such as billing, collection, connection/disconnection, OMS etc.
- x. Ensuring availability of complete AMI system at mutually agreed Service Level Agreements (SLAs)



From our analysis, the rate worked out to approximately US \$1/month per meter for ten years (INR 70/month/meter) wherein no capex is required by the DISCOM.

This scenario is depicted in below Figure.

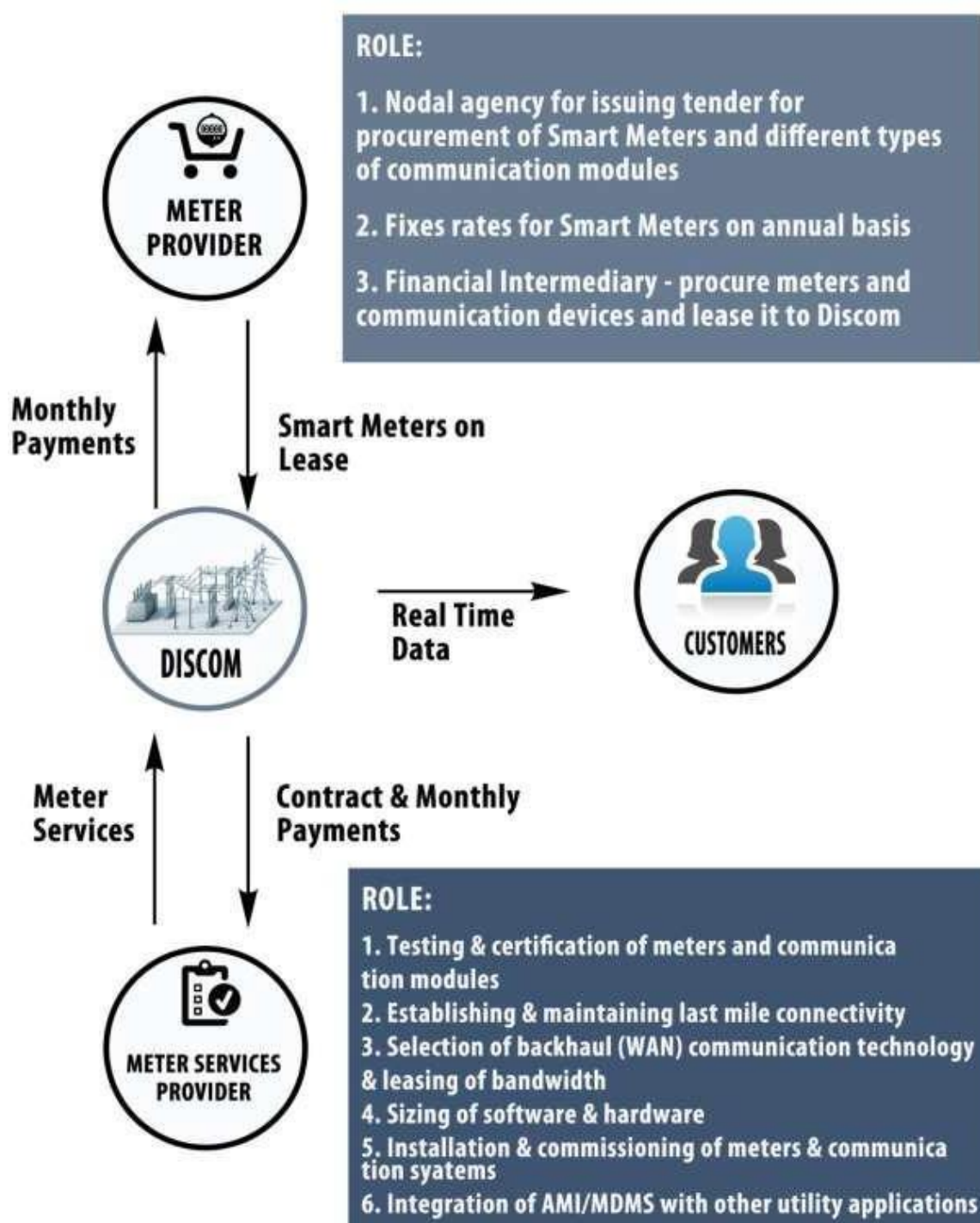


Figure 0-1: AMI rollout framework based on 'Leasing and Services' model



Appendix III Smart Meter Installations and Projected Developments by Investor-Owned Electric Utilities in USA

Table 0-1: Smart meter installations and projected deployments by investor-owned electric companies

Electric Company	State	Meters Installed (2018)	Projected Meters Installed (2019)	Projected Meters Installed (2020)	Notes
Alliant	IA WI	670,000	972,000	972,000	Alliant Energy Corporation is comprised of two subsidiaries, Wisconsin Power and Light (WPL) and Interstate Power and Light (IPL). The WPL smart meter implementation was completed in December of 2011, now totalling 476,000 meters. In Fall of 2017, IPL began deploying smart meters in Iowa, with anticipated full deployment of 497,000 meters by the end of 2019.
Ameren Illinois	IL	1,070,000	1,246,000	1,246,000	Ameren Illinois is expected to fully deploy 1,246,000 smart meters by the end of 2019.
American Electric Power	IN MI OH OK TX VA WV	2,543,000	3,138,000	3,334,000	AEP Indiana Michigan Power has deployed 15,000 meters; AEP Ohio has deployed 675,000 and will complete its Phase 2 deployment of 1,046,000 smart meters by Q1 2020, with approval for phase 3 (approximately 500,000 meters) pending; AEP Texas reached full deployment of 1,082,000 meters; AEP Public Service Company of Oklahoma reached full deployment of 578,000 meters; and AEP Appalachian Power deployed 190,000 smart meters in Virginia through 2018 and expects to deploy roughly 400,000 more throughout Virginia and West Virginia by the end of 2020.
Arizona Public Service	AZ	1,251,000	1,251,000	1,251,000	APS achieved full deployment of smart meters in March 2016.
Avista Corporation	WA	17,000	120,000	256,000	Avista installed 17,000 smart meters as part of a Smart Grid Demonstration Grant project and Phase 1 of AMI deployment. Avista anticipates a full rollout of 256,000



					smart meters in Washington by the end of 2020.
Baltimore Gas & Electric	MD	1,290,000	1,309,000	1,328,000	BG&E, a subsidiary of Exelon Corporation, has fully deployed 1,290,000 smart meters, with anticipated growth through new customer enrolments.
Black Hills Corporation	CO MT SD WY	212,000	212,000	212,000	Black Hills Energy has fully installed 212,000 smart meters in its service territory across four states.
CenterPoint Energy	IN TX	2,493,000	2,646,000	2,646,000	CenterPoint Energy received approval in 2008 to install an advanced metering system across its Texas service territory. It completed deployment in July 2012 and currently has 2,493,000 smart meters installed in the greater Houston area. Vectren, recently acquired by CenterPoint, expects to fully deploy 153,000 smart meters by the end of 2019 in Indiana.
Central Maine Power	ME	632,000	632,000	632,000	Central Maine Power, a subsidiary of AVANGRID, completed its smart meter deployment in 2012 and currently has 632,000 smart meters installed.
Cleco	LA	287,000	287,000	287,000	Cleco fully deployed 287,000 smart meters across the company's entire service territory after receiving approval from the Louisiana Public Service Commission in 2011.
Commonwealth Edison	IL	4,131,000	4,131,000	4,131,000	In June 2013, ComEd, a subsidiary of Exelon Corporation, received regulatory approval for full deployment of 4,131,000 smart meters, which was completed in 2018.
ConEdison	NY	796,000	2,276,000	4,113,000	ConEdison deployed 796,000 smart meters through 2018 and is projected to deploy 4,113,000 by year-end 2020. As of December 2019, ConEdison has deployed 2,276,000 smart meters.
Consumers Energy	MI	1,831,000	1,831,000	1,831,000	Consumers Energy, a subsidiary of CMS Energy, achieved full deployment in 2017. Through 2019, new customer enrollments have led to a total of 1,831,000 smart meters deployed.
Dominion Energy	NC SC VA	453,000	526,000	996,000	Dominion Virginia has completed installation of 475,000 smart meters through 2019 and plans to have more than 1 million deployed by the end of 2021. Dominion South Carolina expects 27,000 smart



					meters deployed by the end of 2019 and 465,000 by the end of 2021. Dominion North Carolina is currently in early stage AMI deployment.
DTE Energy	MI	2,533,000	2,533,000	2,533,000	DTE Energy achieved full deployment in 2016 and currently has 2,533,000 smart meters.
Duke Energy	FL IN KY NC OH SC	3,865,000	6,207,000	7,521,000	Through the end of 2019, Duke has deployed 705,000 smart meters in Florida; 147,000 in Kentucky; 2,974,000 in North Carolina; 741,000 in Ohio; 783,000 in South Carolina; and 857,000 in Indiana. As of end of 2019, deployments are complete in Kentucky, Indiana, Ohio, and South Carolina. More than 7.5 million smart meters are projected to be deployed by 2020; Duke is projected to reach full deployment by 2021 with nearly 8 million customers.
Duquesne Light Company	PA	600,000	600,000	600,000	Duquesne Light has fully deployed 600,000 smart meters.
Emera Maine	ME	122,000	122,000	122,000	Emera Maine has fully deployed 122,000 smart meters in its service territory.
Entergy Corporation	AR LA MSTX	21,000	1,065,000	2,244,000	In 2019, Entergy deployed 1,065,000 smart meters of an enterprise-wide deployment for 2,943,000 smart meters by December 2021. Entergy has deployed 247,000 in Arkansas; 328,000 in Louisiana; 183,000 in Mississippi; 108,000 smart meters in New Orleans; and 199,000 in Texas.
Eversource	KS MO	1,526,000	1,559,000	1,568,000	Eversource expects 1,559,000 smart meters (610,000 in Kansas and 948,000 in Missouri) deployed by the end of 2019.
FirstEnergy Corporation	NY OH PA	1,973,000	2,100,000	2,100,000	Through end of 2019, FirstEnergy subsidiary Penn Power has fully deployed 169,000 smart meters; West Penn Power has deployed 729,000; MetEd has deployed 575,000; and Penelec has deployed 593,000. FirstEnergy operating company The Illuminating Company in Cleveland installed 34,000 meters as part of a pilot.
Green Mountain Power	VT	268,000	268,000	270,000	Green Mountain Power has deployed 268,000 smart meters to customers across Vermont.



Hawaiian Electric Industries	HI	5,000	28,000	50,000	Hawaiian Electric installed 5,000 smart meters during the first phase of its smart grid program. The company filed a grid modernization plan with its state regulatory commission and will make targeted smart meter investments through 2020.
Idaho Power	ID OR	546,000	546,000	546,000	Idaho Power has fully deployed 546,000 smart meters across its service territories in Idaho and Oregon.
Indianapolis Power & Light	IN	147,000	185,000	295,000	IPL, a subsidiary of AES Corporation, has installed 147,000 smart meters and is strategically deploying smart meters where needed. IPL has a pending application for full deployment of smart meters by 2022.
MGE Energy	WI	9,000	9,000	9,000	MGE Energy has deployed 9,000 smart meters.
Minnesota Power	MN	79,000	93,000	109,000	Minnesota Power, a subsidiary of ALLETE, deployed 93,000 smart meters by year-end 2019 in north-east Minnesota and expects to complete full deployment by the end of 2020.
National Grid	MA NY RI	19,000	30,000	30,000	National Grid is piloting 30,000 smart meters in Massachusetts and New York, and actively working on rate cases to fully install smart meters in New York and Rhode Island.
NextEra Energy	FL	5,517,000	5,517,000	5,536,000	FPL has fully deployed 5,054,000 smart meters to residential, commercial, and industrial customers. Gulf Power reached full deployment in 2012 and has 463,000 meters.
NV Energy	NV	1,310,000	1,310,000	1,310,000	NV Energy, a subsidiary of Berkshire Hathaway Energy, has fully deployed 1,310,000 smart meters.
OGE Energy Corporation	AROK	879,000	879,000	879,000	OG&E has fully installed 879,000 meters: 809,000 in Oklahoma and 70,000 in Arkansas.
Oncor	TX	3,611,000	3,611,000	3,611,000	Oncor has fully deployed 3,611,000 smart meters across its service territory.
Orange and Rockland Utilities	NJ NY	217,000	382,000	446,000	Orange and Rockland Utilities, a subsidiary of ConEdison, has installed 217,000 smart meters through end of 2018 and plans to achieve full deployment of 446,000 by 2020.
Pacific Power	CAOR	517,000	655,000	655,000	Pacific Power, a subsidiary of Berkshire Hathaway Energy, expects full deployment of smart



					meters across service territories by year-end 2019 in California (47,000) and Oregon (608,000).
PECO	PA	1,675,000	1,675,000	1,675,000	PECO, a subsidiary of Exelon Corporation, has fully deployed 1,675,000 smart meters.
Pepco Holdings	DC DE MD	1,340,000	1,340,000	1,340,000	Pepco, a subsidiary of Exelon Corporation, has reached full deployment in the District of Columbia with 278,000 smart meters installed. Pepco and Delmarva Power in Maryland have reached full deployment, with 555,000 and 213,000 smart meters, installed respectively. In Delaware, Delmarva Power has reached full deployment with 293,000 meters installed.
PG&E Corporation	CA	5,323,000	5,323,000	5,323,000	PG&E has fully deployed 5,323,000 smart meters across its service territory.
Portland General Electric	OR	888,000	888,000	888,000	PGE's smart meter program was approved by the state regulatory commission in 2008; full deployment was completed by the fall of 2010.
PPL Corporation	KY PA	1,450,000	1,450,000	1,450,000	PPL is in compliance with PA Act 129 and has fully deployed 1,441,000 smart meters in its Pennsylvania service territory. Pilot programs in Kentucky have deployed 9,000 smart meters.
Public Service Enterprise Group	NJ NY	144,000	513,000	882,000	In 2018, PSE&G filed a proposal with the New Jersey Board of Public Utilities to deploy 2.2 million smart meters by 2024. PGE&G's NY service territory has a pilot program with 129,000 smart meters deployed.
Puget Sound Energy	WA	190,000	374,000	564,000	Puget Sound Energy plans to deploy smart meters to all electric customers by the end of 2023.
San Diego Gas & Electric Company	CA	1,449,000	1,449,000	1,449,000	SDG&E has fully deployed 1,449,000 meters across its service territory.
Southern California Edison	CA	5,139,000	5,139,000	5,139,000	SCE has fully deployed more than 5 million smart meters and will continue to accommodate population growth.
Southern Company	AL GA MS	3,951,000	3,951,000	3,951,000	Southern Company's Georgia Power and Alabama Power are fully deployed. Georgia Power reached full deployment in 2012 and has 2,498,000 meters. Alabama Power reached full deployment in 2010 and has 1,453,000 meters.



					Mississippi Power received approval to deploy 200,000 smart meters in late 2018.
Tampa Electric	FL	75,000	145,000	300,000	TECO (an Emera company) has installed 75,000 smart meters through 2018 with plans to complete deployment of 750,000 meters in early 2022.
Texas-New Mexico Power	TX	247,000	247,000	247,000	TNMP, a subsidiary of PNM Resources, has fully deployed 247,000 smart meters.
United Illuminating	CT	237,000	294,000	350,000	United Illuminating, a subsidiary of AVANGRID, has installed 237,000 of its projected 350,000 smart meters by the end of 2020.
Unitil Corporation	MA NH	108,000	108,000	108,000	Unitil has fully deployed 108,000 smart meters across its service territory around Concord, NH, and Fitchburg, MA.
WEC Energy Group	WI	662,000	946,000	1,145,000	WE Energies has deployed 662,000 smart meters to customers in Wisconsin.
Xcel Energy	CO MN	13,000	32,000	40,000	Full deployment of smart meters in Colorado for 1.5 million customers will not begin until 2020 and will conclude in 2024. Xcel has publicly filed for full deployment of smart meters in Minnesota by 2024.
Other		13,000	11,000	11,000	Limited deployments by multiple operating companies account for roughly 13,000 smart meters deployed through 2018.
U.S. Total		64,344,000	72,161,000	78,531,000	



An initiative supported by



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