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ENABLING SMART ENERGY USE

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Abstract:
This work is focused on a specific segment of devices that facilitate a smart use of energy. Throughout this document a Smart Meters Solutions analysis will be showcased. The aim of this work is to combine and explain key information about the technology being implemented, analysis of the impacts of the use of smart meters in the customer consumption of energy, the key benefits offered by the technology in contrast to its predecessor, the functionalities and customer interface options, as well as to address the security concerns that have arose as a result of the expanding smart metering technology deployment.

Key words:
smart meters,
smart metering,
demand-side programs,
energy efficiency,
customer engagement.

INTRODUCTION

Energy and its sustainable use has become the top priority for both developing and developed countries. With the upcoming growth of both population and energy consumption, being able to be more efficient and effective with the allocation of this resource is a challenge that the world and its leaders are embracing. Although of the efforts the impacts of an unbalanced use of natural resources have led the world to a critical situation where the environment and the society are under an unhealthy and dangerous burden. The development of technologies and the engagement of energy users towards a more conscious use of the energy they consume is critical, as well as, the development of the market to allow this innovative solutions to be both reliable and affordable to ensure that their potential is achieved and their expected benefits delivered.

SMART METERS AND SMART METER SYSTEMS

Understanding the role of smart metering and how these systems bring value to the consumer by supporting the sustainable development of the market is a critical step to overcome uncertainty regarding their accuracy and safety. This initial overview compiles different key concepts and characteristics, necessary to understand the state of play in the knowledge regarding smart meters and their role in the industry.

Key conseptand definitions

The concept of smart meter can be defined in general terms as [1] electronic measurements devices, installed by the utilities at the consumer facilities to allow communication of the consumption of energy (gas, electricity, water). These devices have been used by utilities to deliver accurate billing

information, for a part of their customers. A first the devices were mainly used by industrial consumers given the higher consumption and the need of specific consumption data, to allow the right and best quality service to be delivered, and also to provide specific and detailed billing data. The evolution of the market and consumer needs facilitated a decreased price on the technology, and increased need of information by all consumers, leading to the migration of these systems from the industrial sector to all customer classes. From the consumer side smart meters can be defined as [2] communication and control systems, which have the ability to directly empower the consumers to understand, control, produce and earn from energy. Through this definition the consumer becomes an equal partner in the energy value chain. A broad view of smart metering, published by the European Commission [3] states that an intelligent metering system or "smart meter" consists of an electronic device used to measure the consumption of energy, delivering more information than a conventional meter, and that can transmit data

through a communication network. In this perspective, the key feature of a smart meter is the possibility of bidirectional communication between the consumer and the supplier/operator; the system should also promote the dissemination of services that improve energy efficiency within the home. On a market perspective, shifting from old and static meters to smart active devices is a matter of increased importance for competition in energy markets.

A considerable array of definitions for what smart meter and smart metering is, are available in the literature and in industry reports. From the definitions stated above [1],[2], [3] it is possible to build a comparison table to highlight different focus of different authors (Table 1.)

Smart meter definition comparison			
Author	(Obenchain *et al*, 2011)	(SEDC, 2012)	(Martin, 2011)
Key concept	Electronic devices, providing billing information to allow better management by the companies and utilities.	Electronic devices, that allows consumers to manage and benefit from a better control of their energy expenditure.	Intelligent meters, that provide more and better information, allowing energy efficiency to be improved, while increasing competitiveness of the energy market.
Focus on	Utility benefits from smart meters, and management of resources	Consumer benefits from smart meter, as well as, utilities.	Consumer, utilities and the market benefit from the roll-out of smart meter technologies.

Table 1. Smart meter definition comparison

The general structure of the smart meter (Figure 1.) consists on a hardware combination of the meter and the platforms needed to gather the information, and the necessary software and communication layer that transmits, processes and enables the system to communicate consumption data for accurate billing, controlling and monitoring purposes.

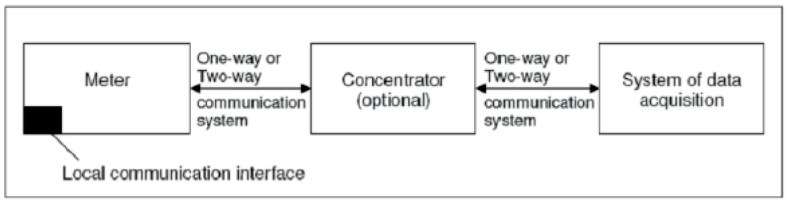

Figure 1. The general structure of a smart meter

The general system architecture as demonstrated in Figure 1.1 represents the possibility of "one-way" or "two-way" communications between the different layers of the structure. The evolution of the systems technology from "one-way" communications to "two-way" communications is linked with the shifting from the Advanced Meter Reading (AMR) systems (one-way communication) to the Advanced Metering Infrastructure, AMI, (two-way communication). The main differences between these two systems, AMI and AMR, are [1]:

AMI: Consists on the combination of the electronic meters with two way communication technology, for information, monitoring and controlling energy use;

AMR: Utilized one-way communications to collect meter data only.

The evolution of the communication system and its impacts on the smart meters capabilities are represented on the diagram below (Figure 2.), including the evolution of functionalities and the stakeholder benefits as a result of these evolutions.

Smart meters represent the new generation of meters, with the ability to replace existing electro-mechanical meters while offering a range of benefits for both the individual consumer and the energy system in general.

BENEFITS AND SYSTEM CHARA CTERISTICS

A smart meter is able to provide more information regarding consumption profile of users, it records customers' actual use of electricity/gas over short intervals of time, which are defined by the utility (e.g. in Portugal, EDP has informationavailable on consumption for clients with smart meters, every 15 minutes, through their website). These meters are connected by a communications system to a network company (or meter data collector). This entity provides the operator with the

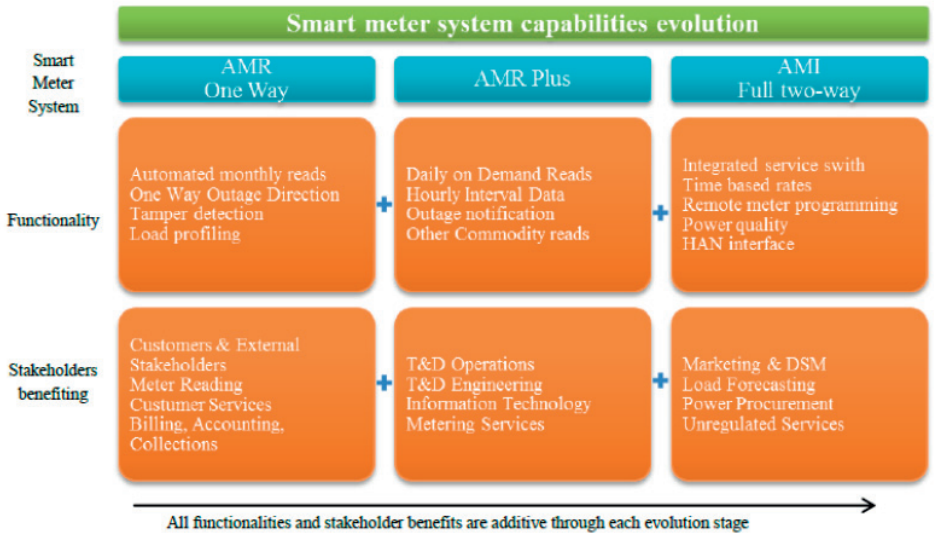

Figure 2. Smart meter system capabilities evolution, adapted from [1].

necessary, up-to-date information on the amount of resources used by its clients. By being able to access this detailed information on consumption, the opportunities to reduce network operations costs arise, including reduced costs as a result of not visiting costumer facilities to carry out the manual meter readings needed for calculation of billable consumptions.

The collection of the data from the smart meters by the network operator/utility, allows also [3] to deliver useful information on consumption profile, and in the case of electricity suppliers it has the ability to support the development of innovative pricing arrangements that can be used as drivers to ensure an efficient use of resources by the customers. Smart metering development also provides more safety to the system as it reduces the amount of technical losses and theft. A possible pricing structure enabled by smart meters is: Time-of-use electricity tariff, (it consists on the case where the price of electricity varies at different times of the day), reflecting the changes in the cost of producing electricity according to demand.

The benefits enabled through smart metering development, synthesized in Table 2., can be divided regarding the benefits delivered to varied stakeholder groups, [1]:

Stakeholder	| Beuefits
Utility customers	Better access aud data to maiiage energy use More accurate and tunely billmg Improved aud mcreased late optons Improved outage restoration Power qnality data
Customer service & field operatious	Reduced cost of Metering readnig Reduced inps for offcycle reads Eliuiinates handlield metei reading equipment Reduced call center transactions Reduced collections and connectidisconnects
Reveaue cycle seraces - Billuig, Accoinitmg, Revenue protection	Reduced bact office rebilling Early detection of nieter tainpering and theft Reduced estunated billing and billmg eirors
Traiisniission and Distribution	Improved transformer load management Improved capacitor bank switchiiig Data for improved efficiency, rchability of service, losses, and loadmg Improved data for ef&cient giid system design Power qnaht)' data for tlie service areas Maiketing & Load Forecastiug
Marketinp & Load forecasting	Reduced costs for collecting load research data
Utility general	Reduced regulatory coniplaints Improved customer premise safety & lisk profile Reduced employee safety mcideuts
Exteraal stakeliolders	Improved enviroiunental benefits Support for the Smart Gnd mitiativcs

Smart meters can facilitate the development of energy efficiency potential by empowering customers with more detailed, accurate and timely information regarding their energy consumption and costs. This will actively contribute to reduce unnecessary, inefficient consumption and to shift flexible load away from peak-time in consumption. Further positive impacts of smart metering would be [4] the ability to facilitate the adoption and feed-in of microgeneration, as well as the societal benefits of increased energy efficiency and reduced greenhouse gas emissions. In order to deliver the benefits presented a framework of, operation besides the meters, themselves has to be implemented [5]. The following four key elements have then to be considered: (1) the access and backhaul; (2) the meter data management system; (3) the tariff management system and (4) the asset management system. These elements are represented below (Figure 3.):

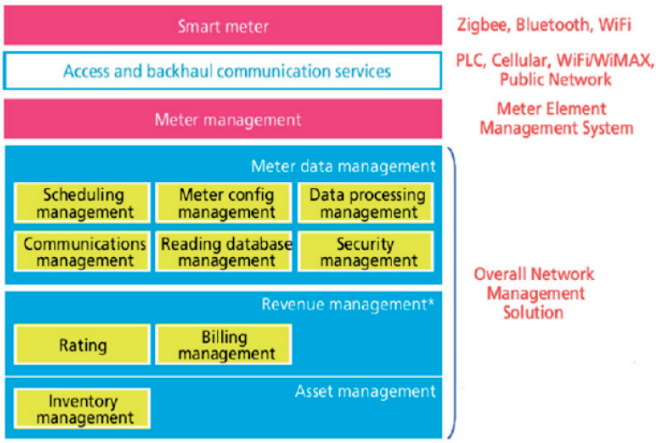

Figure 3. The elements of smart metering implementation [5]

Considering the elements necessary for a fully work smart metering infrastructure (Figure 1.3), the following aspects represent key information on the expected system operation:

- The access and backhaul solution is not universal, since the implementation is dependent on a number of factors (i.e. population density, existing communication infrastructures), and often there is a mix of solutions (e.g. wireless in urban areas, with power line communications in rural areas). In some cases the available technology will allow only one-way communication, but in most scenarios two-way communication is possible, which represent the necessary requirements to enable the utility company not only to measure consumption, but also to actively influence/control it.
- The meter data management system is at the core of the smart metering operating framework. This layer of the smart metering infrastructure undertakes: (1) management and collection of metering data, (2) data organization according to pre-determined criteria, (3) ensuring the consistency and integrity of the data received and ensuring its security, (4) management of customer profiles (i.e. the status of the customer, the meter rating), and (5) management and configuration of the meter itself.
- The tarff management system is also at the core of

the system as it allows the charging flexibility required to mobilize customers toward a more efficient behavior on consumption.

- The final but vital element is the asset management system that allows the operator to keep track of all the different assets encompassed in the wide range of operations that enable the smart metering network to operate.

Technical characteristics among smart meter systems are varied [1] regarding technology and design, but operate through a simple overall process (Figure 4.).

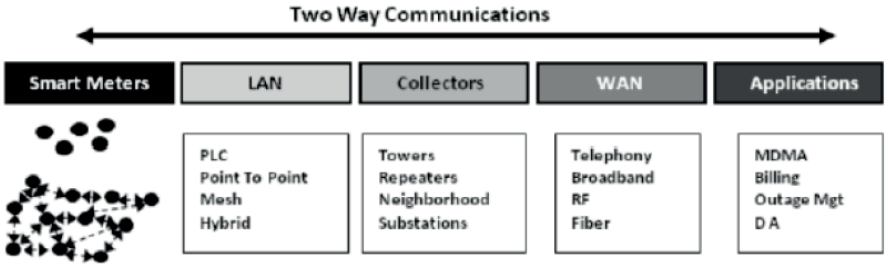

Figure 4. Smart meter systems basic architecture [1]

The smart meter architecture (Figure 1.4) allows the smart meter to collect the data locally at consumer facilities and transmits it via the Local Area Network (LAN) directing it to a data collector. The transmission time range can be defined, as needed, according to the characteristics of the required data. Once the collector receives the information, it retrieves the data via the Wide Area Network (WAN) to the utility data center to be complied on the internal controlling and billing platforms. Since the communication system is built to allow two-way communications, signals and commands can be exchanged from costumer to energy distribution center or vice-versa.

SMARTMETERSASINTERACTIVE DEVICES

Smart meters have the possibility, as defines by [6], to make energy visible, by presenting real-time data to the costumer on their consumption, aiming to a better, more efficient use of available resources. Among the smart meters with interactive capabilities, three different groups can be differentiated [7] Joshnson2010, as stated below (Table 3.):

Interactive smart meter types	
Group 1	Smart meters in this category provide real time display of the energy consumption in the household, as well as, estimate the rough cost of the energy consumed.
Group 2	On this group the features from Group 1 meters are included, with the evolution that these devices monitor energy consumption and alert the user when significant changes occur. It also to set up alerts for when different constraints have been reached or breached.
Group 3	This group of smart meters is the most advanced and encompasses the characteristics of the previous, plus gives the user the possibility to control appliances from anywhere within the house, while providing detailed energy consumption analysis.

Table 3. Interactive smart meter types, adapted from [7]

The interaction with the costumer can happen through different platforms, thus providing different information, the most common ways are: (1) in-home displays (IHD), (2) web- portals.

IHD platforms allow near real-time energy consumption information, driving control to the consumer on his consumption [8]. These displays are often ready to supply electricity and gas consumption and a reasonable level of detail on the information collected [6].

Web portals make usage of the information available from the customers' electricity distributor or retailer [8]. These platforms do not allow a dynamic interaction (the data is often only available the next day after consumption) but provide a solid tool to understand consumption profiles and any unexpected consumption, in abnormal periods of the day.

SMARTMETER ACCURACY & SECURITY

The deployment of smart meter systems has generated concerns, as any change from the "standard" requires new solutions and analysis for new problems. In the case of smart meter systems, there have been raising concerns regarding three main problems [1]: (1) meter accuracy, (2) Radio Frequency (RF) exposure and (3) smart meter security.

1. Smart meter accuracy issues have been surpassed with tests and studies being conducted in the areas with accuracy concerns. In Texas, where concerns arose among the consumers, testing was carried out to understand if smart meters had problems, and concluded that:
   - Smart meters were more stable, with tighter accuracy control then the mechanical counterparts;
   - There was no statistically significant difference in electricity usage that could be attributed to the installation of smart meters.

   The steps to develop this equipment with the necessary accuracy have been taken, as with the previous mechanical meters. The new metering technology has been proven to be more effective and accurate than previous ones, apart from all the benefits of the smart meter value chain that contribute to a more stable and secure energy system. Smart meters provide a better billing and controlling solution than the previous technologies used.
2. The main RF exposure concerns are related to the possible negative health impacts. Reference [9] presents the results of a study carried by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) stating that the overall RF exposure from smart meters is very low and well below exposure limits, even when a number of devices are communicating simultaneously. As part of the study a comparison between the exposure to different devices and the smart meter was conducted.

   The study (Figure 5.) revealed that the radiofrequency of smart meters was among the lowest in the group of

household appliances testes, which are the most common in every house, while smart meters radiation ranked well below other frequently used items, such as, mobile phone, baby monitors and microwave ovens.

Apart from the low radiofrequency power density verified for smart meters, other factors, [1] such as, the location, distance from the transmitter, shielding of the meter, attenuation of building materials and direction of RF emissions, reducer even more the exposure caused to customers.

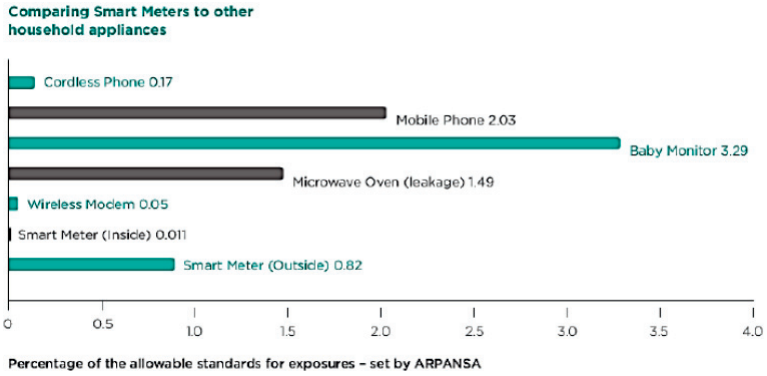

Figure 5. Comparison of radiofrequency (RF) power density from Smart Meters with other household appliances [8]

3. Smart meter security, i.e. the protection of the integrity of the data collected by the meters is essential as it contains detailed information on costumers' consumption necessary for a correct billing. Since the inception of these metering systems the industry has been developing robust security provisions to protect the security of the equipment and the data transmitted. The proliferation of internet use, and the various severe cases of network hacking have contributed to the raising concerns around the globe about the integrity and security of the smart grid.

Concerns regarding meters privacy issues appear around the globe, in Australia an investigation on the security issue of smart meters was conducted [10], Lockstep Consulting investigation report presented that:

- Privacy controls are strong and metering data is suitably protected;
- The security of smart meters is properly designed - all wireless connections are adequately encrypted with no possibility to be disabled, and the governance practices protecting consumer data are strong;
- The industry is adopting good security standards for information;

The state of security and integrity of the customer meters has been and continues to be one of the major concerns, as the networks security systems and possibilities available continue to evolve, the industry will continue to invest in securing the integrity of the information, and the stability of the smart metering system.

Ensuring the risks associated with the deployment and dissemination of smart metering technologies and procedures, is and will continue to be essential. Developing technologies but also information and communication processes will play a key role in diminishing the concerns regarding the technology implementation and its impacts on consumers, the environment and the utilities/retailers revenue streams. Strengthening the efforts in security and disseminating the information on the quality and benefits of smart metering has to be in the agenda of policy makers and key industry players, in order to develop a competitive market, where sustainability and growth are the foundations of every operation.

SMARTMETERS ENABLING ENERGYEFFICIENCY

Smart meters deployments, throughout the world present that is essential to keep the customer interest as a priority, ensuring that smart metering enables consumer benefits, as part of an overarching strategy of increased social well-being and improved energy efficiency [2]. Although without programs that enable the dynamic smart metering architecture to operate, these devices and their integrated system cannot deliver their potential benefits.

Market driving forces presented can be framed in the scope of the potential inherent in smart metering development. Regarding each driving force it is possible to highlight the following:

1. Educating the consumer: Pressure on the utilities for raising the awareness of their consumers has been increasing, with the main goal to enable more efficient behaviors. The education process can take two forms, both of which benefit from the information provided by smart metering systems:
   - Real-time display demonstrating the consumption profile over time, or
   - Detailed information on consumption and environmental impacts

   The goal of educating consumer is aimed at influencing their consumption to reduce peaks in energy use, although this has only been effective where the consumer is already interested in the information made available.
2. Motivating the consumer: By delivering innovative pricing structures that drive new behaviors on the consumers to adapt their energy consumption. One possible scenario [5], by moving to multiple time-of-day tariff that fit the consumer needs and consumption profile. Two examples of time-of-use tariffs are presented by ALACTEL Lucent [5], for a summer weekday (Figure 6.) and for a winter weekday

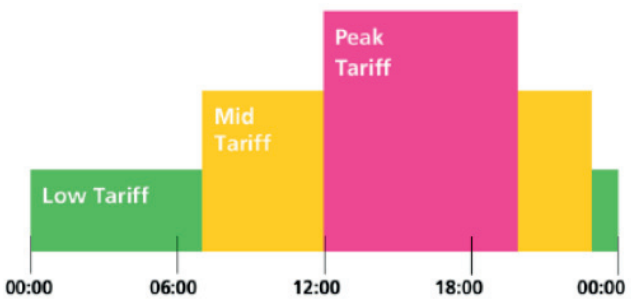

Figure 6. Possible time-of-use tariff for a summer weekday [5]

Another possible situation to motivate the consumers, is to define tariffs by instantaneous demand, (Figure 7.) represented a possible tariff for a home. The curve in the graph represents the demand made by a home throughout the day, a morning peak when the household is using more appliances to get ready for the day and leave the house, and an evening peak when the household returns home for evening activities.

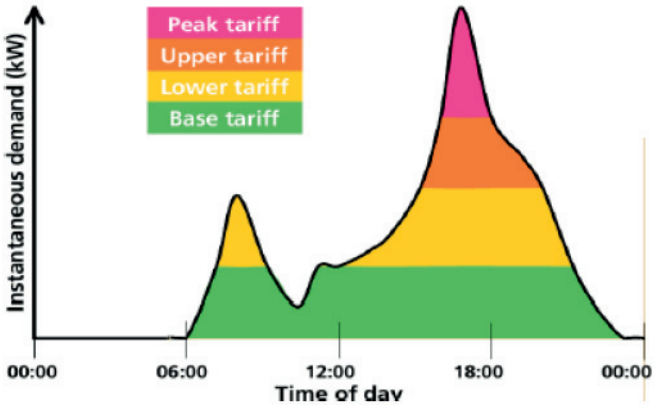

Figure 7. Possible dynamic tariff for a house [5]

SUMMARY

Smart metering is a way to reduce energy consumption, which is otherwise projected to keep growing across the Europe over the next two decades. Smart meters have the proven ability to enable significant changes to the current scenario regarding energy consumption. Their purpose is to improve efficiency, not just at the household level, but utility-wide. For energy providers, smart meters promise to slash uncertainties in electricity consumption data and billing, eliminate the cost of manual meter readings and alert utilities to problems and outages more quickly and effectively.

The development of smart metering and the evolution on has the potential to change the energy industry and the interactions between consumers and distributors of electricity. Providing more and better quality information, these devices set the basis for realistic demand side programs and initiatives, focused on reducing unnecessary consumption, and shifting flexible load outside of peak hours. Reducing the peaks on demand will be possible through dynamic pricing, feedback and strong consumer engagement.

Uncertainties regarding the accuracy, safety and security of the system are considerable but also expected in terms of a technology that is coming to replace an older device, widely known and trusted. Smart meters have shown more accuracy and safety than its predecessor and their application has lower impacts on health than the most everyday household appliances.

Smart energy systems deployment will positively impact safety and the overall service quality achieved, whilst providing distributors and network operator with essential information to enable demand side initiatives and programs to be implemented with success. Realizing the potential benefits linked to smart meter systems and their dissemination will depend on the success of consumer engagement initiatives and how the available information is organized and used to create more value for the energy market, for the society and for the environment.

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