India Smart Grid Forum

ISGF White Paper

AMI Rollout Strategy and Cost-Benefit Analysis for India

Abstract

This Paper examines, in detail, all aspects related to rollout of Advanced Metering Infrastructure (AMI) in India. It covers key issues such as smart meter standards and specification, testing of smart meters, retrofitting of existing meters, communication technology options, procurement strategy and business models for AMI rollout. Under the UDAY program, Government of India plans to deploy smart meters for all customers with monthly consumption above 200 kWh by December 2019. Distribution Companies (DISCOMs) have the responsibility of choosing the most optimum deployment strategy. While the traditional AMI approach proposes deployment of smart meters for all customers on a feeder, another option is to deploy only for customers having monthly electricity consumption greater than 200 units. Part A of this Paper presents a detailed cost-benefit analysis which strongly advocates deployment of smart meters for all customers on a feeder primarily because of the potential to reduce AT&C losses and the substantially lower cost for the last mile communication network when the full feeder is covered. Part B of this Paper covers a set of recommendations for AMI roll out in India.

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About India Smart Grid Forum

India Smart Grid Forum (ISGF) is a public private non-partisan initiative of the Ministry of Power (MoP), Government of India for accelerated development of smart grid technologies in the Indian power sector. ISGF was set up in 2010 to provide a mechanism through which academia, industry; utilities and other stakeholders could participate in the development of Indian smart grid systems and provide relevant inputs to the government's decision making.

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1. Introduction

The Government of India (GoI) announced the UDAY program for financial restructuring and performance enhancement of electricity distribution companies (DISCOMs). Under UDAY, GoI mandated DISCOMs to deploy smart meters (conforming to latest Indian Standards IS 16444 and IS 15959 Part-2) for all customers with monthly electricity consumption above 200 kWh. In the Electricity Tariff Policy announced in February 2016, GoI reiterated the goal of smart meters envisaged in the UDAY program. It is estimated that there are about 35 million customers who consume above 200 kWh/month. The onus is now on the state government owned DISCOMs to choose the most optimum deployment strategy. While the traditional AMI approach is to deploy smart meters for all customers on a feeder, another option is to deploy only for customers having monthly electricity consumption greater than 200 kWh. A detailed cost-benefit analysis is presented in this Paper which strongly advocates deployment of smart meters for **all** customers on a feeder primarily because of the potential to reduce network losses and substantially lower the cost for last mile communication network when the complete feeder is covered. The full benefits of AMI can be realized only when all customers on a feeder are covered. Since the customers who consume above 200 kWh are randomly spread on a feeder, the communications network needs to be established for almost the full feeder in any case. The cost of software systems (Head End, Meter Data Management System, Database, and Operating Systems etc.), computer hardware, system integration and operation and maintenance of the AMI system will be marginally higher for covering all customers on a feeder. Hence deploying AMI on full feeder basis will have only marginal cost difference (cost of meter, communication module and installation, testing and commissioning charges) compared to full feeder deployment.

This Paper also examines key issues such as smart meter standards and specifications, testing of smart meters, retrofitting of existing meters, communication technology choices, procurement strategy and business models for AMI rollout.

Table 1: Comparison of benefits of AMI in two different scenarios

Typical Benefits of AMI A) **For DISCOMs**	**Scenario-A: Full Feeder implementation**	**Scenario-B: Scattered implementation for Customers with monthly consumption >200kWh**
Reduction in meter reading cost	Yes	Significantly less
Reduction in data entry cost	Yes	Significantly less
Reduction in cost of connection/disconnection	Yes	Yes
Faster detection of dead meters	Yes	Yes
Real time energy auditing	Yes	No
Reduction in Aggregate Technical &Commercial (AT&C) losses	Yes	Very little
Identification of phase imbalance	Yes	No
Reduction in time taken for meter reading and bill generation*	Yes	Significantly less
Reduction in human errors in meter reading and billing*	Yes	Significantly less
Faster outage detection and restoration (via last gasp and	Yes	Significantly less

first breathe notifications)*		
Power quality measurement*	Yes	Significantly less
Reduction in peak power purchase cost (through better estimation of loads)	Yes	Significantly less*
Better visibility of loading on the power system which helps faster/delayed capacity enhancement and prevention of failure/under-utilization of equipment*	Yes	No
Reduced load on call centers, customer care center and billing centers*	Yes	Significantly less
Reduction in distribution transformer (DT) failure rate – owing to increased visibility of actual loads on the DTs on real time basis	Yes	No
B) **For Customers**		
Faster restoration in case of outages	Yes	No
Error-free bills and no need for visiting billing centers	Yes	Yes
Time of Use tariff and savings on electricity bills	Yes	Yes
Ability to monitor and manage electricity consumption and options to save money	Yes	Yes
Ability to remotely manage and control appliances at home/office (with additional home/building automation tools)	Yes	Yes
C) **Common to Society**		
Reduction in carbon footprint (reduced patrolling for outage detection, meter reading, connection/reconnection etc.)*	Yes	Significantly less

** These benefits have not been monetised in the cost-benefit analysis presented below owing to lack of base-line data at this point in time.*

2. Part A: Cost Benefit Analysis of AMI

The rollout of Advanced Metering Infrastructure (AMI) encompasses a number of factors, comprising choice of communications technology, the digital architecture, cost per customer per node etc. The cost-benefit analysis (CBA) here compares **two** distinct scenarios, as below:

Scenario-A: Deploying smart meters for all customers on a feeder (using suitable communication technology)

Scenario-B: Deploying smart meters for customers having monthly consumption of 200 kWh or more (using suitable communication technology)

For the purpose of comparing these two scenarios, we have considered a geographic area with 1000 feeders and each feeder having average 1000 customers in which:

- 25% of the customers have monthly consumption greater than 500 units
- 40% of the customers have monthly consumption between 200 and 500 units
- 35% of the customers have monthly consumption less than 200 units

This is depicted in Table 2 below.

Table 2: Demography of customers based on electricity consumption

No. of customers with monthly consumption > 500 units	250,000
No. of customers with monthly consumption between 200 units and 500 units	400,000
No. of customers with monthly consumption < 200 units	350,000
Total for 1,000 feeders	**1,000,000 (1 million)**

2.1 Scenario-A: Deploying smart meters for all customers on a feeder (using suitable communications technology)

In this scenario, it is envisaged to install smart meters for all customers on a feeder using suitable communications technology. So all the 1 million customers spread over 1000 feeders will be covered under the AMI. The cost of various components is described below.

A) Cost at individual customer premises:

Table 3: Cost of equipment at individual customer premises

Item	Unit Cost (INR)	Quantity	Total Cost (INR)
Smart meter with communications module	3000	1 million	3,000,000,000
Meter box	500	1 million	500,000,000
Installation charges	500	1 million	500,000,000
Total	**4,000**	**1 million**	**4,000,000,000**

The cost at customer premises for deploying AMI for all 1 million customers covering 1000 feeders is INR 4 billion (or INR 400 crore).

B) Cost of Neighbourhood Area Network (NAN):

Table 4: Cost of Neighbourhood Area Network (NAN)

Item	Unit Cost (INR)	Quantity	Total Cost (INR)
Data Concentrator Unit/Gateway*	50,000	10,000	500,000,000
Installation and setting up of RF mesh network*	5,000	10,000	50,000,000
Total	**550,000,000**		

Note: For comparison purposes here we have considered RF Mesh technology for the NAN and one Data Concentrator/Gateway for 100 meters.

The cost of setting-up a Neighbourhood Area Network (NAN) for deploying AMI for all 1 million customers on 1000 feeders is INR 550,000,000 (or INR 55 crore).

C) System Cost:

Table 5: Cost of HES, MDMS, computer hardware and software, system integration etc.

Item	Unit Cost (INR)	Quantity	Total Cost (INR)
Head End System (HES)	20 million	1	20 million
Meter Data Management System (MDMS)	20 million	1	20 million
Computer Hardware & System Software and Networking System	50 million	1	50 million
System Integration	50 million	1	50 million
Total	**140 million**		

The system cost for deploying AMI for all 1 million customers on 1,000 feeders is INR 140 million.

D) Operation and Maintenance (O&M) Cost:

Table 6: Cost for O&M of AMI system

Item	Annual Cost (INR)	Lifecycle Cost	Remarks
Annual Maintenance Charges (AMC) of Smart Meters @ 2.5% p.a.	87.5 million	875 million	10 years
Annual Maintenance Charges (AMC) of DCU/Gateway @2.5% p.a.	13.75 million	137.5 million	10 years
Annual Maintenance Charges (AMC) of Head End System (HES) at 20% p.a.	4 million	20 million	5 years
Annual Maintenance Charges (AMC) of Meter Data Management System (MDMS) at 20% p.a.	4 million	20 million	5 years
Application Maintenance Support (AMS) of MDMS and HES @ 10% p.a.	4 million	20 million	5 years
O&M for attending to repairs/replacements/customer complaints/upgradation	100 million	1,000 million	10 years
Communication charges for WAN (leased lines/GPRS)	10 million	100 million	10 years
Total	**223.25 million**	**2,172.5 million**	

AMC and AMS for software are not considered beyond five years.

The O&M cost of the AMI system for all 1 million customers (spread over 1,000 feeders) is INR 2172.5 million for a period of 10 years.

Summary of total cost for deploying AMI for 1 million customers in Scenario A:

Table 7: Total cost of AMI for 10 years in Scenario A for 1 million customers

Item	Cost (INR)	Remarks
Cost of equipment at customer premises	4,000 million	One-time cost
Cost of Neighbourhood Area Network (NAN)	550 million	
System Cost	140 million	
Sub-Total (A)	***4,690 million***	
O&M Cost (including WAN communication) for 10 years **(B)**	2,172.5 million	Certain items for ten years and few items for 5 years
Total Cost for 10 years [(C)=(A) + (B)]	**6,862.5 million**	
Overhead, contingency and other unforeseen/contingency @ 10% of above, i.e.**(D) = 10% of (C)**	686.25 million	
Total cost [(E)=(C) + (D)]	**7548.75 million**	

The capex for deploying AMI for 1 million customers in Scenario-A is INR 4,690 million. The total cost including fixed cost and cost of operation and maintenance of the system for 10 years is INR 7,548.75 million (Rs 754.875 crore) which translates to **INR 7,548.75 per customer for 10 years (or INR 62.9 per customer per month).**

2.1.1 Benefits to DISCOM

In the table below we have described the benefits to the DISCOM for deploying AMI for 1 million customers.

Table 8: Benefits to DISCOM in Scenario 1

Benefits	Value	Annual benefits/savings for 1 million customers INR
Annual savings on meter reading cost (salary, allowances and travel cost of meter readers, stationery etc.) - **(A)**	INR 15* per customer per month considered (=15*12*1 million)	**180 million**
Annual savings on data entry cost for bill generation - **(B)**	INR 7.5* per meter read per bill (=7.5*12*1 million)	**90 million**
Annual savings on cost for disconnections/reconnections - **(C)**	Disconnections/reconnections considered for 1% customers every month and cost taken as INR 500* per visit (including cost of man hours) (=500*10,000*12)	**60 million**
Annual savings due to faster detection of dead meters in the system (taking INR 5* as	No. of dead meters considered for 0.1% customers, time taken to detect dead meters as 30	

average tariff) - **(D)**	days, monthly billed energy as 120 MU and billing efficiency as 90% (=133,333.34*12*5)	**8 million**
Annual savings due to reduction in AT&C losses (taking INR 5* as avg. tariff). This includes energy accounting - **(E)**	Reduction in AT&C losses due to AMI considered as 10% (from 25% to 15%) (=10% of 133.34 MU*12*5)	**800.04 million**
Annual savings from reduction in DT failure rate+ - **(F)**	Reduction in DT failure rate due to AMI considered as 5% (from 8% to 3%), cost of DT as INR 100,000 and 4,000 DTs for 1 million customers. (=5% of 4,000*100,000)	**20 million**
Annual savings due to reduction in peak power purchase cost (through better estimation of loads) - **(G)**	20% load reduction during 4 hours of daily peak period; and energy input cost difference of INR 2/KWh considered (=20% of [133.34 MU/30/24]*4* 2* 30 *12)	**106.67 million**
Total annual benefits (INR/year) (=A+B+C+D+E +F +G)	**1264.71 million**	

** This value is intentionally taken higher than the present value for incorporating the inflation over the lifetime of the AMI project which is considered as 10 years*

+ This excludes the loss of revenue to the DISCOM in case of DT failure

From the above calculation, INR 1264.71 million is the annual benefit of deploying AMI for 1 million customers.

2.1.2 Payback Period

Payback Period = (Fixed Cost + O&M Cost for 3 years)/Total Annual Benefits

= (4690 million + 223.25 million*3)/(1264.71 million)

= 4.23 years

2.2 Scenario-B: Deploying smart meters for customers in a feeder that have a monthly consumption greater than 200 units (using suitable communications technology)

In this scenario, it is envisaged to install smart meters for those customers in a feeder having monthly electricity consumption greater than 200 units (using suitable communication technology).

A) Cost at individual customer premises:

Table 9: Cost of equipment at individual customer premises

Item	Unit Cost (INR)	Quantity	Total Cost
Smart meter with communications module	3,000	650,000	1,950,000,000
Meter box	500	650,000	325,000,000
Installation charges	500	650,000	325,000,000
Total	**4,000**	**650,000**	**2,600,000,000**

Please note that in this scenario, 65% of the customers have monthly consumption greater than 200 units. Hence, the cost at customer premises for deploying AMI for 650,000 customers on 1000 feeders is INR 2,600 million (Rs 260 crore).

B) Cost of Neighbourhood Area Network (NAN):

Table 10: Cost of Neighbourhood Area Network (NAN)

Item	Unit Cost (INR)	Quantity	Total Cost (INR)
Data Concentrator Unit/Gateway	50,000	8,000*	400,000
Installation and setting up of RF network	5,000	8,000	40,000
Total	**440,000,000**		

** This scenario will have more number of DCU's/Gateways as forming the RF mesh will require additional intermediate elements.*

The cost of setting-up a Neighbourhood Area Network (NAN) for deploying AMI for 650,000 customers is INR 440 million.

C) System Cost:

Table 11: Cost of HES, MDMS, computer hardware and software, system integration etc.

Item	Unit Cost (INR)	Quantity	Total Cost (INR)
Head End System (HES)	20 million	1	20 million
Meter Data Management System (MDMS)	20 million	1	20 million
Computer Hardware & Software and Networking System	40 million	1	40 million
System Integration	40 million	1	40 million
Total	**130 million**		

The system cost for deploying AMI for 650,000 customers is INR 130 million.

D) Operation and Maintenance (O&M) Cost:

Table 12: Cost for O&M of AMI system

Item	Annual Cost (INR)	Cost for 10 years	Remarks
Annual Maintenance Charges (AMC) of Smart Meters @ 2.5% p.a.	56.875 million	568.75 million	10 years
Annual Maintenance Charges (AMC) of DCU/Gateway @2.5% p.a.	11 million	110 million	10 years
Annual Maintenance Charges (AMC) of Head End System (HES) at 20% p.a.	4 million	20 million	5 years
Annual Maintenance Charges (AMC) of Meter Data Management System (MDMS) at 20% p.a.	4 million	20 million	5 years
Annual Maintenance Support (AMS) of MDMS and HES @ 10% p.a.	4 million	20 million	5 years
O&M for attending to repairs/replacements/customer complaints/upgradation	80 million	800 million	10 years
Communication charges for WAN (leased lines/GPRS)	10 million	100 million	10 years
Total	**169.875 million**	**1,638.75 million**	

The O&M cost the AMI system for 650,000 customers (spread over 1,000 feeders) is INR 1,638.75 million for a period of 10 years.

Summary of total cost for deploying AMI for 650,000 customers in Scenario B:

Table 13: Total cost of AMI system for 10 years

Item	Cost (INR)	Remarks
Cost of equipment at customer premises	2,600 million	One-time cost
Cost of Neighbourhood Area Network (NAN)	440 million	
System Cost	130 million	
Sub-Total (A)	***3,170 million***	
O&M Cost (including WAN communication) for 10 years **(B)**	1,638.75 million	Certain items for ten years and few items for 5 years
Total cost for 10 years (C)=(A) + (B)	**4,808.75 million**	
Overhead, contingency and other unforeseen @ 10% **(D)**	480.875 million	
Total cost [(E)=(C) + (D)]	**5289.625 million**	

The fixed cost for deploying AMI for 650,000 customers in Scenario 2 is INR 3,170 million. The total cost including fixed cost, installation cost and cost of operation and maintenance of the system for 10 years is INR 5,289.625 million which translates to INR 8137.884 per customer for 10 years (or INR 67.81 per customer per month).

2.2.1 Benefits to DISCOM

Note: *These are the benefits for deploying AMI for 1 feeder having 1,000 customers.*

Table 14: Benefits to DISCOM in Scenario B

Benefits	Value	Annual benefits/savings for 1 million customers INR
Annual savings on meter reading cost (salary, allowances and travel cost of meter readers, stationery etc.) - **(A)**	INR 15* per customer per month considered (=15*12*650,000)	**117 million**
Annual savings on data entry cost for bill generation - **(B)**	INR 7.5* per meter read per bill (=7.5*12*650,000)	**58.5 million**
Annual savings on cost for disconnections/reconnections - **(C)**	Disconnections/reconnections considered for 0.7% customers every month and cost taken as INR 500* per visit (=500*7,000*12)	**42 million**
Annual savings due to faster detection of dead meters in the system in INR (taking INR 5* as average tariff) - **(D)**	No. of dead meters considered for 0.1% customers, time taken to detect dead meters as 30 days, monthly billed energy as 120 MU and billing efficiency as 90% (=133,333.34*12*5)	**8 million**
Annual savings due to reduction in AT&C losses in INR (taking INR 5* as avg. tariff). This includes energy accounting - **(E)**	Reduction in AT&C losses due to AMI considered as 2% (from 25% to 23%) (=2% of 133.34 MU*12*5)	**160 million**
Total annual benefits (INR/year) (=A+B+C+D+E)		**385.5 million**

** This value is intentionally taken higher than the present value for incorporating the inflation over the lifetime of the AMI project which is considered as 10 years*

From the above calculation, the annual benefit for deploying AMI for 650,000 customers (spread over 1,000 feeders) will be INR 385.5 million.

2.2.2 Payback Period

Payback Period = (Fixed Cost + O&M Cost for 3 years)/Total Annual Benefits

= (3,170 million + 169.875 million*3)/(385.5 million)

= 9.54 years

2.3 Comparison of Scenario A and Scenario B

The following tables compare the two Scenarios:

Table 15: Comparison between deployment of AMI in Scenarios A and B

Item	Scenario A	Scenario B
Cost of equipment at customer premises for 1 million customers in INR	4,000 million	2,600 million
Cost of Neighbourhood Area Network (NAN) for 1 million customers in INR	550 million	440 million
System Cost for 1 million customers	140 million	130 million
Operation and Maintenance (O&M) Cost for 1 million customers in INR per annum	223.25 million	169.875 million
Annual saving due to reduction in meter reading for 1 million customers in INR	180 million	117 million
Annual saving due to reduction in data entry cost for 1 million customers in INR	90 million	58.5 million
Annual saving on connect/disconnect of meter for 1 million customers in INR	60 million	42 million
Annual savings due to faster detection of dead meters for 1 million customers in INR	8 million	8 million
Annual savings due to reduction in AT&C losses for 1 million customers in INR	800.04 million	160 million
Annual savings from reduction in DT failure rate for 1 million customers in INR	20 million	NIL
Annual savings due to reduction in peak power purchase cost (through better estimation of loads) for 1 million customers in INR	106.67 million	NIL
Total annual benefit to DISCOM for 1 million customers in INR	1264.71 million	385.5 million
Payback Period	4.23 years	9.54 years

2.4 Inferences

The following inferences can be drawn from the above analysis:

- Scenario A offers significant reduction in meter reading cost, time taken for meter reading, data entry cost, human errors and the carbon footprint. On the other hand, Scenario B offers significantly less benefits in these areas
- Scenario A provides significantly more assistance in outage detection and restoration via last gasp and first breathe notifications, and in power quality measurement, as compared to Scenario B
- In both scenarios, the system cost, which includes HES, MDMS, computer hardware & software, networking equipment and system integration, is almost same
- As shown in Scenario A, by a marginal increase in the deployment cost, the DISCOM can avail a lot more benefits from AMI
- Scenario A leads to achieving a total annual benefit of INR 1264.71 million, whereas, Scenario B exhibits a total annual benefit of INR 385.5 million only
- The prime reason for the large difference in these values is that when AMI is **NOT** deployed on the whole feeder, energy auditing cannot be performed in near real-time. Hence the sources of AT&C losses cannot be traced correctly. On the other hand, when AMI is deployed on the whole feeder, online energy auditing is possible and hence AT&C losses can be traced and appropriate measures can be taken to reduce it substantially
- Scenario A leads to the establishment of last mile communication connectivity in the most cost effective manner, whereas, in Scenario B it is expensive
- Scenario A provides an extremely good payback period of 4.23 years, whereas, Scenario B has a long payback period of 9.54 years
- Scenario A leads to a reduction in the distribution transformer failure rate, while Scenario B does not provide this benefit
- Several other benefits of AMI can be leveraged (which are not monetised in this cost-benefit analysis) when it is rolled out on full feeder

3. Part B: Recommendations on AMI Rollout Strategy for India

This section of the Paper clarifies certain common issues raised by various stakeholders on AMI deployment with respect to applicability of standards, testing facilities, industry capability to meet the targets set by GoI, communication technology choices, procurement framework, rollout strategies and business models.

3.1 Meter Standards and Specifications

All meters may 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 February 2016
    - No standard required for Communications – each DISCOM 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.

c. Specifications for Smart Meters and Functional Requirements of AMI in India

In June 2016, the Central Electricity Authority (CEA) issued the specifications of single phase and three phase smart meters, and functional requirements of AMI in India. All DISCOMs may be advised to abide by these specifications and minimum functional requirements.

3.2 Test Infrastructure for Testing Meters conforming to IS 16444

New tests mentioned in the smart meter standard are:

- The power consumption has increased. Test infrastructure only needs to change its THRESHOLD values
- Test for Communicability of smart meters and check connect-disconnect functionality
  - This is optional in IS 15959 (Part 2)
  - A DISCOM can test connect-disconnect function using any available communication technology in the test lab; and it will still work if a connect/disconnect signal is sent to the same meter using any other communication technology when deployed in the field

3.3 Retrofitting of Old Meters

As per IS 16444, the communication module has to be a part of the smart meter (either in-built or pluggable units). Hence retrofitting will not be possible. This was a decision taken by the technical committee at BIS as the stakeholders cited the following concerns if the communication module is retrofitted on existing meters:

- Theft of communication module
- Increased points of failure
- The unsuccessful use case of AMR in R-APDRP (where meter manufacturers were blaming the MODEM makers who in turn blamed the telecom network operators for poor bandwidth and vice versa)

Sending engineers and technicians to customer premises again and again to check and rectify the meter-modem-bandwidth issues is several times more expensive than the cost of new meter and communication device. **Hence retrofitting communication modules on already-installed meters should not be considered.**

3.4 Communication Technologies for AMI

The following table depicts some of the available choices for communication technologies for AMI deployment.

Table 16: 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, Millimeter Wave Technology	6LoWPAN-based RF mesh, ZigBee, Wi-Fi, Bluetooth, Z-Wave, NFC	Cellular, Satellite, LPWA, Long Wave Radio, TVWS, Private Microwave Radio links (P2P and P2MP)
Wired	PLC, Ethernet, Serial interfaces (RS-232, RS-422, RS-485), DSL	PLC, Ethernet, Serial interfaces (RS-232, RS-422, RS-485)	Optical Fiber, Ethernet, PLC, DSL

Note: This list is indicative only.

3.5 Manufacturing Capacity and Capability

As we understand, all the large meter manufacturers in the country are working on smart meters complying with IS 16444 requirements. If they speed up they can complete testing in 4-6 months. Several small players claim they have meters complying with IS 16444. The UDAY program has set a target of 35 million smart meters by December 2019 which is possible considering the AMI work undertaken in other countries. The table below depicts a snapshot of the AMI rollout plans in other countries.

Table 17: Snapshot of AMI rollout plans in other countries

Country	No. of meters in the country by 2020 (in million)	Expected penetration rate by 2020 (%)	Total no. of smart meters expected to be installed by 2020 (in million)	Rollout timelines
Austria	5.7	95	5.4	2012-2019
Denmark	3.2	100	3.2	2014-2020
Estonia	0.7	100	0.7	2013-2017
Finland	3.3	100	3.3	2009-2013
France	35	95	33.2	2014-2020
Greece	7	80	5.6	2014-2020
Ireland	2.2	100	2.2	2014-2019
Italy	36.7	99	36.3	2001-2011
Luxemburg	0.26	95	0.24	2015-2018
Malta	0.2	100	0.2	2009-2014
Netherlands	7.6	100	7.6	2012-2020
Poland	16.5	80	13.2	2012-2022
Romania	9	80	7.2	2013-2022
Spain	27.7	100	27.7	2011-2018
Sweden	5.2	100	5.2	2003-2009
UK – Great Britain	31.9	99.5	31.8	2012-2020

Source: *EU document on 'Country fiches for electricity smart metering'*

North America is expected to achieve a penetration of about 80% for deployment of smart meters by 2020.

3.6 Procurement Strategy

Having explored various options, the following procurement framework is recommended:

1. International Competitive Bids (ICB) for lots of 5-10 million meters may be issued by a Nodal agency (central or state) so that price discovery is achieved faster. PFC, REC or a state Nodal agency may issue such RFPs according to the functional requirements of AMI and smart meter specification finalized by CEA
2. From the above tender, manufacturers/suppliers of meters and different communication devices based on the best evaluated prices may be empanelled. The rates may be made firm for a given timeline and the annual capacities of each supplier may be declared
3. A DISCOM may appoint an AMI Implementation Agency (ideally a System Integrator or a large engineering company) through a transparent procurement process. The DISCOM in consultation with the appointed AMI Implementation Agency will select the meters, suitable communications technology for AMI only OR also capable of providing connectivity for multiple applications such as smart metering, distribution automation, street light management, distribution transformer monitoring, electric vehicles etc. based on their smart grid roadmap. This may be achieved through undertaking pilot implementations or trial with select communication technologies shortlisted by the Nodal agency as described above
4. Once the communications technology is selected, the DISCOM can choose any of the meter suppliers empanelled (step-2) whose meters can be integrated with the chosen communications technology selected by the DISCOM. This process ensures device-level interoperability; and if a meter fails to operate, the DISCOM can purchase another meter from any manufacturer from the empanelled list at empanelled rates and hence will not be locked to a specific manufacturer

<u>It is recommended to procure 10% of the meters from Micro, Small and Medium Enterprises (MSME) sector to promote innovation and start-up ecosystem in the country.</u>

3.7 Rollout Methodology

The DISCOM may prioritize the customers and locations for deployment of AMI according to

i. Feeders having majority of customers with high monthly consumption (>1000 units, >500 units, >200 units in that order of priority)
ii. Feeders/pockets with high AT&C loss areas (>15% pockets/feeders)
iii. Feeders/towns with high annual energy sales (above a certain million units/year)

AMI rollout may be undertaken for full feeders that will enable online energy auditing. All new meters to be purchased from July 2016 to be smart meters conforming to latest amendments of IS 16444 and IS 15959. All feasible communication technologies may be allowed to operate in order to encourage innovation in view of the fact that the communication technologies advance much faster compared to other electrical technologies.

IPv6 shall be made mandatory as this is in line with the IPv6 roadmap of the Ministry of Communications & IT.

3.8 Business Models

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-1 to this Paper. 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.

4. Conclusion

From the detailed analysis it is recommended that:

i. DISCOMs may deploy AMI for ALL customers on a feeder which will help substantial reduction in AT&C losses through online energy auditing (which is not possible if all customers do not have smart meters) and faster detection and restoration of outages besides several other advantages

ii. DISCOMS may explore innovative business models in which they can reduce the capex as well as technology risk through engagement of AMI Services Providers on a monthly rate per customer for ten years at mutually agreed service level agreements

iii. The unit prices of meters and other communication equipment considered in this Paper are applicable when procurement is done in millions. Hence it is recommended to appoint a Nodal agency (either at central or state level) such as PFC, REC to issue RFP for procurement of meters and other communication equipment in millions so that best price discovery is achieved. From such an RFP process and best price discovery, successful OEMs/vendors may be empanelled and the prices and annual capacities may be declared for a given time frame. The DISCOMs can directly engage such OEMs/vendors at the empanelled prices or lower. It is pertinent to mention if each DISCOM undertakes tendering of thousands of smart meters, the prices of smart meters are not expected to come down. When there is a clear indication from the Government for deployment of AMI for millions of customers, OEMs/vendors will enhance their capacity which will lead to lower prices faster.

Appendix-1: Framework for Smart Meter Rollout based on Leasing and Services Model

In April 2016, ISGF released a Paper on 'AMI Roll-Out 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 requirements. 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 Figure 1 on the next page.

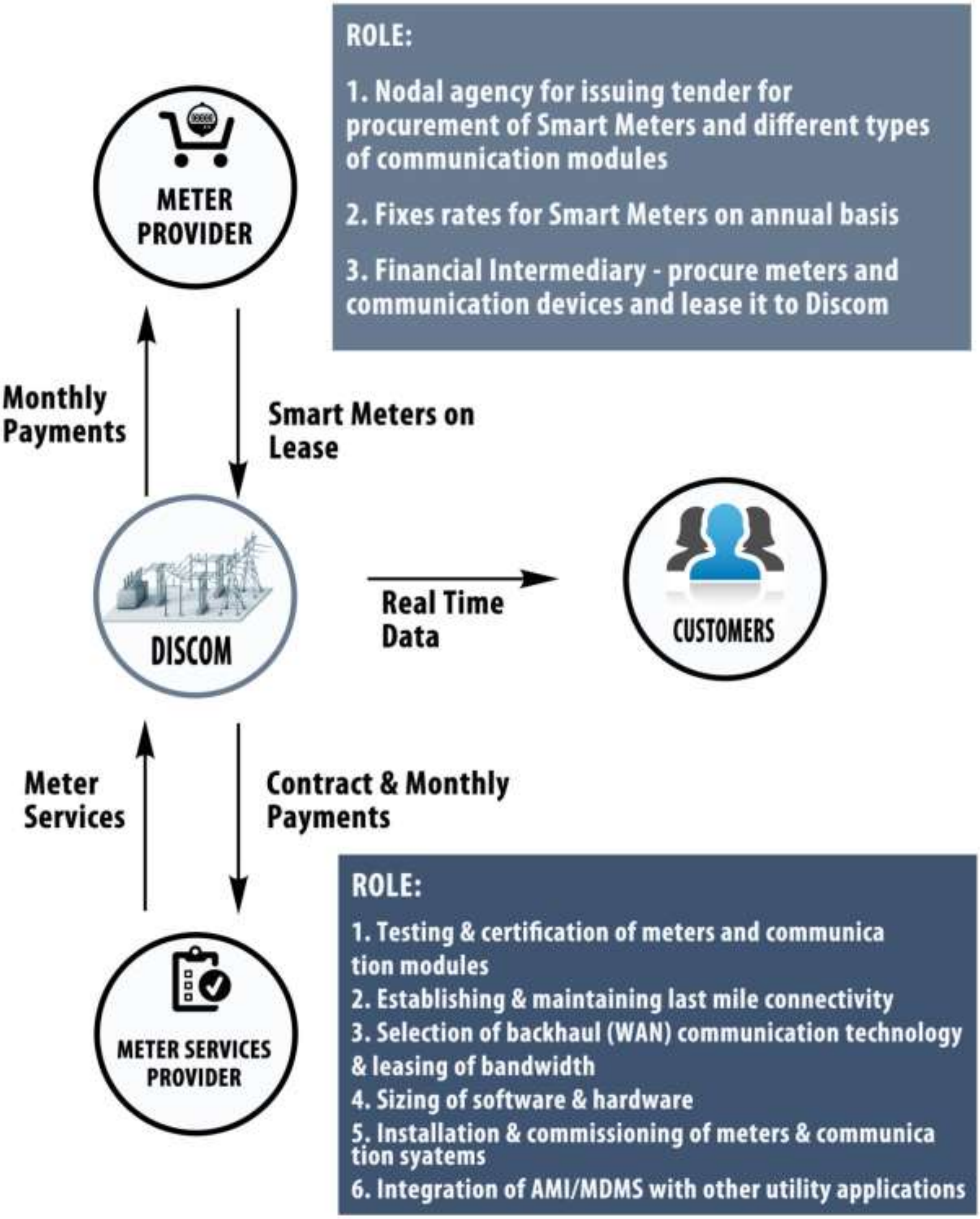


Figure 1 – AMI rollout framework based on 'Leasing and Services' model

Appendix-2: Wi-Fi as a Viable Option for AMI Communications

In September 2015, ISGF released a Paper on 'Next Generation Smart Metering: IP Metering' that unveiled the compelling vision for next generation smart metering using internet in the recently published White Paper: "Next Generation Smart Metering – IP Metering". The widely adopted communication architectures deployed in smart metering projects involve RF/PLC/BPL for last mile connection from a Data Concentrator Unit (DCU) to a group of meters; and the DCUs transmit the data to the utility's sever over the wide area network – GPRS/fiber networks. This architecture evolved over the past ten years particularly because the early mover utilities wanted dedicated communication networks which they could control. Now that most buildings (even in smaller towns in developing countries) have broadband internet connections, utilities can leverage the existing communication infrastructure for smart metering. The meters may be directly connected to internet using Wi-Fi in buildings/factories/commercial centres etc. Once meters are connected on the internet, the meter data can be aggregated on a server anywhere – in utility's control room or on the cloud.

Smart metering or Advanced Metering Infrastructure (AMI) architecture with RF mesh for last mile connectivity has emerged as a popular solution amongst utilities in many geographies as depicted in the diagram below:

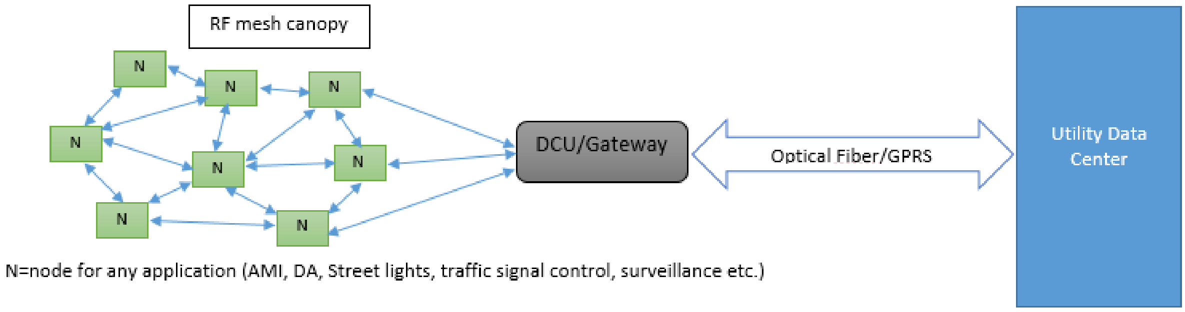
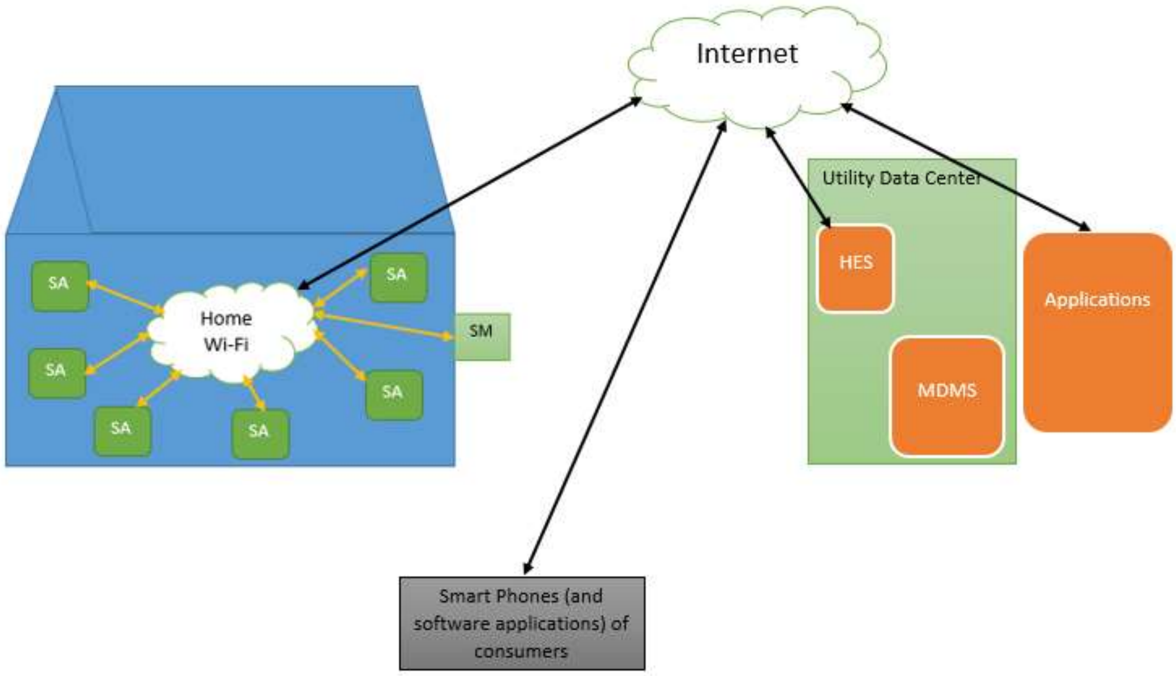


Figure 2 – Emerging architecture for smart grid and smart city applications – RF mesh canopy

ISGF Vision for Next Generation Communication Architecture for Smart Metering – IP Metering

We at ISGF believe that by 2020, almost every building (residential/commercial/industrial/public institutions etc.) in urban and semi-urban areas on earth will have broadband internet connectivity (perhaps except in some conflict regions). The smart meter, smart appliances, utility's Head End System (HES) and other applications can connect to the Internet and eliminate the need of intermediate entities such as DCUs/gateways. As shown in Fig. E, smart meters and smart appliances can be connected to the Wi-Fi network in the home/building/campus. Meter data is sent over the broadband internet which can be accessed by the utility's HES and received in the MDMS which integrates the meter data with all utility applications; and applications with consumers on their smart phones eliminating the need for in-home displays (IHDs).



Legend:

SA	Smart Appliances
SM	Smart meter
HES	Head End System
MDMS	Meter Data Management System

Figure 3 – Communication architecture for next generation smart metering – IP Metering

Rationale for IP Metering in India

The Govt. of India was pursuing a program, National Optical Fiber Network (NOFN), to provide broadband connectivity to 250,000 villages, which the Modi-Government has decided to expand to 600,000 villages under the "Digital India" program for providing universal broadband access to all. Ministry of Power has proposed to fund the extension of NOFN to all 33kV and above substations as part of Integrated Power Development Scheme (IPDS) and Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY) programs. These schemes are going to provide broadband access to most part of the country as well as create a dedicated fiber backbone network for the power system.

The advantage of the proposed architecture is that it leverages the existing communication infrastructure, that is, broadband connection in buildings and homes, and hence reduces the total cost of ownership as additional network elements such as data concentrator units, gateways etc. are not required. Wi-Fi connectivity is maintained by Broadband Service Providers (BSP) who have the expertise and resources to maintain such networks with very high reliability. IP networks are scalable and reliable and can be monitored and controlled in real time. Questions regarding the security of Wi-Fi networks cannot pose a major threat as people are widely using their laptops and other mobile devices for all kinds of online transactions when connected to Wi-Fi networks. As far as inter-operability is concerned, if all the meters follow common data models/routing tables, the MDMS can accept data from different makes of meters – similar to smart phones of different makes with different operating systems connected on Wi-Fi are able to communicate with each other so long as the users understand the same language.

Conclusion

The communication architectures presently deployed for smart metering include intermediate entities such as data concentrator units/gateways and creation of a dedicated parallel communication network for the electric utility which they have no expertise in maintaining and upgrading as new communication technologies are evolving at a faster pace. This also involves use of wireless spectrum which is a limited and expensive resource in every country today. Experiences from around the world indicate that none of the communication solutions presently deployed for smart metering have 100% reliability despite having a dedicated network. These architectures not only increase the total cost of ownership but also fail to offer reliable, scalable and interoperable last mile connectivity.

In today's world where internet is everywhere, smart meters and smart appliances could be connected directly on internet; and utility's HES can leverage internet to collect the meter data on the server and the MDMS can integrate that with other applications. In other words, the broadband internet that is present in almost all homes, buildings and campuses, can be used for providing last mile connectivity for smart metering. By doing do, devices such as data concentrator units, gateways and in-home displays will not be needed and highly reliable, scalable and interoperable last mile connectivity can be provided. Wherever there is no Wi-Fi, the electric utility may provide Wi-Fi which will be cheaper than other last mile connectivity options.

In the IPv6 regime where every meter can have an IP address, the proposed IP Metering solution can offer multiple benefits to utilities and governments:

- No need for a parallel telecom infrastructure – huge savings in cost of deployment and maintenance for the utility
- No need for separate spectrum for utility applications – instead government can allocate that spectrum to telcos and/or other users for additional revenue
- More reliability, scalability, security and capability to monitor and control – IP networks can be monitored in real time which itself is a good measure against cyber attacks

Appendix-3: Last Mile Connectivity Options and Interoperability for Smart Metering

In December 2015, ISGF released a Paper on 'Last Mile Connectivity Options and Interoperability for Smart Metering ' that described options for achieving interoperability in smart metering which are mentioned below:

- **Long-term rate contract:** While procuring smart meters (and associated hardware and software for AMI), a rate contract of 7-10 years with select meter vendor (s) whose meters are interoperable may be considered. Hence when new customers are to be added to the AMI network, the same meter manufacturers can provide the existing/already deployed solution to the Utility at previously agreed rates. This will enable seamless integration of new smart meters.

- **Choose communications technology first:** Another approach is to first choose the communication technology and then select the meter manufacturer/s. In such a case, all potential meter manufacturers will have to integrate this communication technology into their meters. Hence Device-Level interoperability will be easily achieved. The communication solutions provider will certify that their network interface card (NIC) is integrated with the meters that will connect with the Head End System (HES).

- **Third-party certification**: A Utility can also opt for a third-party certification for ensuring Device-Level interoperability. In such a case, a Utility will ask the meter manufacturers to present an Interoperability Certificate acquired from the certification agency.

- **Wi-Fi for last mile connectivity:** By 2020, almost every building (residential/commercial/industrial/public institutions etc.) in urban and semi-urban areas on earth will have broadband internet connectivity. Hence the smart meter and smart appliances can connect to the Utility servers using Wi-Fi. Moreover, choosing Wi-Fi for providing last mile connectivity can solve issues of interoperability, scalability, maturity, reliability and cost effectiveness.

- **Multiple HES with one MDMS**: In case multiple communication technologies for smart metering are selected by a Utility (over successive tendors) each having its own Head End System (HES), a common MDMS may be chosen that can interface with multiple HES. In such a case, all communication interfaces will have to be standardised as per ***IEC 61968: Application integration at electric utilities - System interfaces for distribution management***. This is a series of standards that define interfaces for the major elements of an interface architecture for Distribution Management Systems in DISCOMs. This option is often the last resort if all the above options are not possible.

Table 18: Comparison of options for achieving interoperability in smart metering

Option / Parameter	Long-term rate contract	Choose communications technology first	Third-party certification	Wi-Fi for last mile connectivity	Multiple HES with one MDMS
Feasibility	High	High	Moderate	High	Moderate
Cost effectiveness	High	High	High	High	Low
Integration Time*	Minimum	Minimum	Moderate	Minimum	Maximum
Expertise required by Utility	Least	Moderate	Least	Least	High

* Integration time is the time required to integrate new smart meters into the Utility's AMI network.

In addition, a comparison of the communication technologies for smart metering is mentioned in this Paper which is described below:

Table 19: Communication options for smart metering

SMART METERING – COMMUNICATION OPTIONS		
Communications options	**Advantages**	**Disadvantages**
GPRS	• Mature technology • Rapid deployment • Communication modules are low cost and standardised • Best solution to get meter readings automatically from select set of customers scattered over a large geographical area	• Limited coverage (data network is poor in villages) • Limited reliability (cellular operators only guarantee performance on "best effort" basis) • Short technology lifecycle (2G => EDGE => 3G => LTE • Limited scalability (50 million smart meters would need additional towers) and spectrum • High operating cost - monthly recurring cost to cellular operators per SIM card • Most benefits of AMI cannot be achieved except meter reads
RF Mesh	• Lightweight (communication stack size) • Scalable (only DCUs/Gateways are needed) • Negligible operating cost • Can be used in multiple frequency bands (2.4 GHz and 865 MHz) • Relatively long technology lifecycle (v/s GPRS) • Other electrical network elements such as DT monitoring devices, street light controllers, RTU/FRTUs for distribution automation etc. can also be connected to the same RF Mesh network • Best solution as of now for deriving most benefits of AMI such as: outage detection and faster restoration, remote load curtailment when needed, demand response signals, ToU tariff signals, online (almost real-time) energy auditing,	• Initial cost of building the RF mesh network high • Trained engineers required to setup the RF Mesh network

	detection of phase-imbalances etc. • Several options for backhaul (WAN) connectivity	
PLC	• Ready infrastructure (power cables) • Communications possible in challenging environments such as underground installations, metal-shielded cases etc. • Relatively long technology lifecycle (v/s GPRS) • Good option for new residential colonies and newly electrified villages with new electrical network designed and built for PLC applications • Broadband PLC (BPL) can offer telephone and internet connections as well to customers	• Requires good quality power cables with crimped joints (in India mostly aluminium wires are have twisted joints which are not good for PLC) • Requires filters to clean the communication signal (from noise) • High total cost of ownership due to initial and on-going line conditioning and maintenance • Communication not possible in case of power outage (unless batteries are used in the modules and repeaters which is expensive) • Requires Bespoke engineering and trained manpower for O&M – every time new connections are added, all devices in that node need to be tuned (re-set)
Wi-Fi	• Use existing infrastructure (broadband internet connections in buildings and public places) to create Wi-Fi hotspots in meter rooms and public places; or share the customers broadband connectivity • Very low total cost of ownership o DCUs, Gateways, Routers not required o Low cost communication modules o Negligible operating cost • Mature technology and standardised equipment available • DISCOMs need not deploy telecom engineers to maintain and manage the communications network • Easy to implement • Relatively long technology lifecycle (v/s GPRS)	• Idea is relatively new (ISGF proposed in 2015) and few field trials are being undertaken now • Interference due to other devices operating in 2.4 GHz frequency band

The DISCOM may choose the appropriate option to achieve interoperability in smart metering. Selecting Wi-Fi for providing last mile connectivity option proves to be the best solution as it is mature, scalable, reliable and cost effective.