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Smart metering projects: an interpretive framework for successful implementation

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Abstract

Purpose. We analyze a set of smart meters implementation projects and provide insights and recommendations to facilitate smart metering deployment strategies.

Design/methodology/approach. Several significant projects are analyzed on different fronts: scale, technology, economics, and regulation using a common methodology to unfold patterns that constitute key components of successful smart meters diffusion.

Findings. Key elements and controllable enabling patterns from Europe-wide SM implementation projects are identified together with drivers and barriers for patterns replication.

Practical implications. We provide a framework considering different stakeholders that will help distribution system operators to accelerate and extend smart meters' penetration.

Originality/value. Based on the Meter-ON project (supported by the 7th Framework Program of the European Commission) we put valuable information on the same basis for comparison purposes to facilitate the large-scale deployment of smart meters in Europe.

Keywords
Smart meter projects, Smart grid, DSO, industrial policy, energy efficiency, directive 2012/2/EU

1. Introduction

The energy sector has significantly changed in recent years and has introduced new challenges, especially for policymakers and distribution system operators (DSOs). Among other challenges, there is the management of the smart metering (SM; abbreviation also used for smart meter) technologies and their rollout. Several SM implementation projects have been initiated throughout Europe because of the EU directive on energy efficiency 2012/27/EC and priors. No wonder that scholars and industry experts consider SMs essential for the healthy functioning of the energy distribution market and for energy efficiency (Nachreiner et al., 2015). Also, SMs represent an important part in the efforts aimed at transforming a typical grid into a smarter grid (Erlinghagen et al., 2015; D'Oca et al., 2014). Prior research suggests that SMs penetration efforts occur in a dynamic environment (Luthra et al., 2014) where consistent industrial policies and smart regulation boost diffusion targets (Pupillo and Bérenger, 2013). At the time of this writing, regulatory and techno-economic barriers still prevent a smooth and capillary diffusion across Europe. As the rollout of SMs requires close partnership working with stakeholders, it is important to count on information about implemented projects so far in a systematic way. This is particularly important as most of European countries will invest additional efforts to harmonize policies, regulatory mechanisms and standards. Thus, based on an empirical evaluation of different projects, our purpose is twofold. First, we provide stakeholders with recommendations aimed at weakening such barriers; second, we introduce some future opportunities. The ongoing situation presents governments, energy suppliers and DSOs with new challenges for which they need to develop new expertise. In this regard, it is important to understand how the level of functionalities of SMs impact costs and benefits for DSOs and society. We follow on the issues behind the purpose of the Meter-ON project whose objective was to facilitate the large-scale deployment of SMs across Europe. We provide a comparable framework that, based on recent experiences, sheds some light on appropriate approaches for implementing SM projects. We develop these ideas in more details, analyzing some recent highly representative and successful projects starting from validated outcomes of the Meter-ON project. The empirical study sought the direct participation of DSOs involved in SM projects, and we carefully considered both technical and non-technical issues in strong cooperation with them. Therefore, we undertook the analysis considering a range of additional factors that emerged to be significant in influencing the performance of SM projects. We gathered and collected the data via extensive review of previous works and empirically in close cooperation with the stakeholders involved. We identified a set of cause-effect relations, namely, patterns. These patterns represented the key element for discussion and delivering concluding remarks. Our results support DSOs in their strategies aimed at effectively deploying SMs and SM technology, governments in their processes aimed at liberalizing the market and NRAs in their procedures aimed at defining regulations. Other stakeholders can take advantage from our results and implications by examining the set enabling patterns for implementation projects. This paper is organized as follows. First, we discuss the current issues in SM implementation research, as well as ways to overcome some of the obstacles that deter the field's development; then we outline the research objectives; the following paragraphs define the field of our manuscript as well as the data collection and analysis methodologies; next, we present main results from the present study that add to those of previous literature; the results section is followed by the discussion, implications and concluding remark.

2. Background

2.1. State of the art and research focus

SMs are electronic systems that can measure energy consumption, provide more information than a conventional meter, and can exchange data using a form of electronic communication (European Parliament, 2012). SM technology trends have been well documented (Pepermans, 2014; Sharma and Mohan Saini, 2015), and arguably represent one of the most important themes addressed in several studies dealing with smart grid development and modernization (Colak et al., 2015; European Commission, 2011; López et al., 2015). Modern SMs are equipped with two communication channels: a communication channel to the electrical system and a communication channel to customers, providing two possible connection solutions for remote reading and remote management: through the electricity grid or radio frequency. Some important goals of SMs are, for example, the increase of remote reading and remote management efficiency, the increase of the granularity of energy measurements detected in remote reading, the development of data available in real time. This implies the possibility of new processes and services, thanks to the faster availability of data to the door users and customers. Policymakers and NRAs should establish incentive mechanisms for recognizing the costs. Many different approaches have been proposed to shed some light on the impact of SMs on the efficiency of energy distribution systems, prompting a growing literature (Du et al., 2013) in different disciplines. Besides, measuring efficiency improvements related to SMs is a complex issue which may be approached from various angles. It has been suggested, for example, that many market agents, e.g. policymakers perceive efficiency as a physical or financial output/input ratio (Lovins, 2004). Provided different definitions that align with the dominant paradigm of the respective disciplines, to take full advantage of the potential that SM large-scale deployment can produce, a multidisciplinary interpretation is desirable (IEA, 2014). In fact, not only the technological factors like different paths in technology adoption between countries but also social aspects, for example, information gap (Palmer et al., 2013), equally concur in the diffusion of this technology. To this extent, several studies have added pieces of evidence on the capabilities of SMs to fulfill primary goals, such as enhance demand response and load control (Joung and Kim, 2013) and transform customer energy use behavior, (Gellings and Samotyj, 2013; Winther and Ericson, 2013), especially, providing homeowners with real time feedback on their electricity consumption (McKerracher and Torriti, 2013). From the works mentioned above, a common feature emerges; SMs play a central role as enabling technologies as long as capable of underpinning the shift to a greener economy (Ivanov et al., 2013). Such enabling technology frequently struggles when it comes to replacing existing products on call for behavior changes across users. Therefore, well-designed policies can help to guide new directions of existing regimes by reducing market barriers and enabling innovation and business development (Pupillo and Bérenger, 2013; Ruby, 2015). These studies hinted that market penetration might be predictable based on the appropriateness of the policies and industrial strategies. Nonetheless, a large-scale deployment of these innovations would prompt economic and social transformations with uncertain impacts on economic growth (Carlsson et al., 2013). A recent study furthered this idea stating that infrastructure plans and green industrial policies are two important management tools for stimulating a sustainability transition that should be implemented following complementary channels (Giordano, 2015). Specifically, a recent study sheds light on missing aspects in the current regulation, recognizing DSOs as regulated monopolies and key players along the supply chain (Ruester et al., 2014). Despite the corpus of studies dealing with the forces that drive R&D and the barriers that firms face in innovating in the energy industry (Costa-Campi et al., 2014), as far as we know, only a few have investigated the real-world issues affecting the widespread deployment.

Thus, our goal is to bridge the gap between basic research and markets, controlling for the most important contextual factors which are expected to influence SM deployment; this is done using a mixed-method research approach. At the time of this writing, there is need for additional information about the situation regarding the programming and benchmarking of SM project across Europe which are of strategic significance from both industry and policy-making.

2.2. Context

As SMs will play a significant part in EU's transition to a low-carbon economy, the Commission has undertaken a comprehensive regulatory framework intended to facilitate their diffusion (Tobergte and Curtis, 2013). The Meter-ON project ended with the provision of recommendations to stakeholders on how to tackle common obstacles endangering the uptake of SM solutions. The main value added of the research project was its contribution to effectively collecting the most successful experiences in the field and highlighting the conditions that enabled their development. The results, including data, tables and charts related to each case, have been published in a report available online. Nevertheless, the target audience of the project was wide, namely, all current and potential stakeholders. We go beyond such results and deeply investigate the implementation projects from a specific point of view to support, especially DSOs and policymakers. Indeed, we specifically focus and unfold the opportunities and challenges that DSOs – who are in most European countries responsible for rollout and operation – face to generate, acquire and deliver value for the collectivity.

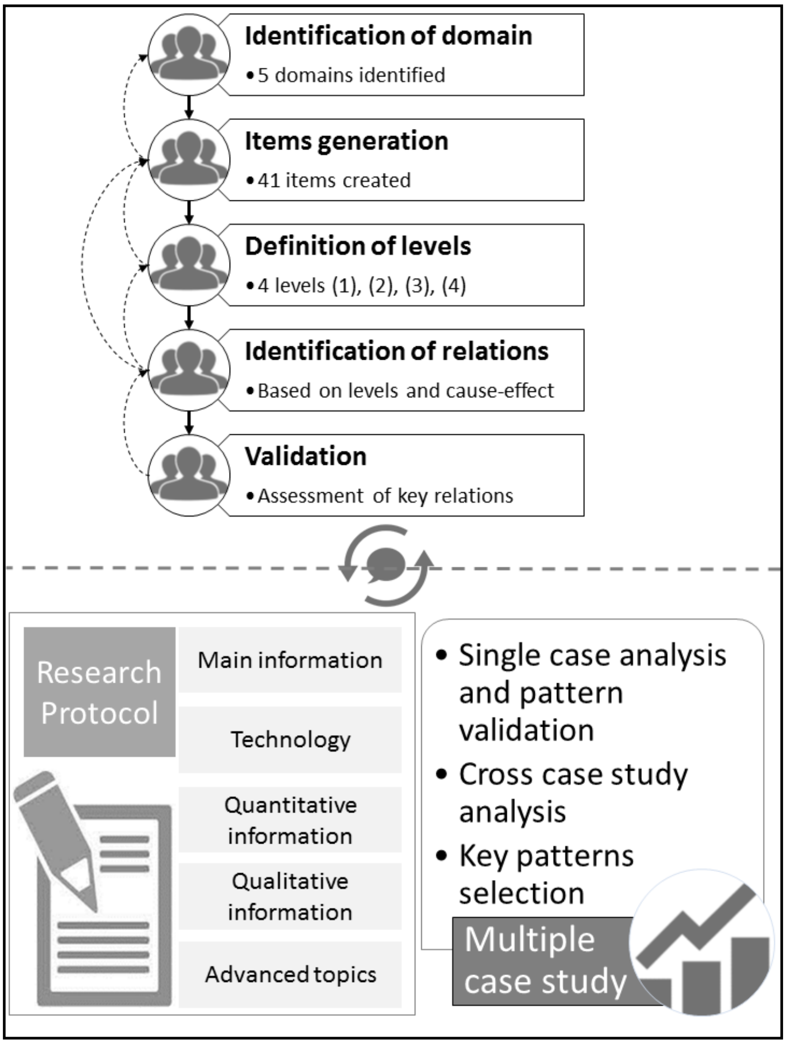
3. Research objectives and design

This document provides practical information regarding the viability of SM implementation projects according to a common framework. Results highlight the best practices, patterns and the activities that DSO carried out during their projects. Beside implications for policymakers, the document primarily serves the DSOs with the aim to promote the adoption of best practices to support the industry in the process of SM implementation. DSOs may evaluate the patterns presented in this paper and adapt them according to different business environments. In fact, patterns are sufficiently general, adaptable and worthy of imitation that they can be adapted to different situations. The document outlines several patterns and provides explanatory notes aimed at further defining a common understanding of the requirements to set a successful industrial strategy in this respect.

3.1. Approach, workflow, and data collection

Our research method merged quantitative and qualitative analysis and aimed to explain "how to" questions. To this extent, the multiple case study approach perfectly complied with our purposes and enabled both replication and extension. Thanks to this approach, the results were more robust and generalizable (Santos and Eisenhardt, 2004). Consistently, we used a combination of tools to collect data: a protocol directed at DSOs officers involved in the research along with qualitative semi-structured interviews of stakeholders. The rationale of this approach was underpinned by the principle of triangulation (Hastings, 2010) to enhance confidence in findings (Bryman, 2004). As said, the primary source of data acquisition was a protocol that contained the rules to be followed to fill it correctly (Yin, 2014). The protocol – reported in Figure 1 – was designed to guarantee clearness, correctness in items, order and effectiveness of the items contained (Brace, 2004). First, supported by the focus group, we decided what information to call for. After that, we selected how to reach the target respondents (using different communication channels). Items of the protocol were combined into different sections according to their main domains. Considering the pros and cons of the selected research method (Ruggiero et al., 2015; Chiesa et al., 2009; Mallaburn and Eyre, 2014), it is emerged that it is consistent with our purposes including market development opportunity (Di Foggia, 2016) and benefits for the society.

Figure 1: Research approach and protocol



Source: own elaboration

Over the course of the 24 months, we completed three data collection campaigns which are as follows: first campaign: Portugal, Romania, Italy, Spain and France; second campaign: Belgium, Hungary, Finland, The Netherlands and Austria; third campaign: Finland, Denmark, Sweden, Bulgaria, Poland and Latvia. This corresponded to approximately 41 million meters installed across Europe – given additional 100 million meters due to be installed by 2020. The mentioned campaigns allowed us to gather and analyze information from a remarkable number of projects. As a result of the data collection campaigns, we relied on highly representative and successful projects and experiences. Differently from some other studies carried out previously, we benefited from the direct participation of DSOs involved in SM projects.

3.2. Information domains and items

A considerable amount of information from different perspectives (general, economics, regulation, technology and advanced topics) was required to perform the analyses. Thus, for respondents' convenience, questions were classified into five different sections, i.e. five information domains as Figure 1 shows. The first domain contained general information on DSOs and the projects they were carrying on. The second domain focused on technological analysis: grid information, information on electricity SM solutions, information on SMs, cybersecurity and privacy. The third section delimited questions referred to the quantitative analysis domain: financial information, make-or-buy and development process, and actors involved in the supply chain. The fourth domain targeted the qualitative aspects: regulatory and legal framework, user acceptance and customer involvement. The last domain focused on advanced topics, e.g. impact of on distribution network operation, electric vehicle charging infrastructure, support to distributed generation, demand response and other solutions. Each domain contained a set of items as presented in Table 1.

Table 1: Information domains and items

ID	Code	Label	Definition
A	A1	N° of customers served by the DSO	Number of customers served by the DSO within the national boundaries
	A2	Decision power of the DSO	Power decision of the company carrying out the project within and outside the national boundaries
	A3	Project Scale	Type of the project (R&D, pilot, demonstration project or a rollout program)
	A4	Customers involved in the project	Amplitude of the project. The metric is the N° of customers involved in the project
	A5	Duration	interval from the start of the project execution until the moment the project is completed
	A6	Type of customers:	Customers involved in a project: residential customers, commercial and industrial customers, or both
B	B1	Type of communication technology	Technology used for the interfaces between the meters and the other SM devices. We refer to the lower layers of the OSI stack. Focus: technical solution used to send the information
	B2	Type of upper layer protocol	Upper layer of the OSI stack. The protocol used to send data, the way in which data are elaborated and the managing of who can transmit data
	B3	Type and number of interfaces	Number of interfaces to communicate with the user (e.g. display, optical output, serial port, ZigBee…) and with the concentrator (e.g., power line communication, Wi-Fi, or ZigBee modem …)
	B4	Elaborated data	The indirect measures (e.g., active power, reactive power, frequency, energy etc.) that are performed from the meter starting from the direct measure of voltage and current
	B5	Compliance with standards	Compliance with international standard, i.e. if the parts of a meter (HW, SW, communication, etc.) are compliant to the related international standards
	B6	Data security level	The issues involved in data security and the way in which they are ensured
C	C-EF1	Customer benefits	Benefits for the end customers. It includes also non-monetized benefits
	C-EF2	Business benefits	Benefits for the utility carrying out the project. It includes also non-monetized benefits.
	C-EF3	Countrywide benefits	Benefits for the whole society. It includes also non-monetized benefits
	C-EF4	Degree of Feasibility	The project's creation of value. As the weighted average cost of capital is the expected future cost of funds
	C-EF5	Cost Distribution	This item embeds the three typologies of costs: operating, capital, social.
	C-EF6	Source of financial support	Projects need financing from various sources, in some combination of equity and debt.
	C-SP1	Proximity to end user	Degree of proximity of the DSO to the end user, in terms of quantity of the final activities performed by the DSO itself. This item refers to the activities directly experienced by the end users, performed by the DSOs
	C-SP2	Level of integration	Number of supply chain activities performed by the DSO out of the total (that is, out of the six: manufacturing and assembly, logistics, installation, maintenance, data communication, data management)
	C-SP3	Within group acquisition	Existence of acquisitions from suppliers belonging to the DSO group
	C-SP4	Number of suppliers	Number of suppliers to supply each of the activities outsourced (contrasting 1 supplier vs. more than 1).
	C-SP5	Exclusiveness of supplier	Exclusiveness of supply in terms of number of DSO competitors supplied by the DSO suppliers for each of the activities outsourced (suppliers supplying only to the DSO vs. suppliers supplying also competitors)
	C-SP6	Buyer supplier relationship	Kind of buyer-supplier relationship, in terms primarily of duration of the relationship set-up with the supplier(s) for each of the activities outsourced (typically, ranging from short-term to long-term relationship
D	D1-1	Mandate on SM	Status of obligation to implement SM in a country, what are the legal conditions related to SM deployment
	D1-2	Country cost benefit analysis status	Status of cost benefit analysis, overall result, and output
	D1-3	Unbundling	What type of unbundling has been adopted (as per the EC directive 2009/72/EC) and what is the current market structure (responsible, beneficiaries etc.)?

	D1-4	Minimum Functionalities requested	The set of Minimum functionalities set in a country in accordance with EU Directives (having in mind each country perspective on SM)
	D1-5	Tariff Schemes	How tariffs are set: bundled pricing i.e. where the charges that make up the rates are shown as a combined rate on the bill. Unbundled pricing when the network charges are split out from the energy charges
	D2-1	Marketing and Customer Involvement	This item is aimed at testing whether he utility dedicated initiatives to improve consumer involvement and acceptance as well as the feedback.
	D2-2	Customer Service Adaptation	Presence or not of a dedicated initiative inside the utility to train personnel
	D2-3	Opt-out option implications	Presence of the opt-out option. How are opt-out cases handled
	D2-4	National Regulatory Authority (NRA) involvement in customer issues	NRA activities to create awareness. Focus in the discussion on the connection between NRA involvement supporting the utility and on how a better the collaboration can be achieved
	D2-5	Vulnerable customers	This refers to the socially vulnerable customers (health - special needs, life support; economic)
	D2-6	Privacy level	Issues related to privacy and data security and the way in which they are ensured
E	E1	Beneficiaries	This item describes the list of market agents who are beneficiaries of each advanced solution. Benefit preference orders this list
	E2	Incentives	Structure of incentives to enable the deployment of advanced solutions, specially focused on regulated incentives for the meter operator (or DSO). Includes crossed incentives between market agents
	E3	DSO role	It describes the role of DSO in developing advanced solutions, considering the degree of implication (no role, client, network access provider, facilitator, operator, competitor).
	E4	Deployment Scale	This item defines the degree or scale of the deployment foreseen for each advanced function
	E5	Compliance with tech requirements	Compliance of existing SM solution with technology requirements for advanced solutions, i.e. the gap between the SM solution capabilities and the advanced solution needs (i.e. real-time requirements)
	E6	Openness of the advanced solution	This item describes the degree of standardization of each advanced solution (standardized versus proprietary solution), with a special focal point on communication interfaces and protocols

Source: own elaboration

For each information domain, common relevant patterns among the SM projects (for example, regarding approaches, choices and strategies) were identified. Based on an in-depth focus group highlighting the theoretically most influential factors and patterns, a cross-case analysis was performed. From the cross-case analysis, we inferred the most relevant relationships and interactions among the information domains. Where the conceptual relationships – identified by the panel of experts – differed from the experience in the projects, feedback from the projects was used to review these relationships.

3.3. The focus group and stakeholders

Typically, focus groups involve a group of people who come from similar backgrounds with similar experiences and concerns (Krueger, 2004). In this research, focus group members corresponded to representatives of all stakeholders along with representatives of DSOs and research institutions. Precisely, the members reflected the instances of the following stakeholders. ESMIG, an industry association which represents European companies which provide products, technologies and services within the metering industry; AIT, a technology institute specialized in the key infrastructure issues; EDSO, the DSOs association for smart grids; IEC, the international standards and conformity assessment body for all fields of electro-technology; METERS and MORE, a consortium for the implementation of global SM solutions; GEODE, a European DSO representing local energy companies; CEER, Council of European Energy Regulators; BEUC: the European consumer association; and Government officers from different countries. The focus group supported the entire research workflow, specifically in the evidence evaluation and in forward-looking appraisal to enhance the reliability of the analysis. Focus group sessions were dedicated to specific areas of interest allowing participants to discuss the topic in greater detail. As it was a European project and participants came from different countries, the project leader acted as a facilitator in it. The facilitator thus played a major role in obtaining good and accurate information from the focus groups. With the support of focus group members, we fine-tuned the research domains, the items, the measurement levels, the relations and the results.

3.4. Items operationalization and measurement

To convert the information into measurable data, the items were operationalized (Mueller, 2004) and levels to be assigned to each item were defined. Such levels complied with two criteria: interest and controllability. The interest was defined as a factor aimed at capturing the relevance of an item for each stakeholder. The controllability criteria aimed to capture the stakeholder's ability to influence a specific item. Each item was ranked from1 to 4 according to a ordinal scale (Brace, 2004). The scale properties were adapted according to the characteristics of the items, e.g. (1) low, (2) medium-low, (3) medium-high, and (4) high. To evaluate the relevance for the actor involved or stakeholder, a scale of values ranging from 1 to 4 was adopted, namely, low relevance, medium-low relevance, medium-high relevance and high relevance. Also, to evaluate the level of controllability of an actor, namely, how much this actor could do to manage the item, a scale of values ranging from 1 to 4 was adopted, namely, low controllability, medium-low controllability, medium-high controllability and high controllability. In this way, it was possible to identify a relationship (cause and effect according to decisions taken in the focus group) for each interaction among items. Based on this conceptualization, research questions were developed to isolate the specific correlational relationships among items (DeForge, 2010). The procedure used to evaluate the relations among items made it possible to focus on reduced number of cases. The discriminating factor was the relation robustness. The causal effects of such relations were confirmed by the focus group members who also confirmed empirical evidence. The next task was to arrange the items into a relation matrix containing the relations to select the most viable reported in Annex 2 (Appendix). The matrix was filed to the focus group for final validation.

4. Results

The analyses showed that most of the items were connected and that several causal links among relevant items emerged. The significance of the links was evaluated in terms of strength of the relations as well as length of the chain, specifically patterns leading to an item having level of interest (4) at least for one stakeholder, patterns including only links characterized by strongest relationships (4), patterns including at least one item controllable at the highest level (4) by at least one stakeholder. Only the 50 most significant patterns showed in Table 2 were examined.

Table 2: identification of patterns

Pattern	Pattern	Pattern
(A6) →(B1)→(B6)→(B2)→(C-EF1)	(A6)→(B2)→(C-EF1)	(A6)→(C-EF3)
(A6)→(B1)→(B6)→(B2)→(C-EF2)	(A6)→(B2)→(C-EF2)	(B3)→(C-EF1)
(A6)→(B1)→(B6)→(B2)→(C-EF3)	(A6)→(B2)→(C-EF3)	(D1-1)→(C-EF6)
(A6)→(B1)→(B6)→(B5)→(C-EF2)	(A6)→(B4)→(C-EF1)	(D1-1)→(D1-4)
(A6)→(B1)→(B6)→(B5)→(E5)	(A6)→(B4)→(C-EF2)	(D1-1)→(D2-1)
(A6)→(B4)→(B2)→(C-EF1)	(A6)→(B4)→(C-EF3)	(D1-1)→(D2-2)
(A6)→(B4)→(B2)→(C-EF2)	(D1-1)→(D2-3)→(D2-1)	(D1-1)→(D2-3)
(A6)→(B4)→(B2)→(C-EF3)	(D1-1)→(D2-3)→(D2-2)	(D2-5)→(D2-2)
(A6)→(B1)→(B6)→(B2)	(D1-1)→(D2-4)→(D2-1)	(B3)→(D2-2)
(A6)→(B1)→(B6)→(B5)	(D1-1)→(D1-4)→(E5)	(D1-3)→(E1)
(A1)→(A4)→(C-EF2)	(A6)→(B4)→(D2-1)	(A3)→(A4)
(A1)→(A4)→(C-EF3)	(A6)→(B4)→(D2-2)	(A3)→(A5)
(A3)→(A4)→(C-EF2)	(A1)→(A4)→(A5)	(A6)→(B1)
(A3)→(A4)→(C-EF3)	(A3)→(A4)→(A5)	(A6)→(B2)
(A6)→(B1)→(C-EF1)	(A6)→(B1)→(B6)	(A6)→(B4)
(A6)→(B1)→(C-EF2)	(A6)→(B4)→(B2)	(E2)→(E4)
(A6)→(B1)→(C-EF3)	(C-SP1)→(D2-1)	

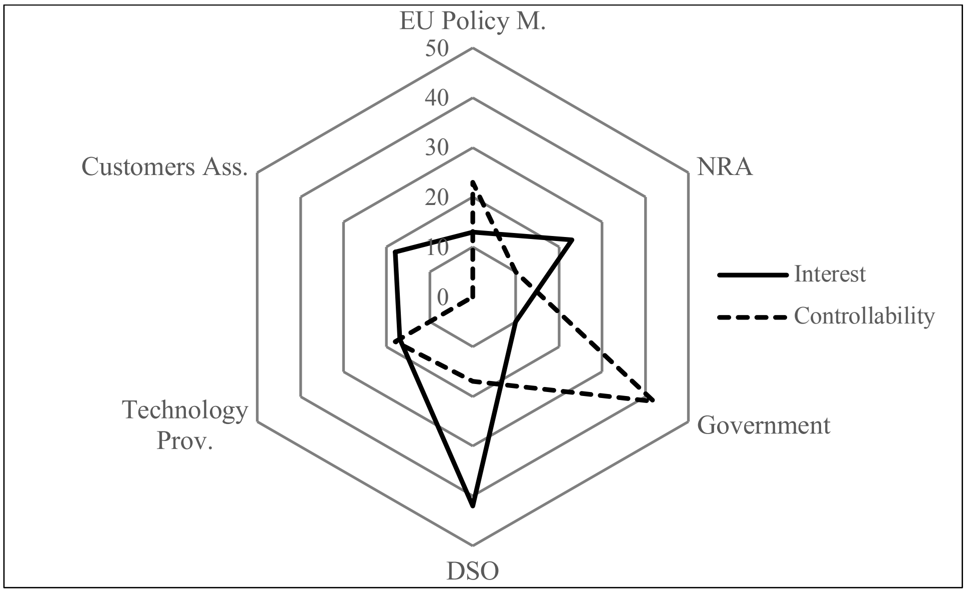
Source: own elaboration *arrows are one-directional

Beside the most significant patterns, Table II also displays the number of times that items from a section compose the relations. First comes section A that appears in 35 patterns, second comes section B with 28 occurrences, third comes section C in 24 cases, fourth comes section D in 15 patterns and fifth comes section E with 4 cases. The most frequent item is A6 that represents the "type of customers" and appears in 27 patterns; then item B1 and B2 are the second most frequent ones, they represent respectively "Type of communication technology" and "Type of protocol used to send the data." Each of them appears in 12 patterns. The items B4 and D1-1 represent the "Type of elaborated data" and "Status of obligation to implement SM," respectively, and both appear in 10 patterns. Technological aspects, customer management and level of mandate are confirmed the most important elements in the composition of patterns.

4.1. Stakeholders' interest and controllability

This section sets out our assessment of stakeholders' interest and controllability of patterns. The European Union (EU) policymakers showed interest for 13 patterns, four of which are directly controlled by the EU policymakers with other actors, while other actors controlled the remaining nine patterns. The NRAs showed interest for 23 patterns, among those, two are directly controlled by the National Regulatory Authority (NRA). The two patterns under the only control of NRA allowed influencing the type of data elaborated and the customers' benefits, through respectively the type of customers involved in the project and the type and number of communication interfaces present in the meters. The Government showed interest for 10 patterns; two of these patterns directly controlled with other actors. The DSOs showed interest for 42 patterns; one of those autonomously controlled, while 21 patterns controlled together with other actors. The pattern by DSO reflected the possibility of promoting the involvement of the customers in the project development and their acceptance to the new meters through the supply chain configuration. The technology providers showed interest in 17 patterns, while the customers' association showed interest for 18 patterns, without any form of direct control of them.

figure 2: Controllability and interest

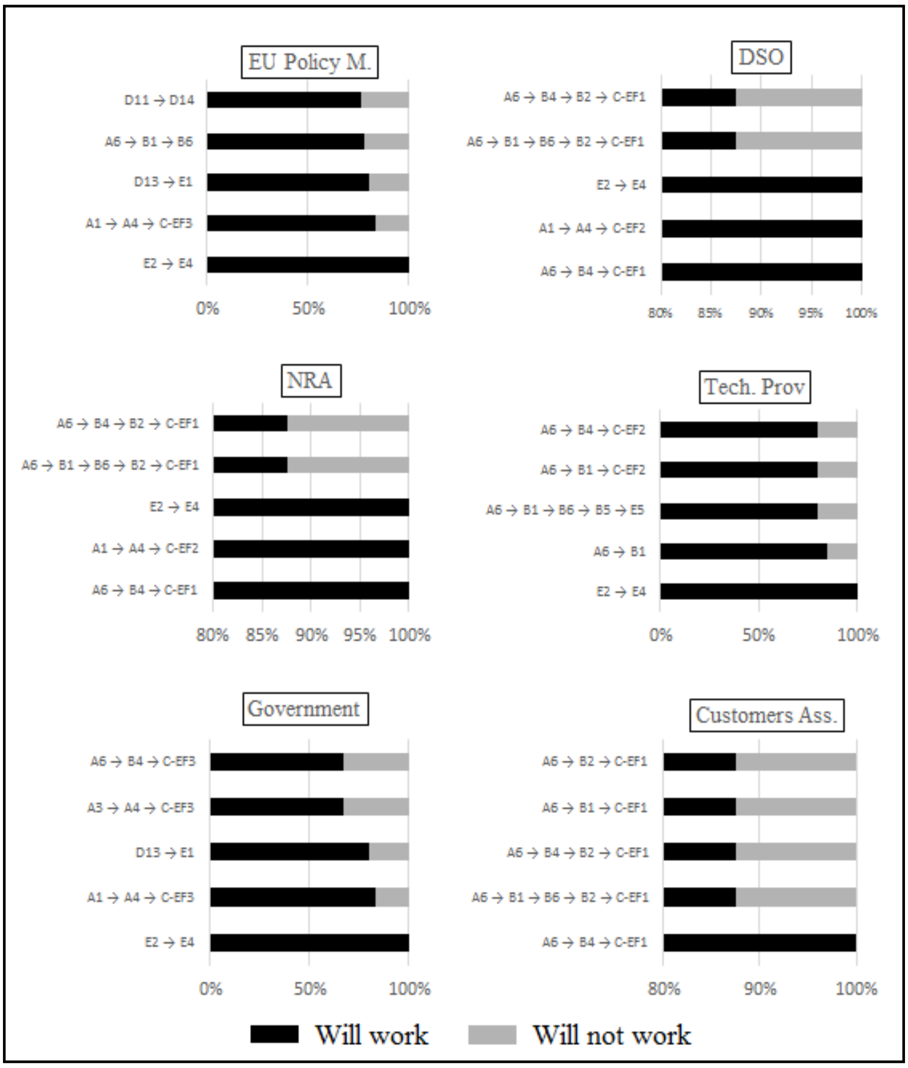


Source: own elaboration

4.2. Forward-looking enabling patterns

It is necessary to put forward a consistent set of projections for how well the patterns will perform in the near future. The outlook includes expectations for performance in terms of probability of working of different identified patterns. We particularly wanted to ascertain the views of the stakeholders about patterns that will work and those that will not, respectively. For patterns that will work we mean those patterns that can be exploited, adapted or replicable, especially in the near future. Considering that forecasts are exposed to many unforeseeable items, the integration of information from more sides makes it more reliable. Figure 3 contains top five patterns according to their support for future SM implementation projects.

Figure 3: Enabling patterns



Source: own elaboration

Figure 3 shows prominent enabling patterns, namely, patterns that lead to successful projects according to different stakeholders, thus, to be considered in the projects' business models given that an appropriate business model can lead to a competitive advantage (Björkdahl, 2009). The overall direction of results showed trends that could be helpful to learning about the factors that may undermine the diffusion of SMs. The stakeholders' contribution seemed to play a key role in defining the direction of this technology evolution (Baden-Fuller and Haefliger, 2013). Taking into consideration the set of functionalities, evidence suggested that the communication technology should offer more advanced functions to enhance the security level. Another aspect that emerged is the need for more advanced functions offered by the upper layers' protocol. In terms of effectiveness, our results showed that the higher the value of advance functions, the higher are the business benefits: loss reductions, less operation managements and quality of supply.

5. Discussion

The results highlight the complementarity between DSOs and the government bodies. This can be noticed by examining the level of controllability and interest. The ratio between items of interest for DSOs and those they can control is almost 1 to 3. In the same way, the government can control a remarkable number of items, but these do not necessarily fall within its field of interest. More specifically, a key point that emerges from the results is the identification of patterns characterized by a high level of controllability of national governments and DSOs. Thus, they are among the first elements to be considered in the development of new projects. In the light of information on the number and type of controllable items, it is appropriate to consider the main drivers and barriers. Drivers and barriers in rolling out SM project can be arranged in different areas, e.g. economics, financial schemes, regulation, technology and social aspects. As per the economics and financial schemes, given the economies of the scale that exists in this industry, it is necessary to reach a critical mass of production of standard products (Carlsson et al., 2013; Gottinger, 2003; Brown et al., 2014) to enhance the effectiveness of projects. It is widely recognized that regulations and directives have become key driving factors for energy distributors and, as expected, only in a few cases, regulation has not supported the development of advanced solutions with monetary incentives. Then come the technological aspects. As for the data communication, in most of the projects, the communications were encrypted with standard algorithms, to ensure a high level of security. Nonetheless, in a few cases, the DSOs were not able to achieve high levels in data security at the first phase of the project as the chosen technology did not support encrypted data communication or did not work properly. However, appropriate encryption and authentication mechanisms should be a priority as the beginning for all the projects to guarantee data security. SMs introduce a lot of new features that constitute a driver for the operators; for example, the device functionalities make faster, remote and accurate operations possible. These new functionalities allow an improvement in the commercial and technical services. Nevertheless, that the deployment of a communication network in some localities might be difficult due to terrestrial difficulties and the lack of proper infrastructure for synchronizing new with the existing technology might interrupt the introduction of SMs. Within the technology domain fall the new solutions that the DSOs can implement to improve their offer: new services, markets and products are enabled by the new SMs, but a key barrier to be addressed is the customer's willingness to pay and rebound effects. Another important result enabled by the new SMs, if properly supported by innovative policy and regulation, is the integration of higher proportion of renewables into the energy mix. Finally, the paper considers social aspects. In the social field two main aspects encourage the DSOs to implement SM solutions: the first refers to the reduction of greenhouse gas emissions and more energy efficient use; the second refers to the role of the consumers that become progressively active in energy management and consumption. Beside the stakeholders' controllability and interest of different items, our results also show many interconnections between the items considered in this paper. As mentioned, the significance of the links was evaluated in terms of strength of the relations as well as length of the chain. The item that appears most, corresponding to type of customers, appears in 27 patterns and this highlights the importance of analyzing the customer needs to propose the right solution. In fact, as mentioned, required futures of SMs diverge according to the customer type specifically as per the multi-tariff functions to prompt demand response techniques and for automatic control of SM. The latter relates to items that rank second in terms of frequency in patterns, i.e. types of communication technology and protocol. What is explained above paves the way for business implications and recommendations for stakeholders.

5.1. Implications and recommendations

If DSOs succeed in optimizing the technological aspects according to the types of customers, they may fine-tune their business models and improve the profitability of SM technology. Therefore, the different solutions for different customers can be well targeted and this will prompt additional benefits coming from the optimization of demand response techniques as well as grid management.

As per key recommendations, first come the market models, incentives, cost distribution and regulation. We recommend policymakers to guarantee regulatory stability as well as the roles and responsibilities of the players involved, to ensure a fair distribution of costs among energy sector actors that benefit from SM. Furthermore, it is important to establish clear procedures and calendar for each SM functionality, to define how and when the functionality must be made available, to further foster smart grid applications. Second, this paper considers data flow, security and privacy issues. Concerning this field, we highlight the need to ensure a high level of end-to-end data and information security in a cost-effective way. Additional actions benefits include fit-for-purpose systems in a protected and secure environment, provide customers with detailed information, to define at national level the information exchanges between DSOs, consumers and other energy sector actors. Switching to the standardization domain, we propose to standardize data interfaces for information exchange among market participants; moreover, the compatibility with existing SMs rollouts through standards for future services and installations (e.g. micro-generation, EV infrastructures) shall be assured. Finally, considering the consumer awareness and engagement, we advise policymakers to run national government-aided communication campaigns to create awareness and foster support among consumers and leverage on SM rollout activities to educate consumers about energy efficiency.

6. Concluding remarks

The The energy sector has introduced new challenges for DSOs, among others the rollout of SM technology. In response, the EU Commission has undertaken a comprehensive European regulatory framework intended to facilitate the diffusion of SM solutions on a European scale (Tobergte and Curtis, 2013). Diverse and intensive SM technology deployment is happening throughout Europe because of EU directives 2012/27/EC and priors even if additional efforts are to be undertaken when it comes to harmonization of measures and standards across countries. In fact, the establishment of a common European policy appears not to be achieved yet (Colak et al., 2015). In this regard, our results may support DSOs to deploy SMs and SM technology effectively, governments to liberalize the energy market and NRAs to define effective regulations, thus allowing the full realization of the mentioned directive. Stakeholders can take advantage from this paper by examining the set enabling patterns for implementation projects. In fact, patterns are sufficiently general, adaptable and worthy of imitation that they can be adapted to different markets. It is worth noting, for example, that all the stakeholders stressed the relationship between incentives and large-scale development of SM solutions. In the same vein, another pattern identified from both DSOs and NRAs relates to the business benefits that increasing projects scale secure. Differently, from the above-cited patterns that refer to projects scale, another important pattern identified by both DSOs and NRAs is the one associated with elaborated data according to the type of customers and the benefits for the end customers. In this respect among stakeholders, DSOs are those who may benefit most from such information. This paper has also given an account of why and how to support the implementation of SM solutions across Europe. We have obtained accurate results proving that DSOs face the challenge of how to develop a sustainable business model for projects implementation, as DSOs face the challenge of how to develop a business model that transforms SMs into sources of economic value creation. Besides serving DSOs to fine-tune deployment projects, the results are a valuable input to regulators for better policymaking. Nationally, our research suggests that government mandates can facilitate the fulfillment of consumer requirements and preferences. Therefore, the policymakers should support the dissemination of SM in their country as it is in the interest of society. Forward-looking estimates strongly depend on how EU policymakers, governments and NRAs support the deployment. Other than from DSOs, most efforts are needed at the national level, from NRAs and governments. National rules are advised spanning issues from fair remuneration to enforcing rollouts to a wide range of consumers. Large-scale consumer campaigns to prepare Europe's citizens for the rollouts are one of many ways that governments can support rollout efforts. To conclude, as expected DSOs are interested in most of the items; nevertheless, they can only control a few. In the same way, the government can control a remarkable number of items, but these do not necessarily fall within its field of interest. Therefore, to facilitate SM implementation projects, close cooperation is necessary, especially between government and DSOs.

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Annexes

Annex 1: controllability of Items (stakeholders' breakdown)

Item	EU Policy Makers	NRA	Government	DSOs	Technology prov.	Customers
A1	1	1	1	1	1	1
A2	1	1	1	1	1	1
A3	2	4	2	4	1	1

A4	1	4	1	4	1	3
A5	3	4	1	3	1	1
A6	1	4	1	3	1	1
B1	1	2	1	4	3	1
B2	3	3	1	4	3	1
B3	3	4	1	3	3	2
B4	3	4	1	4	2	3
B5	4	4	1	4	3	3
B6	3	4	1	4	3	1
C-EF1	1	4	1	4	2	1
C-EF2	2	4	1	3	2	1
C-EF3	4	4	4	1	1	1
C-EF4	1	4	2	3	3	1
C-EF5	2	2	2	4	3	1
C-EF6	1	4	4	3	1	2
C-SP1	1	1	1	4	1	1
C-SP2	1	1	1	4	1	1
C-SP3	1	1	2	4	1	1
C-SP4	1	1	1	3	1	1
C-SP5	1	1	1	3	1	1
C-SP6	1	1	1	3	1	1
D11	4	4	4	1	1	1
D12	2	3	2	1	1	1
D13	4	4	4	1	1	1
D14	3	4	2	1	1	1
D15	1	3	1	3	1	1
D21	1	2	1	4	1	4
D22	1	1	1	4	1	4
D23	3	4	4	1	1	2
D24	1	4	3	1	1	3
D25	1	3	3	1	1	3
D26	3	4	1	4	3	4
E1	1	4	4	1	1	1
E2	4	4	4	1	1	1
E3	4	4	4	2	1	1
E4	3	4	3	3	2	4
E5	3	3	3	4	4	2
E6	3	3	3	3	4	1

Annex 2: Relationship matrix

	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C-EF1	C-EF2	C-EF3	C-EF4	C-EF5	C-EF6	C-SP1	C-SP2	C-SP3	C-SP4	C-SP5	C-SP6	D11	D12	D13	D14	D15	D21	D22	D23	D24	D25	D26	E1	E2	E3	E4	E5	E6
A1	-	x		x																																					
A2		-																																							
A3			-	x	x																																				
A4				-	x									x	x																										
A5					-																																				
A6						-	x	x		x					x																										
B1							-					x	x	x	x																										
B2								-					x	x	x																										
B3									-				x																		x										
B4								x		-			x	x	x															x	x										
B5											-			x									x	x																x	
B6								x			x	-																													
C-EF1													-																												
C-EF2														-																											
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E5																																								-	
E6																																									-