



Smart Metering: Overview and Considerations for South African Municipalities

Sustainable Energy Africa

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Objectives and Contents of this Document

This report reviews the status of smart metering infrastructure rollout within South African municipalities. The report will also look at factors to be considered by municipalities when planning their smart meter pilot or rollout projects including the cost-benefit considerations in this regard. It also aims to understand how municipalities stand to benefit from smart metering functionalities as well as a review of the major challenges to be addressed before deploying the smart meters. The document does provide an overview on smart grids/metering technology and system considerations.

Part 1: Status of smart metering in South Africa and developing a Business Case for smart metering

Background

A number of South African municipalities are currently considering deploying smart meters and smart metering systems, all as part of efforts to improve grid reliability, revenue management, reduce electricity losses, address billing and credit control issues, and promote energy efficiency while providing improved services to their customers. This is in line with global trends of smart metering and local electricity industry regulations. However, a big question is whether South African municipal electricity distributors are ready for smart metering technology investments. Operation and maintenance of a smart metering solution is a relatively new business globally and requires investment in resources and capacity building. Municipalities will therefore have to develop strong business cases for such investments.

Policy and other drivers of smart metering in South Africa

The Department of Energy had published Regulation 773 of the Energy Regulation Act for electricity reticulation services in the Government Gazette of 18 July 2008 which required that end users with a monthly electricity consumption of 1,000kWh and above must have a smart meter system and be on a time-of-use tariff (TOU) by not later than 01 January 2012. In terms of demand side management (DSM) the regulation called for the licensee to be able to remotely control all electric conventional geysers (non-solar), heating systems, cooling and ventilation systems, swimming pool drives and heaters in all existing buildings.

The definition of a smart metering system, as stated in the Government Gazette, is an electricity meter that allows for:

- Measurement of energy consumed on a time interval basis.
- Two-way communication between the customer/end-user and the licensee.
- Storage of time interval data and transfer it remotely to the licensee, and
- Remote load management.

This regulation was not well accepted, and was seen to be unfeasible by many municipalities. Therefore, the set deadline was not met by a large majority of the municipalities and extensions to the deadline were requested. A blanket exemption was not granted for municipalities, however it was agreed that any municipality applying for extension would be given an extension until the regulation had been revised. Municipalities are therefore still expected to look at technology solutions that address both load management and revenue collection challenges, although how this is to be done remains unspecified.

National Smart Metering Standards

The **NRS049:2008 - Advanced metering infrastructure for residential and commercial customers**, specification has been drafted and published to create a standard specification for advanced metering infrastructure (AMI) systems in South Africa. NRS049:2008 specifies that active energy consumption data must be stored on the meter as total register values (normal cumulative energy

data) as well as half-hourly intervals. The data retrieval system (AMI master station) must be able to support both the retrieval of the billing register values as well as half-hourly data. Municipalities will have to decide if they will bill customers through meter register values or half-hourly values.

Apart from billing data it is also specified that the meter must be able to record different events such as tampering, supply outages, under and over voltage conditions, when disconnect commands were applied, when load control was done through the master station, and for meter configuration changes.

An NRS049 compliant smart metering system essentially has the following characteristics:

- Bi-directional communications from the central server to meters and devices and from these devices back to the central server.
- Customers are able to have a portable customer interface unit in their premises that can read information off a meter and receive information from the utility.
- The ability to control up to two relays for load control (such as hot water cylinder and a swimming pool pump).
- Be capable of remote load disconnect for revenue protection of the utility.

Also a national vision document “Smart Grid 2030 Vision” has been compiled by the South African Smart Grid Initiative (SASGI), a South African National Energy Development Institute (SANEDI) initiative developed through one of its Portfolios, the Smart Grid programme. The smart grid vision aims to serve as a guidance for smart grid planning and roll-out by both Eskom and the municipal electricity distributors. SANEDI also has a trained team that can assist municipalities assess their readiness for investing in a smart grid network through a Smart Grid Readiness Test (Smart Grid Maturity Assessment).

Status of smart metering within South African municipalities

Smart metering is in its infancy in South Africa. However, municipalities are increasingly focusing on customer satisfaction, revenue collection, reliability, energy efficiency and cost savings. As a strategic response, a number of municipalities are turning to smart metering/ Advanced Metering Infrastructure (AMI)¹ / Automated Meter reading (AMR). Municipalities on the whole have not yet adopted smart metering on a large scale with only a few municipalities implementing smart metering pilot projects, the City Power Smart metering project in the City of Jo’burg, the City of Tshwane, and the Nelson Mandela Bay. The national utility Eskom as well as the South African National Energy Development Institute (SANEDI) have also piloted smart metering. It is not uncommon for a municipality to have a few large industrial customers being billed on a time-of-use tariff (TOU) through a smart metering system, but residential smart metering is very uncommon.

The record of pilot smart metering rollouts has been mixed – which is unsurprising given the level of complexity involved in such programs. Municipalities risk not realizing the benefits expected from smart meter projects because of project planning and implementation issues.

¹ Advanced metering Infrastructure (AMI) is the collective term to describe the whole infrastructure from smart meter to two way-communication network to control centre equipment and all the applications that enable the gathering and transfer of energy usage information in near real-time. The installation of an AMI is looked upon as a bridge to the construction of smart grids and smart meters are an integral part of the AMI.

Lessons learnt from smart metering related rollouts

This report uses text boxes to present lessons learnt and key outputs from a selected number of smart metering related pilot projects implemented around the country by municipalities, Eskom and the South African National Energy Development Institute (SANEDI).

Box 1

City Power Smart Metering Project (City of Jo'burg)

Project Objective

Install smart meters for large power users and domestic customers to help minimise billing errors, improve revenue collection and reduce non-technical electricity losses. The project also includes the installation of protective enclosures.

The project also piloted a demonstration of systems and processes to dispense Free Basic Electricity (FBE) to a 1,000 indigent customers. Implement an Inclined Block Tariff (IBT) to a selected indigent customers as well as implement a Time of Use (TOU) tariff in both residential and commercial customer base.

Project Location

Johannesburg

Status of Project

Ongoing

Outputs achieved from the installation

- Over 65,000 meters installed in the residential sector by May 2015
- Improved operational efficiency through remote meter reading, more accuracy in billing information
- Smart metering has led to an improvement in stakeholder engagement
- Installation of protective structures must be done simultaneously with the installation of smart meters in target rollout area

There exists a need for a national smart metering strategy which will help standardise technology and optimise application practices on a national basis for both municipalities and Eskom. National government through the Department of Energy (DoE) should aim to standardise on the protocols for meters and metering field devices to ensure interchangeability and interoperability. The protocol to be adopted nationally should be based on internationally accepted open protocols (preferably endorsed by IEC) which will ensure a larger pool of manufacturers who can supply the field metering devices (data concentrators, appliance control devices, customer interface units etc.) and meters. This will ensure that municipalities don't get locked into specific manufacturers of meters or field metering devices.

Box 2

Soweto Split Metering Project (Eskom)

Project Objective

Install split meter technology with protective enclosures to curb growing debt and reduce energy losses.

Project Location

Soweto, Johannesburg

Status of Project

Ongoing

Outputs achieved and lessons learnt from the installation

- Improved operational efficiency through remote meter reading and disconnections
- Project area is the only area in Soweto where customers are unable to bypass electricity meters or buy power from ghost Credit Dispensing Units (CDUs).
- Payment levels increased to 90%, resulting in increased revenues
- Improved public and employee safety
- Improved quality of electricity supply due to reduced outages commonly caused by tampering
- Remote monitoring of access to the steel enclosure securing meters and circuit breakers
- A lesson learnt by Eskom in this project was that customer interface and communication is paramount to any successful project
- Customer involvement from inception is key
- Ongoing community meetings and meetings with the various community forums are essential

Planning Phase of Smart Meter Rollout

In the planning phase of the smart metering project the scope and ambitions of the project will have to be laid out. Municipalities need to conduct a thorough and open assessment of their readiness to rollout a smart metering programme, this can provide valuable insights that will contribute to long-term success. The planning for the installation of smart meters is just as important as the actual installation itself. There are a number of factors that the municipalities will have to consider in their

Box 3
AMI and HomeFlex Project – Phase 1 (Eskom)
<i>Project Objective</i>
Pilot, test and evaluate AMI technology to support automated meter readings (AMR), tamper detection and residential time of use (TOU) tariff implementation.
<i>Project Location</i>
Sandon & Randfontein (Johannesburg) and in Margate (KwaZulu-Natal)
<i>Status of Project</i>
Completed – 2012
<i>Outputs achieved from the installation</i>
<ul style="list-style-type: none">- Automated meter reading of 3,232 customers- Designed and deployed an open (non-proprietary) multi-vendor interface layer (MVIL) to accommodate multiple metering system suppliers.- Developed standardised meter and data concentrator installation specifications and practices- Implemented remote customer supply disconnection and reconnection processes- Identified customers that were not on the billing system- Identified metering and billing errors- Identified incidents of non-technical losses

decision to successfully rollout smart metering technology, these include:

Step 1: Reflect on your municipality’s ability to implement a smart metering project. In assessing the municipality’s capabilities consider the following:

- Decision making (political) stability,
- Financial sustainability,
- Existing or planned smart grid projects, and
- Availability of human resources and capacity.

Step 2: Understand how smart metering relates to the current operation of the municipality's grid and its operation. Hold discussions with senior municipal officials to get an understanding of the municipality's strategic development objectives linked to electricity supply.

Step 3: Identify areas of concern and possible areas of improvement within the municipality's electricity business.

Step 4: Develop a Smart (Grid) Metering Roadmap/Vision: given that smart meters are a component of smart grids, municipalities will have to develop tailored roadmaps specific to their needs and these should be benefits driven. When developing their smart grid visions municipalities should be guided by the high level national Smart Grid Vision developed under the South African Smart Grid Initiative (SASGI) led by the South African National Energy Development Institute (SANEDI).

Step 5: Develop the specific functionality of the technologies proposed to address concerns identified in **Step 3** and those that maximize the benefits.

Step 6: Building a business case the municipality should consider all benefits that can accrue from the proposed smart metering project, these should include both economic (reasonably simple to quantify) and non-economic benefits (more difficult to quantify). GreenCape (2014) proposes that a municipality should perform a multi-criteria analysis that should take the following into consideration:

- Financial impact (costs and benefits)
- Environmental sustainability
- Customer satisfaction
- Safe working conditions for staff

Step 7: A customer communication plan should be in place and the municipality will have to begin communicating its intentions to introduce smart meters before the deployment of meters begin to ensure success of the programme, avoid customer resistance. The municipality should bear in mind that customer satisfaction begins with customer communication and education. There are many pitfalls associated with the absence of, or misdirected communication. Positive examples of communication that can be considered by municipalities include web portal implementation, advance customer notifications and customer education sessions. The municipality will have to be innovative and extend the traditional communication channels with digital supplements like Facebook and Twitter.

It is recommended that municipalities invest significant effort on planning, designing, testing, integrating and piloting smart meter rollouts. Once the municipality is confident with outcomes of its pilot projects it can then embark on an aggressive large-scale rollout programme. A targeted approach to smart metering might be an ideal approach to municipalities instead of mass rollouts. Smart meters can initially be targeted to industrial and commercial large users of power before a massive rollout into the residential sector.

Design issues to be considered by municipalities for their smart metering programs

There are some design issues that can significantly affect the success of the smart metering rollout which municipalities will have to consider when planning a smart metering program. Below are some of the major design issues the municipality should consider around its smart metering programme:

Design Issue	
<p>1. Interoperability (if and how the meter can openly communicate with other devices)</p>	<p>Interoperability refers to the capability of two or more networks, systems, devices, applications, or components to exchange and readily use information securely, effectively, and with little or no inconvenience to the user.</p> <ul style="list-style-type: none"> - The smart meter will have to be able to openly communicate with other devices. Different systems should be able to exchange meaningful and actionable information. The systems will share a common meaning of the exchanged information, and this information will elicit agreed-upon types of response. - The municipality should ensure that the system they select is interoperable and will allow for evolution and growth as smart grid standards evolve. - To manage change in the growing smart grid system, it is essential to be able to upgrade firmware, such as meters, in the field without replacing other system equipment or software. - One of the drivers for interoperability include the need to avoid supplier lock-in i.e. the municipality should not be forced to stick with a certain supplier. With interoperable systems changing suppliers would not require replacement of existing equipment. - Future systems such as outage management systems benefit from being interoperable with AMI. <p>The Interoperable Device Interface Specification (IDIS²) is the preferred companion specification aimed at maintaining and promoting publicly available technical interoperability specifications based on open standards and supports their implementation in interoperable products. IDIS is used by smart meter manufacturers and utilities implementing smart meters to provide interoperable products based on open standards. By specifying that smart meters and field metering devices must comply with open standards and protocols the municipality will ensure that it doesn't get locked into specific manufacturers or system vendors. It is expected that the offering of interoperable meters will promote the faster and broader adoption of AMI devices and services based on open standards.</p>
<p>2. Interchangeability</p>	<p>Interchangeability within meters allows flexibility and promotes simplicity in system upgrading and maintenance:</p> <ul style="list-style-type: none"> - The municipality can therefore stock one type of meter at any given time. - Technicians only need to know one meter installation procedure at a particular time. - Kiosks can accommodate meters from multiple vendors eliminating the need to replace all meters in the kiosk with system changes.

² The Interoperable Device Interface Specifications (IDIS) Industry Association is a non-profit, association established to maintain and promote publicly available technical interoperability specifications based on open standards and supports their implementation in interoperable products. IDIS is an association for smart metering companies which are committed to providing interoperable products based on open standards.

3. Standardisation	<p>Given that different parts of the smart grid system are being developed by different manufacturers it is necessary to pay attention to the standardisation of the format of messages and methods of data exchange. Currently in South Africa there is no testing of smart meters entering the system by South African Bureau of Standards (SABS), which is one issue raised by the South African Smart Grid Initiative (SASGI³).</p> <ul style="list-style-type: none"> - Proprietary systems should be avoided by the municipality to ensure interchangeability between suppliers in a certain area. Most of the AMI systems employed in the world have their own propriety protocols and designs and interchangeability will be almost impossible. - Major manufacturers are currently working on standardisation of communication protocols to allow for interchangeability of components at installed AMI systems. - Municipalities should only procure smart meters from suppliers with standards that conform to the need for interoperability. Only systems that conform to standards issued by an official standardisation organisation (e.g. Cenelec, CEN, or IEC) offer the guarantee that there are no hidden intellectual property rights (IPRs), and therefore lack of interchangeability, attached to it.
4. Future proofing	<p>The municipality should select metering systems with in-built flexibility for possible future changes in technology or application.</p> <ul style="list-style-type: none"> - Such systems will allow for future supply and demand-side applications without the need for large new investments in the metering systems themselves.

Municipalities can benefit from aligning their smart meter rollouts with those of Eskom which has done extensive research around smart metering and is working on standardising smart metering technology and optimising application procedures on a national basis. Eskom aims to standardise the smart metering protocols and metering field devices to ensure interoperability and interchangeability.

Cost Estimates/ Economic Appraisal

The implementation of smart metering, because of the large number of meters involved, will typically represent a very large capital investment that must be fully and carefully justified. Municipalities will have to **critically question the viability of investing in smart metering technology**. A cost-benefit analysis can be used to appraise the financial benefits of the proposed smart metering project. This forms a foundation for conducting a consistent, credible and transparent economic assessment of the long-term costs and benefits of the roll-out of smart metering. This assessment should consider benefits for both the customer and the municipality.

The evaluation of project costs should not be limited to “the average cost per meter” or “average cost per customer” but also a consideration of the municipality’s infrastructure, relative age and flexibility of the underlying information technology (IT) architecture upon which the smart metering solution will be implemented. Also to be evaluated is **the cost of doing nothing** in terms of

³ SASGI is an initiative of South African National Energy Development Institute (SANEDI) SASGI developed the Smart Grid vision for South Africa, and is presently working with industry to provide policy inputs, address the gaps in standards and in the deployment and application of technology.

investing in smart metering. Here the municipality will have to evaluate costs associated with electricity theft or losses impacts on revenues and difficulties in managing its distribution grid.

Costs associated with the hardware, software, installation, training and vendor deployment support should be evaluated. GreenCape (2014) noted that municipalities that are already implementing smart metering are paying anything between R1,500 and R8,500, compared to a conventional meter that can cost them as little as R400. This increased cost limits the viability of smart metering for many customers, as it can be difficult to justify the expenditure on meters when there are other pressing demands on the municipality, such as electrification. In addition, a municipality will need to seriously look at whether it makes **economic sense to install expensive smart meters to monitor the low electricity consumption associated with most low income households.**

Other factors that will also impact on project costs include project size, geography, customer density, functional requirements, meter inventory, municipal strategy among others. **Operation and maintenance (O&M) costs associated with different smart metering systems also vary widely and these will affect annual net benefits.** Municipalities shouldn't invest in meters with too many features that the municipality wouldn't be able to make use of.

The following indicators can be used to for the financial appraisal of benefits of smart metering: ***benefit-cost ratio, net present value*** and ***payback period***.

AMI and Municipal Staff Capacity

Municipal engineering departments are facing a shortage of technical skills and therefore have limited resources available to drive the implementation of smart grids at the municipal level. Efficient operations of the AMI infrastructure requires **competent and well-trained personnel and a set of processes, information technologies and routines** adapted to the needs of the AMI. The field equipment constitutes a large machine-to-machine infrastructure, which requires special competence and skills to operate and maintain which might not be available within the municipality. Smart metering technology needs the support of experienced data scientists who will be able to assimilate and process the data generated by the advanced smart meters. Having the right experts managing the smart meters will give municipalities critical insights into consumption profiles and infrastructure operations. Therefore municipalities will have to conduct a critical and honest evaluation of the skills set that is required to support smart metering.

Municipal staff buy-in, to the metering programme, is required so as to ensure that the metering solution and business process changes are adopted. Internal staff will need to be trained on the following aspects:

- Customer support,
- Technical support, and
- Maintenance requirements and execution.

Box 4

Revenue Enhancement Project (SANEDI)

SANEDI has been providing technical and strategic guidance to municipalities around revenue enhancement. SANEDI has piloted a revenue baseline management study within five municipalities.

Project Objective

Objectives of the project has been to conduct a revenue management within municipal utilities to enhance revenues. The pilot projects aimed to investigate and determine the revenue methodologies used by the target municipalities, identify gaps in the current revenue models. Identify and document policy and regulatory gaps in the electricity business industry. Develop a business case and a 'How to Guide' on findings from the pilot project. SANEDI developed the smart functionality and specification for meters used in the pilot projects.

Project Location

Nala, Naledi, Govan Mbeki, Thabazimbi and Mogale City.

Status of Project

Ongoing (October 2014 – March 2016)

Outputs achieved from the installation and lessons learnt

- Over 2,000 smart meters installed in the 5 pilot municipalities
- Smart meters installed in tamper proof kiosk and are remotely monitored
- Introduce municipalities to new management processes of defining a common vision and communicating it through the municipality
- Introduction of data analytics to drive business sustainability
- Improved visibility and control of municipal network via energy balancing and load management technologies deployed.
- A back office/ control centre is a major requirement for all rollouts
- There has been a positive feedback from pilot areas

Box 5

Active Network Management and ADMS (eThekweni Municipality)

Project Objectives

Project involves the active network management of small-scale embedded generation (SSEG) onto the distribution grid and the implementation of an Advanced Distribution Management System (ADMS). The project's objectives include:

- Demonstrate the systems and processes to manage active elements within the distribution grid.
- Determine the systems and processes to implement an ADMS.
- Design and implement the ADMS
- Determine active elements within the grid and document management of these elements.

Location

Ethekwini (Durban)

Project Status

Ongoing

Outputs achieved and lessons learnt from the pilot project

- Embedded generation is gradually becoming a reality and municipalities/utilities cannot stop customers from installing rooftop PV panels etc.
- Visibility and control is essential for safety and security of supply
- Ethekwini has a very advanced grid with SCADA, GIS, Outage Control and other systems fully integrated
- An integrated system derives more benefits

Municipal Procurement Processes

The procurement process must be planned in detail, involving all parts of the municipality, working out detailed technical, economic and legal requirements and constraints. Municipal procurement processes are complex and comprehensive and subject to several regulations. It is important that municipalities, project developers and smart meter vendors know the procurement processes in detail in order to avoid complications that may befall the smart metering project. These processes may vary per municipality.

According to the GreenCape (2014⁴) the following regulations will have to be considered to ensure the success of a smart metering programme:

- Municipal Finance Management Act, 2003
- Municipal Systems Act, 2000
- Preferential Procurement Policy Framework Act, 2000
- Preferential Procurement Regulations, 2011

⁴ GreenCape, 2014, *Understanding Municipal Procurement Processes: A summary of the South African municipal procurement processes and the underlying legislation*, Cape Town, South Africa

Box 6

General lessons learnt from Pilot Projects

- a. Municipalities have a massive skills gap across all value chains within their structures.
- b. The Smart Grid Maturity Model Assessment tool adds great value to municipalities if carried out before project scope determination.
- c. Municipalities tend to struggle with defining the scope of work for bids on smart metering/ grids and will need support in this regard
- d. National standards on smart metering and smart grids are lacking
- e. Policy and regulations will need to be developed to compliment smart grid initiatives. The DoE has taken on this initiative.
- f. There is a lack of examples on how to develop sound business cases that can be consulted by municipalities.
- g. Energy balancing will assist in taking the strain off Eskom's utility grid.
- h. Present tariffs and revenue collection methods cannot address debt backlogs, both to Eskom and municipalities.
- i. A customer centric approach to smart metering and smart grids should be adopted by municipalities instead of implementing programmes that are utility centric.
- j. Customer buy-in programmes must precede any project implementation
- k. Asset management within municipalities is currently driven from a compliance point of view. Municipalities are not currently seeing their electricity assets as "the goose that lay the golden egg".
- l. There is a misplaced notion that smart meters are a smart grid.
- m. Municipalities are very silo oriented with every unit working in competition with others –

Municipal procurement processes require that if funds are to be spent on the smart metering project, it has to follow the rules and regulations and these involve fitting in with the timing of the municipality's Integrated Development Plan (IDP) and the municipal budgeting cycle. This is regardless of whether the project is funded internally or externally. Given that any part of the smart metering programme will exceed R1 million, it is a requirement that a competitive bidding tender process is used in selecting service providers.

Procurement and contract management:

- The Request for Proposal (RfP) should be explicit on scope and requirements
- A procurement specialist with experience on procurement of technical or IT equipment should lead contract negotiations
- What levels of expertise reside within the municipality to manage the project, and what level of third-party support would be expected?

In terms of the expected benefits of the project, the municipality would have to evaluate how realistic and achievable its proposed benefits are. It should avoid mistakes made by some municipalities that have already piloted smart metering by not undertaking detailed pre-assessments.

Box 7

Advanced Asset Management Project

Advanced Asset Management (AAM) is a project aimed at determining current municipal utility asset management and close the gaps where they exist. Designing and implementing an asset management methodology which is in line with smart grid thinking.

Project Objectives

The objectives of the project were to demonstrate the use and application of data analytics from an integrated back office system to manage utility assets in a smart and highly intelligent manner. Other objectives include:

- Document the current utility asset management methodologies.
- Identify the gaps in the current system and recommend solutions.
- Design and implement an AAM methodology suitable to the two municipalities.
- Design a business case for AAM
- Develop a 'How to Guide' on the demonstration pilot of both customer bases

Location

Msunduzi and Nelson Mandela Bay Municipality

Project Status

Ongoing

Outputs achieved and lessons learnt from the pilots

- Advanced Asset Management (AAM) is the smarter way of managing assets through a lifecycle approach
- Reduction in operation and maintenance (O&M) is a key driver
- Need to prioritise projects in a coordinated fashion
- An integrated approach is key i.e. workforce management and asset management integration
- Critical assets were identified in both municipalities
- Remote monitoring of temperature, voltage monitoring, theft and tampering already addressed in key assets.

Part 2: Overview of Smart Grid and Smart Metering Concepts

Smart Grids

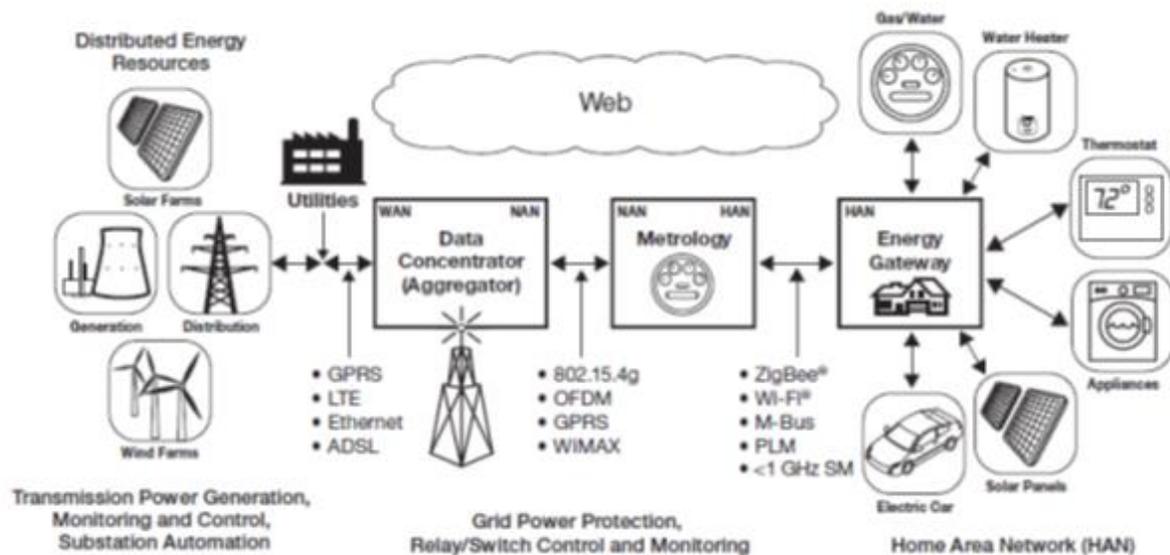


Figure 1: Smart grid conceptual mode⁵

The European Technology Platform Smart Grid (ETPSG) has defined the smart grid *as “an electricity network that can intelligently integrate the actions of all users connected to it – generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies.”* The development of a smart grid is a result of applying significant levels of automation, communications and information technology on the electrical distribution systems to improve reliability. Current changes happening to the electricity grid are said to be driven by the convergence of information and power delivery technologies, and by the need for energy conservation and concerns around climate change (Ipakchi, 2007⁶). Smart grids encompass a variety of individual technologies that span the electricity system.

The key business drivers for the move to smart grids include:

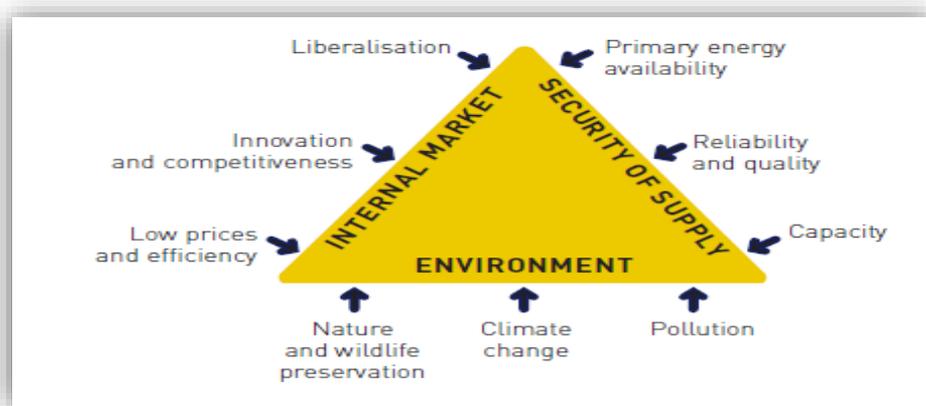


Figure 2: Drivers of the move to smart grids (Source: European Commission)

⁵ Source: Freescale, 2013, *Smart Energy: Energy Efficient, Connected, Secure*, www.freescale.com/smartenergy

⁶ Ipakchi, A, 2007, *Implementing the Smart Grid: Enterprise Information Integration*, KEMA Inc, Grid-Interop Forum 2007. Paper 121.122-1 http://www.gridwiseac.org/pdfs/forum_papers/121_122_paper_final.pdf

Reliability and quality of supply: The ageing electricity transmission and distribution networks threaten the security, reliability and quality of supply. Significant improvements in the reliability of power supply can be achieved through improved monitoring, automation and information management.

The Environment: environmental issues have moved to the forefront of the electricity business with concerns regarding greenhouse gas emissions and their contribution to climate change. This has led to a growing interest in renewable energy, especially small-scale embedded generation, closer to end-use consumption, and a greater reliance on demand-side management and micro-grids.

Operational Excellence: Municipalities are faced with the need to further improve operational efficiencies, at the same time they must deal with challenges associated with an aging infrastructure, and expectations for flexibility and improved services by customers and the national regulator.

Smart grids can provide a municipality with multiple opportunities to automate its grid and supporting systems, manage distributed generation, implement technologies that reduce outages, improve on customer services and improve asset management, amongst others. Smart Grid projects should be implemented so that they can play some meaningful part in an innovative, connected, integrated and sustainable energy future. **Smart metering often represents the starting point for a broader set of smart grid initiatives and – as such – they are fundamental to the modernisation of today’s energy networks.**

Advanced Metering Infrastructure (AMI)

Advanced metering infrastructure (AMI) involves the deployment of a number of technologies – in addition to advanced or smart meters that enable two-way flow of information, providing customers and utilities with data on electricity price and consumption, including the time and amount of electricity consumed. AMI is the sensor network of the smart grid. The electricity industry’s interest in embracing AMI as opposed to Automatic Meter Reading (AMR) is that the communication system is not dedicated to a single application. Instead, AMI is a flexible, general-purpose communication system that can be used for many applications. **Through AMI, municipalities can meet their basic targets for load management and revenue protection.**

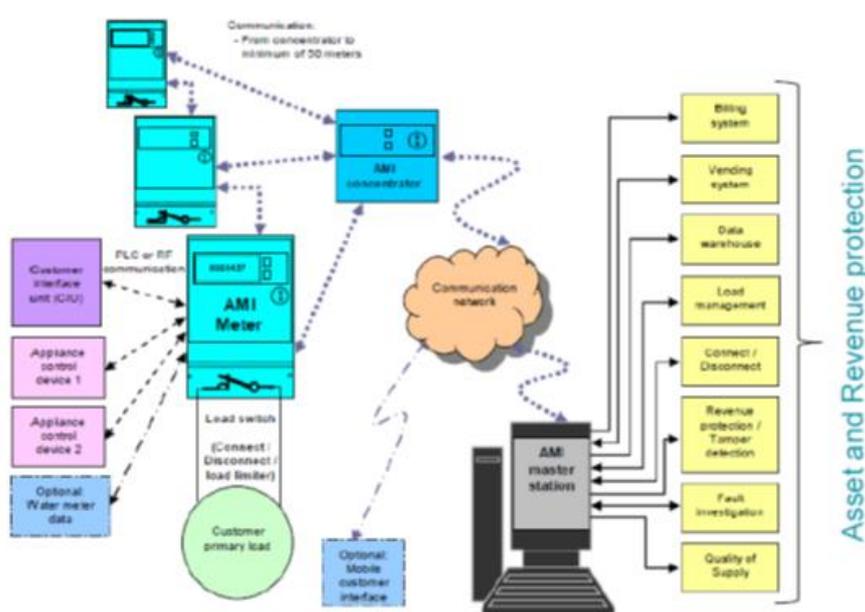


Figure 3: Typical AMI system complying with the NRS 049-1 (Calmeyer, 2012)

AMI can provide a wide range of functionalities which a municipality should consider when developing its business case, these, include:

- Remote consumer price signals, which can provide time-of-use (TOU) pricing information where it exists.
- Ability to collect, store and report customer energy consumption data for any required time intervals or near real time.
- Improved energy diagnostics from more detailed load profiles.
- Losses and theft detection.
- Remote connection and disconnection.
- Ability to identify location and extent of outages remotely via a metering function that sends a signal when the meter goes out and when power is restored.
- Ability for a retail energy service provider to manage its revenues through more effective cash collection and debt management.

An Overview of Smart Metering Systems

Smart meters are a broad class of measurement devices that replace the traditional mechanical or electro-mechanical recording mechanism to record consumption of electric energy. Smart meters enable two-way communication between the meter and the central system. Unlike the conventional electricity meters, smart meters can gather data for remote reporting, involving real-time or near real-time sensors, power outage notification, and power quality monitoring. It also enables



operational commands to be remotely transmitted to the meter, for example to autonomously shut down or limit the customer's usage, or interact with the new breed of "smart" home appliances.

Figure 4: Example of a smart meter (these can be in any shape)

A smart meter has the ability to store metering data in registers, and supports a variety of tariffs (e.g. time of use (TOU), inclined block tariff (IBT), maximum demand, free basic electricity (FBE)) which can be remotely updated. As well as other features that provide utilities with a clear understanding of what happens in a low voltage system in real time instead of around a billing cycle. Smart meters allow electricity customers to track their own energy use on the internet and/or with third-party computer programs. While smart meters have many benefits when implemented alone, it is only when they are part of a full smart grid system that their full potential can be unlocked. Smart metering often represents the starting point for a broader set of smart grid initiatives and – as such – they are fundamental to the modernisation of today's energy networks.

Benefits of smart meters

Smart metering brings a range of benefits for many different stakeholders of the systems. The table below identifies some of the major benefits that can be realised by municipal utilities on smart metering.

Stakeholder	Benefits
Municipal Customers	<ul style="list-style-type: none"> • Better access and data to manage electricity use • More accurate and timely billing • Improved outage restoration • Power quality data
Customer Service & Field Operations	<ul style="list-style-type: none"> • Reduced cost of meter reading • Reduced trips for off-cycle reads • Eliminates handheld meter reading equipment • Reduced call centre transactions • Reduced collections and connects/disconnects
Revenue Cycle Services – Billing, Accounting, Revenue Protection	<ul style="list-style-type: none"> • Reduced back office rebilling • Early detection of meter tampering and theft • Reduced estimated billing and billing errors
Transmission and distribution	<ul style="list-style-type: none"> • Improved transformer load management • Improved capacitor banking switching • Data for improved efficiency, reliability of service, losses and loading • Improved data efficient grid system design • Power quality data for the service areas
Marketing & Load Forecasting	<ul style="list-style-type: none"> • Reduced costs for collecting load research data

Source: Edison Electric Institute, 2011:9

Given that smart meters do not require manual reading, they can be secured with a shield to prevent tampering, or in areas with prevalent energy theft, they can be installed at inaccessible locations to provide even more security. This inaccessibility means that energy theft measures like slowing down or inverting the meter are at least much more difficult. What's more, electronic meters allow utilities to monitor energy use through the network, and identify potentially fraudulent energy use without having to send a meter-reader onto the premises.

Integration of Renewable and Distributed Generation

Smart meters, as part of a smart grid system, can help municipalities to better manage concerns of distributed power generation. Distributed generation has a number of impacts on the distribution network, and can impact losses, voltage control, power quality, short circuit power, and system protection. Smart metering can provide essential information to the utility to help it better manage the impact of distributed generation on the distribution network. Smart meters can provide real time information on the generation that is currently active, and the energy on the grid. Once smart meters are combined with a full smart grid the grid will be able to automatically manage and react to distributed generation.

While smart metering can aid with power quality when combined with a smart grid system, its most direct effect on distributed generation is related to billing especially when applied to customers that are net generators. Smart meters will communicate power data - both power consumed from the grid and returned to the grid by customers who generate alternative energy. With conventional mechanical disk meters the outcome of the customer exporting electricity depends on the existence

of a detent⁷ on the meter. If the meter is equipped with a detent the customer will not receive any benefit from exporting energy as the meter will only record in one direction. Without a detent, the meter will simply spin in the reverse direction when the customer is exporting electricity. Meters running in reverse can also cause administration problems for the municipality, because, if the meter reading is lower than the previous one, the system will assume that user has rolled over the meters maximum reading, resulting in a large, inaccurate bill.

Smart meters can provide the municipality with up-to-the-minute information on the status of energy flow in the network. When information from smart meters is gathered and combined in a meter data management (MDM) system it can provide a wealth of information to the municipal electricity distributor which can be used to better understand the power flows within the network. This information can be used to prevent blackouts.

Smart meters can offer municipalities new options for demand response. Connecting interruptible loads (loads which can be turned off without issue) to the network allows the utility to respond to situations where demand is too high for the supply to handle. Smart meters can work in prepayment or credit (post-paid) modes making it possible for consumers to pay as they normally would.

Communication protocols in smart metering systems

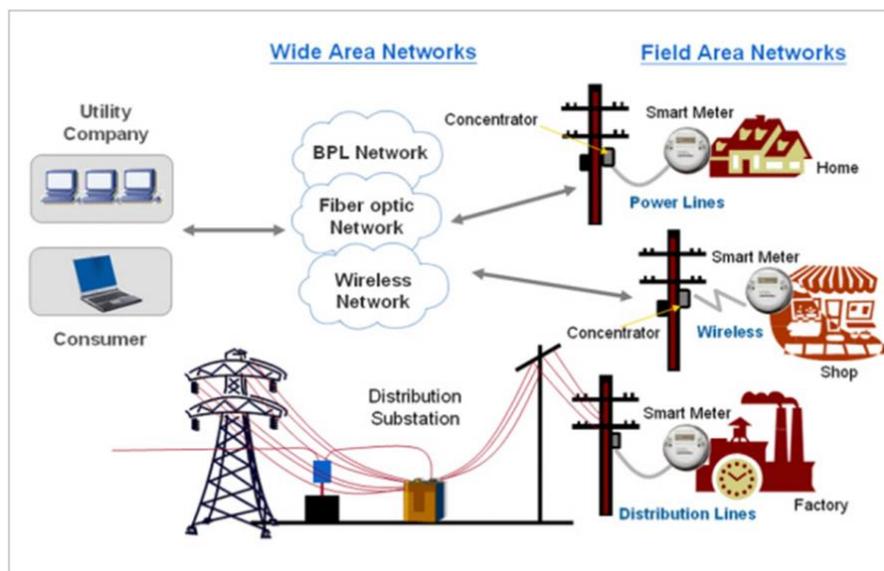


Figure 5: Basic architecture of a smart metering system (Source: Billion Electric Co. Ltd)

Smart grids will depend to a large extent on the ability to communicate between devices, customers, distributed generators, and the grid operator. The figure above shows a basic architecture of the smart metering system operations. Several basic networks make up the smart grid:

- i. Home Area Network (HAN) – communications between a building’s interior and a smart meter.

⁷ A detent is a facility in a meter that prevents the meter from measuring reverse energy, e.g. when site is generating more power than it consumes. A detent can be a mechanical ratchet-like device or a meter software feature.

- ii. Field Area Network - communications between the user's smart meter and a concentrator (or aggregator). This data transfer can occur as frequent as every 15 minutes or as infrequently as daily as determined by the municipality's needs.
- iii. Wide Area Network (WAN) – a high bandwidth backhaul communications link between the concentrator and the municipality. Data is transmitted via the WAN to the municipal central collection point for processing and use by municipal electricity business applications.

Many types of communication channels are possible in a smart metering system. The two dominant technologies are wireless radio frequency (RF) – using the unlicensed industrial, scientific, and medical (ISM) band – and power line carrier (PLC). According to South Africa's **NRS049:2008** for AMI, the communications medium that connects devices in the system downstream of the data concentrator can either be PLC or wireless RF. In terms of this specification, it is envisaged that either PLC or RF communications would be deployed between individual meters and the data concentrator, with the communications between the data concentrator and the master station typically through the cellular network.

Radio Frequency (RF)

According to the Edison Electric Institute (2011), RF technology uses low-power, low-cost radios to wirelessly transmit the meter information, whereas PLC uses the power line itself. Smart meter measurements and other data are transmitted by wireless radio from the meter to a collection point. The data is then delivered to the municipality's data systems for processing at a central location by various methods. RF technologies are usually two different types:

1. Mesh Technology

The smart meters talk to each other (hop) to form a LAN cloud to a collector. The collector then transmits the data using various WAN methods to the municipality's central data location.

- Mesh RF Technologies' merits include acceptable latency⁸, large bandwidth, and typically operate at 915 MHz frequencies.
- Demerits of Mesh technologies include terrain and distance challenges (for rural areas), proprietary communications, and multiple collection points.



Figure 6: Mesh wireless communication

2. Point-to-Point Technology

The smart meters talk directly to a collector, usually a tower. The tower transmits the data using various methods to the municipality central location for processing.

⁸ Latency is the delay from input into a system to desired outcome. Latency in communication is demonstrated in live transmissions from various points on the earth as the communication hops between a ground transmitter and a satellite and from a satellite to a receiver each take time (<http://whatis.techtarget.com/definition/latency>)

- Point-to-Point RF technologies have little or no latency, direct communication with each endpoint, large bandwidth for better throughput, some are licensed spectrum i.e. they require a license to operate them within the portion of the radio spectrum allocated to the organisation that has been licensed by the Independent Communications Authority of South Africa (ICASA) to operate the devices. With exclusive rights, a license holder operates without interference or spectrum crowding. RF networks can cover longer distances.
- The disadvantages of point to point RF networks include the requirement for licensing (except for the 900MHz which is a license-free band), terrain may prove challenging in rural areas, proprietary communications used for some technologies, and less interface with Distribution Automation (DA)⁹.

Power Line Carrier – PLC

Power Line Communication (PLC), also known as Power Line Digital Subscriber Line (PDSL), mains communication, Power Line Networking (PLN) or Broadband Over Power Lines (BPL) which are systems for carrying data on existing municipal power lines, used for electric power transmission, from the meter to a collection point, usually in the distribution substation feeding the meter. It is also possible to have the collection point located on the secondary side of a distribution transformer. The data will then be delivered to the municipality’s data systems for processing at a central location.

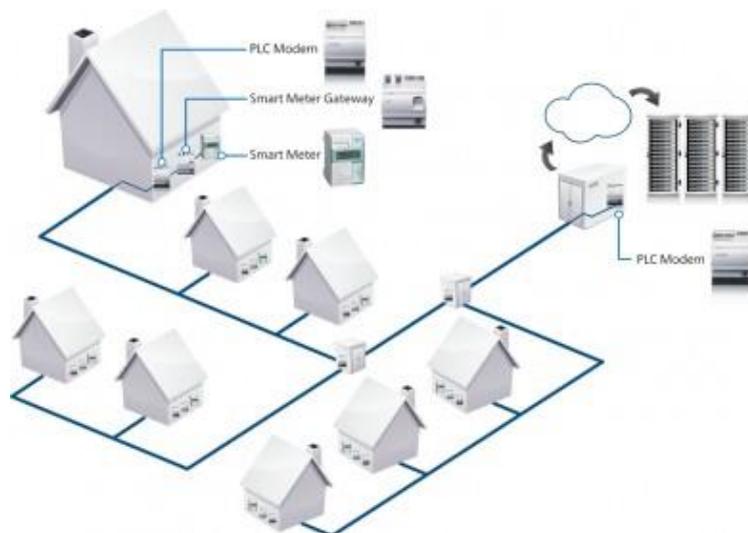


Figure 7: Schematic layout of PLC communication system (Devolu, 2015¹⁰)

PLC based systems are proving an attractive and cost-effective solution for smart metering deployments in the residential domain.

- Advantages of PLC technology include leveraging the use of the existing municipal electricity infrastructure of poles and wires, improved cost effectiveness for rural located lines, more

⁹ DA concerns the operational control of the grid, i.e. monitoring currents and voltages in the distribution grid and issuing commands to remote units such as switches and transformers.

¹⁰ Source: Devolo, 2015, Powerline-Technologie für eine effiziente Kommunikation im Smart Grid, <http://www.devolu.com/at/SmartGrid/Produkte/devolo-G3-PLC-Modem-500k>

effective in challenging terrain, and the capability to work over long distances. Installation and operation costs for PLC technology are extremely low.

- PLC disadvantages include more latency (longer data transmit time), less bandwidth and throughput, limited interface with Distribution Automation (DA) devices, and higher cost in urban and suburban locations. PLC also needs many repeaters. The PLC network is also unavailable during power failures; during abnormal substation, feeder or phase switching events; or when protective switch gear has opened the power lines, making the communications path unavailable¹¹.

The selection of the technology requires a thorough evaluation and analysis of existing needs and future requirements into a single comprehensive business case. The municipality should aim for the following goals:

- Ensure functional requirements are met
- Low cost of implementation
- Low cost of maintenance
- Adaptable
- Interoperable
- Protocol independent
- Scalable
- Broad industry support

Eskom, in its draft smart metering strategy (2015), has indicated that where PLC is the preferred communication technology between meters and data concentrators, meters and CIU's, meters and appliance control devices, or between any field devices and meters, G3 PLC¹² shall be employed.

The municipality will need to select the best technology to meet its demographic and business needs. Factors that impact the selection of the technology include evaluation of existing infrastructure; impact on legacy equipment, functionality, technical requirements as well as the economic impact to the municipality's customers. However, given that each of these communication platforms holds benefits and disadvantages in terms of system costs, functionality and reliability. It is therefore advisable that the municipality, when implementing its AMI, considers using a blend such as using PLC to communicate from the data collector to the electricity meter and using RF between the electricity meter and other in-home meters or devices.

In areas where other communication technologies like RF, fibre optic cable, GSM etc. are employed Eskom has specified that it will make use of the DLMS/COSEM protocol and the IDIS companion specification will be applied to ensure interoperability and interchangeability.

The table below provides a comparison of the physical communication technologies¹³.

¹¹ Source: http://www.utilityproducts.com/articles/print/volume-7/issue-7/product-focus/amr_ami/licensed-vs_unlicensed.html

¹² G3 PLC is an orthogonal frequency division multiplexing (OFDM) based technology, which is a modulation format used for many of the latest wireless and telecommunications standards. It enables fast and cost-efficient data transfer over existing power lines.

¹³ Source: GreenCape, 2014, *Smart Meters: Technology Review and Role in the Western Cape 2013 – 2014*, Cape Town, South Africa pp 10

Table 1: Comparison of physical communication technologies (GreenCape, 2014)

Parameter	GSM at 900 MHz	LTE at 800 MHz	CDMA at 450 MHz	Fiber Optics	DSL	Power line
Scalability	Competition on resources	Competition on resources	No competition on resources			
Low latency	No	Yes	Yes	Yes	Yes	Narrowband no
Data rates are sufficient	Problematic	Yes	Yes	Yes	Yes	Narrowband no
Enhanced resilience	Not available	Not available	Available	Available	Only limited SLAs	Not available
Indoor penetration/availability	Fair	Fair	Good	Good	Good	Good
System availability	Constrained	Constrained	Yes	Yes	Yes	Constrained
Network and system optimisation for M2M applications	No	No	Yes	No	No	No
Interference with other services (e.g. broadcasting)	No	No	No	No	No	Expected
Cost-effective nationwide coverage available/possible	Yes	Yes	Yes	Very limited	Partially limited	Limited
Installation/rollout	Simple	Simple	Simple	Difficult	Difficult	Simple
Security	Public Grid	Public Grid	Closed Network	Public Grid	Public Grid	Closed Network
Long-term system availability	No	Yes	Yes	Yes	Yes	Yes
Exposure to customer behaviour	No	No	No	Yes	Yes	No
Exposure to developments in the broadband market	No	Yes	No	No	Yes	No

Data Management

Smart meters generate an incredible amount of data when compared to the metering data from conventional meters. Conventional meters are only read once a month and only a total consumption (kWh) reading is recorded. Smart meters on the other hand can be read every five minutes and the full usage profile of the customer can be read. This increased information could be very useful to the municipality, but only if it is properly managed, stored and interpreted.

In implementing a smart metering system the municipality will need a software system called a Meter Data Management system (MDM), which is not part of the municipal traditional metering system but is required to handle the metering data. This software system performs long-term data storage and management for the vast quantities of data delivered by smart metering systems. This data consists primarily of usage data and events that are imported from the head-end¹⁴ servers that manage the data collection in AMI or AMR systems. An MDM system will typically import the data, then validate, cleanse and process it before making it available for billing and analysis.

¹⁴ The AMI Head-End is the back office system that controls the Advanced Metering Infrastructure.

The MDM system should be designed to meet the municipality's core business needs as well as smart meter support. The municipality will have to determine technical and business requirements, including data storage needs before MDM system application selection. Data requirements and the size of customers have an influence on the data system required. In the event that smart meters will be deployed to less than 100,000 customers, the smart meter head-end should be able to handle the data management needs eliminating the need for a more sophisticated MDMS (mainly required for medium and large deployments of smart meters). Where a MDMS is required, it will act as the interface from the smart meter head end to the utility legacy applications to address interface issues and provide the necessary data requirements. The MDM software system will have to be installed and made operational prior to the deployment of smart meters.

It is important for the municipality to decide on who owns the data generated from the smart metering system. It is possible that all technology in an AMI system is proprietary and not open architecture. The suppliers of the AMI system may offer services to read, process and export information to your systems. In such situations there might be a risk that sensitive customer information may be managed by an external source. **If the external source were to part ways with the municipality, the data could be used to the detriment of the municipality. This is an issue that the municipality should look into.**

Smart Meters and Customer Communications

To ensure the success of any smart metering rollout programme the municipality will require proactive and careful communication with its customers. Smart metering technology projects create profound changes to "business as usual" within the municipality; this requires a well skilled municipal workforce that understands how to effectively implement the solutions to ensure maximum engagement with its customers.

If customers do not support the rollout the programme might be forced to stop which may lead to severe unintended consequences. A case in point is the negative customer backlash experienced by Eskom in Soweto when it was implementing a prepaid meter rollout programme. Also important is having political buy-in, within the municipality, into the smart metering programme, before any large scale rollout can be implemented. A rigorous social awareness raising campaign around the programme might be necessary to ensure community empowerment. It is also necessary for municipalities to understand the primary concerns and desires of its members. A municipality should aim to find a conducive environment to engage on face-to-face interactions with communities - a space where people are comfortable e.g. at home or at church.

Communications should inform the customer about the new smart metering system, its benefits, and how this will affect their energy delivery and billing. It is also important to address concerns or issues that may have been raised earlier or in other municipalities, e.g. in Johannesburg and Tshwane, which have taken the lead in rolling out smart meters.

Once deployment begins, customers should be informed before their meter is changed about the procedures and impacts on their specific property. It is important that the municipality address the misconception or concern around thinking that smart meters use a lot of power, which is mainly a result of poor customer education.

Appendix: Questions a Municipality Should Ask Before Procuring a Smart Meter

Extracted from “*20 Questions to ask before you buy a smart meter*” by Jeff Richardson (2014), Senior Product Manager – Electricity Metering, Elster Solutions, USA <http://elsterexecutiveguide.com/wp-content/uploads/2014/06/20-Questions-hires.pdf>

The municipality will have to be careful when choosing meters as not all meters are created equal. They will have to look for the following when comparing the different smart meters in the market:

Safety First

1. Can the smart meter’s service switch be left in an indeterminate state?

Look for a meter with a service switch that cannot be left in an indeterminate state – a system that identifies the status of the switch and a sensor that can report whether a load-side voltage is present. If a customer uses a backup generator during a major power outage and the switch suddenly closes in to the independently energized circuit, the result may be irreparable physical damage.

2. Does it have a surface-mounted load break switch?

Smart meters that come equipped with a surface-mounted button for operating the load break switch may seem like a good idea initially. It’s best, however, if meters don’t have them. Meters are often located in hard to access places and requiring your customers to interact with the meter is unnecessary and potentially unsafe.

3. Do the blades adjust?

Some meters incorporate blades (found at the back of the meter and have to be aligned with the jaws on the socket the meter gets placed in) that are capable of slightly adjusting their alignment. This is a useful, but not always standard feature that makes them better able to make a solid connection with a less-than-perfect socket. Meters that fail to make a strong connection could generate excess heat, which can lead to fires.

4. Are the connections secure?

Secure connections are essential to safe operation over an extended period of time. To check, open the meters and compare the way in which its components are secured, especially the strength of the connections in the primary current path.

Accuracy and Reliability

5. What is the failure rate?

Most smart meters have a failure rate of approximately 0.5%. Some – subject to a more rigorous verification strategy – have surpassed this, achieving a failure rate of 0.3% and in some cases, as low as 0.2%. Though the difference may seem small, it is significant when tens of thousands of meters are installed.

6. Is the resolution precise?

Resolution also varies, from as low as 8 bits to as much as 21. Resolution is important to measurement precision, which is the ability to repeatedly measure accurately. With increased

municipal grid automation (especially self-healing¹⁵), precision is vital to the ongoing health of the electric system.

7. Does it have a supercapacitor?

Some smart meters use batteries to keep time across a power outage. The use of a supercapacitor can either prolong battery life or reduce the need for a battery in a meter. Some smart meter designs don't require a battery. Therefore the municipality should check what its chosen meter uses and why.

8. Does it store data in the meter, not the communication module?

The meter is still the cash register. The meter shouldn't sacrifice any measurement accuracy or precision for the sake of achieving convenience. Choose one that performs all functions and stores all the data in the meter itself, not in the communications module. Meters that conduct these functions internally are more accurate and much easier to audit.

9. Does it identify and report anomalies?

Unfortunately, anomalies sometimes occur in interval data, due to power outages and clock adjustments, for example. Choose a meter that is able to identify and report these anomalies so that the data can be correctly interpreted. Accuracy and billing verification will both be enhanced.

Dependable Performance

10. Is the cover opaque?

Opaque plastic covers or housings significantly reduce thermal gain and internal heating, improving accuracy and extending the life of the meter.

Extended Life Expectancy

11. What are the warranties and return rates?

Meter failure rates tend to follow a "bath-tub" curve – that is, they're highest immediately following deployment and as the end of their normal life expectancy approaches. Ask about a meter's longevity, and for added assurance check the manufacturer's warranty and return rates.

12. What is the technology lifecycle, and is firmware field upgradable?

Choose a meter provider that won't force obsolescence. Technology is changing rapidly, you want a meter that can be readily and remotely modified or upgraded. Look for a vendor whose newer firmware for smart grid metrology¹⁶ and communications is downloadable to current hardware.

13. How many openings does it have in the base (and how small are they)?

Look for a meter that has fewer or smaller openings in the base. Openings can let in water or insects that may cause damage to the meter.

¹⁵ A self-healing grid is a system comprised of sensors, automated controls, and advanced software that utilizes real-time distribution data to detect and isolate faults and to reconfigure the distribution network to minimize the customers impacted (Eaton, 2015). The power system can therefore identify and fix its own problems, without direct human intervention.

http://www.cooperindustries.com/content/public/en/power_systems/solutions/self-healing.html

¹⁶ Smart grid metrology systems are end-use measurement devices (EUMD) that measure and communicate energy usage information to ensure accurate consumption readings and fair billing.

Minimal Environmental Impact

14. Does it snap together and have the recycling symbol?

For minimal environmental impact, choose meters that snap together. They're easier to disassemble and therefore easier to recycle or repurpose.

15. Does the manufacturer use sustainable manufacturing?

By using common components across the product line, some meter manufacturers exhaust surplus materials from one product by employing them in another, different product. Besides reducing waste, this eliminates the need to invest in additional designs and materials thus diminishing the cost of production and the price of the meter.

16. How much energy does it use?

Some manufacturers have also managed to decrease the amount of energy their meters need to function properly. Thus, they've also lowered the meter's internal temperature (improving safety and reliability) by reduced parasitic load (thus also lowering operating costs).

Beyond Traditional Metering

The uses and associated value of smart meters are growing, including applications extending beyond traditional revenue billing. To support these emerging applications, the following features are important.

17. Does it have accurate and flexible voltage monitoring?

Meters must measure voltage accurately and need to be able to detect changes using programmable thresholds with event logging and notification. Voltage profiling stored in the meter's non-volatile memory is also essential for post event analysis.

18. Does it have flexible communications?

Meters need communication flexibility to allow transport of appropriate messages based on the application. They should also offer the ability to be remotely and securely reprogrammed, especially for communications capability and protocols.

19. Does it have robust security?

Meters and metering communications modules must support robust data security capabilities, including encryption as well as segregation of differing types of data traffic. This is increasingly important as distribution applications more tightly converge with traditional revenue metering.

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