ISGF
India Smart Grid Forum

ISGF White Paper

Smart Metering Program in India – A Critical Assessment – Revision 1 (October 2023)

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Abstract

Electric utilities in Western Europe and North America embarked on Smart Metering or Advanced Metering Infrastructure (AMI) implementation at the beginning of the 21st century and today there are over 1.15 billion smart meters in operation around the globe. The early AMI projects had limited functionalities. As large volumes of smart meter data accumulated, forward looking utilities deployed advanced digital tools for analyzing the energy consumption data and realized that the time-stamped meter-reads offer a goldmine of information to fine-grain the distribution grid including accurate demand forecasting, power purchase cost reduction and asset optimization. Some of the early mover utilities in the AMI domain have also deployed Smart Meter Operations Center (SMOC) with Artificial Intelligence (AI) and Machine Learning (ML) tools for advanced analytics; and this current level of smart metering is referred as AMI 2.0 which offers several more benefits to utilities to transform as the next generation digital utilities. This updated version of the White Paper highlights the threat of potential claims for IPR fees by cellular technology patent holders for using their technologies in smart metering which could find attractive to these patent holders when tens of millions of smart meters are connected on cellular networks.

India is presently rolling out 250 million smart meters on fast track and can leapfrog to AMI 2.0 by leveraging the experiences of global utilities who have successfully ascended to AMI 2.0. This paper examines the ongoing AMI rollout in India and suggests the measures for mid-course correction to protect the investments.

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About India Smart Grid Forum

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

1 INTRODUCTION

In 2021, Government of India (GOI) launched the world's largest smart metering or Advanced Metering Infrastructure (AMI) program to replace 250 million electricity meters with smart prepayment meters under the Revamped Distribution Sector Scheme (RDSS) applicable to all the state government owned electricity distribution companies (Discoms) in India. The smart meter rollout proposed under this scheme envisages the appointment of an AMI Services Provider (AMISP) who will implement the AMI system and maintain it for ten years against a monthly fee per meter based on specified service level agreements (SLAs). Under RDSS, GOI will provide 15% of the cost of the project as grant to the Discoms which will be passed on to the AMISPs. Power Finance Corporation Ltd (PFC) and Rural Electrification Corporation Ltd (REC) are the nodal agencies for RDSS – half the Discoms are with PFC and rest with REC. A standard bidding document (SBD)[1] has been issued by REC for appointment of AMISPs which all the Discoms are mandated to follow for availing the grant under RDSS. Also, several AMISPs has been empaneled for this program[2] who are only eligible to bid for the AMI projects in Discoms. As of September 2023, 51 AMISPs have been empaneled; but majority of them have no prior experience with smart metering and many of them have never undertaken any kinds of projects with Discoms. This is a cause of concern as their understanding of what it takes to implement a large AMI project involving millions of meters is doubtful. The AMI system must be maintained by the AMISP for about 93 months after commissioning including replacement of faulty meters, maintaining the last mile connectivity, IT systems upgrades as and when required; and complying with the cyber security norms. As per the SBD, there are steep penalties for not meeting the SLAs. AMISPs need to factor all these risks in their project budget – not to speak of minimum two changes of the elected state governments who control the Discoms during the ten year project life that brings its own challenges.

As of 15 August 2023, AMI projects totaling about 230 million meters have been approved by the nodal agencies (PFC and REC) and contracts for 56 million meters have been awarded; tenders for the rest are under various stages of finalization. During the RDSS finalization and program rollout in the past 2 years, the SBD has gone through several rounds of amendments. Additionally, certain conditions imposed on the project implementation methodology do not align with successful practices from smart metering experiences worldwide over the past two decades. This paper provides insights gained from experts with decades of hands-on experience in implementing and maintaining large AMI systems in different utilities around the globe. It also offers a practical implementation roadmap for smart metering in Discoms in India.

2 KEY CONSIDERATIONS IN SMART METERING IMPLEMENTATION

Some of the key components of the AMI systems and the considerations for their selection and implementation are discussed here.

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[1] *Latest version of the SBD can be accessed here: https://recindia.nic.in/SBD-AMISP*

[2] *List of empaneled AMISPs can be accessed here: https://recindia.nic.in/ami-test-demonstration*

2.1 Smart Meters

Smart meters are a significant improvement over traditional meters in many ways. They offer several unique characteristics that can greatly benefit both consumers and utilities. One key feature of smart meters is their ability to transmit detailed and accurate energy usage data in real-time. This enables consumers to monitor and adjust their energy consumption patterns, leading to greater energy-efficiency and cost-saving benefits over time. Additionally, smart meters have the potential to support a more reliable and efficient power grid owing to their ability to remotely detect and report power outages and other issues. Smart meters eliminate the need for manual meter readings which saves time, reduces costs and labor, and improves accuracy. With benefits ranging from improved energy-efficiency, reduced costs, to better monitoring and reporting capabilities, smart meters are a valuable upgrade for any utility looking to improve their services.

India is one of the few countries that have a national-standard for smart meters. IS:16444 standard for smart meters was issued by Bureau of Indian Standards (BIS) in 2015 and the associated data communication standard IS:15959 Part-2 was issued in 2016. Presently there are 87 BIS certified meter manufacturing units with cumulative annual capacity of over 100 million meters in India[3]. While new domestic companies are setting up manufacturing facilities, some of the existing players are augmenting their manufacturing capacities as well. Foreign players are not expected to jump in due to very competitive pricing by domestic players and ban of import of smart meters from countries sharing land border with India (which precludes Chinese firms from participating in the smart metering projects in India). Overall, availability of smart meters is not expected to be a constraint for the 250 million smart meter rollout program. Smart meters record meter readings every 15 mins and have the memory to keep the data for 45 days in the meter.

2.2 Communication System

AMI requires two-way communications between the smart meter and the Discom's computers in the control room (or on the cloud). Various communication technologies, either individually or in combination, have been used by utilities worldwide for AMI. Major utilities in North America, Australia, Japan, Nordic Europe, South America, and South Korea have opted for the radio frequency mesh (RF Mesh) solution for their last mile connectivity. Chinese[4] and some European utilities have chosen power line communication (PLC) technology, along with RF Mesh, for their last mile communication. Meanwhile, utilities in the UK[5] and a few other Scandinavian countries have adopted cellular technologies. Detailed features, architecture and comparison of these different communication solutions are described in the next section 3.

Claim for IPR fees for using cellular technology for smart metering by cellular technology patent holders is a new development that started in Europe. As the number of smart meters deployed on cellular technologies scale up massively, such claims can arise in India as well. This issue is explained in APPENDIX-A

[3] *List of BIS approved smart meter manufacturing units in India is given in this link:* *https://www.services.bis.gov.in/php/BIS_2.0/bisconnect/manufacturers/RGlyZWN0IENvbm5lY3RlZA==*

[4] *Initially, smart metering with limited functionalities was rolled-out in China on PLC connectivity; later they experimented with RF Mesh, Cellular and NBIoT technologies. The second-generation AMI which is about to begin in China is expected to deploy RF Mesh for last mile connectivity*

[5] *The UK launched the AMI rollout on cellular communications; but soon realized that cellular communication cannot reach meters installed in the basement of buildings; hence they had to install RF based range extension systems. Out of 35 million smart meters installed so far in the UK, about 40% of them are connected through RF communication*

2.3 Software Solutions for AMI

Head-End System (HES) and Meter Data Management (MDM) System are the most important software solutions in an AMI system.

HES is a software that is responsible for fetching the meter data from the smart meters to the Discom's computers. Another important software for AMI system is the MDM which is installed in the Discom's computers where all meter data is collected and stored. In India, utilities record the meter readings every 15 minutes – 96 reads per day and this will be brought from millions of meters to the MDM by the HES. The meter data organized in specified formats in the MDM helps to integrate it with the Discom's billing system, customer care system, geographical information system (GIS); and other IT applications. While there can be several makes of meters, different communication technologies in different regions and several HES in a smart metering solution of one utility, it is recommended to have only ONE MDM in a Discom which will integrate all meter data with the billing systems and other Discom applications.

Having a single MDM for a Discom has several advantages over the use of multiple MDM systems. First, a single MDM reduces integration costs by streamlining the process of data collection, analysis, and storage. This eliminates the need for extensive customization and specialized staff training, resulting in significant savings to the Discom. Another benefit of using a single MDM is the ability to standardize data reporting, ensuring consistency and accuracy across the entire utility system. This not only simplifies data analysis, but also improves system reliability and reduces the risk of errors, leading to an improved customer experience. Additionally, the use of a single MDM system can alleviate the challenge of managing multiple competing data systems. With a common data environment, Discoms can better coordinate their operational functions, optimize resource management, and improve decision-making processes. In summary, the adoption of a single MDM will help Discoms to streamline operations, reduce costs, and improve system reliability. By consolidating data collection and analysis into one standardized platform, Discoms can successfully manage the energy landscape and customer demands with greater efficiency and effectiveness.

2.4 Smart Meter Operations Centre (SMOC)

Smart Meter Operations Centre (SMOC) is the control center with network monitoring system and advanced analytical software solutions. The first-generation AMI projects did not have SMOC and as AMI data started piling up, the utilities created SMOC with advanced analytical tools to handle the smart meter data. The time-stamped meter-reads offer a goldmine of information about the power flows in the low voltage network which helps to fine-grain the distribution grid including accurate demand forecasting that will reduce power purchase cost and improve asset optimization. SMOC has proven to be beneficial in monitoring and management of smart meter rollout as well. The standard bidding document (SBD) for the AMI program of RDSS covers the functions of SMOC under Network Management Systems (NMS) and Network Operation & Monitoring Centre (NOMC)[6]. Several functionalities and technical requirements of NMS and NOMC are mentioned in these sections of the SBD. Detailed architecture for SMOC is not included in the SBD which is left to the bidders to propose. For large scale AMI rollout, it is essential to have a well-designed SMOC that can manage meter roll outs, data collection, data integration, data provisioning and data analytics. SMOC typically provide/responsible for:

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[6] *Section 6; Clause 2.2.2; and Clause 2.6 of the Model Standard Bidding Document for AMI*

- Centralized Project Management
- Platform for Business Intelligence
- AMI Events Management
- Enterprise Asset Management and Monitoring
- Consumer and Consumption Analytics
- AMI ROI Matrix Tracking such as Revenue Protection, Load Planning etc
- Consumer Engagement Modelling
- SLA Management
- Service Ticket Management for Helpdesk
- Training Simulator
- Audit Trail

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

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

Since most of the empaneled AMISPs are new to the AMI domain, it is recommended to include the detailed architecture of state-of-the-art SMOC in the SBD.

2.5 AMI Architecture

In an ideal AMI system, there could be multiple makes of meters, different communication technologies, different HES, but only ONE MDM. There are very few COTS[7] MDMs in the world that are scalable to muti-million meters. MDM software is expensive and its installation and integration with utility applications such as billing system, customer care system, GIS; and outage management system is a very specialized job and it takes minimum 6-9 months depending on the interfaces and the skill levels of the system integration team – this is irrespective of the number of meters involved (whether 1 meter or 1 million meters).

There should be a standard middleware that should act as the integration platform through which different Discom applications can call different data sets as and when required from the MDM. The selection and sizing of the MDM and the middleware are very critical; and the hardware (on the cloud) sizing depends on the software sizing. If the AMISP and their System Integrator (SI) get the sizing calculations (of software and hardware) wrong initially, it will prove to be too expensive to correct them at a later stage. This is where prior experience of handling humongous data generated by millions of meters and its integration with Discom

[7] Commercially available Off the Shelf (COTS) refers to popular software products for which experts can be hired from the open market. For proprietary software products one must always depend on the OEM for support. Most proprietary products may not follow standard protocols and it may be difficult to integrate with other utility applications – all such integrations may be bespoke developments which will be very difficult and expensive to maintain.

applications should be valued. As mentioned already, majority of the empaneled AMISPs have no such experience or exposure. The size of AMI contract packages being awarded by Discoms is in the range of 4-6 million meters which is too huge to be executed in a reasonable time frame even by experienced agencies; and most of such large contracts have been awarded to AMISPs who have never undertaken any AMI projects in the past. This is a serious cause of concern.

Typical AMI Architecture is presented below.

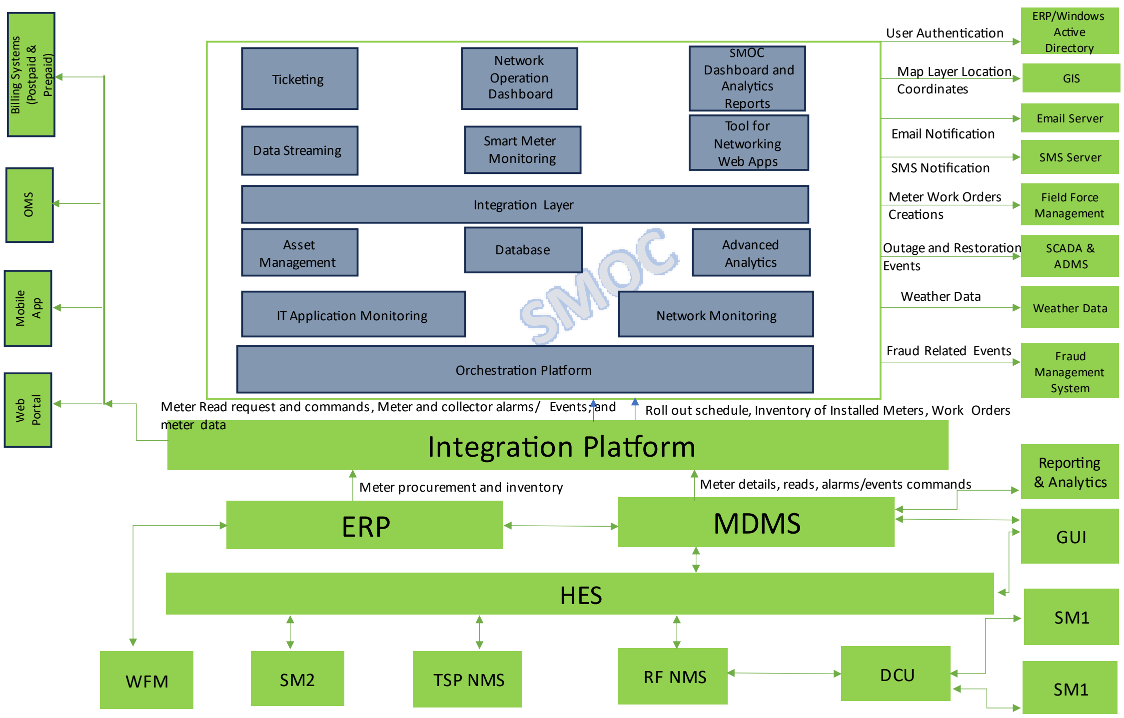

Figure 1: Typical AMI Architecture

(SM1 – smart meters connected on RF mesh; SM2 – smart meters connected on cellular network; TSP NMS – network monitoring system by telecom service providers for the meters connected on cellular communication; RF NMS – network monitoring system for meters connected on RF mesh provided by the RF solution provider; DCU – data concentrator unit; GUI – graphical user interface; WFM – workforce management system)

What is presented above is a Service Oriented Architecture (SOA) with micro-services which is the state-of-the-art (SOTA) practice today. In the recent tenders from a few states, it is noticed that for each tender package a separate MDM is provisioned which is not only expensive, but also prevents realization of several benefits of smart metering. As mentioned already, with multiple MDMs (perhaps of different makes) in one Discom, proper integration with billing system and energy accounting will be difficult. This approach is erroneous and should be corrected immediately.

3 COMMUNICATION SOLUTIONS FOR AMI

AMI requires two-way communication between the smart meters installed at the customer premises and the Discom's computers; and this two-way communication facilitates meter data transfer from the smart meters to the Discom's computers as well as sending commands from the Discom's computers to the smart meters. This is the most critical function for the reliable operations of the AMI system. Typical AMI communication architecture is depicted below.

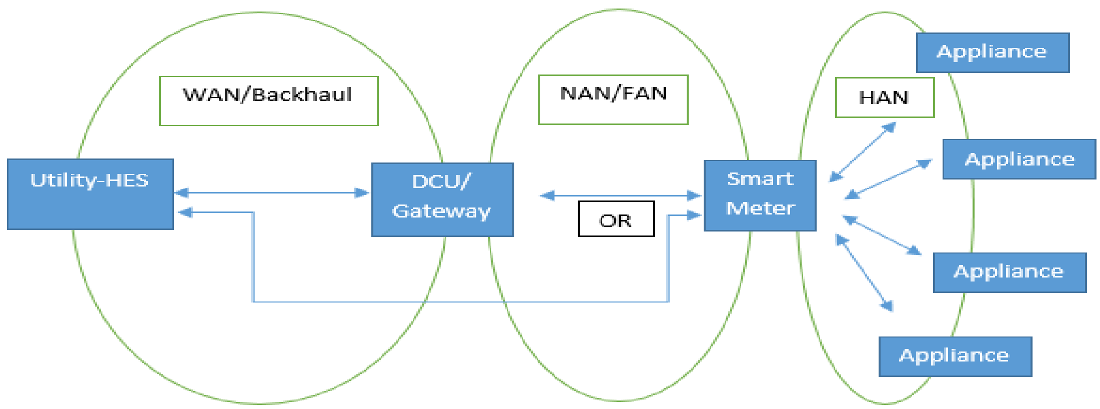

Figure 2: AMI Communication Architecture
(WAN: Wide Area Network; NAN: Neighborhood Area Network; FAN: Field Area Network; HAN: Home Area Network; DCU: Data Concentrator Unit)

Public telecom network or the utility's fiber network (wherever available) is used for Wide Area Network (WAN) solutions for AMI systems. The main challenge in a successful AMI system is the last mile connectivity for which several solutions are available. The most successful AMI projects around the world have either chosen RF Mesh technology or PLC technology for the last mile connectivity. In case of cellular technology, the SIM card inside the meter is directly connected to the telecom network and there is no need for a separate WAN network. The success of this depends on the data communication capabilities of the public telecom network in a particular area. Different technologies available for last mile connectivity (NAN/FAN), wide area network (WAN) and home area network (HAN[8]) are presented in the table below.

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[8] Home Area Network (HAN) to connect the appliances inside home with smart meter was deployed during the first generation of AMI. Now that smart apps are popular, the appliances can be connected to the broadband network at home and can be remotely managed through apps on the smart phones; and their electricity consumption can be monitored through the customer portal of the utility which has now become an integral part of the AMI system. Separate HAN is not being built these days.

Table 1: Different Technologies Available for Last Mile Connectivity

Technology	Home Area Network (HAN)	Last Mile (NAN/FAN)	Wide Area Network
Wireless	▪ RF Mesh ▪ 6LowPAN ▪ ZigBee ▪ Wi-Fi ▪ Bluetooth ▪ Z-Wave ▪ NFC	▪ RF Mesh ▪ ZigBee ▪ Wi-Fi ▪ Millimeter Wave Bluetooth Low Energy (BLE) and BLE 5 ▪ Long Range Radio (LoRA) ▪ Narrow Band IoT (NB IoT) -CAT M1; LTE	▪ Cellular ▪ Satellite ▪ LPWAN ▪ Long Wave Radio ▪ TV White Space ▪ Private Microwave Radio
Wired	▪ PLC ▪ Ethernet	▪ PLC (narrow band) ▪ Broadband over Power Line (BPL) ▪ Ethernet ▪ Control Area Network (CAN)	▪ Telecom Cables, Fiber Optic Cables ▪ Power Line Carrier Communication (PLCC)

3.1 Choice of Communication Technologies

Criteria for choice of different communication technologies is presented below.

Table 2: Choice of Different Communication Technologies

Parameters	RF Mesh	Cellular	PLC	NarrowBand IoT (NB IoT)	LoRA
Network Type	Deployed and Managed by Utility or their Service Provider	Managed by the Telcos	Deployed and Managed by Utility or their Service Provider	Managed by Telco	Deployed and Managed by Utility or their Service Provider
Topology	Mesh	Point-to-Point	Star	Point-to-Point	Star
Spectrum Type	Free	Paid	Free	Paid	Free
Dependency (Service Provider)	No	Yes	No	Yes	Yes
Latency	Medium	Low	High	Low	High
Reliability/Availability	>99%	Depends on Service Provider	Depends on the Condition of the Power Line	Depends on Service Provider	Depends on Service Provider
Redundancy	Self-Healing	No	No	No	No
Data Handling	Large	Large	Packet	Small	Small

Appendix-B presents a list of utilities who have implemented AMI around the globe and their chosen communication technologies for their AMI systems.

3.2 Telecom Operators Interest in AMI Projects

Cellular Operators Association of India (COAI) has appealed to the Telecom Ministry regarding security risk in deploying license-free spectrum for smart metering; and subsequently, Telecom Ministry has invited comments from various stakeholders on this issue. ISGF has examined this issue and found no merit in the argument of security risks in using license-free spectrum by deploying RF mesh solutions for last mile connectivity for the AMI projects. As presented in the Appendix-B, 179 million smart meters are operating with RF Mesh technology in different countries successfully for about a decade or more. Another 748 million smart meters are operating on PLC technologies; and 156 million meters on combination of PLC and RF technologies. Compared to these, the total number of smart meters operating on cellular networks is only 57 million. The key issues with cellular communication system for smart metering are briefed below:

a. **Service Level Agreement (SLA)**: The AMI Service Providers (AMISPs) are bound to commit certain SLAs (99%) for AMI system availability whereas none of the cellular service providers are ready to commit guaranteed SLAs. Experiences with cellular communication for AMI in India indicate SLA below 95% even in urban areas; which could be much lower in rural areas where data network is weak.
b. **Technology Changes**: Cellular operators upgrade their technologies frequently – 2G, 3G, 4G, 5G and will move to 6G. Changing the network interface cards (NIC) and the SIMs in millions of meters is too expensive and nearly impossible[9]. UK Government has recently sanctioned a £4 billion plan to replace the 3G modems in smart meters with 4G, as the telecommunications companies will no longer provide support for 3G. It is worth mentioning that, historically, the cellular telecom industry tends to undergo upgrades every 5 years, leaving the previous infrastructure outdated which is closely aligned with the handset replacement cycle.
c. **Mis-match of Rollout Plans**: Cellular operators primarily target urban areas for their new technology rollout whereas electric utilities need to cover customers in urban and rural areas.
d. **Cost**: The initial installation cost of both RF Mesh (network interface cards + DCU/Gateway) and Cellular (NIC + SIM) is nearly the same. But for cellular technology, there is a fee per meter per month to be paid to the cellular operators which will be a huge burden that will eventually get passed on to the common man (electricity consumer). Even at a modest fee of Rs 10 per meter per month, it works out to about Rs 3000 crore per year to cellular operators for 250 million meters. The annual maintenance fee for RF Mesh solution for AMI will be a small fraction (<10%) of that amount.
e. **Reliability of Communication**: Reliability of the cellular network in a given area depends on the user density and when the utility wants to ping a particular meter, there is no guarantee that it will be reachable at that moment as we often face with mobile calls not getting connected due to poor bandwidth or network congestion. Last Gasps and First Breaths[10] are to be logged by a smart meter in case of power-off and power-on with in 20 seconds as per the SBD. When the Discom receives the last gasp, they alert the maintenance teams on the power outage in a particular location and dispatch the maintenance crew. This is one of the important benefits of AMI. With cellular connections, it is

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[9] *In Uttar Pradesh, EESL deployed about 1.2 million smart meters with 3G during the period 2018 to 2020; and the telecom service provider discontinued 3G service in UP. These meters are now operating on 2G as a fallback arrangement. New installations are on 4G; but future of 4G is uncertain as at some point, Telcos will stop 4G when 5G penetration achieve certain level of nation-wide coverage*

[10] *Last Gasp is the message of power outage communicated by a smart meter to the Discom; similarly, First Breath is the message communicated to the Discom when power supply is resumed. Per SBD for RDSS, both Last Gasp and First Breath should be communicated with in 20 seconds of the events. HES need to be programmed to act differently when one meter sends the last gasp and when a large group of meters send the last gasp – if there is a power outage in a large community, thousands of meters will send last gasp messages which the communication bandwidth may not be able to handle; and in such cases only select few meters including the feeder/distribution transformer meters may be prioritized to transmit the last gasp. Such use cases should be configured in the HES*

almost impossible for last gasps to be communicated to the Discoms within 20 seconds of a power outage. There are steep penalties for not meeting these SLAs in the SBD.

f. **AMI Benefits**: There are 16 benefits[11] to a Discom from smart metering and many of the high-impact and high-value benefits may not be available if utility cannot reach a meter when required as is the case often with cellular communication.

g. **Standards for RF Mesh**: The equipment deployed for RF Mesh for smart metering conforms to standards such as ITU, IEC, IEEE, CEN/CENELEC/ETSI, NIST, ANSI, Wi-SUN etc. The security technologies are same for equipment deployed in licensed and license-free spectrums. It is a frivolous argument to suggest that conducting important banking, social, financial, and essential exchanges over Wi-Fi – which is also local RF is unsafe. The security of these transactions relies on the built-in transmission layer protocols, not the specific choice, ownership, or frequency of radio waves. It is important to understand that the frequency of radio transmission impacts the propagation, but it does not impact the security of data. Therefore, the public telecommunications infrastructure is vulnerable to a greater number of threats and vulnerabilities.

h. **Equipment Registrations**: All equipment deployed in wireless networks whether in licensed spectrum or license-free spectrum must be tested and registered with Wireless Planning Committee (WPC). There is no technical reason for equipment deployed in license-free spectrum to be inferior than those used in the licensed spectrum by the cellular operators. The experience with hundreds of millions of wireless devices deployed in the license-free spectrum have been working satisfactorily around the globe for a variety of IoT applications including smart metering. Hence, the argument by the COAI is baseless and is driven purely by profit motive alone – not in the national interest.

RF Mesh solution providers should register with the Department of Telecommunications (DOT). The details about the **M2M Service Providers Guidelines** published by DOT can be found on the website of DOT[12]. It is recommended to include this in the SBD.

More recently, the telecom service providers have approached MOP (and REC which is the nodal agency for the SBD) through Telecom Standards Development Society of India (TSDSI) to make changes in the SBD and IS:16444 and IS:15959 so that cellular operators can meet the SLAs. This is another attempt of the telecom operators to hijack the ongoing AMI rollout. They want to relax the standards so that their technologies (4G and NBIoT) could meet the SLAs prescribed in the SBD. These attempts by the telecom operators must be rejected.

4 BENEFITS OF AMI TO DIFFERENT STAKEHOLDERS

As indicated in the beginning, AMI is not just to improve the metering and billing processes in a Discom. The impact of AMI on the overall utility operations is much more as described in the table below. Several of the benefits from AMI system depends on the reliability of the communication system deployed.

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[11] The 16 benefits to the Discoms and benefits to other stakeholders are presented in the Section- 4 of this paper

[12] The details about the M2M communication equipment registration can be accessed here: https://dot.gov.in/sites/default/files/M2MSP%20Guidelines%20.pdf?download=1

Sl No	Benefits	Financial Impact	Dependence on Communication Technology
A. Benefits to Discoms			
1	**Reduced metering reading and data entry cost** *Without smart meters, Utilities must send personnel to customer premises to manually read the meter. Implementation of AMI enables remote meter reading both regularly and on-demand. Data entry and processing is performed automatically. Overall, AMI should deliver greater convenience at reduced cost relative to traditional meter reading.*	Medium	Low
2	**Reduction in time taken for meter reading and bill generation as well as reduction in errors** *There are always chances of human errors when meters are read manually or even via automatic hand-held devices. In addition, the process is time consuming. By delivering meter data automatically over communication networks, AMI eliminates human error from the meter reading process as well as make the entire process faster*.	Medium	Medium
3	**Reduction in cost of disconnection and re-connection** *as it can be managed through remote operation of the AMI system*	Medium	Medium
4	**Faster detection of dead meters** *and hence enhanced revenue protection*	High	Medium
5	**Enhanced Revenue per Month** *Large share of meters existing in DISCOMs are old and hence the readings are not very reliable. With new smart meters, the accurate energy consumption can be captured which will enhance the monthly revenue considerably. It is expected that the monthly payment to AMI Service Provider (AMISP) can be met from the increased revenue. This has been the experience in DISCOMs where AMI has been implemented (eg: Mysore, Indore, Gujarat, NDMC, Bihar). With 15% grant from GOI, and the rest 85% paid monthly over 10 years from increased revenue on a monthly basis is a very attractive option for Discoms*	High	Low
6	**Reduction in Aggregate Technical & Commercial (AT&C) losses** *AMI can remotely detect meter tampering and enable real time energy accounting. This reduces theft through by-passing the meter, thereby substantially reducing aggregate technical and commercial (AT&C) losses. AMI will also streamline the billing, or meter-to-cash process considerably by reducing the human errors in meter reading and billing*	High	Medium
7	**Enabling faster outage detection and service restoration after faults** *Traditionally utilities know about an outage only when they receive complaints from affected customers. Service restoration requires utility crews to identify the area and rectify the fault – a time consuming and expensive process. The Bureau of Indian Standards requires all smart*	High	High

	meters to be capable of sending 'last gasp' and 'first breath' messages, which informs the utilities when power has failed or resumed. This will reduce outage restoration times leading to financial savings and improved customer satisfaction.		
8	**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 DISCOM's load forecasting and enhances the ability to procure the right volumes of power. Utility 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.*	**High**	**High**
9	**Power quality measurement and management** *Smart meters are capable of measuring specific aspects in near real-time, such as power factor, over or under voltage, and over current. This helps DISCOM to enhance system power quality in conjunction with power quality data from other sources. Improved power quality also leads to lower power losses. Also, avoid costs associated with investigation of voltage complaints.*	**Medium**	**Low**
10	**Asset optimization** *AMI data supports granular monitoring of power flows on the distribution network which can help DISCOM identify segments of over- and under-loading. This is valuable information for system planning and optimizing network upgrades. AMI data can also help balance load, which reduces power losses. Better visibility of loading on the power system will help faster/delayed capacity enhancement and prevention of failure/under-utilization of equipment. Furthermore, network monitoring can decrease equipment failure rate by identifying phase imbalances and over loading in advance which can be corrected*.	**High**	**High**
11	**Ability to operate in pre-paid and post-paid modes**	**Medium**	**High**
12	**Remote operations** *Smart meters typically include remote switching, which allows utilities to remotely disconnect or reconnect where necessary, such as when load is exceeded, for predetermined events, in the case of non-payment, or when a customer moves. Additionally, Discoms can monitor the health of the meter and dispatch maintenance only where necessary*	**Medium**	**High**
13	**Improvement in reliability indices and its accurate measurement** *Enhanced monitoring of the distribution network operations would significantly improve the reliability indices like CAIDI/CAIFI, SAIDI/SAIFI as well as help measure these indices accurately*	**Medium**	**Medium**
14	**Real time energy auditing and accurate energy accounting from time-**	**High**	**High**

	stamped meter data		
15	**Reduced load on call centres, customer care centres and billing centres**	**Medium**	**Low**
16	**Smart meters act as feedback points** *for understanding the behavioural interpretations of energy demand as consumption which can be modified*	**Low**	**Low**
B.	**Benefits to Generation and Transmission Companies**		
1	Deferred or avoided transmission capacity investments	**High**	**Medium**
2	Deferred or avoided generation capacity investments on peak load plants and spinning reserves	**High**	**Medium**
C.	**Benefits to Customers**		
1	Error-free bills and no need for visiting billing centers	**Medium**	**Low**
2	Innovative tariff schemes	**Medium**	**Medium**
3	Faster restoration in case of outages	**High**	**High**
4	Remote control of loads in customer premises	**High**	**High**
5	Ability to remotely manage and control appliances	**Medium**	**Medium**
6	Potential to save money	**Medium**	**Medium**
D.	**Benefits to Society**		
1	Reduction in carbon footprint owing to avoided travel by Discom personnel for meter reading, disconnection, and reconnection	**Medium**	**Medium**
2	Better customer engagement on energy conservation and demand side management initiatives	**Medium**	**Medium**
3	Enhanced customer satisfaction	**Medium**	**Medium**
4	Energy efficiency and energy conservation	**Medium**	**Medium**

5 CYBER SECURITY OF THE AMI SYSTEM

With 250 million smart meters having two-way communication facility with the Discom's IT systems, 250 million more entry points to the utility network will be created. This increases the vulnerability and the potential for cyber-attacks. The possible attacks are:

- Bad data injection
- Spoofing
- Man-in-the-middle-attack
- Decryption attacks
- Energy theft attacks
- Distributed denial of services (DDoS)

Hence, cyber security in AMI is very critical to ensure the robust security of the power system. Security breaches in smart meters/AMI systems can lead to revenue loss, consumer data misuse, and potential blackouts, affecting critical infrastructure and other sectors. The AMI system should address cyber security requirements and conformance at four levels: manufacturer/vendor security certifications, device/equipment/component level security conformance certifications, asset owner/utility security certifications, and operator/staff handling critical infrastructure operations certifications.

AMISPs should partner with best-in-class solution providers having standards-based security solutions. Key standards include the NIST, NERC and ISO/IEC family of standards - ISO/IEC 27001, 27002, 27019 and 27035. India has developed its own cyber security standards IS:16335[13], focusing on operational technology (OT) in the power sector. Smart meter standards IS:16444 and IS:15959, along with IEC:62056 series, define communication protocols and associated security. IEC:62443 and IEC 62351 standards define the compliances for cyber security for electrotechnical equipment and automation systems. In December 2021, CEA issued Cyber Security Guidelines for Power Systems[14] which should be followed by Discoms and the AMISPs. Periodic security auditing, conformance testing of smart meters and devices, and cyber-security lifecycle testing are essential to maintain compliance. Training the personnel associated with critical infrastructure assets is important to enhance cyber security. Cyber-physical test beds need to be created to test individual devices in integrated environments.

Some of the general security practices from the experiences of utilities who have implemented large scale AMI in North America and Europe are summarized below for the considerations of Discoms and AMISPs.

a. **Threats from Outside and Inside**: Smart meters can be hacked by accessing onboard memory, thereby reading diagnostic ports and other network interfaces. Besides, cyber criminals, employees and vendors can unknowingly (or even knowingly) release sensitive information. To prevent such attacks, utilities should impose intelligent controls on how employees, consumers and partners access applications and data.

b. **Security Principles:** The global industry standard is the Confidentiality, Integrity and Availability - CIA model of security. For AMI systems, Authentication must be added to this CIA model. **Confidentiality** is to prevent sensitive data from reaching wrong people while ensuring that the right people still have access. **Integrity** means data is consistent, accurate and trustworthy over the entire lifecycle; and unauthorized people cannot alter data. This requires strong cryptographic mechanisms to ensure the integrity of meter readings, command and control of the data. **Availability** of data and equipment must be ensured by rigorous maintenance of hardware, prompt repairs; and upkeep of the software free of corruption and conflicts. Firewalls and proxy servers could prevent downtime and mitigate malicious actions such as denial of service (DoS) attacks. **Authentication** is to prevent unauthorized access which happens often due to unmodified default access policies or lack of clearly defined access policy documentation. Utilities must ensure that only authorized personnel can view information and perform permitted actions. The HES, the field-tools and network devices must be deployed with

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[13] *IS:16335 is presently under revision and the updated version may be issued by end of 2023*

[14] *CEA's Cyber Security Guidelines for Power Systems: https://cea.nic.in/wp-content/uploads/notification/2021/10/Guidelines_on_Cyber_Security_in_Power_Sector_2021-2.pdf*

certified Root of Trust[15]. In the absence of a proper authentication system, a malicious attacker could attempt to spoof themselves as an HES, a field-tool or a network device and attempt to send illicit command or inject malicious code in to the network.

c. **People and Process:** Insider attack is a key area of risk whether accidental or intentional. While an outsider may be attempting to breach HES security which is being resisted by the system, it should ensure that assigned employees are given legitimate access to the system. HES with role-based access control (RBAC) may be deployed to provide capabilities to the Security Administrator to assign appropriate permissions to each user of the system. HES could streamline user administration by integrating with enterprise single sign-on solutions.

d. **Data Protection:** Meter data, customer billing information and other important data to be encrypted end-to-end for maximum protection whether it is in a public or private cloud, on a device or in transit. The end-to-end encryption help to combat advanced threats and maintaining regulatory compliance.

e. **Advanced Security:** Advanced security solutions should include signed and verified firmware, disabled JTAG[16]-debug communications interface, encrypted flash memory, locked optical ports (configurable), meter tamper detection, backhaul protection, certified root of trust; and other physical and system level security features.

f. **Key Management:** The security solution must provide encryption key segmentation at individual and group levels. Each end point (meters, DCU/gateway) is to generate its own AES 256-bit encryption key to encrypt upstream and downstream messages sent to and from each end point. All the individual keys of end points are vaulted in a Key Manager. HES can assign segment keys to a group of end points. Device specific keys (protected through encryption) are stored securely during system use and during rest. Device specific keys and network specific keys should follow configurable and matured key rolling and lifecycle management processes.

g. **Firmware Integrity:** All firmware upgrades released are digitally signed using the utility's ECC private key. Each end point within the network will validate the signature using the public key provided by the HES. In case of signature mismatch, the end points will not upgrade the firmware.

h. **Message Authentication:** All commands may be signed with ECDSA[17] standard using utility's ECC private key. End points will execute signature validation before acting on any command, thus providing a control mechanism to prevent rogue commands or man-in-the-middle vulnerability.

i. **Third Party Penetration Testing:** Utilities should engage certified third parties for penetration testing to identify vulnerabilities and fix them periodically.

A comprehensive cyber security approach is crucial to safeguard the AMI system. For establishing secure and

[15] *Root of trust is ensured through Hardware Security Modules (HSM) where the Utility's private key (encryption key) is vaulted*

[16] *Joint Test Action Group (JTAG) is an industry standard for verifying and testing printed circuit boards after manufacture. It gives a pins-out view from one IC pad to another so that faults could be discovered. JTAG became the IEEE 1149.1 standard in 1990.*

[17] *Elliptic Curve Digital Signature Algorithm (ECDSA) is a variant of the Digital Signature Algorithm (DSA) which uses Elliptic-Curve Cryptography (ECC). ECC uses much smaller public keys compared to the other popular encryption methodology called RSA. For AES 128 encryption, the ECC key is 256 bits whereas RSA key is 3072 bits; and for AES 256 level encryption, the ECC key is 512 bits (64 bytes of 8 bits each) while RSA key is 15360 bits. ECC needs much lower processing power and gives faster SSL handshaking and consequently faster web page loading.*

resilient AMI systems, a standardized cybersecurity framework should be adopted by the AMISP in consultation with the Discom and other stakeholders. These steps are prescribed in detail in the SBD Section 2.7.7. Some of the key actions that AMISPs should adhere to make the entire AMI system immune to cyber-attacks are reproduced from the SBD below:

a) All the hardware, operating systems and application software should be hardened
b) Application, scanning and hardware scanning tools should be provided to identify vulnerability and security threats
c) Data should be encrypted at system/device/technology level
d) Network zoning should be implemented as per the proposed architecture (or other methods of network architecture without compromising the security of the system)
e) Internal users should be allowed to access all adjacent zones - they will not have access to remote network zone
f) While procuring cyber security items testing must be done and the system must be secure by design
g) Residual information risk should be calculated by AMISP and same should be submitted to the Discom for approval
h) All default user ID and passwords should be changed
i) All log in/out and cable plugs in/ out should also be logged in Central Syslog Server
j) Penetration and vulnerability assessment test by CERT-IN certified auditors during SAT and operation and maintenance period
k) Auditing by third party during SAT and annually during operations and maintenance period should be in the scope of AMISP[18]
l) As the computer system in NOMC (SMOC) has access to external environment, the AMISP should document and implement Cyber Security Policy/Plan in association with the Discom to secure the system
m) Discoms and AMISPs to follow the latest Cyber Security Guidelines issued by CERT-In (http://www.cert-in.org.in/); and the provisions under "***Testing of all equipment, components, and parts imported for use in the Power Supply System and Network in the country to check for any kind of embedded malware /trojans/ cyber threat and for adherence to Indian Standards – Regarding***" vide Order No. No.9/16/2016-Trans-Part(2) issued by MOP on 18 November 2020 and amended from time to time or any other competent authority
n) AMISP should adhere with the appropriate security algorithm for encryption and decryption as per established cyber security guidelines. For smooth functioning of the entire system, it is essential that the AMISP shall provide in the form of a document enough details of such algorithm including the mechanism of security key generation to the Discoms. In case of proprietary or secret mechanism, the same shall be kept in a secured escrow account.

Similarly, Section 2.7.8 of the SBD prescribes the measures to be adopted for data privacy and data security. AMISPs should ensure that the system is compliant with the applicable provisions of the "*Reasonable security practices and procedures and sensitive personal data or information Rules, 2011 (IT Act*)" as well as should be committed to work with Discoms for compliance to personal data protection requirements. The Discom should be the sole custodian of the smart meter data[19]. The AMISP and its contracted vendors will have

[18] *We hope all Discoms have incorporated these clauses in their RFPs and contracts*
[19] *By law many countries have established that the consumer is the sole owner of the smart meter data; and Discom is the custodian*

limited need-based access to the data[20]. AMISP is required to prepare and submit a "Privacy by Design" document to the Discom which details out all the policies, practices, processes, and technologies deployed to manage, and process the smart meter data in a secure manner; including the details on methods of anonymization applied to the personal smart meter data for **Aggregated Data, Anonymized Data** and **Personal Data**.

SBD Section 2.2.3 describes the measures for Network Protection and Security; and section 7.4.1 mandates that the AMISP should be responsible for monitoring of the system from a cyber-security perspective. The logs of the system shall be analyzed for exceptions and the possible incident of intrusion/trespass should be informed to the Discom and analyzed to discover the root cause. The monitoring should encompass all cyber security devices installed in the cloud data center as well as at the NOMC (SMOC) such as firewalls, all types of intrusion prevention systems, routers etc. The cyber security system should also be subjected to Annual Security Audit from CERT-In approved auditors at the cost of the AMISP during the contract period. AMISP should share with Discom such audit reports and implement the recommendations/remedial actions suggested by the Auditor. Again, we are afraid whether all the AMISPs who are bidding in different Discoms have any idea about what it takes to comply with the above provisions in the SBD related to cyber security.

Telecom Engineering Center (TEC) under the Department of Telecoms (DOT) has published the Technical Report on **Security by Design for IoT Devices Manufacturers** (TEC 31328: 2023)[21]. AMISPs and their project partners may be mandated to study and comply with these procedures as well. REC may consider adding this provision in the SBD.

6 AMI ROLLOUT STARTEGY AND IMPLEMENTATION METHODOLOGY

As part of R-APDRP, 14 Discoms in India were allotted smart grid pilot projects in 2013. Out which only 11 projects have been completed and all these projects had smart metering ranging from 1200 to 30000 customers. Most of these projects took 4-5 years to implement. Having observed the trials and tribulations of Discoms with these first set of smart metering projects, ISGF was convinced that the state government owned Discoms will not be able to procure right AMI systems; and even if they install the right systems, they will not be able to maintain it for ten years. ISGF published a White Paper in 2016 (which was re-issued in March 2017 as a joint paper by ISGF and BNEF) that articulated the idea of engaging a Metering Services Agency (MSA) who will install the AMI system and maintain it for 10 years for a monthly fee per meter. This is the same business model which is adopted for the 250 million smart metering projects under RDSS. Only difference is that under RDSS, GOI is giving 15% of the project cost as a grant; and the rest is paid in monthly installments over 93 months. In our original paper we estimated the cost of a single-phase smart meter at INR 2250 and the MSA service fee at INR 69 per meter per month for ten years for a project with one million (or more) meters, which was about one US dollar per meter per month in those days. Today under RDSS, the average price being quoted by AMISPs is about INR 80 per meter per month for 93 months (which is about one US dollar).

[20] AMISP should commit to ensuring that the data is kept safe by them and their sub-contractors/project partners and not used for any other purpose

[21] https://tec.gov.in/pdf/M2M/Security%20by%20Design%20for%20IoT%20Device%20Manufacturers.pdf

There are several key issues that needs re-examination in the ongoing program as described below.

a. Is it appropriate to go for 100 % prepaid meters in the country?

In our opinion this is neither practical nor logical to have 250 million smart meters operating in the prepayment mode. In most Discoms, the high-value customers contribute 70-80% of the revenue who may be only 15-20% in numbers; and majority of them pay several million rupees per month[22]. Moving them to prepayment mode will have commercial and technical challenges. Regular customers who consume above 500 kWh per month (or an appropriate limit set by the state regulator) may be allowed to opt for either post-paid or pre-paid modes. Those opting for pre-paid in this category may be offered a small rebate to motivate them. All customers with less than 500 kWh monthly consumption and government offices may be brought under mandatory prepayment mode. Even their numbers may be in millions in most Discoms.

The smart meters can be configured in either prepaid or post-paid mode. But the trouble with prepayment operation of smart meters is that most of the HES are not designed to respond to a large number of disconnect/reconnect requests in less than ten minutes as prescribed in the SBD. If thousands of customers recharge their meters online, immediately a reconnect order will be generated by the system; but it will get into a que in the HES – particularly when HES has already issued a command to download the interval read of millions of meters. In this scenario, the recharge may be updated and electricity supply resumed after few hours. This can be fixed to certain extent by modifying the HES provided the communication system is reliable; but most of them would still find it difficult to meet the SLA of ten minutes to reconnect supply after recharge.

Each Discom in consultation with their state government and respective electricity regulatory commission may decide what all categories of customers in which all regions should be brought under prepayment mode. MOP may allow the states to take this decision as appropriate. Afterall, the net-grant from GOI for AMI under RDSS is only 6% of the project cost[23].

b. What is the right price range for the AMI projects?

It is understood that when the RDSS program was launched, the project cost was calculated at INR 6000 per meter and accordingly the 15% GOI grant was capped at INR 900 per meter. There is confusion about this number while one argument is that this amount of INR 6000 was the capex cost under the EPC model of project implementation; while the other argument is that it was the life-cycle cost of AMI implementation that EESL offered in UP and Haryana in 2017 which was for 6 years (72 monthly installments versus the 93 monthly installments in RDSS). In our view, the life-cycle cost needs to be revised to the range of INR 9000 to 12000 per meter depending on the geographical challenges and the total number of meters involved. The prices could be higher for very low volume contract packages (below 200,000 meters) as well as for very high-volume contract packages (above 5 million meters)[24].

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[22] *Large C&I customers have HT or LT-CT meters which have no built-in switch for disconnect-reconnect operations; and hence cannot be moved to prepayment mode*

[23] *GOI is offering 15% grant under RDSS for smart metering; but collects 18% GST on the project cost including the monthly installments. Out of this 50% is passed on to the state governments; hence the net-grant from GOI for smart metering is only 6% of the project cost*

[24] *For a project with 5 million meters, even 1% of the meters that cannot be read in a month will be about 50,000 and manually*

c. Who should bear the monthly installments to be paid to the AMISPs?

This is another big question haunting the decision makers in the states. In some states the Discoms have approached their regulators for a pass-through in the tariff for the monthly installments. Their argument is that in the initial years Discoms may not be able to bear the additional burden of the monthly installments to be paid to the AMISPs as it would take few years to realize the full benefits of the AMI system; and such efficiency gains when realized will be passed on to the customers in tariff relief. If adopted, this approach will place a huge burden on low-income communities whose electricity bills are in the range of INR 200-300 per month which will go up by another INR 80-100 per month. The promised tariff reductions after a few years will not motivate them to get their buy-in for the AMI program. In some states where the existing metering and billing systems are in poor condition, the benefits of AMI can be realized right from the very beginning through increased revenue per month which itself will take care of the monthly installments[25].

We suggest to offset this monthly fee by dividing it in to 3 buckets – one part may be added to the meter rent that all Discoms levy in the electricity bills; another part may be borne by the Discoms and the third part may be funded through a low-interest loan from REC/PFC which may be paid back from the efficiency gains. The percentage of each of these 3 parts may be decided by each Discom in consultation with their governments and regulators.

d. What is the appropriate AMI rollout strategy?

Ideally, AMI rollout should start with one city/division in a Discom which has about 1 million meters. This first contract package should have MDM and system integration components; and the system integrator (SI) should successfully integrate the MDM with the billing system and other applications and test it. Once the backend systems are stabilized and the first batch of meters (>100,000) can be read remotely and the monthly bills can be generated (without human interventions), the Discom should engage multiple agencies to rollout the smart meters in other cities/divisions. Those new contract packages should have smart meters, communication, and HES (no MDM). The responsibility for integration of the new HES with the MDM should be under the scope of the SI of the first contract package.

We recommend a three-phase rollout – first in the pilot city with about 1 million meters, next in all other urban and semi-urban areas; and lastly extend to the rural areas. This approach gives time to the Discoms to extend their billing system to non-RAPRDRP towns and rural areas that are still having multiple billing systems. AMI implementation may not be feasible in several hamlets and habitations in the hill areas and tribal communities in the forests. Discoms may be allowed to decide which are the pockets/communities where AMI is not feasible. In such cases, Discoms may install smart meters for feeders (wherever feasible) and monitor the community's consumption to prevent misuse.

Some of the Discoms are making changes in qualifying requirements, SLAs and other important parameters specified in the SBD. These are primarily vendor driven. REC and PFC (MOP) should stop such changes in

reading them in a diverse geography will be very expensive; and these unreadable meters are not the same every month

[25] *In one of the states, it was estimated that the average revenue growth after AMI implementation was above INR 200 per month per customer while the monthly installments to the AMISP was well below INR 100 per meter per month*

tender conditions and specifications to favor select vendors and OEMs at Discom level to prevent cartelization and cost escalation.

In our observation, the preparedness of Discoms for large scale AMI rollout is still lacking in almost all states. Many states do not have a single Discom-wide billing system which is a prerequisite for successful AMI deployment. Home grown billing systems that exist in several states may not be easy to integrate with standard MDMs. Too much of customization of the MDM will diminish its true potential; and prove to be too expensive to maintain in the long run. Discoms do not regularly update their GIS maps with customer indexing. Also changes in the field are not communicated to GIS team hence even after the consumer indexing is done the data mismatch appears. Adequate manpower and other resource constraints continue to haunt the Discoms. These issues need to be addressed on priority to reap the benefits of the AMI system.

e. Life of Smart Meters

What should be the ideal life of smart meters? As per the BIS certificates issued to the meter manufacturers it is mentioned that 5½ years of warranty from the date of delivery or 5 years of warranty after the meter is installed. Hence, typically meter OEMs in India have been giving 5 years warranty. Now for the RDSS projects, most of the OEMs are offering up to 10 years warranty.

Utilities in USA and Europe mandates minimum 12-15 years life for meters. This is one way of reducing the overall cost of smart metering. One issue that could hamper long life of smart meters in India is the battery life[26] in high ambient temperatures.

We recommend that BIS amend the certification with minimum 10 years warranty; and mandate highly accelerated life test (HALT) for meter-life expectancy testing in India.

f. Training and Capacity Building in Discoms and Industry

In general, very few agencies in the country understand the complexity in installing multi-million-meter AMI systems and maintaining them for nearly 8 years (93 months as per SBD). AMISPs with no prior experience of smart metering are signing up for implementing 5-6 million smart meters in 28 months! Most of the Discoms and AMISPs do not seem to be taking any serious efforts to train their engineers in AMI.

This reminds us of the R-APDRP Part-A projects that were awarded by Discoms during 2008-2012. There was a set of System Integrators (SI) who were empaneled by PFC – mostly large IT companies, both domestic and foreign. The project implementation time specified was 18 months. R-APDRP Part-A scope included indexing of Discom's assets and consumers in 1411 towns on the GIS maps which required thousands of trained technicians who could handle DGPS equipment (which was the only way to do GIS mapping those days); and there were not even few hundred trained technicians in India at that point in time. Hence, all foreign IT companies stayed away from bidding for R-APDRP projects. Large Indian IT majors competed aggressively and signed up to execute projects within 18 months at prices way lower than the amounts budgeted by MOP. However, all R-APDRP projects took 5-7 years to complete; and all the Indian IT companies who executed those projects incurred huge financial losses. None of them are participating in the ongoing AMI project tenders.

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[26] *All smart meters have lithium-ion batteries that lasts typically 10-12 years in moderate temperatures. At >45° centigrade temperatures the long-life expectancy of these batteries is doubtful.*

Similar picture we are witnessing presently – AMISPs with no prior experience of multi-million-meter AMI projects are aggressively bidding and signing up for large projects, while international companies who have rich experience in large AMI projects are staying away and watching the scene. Majority of the empaneled AMISPs do not have deep pockets to incur huge losses which the Indian IT majors could afford during the R-APDRP phase. To implement 250 million AMI rollout in 50+ Discoms in next 5 years, we need several thousand IT experts who are proficient in HES - MDM - Billing System integration which is lacking in the country presently. None of the AMISPs have realized this shortage of talent in the market; but enthusiastically bidding for projects which is a clear indication that they have no idea what it takes to deliver those multi-million-AMI projects. Looking at the current situation, we foresee the scenario in which many AMISPs will fail to execute the large projects awarded which the Discoms will have to re-tender (at much higher prices); and many AMISPs going bankrupt!

MOP may review the situation and take appropriate measures to ensure that personnel engaged in AMI projects from both Discoms and the industry are given proper training. The Part-C of R-APDRP had over INR 2 billion for training and capacity building; but actual spend was a minuscule portion of that. PFC engaged agencies with no prior experience to develop training modules at very low cost. The results and experience of R-APDRP are evident. We strongly advocate for spending minimum 5% of the project cost of the RDSS program in training and capacity building for Discom personnel so that 95% of the investment is well spent and the intended benefits are realized. It is high time for GOI to realize that in areas like training and capacity building in emerging technologies where best-in-class agencies must be engaged, procurements cannot be done on the regular L1 bid route.

g. Customer Engagement

For successful AMI rollout and customer's participation in leveraging the full benefits of the AMI systems, it is essential to have customer engagement in the program right from the beginning. In many countries customer groups opposed smart metering. In USA, 15 states had to include Opt-Out option in their AMI programs because of customer objections; and in many countries AMI rollouts were suspended mid-way and engaged in long consultations with customer groups for their buy-in. We do not see customer engagement activities in the ongoing AMI rollout in any of the states in India so far.

7 AMI 2.0

As stated in the beginning, Indian Discoms have the great opportunity to leapfrog to AMI 2.0 as we have done with our mobile telephony two decades ago. The new features of AMI 2.0 which was not there in the first set of smart metering projects are additional functionalities that can be realized at marginal cost as explained below.

a. **Advanced Analytics**: The time stamped electricity consumption data captured from smart meters can be analyzed with the help of Artificial Intelligent (AI) and Machine Learning (ML) tools to understand the power flows in real time and identify overloaded/stressed assets; locate which transformers to be replaced with higher capacity ones; which transformers have phase imbalance issues that must be corrected[27]; detect meter tampers and irregular usage patterns; detect

[27] *In an AC distribution network, typically loads are segregated amongst the 3 phases based on contracted load; but in real-life, load*

theft/unmetered loads; improve connectivity models; and conduct reliability analysis, storm analysis and momentary analysis.

b. Grid Management - Distribution Automation and Voltage Management: Modern AMI networks can support many more devices than smart meters. Devices that add intelligence to the distribution grid are now common place within an AMI network. These include Reclosers and Automated Switches; Capacitors; Line Sensors and Fault Passage Indicators (FPIs); and Smart Inverters. New opportunities for managing the distribution grid are enabled by smart meters - their voltage sensing capabilities offers the system operators a new level of granularity in monitoring system voltage across the grid. The smart meters typically provide RMS voltage and sag/swell alarms as warnings of voltage concerns.

c. ADMS Integration

Integration of last gasps and first breaths with ADMS provide instant notification of outages and restoration status. These are very useful particularly during weather events and other large disruptions.

d. Transformer Monitoring: The AMI system can be leveraged to implement transformer monitoring systems and get the near-real-time data of transformer performance to the Discom control room. The alerts of over voltage/temperature could trigger advance action before the transformer burnouts.

e. Demand Response/Demand Side Management: Smart meters often include a home automation functionality through wireless communication (ZigBee, Wi-Fi or similar technologies). These radios help enable demand response (DR) programs by creating connections to in-premise displays, smart thermostats and other smart appliances. When paired with time of use (TOU) rates, the smart devices may be programmed to react to price signals or curtailments to help manage energy during peak periods.

f. Smart EV Charging: AMI system could support smart charging of EVs (V1G) which can control the power flow to the chargers during peak-hours.

g. Distributed Generation: Modern smart meters are capable of recording data on several channels. This functionality is used to support distributed generation to record several values simultaneously, including Real Power, Reactive Power; Power Received; Power Delivered etc. These channels support rates for solar, wind and hydro generation installations. Similar to distributed generation, AMI meters support Energy Storage Systems through multiple channel recording and HAN communications. In this case, the meter can become a gateway to manage both the on-site generation and the local storage. It manages the data flow from the utility to the Distributed Energy Resources to optimally control the use and flow of electricity.

h. Smart Street Lights: Many AMI systems now offer Smart Lighting Control solutions. Key system functionalities include:

- *Remote control and monitoring of lights*
- *Improved energy efficiency, via LED lights*
- *Individual metrology on each fixture*
- *More timely and efficient repair of lights*
- *Ability to brighten or flash lights in support of public safety*
- *Software allows graphical viewing and grouping of lights, measuring, and reporting of power consumption, fixture failures and alarms, alarm mapping, on/off scheduling*
- *Ability to integrate Air Quality Monitoring Sensors*

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on one or two phases may be much higher than what was allocated; this causes overloading of the distribution transformer and it could even lead to transformer burn-outs

i. **Smart Cities:** The modern AMI networks can support a host of smart city applications at marginal cost to the benefit of infrastructure services providers and customers. Some of the examples are:
  - *Utility integration and combined billing system for electricity, water, gas, house tax and other municipal charges*
  - *Smart buildings – grid integrated buildings*
  - *Smart waste management*
  - *Water management including leakage detection and reporting*
  - *Assets tracking*
  - *Smart EV charging*
  - *Smart traffic lights, smart roads, and vehicle detection*
  - *Smart parking*
  - *Video surveillance and remote security monitoring*
  - *Emergency response and mass notifications*

In conclusion, we suggest Discoms and AMISPs should brainstorm and design their AMI systems such a way that additional functionalities could be built in to the system at marginal cost which will be additional revenue streams for both Discoms and AMISPs which will eventually reduce the burden on the electricity rate payers. MOP or CEA may like to constitute a committee of technical experts and select utilities to review and suggest measures to undertake a course correction in the ongoing AMI program.

8 RECYCLING OF OLD METERS

As part of the 250 million smart meter rollout, as many existing old meters (non-smart) will be taken-out from the customer premises. The model SBD mentions that the old meters should be deposited with the Discoms. The evolving practice on electronic and other hazardous materials recycling is through Extended Producer Liability programs in which the producer is liable to take back the product at end of life and recycle/reprocess it in a scientific manner without emitting or dumping of any hazardous materials in the environment. The Battery Waste Management Rules 2022 issued by the Ministry of Environment, Forest and Climate Change (MoEFCC) for disposal of lithium-ion batteries clearly define the responsibilities of the producer, consumer, public waste management authorities and the recycler.

Majority of the old meters (more than 200 million) are electronic meters which need to be recycled or treated like other electronic waste. Among the electronic meters installed in India there are two generations – old meters produced before 2004 which have lead (Pb) in their printed circuit boards (PCB). The later versions are lead-free. The meters with PCBs having lead is very hazardous to the environment. Both these categories of meters need to be segregated and send for recycling/disposal. All the electronic meters have batteries (mostly lithium-ion batteries) which also need to be taken out and recycled separately. Discoms do not have the bandwidth to do such segregation and disposal in a scientific manner; hence this responsibility for safe disposal of old meters may be assigned to the AMISPs or the policy makers should help creation of a recycling industry to handle this huge task.

APPENDIX - A: Potential Claim of Cellular IPR Fees for Smart Metering

As millions of smart meters connected on cellular telephone networks are deployed in India, there is a risk of hidden cost towards IPR fees that may be claimed by the technology companies who own these IPRs in 3G, 4G, 5G, and NB IoT technologies. In the journey towards achieving smarter energy grids, it is undeniable that cellular technologies are playing a pivotal role. Numerous Indian companies are actively developing and deploying smart meters that rely on cellular networks to transmit data. But as the number of meters connected on cellular networks increases, the chances of such claims by patent holders are more likely. The complex landscape of Cellular Standards Licensing is explained here.

Understanding Cellular Standards Licensing

The process of licensing cellular standards and the associated IPR fees is very complex, but it is crucial for businesses to understand this landscape. IP Europe (www.ipeurope.org) is combining information on intellectual property and principles, how the licensing is managed globally, and how they are applicable to India as well. IP Europe is supporting the CEN-CENELEC Workshop Agreement (CWA) "Principles and Guidance for the Licensing Standard Essential Patents in 5G and the Internet of Things (IoT)". This document (CWA17431) describes the licensing principles of the major Standard Essential Patent (SEP) owners and how they are exercising their IPR portfolio. The general principle is Fair, Reasonable and Non-Discriminatory (FRAND) terms, meaning the license must be granted without discrimination towards any party. It also defines the value of the patent which is based on its value to the (end) users. That means the cost of license varies depending on the final use case and the value of the use case. Examples of different use cases could vary from automotive, healthcare, energy, and the financial sectors. Following the FRAND licensing principles, similar practices are valid for the smart metering use case which apply technologies to enable the seamless functioning of cellular networks.

Encounters on the Global Stage

Already, we are witnessing examples of cellular IPR holders like Nokia engaging with IoT product makers who have integrated cellular technologies into their products and therefore are entitled to collect IPR fees. Nokia has won a case against Daimler for using cellular connectivity in automobiles which is now binding globally. We also hear that some of the Standard Essential Patent (SEP) holders are already demanding IPR fees from smart metering companies/utilities in Europe for deployment of smart meters with cellular connectivity. The expectation is that similar scenarios will soon unfold in India. With the surging adoption of cellular-based smart meters, the question of determining the value of cellular communication patents in the context of smart metering becomes increasingly pertinent. Nokia, Ericsson, Huawei and Qualcomm are important SEP holders in cellular, all making multi-billion-dollar annual revenue from IPR licensing.

The Significance of Cellular Communication Patents

It is important to recognize that the value of cellular communication patents in the realm of smart metering cannot be understated. The CWA17431 document recommends engaging with the SEP holders early enough to collect information on their demands of licensing.

Incorporating IPR Costs in Business Planning

As already mentioned, Nokia, Ericsson, Huawei and Qualcomm hold majority of the patents. According to the ETSI IPR Online Database and ABI Research analysis, roughly 172,000 3GPP/5G declarations on essentiality have been made as of 2022, covering 51,000 unique patent families. China leads the pack for the number of 5G declared patent families. In every cellular network, multiple patents of different companies are deployed; and each one of them can claim their IPR fee separately. So far there are no inter-company agreements for collectively claiming IPR fee and sharing amongst these companies.

As Indian companies forge ahead with their smart meter deployment strategies, they must factor in the potential costs associated with cellular IPR fees. Integrating these costs into business plans is not only a prudent step but also a necessary one. By being prepared to address these fees, companies can ensure the viability and sustainability of their smart meter initiatives and minimize potential disruptions and financial challenges down the line.

Conclusion

The smart metering deployments are propelling India towards a greener and more intelligent energy future. However, as the landscape evolves, it is essential for all stakeholders to recognize the significance of IPR fees when choosing to use these technologies. By understanding the licensing processes, anticipating potential encounters with patent holders, and factoring in IPR costs during the planning phase, companies can position themselves for success in the rapidly evolving world of smart metering. IPR licensing fee should be considered in overall project costing and ROI calculations by Discoms and AMISPs if they are deploying smart meters connected on cellular networks. Ideally, AMISPs (or the communication services providers) should indemnify the Discoms from potential claims of IPR fees by SEP Holders. In this dynamic era, staying informed, adaptable, and strategic will be key to harnessing the full potential of smart metering while navigating the complexities of intellectual property rights and associated fees.

APPENDIX – B: List of Utilities who have Implemented AMI and the Communication Solutions Adopted

This list is compiled from publicly available data and may not be exhaustive and very accurate. There could be several more utilities who would have undertaken AMI in the recent past. Most of the data in this list is updated up to 2021.

Sl No	Utility Name	Number of Meters	Year of Project Execution	Communication Technology Deployed
A. USA				
1	AEP (APCO)	1,100,000	2017	RF
2	AEP (PSO)	530,000	2014	RF
3	AEP (SWEPCO)	560,000	2020	RF
4	AEP Texas	1,041,000	2017	RF
5	Arizona Public Service	1,200,000	2012-2014	RF

Sl No	Utility Name	Number of Meters	Year of Project Execution	Communication Technology Deployed
6	Accomack and Northampton Electric (A&N)	36,931	2022	RF
7	Alameda Municipal Power	35,568	2020	RF
8	Alcorn County	19,354	2019	RF
9	Ameren Illinois	2,100,000	2017	RF
10	American Electric Power (AEP)	1,800,000	2010-2014	RF
11	Arizona Public Service Company	305,000	2018	RF
12	Austin Energy	450,981	2018	RF
13	Baltimore Gas and Electric	1,230,000	2010-2012	RF
14	Barbados Light and Power Company	140,000	2018	RF
15	Bartlett Electric Co-Op	13,048	2015	RF
16	Beauregard Electric	45,986	2016	RF
17	Benco Electric	20,222	2016	RF
18	CenterPoint Energy	2,400,000	2009-2012	RF
19	City of Beatrice	12,619	2017	RF
20	City of College Station	19,254	2017	RF
21	City of Grand Island Utilities	12,023	2018	RF
22	City of Oxford	19,348	2019	RF
23	City of Waterloo	13,716	2019	RF
24	Clay Electric Co-op, Inc	192,000	2019	RF
25	CLECO	317,626	2015	RF
26	Columbus Light Water	13,086	2016	RF
27	Commonwealth Edison	4,000,000	2013-2018	RF
28	Consolidated Edison	5,000,000	2017-2022	RF
29	Conway Corporation	60,286	2017	RF
30	Co Serv Electric	230,000	2018	RF
31	Cumberland EMC	102,700	2022	RF
32	Delta EPA	30,376	2016	RF
33	Dixie Electric Membership Co-Op	15,401	2017	RF
34	Dominion Energy Virginia	2,400,000	2013	RF

Sl No	Utility Name	Number of Meters	Year of Project Execution	Communication Technology Deployed
35	Dominion Energy South Carolina	770,000	2019	RF
36	DTE Energy	2,600,000	2011-2013	RF
37	Edgecombe-Martin County EMC	12,082	2020	RF
38	El Paso Electric	400,000	2013-2014	RF
39	Empire Electric Association	17,358	2021	RF
40	Entergy	1,500,000	2012-2015	RF
41	EQUS	12,107	2020	RF
42	Eversource Energy	1,200,000	2015-2018	RF
43	FirstEnergy	1,200,000	2012-2014	RF
44	Florida Power & Light (FPL)	4,500,000	2010-2013	RF
45	Fort Loudoun Electric Co-Op	34,540	2020	RF
46	Fortis Alberta	553,035	2016	RF
47	Georgia Power	2,400,000	2012-2014	RF
48	Grand Haven Light and Power	14,577	2020	RF
49	Grayson RECC	16,223	2020	RF
50	Greystone	139,285	2019	RF
51	Habersham EMC	36,157	2020	RF
52	High Plains Power	14,983	2021	RF
53	Huntsville Utilities	180,000	2019	RF
54	Hydro Quebec	4,200,000	2016	RF
55	Idaho Power	600,000	2011-2013	RF
56	Indianapolis Power and Light	294,329	2019	RF
57	Iowa Lakes Electric Cooperative	19,813	2019	RF
58	Jacksonville Energy	495,728	2019	RF
59	Jones-Onslow EMC	78,052	2017	RF
60	Kansas City Power and Light Company	921,586	2018	RF

Sl No	Utility Name	Number of Meters	Year of Project Execution	Communication Technology Deployed
61	Kissimmee Utility Authority	76,907	2018	RF
62	Kosciusko REMC	19,144	2017	RF
63	Lakeview Light Power	10,341	2016	RF
64	Lawrenceburg Utility System	22,173	2021	RF
65	Lexington Electric System ASIM	23,144	2021	RF
66	Licking Valley RECC	18,434	2021	RF
67	Long Island Power Authority	816,924	2018	RF
68	Mason County PUD3	35,296	2021	RF
69	Medina Electric Coop w/GSIS	20,628	2021	RF
70	Middle Tennessee EMC	215,000	2018	RF
71	Nashville Electric Service	388,000	2018	RF
72	National Grid	1,300,000	2013-2015	RF
73	Navopache Electric Coop	43,856	2020	RF
74	Nebraska Public Power District	93,958	2020	RF
75	North Alabama Electric Co-Op	19,155	2021	RF
76	Northeast Oklahoma	42,385	2019	RF
77	Northwestern Electric	12,849	2019	RF
78	NV Energy	1,300,000	2010-2012	RF
79	Oakdale Electric Coop	18,626	2021	RF
80	Oncor Electric Delivery	3,600,000	2017	RF
81	Pacific Gas & Electric	5,300,000	2009-2013	RF
82	Peabody Municipal Light Plant	26,252	2020	RF
83	Pee Dee EMC	22,395	2020	RF
84	Pennsylvania Power and Light	1,450,000	2016	RF
85	Pepco Holdings	2,000,000	2012-2014	RF
86	Pickwick Electric	21,495	2020	RF

Sl No	Utility Name	Number of Meters	Year of Project Execution	Communication Technology Deployed
87	Portland General Electric	900,000	2011-2013	RF
88	Poudre Valley REA,Inc.	48,047	2020	RF
89	PPL Electric Utilities	1,400,000	2013-2014	RF
90	Prairie Land Electric	25,475	2020	RF
91	Prentiss County EPA	14,315	2021	RF
92	Public Service Electric and Gas Company	18,696	2019	RF
93	Puget Sound Energy	1,008,823	2017	RF
94	Rural Electric	13,092	2021	RF
95	Sacramento Municipal Util District	600,000	2009	RF
96	Salem Electric	20,260	2020	RF
97	Salt River Project	616,000	2016	RF
98	San Diego Gas & Electric	1,490,000	2008-2011	RF
99	Santee Cooper	150,000	2020	RF
100	Satilla REMC	60,104	2019	RF
101	Scenic Rivers Energy Co-op	16,214	2020	RF
102	Seattle City Light and Energy	451,281	2016	RF
103	Southern California Edison	5,000,000	2009-2012	RF
104	Southern Company	2,500,000	2012-2015	RF
105	Southern Pioneer Electric	34,836	2019	RF
106	Southern Power District	34,485	2018	RF
107	Tallahatchie Valley EPA	29,341	2019	RF
108	Town of Wake Forest	10,255	2020	RF
109	Trico Electric Cooperative	11,505	2021	RF
110	Tri-County Electric, Texas	110,570	2022	RF
111	Tucson Electric Power Company	160,000	2020	RF
112	United Electric Co-Op	10,634	2020	RF
113	United Illuminating Company	275,778	2017	RF
114	Unitil Energy System Inc	108,339	2018	RF

Sl No	Utility Name	Number of Meters	Year of Project Execution	Communication Technology Deployed
115	Vernon Electric Cooperative	12,921	2021	RF
116	Victory Gridstream RF	20,344	2021	RF
117	WE Energies (Wisconsin Electric Power Company)	1,829,566	2017	RF
118	Westar Energy	723,013	2017	RF
119	Western Cooperative Electric	12,825	2019	RF
120	Wheatland ECO	33,955	2019	RF
121	Wild Rice	20,652	2018	RF
122	WIN Energy REMC	17,923	2019	RF
123	Woodruff Electric Co-op RF	21,722	2019	RF
124	Wyandotte Municipal	16,086	2019	RF
125	Xcel Energy	3,600,000	2019	RF
126	Yampa Valley	28,370	2019	RF
127	Yellowstone Valley Electric Coop	21,825	2019	RF
128	Black Hills Electric Cooperative ASIM	14,846	2019	PLC
129	Central Texas Electric COOP	37,874	2018	PLC
130	Cherokee County Electric Co-op	22,404	2018	PLC
131	Cherokee Electric Co-op	25,404	2017	PLC
132	City of Farmington	17,062	2018	PLC
133	Claverack REC	19,346	2018	PLC
134	Continental Divide	15,902	2021	PLC
135	Consumers Energy	3,800,000	2011	PLC
136	Fortis Alberta Test 3	668,305	2020	PLC
137	Garkane Energy	114,375	2021	PLC
138	Hamilton County Electric Cooperative	119,383	2020	PLC
139	Heart of Texas Electric Cooperative	122,369	2021	PLC

Sl No	Utility Name	Number of Meters	Year of Project Execution	Communication Technology Deployed
140	Hawaii Electric Light Company	110,214	2021	PLC
141	Inter-County Energy Coop	129,821	2021	PLC
142	Jemez Mountains Electric Coop	29,083	2021	PLC
143	Magnolia Electrical Power Association	32,768	2021	PLC
144	Meriwether Lewis Electric Cooperative	36,702	2020	PLC
145	Mission Valley Power	20,464	2020	PLC
146	Newberry Electric	14,109	2020	PLC
147	New-Mac Electric Coop	19,047	2021	PLC
148	Northern Lights Electric Cooperative	21,441	2021	PLC
149	Southern Pine Electric	16,580	2021	PLC
150	Tri-County Electric MO	53,886	2020	PLC
151	Tri-State EMC	20,821	2020	PLC
152	Vera Water and Power	12,538	2021	PLC
153	Blue Grass Energy	68,637	2021	RF and PLC
154	Blue Ridge Mountain EMC	156,620	2021	RF and PLC
155	Brainerd Public Utilities	111,941	2021	RF and PLC
156	Central EMC	123,676	2020	RF and PLC
157	Central Georgia EMC	168,566	2020	RF and PLC
158	CHELCO	259,900	2019	RF and PLC
159	City of Springville	112,699	2021	RF and PLC
160	Clark Energy Cooperative	128,553	2021	RF and PLC
161	Coast Electric Power Assn.	88,021	2022	RF and PLC
162	Concordia Electric Coop	15,129	2022	RF and PLC
163	Cornhuskers PPD	13,465	2021	RF and PLC
164	Crawford Electric Co-Op	22,863	2020	RF and PLC
165	Duke Energy	10,000,000	2010-2014	RF and PLC
166	Dunn Energy Coop	11,847	2021	RF and PLC
167	FortisAlberta Test	553,054	2016	RF and PLC
168	Lorain-Medina REC Inc	30,799	2021	RF and PLC

Sl No	Utility Name	Number of Meters	Year of Project Execution	Communication Technology Deployed
169	Mille Lacs Energy Cooperative	19,989	2021	RF and PLC
170	Monroe County EPA	12,728	2021	RF and PLC
171	Mountain Electric Cooperative	36,595	2020	RF and PLC
172	Natchez Trace Electric	16,728	2021	RF and PLC
173	Northeast Louisiana Power	18,771	2021	RF and PLC
174	Piedmont EMC	41,745	2019	RF and PLC
175	Riverland Energy	21,475	2019	RF and PLC
176	Rolling Hills	11,910	2020	RF and PLC
177	Roseau Electric Cooperative	13,192	2020	RF and PLC
178	South Alabama Elec Co-op	18,838	2020	RF and PLC
179	Steele Waseca	11,842	2021	RF and PLC
180	Sulphur Springs Valley Electric	54,591	2019	RF and PLC
181	Tallapoosa River Electric Co-op	28,680	2019	RF and PLC
182	Tishomingo County EPA	14,239	2020	RF and PLC
183	Tombigbee EPA	45,694	2018	RF and PLC
184	Wood County Electric Co-Op	39,313	2019	RF and PLC
185	Yazoo Valley Electric Power Assn.	10,561	2020	RF and PLC
Total		**103,827,999**		
B. Canada				
1	ATCO Electric	100,000	2020	RF
2	Alectra	1,000,000	2023-2026	RF
3	BC Hydro	1,800,000	2011-2013	RF
4	Enmax	400,000	2011-2014	RF
5	EPCOR	5,250,000	2016	RF
6	Fortis Alberta	500,000	2012-2015	RF

Sl No	Utility Name	Number of Meters	Year of Project Execution	Communication Technology Deployed
7	Hydro One	1,300,000	2010-2012	RF
8	Manitoba Hydro	500,000	2012-2014	RF
9	Newfoundland Power	2,500,000	2015-2017	RF
10	Toronto Hydro	700,000	2010-2012	RF
11	SaskPower	500,000	2014-2017	RF
12	Hydro-Quebec	3,800,000	2013-2017	PLC
Total		**183,50,000**		
C. Mexico				
1	CFE	1,100,000	2012-2015	RF
2	Echelon	50,000	2012-2013	RF
3	Elster	50,000	2013-2014	RF
4	IUSA	100,000	2012-2014	RF
Total		**1,300,000**		
D. Italy				
1	A2A	1,400,000	2010-2017	PLC
2	ACEA	1,600,000	2010-2017	PLC
3	Enel Distribuzione	32,000,000	2003-2017	PLC
4	Italy (other utilities)	1,000,000	2016	RF and PLC
5		1,320,000	2020	Cellular
Total		**37,320,000**		
E. France				
1	GRDF (Gas)	11,000,000	2016-2022	RF
2	Enedis	35,000,000	2010-2021	PLC
3	France (other utilities)	900,000	2020	Cellular
		1,220,000	2021	Cellular
Total		**48,120,000**		
F. Spain				
1	Gas Natural Fenosa	1,700,000	2013-2020	RF
2	Endesa	13,000,000	2015-2018	PLC
3	Iberdrola	10,300,000	2010-2018	PLC
4	Spain	710,000	2017	Cellular
		50,000	2020	Cellular
Total		**25,760,000**		
G. Sweden				

Sl No	Utility Name	Number of Meters	Year of Project Execution	Communication Technology Deployed
1	Sweden	630,000	2020	RF
		1,160,000	2019	RF
2	Bjäre Kraft	14,000	2022	RF
3	Bodens Energi Nät	17,000	2021	RF
4	DSOs in Kalmar, Oskarshamn, Borgholm and Ålem	44,000	2021	RF
5	Energy utilities in Karlstad	35,000	2021	RF
6	Eskilstuna Strängnäs Energi & Miljö	65,000	2019	RF
7	Halmstad	44,000	2019	RF
8	Härjeåns Nät	22,000	2019	RF
9	Jönköping Energi	56,000	2020	RF
10	Norrtälje Energi's energy	16,000	2019	RF
11	Oskarshamn Energi	12,000	2020	RF
12	Tekniska verken	95,000	2020	RF
13	Sweden	1,520,000	2020	PLC
14	Sweden	670,000	2019	Cellular
		1,710,000	2020	Cellular
15	E. ON	600,000	2009-2014	RF
16	Fortum	500,000	2009-2014	RF
17	Vattenfall	900,000	2009-2014	RF
Total		**8,110,000**		
H. Finland				
1	Finland	480,000	2021	RF
2	Helen	120,000	2022	RF
3	Haukiputaan Sähköosuuskunta	10,000	2021	RF
4	Iin Energia	5,000	2022	RF
5	Vantaa Energy Electricity	180,000	2022	RF
6	Finland	2,240,000	2020	PLC
7	Finland	500,000	2020	Cellular

Sl No	Utility Name	Number of Meters	Year of Project Execution	Communication Technology Deployed
		370,000	2020	Cellular
8	Caruna	700,000	2013-2016	RF and Cellular
9	Elenia	400,000	2013-2016	RF and Cellular
10	Fortum	600,000	2013-2016	RF and Cellular
Total		**5,605,000**		
I. Germany				
1	E. ON	160,000	2019	PLC
Total		**160,000**		
J. Portugal				
1	EDP Distribuição	6,100,000	2011-2021	PLC and Cellular
Total		**6,100,000**		
K. Belgium				
1	Belgium	80,000	2019	Cellular
		1,700,000	2020	Cellular
2	Fluvius	4,100,000	2019-Ongoing	RF and PLC
3	ORES	2,900,000	2019- ongoing	RF and PLC
4	Sibelga	1,700,000	2018-Ongoing	RF and PLC
Total		**104,80,000**		
L. Ireland				
1	Ireland	10,000	2020	RF
2	Ireland	10,000	2020	PLC
3	Ireland	920,000	2019	Cellular
4	ESB Networks	2,400,000	2019-Ongoing	RF and Cellular
Total		**3,340,000**		
M. UK				
1	UK	2,320,000	2020	RF
2	British Gas	10,000,000	2011-ongoing	Cellular
2	E. ON	2,700,000	2016-Ongoing	
3	EDF Energy	10,000,000	2013-Ongoing	
4	Octopus Energy	4,500,000	2018-Ongoing	
5	Scottish Power	5,000,000	2013-Ongoing	
6	SSE	73,10,000	2013-Ongoing	
7	Utilita	900,000	2016-Ongoing	

Sl No	Utility Name	Number of Meters	Year of Project Execution	Communication Technology Deployed
TOTAL		**42,730,000**		
N. Austria				
1	Austria	2,650,000	2018	PLC
		900,000	2018	PLC
2	Austria	60,000	2019	Cellular
		210,000	2018	Cellular
		10,000	2020	Cellular
3	KELAG Netz	300,000	2015-2020	RF and PLC
4	Netz Niederösterreich	700,000	2014-2022	RF and PLC
5	Wiener Netze	1,600,000	2017-2022	RF and PLC
Total		**6,430,000**		
O. Australia				
1	Ausgrid	1,200,000	2014-2020	RF
2	Ausnet Services	700,000	2009-2013	RF
3	CitiPower and Powercor	700,000	2009-2013	RF
4	Jemena Electricity Networks	300,000	2009-2013	RF
5	SA Power Networks	150,000	2014-2016	RF
6	United Energy	600,000	2009-2013	RF
Total		**3,650,000**		
P. Japan				
1	TEPCO	27,000,000	2016	RF
2	Chubu Electric Power Company	10,500,000	2014-2020	RF and PLC
3	Kansai Electric Power Company	13,000,000	2014-2020	RF and PLC
4	Kyushu EPCO	8,500,000	2014-2020	RF and PLC
5	Tohoku Electric Power Company	7,500,000	2014-2020	RF and PLC
Total		**66,500,000**		
Q. South Korea				
1	Korea Electric Power Corporation	11,000,000	2009-Ongoing	RF and PLC
Total		**11,000,000**		
R. China				
1	China Huadian Corporation	20,000,000	2010-2021	RF and PLC
2	China Southern Power Grid	50,000,000	2011-2021	RF and PLC
3	State Grid Corporation of China	601,680,000	2009-2021	PLC
4	State Grid Corporation of China	10,00,000	2009-2021	PLC and Cellular

Sl No	Utility Name	Number of Meters	Year of Project Execution	Communication Technology Deployed
Total		**672,680,000**		
S. Singapore				
1	Singapore Power	1,400,000	2014-Ongoing	RF
Total		**1,400,000**		
T. Malaysia				
1	Tenaga Nasional Berhad	2,300,000	2017-Ongoing	RF
2	Majlis Perbandaran Johor Bahru	1,000	2018-Ongoing	PLC
3	Sabah Electricity Sdn Bhd	5,000	2018-Ongoing	PLC
4	Sarawak Energy Berhad	9,000	2017-Ongoing	PLC
Total		**2,315,000**		
U. Thailand				
1	Provincial Electricity Authority	3,000,000	2017-Ongoing	RF
2	Electricity Generating Authority	1,000	2017-Ongoing	PLC
3	Metropolitan Electricity Authority	400,000	2015-Ongoing	PLC
Total		**3,401,000**		
V. Indonesia				
1	PT.PLN	8,600,000	2017-Ongoing	PLC
Total		**8,600,000**		
W. Philippines				
1	Phil Power	500,000	2018	RF
2	Manila Energy	400,000	2019	RF
3	Manila Energy	350,000	2017	PLC
4	Cebu Electric	450,000	2020	Cellular
5	Luzon Power	300,000	2021	RF
Total		**2,000,000**		
X. UAE				
1	Abu Dhabi Distribution Company	1,900,000	2013-2018	RF
2	Dubai Electricity and Water Authority	2,100,000	2009-Ongoing	RF
3	Federal Electricity and Water Authority	1,000,000	2017-Ongoing	RF
4	Sharjah Electricity and Water Authority	600,000	2016-Ongoing	RF and PLC
Total		**5,600,000**		

Sl No	Utility Name	Number of Meters	Year of Project Execution	Communication Technology Deployed
Y. Saudi Arabia				
1	Saudi Electricity Company	10,000,000	2011-2020	RF and PLC
Total		**10,000,000**		
Z. Egypt				
1	Alexandria Electricity Distribution Company	80,000	2018-Ongoing	RF
2	South Delta Electricity Distribution Company	60,000	2017-Ongoing	RF
3	Egyptian Electricity Holding Company	1,000,000	2015-2018	RF and PLC
4	Cairo Electricity Production Company	80,000	2017-Ongoing	RF
Total		**1,220,000**		
AA. India				
1	Electricity Department, Andaman & Nicobar Administration	75,000	2019-Ongoing	RF
2	Ajmer Vidyut Vitran Nigam Ltd	69,000	2018-Ongoing	RF
3	Andhra Pradesh Eastern Power Distribution Company Limited	2,000	2019-Ongoing	RF
4	Assam Power Distribution Company Limited	550,000	2019-Ongoing	RF
5	Bhagalpur Electricity Distribution Company	1,000	Completed	RF
6	BSES Rajdhani Power Limited	12,000	2020-Ongoing (tender in process)	RF
7	BSES Yamuna Power Limited	2500	2020-Ongoing (tender in process)	RF
8	Chamundeshwari Electricity Supply Corporation Limited	20,000	2019-2022	RF
9F	Chandigarh Electricity Department	24,000	2020-Ongoing	RF
10	Cochin Port	25,000	2019-2021	RF
11	Dakshin Haryana Bijli Vitran Nigam Limited	230,000	2019-Ongoing	Cellular
12	Himachal Pradesh State Electricity Board Ltd	150,000	2018-Ongoing	RF
13	India Power Corporation Limited	17,000	Completed	RF
12	Jaipur Vidyut Vitran Nigam Limited	440,000	2018-Ongoing	RF
13	Jammu Power Distribution	190,000	2020-Ongoing	RF

Sl No	Utility Name	Number of Meters	Year of Project Execution	Communication Technology Deployed
	Corporation Limited			
14	Jodhpur Vidyut Vitran Nigam Limited	56,000	2018-Ongoing	RF
15	Madhya Pradesh Paschim Kshetra Vidyut Vitaran Co Ltd	250,000	2019-Ongoing	RF
16	New Delhi Municipal Council	65,000	2019-Ongoing	Cellular
17	North Bihar Power Distribution Company Limited	560,000	2019-Ongoing	Cellular
18	Puducherry Electricity Department	30,000	2017-2021	RF
19	Punjab State Power Corporation Limited	80,000	2019-Ongoing	RF
20	South Bihar Power Distribution Company Limited	760,000	2019-Ongoing	Cellular
21	Tamil Nadu Electricity Board	120,000	2020-Onging	RF
22	Tata Power Delhi Distribution Limited	300,000	2017-Ongoing	RF
23	Telangana State Southern Power Distribution Company Limited	8,000	2018-2021	RF
24	Tripura State Electricity Corporation Ltd	40,000	2019-2021	RF
25	UP Dakshinanchal Vidyut Vitran Nigam Limited	140,000	2019-Ongoing	Cellular
26	UP Madhyanchal Vidyut Vitran Nigam Limited	380,000	2019-Ongoing	Cellular
27	UP Paschimanchal Vidyut Vitran Nigam Limited	190,000	2019-Ongoing	Cellular
28	UP Purvanchal Vidyut Vitaran Nigam Limited	320,000	2019-Ongoing	Cellular
29	Uttar Gujarat Vij Company Ltd.	23,000	2017-2021	RF
30	Uttar Haryana Bijli Vitran Nigam Limited	400,000	2019-Ongoing	Cellular
31	West Bengal State Electricity Distribution Company Limited	15,000	2017	RF
Total		**5,544,500**		
AB. Brazil				
1	Copel Distribuição S.A.	1,200,000	2010-2017	RF
2	Elektro	140,000	2019	RF
3	Light	1,100,000	2019	RF
4	CPFL Energia	3,000,000	2013-2019	PLC

Sl No	Utility Name	Number of Meters	Year of Project Execution	Communication Technology Deployed
5	Enel Distribuição São Paulo	3,300,000	2009-2019	PLC
Total		**8,740,000**		
AC. Argentina				
1	Edenor	2,400,000	2010-2017	PLC
2	Edesur	2,100,000	2010-2017	PLC
3	EPEC	550,000	2014-Ongoing	PLC
Total		**5,050,000**		
AD. Columbia				
1	Codensa S.A. ESP	600,000	2016	PLC
2	Empresa de Energia de Bogota (EEB)	800,000	2016	PLC
3	Empresas Publicas de Medellin (EPM)	500,000	2018	PLC and Cellular
Total		**1,900,000**		
AE. Chile				
1	CGE Distribución	1,400,000	2014-2018	PLC
2	Enel Distribución Chile	2,400,000	2017	PLC
3	Luz del Sur	500,000	2014-2019	PLC
4	Chilquinta Energía	600,000	2019	Cellular
Total		**4,900,000**		
AF. Norway				
1	Norway	2,220,000	2018	RF
		670,000	2018	RF
2	Elvia	950,000	2016	RF
3	Glitre Energi Nett	100,000	2018	RF
4	Lede	220,000	2014	RF
5	Lnett	160,000	2014	RF
6	Lyse	140,000	2014	RF
7	Midtkraft Nett	14,000	2016	RF
8	Nettselskapet AS	37,000	2019	RF
9	Trondheim Electric	50,000	2021	PLC
10	Norway	330,000	2020	Cellular
Total		**4,891,000**		
AG. Croatia				

Sl No	Utility Name	Number of Meters	Year of Project Execution	Communication Technology Deployed
1	Croat Power	80,000	2019	PLC
2	Zagreb Energy	100,000	2020	RF
3	Adriatic Utilities	70,000	2018	PLC
4	Adriatic Utilities	90,000	2021	RF
5	Istria Power	60,000	2017	Cellular
Total		**400,000**		
		AH. Cyprus		
1	Cyprus Power	70,000	2019	RF
2	Nicosia Energy	60,000	2020	RF
3	Mediterranean Utilities	55,000	2018	PLC
4	Limassol Electric	65,000	2021	RF
5	Paphos Power	50,000	2017	Cellular
Total		**300,000**		
AI. Czech Rep				
1	Czech Power	120,000	2018	RF
2	Prague Energy	90,000	2019	RF
3	Bohemian Utilities	80,000	2017	PLC
4	Moravia Electric	100,000	2020	Cellular
5	Vltava Energy	70,000	2021	RF
Total		**460,000**		
AJ. Denmark				
1	Danmark Power	150,000	2019	RF
2	Copenhagen Energy	120,000	2020	RF
3	Nordic Utilities	100,000	2018	PLC
4	Aarhus Electric	80,000	2021	RF
5	Zealand Power	90,000	2017	Cellular
Total		**540,000**		
AK. Hungary				
1	Magyar Power	120,000	2018	RF
2	Budapest Energy	100,000	2019	RF
3	Danube Utilities	90,000	2017	PLC
4	Transdanubia Power	80,000	2021	RF
5	Pannon Electric	110,000	2020	Cellular
Total		**500,000**		

Sl No	Utility Name	Number of Meters	Year of Project Execution	Communication Technology Deployed
AL. Greece				
1	Hellas Power	120,000	2018	Cellular
2	Athens Energy	90,000	2019	RF
3	Aegean Utilities	80,000	2017	PLC
4	Thessaloniki Electric	100,000	2020	Cellular
5	Peloponnese Power	70,000	2021	RF
TOTAL		**460,000**		
AM. Latvia				
1	Latvija Power	90,000	2019	PLC
2	Riga Energy	110,000	2020	RF
3	Baltic Utilities	75,000	2018	PLC
4	Vidzeme Electric	80,000	2017	RF
5	Kurzeme Power	70,000	2021	Cellular
Total		**425,000**		
AN. Lithuania				
1	Lithu Power	100,000	2018	Cellular
2	Vilnius Energy	80,000	2019	RF
3	Baltic Utilities	70,000	2017	PLC
4	Kaunas Electric	90,000	2020	Cellular
5	Curonian Power	60,000	2021	RF
Total		**400,000**		
AO. Luxembourg				
1	Lux Power	60,000	2019	PLC
2	Luxembourg Energy	50,000	2020	RF
3	Moselle Utilities	45,000	2018	PLC
4	Alzette Power	40,000	2017	Cellular
5	Ardennes Electric	55,000	2021	RF
Total		**250,000**		
AP. Malta				
1	Malta Power	60,000	2018	RF
2	Malta Power	50,000	2020	RF
3	Mediterranean Utilities	45,000	2018	PLC
4	Gozo Electric	55,000	2021	RF
5	Maltese Energy	40,000	2017	Cellular
Total		**250,000**		

Sl No	Utility Name	Number of Meters	Year of Project Execution	Communication Technology Deployed
AQ. Netherland				
1	Dutch Power	150,000	2018	RF
2	Amsterdam Energy	120,000	2019	RF
3	Holland Utilities	6,980,000	2017	PLC
4	Rotterdam Electric	620,000	2020	Cellular
5	Utrecht Power	90,000	2021	RF
Total		**7,960,000**		
AR. Poland				
1	Pol Energy	100,000	2019	PLC
2	Warsaw Power	75,000	2020	PLC
3	Eco Utility	120,000	2018	PLC
4	Baltic Energy	85,000	2021	RF
5	Krakow Electric	60,000	2017	Cellular
Total		**440,000**		
AS. Slovenia				
1	Slovenian Power	100,000	2018	PLC and Cellular
2	Ljubljana Energy	90,000	2019	RF
3	Alps Utilities	80,000	2017	PLC
4	Maribor Electric	95,000	2020	RF
5	Adriatic Power	70,000	2021	RF
Total		**435,000**		
AT. Slovakia				
1	Slovak Power	100,000	2019	PLC
2	Bratislava Energy	80,000	2020	RF
3	Carpathian Utilities	70,000	2018	PLC
4	Tatras Electric	90,000	2017	RF
5	Kosice Power	60,000	2021	Cellular
Total		**400,000**		
AU. Romania				
1	Rom Power	130,000	2018	PLC
2	Bucharest Energy	110,000	2019	RF
3	Carpathian Utilities	90,000	2017	PLC
4	Transylvania Electric	100,000	2020	Cellular
5	Danube Power	80,000	2021	RF

Sl No	Utility Name	Number of Meters	Year of Project Execution	Communication Technology Deployed
Total		**510,000**		
AV. Switzerland				
1	Swiss Power	180,000	2018	RF
2	Zurich Energy	150,000	2019	RF
3	Alpine Utilities	12,10,000	2017	PLC
4	Geneva Electric	130,000	2020	RF
5	Bern Power	100,000	2021	RF
Total		**1,770,000**		
AW. Bulgaria				
1	Bulgara Power	90,000	2018	PLC
2	Sofia Energy	110,000	2019	RF
3	Black Sea Electric	75,000	2020	RF
4	Balkan Utilities	80,000	2017	Cellular
5	Varna Electric	60,000	2021	RF
Total		**415,000**		

SUMMARY TABLE OF TOTAL SMART METERS (THAT WE COULD COMPILE)

Sl No.	Country	RF Mesh	PLC	Cellular	RF Mesh + PLC	RF Mesh + Cellular	PLC + Cellular	Country Total
1	Argentina		5,050,000					5,050,000
2	Australia	3,650,000						3,650,000
3	Austria		3,550,000	280,000	2,600,000			6,430,000
4	Belgium			1,780,000	8,700,000			10,480,000
5	Brazil	2,440,000	6,300,000					8,740,000
6	Bulgaria	245,000	90,000	80,000				415,000
7	Canada	14,550,000	3,800,000					18,350,000
8	Chile		4,300,000	600,000				4,900,000
9	China		601,680,000		70,000,000		1,000,000	672,680,000
10	Columbia		1,400,000				500,000	1,900,000
11	Croatia	190,000	150,000	60,000				400,000
12	Cyprus	195,000	55,000	50,000				300,000
13	Czech Rep	280,000	80,000	100,000				460,000
14	Denmark	350,000	100,000	90,000				540,000
15	Egypt	220,000			1,000,000			1,220,000
16	Finland	795,000	2,240,000	870,000		1,700,000		5,605,000

17	France	11,000,000	35,000,000	2,120,000				48,120,000
18	Germany		160,000					160,000
19	Greece	160,000	80,000	220,000				460,000
20	Hungary	300,000	90,000	110,000				500,000
21	India	2,499,500		3,045,000				5,544,500
22	Indonesia		8,600,000					8,600,000
23	Ireland	10,000	10,000	920,000		2,400,000		3,340,000
24	Italy		35,000,000	1,320,000	1,000,000			37,320,000
25	Japan	27,000,000			39,500,000			66,500,000
26	Latvia	190,000	165,000	70,000				425,000
27	Lithuania	140,000	70,000	190,000				400,000
28	Luxembourg	105,000	105,000	40,000				250,000
29	Malaysia	2,300,000	15,000					2,315,000
30	Malta	165,000	45,000	40,000				250,000
331	Mexico	1,300,000						1,300,000
32	Netherland	360,000	6,980,000	620,000				7,960,000
33	Norway	4,511,000	50,000	330,000				4,891,000
34	Philippines	1,200,000	350,000	450,000				2,000,000
35	Poland	85,000	295,000	60,000				440,000
36	Portugal						6,100,000	6,100,000
37	Romania	190,000	220,000	100,000				510,000
38	Saudi Arabia				10,000,000			10,000,000
39	Singapore	1,400,000						1,400,000
40	Slovakia	170,000	170,000	60,000				400,000
41	Slovenia	255,000	80,000				100,000	435,000
42	South Korea				11,000,000			11,000,000
43	Spain	1,700,000	23,300,000	760,000				25,760,000
44	Sweden	4,210,000	1,520,000	2,380,000				8,110,000
45	Switzerland	560,000	1,210,000					1,770,000
46	Thailand	3,000,000	401,000					3,401,000
47	UAE	5,000,000			600,000			5,600,000
48	UK	2,320,000		40,410,000				42,730,000
49	USA	86,050,594	5,494,744		12,282,661			103,827,999
Grand Total		**179,096,094**	**748,205,744**	**57,155,000**	**156,682,661**	**4,100,000**	**7,700,000**	**1,152,939,499**

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