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Smart Grid Technologies and the 2030 Agenda for Sustainable Development: Drivers for Innovation

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Abstract: Because of the significant enabling role smart meters can play in securing the transition towards sustainable energy distribution, the paper provides insights to support smart meters implementation projects. Energy utilities must propose adequate solutions to manage grid-upgrading projects and, in the meantime, increase efficiency levels. Based on empirical data analysis the paper provides insights aimed at maximize probability of success of smart meters projects. Results show common patterns of variables that may support project undertakers, policymakers and scholar when it comes to analyze projects to predict to maximize opportunities. For smart meters projects to succeed, regulatory stability is essential as long-period investments grids produce benefits for energy utilities, and for society.

Keywords: smart grid; SDGs; sustainable energy; smart meters; energy access; sustainability; utilities; development

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1. Introduction

The United Nations 2030 Agenda for Sustainable Development includes key elements for tackling climate change, improving energy efficiency, and access to modern energy services, i.e., for sustainable development. Specifically, SDG 7 aims to ensure access to affordable, reliable, sustainable, and modern energy for all, and SDG 9 refers to resilient infrastructure, inclusive, and sustainable industrialization and innovation.

Governments worldwide have assured unprecedented commitment to upgrade energy grids [1] that calls for huge investments and innovative upgrade projects from energy utilities. If the implementation of the United Nations 2030 Agenda for Sustainable Development requires the active involvement of business [2] included utilities, in today's business environment, energy utilities are asked to manage the increasing complexity of power grids technological characteristics. In the context of electricity, grid-upgrading projects are required to allow an ever-closer connection between distributed energy resources and the consumer. Therefore, selecting the appropriate power grid innovation project to maximize value for industry and consumers has become as crucial as complex.

Determining which solutions and technologies are best suited to deploy in specific grids requires an understanding of the current situation and future needs; therefore the appraisal of benefits is thought-provoking and forward-looking [3].

It is well-known that serious upgrading of grids is required to manage renewable energy generation, to support smart cities initiatives, to enable digitalization-driven services, and to create opportunities for energy saving and energy efficiency, to name a few. Of course, there are a plethora of prominent grid upgrading solutions available to energy utilities to comply with increasing tasks they are called on to manage. Among such solutions, there are for example the following: replacement of aging transformers and transformer switching, increase in ratings through line rebuilds, replacement of conductors, dynamic line rating, increase in voltage level, VRES hosting capacity, load flexibility, network reconfiguration, capacitor banks, and smart meters. Smart metering applications play a central role in power grid transformation and energy efficiency [4], supporting the transformation of traditional grids into smart grids [5], [6]. This paper examines the literature on the implementation of smart grid innovation projects [7] focused on smart meters implementation and provides additional insights on how different factors intertwine and how to manage them to create value for business and society.

Based on empirical data obtained during, and after, the meter-on project, the paper focuses on the analysis of the relationships that emerged from the analysis of the information collected by mean of an international survey conducted across some European countries. From the analysis of the results, 34 patterns emerged. The patterns resembled unidirectional relationships among variables that were surveyed using as a screening criterion the number of variables encompassed in the patterns that were set to 3 as a minimum. Each pattern serves as a tip, confirm, or insight for stakeholders involved in the development of smart meters projects. The higher the number of relations, the higher the complexity of management. A recent study recognizes energy utilities as regulated monopolies and key players along the supply chain [8], consistently paper provides political implications too as similarly done in other environmental services [9].

The remainder of this paper is organized as follows: Section 2 provides a survey of materials and methods used to gather the data and. Section 3 presents main results of the analyses. Section 4 discusses prominent solution to smart grid upgrades. The conclusion follows.

2. Materials and Methods

The paper examines the issues behind the purpose of the literature on smart metering projects' drivers and barriers [7]. Notably, smart meter technology trends have been well documented [10], [11], and arguably represent one of the most important themes addressed in several studies of smart grid modernization [3], [12], [13]. In addition to previous literature, this paper put together relations among different factors that influence the performances of smart meters projects. The paper bases on a survey of which the source of data acquisition was a questionnaire submitted to Energy utilities. The questionnaire was designed to guarantee clearness, correctness in items, order, and effectiveness of the items contained [14]. The data collection campaign occurred during the meter-on project and comprehended the following countries: Austria, Belgium, Bulgaria, Hungary, Italy, Portugal, Poland, Romania, Spain and France, Finland, The Netherlands, Denmark, Sweden, Finland, Latvia. The questionnaire contained five sections: general information on energy utilities and the projects they were conducting, technological analysis, economic analysis, regulatory and legal frameworks included user acceptance, and customer involvement, and advanced topics. Table 1 summarizes the variables.

Table 1: variables

Code	Definition
A1	Number of customers served by the utility
A2	Power decision of the utility conducting the project
A3	Type of the project: R&D, pilot, demonstration, or rollout
A4	Number of customers involved in the project
A5	The interval from the start of the project execution until completion
A6	Types of users: residential (basic) or commercial and industry (advanced smart meters)
B1	The technology used for interfaces between meters and other devices.
B2	How data are elaborated, and the management of who can transmit data
B3	Number of interfaces to communicate with the user and with the concentrator
B4	Indirect measures performed from the meter
B5	Compliance with the international standard
B6	Data security and how it is ensured
C1	Benefits for the end customers
C2	Benefits for the utility conducting the project
C3	Benefits for society
C4	The project’s creation of value
C5	Typologies of costs: operating, capital, and social

C6	Projects need financing from various sources
D1	Status of obligation to implement smart meters
D2	Status of cost-benefit analysis, overall result, and output
D3	Type of unbundling
D4	Minimum functionalities following EU Directives
D5	Tariff design
D6	Initiatives to improve consumer involvement and acceptance
D7	Dedicated initiative inside the utility to train personnel
D8	Presence of the opt-out option. How opt-out cases are handled
D9	Regulators' activities to create social awareness and acceptability
E1	Market agents who are beneficiaries of each advanced solution
E2	Structure of incentives to enable the deployment of advanced smart meter solutions
E3	The role of utility in developing advanced solutions
E4	Degree of the deployment foreseen for each advanced function
E5	Compliance of existing smart meter with technology requirements for advanced options
E6	Degree of standardization of each advanced solution

Source: own elaboration

Table 2 contains the variables with the values they took according to the project characteristic, or according to the features they were meant to capture.

Table 2: variables

Var	1	2	3	4
A1	Up to 1 million	From 1 million to 5 million	From 5 million to <= 10 million	More than 10 million
A2	Only national	Cross-country	Incumbent utility + cross-country	Incumbent utility + market share > 50% + cross-country
A3	R&D	Pilot	Demonstration	Roll out
A4	Up to 1 million	From 1 million to 5 million	From 5 million to <= 10 million	More than 10 million
A5	Up to 6 months	From 6 months to 1 Year	From 1 Year to <= 5 Years	More than 5 years
A6	Residential	na	na	Residential and C&I
B1	Low: suitable for the minimum functionality	na	na	High: suitable for advanced function
B2	Suitable for the minimum functionality	na	na	suitable for advanced function
B3	Only basic interface	na	na	possibility to interface the smart meter with other devices
B4	Only basic elaboration	na	na	4-quadrants measure,
B5	No compliance	na	na	total compliance
B6	Only the basic mechanism provided by the used protocol is implemented	na	na	data are encrypted in all the communication with a standard algorithm

C1	From 0% to 25% is low	From 25.01% to 50% is medium-low	From 50.01% to 75% is medium-high	From 75% to 100% is high
C2	From 0% to 25% is low	From 25.01% to 50% is medium-low	From 50.01% to 75% is medium-high	From 75% to 100% is high
C3	From 0% to 25% is low	From 25.01% to 50% is medium-low	From 50.01% to 75% is medium-high	From 75% to 100% is high
C4	DOF is < -0,5 then the project appears to be financially week	if -0,5<DOF<0 then it "tends to be not desirable"	if 0<DOF<0,5 "tends to be desirable"	DOF>0,5 the project is "opportune"
C5	In premises costs up to 25 %"	25,01% < In premises costs <50%"	50,01% < premises costs < 75,01%	In premises costs add up to more than 75,01%
C6	Private share is from 0% to 25%	Private contribution lies between 25,01% to 50%	The private source is between 50,01 up to 75%	From 75,01% to 100%.
D1	No obligation, no actions done	some initiatives available	No specific obligation, presence of SM rollout	Obligation
D2	Negative CBA	No CBA yet and negative trend	No CBA yet and positive trend	positive CBA
D3	Integrated	Partly unbundled; no a clear structure	Partly unbundled as per EU directives	unbundled
D4	some of the functionalities implemented based on national views, not EU implemented in the SM deployment	some of the minimum functionalities have been implemented	a minimum set of functionalities implemented as provided by EU	a minimum set of functionalities and more have been
D5	Basic tariff schemes/no info provided	na	na	detailed tariff schemes and relevant info provided
D6	No initiatives or no information provided on them	some initiatives but not relevant to the wide consumer base	some initiatives with acceptable feedback	many initiatives to ensure SM awareness
D7	No initiatives or no information	Medium Low - CS is considered but no initiatives	references that CS adaptation is done, but no clear strategy	dedicated projects on adjusting CS
D8	Opt-out not available	opt-out is under discussion	opt-out is available in certain conditions	opt-out is available in all conditions and applied
D9	No involvement or no information	na	na	clear initiatives from the NRA on this
E1	Mainly deregulated	na	na	Mainly regulated
E2	Mainly private	na	na	Mainly public

E3	No role, and no plans to be involved	No role, but plans to be involved	Partial	Whole
E4	<10% of utility market	na	na	>10% of utility market
E5	No compliance	No compliance, but to be considered in future	Partial compliance	Compliance
E6	No standards	Standardization in progress	Partial standardization	Standardized solution

Source: own elaboration

Consistently with previous literature on energy efficiency policies and SDGs [15] The theoretical framework of this study was designed to capture the importance of the variables, and their interaction for supporting the successful implementation of smart meters projects which is the focal point of the analysis.

3. Results

From the analysis of all the relations among the variables used in the survey, 34 significant patterns emerged i.e., unidirectional relationships among variables that were surveyed. The significance criteria were the numbers of relationships in line using as a screening criterion the number of variables encompassed in the patterns that were set to 3 as a minimum. It shall be pointed out that the relationships among two variables that were excluded in the results of this paper are interesting anyway. Indeed all the patterns included those made up by two variables serve as a tip, confirm of assumptions, or insight for stakeholders involved in the development of smart meters projects. Table 3 reports the patterns among variables.

Table 3. identification of patterns

N	pattern	n	pattern
1	A6→B1→B6→B2→C1	18	A6→B2→C1
2	A6→B1→B6→B2→C2	19	A6→B2→C2
3	A6→B1→B6→B2→C3	20	A6→B2→C3
4	A6→B1→B6→B5→C2	21	A6→B4→C1
5	A6→B1→B6→B5→E5	22	A6→B4→C2
6	A6→B4→B2→C1	23	A6→B4→C3
7	A6→B4→B2→C2	24	D1→D8→D6
8	A6→B4→B2→C3	25	D1→D8→D7
9	A6→B1→B6→B2	26	D1→D9→D6
10	A6→B1→B6→B5	27	D1→D4→E5
11	A1→A4→C2	28	A6→B4→D6
12	A1→A4→C3	29	A6→B4→D7
13	A3→A4→C2	30	D1(→)C6
14	A3→A4→C3	31	A1→A4→A5
15	A6→B1→C1	32	A3→A4→A5
16	A6→B1→C2	33	A6→B1→B6
17	A6→B1→C3	34	A6→B4→B2

Source: own elaboration

Table 5 tabulates the description of the emerged patterns from which it is possible to infer that the higher the number of relationships within patterns, the higher the complexity of management as a multitude of additional circumstances may emerge.

Table 4: summary of patterns

N	Description of relationships among the variables
1	Advanced smart meters require more advanced ICT functions; if technologies support advanced functions, higher data security level is achieved, so enhanced data security needs upper layer protocol; if the value of advanced functions increases, so do the benefits for users: savings, awareness, quality of supply and service.
2	Advanced smart meters require advanced ICT functions; if technologies support advanced functions, higher data security level is achieved, so enhanced data security needs upper layer protocol; the higher is the value of advanced functions, the higher the business benefits: loss reductions, fewer operation managements, quality of supply.
3	Advanced smart meters require more advanced ICT functions; if technologies support advanced functions, higher data security level is achieved; enhanced data security needs upper layer protocol suitable for advanced functions, if the value of advanced functions increases, so do the benefits for countries: carbon dioxide reductions, energy efficiency.
4	Advanced smart meters require advanced ICT functions; if technologies support advanced functions, higher data security level is achieved, so to reach a high data security level implies to be compliance with the corresponding standards; more compliance implies more manufacturers, lower price and more business benefits.
5	Advanced smart meters require advanced ICT functions. If technologies support advanced functions, higher data security level is achieved. So, to reach a high data security level implies to comply with the corresponding standards. SM solutions compliance with the standards correlates with compliance with smart grids solutions and technical requirements.
6	Advanced smart meters require elaborated data; there are some type of elaborated data that can be given only by an advanced upper layers protocol, so if the value of advanced functions increases, so do the benefits for users: savings, awareness, quality of supply, quality of the service.
7	Advanced smart meters require elaborated data; there is some type of elaborated data that can be given only by an advanced upper layers protocol, so the higher is the value of advanced functions, the higher business benefits: loss reductions, fewer operation managements, quality of supply.
8	Advanced smart meters require elaborated data; there are some type of elaborated data that can be given only by an advanced upper layers protocol, if the value of advanced functions increases, so do the benefits for countries: carbon dioxide reductions, energy efficiency.
9	Advanced smart meters require advanced ICT functions; if technologies support advanced functions, higher data security level is achieved, so enhanced data security needs upper-layer protocol.
10	Advanced smart meters require more advanced ICT functions; if technologies support advanced functions, higher data security level is achieved, so to reach a high data security level implies to be compliance with the corresponding standards.
11	The greater the number of customers served by the utility, the greater the number of customers involved in the project, so the higher the number of customers involved, the better economy of scale.
12	The greater the number of customers served by the utility, the greater the number of customers involved in the project, so the higher the number of customers involved, the greater the number of energy efficiency initiatives and emissions reductions.
13	The higher the value of the project scale, the greater the number of customers involved in the project, so the higher the number of customers involved, the better economy of scale.
14	The higher the value of the project scale, the greater the number of customers involved in the project, so the higher the number of customers involved, the greater the number of energy efficiency initiatives and emissions reductions.

15	Advanced smart meters require more advanced ICT functions; if technologies support advanced functions, higher business benefits are achieved: loss reductions, fewer operation managements, quality of supply.
16	Advanced smart meters require more advanced ICT functions; if technologies support advanced functions, the greater customer benefits are given: savings, awareness, quality of supply, quality of the service.
17	Advanced smart meters require more advanced ICT functions, so if technologies support advanced functions, the benefits for countries increase carbon dioxide reductions, energy efficiency.
18	With advanced smart meters, more advanced functions are required by the upper layers protocol; so if the value of advanced functions increases, so do the benefits for users: savings, awareness, quality of supply, quality of the service.
19	With advanced smart meters, more advanced functions are required by the upper layers protocol, so the higher is the value of advanced functions, the higher the business benefits: loss reductions, fewer operation managements, quality of supply.
20	With advanced smart meters, more advanced functions are required by the upper layers protocol, if the value of advanced functions increases, so do the benefits for countries: carbon dioxide reductions, energy efficiency.
21	Advanced smart meters require elaborated data, so the higher the value of elaborated data: the greater the number of customer benefits are given: savings, awareness, quality of supply, quality of the service.
22	Advanced smart meters require elaborated data, so the higher the value of elaborated data, the higher the business benefits: loss reductions, less operation management, quality of supply.
23	Advanced smart meters require elaborated data, so the higher the value of elaborated data; the higher the countrywide benefit: carbon dioxide reductions, energy efficiency.
24	The mandate of a rollout refers implicitly to the opt-out options/implications, so if opt-out available, the utility should have in place initiatives to convince the customers of the benefits of the SM.
25	The mandate of a rollout refers implicitly to the opt-out options/implications, so if opt-out available, the utility needs to have in place well-adapted customer service to cope with possible inquiries.
26	The mandate provides certain roles and actions that the NRA should take related to customers and smart meters, so if there is a high level of NRA involvement in customer initiatives, they are/should be linked with the utility ones and vice versa.
27	The higher the level of mandate available, the higher the level of correlation with minimum functionalities specified, so high implementation (specification) of minimum requirements will influence future high level of compliance with tech requirements for advanced solutions.
28	Advanced smart meters require elaborated data, so the higher the level of elaborated data, the higher the level of customer-related initiatives.
29	Advanced smart meters require elaborated data, so the higher the level of elaborated data, the higher the level of customer service adaptation.
30	Depending on the conditions of the rollout (mandate wise), private investment can be meager of very high.
31	The greater the number of customers served, the greater the number of customers involved in the project. The higher the number of customers involved, the longer the duration of the project.
32	The higher the value of the project scale, the greater the number of customers involved. So, the higher the number of customers involved, the longer the duration of the project.
33	Advanced smart meters require advanced ICT functions; if technologies support advanced functions, higher data security level is achieved.

34	Advanced smart meters require elaborated data; there is some type of elaborated data that can be given only by an advanced upper layers protocol.

Source: own elaboration

From a reading of table 5, interesting insights arise both for energy utilities and for policymakers. Indeed even if given that our findings are based on a limited number of projects, the patterns that emerged from such analyses should consequently be treated with caution. The implications for policy are clear. Indeed thanks to the global commitment to decarbonization, international legislation, for example, the clean energy package in Europe, refers to the development of next-generation technologies related to renewable energy sources; smart meters, active energy consumers; energy efficiency; sustainable transport; and carbon capture storage solutions. Consequently, well-designed policies reduce market barriers and enable innovation [16] such as the solutions as mentioned above.

The role of energy utilities in the grid management and in the decarbonization process through energy efficiency projects is increasingly important. One of the main challenges energy utilities must manage is flexibility that can be used to adapt demand profiles to supply peaks in renewable generation or available capacity in distribution networks. Flexibility is defined as the modification of generation, at the individual or aggregate level, to provide a service within the energy system or maintain stable grid operation [17]. In this context, smart grid technologies are projected to change the distribution of electricity, requiring a more active role from energy utilities in managing the network.

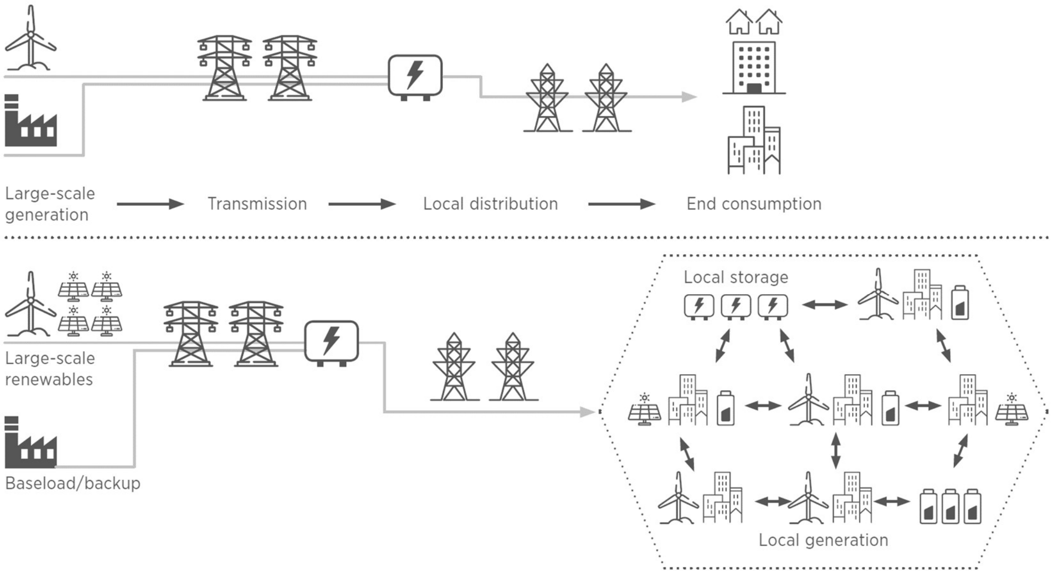

Figure 1: Role of energy utilities in the new market design. Source: [18]

The role of energy utilities in the new market design differs from their traditional role. Traditionally, energy utilities managed the connection and disconnection of distributed energy sources, planning, maintenance and management of networks, management of supply outages, and energy billing if vertically integrated. At a European level the Market Design Regulation COM (2016)861 outlines that the new tasks of energy utilities include the fundamental cooperation mechanisms to ensure a smart energy network and an efficient market, open to consumer empowerment and optimal use of distributed energy sources. Notably, energy utilities will play a more dynamic role in the new market configuration than in the past because distributed energy sources require a more active role because of the increasing number of players in the electricity system at the distribution network level. Investments in power grids entail significant technical, implementation, and strategic risk, as a consequence, are active efforts required to minimize uncertainties, costs, and risks to stakeholders [19] in general and the projects' undertakers in particular

4. Discussion

SGG 7 aims to ensure access to affordable, reliable, sustainable, and modern energy for all. Specifically, SDG 7 contains four targets. The first target deals with universal access to modern reliable energy services at affordable prices. The second states that the share of renewable energy must increase. The third aims to double the overall rate of energy efficiency improvement. The fourth aims to improve international cooperation to facilitate access to energy research and technology and to promote investment in energy infrastructure and clean energy technologies.

Power grids and their components are undergoing radical transformations to fulfill environmental objectives and allow proactive demand–response user behavior. The technological switch from the current centralized model to distributed generation and the integration of non-network assets requires substantial investments [20]. If it is well-known that the replacement of aging transformers increases the energy efficiency of the power system because of lower fault rates, the cost of such a solution depends on many variables: power rating, materials, and capacity. Typical lifetime is 40 years, and a frequent 20% operating time extension with a 1.75 factor on fixed losses for transformers aged over 40 years. Replacing such transformers can reduce these losses by 80% [21], [22]. Consistent with other estimates, the remarkable potential is observed in terms of loss reduction because the loss reduction is 0.1% if the asset replaced is 0.3%; thus, 25%–30% of loss reduction is attainable if 100% of transformers are replaced [23].

Regarding the line capacity increase, the integration of different energy sources into the power system calls for both modernization and the upgrading or expansion of distribution infrastructure. Increases in line capacity can facilitate the integration of distributed energy sources and the hosting capacity for energy storage and other storable loads. Based on the EU infrastructure package proposal, approximately 10% of the total investment for electricity transmission is from public funds. However, energy utilities have not been able to finance the required scale of investment by raising debt. Thus, both the costs of debt and the concerns about equity investors that own utility assets as low-risk assets would increase [24]. Grid technologies that increase the efficient use of the existing power infrastructure (e.g., by maximizing the use of the capacity) have not yet been sufficiently deployed because of the appropriate regulatory framework is unavailable. Considering the replacement of conductors, to avoid power outages from component and equipment failures, the industry should replace 0.5% to 1.0% of the distribution network annually. Dynamic line rating can significantly increase efficiency and network capacity, avoiding permitting issues, in the short run. This solution is cost-effective: 10%–30% additional capacity is realized at 5%–10% of the cost of alternative solutions such as conductor replacement. In addition to cost, a key added value of the dynamic line rating are tools that enable operators to minimize their interventions to make system adjustments [25]. Measuring the financial benefits of dynamic line rating systems is challenging. Although the savings potential from dynamic line rating is up to 3%, forecasting the economic outcomes is difficult because they relate to grid capabilities and congestion that are difficult to predict. Nevertheless, the implementation of regulatory measures that guarantee the fair recovery of investments is necessary.

Another typical solution is to increase the voltage level. Ceteris paribus, the higher the voltage level, the lower the current necessary to distribute the same amount of electricity, voltage drops, and line losses, the higher the grid's current capacity. Broadly, significant benefits occur in an MV network where multiple voltage levels exist. Many factors influence the cost of this solution, for example, the age of the infrastructure, the number of already fitted assets, the position, underground or overhead, and the terrain (with different multipliers). In this sense, insulation and protection play a key role. The price of the insulation is approximate 5%–8% of the total price of the conductor. Prices for the different insulator string types vary widely according to voltage, typology of string, number of caps, material, and other components. Insulators are frequently used for low voltage and medium voltage, and insulator strings (V-string or I-string) are commonly used for higher voltage. Ceteris paribus, higher voltage levels reduce the current flow through the conductors. Thus, networks' reinforcement can be deferred, specifically, if the number of assets to be replaced is limited.

Based on the targets of renewable energy sources, a decentralized grid both leads to loss reduction and improves the reliability of the system.

Regarding the distributed energy sources hosting capacity, their current penetration trend into the power sector implies significant power infrastructure expansion and upgrades. Due to the decrease in core photovoltaic module prices, especially in smaller photovoltaic plants where the share of the balance of system components represents typically 50%–60% of the total system capital costs. Regarding transformer switching, until quite recently, there was no overall standard for serial communications in enabling technologies for transformer switching. Smart substations require new infrastructure capable of supporting the higher level of information monitoring, analysis, and control required for grid operations, and the communication infrastructure. The smart substation must integrate variable power flows from renewable energy systems in real-time and maintain a historical record or have access to a historical record of equipment performance. Combined with real-time monitoring of equipment, the smart substation facilitates reliability-centered and predictive maintenance. A recent study estimates a cost of €45th–€70th per substation to achieve the optimal performance level. New substations will incorporate communications and IT infrastructure at the time of construction [26]. Network reconfiguration has also gained importance among the solutions to upgrade grids. Real-time monitoring of the power flow in the network and the condition of networks' assets can contribute to significantly improved asset management decisions. This requires efficient handling of a massive quantity of data from the smart grid monitoring sensors. Increasing the number of remotely controlled switches reduces the number of substations to be inspected when a fault occurs. The use of remotely controlled switches reduced the number of interrupted customers by 35%. The use of automatic control for fault management leads this number to 55%. Capacitor banks also play a prominent role because these components support the balance of the overall system [27]. Finally, the introduction of controlled phase switches in the low voltage network is worthwhile to consider. Low voltage networks often are characterized by imbalances because single or double phase customers are connected to the three-phase system. An effective phase balancing can be performed by dynamically switching the phase a user is connected to, according to the user's load. Finally, replacing three-phase inverters by three single-phase inverters can control the injection phase by phase to balance the network [23]. A prominent role in the grid upgrading process is played by smart meters. Smart meter implementation projects have been initiated throughout Europe because of EU directives 2012/27/EC and priors. Unsurprisingly, smart meters are considered essential for energy efficiency [4], the transition to a cleaner economy, and as a step in transforming a typical grid into a smarter grid [5], [6]. Nonetheless, smart meter investments occur in a dynamic environment [28], where consistent policies boost lead to diffusion targets achievement [29].

Many approaches have been proposed to provide insights into the impact of smart meters on the efficiency of energy distribution systems, prompting a growing literature [30]. A suggestion was, for example, that many market agents (e.g., policymakers) perceive efficiency as a physical or financial output/input ratio [31]. To take full advantage of the potential of smart meters large-scale deployment, a multidisciplinary interpretation is desirable [32]. Notably, for example, information [33] equally concurs in the diffusion of this technology. To this extent, several studies have added pieces of evidence on the capabilities of smart meters to fulfill primary goals such as enhance demand response, load control [34], and control of user behavior [35], [36] by providing them with real-time feedback [37], [38].

The deployment of these innovations would prompt economic and social transformations toward a cleaner economy [39], where infrastructure plans and green industrial policies are prominent management tools for stimulating sustainability [40]. Scholars proposed recommendations to stakeholders on how to overcome the common obstacles endangering the uptake of SM solutions [7]. The primary value-added of such a study would be its contribution to effectively collecting the most successful experiences in the field and highlighting the conditions that enabled their development.

5. Conclusions

The need to better understand the role of smart meters in the energy transition process justifies the analyses presented in this article. Because SDG 7 aims to ensure access to affordable, reliable, sustainable, and modern energy for all, this paper has provided accurate indications regarding smart metering because they are considered enabling technologies for the transition to happen. The work advances the literature on the factors that favor the success of smart metering development projects. A great deal of information has emerged from 34 significant patterns that stakeholders shall consider. All the patterns serve as a tip, confirm of assumptions, or insight for stakeholders involved in the development of smart meters projects. Notably, energy utilities play a crucial role in achieving a more sustainable urban environment through improved performance in the management and delivery of energy services. It is no wonder that today energy utilities manage and provide many smart services, and more and more systems based on smart meters, advanced energy management solutions, and applications that favor an active role for customers are being developed. In this respect, energy utilities must be able to develop well-design revenues management systems to capture the value they create [41], being in a regulated environment. For this to happen, policymakers should ensure regulatory stability and the fair distribution of costs between operators and users in the energy sector who benefit from the development of technologies because the long-period investments in power grids benefit energy utilities, users, and society.

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