Economic opportunities of AMI implementation: A review

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Abstract

Advanced Metering Infrastructure (AMI) is rapidly becoming a key element for the modernization and disruption of power grids, generating benefits and opportunities to all actors involved in its implementation. In order to guarantee a correct deployment of AMI, a wide knowledge of its advantages and challenges is needed, that takes into account previous experiences and latest advances that have been made in the field. In this paper, a review of literature is used as a mean to collect the relevant information concerning AMI, so as to conclude which are the opportunities that AMI provides to all parties involved. This is achieved by searching in the most important data bases and specialized sources such as IEEE and IEA. It was found that this infrastructure, does indeed help improve efficiency and leads to positive economic effects impacting variables like costs and prices.

1. Introduction

The world is facing a boom in the use of technological devices and systems, people are using them in their daily life, and in their productive and industrial activities. Therefore, it has become essential to rethink the way traditional markets are structured, to avoid the current outlook of high contamination and pollution. Since the begging of this century, energy markets have been changing rapidly, leaning towards a transition from conventional energies such as coal and fossil, to renewables like solar and wind sources. The integration of these energies requires a system that is effective given their great dependence on environmental conditions, which causes fluctuations and prevent an absolute balance between electricity's supply and demand.

Electricity market has maintained a constant evolution since its creation, it has continued to look for efficiency and improvement of its processes, and grids, so that fewer losses occur and more profits are obtained (International Energy Agency, 2018). The continuous increase in the global electricity consumption levels, has caused that the agents unceasingly look for different ways to attend the demand levels and find energy sources that are more environmentally friendly, that's why non-conventional and renewable energy sources (RES) are playing a key role in this market, as they are responsible of the generation of 13 % of the total amount of the energy produced worldwide, and they are a viable substitute of more polluted energy sources like coal and oil (WWF, ECOFYS, & OMA, 2011).

Decreasing costs are one of the main characteristics of electricity markets, therefore the companies in this industry tend to have naturally highly concentrated market structures, which count with the approval of governments, who recognize the difficulty to guarantee high infrastructure investments if there aren't enough incentives to make it profitable (Pindyck & Rubinfeld, 2013). Furthermore, these high costs are also assumed by consumers who don't have significant market power when it comes to choosing their service provider (Garcia-rendon, Gómez, Ceballos, & Tobón, 2018).

A new infrastructure has been leading the way in electricity markets to meet the efficiency requirements and to reach more environmentally friendly systems; Advanced Metering Infrastructure (AMI), is compounded of several elements, like Smart Meters (SM), communication networks, and data management systems, all of which constitute a network that allows direct communication between service providers and consumers. The core element of this system are SMs, they are in charge of calculating user's electricity consumption for intervals of 5, 10, 15 or 60 minutes. They measure the voltage and monitor the on/off status of electrical services, SM should communicate through the network with the parts in charge of the distribution of electricity so that they process, analyze, and give feedback to consumers in matters concerning them, like billing and consumption behavior (Department of Energy, 2016).

Nowadays, consumers feel the need to make rational decisions based on information available, and thus they are demanding better quality facts. In response to those necessities, the new technologies are playing an important role in creating new ways to fulfill consumers' requirements. The adoption of AMI, allows a real-time visualization of the changes in agents' consumption, and the verification of contractual compliance, facilitating the generation of more accurate information that can lead to a wider knowledge of consumption patterns, and a supply that more precisely responds to final agents' needs, creating, as a consequence, a decrease in asymmetric information (Garcia-rendon et al., 2018). Therefore, allowing consumers to have greater decision making power and thus, a better capability to make rational decisions that come closer to their optimal combination of factors (Department of Energy, 2016).

The main purpose of this work is to analyze the economic effects that the implementation of Advanced Metering Infrastructure brings to the markets where this kind of systems were already introduced, in order to set a guideline that presents opportunities and lessons learnt looking to motivate its implementation. Keeping in mind the different parties and institutions who have a role in its management and development.

This work seeks to find which are the effects that the implementation of AMI has on variables like prices, costs, asymmetrical information, and efficiency in the electricity retail market. This, in order to encounter the replicable points, and which processes and experiences should be modified with the purpose of guaranteeing a correct and effective deployment. It will be achieved by executing a literature review, that focuses on the experiences of the markets previously mentioned where AMI has already been implemented. First an extensive search of the relevant literature was performed, to later find the common points and categorize the papers, to finally encounter how AMI helps improve efficiency and reduce electricity losses.

This work is relevant because it provides a framework of tools that give an outlook of the tendencies and the state of the art of the approaches to Advanced Metering Infrastructure. It collects high-quality information taken from valuable journals and specialized authorities, in order to create a complete and compact document that facilitates the readers' understanding of why the implementation of such infrastructure is important. Although this topic has been in the scientific scope for the last decade, it has remained relevant and it has gained momentum because of the current juncture and the increased concerning to protect the resources and improve efficiency (as studies have proven that it has the highest impact on CO^2 emissions reduction) (Tajudeen, Wossink, & Banerjee, 2018), and therefore this research could serve as a reference for emerging economies that are looking to adopt these technologies.

The remainder of this paper is organized as follows. Section 2 presents the main concepts found in the literature. Section 3 introduces the methodology used in this work to achieve the objectives set. Section 4 describes the main results, classified in three main categories, which are, information management, privacy and regulation, and implementation of AMI. Section 5 gathers the most important remarks and the opportunities of implementing AMI observed throughout this review. Section 6 presents the challenges that need to be consider. Finally, section 7 concludes the study.

2. Main concepts

Smart Grids are leading the way in electricity markets, as they are crucial for the transition to cleaner energy production. They are defined as a modernized network which put together information technologies, advanced communication, and computational systems in order to create an improved grid that allows a more optimal distribution and management of electricity, along with a minimization of power losses and a better interconnection and communication between generators (Benmalek, Challal, Derhab, & Bouabdallah, 2018; Ponce-Jara et al., 2017). Because of its characteristics and properties, AMI has become the core element of the Smart Grids system and a key factor to be considered before the implementation of such technologies (Mohassel, Fung, Mohammadi, & Raahemifar, 2014).

2.1 AMI definitions and environment.

In the literature Advanced Metering Infrastructure (AMI) is defined as an infrastructure system that combines different technologies which are responsible of collecting customers electricity consumption's data and transmitting it to the service providers in order to analyze and monitor the information and use it for billing accuracy, (Benmalek et al., 2018; Luhua & Zhonglin, 2010). It is used also, for implementing actions that are intended to empower consumers and help suppliers, presenting them with real-time information that can be used as a tool for a better understanding and adjustment to demand patterns and behaviors, and thus a more efficient electricity market (Benedikt, Reichhart, Kranz, & Picot, 2012).

As mentioned before AMI clusters several elements, which are; Smart Meters (SM), network communication divided into, Home Area Network (HAN), Neighbor Area Network (NAN) and Wide Area and Communication Networks (WAN), and finally Meter Data Management Systems (MDMS) (Mohassel et al., 2014; Ye, Qian, & Hu, 2015). The first one required for an AMI roll-out, are Smart Meters that are in charge of collecting consumers data and transmitting it through the communication networks, their role is to support the two-way channel interaction between consumers and utilities.

Furthermore the network communication, combines by the following components, HAN that communicates appliances inside the house, NAN which is in charge of communicating houses close to each other and the outdoors, while WAN integrates devices in broader areas including NAN (Avancini et al., 2019). Finally, MDMS, receive, manage and analyze the information in order to guarantee optimal performance of the market by providing the different stakeholders with the input that allows them to implement strategies such as demand response, billing, manager of loads and price signals (Benmalek et al., 2018).

Smart Meters are the key component in the AMI system, they collect and provide real-time information of customer’s consumption behaviors to both consumers and utilities, and the logs/events of the system. In contrast with traditional meters that only signal the current consumption and have little or null communication amongst the parties concerned. Most importantly SM offer detailed and categorized consumption information in specific time interludes, allowing parts to adjust their behaviors according to their interests and preferences (Hoenkamp, Huitema, & Vugt, 2011). It serves to detect network failures, energy theft and abnormal behavior, losses minimization, as well as allowing remote command, load quality monitoring and communication with other intelligent devices and to make energy forecasting (Do

Amarai, De Souza, Gastaldello, Fernandes, & Vale, 2014; Lighari & Akbar Hussain, 2017; Mohassel et al., 2014).

Subsequently, Area Communication Networks, enhance the complex task of transmitting high volume of information from the meters to the management centrals, and therefore compound various communication technologies such as Power Line Carrier (PLC), cellular and wireless networks, IP based and optical fiber as well as Peer-to-Peer and Satellite communications, such mediums constitute the slope of options from which the service providers select the ones that consider factors such as the transmission of big amounts of data, information veracity, privacy and accuracy, with the sole purpose of maintaining cost efficiency (Mohassel et al., 2014). Data concentrators is the commonly used architecture for the collection of data produced by a group of smart meters, due to its lower costs and optimization of information gathering (Bago & Campos, 2015).

The last piece of the puzzle is the Meter Data Management Systems that constitutes the operation center for information in the AMI ecosystem, it collects, processes, and analyzes data and transforms it into valuable commands, like price signals, load and demand management and billing differentiation. MDMS focuses on achieving the following points, guaranteeing optimal performance and maintenance of the grid, improvement of the utility management, and the execution of consumers programs like demand response and customer service. The data center infrastructure must count with servers and hardware's, storage, data base and visualization systems in order to meet the expectations of parties concerned (Benmalek et al., 2018; Mohassel et al., 2014). In this final step Big Data and Analytics play a key role in guaranteeing an optimal processing, so that the huge amount of data provided by SM, becomes real knowledge and gives insights to all parties involved (Wilcox, Jin, Flach, & Thumim, 2019).

2.2 Demand response.

In order to achieve energy efficiency in a SG, the implementation of AMI is not enough, it is also a requirement that a set of activities and tools are implemented to the demand-side of the market, which allows a meeting between supply and demand, especially with the high volatility of energy prices and the increasing utilization of Renewable Energy Sources (RES), that hinders the stabilization of the grid (Fusco, Venayagamoorthy, Member, Piazza, & Member, 2016). This is commonly known as Demand Side Management (DMS) which offers different approaches to accomplish a change in the consumer's behavior and demand, so it can equal energy generation at any period of time, one of its key actions are Demand Response Programs (Vardakas, Zorba, Verikoukis, & Member, 2015).

DR is defined by the US Department of Energy as:

> Changes in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high

> wholesale market prices or when system reliability is jeopardized (as cited in Cappers, Goldman, & Kathan, 2010, p. 1526).

Demand response can be executed as long as a technological system as AMI that enables its physical implementation exist (Paterakis, Erdinç, & Catalão, 2017). According to Vardakas et al.(2015), DR's main objectives are to decrease electricity's cost, reduce the total power consumption and generation demanded, eliminate the overloads and losses in the distribution system, make modifications on the demand-side to diminish the peak energy demand so it encounters the available supply, and consequently, improve efficiency and augment the reliability in the electrical system.

There are different classifications of DR, it can be categorized by its control mechanism, by the kind of motivation given to the customer, and by the way the variable of decision is made. In the first category, there are two methods for controlling the program, centralized, in which there is direct and independent communication between the power provider and the end-customer, and distributed, characterized by collecting the information of various users (Vardakas et al., 2015).

Secondly, demand response can motivate consumers by offering them varying prices depending on their current electricity cost and consumption, this is known as price-based DR (Alasseri, Rao, & Sreekanth, 2018), on the other side, incentive-based DR, promises payments that are fixed or that can change through time (Vardakas et al., 2015)

Lastly, consumers can choose when to activate the use of loads, this is known as Task Scheduling DR Methods, or they can opt to reduce the load of specific devices to achieve the demand's energy goal, also, consumers can authorize utilities to directly control the load of a device like a thermostat given some previously stablished conditions, this is called Energy-Management-Based DR Methods (Cardenas, Amin, Schwartz, Dong, & Sastry, 2012; Vardakas et al., 2015)

2.3 Efficiency, prices and asymmetry of information.

Furthermore, AMI helps improve the communication between utilities and customers, through information technologies allowing the first ones to encourage consumers to manage their energy load and change their consumption patterns and habits (Albani & Winter, 2017; Luhua & Zhonglin, 2010), this will guarantee that parties will have a better idea of how consumers behave and thus, adjust their supply and demand accordingly, improving energy efficiency by generating a more accurate amount of electricity to meet the demand (Morrissey, Plater, & Dean, 2018).

Along with the integration of renewable energies in the generation system, and with the improvement of distributed generation, it has become a necessity to implement other pricing schemes for electricity market that enhance social benefits for consumers and utilities, thus, aligning more efficiently the resources through price-cost signals(Nieto, 2016). The existing energy tariffs does not indicate the temporal changes in electricity's cost (Faruqui, Hledik, & Tsoukalis, 2009), that's why the implemented pricing rates need to disincentivize the demand of energy at critical energy peaks, when its generation cost its very high and the stability of the grid is compromised, leading to high energy prices (Lanahan et al., 2019). The literature contemplates several pricing strategies such as Time-Of-Use (TOU) pricing, Real-Time Pricing (RTP), and Critical Peak Pricing (CPP) (Vardakas et al., 2015).

Finally, concerning asymmetry of information, some authors affirm that:

> Data privacy leads to incomplete information of agents on their peers' behavior, which in turn, contributes to uncertainty in their decision models. In other words, an agent-based framework in combination with machine learning techniques corresponds to the natural state of decentralized and distributed decision- making structure of the interoperable retail energy markets (Dehghanpour, Hashem Nehrir, Sheppard, & Kelly, 2018).

Meaning that the access to these new technologies could help decrease the uncertainty that agents face due to lack of information, and also, availability of real hourly consumption data can indeed improve the billing process (Repo, Pylvanainen, Kauppinen, Repo, & Jarventausta, 2018). However it is crucial that consumers and utilities perceive the value of this technology so that they become interested in adopting it (Kaufmann, Künzel, & Loock, 2013).

3. Methodology

As this is a review of the literature, this work only considers indexed academic publications and articles, conference proceedings, and technical documents published by official institutions and authorities in the matter.

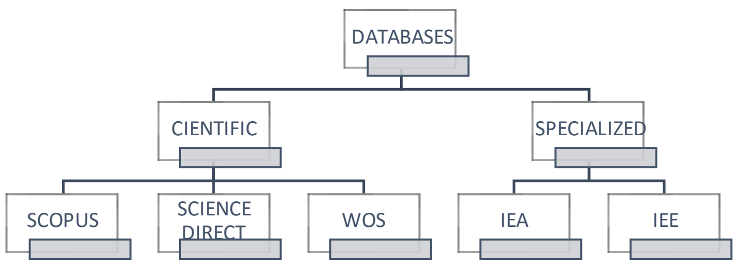
In order to find to find relevant information, various combinations of the following keywords were used, by taking advantage of the Boolean "AND", always maintaining the words AMI, smart meters or energy, as a parameter for the search. The keywords were: Energy, retail, prices, efficiency, cases, distributed generation, privacy, and demand response.

In that process it was found that there is vast literature that approaches the new systems created for the electricity markets, especially referring to smart meters, demand response programs, energy storage, and data architecture as well as the concerned regulation, legislation, and privacy issues.

This literature was obtained from three of the most important scientific databases, Web of Science (WOS), Scopus and Science Direct, in addition, two more sources were considered, IEEE and International Energy Agency (IEA), because of their specialized knowledge of the subject in question. However, a large amount of the literature found on the mentioned data bases, came from the specialized sources already mentioned.

Papers were considered if they were published after 2000, this decision was made because relevant papers from those years were found, that provided the basis of the implementation of such infrastructure. When the first research was made, there were a lot of results, so two criteria were employed to narrow their amount considering the ones that had an important number of citations, even though they weren't from recent years, and those who are at the forefront of the subject whether they are highly cited or not. As it can be observed in the Figure 2, the majority of the papers obtained are from the last five years, which denotes the relevance of this topic in the advancement of science.

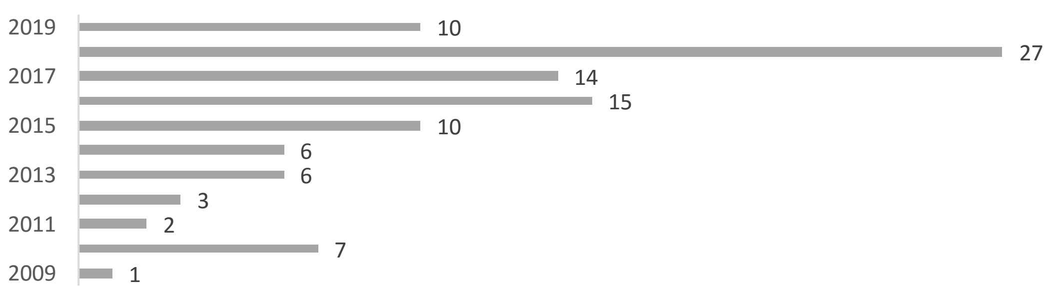
Figure 1: Databases used for the review of the literature.



Source: Own elaboration

A high proportion of the found literature was too focused on the engineering approach of this subject, that's why a second depuration was made by reading the abstract, introduction and conclusions in order to use only the ones that could in fact be useful for the research. As it is shown in Table 1, the information was obtained from a wide variety of journals that are constantly contributing to the research on this topic, and they are relevant as it is proven by the number of citations observed.

Figure 2: Classification of papers by year



Source: Own elaboration

After having collected the data, the next step was to classify the literature by categories in order to homogenize the concepts and information in common sections to facilitate the development of this research. The information was classified into three main categories that encompass the spectrum of the topic, they are: Information management, privacy and regulation, and implementation, these are at the same time, divided into subcategories according to the width of the topics.

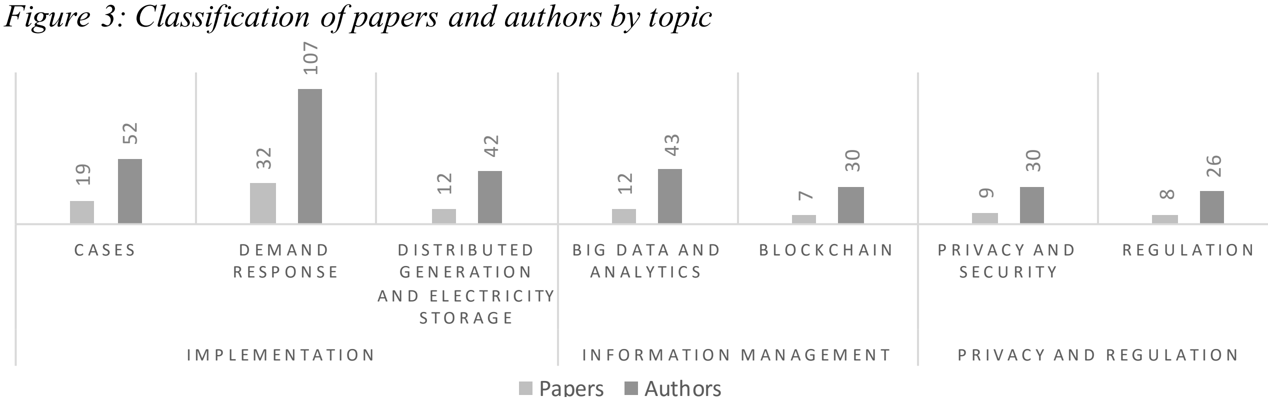
Table 1: Most cited journals in this paper and number of citations

Most used journals	**Papers used by journals**	**N° of citations**
IEEE Transactions on Smart Grid	8	771
Renewable and Sustainable Energy Reviews	8	156
Energy Policy	5	164
Applied Energy	4	91
Energy	4	292
Energy Economics	4	24
The Electricity Journal	3	76
Energy Procedia	3	9
IEEE Journal on Selected Areas in Communications	2	73
Journal of Cleaner Production	2	7
Electricity Journal	2	3
Electrical Power and Energy Systems	2	0
Energy Strategy Reviews	2	12

Source: Own elaboration

The first category contains the information regarding to big-data, and analytics, asymmetry of information and data management technologies, the second one deals with issues related to regulation, legislation and security of information, whilst the last category contains subcategories like implementation of demand response programs and distributed generation, energy storage devices, consumers behavior, willingness to pay, billing and pricing matters, and countries' experiences with AMI. For the latter category, a wider amount of papers was found, this happens because its amplitude and importance.

Figure 3: Classification of papers and authors by topic



Source: Own elaboration

4. Results

4.1 Information Management.

Given the increasing importance of RES, and the growing need to integrate systems that work more efficiently, and autonomously, various technologies have emerged intending to facilitate transactions, and the processing of high amounts of information produced by the electric market, and simultaneously guaranteeing that the information is kept secure, transparent and protected. Among these technologies the most significant are Blockchain, Big Data, Artificial Intelligence (AI), and Internet of things (IOT) (Imbault, Swiatek, De Beaufort, & Plana, 2017).

4.1.1 Blockchain.

Blockchain is a shared data structure that allows users to record information (records, events, transactions) without an intermediary (computers communicate with each other instead of with a centrally managed server, which increases resilience), this information is encrypted, bundled and stored locally, validated by the different users of the network who also hold a copy of the ledger, implementing a consensus mechanism, always maintaining a chronological order, aggregating the information into a chain of blocks cryptographically linked and thus, acting as a warrant of the integrity of the recording (Andoni et al., 2019; Brilliantova & Thurner, 2018; Meeuw et al., 2019).

Blockchain has different applications in the electricity markets, some authors have enhance the importance of blockchain for the implementation of peer to peer markets (P2P) and Machine to Machine interaction (M2M), as it allows parties to trade energy and have efficient transactions with reduced latency, in this order, prosumers (people who produced and consume their own energy) sell it to their "peers" creating a decentralized community market of energy called "microgrid" (Ahl, Amanda Yarime, Masaru Tanaka, Kenji Sagawa, 2019; Brilliantova & Thurner, 2018; Sikorski, Haughton, & Kraft, 2017). Trials have been run in several places like Brooklyn and France, they try to test if blockchain servs as a proper architecture to operate the microgrid networks and to help reach equilibrium between supply and demand of electricity (Andoni et al., 2019; Imbault et al., 2017).

Blockchain implementation in microgrids, empowers consumers to choose their energy source, have wider knowledge of their behavior and allows them to produce their own energy, and sell the surplus to neighbors (Andoni et al., 2019). Consumers would then have more accurate information about the cost of energy and price signals, decreasing the asymmetry of information, causing a more rational use of resources, which can motivate investment in prosumer networks for RES generation (Ahl, Amanda Yarime, Masaru Tanaka, Kenji Sagawa, 2019).

Implementation of blockchain in P2P markets would give consumers a bigger role in the everyday activities of the market, which come as an improvement from the current situation where regulation maintains a centralized market where utilities hold most of the power (Andoni et al., 2019; X. Wang et al., 2019).

Another feature that blockchain enables is the improvement of transactions by the implementation of blockchain-based smart contracts (a computer program that can save information, values, and makes changes in the ledgers if certain conditions are met, considering legal constrains and terms of agreement). These are executed when an agreement between the transaction parties is reached, they decrease transaction value and improve cost efficiency by eliminating the need of a mediator, and by shielding the parties from tampering threats (Andoni et al., 2019; X. Wang et al., 2019).

4.1.2 Big Data and Analytics.

The large amount of data produced by SM and AMI implementation, requires special treatment and techniques for its processing and analysis so as to enhance their operational efficiency and to develop customer facilities (Luan, Peng, Maras, Lo, & Harapnuk, 2015; Q. Wang, Gebremariam, Palacios-Trujillo, & Granelli, 2016). As mentioned before, the greatest advantage of having a system to process all the information, has given utilities the ability to understand and develop programs they couldn't before, such as tracing customer demand, system failures, technical losses and thefts. That's why technologies such as Big Data, artificial intelligence and mining data techniques allow the transformation of the individual data into useful information and insights that can become into applicable actions to improve the system, and could make market performance more easily observable, giving energy economic modelers more information to confront their assumptions (F. G. N. Li, Bataille, Pye, & O'Sullivan, 2019; Mohammad, 2018).

Different Big Data architectures have been developed in the literature, Wilcox et al. (2018), propose a SMASH platform, that has demonstrated a good performance for data storing, analysis and visualization of large data sets for smart meters. Harum (2018), uses various methods like clustering and regression algorithm, time series forecasting models among others to process smart meter's data, Niaz and Akbar (2017), implement Apache Spark as the surveillance tool to make the firewall stream process more efficient, along with cluster methodologies to secure the information and produce valuable analysis. Authors agree that processing, analyzing and managing SM's data is a complicated procedure that requires deeper investigation and several trials.

Network operators benefit from the increase in customer's information, as they can enhance in more accurate actions, cluster electricity consumption and create load profiles and closer monitoring of the performance, this is achieved by using data mining, which lets utilities attain a more precise forecasting of the electricity consumption, discover valuable knowledge of rare and unusual patterns, by filtering and differentiating the important information from the totality of data produced by SMs, in which each cluster represents a particular type of demand curve given the consumer's specificities. Techniques like outlier data mining, historical data of consumers' patterns and GIS- based algorithm are implemented to analyze voltage from consumer's SMs, and behavior patterns (Blazakis, Davarzani, Stavrakakis, & Pisica, 2016; Luan et al., 2015; Sun, Zhou, Zhang, & Yang, 2018).

Finally, some authors have emphasized the importance of improving the actual system, they have proposed the implementation of artificial intelligence in smart meters that will track consumption of the appliances, and recommend a schedule for their usage to households, as well as converging Distribution Automation with AMI in order to provide additional capabilities to the operation. (Aziz, Khalid, Mustafa, Shareef, & Aliyu, 2013; Balakrishna, Rajagopal, & Swarup, 2014). Methods for extracting activities from power consumption data are developed, this, in order to generate better feedback to consumers about their behavior (Cho, Yamazaki, & Hahn, 2010). Additionally time synchronization architectures have been a recurring topic in the AMI literature, as it is crucial to maintain a reliable communication to guarantee appropriate billing and pricing, authors have found that broadcast mode has a more efficient performance in this matter (Lu, Liu, Ye, Dou, & Zheng, 2018).

The implementation of the data processing and analysis technologies and architectures brings several benefits to all parties involved, such as utilities and consumers, in the first case it does so by enhancing new customer services, increasing grid's efficiency, and lowering costs, for consumers, it helps reduce bill's costs, and increases the information available for decision making and provides them with feedback from their historical behavior, so that they can achieve energy saving.

4.2 Privacy and Regulation.

As we mentioned before, in order to execute smart grids, AMI is an essential step to be taken, being smart meters the core element of this infrastructure, because it is the one that gives the ability to collect real time information of the electricity consumption, however, the data collected by SMs, is a vulnerable target for attackers, creating threats to user's privacy and security of the whole system (Tan, Deniz, & Poor, 2013). That's why it is a requirement for governments to evaluate their current legislation, to guarantee that the system effectively protects users' information and simultaneously adapts the regulation so that the sector behaves in a more flexible way and generates incentives to stakeholders involved, so that investments are made, and thus ensuring that the implementation of AMI is executed in a way that maximizes social welfare, and maintains utilities' income over time (Gui, Diesendorf, & MacGill, 2017; Lo Schiavo, Delfanti, Fumagalli, & Olivieri, 2013).

4.2.1 Privacy and Security.

Information collected by smart meters can reveal consumer's habits, routines, and preferences, if this information is utilized for malicious purposes, it could endanger their safety and integrity. Attackers can accurately categorize consumers, and choose their target assessing their vulnerability (Ismail, Leneutre, Bateman, & Chen, 2014; Oriero & Rahman, 2018). Smart Meters can tell if a person is home, detect the channel display on a television, show which appliances consumers' use more frequently, it can even revel what kind of food people consume, and if they suffer mental illnesses (Lazowski, Parker, & Rowlands, 2018; Tan et al., 2013).

On the other hand, Cárdenas et al., (2012), and Ismail et al. (2014), asses the problem of electricity theft trough a game theory approach looking to predict consumers and attacker's behavior. Other authors propose different data aggregation schemes for the network, such as, cryptographic algorithms, key graph structure, vector regression and fine-grained approach to guarantee the security of the data while maintaining the reliability of the system and high-quality communications (Bae, Kim, & Kim, 2016; Benmalek et al., 2018; Gope, 2018; Yang Liu, Hu, & Ho, 2015; Oriero & Rahman, 2018).

AMI is vulnerable to several attacks that can affect the integrity, safety, and confidentiality of the system, they can target the different elements such as SM, WAN, data collectors among others, they can be both virtually and physically attacked. The main reasons to tamper with AMI are; data and power theft, localized denial of power (when an attacker manipulates the power inflow of a consumer or group of consumers), widespread denial of power (when a large amount of SM's are disabled or damaged in a single event) and finally, disruption of the grid, which implies mischievous management of a high amount of SMs to affect the power grid, in order to cause energy outages and losses. As a consequence it is crucial to create a secure environment and to count with plans that intend to mitigate the impact of possible attacks to the system, as well as a robust risk management program (Hansen, Staggs, & Shenoi, 2017; Ourahou, Ayrir, EL Hassouni, & Haddi, 2018).

4.2.2 Regulation.

Authors affirm, that SM diffusion and AMI deployment behave as a positive externality, as investment in these technologies are below the socially desired levels, even though a widespread use is desirable because of the increase in information transparency and control that they offer. This situation justifies the adjustments to legislation and a creation of a regulative framework, that creates incentives for investors (Benedikt et al., 2012).

The literature emphasizes that current market structure and regulation of the sector don't provide enough incentives to execute smart grid systems, that's why a restructuration is a main requirement and primary step to be taken, several authors highlight the importance of an incentive-based regulatory framework so that stakeholders accelerate the adoption of more efficient technologies that meet customers' electricity needs (Lo Schiavo et al., 2013).

It is critical to create a pricing structure that adapts more accurately to the flexible landscape of microgrids and RES and that better reflects the costs in which the parts incur, to provide better signals to consumers and to exploit the potential that the information unbidding gives to weaken the natural monopoly and to construct a stronger interplay between demand and supply (Ahmad, Mourshed, Mundow, Sisinni, & Rezgui, 2016; Peterson & Ros, 2018). Other approach is to create pooling property rights and cooperative business models and incentivize collaboration among stakeholders to bear the costs of the investment (Benedikt et al., 2012).

Different policies have been created and evaluated such as universal smart meters roll-out, incentives to R&D, among others. There are mixed opinions about the effectiveness of these measures, however, authors agree that is essential to take into consideration the community's and users' perspectives by effectively communicating the benefits that the adoption of such technologies brings to them (Rosental et al., 2018).

Moreover, governments are more concerned to reduce CO^2 emissions along with pollution, since the Paris agreement, that's why it has become essential to introduce changes in the actual regulation of electricity markets, to stimulate the usage of RES and to increase energy efficiency. As a consequence, utilities are in danger and expected to reduce their sales and profits, leading them with the only viable solution of increasing their electricity rates, thus encouraging further utilization of distributed generation and RES, and incentivizing customers to be more self-sufficient, this is commonly known as "utility death spiral". This gives authorities the task to create a regulation that aligns with both consumers and utilities interests in a renewable integration and energy efficiency context (Tarui, 2017).

4.3 Implementation.

4.3.1 Demand side management.

As it was mentioned previously, the demand of electricity is having a different role in comparison to the one it has traditionally played, it is evolving from being highly inelastic and inflexible, and thus forcing electric generation to adapt to it, to give customers stronger participation in which they are able to influence the decisions of the market concerning energy consumption, because they can take action in order to reduce demand congestion and make more rational decisions. Demand Side Management consist of four main actions which are energy efficiency, self-production, savings and load management. This last one has been widely implemented as demand response boost's its expansion (Paterakis et al., 2017).

These actions come as a solution to both short-term (Generation and pricing during peak hours, and constrained networks), and long-term problems (environmental impacts caused by expensive and pollutive energy sources) (Balijepalli, Pradhan, Khaparde, & Shereef, 2011).

4.3.1.1 Demand Response.

It consists of the creation of a network of end customers, to whom, in return for reducing their energy consumption in specific time frames, especially the ones where the system is more congested and prices increase as a result of high demand, utilities offer a variety of incentives of two main types: implicit or explicit (SEDC, 2017; Yongli Wang et al., 2018).This mechanism has indeed helped smooth electricity demand curves in peak hours, and assure a continuous flow of energy when lower cost sources are unavailable, making it possible that less generation plants are built and used exclusively to cover peak hour demand (Eissa, 2019; Garcia-rendon et al., 2018).

DR can be used in sever levels, such as industrial, service, residential and transport, it has the potential to decrease transaction costs related to the optimization of the electricity consumption curve, also, it has different objectives including, reducing peak consumption, increasing consumption in hours where RES can be the main source, and smoothing the transition between peaks and valleys of the hourly consumption curve (International Energy Agency, 2016).

If properly implemented DR could guarantee that markets balance supply and demand, enhance reliability, reduce congestion and save costs, build a market with less price uncertainty, disrupt the highly concentrated market, and position new technologies (Greening, 2010; Minchala-Avila, Armijos, Pesántez, & Zhang, 2016; Tabandeh, Abdollahi, & Rashidinejad, 2016). It is necessary to understand if consumers needs and interests are homogeneous or heterogenous, there have been different approaches that intend to gain insight on their preferences, characteristics, and willingness to pay for the adoption of such technologies and to avoid outages caused by load collapse, some of these approaches were clustering and choice experiments which conclude that efficiency of the system would benefit if the services target consumers considering their particularities (Balijepalli et al., 2011; Morrissey et al., 2018).

Profitability is a frequent concern when it comes to the implementation of DR, authors have evaluated the costs and benefits, it has been mentioned that DR can be more beneficial for utilities if SM’s roll-out is restricted to large customers (Feuerriegel, Bodenbenner, & Neumann, 2016). In order to guarantee the effectiveness and thus the profitability of the projects, authors have proposed load-profiling strategies that implement clustering algorithms to help find the ideal customer targets, and to understand more profoundly the behavioral conducts of power consumption (Quilumba, Lee, Huang, Wang, & Szabados, 2015; Roy, Bedanta, & Dawnee, 2015; Vercamer, Steurtewagen, Van Den Poel, & Vermeulen, 2016; Y Wang et al., 2015).

There have been different levels of development of DR across the world, US is leading the way by implementing diverse actions to take advantage of different types of consumers' response and making diversifications according to the characteristics of each energy market, the most popular DR programs are developed by American main ISO/RTO's (independent system operator-regional transmission organizations) which are PJM (Pennsylvania-Jersey-Maryland), NYISO (New York ISO), ISONE (ISO New England) and CAISO (California ISO), each program has their own requirements, features and objectives. Some of them are incentive-based and others are time-based, there are cases in which they are mandatory and the failure to accomplish the terms of the programs can lead to penalties for customers (Paterakis et al., 2017; Rahimi, Member, & Ipakchi, 2010).

Europe is making a great advance in implementing and deploying DR, being United Kingdom, Belgium, France, Norway, Sweden, the Netherlands and Germany the ones that have made more progress in this matter (Paterakis et al., 2017; Rahimi et al., 2010). In the Latin-American context, however, there is still much progress to be done for DR implementation, there, demand does not play an active role in energy markets. Nonetheless, countries such as Brazil, Chile and Colombia have started initiatives to promote energy efficiency and to empower the demand-side, to achieve this, it is essential that DR schemes are carefully planned and designed, it is also crucial that a regulatory environment that incentivizes these initiatives is created, that awareness and motivation to the costumers is provided, and that governments make efforts in terms of investments and legislations (Alasseri et al., 2018; Martinez, Ieee, Rudnick, & Ieee, 2012).

Most frequent barriers that literature brings up when referring to DR are, the difficulty of assuring an overall infrastructure implementation as it represents a high investment, along with the uncertainty of who should cover this costs, also, a lack of knowledge, understanding and motivation of consumers concerning the benefits and the behavior of the energy market, as well as, the ambiguity created when there isn't a proper regulation to support the system. In order to get pass these difficulties authors enhance the necessity to coordinate planning, action and implementation of stakeholders involved, so that roles and responsibilities in each stage and process are clearly defined (Greening, 2010).

The most used and explored type of DR is the one that according to price signals and economic variations motivate users to diminish its loads. Dynamic pricing has emerged as an important alternative to regular pricing schemes that have proven to be inflexible and insufficient to cover the system's new technological requirements given the decentralization that is facing. Flat pricing is a scheme that charges in terms of average cost of electricity supply, it doesn't consider temporal variations of electricity costs, an thus utilities have to cover the risks associated with high volatility in wholesale energy prices, these systems leave consumers with no possibility of action, and don’t create incentives for them to change their consumption behavior (Faruqui & Sergici, 2008; Schreiber, Wainstein, Hochloff, & Dargaville, 2015).

Dynamic prices are intended to answer to several needs, like better adoption of RES, having a price scheme that reflects dynamic changes in short periods of time, so that it will allow a more efficient use of energy, reliving pressure on the system, and decreasing costs by permiting load shaping and thus, reducing the need for peaking reserve capacity (Braithwait, 2018; Jiang, Member, Cao, Yu, & Wang, 2014). Even though, authors have different opinions on which are the main categories among Dynamic pricing, the most referenced in the literature are: Time of Use Pricing (TOU), Real Time Pricing (RTP), and Critical Peak Pricing (CPP) (Bayindir, Colak, Fulli, & Demirtas, 2016; Repo et al., 2018; Vardakas et al., 2015)

Time of Use Pricing, is a flat pricing strategy that considers different periods of time, charging diverse rates for consumption in peak, mid-peak and off-peak intervals, evidently the price increases as the congestion is higher. In these schemes, prices are not affected by market movements, which has as a consequence the minimization of consumers’ uncertainty with respect to electricity consumption charges and motivates them to shift consumption to off-peak hours. That’s why some authors exclude TOU from the dynamic pricing status (Faruqui et al., 2009). Similarly, Critical Peak Pricing (CPP), is also based in fixed prices for certain time intervals, but some prices could change according to the system’s congestion, if such changes are effective, customers are informed of it, a day in advance (Vardakas et al., 2015). Real Time Pricing on the other hand, relies entirely on wholesale market prices, it is based on hourly electricity tariffs, which are announced either a day or an hour ahead, what it seeks is the integration of the costs incurred in the different stages like generation, transmission and distribution so that they are reflected in the retail tariffs. In RTP, a committed participation from consumers is vital (Blazakis et al., 2016). It has been also implemented to prevent byzantine faults that threaten the security of AMI (Durgvanshi, Singh, & Gore, 2017).

Authors have incurred in different analysis looking to asses which is the price that will get the market closer to its optimal level, analysis on sensitivity and elasticity are developed, they have concluded that adoption of AMI helps increase price elasticity of demand, and thus achieve a reduction of prices and a decrease of the market power that generation and transmission companies hold. Price differentiation is also a common approach of electricity tariffs, justified by the variety of costs incurred due to the heterogeneity of consumers, and the necessity to charge differently considering the efforts made to provide the service and guarantee an adequate return, they conclude that price dispersion leads to an increase of competition (Aghaebrahimi & Taherian, 2016; Nelson, McCracken-Hewson, Whish-Wilson, & Bashir, 2018; Thimmapuram & Kim, 2013).

In contrast, explicit DR references to incentive-based programs, in which consumers are encouraged to change their energy demand behavior through direct payments so it can adjust to the requests specified in contracts. It can also be sub-classified into classical incentive-based, in which the incentives are presented as discount rates or credit bills, and market-based, that pays in cash depending on the actual reductions of energy consumption. The enrollment into this programs is voluntary and that's why the non-compliance can lead to penalties(SEDC, 2017; Vardakas et al., 2015). Alternatively, Li, Wang, Zheng, León & Hong (2018), propose a mechanism in which consumers are rewarded by coupons, when they achieve reduction of their demand, and they found that it had positive effects on decreasing energy losses and operational costs.

Authors suggest that all energy services should be offered in a bundle, this, with the aim of getting a benefit from synergies generated by overall installation, keeping in mind that these ES behave as complementary services. Moreover, even though stakeholders are seeking for their individual interests, they should consider that the goal is to achieve efficient and sustainable energy system, and, that only by cooperating, the advantages of implementing new technologies would surpass the costs, it also will increase consumers' willingness to engage. According to studies, customers increase their participation in SG, mainly due to perception of economic benefits and for social pressure (Kowalska-pyzalska, 2018). Richter & Pollitt (2018) studied the value that consumers give to electricity services and their preferences via contracts, they conclude that consumers, as mentioned before, highly value monitoring and assistance when it comes to engaging in the enrollment of this services and demand a compensation for their participation.

Customer acceptance of AMI and its energy services (ES) is key to guarantee an effective deployment and to reach the expected impact for its purpose to increase flexibility of the electricity demand. In order to achieve that, effective communication between all stakeholders should be present both before and after its implementation, so that they have a clear understanding of the benefits that they will gain by adopting this technology in order to increase the probabilities to engage them into the programs offered, communication should be complemented by regular feedback to consumers, so as to provide the information they need to modify their conduct regarding energy consumption and thus making their benefits a reality (Kaufmann et al., 2013). Energy Management Tools (EMT) such as web-sites, educational campaigns, and new coverage among others, are an important factor, and have proven to be highly effective to achieve residential energy reduction (Faruqui, Ahmad Arritt, Kevin Sergici, 2017; Shahzad, Bajwa, Ansted, Mamoon, & Khaliq-ur-Rehman, 2016).

4.3.1.2 Distributed Generation and Energy Storage.

Distributed Generation (DG) are small-scale generation technologies, that are located near the distribution spots and are connected directly to the distribution networks instead of to the transmission grids, it includes solar photovoltaic (PV), wind and biomass power plants. It brings several benefits for stakeholders, like a better availability of electricity and a reduction of power losses (International Energy Agency, 2016; Nazari & Ilić, 2010).

DG integrated with AMI, allows final users to adopt electricity efficiency's criteria, to adjust their consumption behavior and, if it is complemented with an optimal location of the power plants, it could guarantee the minimization of costs and maximization of consumers' welfare (Nazari & Ilić, 2010). On the other hand, network operators can manage more efficiently the energy, reduce electricity outages and thus operating costs and increase productivity. Finally, environmental benefits are to be considered, DG-AMI implementation can be an important strategy when it comes to achieving sustainability objectives, as it allows a better load efficiency, covering a broader amount of customers, with the same amount of power produced (Duque, Plata, & Pinto, 2018; Ferreira et al., 2017).

Energy Storage System (ESS), come as a solution to the main cause of inefficiency in the power systems, which is that electricity should be produced at the same time that it is consumed if it does not want to be wasted, with RES this problem is intensified due to their variability and uncertainty. ESS, provides wider flexibility and handling of energy functionalities, permitting the generation and storage in low-cost hours, to its usage during high-cost hours, causing a better distribution of the demand (Arcos-vargas, Lugo, & Núñez, 2018; Jeon & Mo, 2018).

Most common type of storage is centrally installed pumped hydro, but, because it has limited expansion prospects, authors, highlight the importance of batteries, as they can be implemented for decentralized systems, and the simplicity and flexibility that they offer, these technology is expected to become cheaper over time given the market interest in its development (Benedikt et al., 2012).

Different types of batteries are mentioned in the literature, lithium-ion and lead-acid being the most important ones. It is important to emphasize that even though there are similarities in the purposes of DR and ESS, implementing ESS has less requirements, does not involve the creation of process and infrastructure to manage high amounts of information, and thus makes it more profitable in the short term mainly for residential customers (Arcos-vargas et al., 2018; Benedikt et al., 2012). However other authors believe that the popularization of battery electricity storage has yet a lot of barriers to surpass, and that its short-term deployment seems unfeasible, because same results can be achieved by implementing load shedding and load management (Mishra & Palanisamy, 2018). There are some authors that propose a mix of different strategies such as energy storage and dynamic pricing schemes to create a framework that allows saving costs and a more flexible grid (Lanahan et al., 2019).

4.3.2 Cases.

The information gathered throughout this review, is acquired thanks to years of research, implementation of pilot programs, and real-life cases that have as a purpose the achievement of having a system that meets the needs of the energy markets, given their singularities and prospects. The development of AMI can be classified according to the maturity that they evidence, United States is the country that has more experience, mainly in the PJM, NYISO, ISONE and CAISO markets that have stablished deployment of AMI for the longest time, and whose main goal is to meet the increasing energetic demand needs (F. G. N. Li et al., 2019; Yingqi Liu, 2017; Paterakis et al., 2017; Ponce-Jara et al., 2017; Rahimi et al., 2010).

Other countries that also have broad experience but not as much as US, are those belonging to the EU, Netherlands, Belgium, France, Switzerland, Finland and Ireland as well as UK, Australia (state of Victoria) and Canada (Toronto and Ontario), these countries main motivation for implementing AMI and SG, is to diminish the reliance in fossil fuels, facilitate the adoption of RES, and achieve decentralization of the energy system (Aubel & Poll, 2018; Kaufmann et al., 2013; Lazowski et al., 2018; Mohassel et al., 2014; Nelson et al., 2018; SEDC, 2017).

In the third group is constituted mainly by developing and emerging countries, they are in the preliminary phase of deploying AMI, making efforts concerning researching and development, and finding the better way to implement these technologies given their specific context. The advance of AMI in these countries is sometimes motivated by developed countries who are experienced and a want to help them fulfill certain energetical concerns, to this group belong countries like Brazil, India, Pakistan, Chile, China and Korea (Do Amarai et al., 2014; Joseph, 2015; Luhua & Zhonglin, 2010; Martinez et al., 2012; Ponce-Jara et al., 2017; Rosental et al., 2018; Shahzad et al., 2016).

5. Opportunities

It is important to highlight the benefits and opportunities that the implementation of AMI brings to all parties involved, so that the convenience of its adoption is correctly measured. The main findings obtained through the research are going to be summarized for each actor, so there is a clear understanding of what they would gain if they opt to follow the path of AMI deployment.

The main reasons why governments and regulatory entities should consider implementing AMI, come from the efficiency gains that it brings to systems where it is deployed, as well as a reduction of emissions and increase in sustainability which is a crucial concern of governments nowadays. It is important to mention that the compatibility that AMI has with the system's deregulation, generates incentives and means to spread DG, and it helps to mitigate the natural monopoly condition inherent to this market which is in the scope of regulatory agencies. Moreover, governments find very useful that the increase in the amount of information and the frequency at which it is produced, allows them to have more control over the quality and the operation of grids, it is among their interest that the energy market functions in an optimum level as it reflects their capabilities as regulators.

Utilities and retailers of energy have several benefits of implementing AMI, such benefits include, cost reductions, that come from synergies, and decrease in operating costs generated by adopting data management technologies which could facilitate tasks such as billing. Another significant improvement would come from the insights obtained of consumers' habits regarding their electricity consumption, which will allow a precise load forecasting, taking the system to a more efficient level, and if this is complemented by the execution of programs like DR, it could lead to a smoothening of the hourly energy consumption curve. Additionally, these companies will have the opportunity to have two-way real time communication with end users and the status of the grid, facilitating the detection of non-technical losses and electricity theft.

AMI helps improve energy efficiency by enhancing a better understanding of demand patterns and thus facilitating that the supply-side can adapt accordingly, creating benefits for generators and transmission operators. The first ones benefit because load forecasting gives them insights of consumption behavior, and along with Demand Side Management reduces the extreme variability of hourly energy consumption thus eliminating the necessity to have generators that work exclusively to cover peak-hour demand (that normally work with fuel and coal and are more expensive), this leads to significant cost savings and less emission of contaminating particles. AMI also helps in the transition for suppliers to adopt RES in a large scale. On the other hand, transmission operators, because of AMI deployment can improve voltage monitoring enhancing the reliability of the grid and reducing uncertainties regarding misbalances that could result in outages and losses, this is especially important for them because it is vital to ensure a continuous flow of energy.

Meanwhile, households and companies that are the end customers, would gain the most if AMI is implemented, they will become main players in the market's operation, as they will have more access to information, reducing such asymmetry, this thanks to SMs along with display and feedback technologies. They can benefit even more if they engage in DR programs, and become more active and interest in market's behavior. Ultimately, they can benefit from price decreases and a wider offer and quality of services, particularly by the reduction in response times when there are failures such as outages.

Finally, throughout this review, it was found that a new figure has emerged that adopts characteristics both from end-users and producers, as it was mentioned before they are called prosumers. With the implementation of AMI, electric decentralization and flexibilization have been possible, facilitating the creation of microgrids where a community creates their own market of energy getting involved in transactions that look forward to balance surpluses and defaults among the members that own generation sources such as PV. This system not only allows them to be self-sustainable and gain profits for selling their surplus of energy, but it also guarantees that they always have access to energy even when they cannot produce enough to meet their demand, this thanks to the adaptability that AMI brings.

Table 2: Benefits of implementing AMI by actor

	Households	Compani-es	Prosu-mers	Generation	Transm issi-on	Retail utilities	Government
Energy Efficiency	✓	✓	✓	✓	✓	✓	✓
Reduction of emissions	✓	✓	✓	✓	✓	✓	✓
Reduction of market power	✓	✓					✓
Cost reduction			✓	✓	✓	✓	
Facilitation of tasks	✓	✓	✓	✓	✓	✓	✓
Load forecasting				✓	✓	✓	✓
Smoothening consumption curve	✓	✓	✓	✓	✓	✓	✓
Theft and attack detection	✓	✓	✓	✓	✓	✓	✓

Losses detection				✓	✓	✓	✓
More access to information	✓	✓	✓	✓	✓	✓	✓
Less asymmetry of information	✓	✓	✓	✓	✓	✓	✓
System flexibilization	✓	✓	✓	✓	✓	✓	✓
Elimination of intermediaries	✓	✓	✓				✓
Reduction of retail prices	✓	✓	✓				✓
Increase of RES sources	✓	✓	✓	✓	✓	✓	✓
Reduction of outages	✓	✓	✓	✓	✓	✓	✓
Enhance reliability	✓	✓	✓	✓	✓	✓	✓
Improvement of customer services	✓	✓				✓	
Voltage monitoring	✓	✓	✓	✓	✓	✓	✓
Increase in	✓	✓	✓	✓	✓	✓	✓

adaptability							
Reduction of volatility in prices	✓	✓	✓	✓	✓	✓	✓

Source: Own elaboration

6. Challenges

Even though there are several benefits that come with the implementation of AMI, there are still challenges and unsolved questions that need to be faced so that expected results can occur in the desired level. First of all, a complete and clear framework and standardization guidelines is essential to accomplish an efficient roll-out. One of the most important lesson, comes from the Dutch and British experience concerning the roll-out of SM, as they faced several difficulties referring compellability of the roll-out and privacy issues that its adoption raised, this along with the lack of a clear standardization framework that considered consumers' interests instead of focusing only in the technical and commercial interests (Brown, 2014; Cuijpers & Koo, 2012; Hoenkamp et al., 2011). Therefore, the main responsibility regulators have is to create incentives to motivate investment in AMI and participation from the different actors throughout the entire process.

Furthermore, facing uncertainties like responsiveness of customers given cultural beliefs and comfort standards is one of the key issues that needs to be more investigated to improve their engagement in Demand Side Management programs, and also in the adoption and investment in these technologies (Faruqui & Sergici, 2008; Lazowski et al., 2018). It is also important to implement workforce training to develop skillsets to manage information and deal with technological requirements, as well as improving communication and data analysis divisions to support AMI instauration (Mohassel et al., 2014).

Finally, a customized pricing structure that creates incentives to motivate agents for the adoption of these technologies and that can reflect the reality of each market is a responsibility that needs to be assumed (Do Amarai et al., 2014). In conclusion, the challenge is to create the bases and the proper conditions to face the future in an innovative way taking into account the constant evolution that energy market is having in order to serve to society (Ourahou et al., 2018).

7. Adverse Effects

Even though implementation of AMI brings a large amount of benefits for all stakeholders, some of them need to adjust to the modernization of the system in order to get to the process and gain benefits, instead of finding themselves obsolete and out of business.

One particular situation mentioned in the literature is "Utilities death spiral", that occurs when the adoption of DG in large scale, causes electricity rates to increase, increasing the burden for remaining customers, thus incentivizing further DG adoption. This affects utilities as they might not be able to cover their costs due to the loss of volume in terms of quantity of customers(Felder & Athawale, 2014). It is also mentioned that the implementation of dynamic pricing, can lead to an increase in price transparency and a reduction in the markets' asymmetries, threatening utilities with a reduction in their dominant position and high margins, as a solution it is suggested that a restructuration of the utility's business model is executed so as to overcome possible difficulties presented by the implementation of these new technologies (Benedikt et al., 2012).

It is also important to consider the effects that the implementation of AMI and particularly of dynamic pricing has on those customers who cannot change their consumption patterns and on lower income households whose usage of energy is already limited and have little capacity to reduce even more their consumption during peak hours. For this particular group of consumers, strategies such as dynamic pricing could lead to an increase in their bill, and discomfort and potential health issues(Felder, 2010). However some authors have proposed different policies that intend to mitigate the adverse effects on this groups of customers, these policies include designing two-part rates, providing bill protection, and offering tools and education (Faruqui, 2012).

8. Conclusions

Throughout this review of literature, a summary of information regarding AMI was made, and it was found that, even though deployment of such technologies seem to be costly, the benefits obtained for its implementation surpass by far the cost inquired, cost savings, caused by the synergies and coordination among different stakeholders are a condition in order to achieve that. It was learnt that better results are obtained when communication with consumers is correctly handled, because when they have better understanding of the benefits that reflects on their behavior, they can impact their economy and reduce their environmental impact.

It was found that thanks to the two-way real-time communication AMI allows that energy supply meets the demand improving efficiency, and also it has helped reduce information asymmetry among actors, this along with the reduction of the system's congestion caused by the drop on demand during peak hours, will finally lead to a reduction of prices.

Ultimately, the adoption of AMI in the near future, is not an option, but a necessity given the current scarcity of resources and the growing concern of reducing pollution and emissions, that's why all efforts need to be focused in coordinating a proper deployment of such infrastructure that could disrupt the actual structure of energy market.

References

Aghaebrahimi, M. R., & Taherian, H. (2016). Short-term price forecasting considering distributed generation in the price-sensitive environment of smart grids. *4th Iranian Conference on Renewable Energy and Distributed Generation, ICREDG 2016*, 92–97. https://doi.org/10.1109/ICREDG.2016.7875901

Ahl, Amanda Yarime, Masaru Tanaka, Kenji Sagawa, D. (2019). Review of blockchain-based distributed energy: Implications for institutional development. *Renewable and Sustainable Energy Reviews*, *107*(November 2018), 200–211. https://doi.org/10.1016/j.rser.2019.03.002

Ahmad, M. W., Mourshed, M., Mundow, D., Sisinni, M., & Rezgui, Y. (2016). Building energy metering and environmental monitoring - A state-of-the-art review and directions for future research. *Energy and Buildings*, *120*, 85–102. https://doi.org/10.1016/j.enbuild.2016.03.059

Alasseri, R., Rao, T. J., & Sreekanth, K. J. (2018). Conceptual framework for introducing incentive-based demand response programs for retail electricity markets. *Energy Strategy Reviews*, *19*, 44–62. https://doi.org/10.1016/j.esr.2017.12.001

Albani, A., & Winter, R. (2017). Implications of customer value perceptions for the design of electricity efficiency services in times of smart metering. *Information Systems and E-Business Management*, *15*(4), 825–844. https://doi.org/10.1007/s10257-016-0332-9

Andoni, M., Robu, V., Flynn, D., Abram, S., Geach, D., Jenkins, D., … Peacock, A. (2019). Blockchain technology in the energy sector: A systematic review of challenges and opportunities. *Renewable and Sustainable Energy Reviews*, *100*(October 2018), 143–174. https://doi.org/10.1016/j.rser.2018.10.014

Arcos-vargas, A., Lugo, D., & Núñez, F. (2018). Residential peak electricity management . A storage and control systems application taking advantages of smart meters. *Electrical Power and Energy Systems*, *102*(March), 110–121. https://doi.org/10.1016/j.ijepes.2018.04.016

Aubel, P. Van, & Poll, E. (2018). Smart metering in the Netherlands : what , how , and why. *Electrical Power and Energy Systems*, *109*(November 2018), 1–8. https://doi.org/10.1016/j.ijepes.2019.01.001

Avancini, D. B., Rodrigues, J. J. P. C., Martins, S. G. B., Rabêlo, R. A. L., Al-Muhtadi, J., & Solic, P. (2019). Energy meters evolution in smart grids: A review. *Journal of Cleaner Production*, *217*, 702–715. https://doi.org/10.1016/j.jclepro.2019.01.229

Aziz, A. F. A., Khalid, S. N., Mustafa, M. W., Shareef, H., & Aliyu, G. (2013). Artificial intelligent meter development based on advanced metering infrastructure technology. *Renewable and Sustainable Energy Reviews*, *27*, 191–197. https://doi.org/10.1016/j.rser.2013.06.051

Bae, M., Kim, K., & Kim, H. (2016). Preserving privacy and efficiency in data communication and aggregation for AMI network. *Journal of Network and Computer Applications*, *59*, 333–344. https://doi.org/10.1016/j.jnca.2015.07.005

Bago, R., & Campos, M. (2015). Smart meters for improved energy demand management: The

Nordic experience. In J.-L. Bessède (Ed.), *Eco Friendly Innovation in Electricity Transmission and Distribution Networks* (pp. 339–361). Woodhead Publishing. https://doi.org/https://doi.org/10.1016/B978-1-78242-010-1.00016-1

Balakrishna, P., Rajagopal, K., & Swarup, K. S. (2014). Analysis on AMI system requirements for effective convergence of distribution automation and AMI systems. *Proceedings of 6th IEEE Power India International Conference, PIICON 2014*, 1–7. https://doi.org/10.1109/34084POWERI.2014.7117764

Balijepalli, V. S. K. M., Pradhan, V., Khaparde, S. A., & Shereef, R. M. (2011). Review of Demand Response under Smart Grid Paradigm AM I AT C. In *2011 IEEE PES Innovative Smart Grid Technologies* (pp. 236–243). IEEE. https://doi.org/10.1109/ISET-India.2011.6145388

Bayindir, R., Colak, I., Fulli, G., & Demirtas, K. (2016). Smart grid technologies and applications. *Renewable and Sustainable Energy Reviews*, *66*, 499–516. https://doi.org/10.1016/j.rser.2016.08.002

Benedikt, R., Reichhart, P., Kranz, J., & Picot, A. (2012). The role of smart metering and decentralized electricity storage for smart grids : The importance of positive externalities. *Energy Policy*, *50*, 486–495. https://doi.org/10.1016/j.enpol.2012.07.047

Benmalek, M., Challal, Y., Derhab, A., & Bouabdallah, A. (2018). VerSAMI : Versatile and Scalable key management for Smart Grid AMI systems. *Computer Networks*, *132*, 161–179. https://doi.org/10.1016/j.comnet.2018.01.010

Blazakis, K., Davarzani, S., Stavrakakis, G., & Pisica, I. (2016). Lessons Learnt from Mining Meter Data of Residential Consumers. *Periodica Polytechnica Electrical Engineering and Computer Science*, *60*(4), 266–272. https://doi.org/10.3311/ppee.9993

Braithwait, S. D. (2018). Retail pricing responses to the challenge of distributed energy resources. *Electricity Journal*, *31*(8), 38–43. https://doi.org/10.1016/j.tej.2018.09.001

Brilliantova, V., & Thurner, T. W. (2018). Blockchain and the future of energy. *Technology in Society*, (July), 1–8. https://doi.org/10.1016/j.techsoc.2018.11.001

Brown, I. (2014). Britain’s smart meter programme: A case study in privacy by design. *International Review of Law, Computers and Technology*, *28*(2), 172–184. https://doi.org/10.1080/13600869.2013.801580

Cappers, P., Goldman, C., & Kathan, D. (2010). Demand response in U.S. electricity markets: Empirical evidence. *Energy*, *35*(4), 1526–1535. https://doi.org/10.1016/j.energy.2009.06.029

Cardenas, A. A., Amin, S., Schwartz, G., Dong, R., & Sastry, S. (2012). A game theory model for electricity theft detection and privacy-aware control in AMI systems. *2012 50th Annual Allerton Conference on Communication, Control, and Computing, Allerton 2012*, 1830–1837. https://doi.org/10.1109/Allerton.2012.6483444

Cho, H. S., Yamazaki, T., & Hahn, M. (2010). AERO: Extraction of user’s activities from electric power consumption data. *IEEE Transactions on Consumer Electronics*, *56*(3), 2011–2018. https://doi.org/10.1109/TCE.2010.5606359

Cuijpers, C., & Koo, B. J. (2012). Smart metering and privacy in Europe : lessons from the Dutch case. *European Data Protection: Coming of Age*, *Dordrecht:*(16 Feb 2013), 269–293. Retrieved from https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2218553

Dehghanpour, K., Hashem Nehrir, M., Sheppard, J. W., & Kelly, N. C. (2018). Agent-Based Modeling of Retail Electrical Energy Markets with Demand Response. *IEEE Transactions on Smart Grid*, *9*(4), 3465–3475. https://doi.org/10.1109/TSG.2016.2631453

Department of Energy. (2016). *Advanced Metering Infrastructure and Customer Systems: Results from the Smart Grid Investment Grant Program*. https://doi.org/10.1002/ejoc.201200111

Do Amarai, H. L. M., De Souza, A. N., Gastaldello, D. S., Fernandes, F., & Vale, Z. (2014). Smart meters as a tool for energy efficiency. *2014 11th IEEE/IAS International Conference on Industry Applications, IEEE INDUSCON 2014 - Electronic Proceedings*. https://doi.org/10.1109/INDUSCON.2014.7059413

Duque, A. P., Plata, G. O., & Pinto, G. A. O. (2018). Proposal for Advanced Metering Infrastructure in Distribution Systems with Generation Distributed in Low Voltage Electrical Networks. In *2018 IEEE ANDESCON, ANDESCON 2018 - Conference Proceedings*. Santiago de Cali: IEEE. https://doi.org/10.1109/ANDESCON.2018.8564587

Durgvanshi, D., Singh, B. P., & Gore, M. M. (2017). Byzantine fault tolerance for real time price in hierarchical smart grid communication infrastructure. *2016 IEEE 7th Power India International Conference, PIICON 2016*, 1–6. https://doi.org/10.1109/POWERI.2016.8077386

Eissa, M. M. (2019). Developing incentive demand response with commercial energy management system (CEMS) based on diffusion model, smart meters and new communication protocol. *Applied Energy*, *236*(November 2018), 273–292. https://doi.org/10.1016/j.apenergy.2018.11.083

Faruqui, Ahmad Arritt, Kevin Sergici, S. (2017). The impact of advanced metering infrastructure on energy conservation: A case study of two utilities. *Electricity Journal*, *30*(3), 56–63. https://doi.org/10.1016/j.tej.2017.03.006

Faruqui, A. (2012). The Ethics of Dynamic Pricing. *Smart Grid*, *23*(6), 61–83. https://doi.org/10.1016/B978-0-12-386452-9.00003-6

Faruqui, A., Hledik, R., & Tsoukalis, J. (2009). THE POWER OF DYNAMIC PRICING. *The Electricity Journal*, *22*(3), 42–56. Retrieved from https://doi-org.ezproxy.eafit.edu.co/10.1016/j.tej.2009.02.011

Faruqui, A., & Sergici, S. (2008). *Household Response to Dynamic Pricing of Electricity - A Survey of the Empirical Evidence*. *SSRN*. https://doi.org/10.2139/ssrn.1134132

Felder, F. A. (2010). The practical equity implications of advanced metering infrastructure. *Electricity Journal*, *23*(6), 56–64. https://doi.org/10.1016/j.tej.2010.06.002

Felder, F. A., & Athawale, R. (2014). The Life and Death of the Utility. *The Electricity Journal*, *27*(6), 9–16. https://doi.org/10.1016/j.tej.2014.06.008

Ferreira, V., Borba, B., Silva, M., Correia, W., Maciel, R., Fritz, L., … Zamboti, M. (2017). DG impact evaluation on LV distribution grids using AMI data: a Brazilian case study. *CIRED - Open Access Proceedings Journal*, *2017*(1), 1699–1702. https://doi.org/10.1049/oap-cired.2017.1284

Feuerriegel, S., Bodenbenner, P., & Neumann, D. (2016). Value and granularity of ICT and smart meter data in demand response systems. *Energy Economics*, *54*, 1–10. https://doi.org/10.1016/j.eneco.2015.11.016

Fusco, V., Venayagamoorthy, G. K., Member, S., Piazza, F., & Member, S. (2016). Smart AMI based Demand-Response Management in a Micro-grid Environment. In *2016 Clemson University Power Systems Conference (PSC)* (pp. 1–8). Clemson, SC: IEEE. https://doi.org/10.1109/PSC.2016.7462866

Garcia-rendon, J. J., Gómez, A. G., Ceballos, H. V., & Tobón, L. V. (2018). *Smart grids and demand response mechanism : the case of the Colombian electricity market ? Centro de*

Investigación Económicas y Financieras de la Universidad EAFIT (Vol. 18–20). Medellín.
Gope, P. (2018). An Efficient Data Aggregation Scheme for Billing and Demand-Response Management in Smart Grids. *IEEE Internet of Things Journal*, *5*(4), 3126–3135. https://doi.org/10.1109/JIOT.2018.2833863
Greening, L. A. (2010). Demand response resources : Who is responsible for implementation in a deregulated market ? *Energy*, *35*, 1518–1525. https://doi.org/10.1016/j.energy.2009.12.013
Gui, E. M., Diesendorf, M., & MacGill, I. (2017). Distributed energy infrastructure paradigm: Community microgrids in a new institutional economics context. *Renewable and Sustainable Energy Reviews*, *72*(August 2016), 1355–1365. https://doi.org/10.1016/j.rser.2016.10.047
Hansen, A., Staggs, J., & Shenoi, S. (2017). Security analysis of an advanced metering infrastructure. *International Journal of Critical Infrastructure Protection*, *18*, 3–19. https://doi.org/10.1016/j.ijcip.2017.03.004
Hoenkamp, R., Huitema, G. B., & Vugt, A. J. C. D. M. (2011). The Neglected Consumer : The Case of the Smart Meter Rollout in the Netherlands. *Renewable Energy Law and Policy Review*, *2*(4), 269–282.
Imbault, F., Swiatek, M., De Beaufort, R., & Plana, R. (2017). The green blockchain: Managing decentralized energy production and consumption. *Conference Proceedings - 2017 17th IEEE International Conference on Environment and Electrical Engineering and 2017 1st IEEE Industrial and Commercial Power Systems Europe, EEEIC / I and CPS Europe 2017*, 1–5. https://doi.org/10.1109/EEEIC.2017.7977613
International Energy Agency. (2016). *Re-powering Markets: Market Design and Regulation during the transition to lowcarbon power systems*. *International Energy Agency Electricity Market Series*. https://doi.org/10.1787/9789264209596-en
International Energy Agency. (2018). *World Energy Outlook EXECUTIVE SUMMARY*. Retrieved from www.iea.org/t&c/
Ismail, Z., Leneutre, J., Bateman, D., & Chen, L. (2014). A game theoretical analysis of data confidentiality attacks on smart-grid AMI. *IEEE Journal on Selected Areas in Communications*, *32*(7), 1486–1499. https://doi.org/10.1109/JSAC.2014.2332095
Jeon, W., & Mo, J. Y. (2018). The true economic value of supply-side energy storage in the smart grid environment – The case of Korea. *Energy Policy*, *121*(June), 101–111. https://doi.org/10.1016/j.enpol.2018.05.071
Jiang, T., Member, S., Cao, Y., Yu, L., & Wang, Z. (2014). Load Shaping Strategy Based on Energy Storage and Dynamic Pricing in Smart Grid. *IEEE Transactions on Smart Grid*, *5*(6), 2868–2876. https://doi.org/10.1109/TSG.2014.2320261
Joseph, A. (2015). Smart Grid and Retail Competition in India: A Review on Technological and Managerial Initiatives and Challenges. *Procedia Technology*, *21*, 155–162. https://doi.org/10.1016/j.protcy.2015.10.083
Kaufmann, S., Künzel, K., & Loock, M. (2013). Customer value of smart metering : Explorative evidence from a choice-based conjoint study in Switzerland. *Energy Policy*, *53*, 229–239.
Kowalska-pyzalska, A. (2018). What makes consumers adopt to innovative energy services in the energy market ? A review of incentives and barriers. *Renewable and Sustainable Energy Reviews*, *82*(September 2017), 3570–3581. https://doi.org/10.1016/j.rser.2017.10.103
Lanahan, M., Engert, S., Kim, T., Tabares-velasco, P. C., Lanahan, M., Engert, S., … Tabares-, P. C. (2019). Rapid visualization of the potential residential cost savings from energy storage under time-of-use electric rates. *Journal of Building Performance Simulation*, *12*(1),

68–81. https://doi.org/https://doi.org/10.1080/19401493.2018.1470203

Lazowski, B., Parker, P., & Rowlands, I. H. (2018). Towards a smart and sustainable residential energy culture: Assessing participant feedback from a long-term smart grid pilot project. *Energy, Sustainability and Society*, *8*(1), 1–21. https://doi.org/10.1186/s13705-018-0169-9

Li, F. G. N., Bataille, C., Pye, S., & O'Sullivan, A. (2019). Prospects for energy economy modelling with big data: hype, eliminating blind spots, or revolutionising the state of the art? *Applied Energy*, *239*(February), 991–1002. https://doi.org/10.1016/j.apenergy.2019.02.002

Li, Z., Member, S., Wang, S., Zheng, X., & León, F. De. (2018). Dynamic Demand Response Using Customer Coupons Considering Multiple Load Aggregators to Simultaneously Achieve Efficiency and Fairness Zhechao. *IEEE Transactions on Smart Grid*, *9*(4), 3112–3121. https://doi.org/10.1109/TSG.2016.2627140

Lighari, S. N., & Akbar Hussain, D. M. (2017). Reviewing the security surveillance of AMI using big data analytics. In *International Conference on Communication Systems and Network Technologies Reviewing* (pp. 17–20). https://doi.org/10.1109/CSNT.2017.44

Liu, Y. (2017). Demand response and energy efficiency in the capacity resource procurement_ Case studies of forward capacity markets in ISO New England, PJM and Great Britain. *Energy Policy*, *100*(March 2016), 271–282. https://doi.org/10.1016/j.enpol.2016.10.029

Liu, Y., Hu, S., & Ho, T. Y. (2015). Vulnerability assessment and defense technology for smart home cybersecurity considering pricing cyberattacks. *IEEE/ACM International Conference on Computer-Aided Design, Digest of Technical Papers, ICCAD*, *2015–Janua*(January), 183–190. https://doi.org/10.1109/ICCAD.2014.7001350

Lo Schiavo, L., Delfanti, M., Fumagalli, E., & Olivieri, V. (2013). Changing the regulation for regulating the change: Innovation-driven regulatory developments for smart grids, smart metering and e-mobility in Italy. *Energy Policy*, *57*, 506–517. https://doi.org/10.1016/j.enpol.2013.02.022

Lu, J., Liu, X., Ye, A., Dou, J., & Zheng, G. (2018). Research on advanced metering infrastructure time synchronization based on NTP. In *Proceedings of the 30th Chinese Control and Decision Conference, CCDC 2018* (pp. 5701–5704). Shenyang: IEEE. https://doi.org/10.1109/CCDC.2018.8408126

Luan, W., Peng, J., Maras, M., Lo, J., & Harapnuk, B. (2015). Smart Meter Data Analytics for Distribution Network Connectivity Verification. *IEEE Transactions on Smart Grid*, *6*(4), 1964–1971. https://doi.org/10.1109/TSG.2015.2421304

Luhua, Z., & Zhonglin, Y. (2010). Effects of Advanced Metering Infrastructure (AMI) on relations of Power Supply and Application in smart grid. *CICED 2010 Proceedings*, 1–5.

Martinez, V. J., Ieee, G. S. M., Rudnick, H., & Ieee, F. (2012). Design of demand response programs in emerging countries. In *IEEE International Conference on Power System Technology (POWERCON)* (pp. 1–6). IEEE. https://doi.org/10.1109/PowerCon.2012.6401387

Meeuw, A., Schopfer, S., Wortmann, F., Meeuw, A., Schopfer, S., Wortmann, F., & Fournier, J. (2019). Experimental bandwidth benchmarking for P2P markets in blockchain managed microgrids. *Energy Procedia*, *159*, 370–375. https://doi.org/10.1016/j.egypro.2018.12.074

Minchala-Avila, L. I., Armijos, J., Pesántez, D., & Zhang, Y. (2016). Design and Implementation of a Smart Meter with Demand Response Capabilities. *Energy Procedia*, *103*(April), 195–200. https://doi.org/10.1016/j.egypro.2016.11.272

Mishra, S., & Palanisamy, P. (2018). Efficient Power Flow Management and Peak Shaving in a

Microgrid-PV System. In *IEEE Energy Conversion Congress and Exposition (ECCE)* (pp. 3792–3798). IEEE. Retrieved from https://ieeexplore-ieee-org.ezproxy.eafit.edu.co/document/8558312?arnumber=8558312&SID=EBSCO:edseee

Mohammad, R. (2018). AMI Smart Meter Big Data Analytics for Time Series of Electricity Consumption. *IEEE International Conference on Trust, Security and Privacy in Computing and Communications*, 1771–1776. https://doi.org/10.1109/TrustCom/BigDataSE.2018.00267

Mohassel, R. R., Fung, A., Mohammadi, F., & Raahemifar, K. (2014). A survey on Advanced Metering Infrastructure. *International Journal of Electrical Power and Energy Systems*, *63*, 473–484. https://doi.org/10.1016/j.ijepes.2014.06.025

Morrissey, K., Plater, A., & Dean, M. (2018). The cost of electric power outages in the residential sector : A willingness to pay approach. *Applied Energy*, *212*(August 2017), 141–150. https://doi.org/10.1016/j.apenergy.2017.12.007

Nazari, M. H., & Ilić, M. (2010). Potential for efficiency improvement of future electric energy systems with distributed generation units. *IEEE PES General Meeting, PES 2010*, 1–9. https://doi.org/10.1109/PES.2010.5589994

Nelson, T., McCracken-Hewson, E., Whish-Wilson, P., & Bashir, S. (2018). Price dispersion in Australian retail electricity markets. *Energy Economics*, *70*, 158–169. https://doi.org/10.1016/j.eneco.2017.12.026

Nieto, A. (2016). Optimizing prices for small-scale distributed generation resources : A review of principles and design elements. *The Electricity Journal*, *29*(3), 31–41. https://doi.org/10.1016/j.tej.2016.03.004

Oriero, E., & Rahman, M. A. (2018). Privacy Preserving Fine-Grained Data Distribution Aggregation for Smart Grid AMI Networks. In *MILCOM 2018 - 2018 IEEE Military Communications Conference (MILCOM)* (pp. 1–9). Los Angeles: IEEE.

Ourahou, M., Ayrir, W., EL Hassouni, B., & Haddi, A. (2018). Review on smart grid control and reliability in presence of renewable energies: Challenges and prospects. *Mathematics and Computers in Simulation*, (xxxx). https://doi.org/10.1016/j.matcom.2018.11.009

Paterakis, N. G., Erdinç, O., & Catalão, J. P. S. (2017). An overview of Demand Response : Key-elements and international experience. *Renewable and Sustainable Energy Reviews*, *69*(November 2016), 871–891. https://doi.org/10.1016/j.rser.2016.11.167

Peterson, C. R., & Ros, A. J. (2018). The future of the electric grid and its regulation: Some considerations. *Electricity Journal*, *31*(2), 18–25. https://doi.org/10.1016/j.tej.2018.02.001

Pindyck, R. S., & Rubinfeld, D. L. (2013). *Microeconomía*. (C. Alberto, Ed.) (8° Edición). Madrid: PEARSON EDUCASIÓN S.A.

Ponce-Jara, M. A., Ruiz, E., Gil, R., Sancristóbal, E., Pérez-Molina, C., & Castro, M. (2017). Smart Grid: Assessment of the past and present in developed and developing countries. *Energy Strategy Reviews*, *18*, 38–52. https://doi.org/10.1016/j.esr.2017.09.011

Quilumba, F. L., Lee, W. J., Huang, H., Wang, D. Y., & Szabados, R. L. (2015). Using smart meter data to improve the accuracy of intraday load forecasting considering customer behavior similarities. *IEEE Transactions on Smart Grid*, *6*(2), 911–918. https://doi.org/10.1109/TSG.2014.2364233

Rahimi, F., Member, S., & Ipakchi, A. (2010). Demand Response as a Market Resource Under the Smart Grid Paradigm. *IEEE Transactions on Smart Grid*, *1*(1), 82–88.

Repo, S., Pylvanainen, J., Kauppinen, M., Repo, S., & Jarventausta, P. (2018). Automatic Meter Infrastructure (AMI) as a part of flexibility market. *International Conference on the*

European Energy Market, EEM, *2018–June*. https://doi.org/10.1109/EEM.2018.8469765
Richter, L., & Pollitt, M. G. (2018). Which smart electricity service contracts will consumers accept ? The demand for compensation in a platform market ☆. *Energy Economics*, *72*, 436–450. https://doi.org/10.1016/j.eneco.2018.04.004
Rosental, R., Vardiero, P., Brandão, R., Zamboni, L., de A. Dantas, G., Dias, L., … Antunes, C. H. (2018). Public policies for smart grids in Brazil. *Renewable and Sustainable Energy Reviews*, *92*(March), 501–512. https://doi.org/10.1016/j.rser.2018.04.077
Roy, S., Bedanta, B., & Dawnee, S. (2015). Advanced Metering Infrastructure for real time load management in a smart grid. In *Proceedings of the 2015 IEEE International Conference on Power and Advanced Control Engineering, ICPACE 2015* (pp. 104–108). IEEE. https://doi.org/10.1109/ICPACE.2015.7274926
Schreiber, M., Wainstein, M. E., Hochloff, P., & Dargaville, R. (2015). Flexible electricity tariffs : Power and energy price signals designed for a smarter grid. *Energy*, *93*, 2568–2581. https://doi.org/10.1016/j.energy.2015.10.067
SEDC. (2017). *Explicit Demand Response in Europe Mapping the Markets 2017*. *SEDC. Smart Energy Demand Coalition*. Retrieved from https://www.smarten.eu/wp-content/uploads/2017/04/SEDC-Explicit-Demand-Response-in-Europe-Mapping-the-Markets-2017.pdf
Shahzad, K., Bajwa, S. U., Ansted, R. B., Mamoon, D., & Khaliq-ur-Rehman. (2016). Evaluating human resource management capacity for effective implementation of advanced metering infrastructure by electricity distribution companies in Pakistan. *Utilities Policy*, *41*, 107–117. https://doi.org/10.1016/j.jup.2016.06.011
Sikorski, J. J., Haughton, J., & Kraft, M. (2017). Blockchain technology in the chemical industry: Machine-to-machine electricity market. *Applied Energy*, *195*, 234–246. https://doi.org/10.1016/j.apenergy.2017.03.039
Sun, L., Zhou, K., Zhang, X., & Yang, S. (2018). Outlier Data Treatment Methods Toward Smart Grid Applications. *IEEE Access*, *6*. https://doi.org/10.1109/ACCESS.2018.2852759
Tabandeh, A., Abdollahi, A., & Rashidinejad, M. (2016). Reliability constrained congestion management with uncertain negawatt demand response firms considering repairable advanced metering infrastructures. *Energy*, *104*, 213–228. https://doi.org/10.1016/j.energy.2016.03.118
Tajudeen, I. A., Wossink, A., & Banerjee, P. (2018). How significant is energy efficiency to mitigate CO2 emissions? Evidence from OECD countries. *Energy Economics*, *72*, 200–221. https://doi.org/10.1016/j.eneco.2018.04.010
Tan, O., Deniz, G., & Poor, H. V. (2013). Increasing Smart Meter Privacy Through Energy Harvesting and Storage Devices. *IEEE Journal on Selected Areas in Communications*, *31*(7), 1331–1341. https://doi.org/10.1109/JSAC.2013.130715
Tarui, N. (2017). Energy Integration and Distributed Generation. *Environmental Economics and Policy Studies*, *19*(3), 503–518. https://doi.org/10.1007/s10018-017-0183-8
Thimmapuram, P. R., & Kim, J. (2013). Consumers' price elasticity of demand modeling with economic effects on electricity markets using an agent-based model. *IEEE Transactions on Smart Grid*, *4*(1), 390–397. https://doi.org/10.1109/TSG.2012.2234487
Vardakas, J. S., Zorba, N., Verikoukis, C. V, & Member, S. (2015). A Survey on Demand Response Programs in Smart Grids : Pricing Methods and Optimization Algorithms. *IEEE Communications Surveys & Tutorials*, *17*(1), 152–178. https://doi.org/10.1109/COMST.2014.2341586

Vercamer, D., Steurtewagen, B., Van Den Poel, D., & Vermeulen, F. (2016). Predicting Consumer Load Profiles Using Commercial and Open Data. *IEEE Transactions on Power Systems*, *31*(5), 3693–3701. https://doi.org/10.1109/TPWRS.2015.2493083

Wang, Q., Gebremariam, A. A., Palacios-Trujillo, R., & Granelli, F. (2016). Power saving strategy in advanced metering infrastructure for high-density residential community. *2015 IEEE 20th International Workshop on Computer Aided Modelling and Design of Communication Links and Networks, CAMAD 2015*, 201–206. https://doi.org/10.1109/CAMAD.2015.7390509

Wang, X., Yang, W., Noor, S., Chen, C., Guo, M., & van Dam, K. H. (2019). Blockchain-based smart contract for energy demand management. *Energy Procedia*, *158*, 2719–2724. https://doi.org/10.1016/j.egypro.2019.02.028

Wang, Y., Chen, Q., Kang, C., Zhang, M., Wang, K., & Zhao, Y. (2015). Load profiling and its application to demand response: A review. *Tsinghua Science and Technology*, *20*(2), 117–129. Retrieved from https://www.scopus.com/inward/record.uri?eid=2-s2.0-84930677731&partnerID=40&md5=859b36bb44d60831cfa9bc8f9c1ffd5d

Wang, Y., Huang, Y., Wang, Y., Zeng, M., Li, F., & Wang, Y. (2018). Energy management of smart micro-grid with response loads and distributed generation considering demand response. *Journal of Cleaner Production*, *197*, 1069–1083. https://doi.org/10.1016/j.jclepro.2018.06.271

Wilcox, T., Jin, N., Flach, P., & Thumim, J. (2019). Computers in Industry A Big Data platform for smart meter data analytics. *Computers in Industry*, *105*, 250–259. https://doi.org/10.1016/j.compind.2018.12.010

WWF, ECOFYS, & OMA. (2011). The Energy Report: 100% Renewable energy by 2050. Retrieved from https://c402277.ssl.cf1.rackcdn.com/publications/384/files/original/The_Energy_Report.pdf?1345748859

Ye, F., Qian, Y., & Hu, R. Q. (2015). Energy efficient self-sustaining wireless neighborhood area network design for smart grid. *IEEE Transactions on Smart Grid*, *6*(1), 220–229. https://doi.org/10.1109/TSG.2014.2344659