Systematic Analysis of Literature on the Social Benefits and Advantages of The Adoption of Intelligent Electric Energy Meters

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Abstract: This article presents a systematic review of the literature on the use of smart meters. The current approach has shown a focus on data acquisition and processing and, mainly, on automation, which are certainly important factors. However, the non-technical approach has been little explored. This condition leads to reflection on aspects beyond the technical scope, such as social, environmental and economic. This work contributes to broadening the vision of researchers in the field of smart grids, presenting the main aspects of the works that the authors' knowledge until now, emphasizing the lack of investigations beyond the purely technical nature, leading to the conclusion that there is still much to explore in the social field through the implementation of smart grids

Keywords: smart grids; smart meter; social benefit;

1. INTRODUCTION

In the current data acquisition and processing scenario, several smart grid searches come with a focus on automation. Automated services are increasingly present in everyday life, improving quality of life, optimizing increasingly scarce time (R. K. Kodali *et. al.*, 2019). However, it cannot be neglected that automation was born to benefit society and, an incessant search for automation, sometimes does not address factors that actually bring benefits to people.

In the monitoring environment focused on automation, growing is the use of smart meters, which are the initial frontier of the deployment of smart grids. These devices allow, through the telecommunication system, access to information much more frequently than with the use of analog meters.

In this context, this article presents a review of works related to the use of smart meters and their use for the effective good of consumers. The work, B. K. Sovacool *et. al*., 2017, also presents a systematic review of the literature on smart meters, but in the historical scope of the program for the implementation of these meters. The article addresses a number of obstacles and delays in implementation, as well as investigates social and technical challenges, with emphasis on the social side of the equation. Aiming at the importance of this emphasis, as presented in B. Yang *et. al.*, 2019, the social, economic, and behavioral aspects of consumers are rarely considered.

In the context of benefits, one cannot fail to consider the great importance of environmental impacts, especially at such an evident moment of climate change. In the following studies, not only is addressed the issue of reducing carbon dioxide emissions, but also an association is made with the use of renewable sources: H. Boudet *et. al.* 2021; J. Lee and M. M. Shepley 2020; S. Sareen and K. Rommetveit 2019; D. Peters, J. Axsen and A. Mallett 2018 and G. d. A. Dantas *et. al*. 2018. In this sense, other works address the penetration / integration of renewable distributed generation, as in: V. Costa *et. al.* 2021 and A. C. Zambroni *et. al*. 2020.

Because it is a system still under development and with promising expansion, there are still a number of challenges along the path of implementing smart meters. One of them, and perhaps the biggest, is to convince the consumer to have one of these meters, being privacy one of the biggest concerns. (B. Yang *et. al.* 2019), (W. Chen *et. al.* 2019), (E. Melville *et. al.* 2017), (S. Guerreiro *et. al.* 2015), (L. AlAbdulkarim *et. al.* 2014). Cybersecurity comes as a privacy-like concern. Another challenge is what to do with the large volume of data (bigdata) that is generated. (W. Liu *et. al.* 2021), (Y. Chen *et. al.* 2016), (D. Arora and P. Malik 2015), (D. Alahakoon and X. Yu 2013).

In addition, this article meets the global goals for sustainable development of the United Nations (UN), by seeking to expose the themes inherent in accessible and clean energy, sustainable cities and communities, and sustainable consumption and production. It points out what has been discussed in the scientific community regarding measures that ensure reliable, sustainable, modern, and affordable access to energy for all; inclusive, safe, resilient, and sustainable human cities and settlements; sustainable production and consumption patterns.

The greatest contributions of this work are the responsibility of investigating information regarding the determination of what data is collected and what is made of this data, the level of guarantee of security, confidentiality and integrity of the data, the benefits offered to consumers, the benefits to energy distributors, the costs of implementing smart meters for the end consumer and the communication technologies used.

The structure of this article presents the contextualization of the problem in this first section – Introduction. In the second section are presented the main concepts covered in this work, which are smart meters and smart grids. In the third section is presented the methodology used to support the next section of results and analyses. And finally, in the fifth section are presented the conclusions of this work, including proposals for future work.

2. SMART GRIDS AND SMART METERS

In recent decades there has been a considerable increase in global electricity consumption. According to the International Energy Agency (IEA) portal, the growth trend remained reasonably constant until the 2000s, when the consumption curve increased substantially, mainly leveraged by the demands of the industrial, residential, commercial, and public services sectors ("World electricity final consumption by sector", online, 2019) as can be seen in Figure 1.

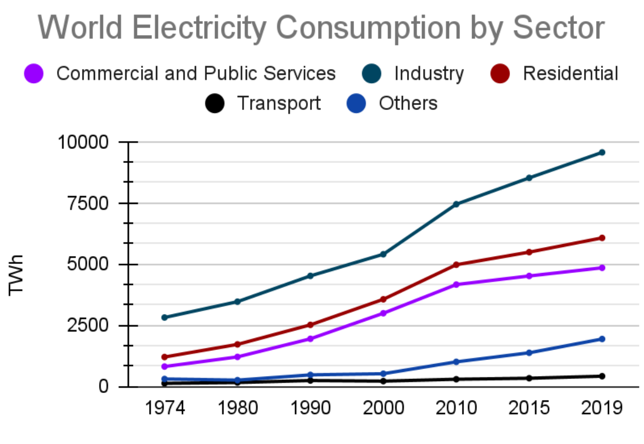

Figure 1: World electricity final consumption by sector, 1974-2019.

As a result, academics, energy utilities, energy and telecommunications regulators, technology developers for electrical grids, and information technology have focused on optimizing resources in both generation, distribution, and consumption.

Then comes the concept of Smart Grids (SG), first cited in 2005 in an article entitled "Towards a Smart Grid", written by S. Massoud Amin and Bruce F. Wollenberg. Since then, several definitions have emerged for the concept of smart grids. However, the core of its definition is always associated with the use of information and sensing technology applied in a large-scale, interconnected, bidirectional, sustainable network infrastructure that implements agility and security in search of being resilient against threats and conditions not foreseen in the transportation of energy. (S. Massoud Amin and B. F. Wollenberg, 2005) and (A. Smadi *et. al.*, 2021).

These networks can provide economic, social, and environmental benefits, but there are numerous challenges to be overcome, such as coexistence with conventional networks, real-time data traffic performance, treatment applied to the large volume of data acquired, software implementations and specific hardware development, in addition to the vulnerabilities of information systems among others. (A. Smadi *et. al.*, 2021).

In this sense, there is a need to improve existing infrastructures allowing not only integration with innovative digital technologies, such as Internet of the Things (IoT), but also with substations and smart meters that can detect network problems in order to provide better services to its consumers, as well as increase reliability and greater control over electricity demand.

As a consequence, the replacement of electromechanical meters by electronic meters, called smart meters or Advanced Measurement and Management Systems (AMS), gains its relevance: they provide more accurate measurements, automatic reading of consumption data and indicators, integration between generation and demand (bidirectional communication) via the Internet and, in addition, allow the flexibility of changing tariffs according to the consumption profile.

Finally, smart meters, in addition to providing a huge volume of data that can be translated into information, have a focus on automating processes, reducing costs with technical support teams, since suspension or reconnection actions can be performed remotely, the faults are automatically perceived without contact by the consumer.

Estimates indicate that approximately 950 million smart meters have been installed worldwide by 2019, equivalent to 41.2% of equipment in use (see Figure 2) and that the overall deployment rate of these meters is expected to increase to something close to 59% by 2028, accounting for about 1.5 billion equipment. ("Market Data: Smart Meter Global Forecasts," online, 2019).

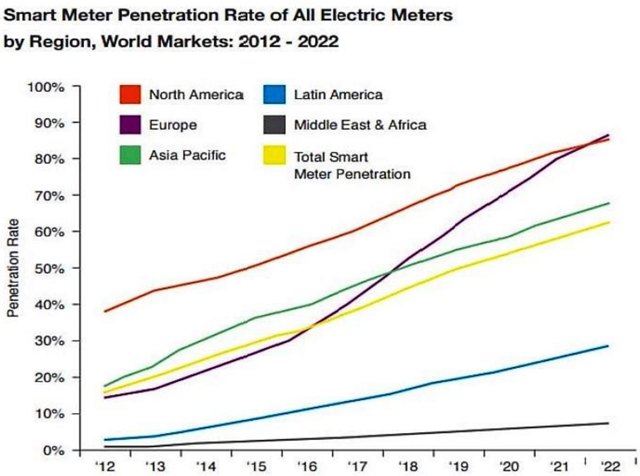

Figure 2: Smart meter penetration rate (source: Navigant research).

It is estimated that among all regions of the globe, Latin America, the Middle East, and Africa are heading for a greater growth potential for the use of smart meters, while North America must continue at a pace of stability. Asia and Europe already stand out for their use and will continue to do so by forecasts (Figure 3). ("Market Data: Smart Meter Global Forecasts," online, 2019).

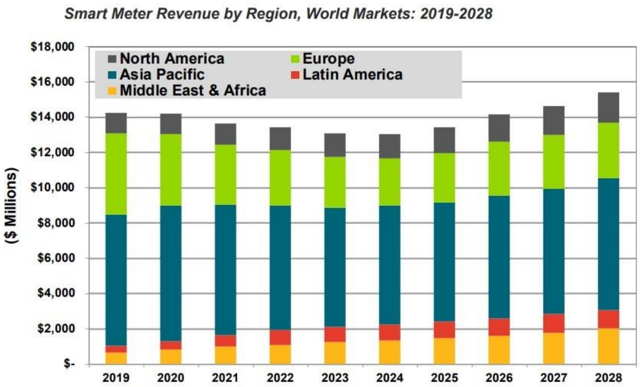

Figure 3: Smart meter revenue by region (source: Navigant research).

Unfortunately, however, many utilities when replacing their electricity meters pass on their deployment costs to consumers without a prior study that justifies the return on investment and whether it will actually bring benefits to the two parties involved in the process. (F. D. Garcia *et. al.*, 2017).

Consumers' adherence to new products or services comes from the perception that they will receive some positive feedback. To arrive at this simple equation, the consumer generally analyzes what is received (benefits), deducted from his obligations and/or counterpart (disadvantages). However, this data is not always clear, but based on experience and consumer perception (V. A. Zeithaml, 1988). Thus, it is relevant that articles and academic papers explain the social advantages and benefits behind the adoption and use of intelligent energy meters.

3. METHODOLOGY

In view of the subject presented, the method of systematic review of the literature was adopted in order to expose what is known and explored, as well as instigate new research perspectives. The following data show how deep studies are related to data acquisition and processing, the development of mathematical tools, and finally, what is actually done to benefit electricity consumers.

Smart power meter manufacturers propagate information that their products meet the metrological needs of residential and commercial consumers, allowing the power distributor access to various consumption data and indicators that allow for a more accurate assessment of how electricity is being delivered and consumed. In this context, some questions are raised:

- What data is collected?
- What is made of this data?
- At what level are the mechanisms for ensuring data security, confidentiality, and integrity?
- What is the return (benefits) offered to consumers in exchange for this collected data?
- What return (benefits) does the energy distributor achieve with the use of these equipment?
- What are the costs of deployment to the final consumer?
- What communication technologies are used?

These questions guided the research.

First, the research focused on the search for works related to smart meters, through which a large number of works with a purely technical approach were obtained. The research continued in search of works that are fully related, or at least mostly, to non-technical aspects, something that actually brought benefits to the population. At first, there was no temporal restriction in the search parameters, having as its oldest work an article from 2009. Although the term "smart grids" was first mentioned in 2005, "smart meters", not necessarily named, have been used since 2000. (Z. Al-Waisi and M. O. Agyeman, 2018).

The bibliographic research was carried out in October 2021 on the bases of the virtual platform "Web of Science" (Clarivate, 2021), which has more than 9000 indexed journals. The following search descriptors were used:

(1) "smart meter" AND social OR (advantage OR benefits); and

(2) "smart meter" AND social OR (advantage OR benefits) AND Brazil;

In addition to the focus on smart meters, social application, benefits, and advantages, it was also decided to research what is related to smart meters in Brazil, thus ensuring broader conclusions.

4. RESULTS AND ANALYSIS

From the search result, articles were found that were listed in more than one set of keywords. When filtering the multiple listing, 230 articles were obtained.

During development, it was perceived that most of the studies that presented social benefits also dealt with economic and environmental benefits.

Table I shows the result of direct and indirect relationship analysis. The articles where their nucleus dealt essentially with social benefits were considered as a direct relationship, while the other articles, which addressed, in a secondary way, social issues or other types of benefits, were classified as indirect relation.

In the years 2009, 2010, and 2011 only one article was found for each year. However, the articles of 2010 and 2011 were not related to the theme.

TABLE I. DIRECT/INDIRECT RELATIONSHIP

Year	Direct Relationship	Indirect Relationship
2021	4	15
2020	8	8
2019	17	7
2018	6	15
2017	15	1
2016	4	10
2015	15	3
2014	9	5
2013	10	0
2012	3	1
2011	0	0
2010	0	0
2009	0	1

By reading the articles, of the 230 previously selected, 157 were directly or indirectly related to the theme, representing 68.3%, and 73 had no relationship, representing 31.7%.

As can be seen in Table I, the largest number of studies directly related to the theme occurred in publications of the year 2019. In 2020 there was balance. In 2021, up to the moment of the research, articles indirectly related (purely technical) represented more than three times the number of articles that presented a direct approach (social aspects).

In order to deepen the analysis, the articles were classified comprehensively into more specific factors, as presented in Table II. Table II also presents the papers found related to Brazil.

With regard, specifically to Brazil, the research can show that little was disseminated on the themes addressed in this article, indicating the need for more work related to the impact of the implementation of smart meters in our energy networks. There is a need for further studies and presentation of relevant data, mainly by concessionaires.

TABLE II. TOPICS

	Ano	2021	2020	2019	2018	2017	2016	2015	2014	2013	2012
Non-technical factors	Social	3	2	7	1	5	2	1	4	1	
	Environmental	5	2	3	2	4	2		3	1	1
	Economic	3	6	6	6	6	4	1	5	4	2
Technical factors	Mathematical tools	1	1	1	2	2	1	1			
	Big data	2		2	1	2	3	1		1	
	Obtaining indexes	1				3		1			
	Load forecast / peak reduction	2	1	1		2		1	3	1	
	Data acquisition and/or processing	5	3	2	4	6	4	1	2	2	
	Renewable / distributed generation	1	4	1	1			1	3	1	
	Consumption monitoring			1		6		3		4	1
Others	Cybersecurity					1	1	1	1	1	
	Non-technical losses / fraud	2	2			2					1
	Concessionaire benefit	1		3	1	2		9	1	2	
	Water meter	2	1		2	2		1	1		
	Privacy	2		3		3	1	3	1		
	Brazil		4		1		3	7		2	2

As shown in Table II, several aspects were addressed, of which we can highlight the frequency at which social factors are mentioned in 2019 (see Figure 4). However, when analyzing these articles, it is possible to note that they simply allude to the term "social benefits", without even explaining what these would be. What is clear is that the reduction of consumption is considered a social benefit by the economy it can generate, but comparative data or real gains are not presented.

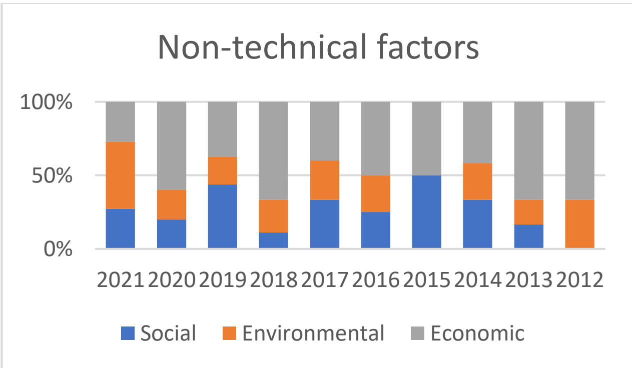

Figure 4: Non-technical factors raised in the bibliographic research.

However, consumer intervention approaches are ineffective. There is a need for more playful conducts that clarify, for example, that the reduction of consumption implies the least need for generation and, consequently, lower will be the costs that can be passed on to consumers. Although obvious to a part of society, the lower-income population needs to notice this in numbers, showing how much (financial resources) they can save from the measure. Why not make this explicit, through campaigns and information on energy bills, for example, with real values, based on the consumer's own invoices?

This reinforces another aspect that appears regularly between 2017 and 2020: economic factors. Almost always linked to social benefits, this term is once again linked to the reduction of consumption, reinforced by the control obtained through smart meters (Figure 4). The savings are often portrayed by reduced maintenance costs and reduced costs with technical support teams since several actions can be performed remotely, such as the perception of absences. However, they once again portray an advantage for energy utilities and not directly to consumers.

With a lower human presence in the process, simple requests become sometimes time consuming through telephone service or more complex through websites and applications, which, once again, can become an impediment in the search for services by the low-income or older population due to the difficulty of access in the Internet and/or technological knowledge.

Two other preponderant factors, especially in the 2017 articles (Figure 5), were data acquisition and/or processing and consumption monitoring. Almost always treated by their technical bias, such as demand analysis, they do not expose secondary data obtained by data collection, such as what is done with the consumption profile obtained through mining the large volume of data.

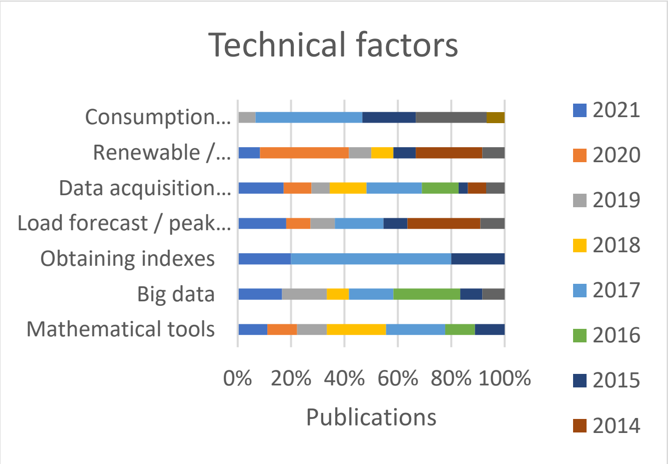

Figure 5: Technical factors raised in the bibliographic research.

This collected data should, at first, be evident, accessed through a panel on the smart meter itself, through access to some kind of web information portal or consumed through applications for mobile phones. The important thing is that they are presented in a way that reports, once again, in a playful way, without technicalities, what real benefits the sharing of their information is bringing financially and, why not, what their consumption profile generates from overload or gains for the environment.

In a statement, it is clear that in the vast majority of articles, the use of the term "benefits for dealerships" has been developed since the origin of the terms smart networks and smart meters, highlighted can be indicated the year 2015 as the most explicitly cited. It reinforces the concept that there is a search for cost reduction and not directly for social benefits and/or advantages.

The 2009 article presented "smart grids" and "smart meters" in general, not fitting the parameters presented in Table II.

Regarding approach of smart meters in Brazil, there was a greater number of papers published in 2015 (7 publications). The focus remained on the dissemination of "benefits to concessionaires", where all published articles talked about the theme pointing out. The smart meter had been treated now as a safety device, because it allowed the operation of concessionaires in regions with lower performance of the state, sometimes by incorporating the promise of monitoring and protection of infrastructure and revenue. In time, no social aspect is directly addressed.

5. CONCLUSION

This article presented a systematic review of the literature on the use of smart meters, through which it is concluded that there is still much to explore in the social field in the midst of smart networks, and questions about how "intelligent" in fact a city can be, without worrying about the population and bringing benefits to citizens.

Although the focus of smart grids is to improve the quality of life, much has been done for automation, but this paper demonstrated that little has been deepened in non-technical aspects.

However, for a network to become intelligent, one cannot observe only the technological issue or its automation. Technologies should be the means to obtain results that provide benefits, not only concessionaires, but also society (direct and indirect consumers) as well as the environment. By enabling efficient integration between renewable energy sources, such as solar and wind, it contributes to reducing dependence on fossil fuels and reducing the emission of polluting gases, such as CO_2, in addition to enabling cost reduction due to the optimization of energy resource consumption.

In view of the deficiency of studies related to the social character of the use of smart meters, as a suggestion of future work, what the benefits for consumers really are can be addressed more deeply and explicitly. A common citation of social benefits was observed without detailing the issue, which aggravates the problem. Also in the suggestions, the questions presented in the third section of this work remain, about what data is collected and what is made of them, at what level are the mechanisms for ensuring the security, confidentiality, and integrity of the data, what the return offered to consumers in exchange for this data, what is the return that the energy distributor achieves with the use of these meters, the costs of deployment to the final consumer and what communication technologies are used.

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