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HOW DOES A SMART METERING PROJECT WORK?

INTERPRETATION OF TWELVE EUROPEAN CASES

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Abstract

Energy demand management is an effective approach to reduce the energy consumption; this approach needs of high level of information to enable improving actions on the energy system.

Smart meter is the core-element of the new energy demand management system; it is an advanced energy meter that measures consumption of electrical energy providing additional information compared to a conventional energy meter. Therefore, smart metering brings benefits to the energy utilities optimizing their business and moreover it could advantage the final customers, even if this latter issue is still debated.

In Europe many smart metering projects have been developed, but it is still not clear which are the figures, the characteristics and the mechanisms internal to projects that bring advantages for the different stakeholders.

The purpose of this research is to highlight which are the dynamics of working of a smart metering project and which are the elements that improve its operation. The work is part of a larger study, the Meter-ON project, which represents the efforts of the European community to have a better understanding of the project's dynamics and adjust them in order to achieve benefits for all stakeholders. The study is developed from the Distribution System Operator point of view and it focuses on the full rollout project.

The main features of the smart metering projects are described with the support of a panel of experts, in this way it is possible to understand their internal dynamics: features are modeled exploiting a system of variables and the interactions between them are described by a list of patterns consisting of cause and effect relationships. Patterns are realised taken into account the interest of all the stakeholders involved into the project with a special highlights of the stakeholders' ability to control them; in addition to the Distribution System Operators, the study considered the European policy makers, National Regulatory Authority, Government, technology providers and the customers association. The model is applied on a relevant number of European cases; in particular twelve projects that cover the whole of Europe area are analysed.

The research's results consist in a scheme of fifty patterns that show to correctly describe the work of a project; case studies have led to the identification of twenty-five

guidelines for rolling out smart metering and steer the action of the Regulators and other stakeholders.

Patterns and guidelines allow the Distribution System Operators to improve the knowledge of their systems and understand where the problems that affected their projects lie; but above all the European policy makers could exploit the results of the research for standardize the activities and ensure better outcomes for everyone.

Keywords: Smart metering; European rollout project; Cross cases analysis; Policy making guidelines.

Sommario

La gestione della domanda di energia risulta essere un approccio efficace per la riduzione dei consumi energetici; tale approccio necessita di un'elevata quantità di informazioni per apportare miglioramenti al sistema energetico.

Lo "smart meter", il contatore intelligente, è il cuore del nuovo sistema di gestione della domanda di energia poiché fornisce maggiori informazioni e quindi maggiori funzionalità rispetto ai contatori precedentemente installati. L'ampia diffusione di questa nuova tecnologia porterebbe numerosi vantaggi per le imprese del settore energetico, le quali riuscirebbero ad ottimizzare il loro business, e seppur con alcune incertezze, aumenterebbe i benefici per gli utenti finali. Molti progetti di "smart metering" sono stati avviati in Europa e nel mondo ma ancora non è chiaro quali caratteristiche, configurazioni e dinamiche interne ai progetti portino a tali vantaggi.

L'obiettivo della ricerca è di evidenziare quali siano le dinamiche di lavoro di un progetto di "smart metering" e quali elementi ne migliorino lo svolgimento. Lo studio si inserisce all'interno di un lavoro più ampio, il progetto Meter-ON, promosso dalla comunità Europea al fine di comprendere meglio le dinamiche che si sviluppano all'interno di un progetto e, correggendole dove necessario, portare benefici ai diversi attori del sistema energetico. Lo studio è sviluppato secondo il punto di vista del Distribution System Operator e si focalizza sui progetti di "rollout".

Le caratteristiche principali di un progetto di "smart metering" sono state descritte con il supporto di un gruppo di esperti, in modo da individuarne con correttezza le dinamiche interne; per modellare tali caratteristiche è stato utilizzato un sistema di variabili e le relazioni di causa ed effetto, presenti tra di esse, hanno portato ad individuare una lista di "patterns". Tali "patterns" permettono di considerare da un lato gli interessi di tutti gli attori coinvolti, dall'altro le loro capacità di intervenire nello svolgimento del progetto; in aggiunta al Distribution System Operator sono stati considerati i "policy makers" europei, gli ente di regolazione nazionale, i Governi, i fornitori di tecnologie e le associazioni dei consumatori. Il modello è stato applicato ad un numero rilevante di casi in Europa; in particolare sono stati analizzati dodici progetti che coprono abbondantemente il territorio europeo.

La ricerca ha portato ad individuare uno schema di cinquanta “patterns” che consentono di descrivere lo svolgimento di un progetto; lo studio dei casi ha invece evidenziato venticinque linee guida per facilitare l’installazione degli “smart meters”, orientando l'azione delle autorità di regolamentazione e le decisioni degli attori coinvolti.

“Patterns” e linee guida consentono ai Distribution System Operators di migliorare la conoscenza dei loro sistemi e capire quali problematiche essi presentino; ma soprattutto a livello europeo i “policy makers” potranno intervenire normalizzando le procedure di “smart metering” al fine di massimizzare i benefici per tutti i soggetti coinvolti.

AKNOWLEDGEMENTS

First and foremost, I wish to express my sincere gratitude to my supervisor Prof. Enrico Cagno who allowed me to pursue this master thesis. Deepest gratitude is also due to my assistant supervisor Guido Jacopo Luca Micheli for his invaluable assistance during my working experience, for his patient guidance and useful critics to the realization of this work and from whom I learned a lot. Furthermore I would like to thank G.T. for the help and guidance provided in the writing of the thesis.

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Contents

List of Figures:

List of Tables:

Executive Summary

Premise

Recent forecasts claim that world energy consumption grows by 53 percent from 2008 to 2035 and the total world energy use is expected to rise from 505 quadrillion British thermal units (Btu) in 2008 to 619 quadrillion Btu in 2020 and 770 quadrillion Btu in 2035; the world demand for electricity, in particular, will increase by 2,3 percent per year from 2008 to 2035, from 19,1 trillion kWh in 2008 to 25,5 trillion kWh in 2020 and 35,2 trillion kWh in 2035.

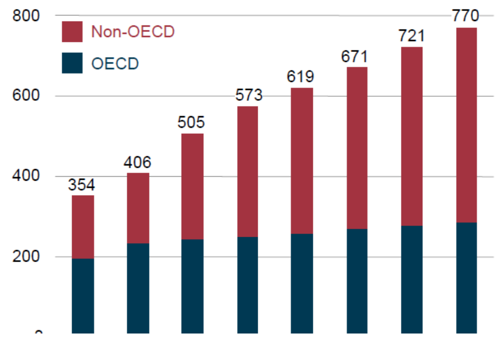


Figure 1 - World energy consumption, 1990-2035 (quadrillion Btu)

The environmental impact of humans' behaviours is getting nowadays an increasing importance in the international community, in the way companies operate and in governments' policies and decision making. This led to a comprehensive examination and redesign of the entire energy lifecycle in all its sectors and forms, aimed at increasing its economic and environmental sustainability. Into this process, essential is the inclusion of each actor of the energy supply chain and without any doubts smart metering, through its pervasiveness, represents a major lever for embracing the vast domestic energy consumption market. The topic has recently attracted much attention, mainly driven by the current technological breakthrough represented by the evolution towards smart grids. Indeed smart electric meters are the cornerstone for the realization of this upcoming paradigm given their ability to real-time monitor customer's consumption behaviours. Countless scientific papers and articles tackled the topic of smart metering on the electricity sector and a thorough literature review is proposed in Chapter 1 of this thesis.

A point of interest is that today there is a big difference between knowing the energy flows along the electricity supply chain and resolving problems in the distribution grid: though in any generation facility and in the transmission grid operators find out complications as soon as they happen; when it comes to the distribution grid, instead, it may take thirty days to three years before there is any idea of where the electricity has gone.

A system of tools is necessary to facilitate the understanding of this use of energy, it allows to measure where power went and reporting this kind of information at regular intervals. Smart metering is the missing link in the understanding of how electricity is used.

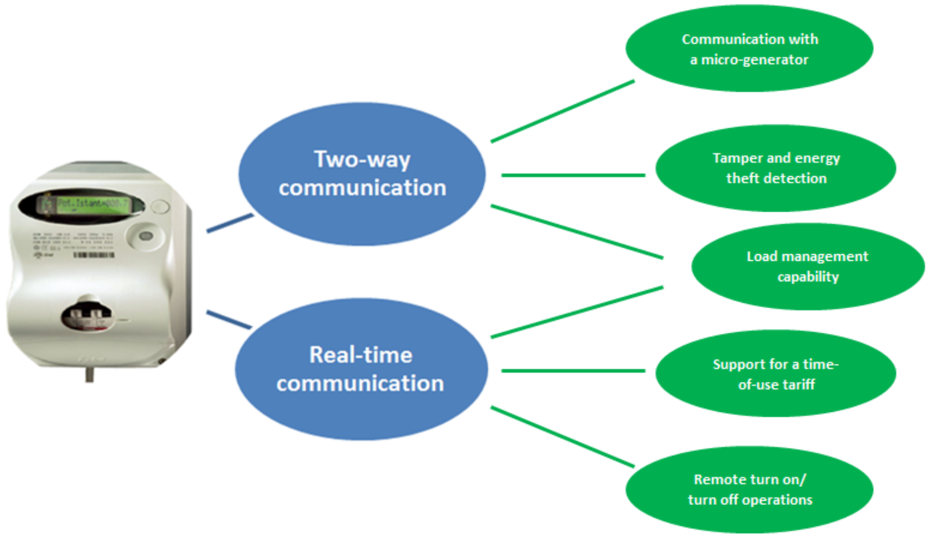


Figure 2 - Functionalities of a new-smart energy meter

But what's exactly meant for Smart Metering? The European Commission (2012/148/EU) defines "smart metering system" an electronic system that can measure energy consumption, adding more information than a conventional meter and that transmit and receive data using a form of electronic communication.

The definition provided by the European Commission suggests that the difference between the conventional metering architectures and the smart metering systems goes far beyond the technological aspect. The way information is transmitted and used is the real innovation of this structure; the ability to communicate directly and in a very limited amount of time changes the way of using energy; using smart meters merely for data collection would miss the point of this technology. For several years the concept of intelligent interconnection among energy networks, known as smart grid, has been developed and the problem of common protocols for data communication and design of the architectures used for data gathering were relevance issues in smart metering system literature.

The design of metering systems is a dynamic process of technology and functionality selection predominantly driven by the strategic objectives of meter manufacturers and utility companies; several configurations may be adopted to manage the energy metering and each of them entails advantages for a different actors.

The most important stakeholders of the whole smart metering value chain are distribution system operators (DSO), meter operators, meter manufacturers, technology suppliers, system integrators, policymakers and technical bodies. This framework of actors is obviously wider than the “dumb” meter value chain; the innovative technology has indeed introduced a number of new roles and interest for the original operators, and created a wide range of competing groups with different objectives.

Each of these interest groups has particular institutional roles and diverse objectives, including economic and environmental efficiency, commercial competitiveness, technical competence and social welfare; in the following figure are represented the relationships between the different actors and the role of smart meter as a “gateway” between producers and consumers.

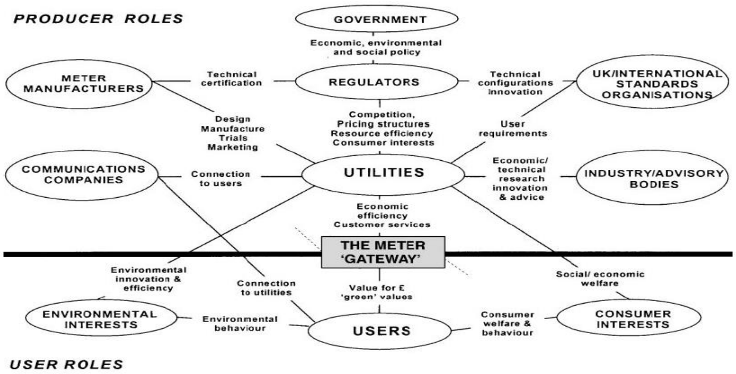


Figure 3 - Shaping metering - roles of key interest groups

Smart meters appear to be the biggest innovative development of the last years, this is because this technology is able to cause at the same time, new technical potentialities and new experiences.

The European Commission itself has recognized as the smart metering “mark a new development on the path towards greater consumer empowerment, greater integration of renewable energy sources into the grid and higher energy efficiency and make a considerable contribution to reducing greenhouse gas emissions and to job creation and technological development in the Union”.

The benefits of a smart metering system include a lot of aspects and it is difficult to identify all of them; in the literature they are often presented by some classifications.

As seen above, a smart metering system involves a lot of subjects, consumers utilities and society as a whole, and each of them could have many benefit from it. It’s important to distinguish the benefits for different groups of actors, because these differences explain many of the problems in the promotion of this new technology.

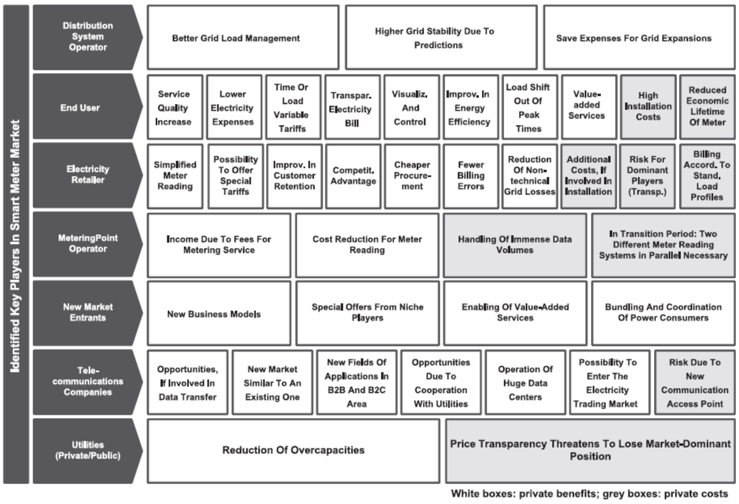


Figure 4 - Key stakeholders in the smart meter market and their private costs and benefits

The process of implementation of smart metering technologies is complex and usually requires simultaneous attention to a wide variety of human, budgetary, and technical variables. In addition, meter implementation is often initiated in the context of a turbulent, unpredictable, and dynamic environment. The “project approach”, however, allows to overcome these difficulties and achieve the success in the smart meter implementation through a set of factors under the project manager's control.

Many initiatives to provide people with a smart energy meter were born in the early years of the new millennium. In 2008, less than 4% of the global installed base were smart; in four years by 2012 smart meter penetration has grown to over 18 %, it is expected to continue to grow and it is projected to exceed 55% by 2020. Many projects have been started around the world, mainly in Europe and North America, but still there are many doubts about what are the best ways to manage a smart metering project.

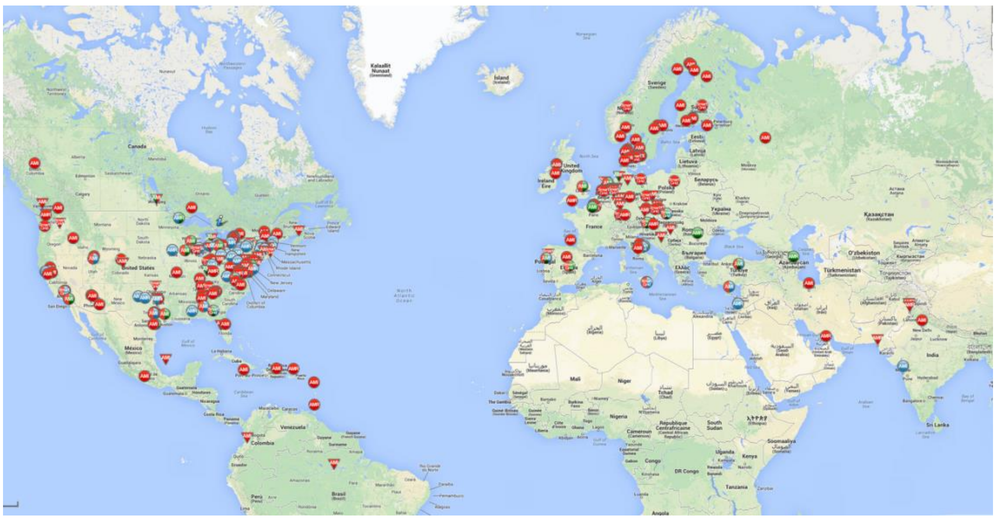


Figure 5 - Diffusion of smart metering project around the world

Objectives of the work

Objective 1. The first macro objective of this research work is the realisation of a model that describes the dynamics of working of a smart metering project. The model consists in a list of patterns, composed by a chain of variables, linked one each other by cause and effect relationships.

The goal is to understand which are the stakeholders really involved in a rollout project of smart meter: stakeholders' interest is the perspective from which the entire analysis was carried out. Study the working of a smart metering project allows to understand how a stakeholder intervenes in the dynamics of the project and influences them.

Objective 2. The second macro objective of this thesis is the study of twelve European smart metering projects. Information on the projects implementation have been collected through the compilation of a survey.

The goal is to understand which are the contextual factors that have influenced the performance of the projects during the development phase and that still affect their results. A clear understanding of the factors that hinder the development of projects allows the European policy makers to take action to correct problems and increase the benefits for the whole society; in addition the Utilities can improve their experience in the large-scale projects' implementation.

Research methodology

In order to reach the goals described in the previous paragraph, the research project is structured into two main phases which will be described as follows.

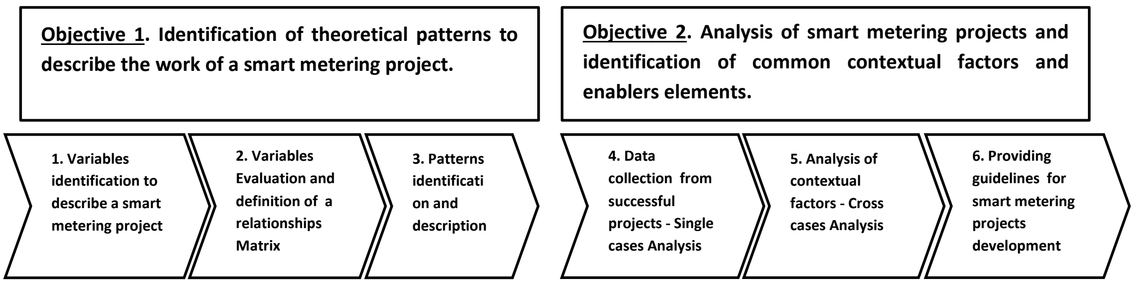


Figure 6 - The research steps

- *Phase 1 - Variables identifications:*

The European Union has decided to study how Smart Metering project work, their mechanisms and their characteristic elements, to steer the implementation of this solution and make greater clarity In the smart-metering community. With these objectives, the "Meter-On project" was launched by a Consortium led by the European Distribution System Operators for Smart Grid, including 12 leading DSOs and association throughout the European Union. The goal of Meter-On will be to provide to any stakeholder an open information platform with clear recommendation on how to tackle the technical barriers and the regulatory obstacle endangering the uptake of smart metering technologies and solutions in Europe.

Figure 7 - The Meter-On project Consortium

In order to identify the key elements that, from the DSO's point of view, have relevance in a smart metering project development, a panel of experts in the energy market sector was formed; the panel's members are delegates of research agencies, Distribution System Operators and academic institutions (see Annex 1). Leveraging on the expertise and experiences of members within the panel, a thorough analysis of the characteristics of a smart metering project was carried out and a set of influencing factors has been identified. The goal is to identify a subset of variables which convey the most relevant part of the information, thus reducing the complexity of the project analysis.

The outcome of their research is a list of 41 variables (described in Annex 2) which address the most relevant aspects that influence the results and the success of a smart metering project; variables are separated in 5 different sections:

- Variables A summarise the "General information" on electricity smart metering project; they indicate the number of customers involved, the scale and the timing of the project.
- Variables B (Table 2, Annex 2) indicate "Technological" characteristics of the project; they focus the attention on the different technologies involved in smart meters.
- Variables C (Table 3, Annex 2) indicate the "Quantitative" characteristics of the project; they focus the attention on the financing mechanisms, cost-benefits

and make-or-buy approach adopted by the company. The objective is point out the financing mechanisms, the contracts the joint ventures and, whether is possible, the economical drivers (e.g., opportunity costs).

- Variables D (Table 4, Annex 2) indicate the “Qualitative” characteristics of the project; they focus the attention on regulatory & legal framework in place in each country and in Europe to outline the framework conditions and their impact on the development of the project.
- Variables E (Table 5, Annex 2) indicate the “Advanced Topics” of the project; they focuses on the possible applications of smart meters as a pillar of the smart grid.

▪ *Phase 2 – Variables evaluation:*

A scale of values has been assigned to each variable in order to quantify them and provide the overall picture of the smart metering environment. The scale adopted varies from case to case in relation to the variable type: generally, for the continuous variables, a value on a scale from 1 to 4 is assigned, meaning:

- 1 – low
- 2 – medium low
- 3 – medium high
- 4 – high

on the contrary, for the binomial variables are used the extremes of the above scale.
Variable A1, for example, indicates the “number of customers served by the DSO” and it is a continuous variable; it assume the value “1” if the number of clients served is less than 1 Million, “2” if it is from 1 to 5 Million, “3” if it is from 5 to 10 Million, “4” if they are more than 10 Million. Variable A6, instead, indicates the “type of customers” involved in the project; it is a binomial variable and thus assume the value “1” if are involved only residential customers and “4” if are also involved industrial and commercial customers.
As shown previously, a series of actors are involved into a smart metering project, at different way and level; therefore to include all the relevant players, maintaining a reasonable number of actors, a list of 6 stakeholders was compiled (see Annex 3).

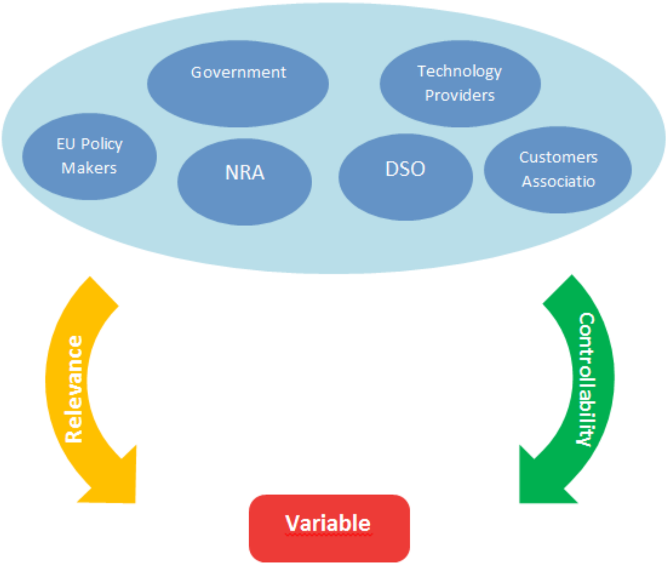


Figure 8 - Relevance and Controllability of Stakeholders on the project variables

Each stakeholders play different roles in the promotion of a smart metering project and consequently show interest and degrees of control different from each other; to clarify their role and ability to influence the characteristic of the project, the relationship among the 6 stakeholder and the 41 variables used to describe the project are been evaluated in terms of “Relevance” and “Controllability”.

With “Relevance” refers to the importance which a specific element, represented by a variable, assume for an actor and the interest that it shows in order to achieve a good results in the project for that item. To evaluate the “Relevance” a scale of values ranging from 1 to 4 has been adopted, meaning:

- 1 – low relevance
- 2 – medium low relevance
- 3 – medium high relevance
- 4 – high relevance

With “Controllability” refers to the stakeholder’s ability to influence a specific element of the project (represented by a variable); stakeholders can improve or reduce the amount and the impact of the different variables, thus they influence the performance of the whole project through their choice and actions.

Also to evaluate the level of “Controllability” of an actor on a specific variable a scale of values ranging from 1 to 4 has been adopted, meaning:

- 1 – low controllability
- 2 – medium low controllability

- 3 – medium high controllability
- 4 – high controllability

Among the 41 variables (described in Annex 2) previously descripted it is possible to identify a cause and effect relationship. The variables have been arranged on rows and columns to obtain a rectangular matrix and facilitate the visual representation of the strongest relationships. To each correspondence between the variables has been assigned a value on a scale from 1 to 4 meaning:

- 1 – low
- 2 – medium low
- 3 – medium high
- 4 – high

In the case where there is no relationship between the assessed row and the column, the value “0” is assigned. If the relationship exist but it is negative, the above scale of values is still observed by adding a sign “-” in front of the value considered.

From the cross topic examination of each variable; different types of relationships have emerged: from very strong ones with relationship level of “4” or very weak ones with level of “1” and even non-existing relationships with “0”.

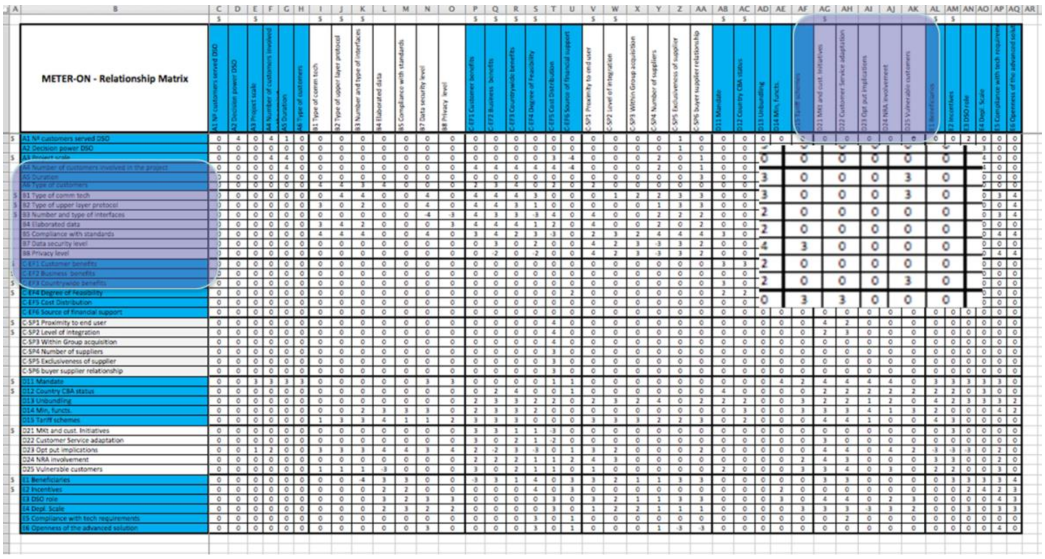


Figure 9 - Relationship Matrix

- *Phase 3 – Patterns identification:*

Considering that each variable is linked to one or more other variables, there are a number of chains of subsequent links among relevant variables later call “patterns”. Considering all levels of relationship among the variables a very high number of patterns may be identify so that the analysis would become unmanageable; in the light of the above a set of criteria is listed to reduce the number of these patterns.

The only patterns under consideration are the ones:

- Leading to a variable having level of interest “4” at least for 1 stakeholder (see Annex 3);
- Only patterns including only links characterized by strongest relationships (“4”);
- Including at least 1 variable controllable at the highest level (“4”) by at least 1 of the stakeholder (see Annex 3).

Under the application of these criteria 50 relevant patterns (Table 1) have been identified; releasing one or more constraints is scientifically possible but it would imply an enormous increase in the number of patterns.

#	Pattern	#	Pattern	#	Pattern
1	A3 → A4	18	A1 → A4 → C-EF2	35	D11 → D14
2	A1 → A4 → A5	19	A3 → A4 → C-EF2	36	A6 → B4 → D21
3	A3 → A5	20	A6 → B1 → C-EF2	37	C-SP1 → D21
4	A3 → A4 → A5	21	A6 → B2 → C-EF2	38	D11 → D21
5	A6 → B1	22	A6 → B4 → C-EF2	39	D11 → D23 → D21
6	A6 → B2	23	A6 → B4 → B2 → C-EF2	40	D11 → D24 → D21
7	A6 → B1 → B6 → B2	24	A6 → B1 → B6 → B2 → C-EF2	41	A6 → B4 → D22
8	A6 → B4 → B2	25	A6 → B1 → B6 → B5 → C-EF2	42	B3 → D22
9	A6 → B4	26	A1 → A4 → C-EF3	43	D11 → D22
10	A6 → B1 → B6 → B5	27	A3 → A4 → C-EF3	44	D11 → D23 → D22
11	A6 → B1 → B6	28	A6 → C-EF3	45	D25 → D22
12	A6 → B1 → C-EF1	29	A6 → B1 → C-EF3	46	D11 → D23
13	A6 → B2 → C-EF1	30	A6 → B1 → B6 → B2 → C-EF3	47	D13 → E1
14	A6 → B4 → C-EF1	31	A6 → B2 → C-EF3	48	E2 → E4
15	B3 → C-EF1	32	A6 → B4 → C-EF3	49	A6 → B1 → B6 → B5 → E5
16	A6 → B1 → B6 → B2 → C-EF1	33	A6 → B4 → B2 → C-EF3	50	D11 → D14 → E5
17	A6 → B4 → B2 → C-EF1	34	D11 (→) C-EF6		

Table 1 - Patterns

Example of pattern construction

Variable of interest: D22 (Customer Service adaptation - Has the Customer Service employees been trained on the Smart Metering topic? Is there a dedicated initiative inside the utility to adapt their current CS with the focus on SM?)

Levels to quantify the variable:

(1) Low-no initiatives or no information

(2) Medium Low-CS is considered but no initiatives

(3) Medium High-references that CS adaptation is done, but no clear strategy)

(4) High-dedicated projects on adjusting CS

- Level of interest "4" for DSOs and Customers/Associations
- Drawing all the possible patterns from D22 "BACKWARDS" (excluding not-strong relationships)
- Identifying patterns INCLUDING variables CONTROLLABLE at the highest level (in example controllable variables are circled in red)

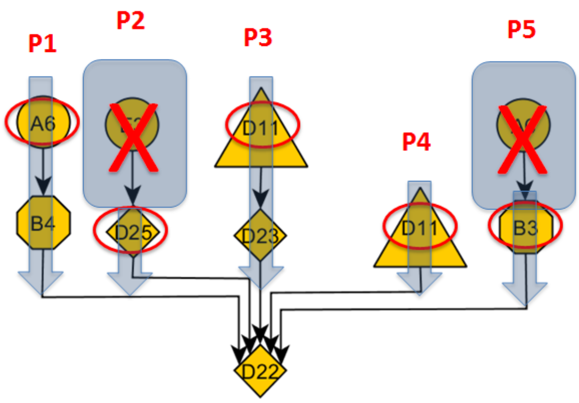


Figure 10 - Example of pattern identification

Pattern P1: A6 → B4→ D22

Variables

A6: Type of customers involved in the project - Indication of which customers are involved in the project: Residential od Industrial

B4: Type of elaborated data- The indirect measures (*eg*. active power, reactive power, frequency, energy) that are performed from the meter starting from the direct measure of voltage and current

Links

A6 → B4: in case c&i are considered in the project more elaborated data should be offered

B4→ D22: the higher the level of elaborated data the higher the level of customer services adaptation

- *Phase 4 – Data collection and Single case Analysis:*

After the identification of all the theoretical patterns that describe the work of a smart metering project, a study of twelve European smart metering projects (listed in Annex 8) is carried out; projects information have been collected through a detailed survey. The survey addresses the most relevant topics on every considered smart meter project, including also contextual information, e.g. regarding regulatory framework, in force laws, information on the initiatives carried out to improve customer acceptance and ongoing smart grids development. The questions proposed in the survey allow to cover technological, qualitative, quantitative and smart grids related topic issues.

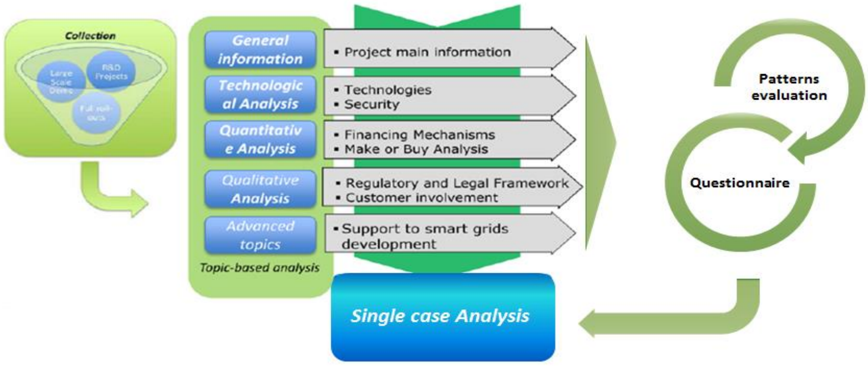


Figure 11 - Steps to study the European smart metering projects

The information gathered through the surveys are exploited to assign values to the 41 variables used for the project's description (see Annex 2); each variable takes a specific value for each Distribution System Operator involved in the study. In Annex 10 are shown the information extracted from the surveys.

The values obtained allow to identify which patterns are confirmed and which are not for each study project: a pattern is confirmed if all the links that compose it are confirmed, only one link that does not work makes the whole pattern "unconfirmed".

A questionnaire was prepared for each Distribution System Operator, in this document have been included links that do not work in their specific case study and a set of questions were annexed in order to gather more information on their development (see an example in Annex 11). The questionnaire allow to better understand which choices or contextual factors explain why the link does not work and to identify which actors, on the participants' perception, can enable the link through their intervention.

The information obtained from the surveys and the insights provided by the questionnaires allow to realise a "single case analysis" for each project. During the single case analysis were identified the contextual elements and the DSO's choices that facilitate the work of the patterns and that influence their on-going development.

- *Phase 5 – Analysis of contextual factors and Cross cases Analysis:*

The single case analyses show that in all of the considered European countries there is attention to the implementation of new smart metering systems. In many countries these systems are already being rolled out or are in an advanced testing phase, confirming the fact that these systems are universally recognized as the main block for the development of smart-grid.

A cross analysis has been performed among the projects to identify the recurring elements that influence the results of a project. The analysis was divided by interested stakeholders' viewpoint. Elements that allow the functioning of the patterns are studied for each stakeholders; a comparison between the different projects was realized to identify the possible levers, which may be used to enhance the success of a smart metering project.

Back to the previous example, the patterns that affect on the variable D22 show different outcomes in the various projects.

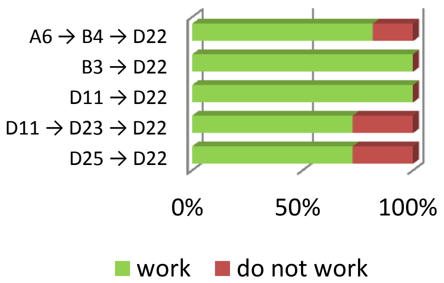


Figure 12 – Final patterns work

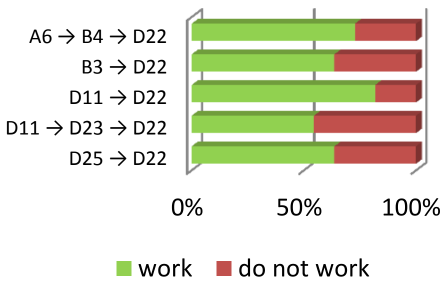


Figure 13 – Currently patterns work

Figure 12 shows that the patterns describe correctly the dynamics of a smart metering project: the majority of the cases studied will work according to the identified relationships; in addition, two patterns are confirm in all the projects. The studied projects shown that many elements lead to an increase of the initiatives developed by the utilities; obviously the involvement of many customers, with different characteristics, forces the DSOs to increase their efforts; but also the government's intervention through high levels of obligations and a specific supply chain configuration can promote the initiatives of the utility.

Figure 13 instead indicates that currently there are more difficulties to the work of the patterns; the contextual factors that mainly hamper the work of the patterns are:

- the lack of EU directives about the meters' functionality;
- the non-adoption of opt-out options at the time of the project implementation;
- the DSO's decision to involve low number of customers so little influence of vulnerable customers.

The actors who mainly foster the work of the patterns are the Technology Providers, the customers associations, the DSO the National Regulatory Authority and Government:

- Regulators have to setting clear well defined and rigorous requirements regarding data measurement and communication; Government also should give a mandate to rollout smart meters, starting date and time frame;
- Technology providers have to making technology and products available, optimizing the delivery period;
- customers associations should exert pressure to modify regulations about vulnerable customers and opt out options, increasing cooperation with regulators.

- *Phase 6 – Drawing guidelines:*

The patterns identified in Phase 3 have been shown to correctly describe the dynamics of a smart metering project. Through this patterns, many project have been studied; therefore they point out how certain goals can be achieved.

The final chapter contains a set of guidelines for rolling out smart metering. Starting to the outcomes of the previous analyses, both single and cross, some indications are listed for each stakeholder.

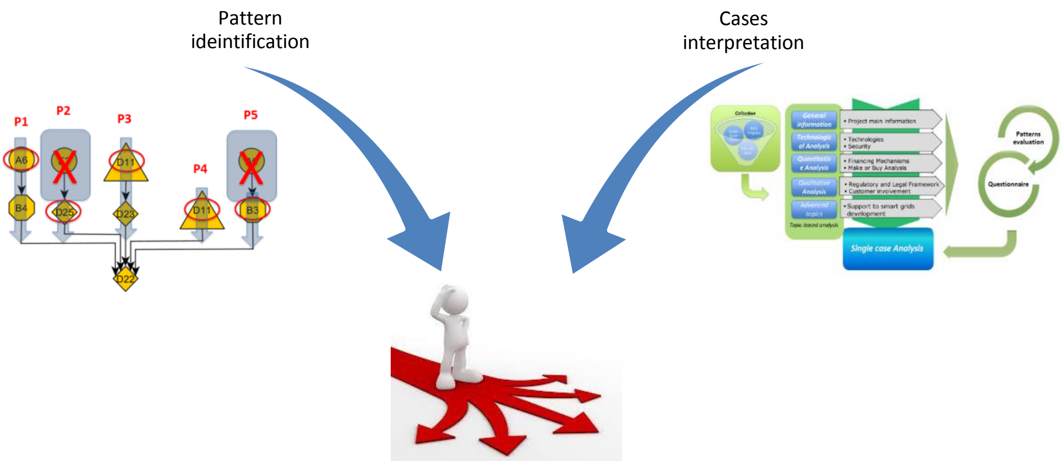


Figure 14– Drawing guidelines

Results

Coherently with the twofold goal of this research thesis, the results will be presented in two sections, each aimed at fulfilling the previously set objectives.

1. **Identification of theoretical patterns to describe the work of a smart metering project.**

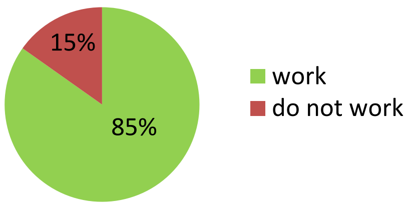


Figure 15 – Final result

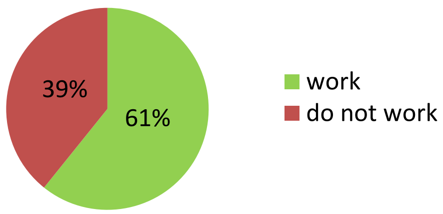


Figure 16 – Currently result

The percentages of patterns that correctly predict the performance of a project are shown in Figure; a high number of confirmed patterns (the green section) shows the validity of the model. Some processes have a longer time to realization and currently they are not still confirmed; to date the percentage of confirmed patterns is lower. If some conditions will be respected, the inertia of the projects leads to the confirmation of these patterns in a short time.

2. **Analysis of smart metering projects and identification of common contextual factors and enablers elements.**

A better understanding of how the smart metering project work has been achieved through the analysis of twelve European cases. The work has allowed to identify the elements that work well in the development phases and some aspects that, instead, impede the progress of the project. Twenty-five guidelines have been recognised for address the operations of the actors involved in the projects; these recommendations are useful to:

- complete the projects still in the implementation phase, ensuring the achievement of excellent results;
- increase the dissemination of smart meters with new projects in the European countries; these projects will be able to prevent the recurrence of operation problems;

- implement large-scale projects. Dissemination projects of innovative technologies have similar characteristics to the smart metering projects; therefore follow the same dynamics.

Chapter 1 – Smart Metering

1.1 Review on Smart Metering Concept

Since the 1980s, radical changes in information and communications technologies have revolutionized the potential of utility meters (Lascelles at al., 1995). The new systems have come to be known as “smart meters”, as a reflection of their enhanced functional and communicational capabilities, when compared with their “simpler” predecessors which merely measured consumption and required manual reading (Marvin at al.,1999). In the last decade billions of electrical smart meters were installed around the world, and today we can see a continuing trend of implementation and development of these devices; the reasons for this widespread adoption are numerous and they involve lots of subjects.

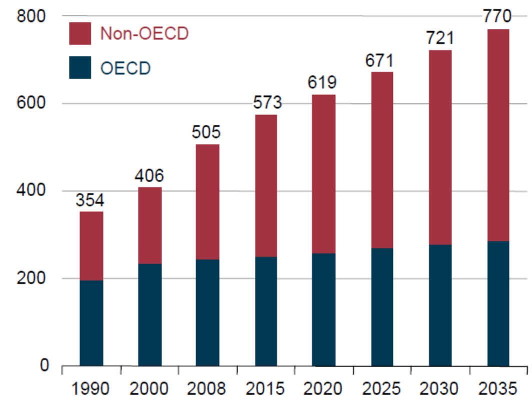


Figure 17 - World energy consumption, 1990-2035 (quadrillion Btu)

Recent forecasts claim that world energy consumption grows by 53 percent from 2008 to 2035 and the total world energy use is expected to rise from 505 quadrillion British thermal units (Btu) in 2008 to 619 quadrillion Btu in 2020 and 770 quadrillion Btu in 2035; the world demand for electricity, in particular, will increase by 2,3 percent per year from 2008 to 2035, from 19,1 trillion kWh in 2008 to 25,5 trillion kWh in 2020 and 35,2 trillion kWh in 2035 (International Energy Outlook, 2011).

For this reason the international community main interest is to develop and disseminate devices that can help to reduce the energy use and permit to achieve savings; in particular the European policy makers have started some initiatives to facilitate the diffusion of new technologies. First step towards this goals is the implementation of advanced energy management systems: the use of smart metering has therefore been heavily promoted as an essential part of the transition to lower impact energy systems, and as a mean of customer engagement.

A point of interest is that today there is a big difference between knowing the energy flows along the electricity supply chain and resolving problems in the distribution grid:

though in any generation facility and in the transmission grid operators find out complications as soon as they happen; when it comes to the distribution grid, instead, it may take thirty days to three years before there is any idea of where the electricity has gone (Houseman, 2005). A system of tools is necessary to facilitate the understanding of this use of energy, it allows to measure where power went and reporting this kind of information at regular intervals. As stated by Houseman, smart metering is the missing link in the understanding of how electricity is used.

But what's exactly meant for Smart Metering? The European Commission (2012/148/EU) defines "smart metering system" an electronic system that can measure energy consumption, adding more information than a conventional meter and that transmit and receive data using a form of electronic communication.

First of all, the term "smart" is to mean primarily "non-dumb", *i.e.* the meters communicate electronically (Darby, 2010); but the definition provided by the European Commission suggests that the difference between the conventional metering architectures and the smart metering systems goes far beyond the technological aspect. The way information is transmitted and used is the real innovation of this structure; the ability to communicate directly and in a very limited amount of time changes the way of using energy; using smart meters merely for data collection would miss the point of this technology.

A smart metering system includes a smart meter, a communication infrastructure and a control device (Depuru at al., 2011a). Smart meter, the core component of the entire system, can communicate and execute control commands remotely as well as locally; it can be used to monitor and also to control all home appliances and devices at the customer's premises. It can also collect diagnostic information about the distribution grid, home appliances, and can communicate with other meters around it; finally it can measure electricity consumption from the grid, support decentralized generation sources and energy storage devices, and bill the customer accordingly (Vojdam, 2008).

The possibility to gather information on the use of energy and the ability for energy suppliers to directly communicate with consumers are the two characteristics which give the opportunity to limit the maximum electricity consumption and, through the network connection, can terminate or re-connect remotely electricity supply to any customer (Hart, 2008).

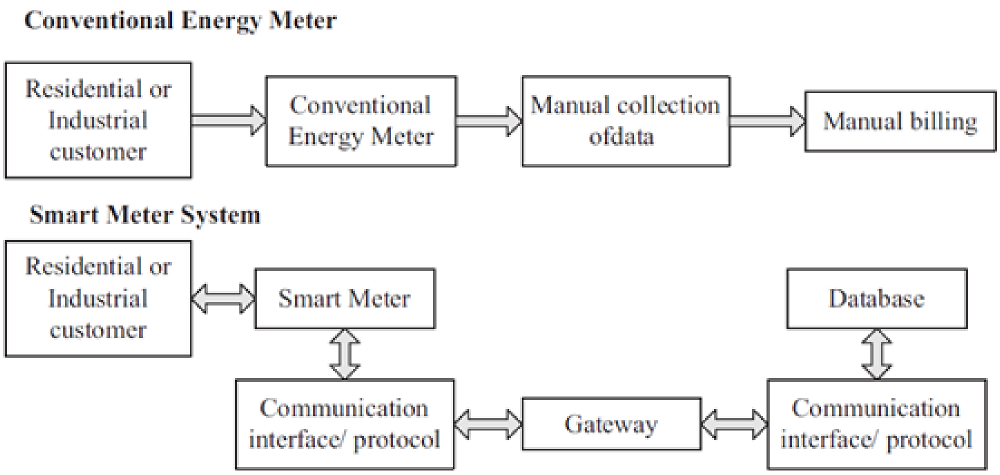


Figure 18 - Metering architectures of conventional energy meter and smart meter

Though the smart meter is the core component of the system , as seen from the previous Figure 18, the design of the communication network and the selection of communication devices are equally important for a proper functioning of the system. A more complex architecture, compared to the traditional scheme, implies a new set of issues, and the introduction of a new component must satisfy multiple complex requirements (Depuru at al., 2011a). When a smart metering system is used, a huge amount of data are transferred along the utility company: smart meter and home appliances are involved in the network. This data are sensitive, confidential and the access to them should be restricted to a few personnel; for this reason security guidelines have been provided for transmission, collection, storage and maintenance of the energy consumption data. The communication standards and guidelines were formulated to ensure that data transfer within the network was secure. It is equally important that this data must represent the complete information regarding the energy consumption by the customer and status of the grids without any potential manipulations or miscalculations. In the end, they must be authenticated and should reflect information about the target correct devices (Cleveland, 2008).

1.2 Smart Meter, what do they do?

1.2.1 Main features of a Smart Meter

Smart metering generally involves the installation of an intelligent meter at residential or industrial customers and the regular reading, processing and feedback of consumption data to the customer.

In his studies Van Gerwen (2006) highlights that a smart meter has the following capabilities:

- real-time or near-time registration of electricity use and the possibly to generate electricity locally *e.g*. in case of photovoltaic cells;
- offering the possibility to read the meter both locally and remotely (on demand);
- remote limitation of the throughput through the meter (in the extreme case cutting of the electricity to the customer)
- interconnection to premise-based networks and devices (e.g., distributed generation)
- ability to read other ones, on premise or nearby commodity meters (e.g., gas, water).

The conventional electromechanical meters have worked as the utility cash register, they simply recorded the total energy consumed over a period of time, typically a month, and led to the realization of energy bills; the customer had to pay a fee calculated on historical consumption and on final adjustment (Hartway et al., 1999).

This method of billing the energy has been changed by the introduction of smart meters; first of all the relationships between customers and utility have become more frequent and intense, but moreover several studies have tried to identify the key features of a smart meter (Darby, 2010; Marvin et al., 1999; Benzi, 2011; U.S. National Energy Technology Laboratory, 2008) and a summary of their results allows to identify thoroughly its functions:

• Support for a range of time-of-use tariffs

• Remote switching between payment modes

• Remote turn on / turn off operations

• Two-way communication to and from the meter

• The capacity to communicate with a micro-generator

• Net metering

• Consumption data for consumer and utility

• Loss of power (and restoration) notification

• Power quality monitoring

• Four quadrant measurement (real, reactive, import, export)

• Load management capability to deliver demand response

• Communications with other intelligent devices in the home

- Tamper and energy theft detection
- Alarm and alert functions

The main features to innovate the operation of new meters to the old “dumb” meters are the real-time recording of the information of power consumption and the remotely reading of the data.

These two main aspects are also the differential factors which allow to distinguish a wide range of “intelligent meters”; Also in literature a lot of authors use different types of definitions, and relative acronym, to refer to the smart metering core components. Soergel (2010) identifies three broad categories of meters: electromechanical, Automatic Meter Reading (AMR) meters, and Advanced Metering Infrastructure (AMI) meters. The traditional electromechanical meters only measure the flow of energy and they need operators to periodically read the value indicated by the meter and, through this reading, to realize the bill. AMR meters are typically read by devices installed in vehicles, allowing the meter reader to slowly drive through a neighborhood until all readings have been collected. AMR readings gathered by handheld devices or through fixed networks consisting of antennas, collectors, repeaters and other permanently installed infrastructure are less common.

Finally, AMI differs from AMR in several ways: the two key differences consist on the existence of two-way communication between the utility and the customer, normally via an in-home display, and provisions that allow consumption to be measured on time-based system (Soergel, 2010).

In others case the authors use the term “advanced” rather than “smart” to refer to a simpler version of communicating meters (Darby, 2006). Advanced meters identify more detailed consumption than conventional meters and communicate through a network back to the utility for monitoring and billing purposes (Climate Group, 2008); this system have only one-way communications , from customer to utility, and they have been used by industrial and commercial customers for many years.

Initially, AMR technologies were deployed to reduce labor costs, improve the accuracy of meter readings and contribute to increase customer satisfaction by reducing the number of estimated and inaccurate bills. A growing understanding of the benefits of two-way interactions among system operators, consumers and their loads and resources led to the evolution of AMR into AMI (AMI White Paper, 2008).

In conclusion, smart metering is often referred to both automated meter reading (AMR) and, in the case of real-time and two-way communications, advanced metering infrastructure (AMI) (Van Gerwen, 2006).

1.2.2 Advanced Metering Infrastructure

Deploying an Advanced Metering Infrastructure is a fundamental early step to grid modernization. AMI provides the framework for meeting one of the modern grid's principal characteristics: motivation and inclusion of the consumer. As described by the National Energy Technology Laboratory for the U.S. Department of Energy, AMI is not a single technology but rather an integration of many technologies that provides an intelligent connection between consumers and system operators. AMI gives consumers the information that they need to make intelligent decisions, the ability to execute those decisions and a variety of choices leading to substantial benefits they do not currently enjoy. In addition, system operators are able to greatly improve consumer service by refining utility operating and asset management processes based on AMI data.

Through the integration of multiple technologies (such as smart metering, home area networks, integrated communications, data management applications, and standardized software interfaces) with existing utility operations and asset management processes, AMI provides an essential link between the grid, consumers and their loads, and generation and storage resources (AMI White Paper, 2008).

An AMI system is thus comprised of a number of technologies and applications that have been integrated to perform as one:

- Smart meters
- Wide-area communications infrastructure
- Home (local) area networks (HANs)
- Meter Data Management Systems (MDMS)
- Operational Gateways

Though the features of smart meters have been widely presented above, the other infrastructure components deserve further consideration.

1.2.2.1 Communications Infrastructure

The AMI communication infrastructure supports continuous interaction between the utility and the consumer; it must employ open bidirectional communication standards, yet be highly secure. Beyond the control of the electrical load it has also the potential to serve as the foundation for a multitude of modern grid functions (Rao at al., 2013). Various architectures can be employed: the most common are the local concentrators that collect data from groups of meters and transmit that data to a central server via a backhaul channel.

1.2.2.2 Home Area Networks (HAN)

A HAN is an interface with a consumer portal to link smart meters to controllable electrical devices. Its energy management functions may include an in-home display (in this way the consumer always knows what energy is being used and how much it is costing), a responsiveness to price signals based on consumer-entered references, a set points that limit utility or local control actions to a consumer specified band and a control of loads without continuing consumer involvement (Faruqui, 2007).

The HAN/consumer portal provides a smart interface to the market by acting as the consumer's "agent." It can also support new value added services such as security monitoring. In the end a HAN may be implemented in different ways: with the consumer's portal located in any of the several possible devices (including the meter itself), the neighborhood collector, a stand-alone utility-supplied gateway or even within customer-supplied equipment.

1.2.2.3 Meter Data Management System (MDMS)

A MDMS is a database with analytical tools that enable interaction with other information systems; one of the primary functions of an MDMS is to perform validation, editing and estimation (VEE) on the AMI data. The main tools are the Consumer Information System (CIS), billing systems, and the utility web site; the Outage Management System (OMS) and the Enterprise Resource Planning (ERP) power quality management and load forecasting systems.

1.2.2.4 Operational Gateways

The operational gateways, in conclusion, are the AMI interfaces with many system-side applications to support the Advanced Distribution Operations (ADO), the Advanced Transmission Operations (ATO) and the Advanced Asset Management (AAM). For each of these applications there are several tools and components which, however, are not discussed here since it is beyond the purpose of this study.

Thanks to these and others tools the data flowing to the systems described above is complete and accurate, and Smart Meter is on the verge of becoming the major element of demand side management strategies (Houseman, 2005).

1.3 Metering Systems

1.3.1 Role of Smart Metering in the integrated energy system

For several years the concept of intelligent interconnection among energy networks, known as smart grid, has been developed . On a different perspective, the final user of the same energy, within the house environment, is nowadays at the centre of a quite extended communication network, including telephone, data transmission, home automation, and the most pervasive of all: the Web. Thus, as observed by Benzi et al. members of the Institute of Electrical and Electronic Engineers, the two worlds (the utility's and the house's) are closely related but still differentiated with respect to many parameters so that such important information, as that related to energy consumption, cannot be easily interchanged. Being exactly at the border of the two worlds, the smart meter can play a crucial role, becoming the component that allows the connection and exchange of data between these worlds (Benzi et al., 2011).

The Figure 20 represents the concept of "smart house" developed by the authors and it highlights the role of a smart meter as the connection point between customer's level and network's level.

It is important to understand the mechanisms by which operates a smart meter, to define common characteristics for devices and communication systems so that they are able to interface effectively. The diagram in Figure 19 shows a classification framework that highlights the wide variety of protocols required for the communication: in this diagram, in fact, the smart meters are included both in the local area networks, providing technologies such as Ethernet, WiFi, and ZigBee, and in the consumer application area, where a significant role of protocols for home automation and metering-dedicated protocols is registered (EPRI, 2005).

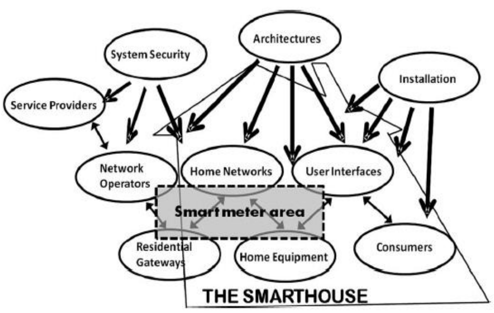


Figure 20 - Smart House areas

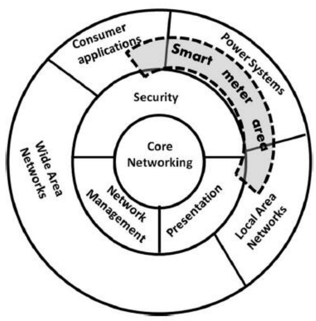


Figure 19 - Service groups

1.3.2 Main technological configurations of smart metering

1.3.2.1 Alternative technological options

The problem of common protocols for data communication and design of the architectures used for data gathering are relevance issues in smart metering system literature (Lasciandare et al., 2007; Choi et al., 2008; Selga et al., 2007; Oksa et al., 2006).

There are three major types of AMI communication networks: power line carrier (PLC), cellular network and short range radio frequency.

The PLC technology allows the transmission of data over voltage transmission lines along with the electricity power. A great interest has been placed on PLC for the AMI backhaul network as no extra cabling is required. Choi et al., (2008) proposed the use of PLC as means for delivering electricity, gas and water consumption data to the utility providers. Indeed, after communicating the meter's data to a concentrator through wireless technologies, the PLC vector is used to transfer aggregated data to utilities; however no metrics of evaluation and comparisons with different network design are provided. Oksa et al., (2006) conversely provided testing results for the communication between two subsequent routers over the PLC vector: the metering prove that, when the cable length reaches 10 meters, the length of the cable and the structure of the power grid affect the throughput causing a 65% reduction. The limits of such vectors are widely discussed and consolidated in the Literature: many researchers deem the PLC technology characterized by a too high data loss rate, affected by high signal attenuation, noisy medium and susceptibility to interface from nearby devices. Furthermore it provides low margins for scalability as they take advantage of already deployed infrastructures (Wang and Schulz, 2006; Lasciandare et al., 2007; Walawalkar et al., 2010). Moreover it is unlikely that the gas and water meters will share the same power line communications infrastructure because utility companies may not share their network infrastructure (Brasek, 2005).

The popularity and the wide area coverage of cellular networks , GSM and GPRS, have attracted researchers towards considering this communication vector for smart metering systems; this solution involves equipping smart meters with a SIM card which allows the unique identification of the customer. In their studies Tan et al. (2007) for instance, have suggested the use of GSM networks for low frequent meter data transmission, i.e. monthly communications, and they have proved through their papers the effectiveness solution for optimizing the consumption-to-bill process. In both systems, both one-way or two-way communication are enabled, however bi-directional communications significantly burdens on the meter energy usage as the meter needs to be active all time to receive commands. Wood et al. (2007) conversely, argued that scalability and reliability of such networks is questionable, especially under high loads.

The Short range Radio Frequencies comprise a set of different communication technologies such as Bluetooth, WiFi, Z-Wave and ZigBee, differing on signal power and frequency band. Although after an initial enthusiasm some of these vectors, e.g. Bluetooth and WiFi, have been discarded in the literature as a solution for smart metering; recent publications portray a growing attention to these wireless technologies as many researchers deem Radio Frequencies to be the future of smart metering. (Anderson et al., 2009; Billewicz, 2008)

Although different standards exist, the research community interest is related to the exploration of solutions for lower power consumption in data transmission. To this respect, Zigbee has attracted much attention as a solution for smart metering, indeed the technology is already designed for low rate applications and consumes minimal energy, enabling a device to last for more years (Asif et al., 2008); furthermore, ZigBee supports a variety of strong routing protocols which allows greater interoperability. Some researchers although claim that this standard provides a too low bandwidth for AMI system, and that by increasing the number of nodes, interference increases significantly, thus making the technology hardly reliable and scalable.

Other studies picture the smart metering infrastructure as a Wireless Sensor Network (WSN): a meter device functionally is a sensor node that provides energy consumption measurement. The number of meters can grow up to thousands, and data are typically aggregated and delivered to a centralized location for processing and decision making. Some studies proposes a WSN structure for networking different meters tackling the problem of the network architecture for reducing meter's energy consumption, because they are powered through batteries (Wasnarat et al., 2006). These studies propose an energy saving system based on the avoidance of long packet transmission, each meter forms sub-trees with a base station and reports its measurement through other meters. The base station then sends aggregated data through the cellular networks to control rooms; this architecture can be used in different sectors and allows the integration of different utility meters.

1.3.2.2 Pathways of smart metering development

After a broad overview of the definitions used in literature and in the composition of an AMI, it becomes important seeing as these structures are really implemented and which of the different types is the most used. A bit of clarity is necessary since over 50 different metering systems were identified through interviews to manufacturers and installers (Marvin at al., 1997). The interest is in how new information and communication technologies can transform the conventional meter into a smart tool for the more efficient environmental management of resources (Aitken, 1996; Stansell, 1993) since meters are the gateway technology through which energy services are delivered to the houses.

The design of metering systems is a dynamic process of technology and functionality selection predominantly driven by the strategic objectives of meter manufacturers and utility companies; standards organizations are now compiling “shopping lists” to cover all the anticipated functional requirements of new metering systems and are undertaking evaluations of the technical configurations required to meet specific utility needs (Dick, 1996; Formby, 1996).

Figure 21 illustrates a menu of the design building blocks that are currently available to transform the meter from a simple measurement device to an extended system, highlighting the range of environmental opportunities that are open to selection.

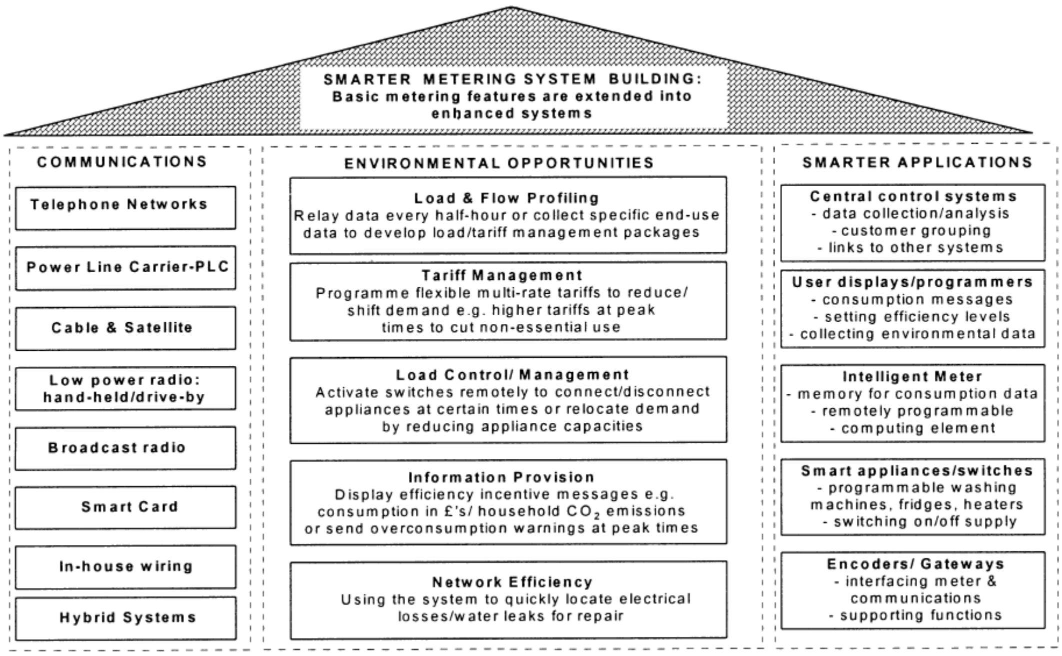


Figure 21 - Alternative technology options for building metering systems

Technological choices are now significantly enlarged with each of the metering and communication systems having differential capabilities to support particular environmental applications (Formby, 1996). Systems designed for load and flow switching applications can be configured with one-way radio tele-switch communications which enable utilities to send messages to the meter to switch-off appliances at peak load times (Woolner et al., 1996). Alternatively, high data capacity two-way communications networks, such as PLC, telephone or cable, link into a meter enable the transfer of information on half-hourly consumption to utility central computer systems. Such information could be used to develop multiple tariff rates allowing utilities to shape demand profiles by shifting consumption in real-time (Craig et al., 1996).

The flexible technical frameworks within which metering systems are now being configured are creating new environmental opportunities which could be built into currently available technologies (Aitken, 1996; Whiteman, 1996).

The precise technical configuration of the meter is strongly shaped by the often conflicting objectives of agencies involved in developing and implementing the systems. The way in which these different groups envisage the social organization of relationships between the utility and the household, and their strength in influencing metering developments, frame the systems which emerge.

By identifying four metering technical development pathways (TDPs), some studies have examined how the creation of new opportunities for environmental action is a much more multi-faceted and complex process. These are summarized in Figure 22. Each TDP represents a number of metering systems that do not necessarily share the same precise technical components and applications, but nevertheless are socially configured in ways which inscribe similar forms of producer/user relationships. An individual TDP produces a distinctive social context that simultaneously creates and delimits particular types of opportunities for utilities and users to participate in resource-saving action.

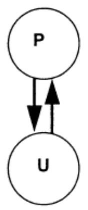
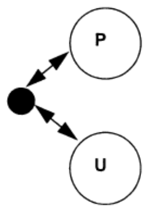
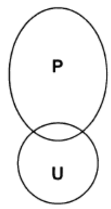
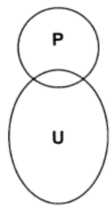
TECHNICAL DEVELOPMENT PATHWAY (TDP)	*MONITORING*	*GATEKEEPER*	*PRODUCER-LED*	*USER-LED*
FORMATION P=Producer U=User				
TECHNICAL CONFIGURATIONS	CONVENTIONAL METER WITH SIMPLE FUNCTIONS	SMART CARD MEDIATES FUNCTIONS	PRODUCER CONFIGURES FUNCTIONS	USER CONFIGURES FUNCTIONS
PRODUCER/ USER RELATIONSHIPS	LIMITED RELATIONSHIP	DISTANT RELATIONSHIP	AUTHORITATIVE RELATIONSHIP	DEVOLVED RELATIONSHIP

Figure 22 - Smart metering technical development pathways

1. Systems representative of the monitoring TDP are basic meters which measure resource consumption for the billing of users. The development of cheap, reliable meters allowed electricity utilities to rapidly extend their networks into the domestic sector (Guy et al., 1995). More recently, experiments have taken place to convert such conventional meters to allow meter readings to be taken automatically, through a hand-held unit, this speeds up door-to-door operations, but offers little extended functionality. Conventional meters, and their more recent adaptations, set up relatively simple, symmetrical social relations between producers and users. The meter acts as an agent in the home recording consumption on behalf of the utility and its relations with users are transacted through the reading, billing and credit control systems. With manual or limited frequency communications and infrequent readings, utilities have relatively little information on users behavior beyond the boundary of the meter. Consequently, the meter only has a limited role in shaping users resource saving action which largely depends on the motivations of households. This monitoring TDP orientation is reflected in the way new technologies are being applied to conventional meters. Utilities are designing them to reduce costs, increase accuracy and solve meter-reading problems, rather than to provide enhanced functions to promote environmental action, which remains firmly the householders' responsibility.
2. The gatekeeper TDP has a distinct technical configuration, highlighted in systems of prepayment meters in the electricity, gas and water sectors. These systems use a transportable medium such as a token, key or smart card to control access to utility

services (Bates, 1996). The meters are configured to remove regular direct contact between utilities and users and are a direct response to theft, nonpayment and staff safety problems associated with traditional coin meters (Cowburn, 1996). In the electricity sector the prepayment meter's coverage is increasing rapidly (Bates, 1996). Utilities have focused on a relatively narrow set of functionalities centered around revenue collection, while environmental applications remain unexploited. The gatekeeper TDP represents a new utility imperative which distances utilities from prepayment users and the high costs of debt and disconnection.

3. A new range of producer-led metering systems are currently being demonstrated and implemented by utilities in trials with selected users. Innovation has thrived in the electricity sector, where meter manufacturers have developed a wide range of innovative new metering technologies. These include "modular meters", where enhanced applications can be added to basic communication units over time (Warwick, 1996), and intelligent meters, which can be remotely programmed by the utility, adding or modifying functions over real-time communication networks (Craig et al., 1996).

   Meter manufacturers argue that these systems have potentially unlimited levels of functionality which leaves utilities grappling with the difficulties of deciding what type of services to offer to different groups of customers (Garrett, 1995). In the context of the liberalization of domestic electricity markets, utilities are particularly interested in using these systems to capture and retain lucrative users; in this sense, the producer-led TDP is about utilities extending their control "beyond the meter" and into the home by offering value-added services, extracting new information about users and targeting new packages of services.

   In trials of systems identified as producer-led TDPs, utilities are most interested in developing applications which will allow them to have more centralized control over their customers' consumption; in contrast, the implementation of environmental applications, such as customer-programmable controllers offering users a more active role in demand modification, are notably absent from emerging configurations.

   This configuration also reflects the much narrower range of social interests shaping producer-led TDPs. When contrasted with the wider range of social interests involved in shaping both the environmental and community implications of other

TDPs there is very little critical debate over the functionality and redistribution of responsibilities implied in producer-led models.

As such, the producer-led pathway can be described as one in which the utility seeks to develop a more authoritative relationship with their preferred customers.

4. The user-led TDP is the most weakly developed; although the technical components of such systems are similar to the producer-led model, they are organized in quite a different way. Instead of extracting information from home and externally controlling tariff levels, the technical configuration re-orientates information flows and programming capabilities towards users. Many meter manufacturers recognize the capabilities of smarter metering systems to provide information on the user-side, and their publicity brochures often show a user-friendly interface which can be plugged into any domestic power socket to give more information on energy consumption. However, support for more active user participation has failed to translate into any significant commercial utility trials of user-led metering systems. Only a few case studies have explored new ways of raising the visibility of resource consumption and have monitored how customers respond to new levels of choice and control; the purpose of this studies is to show how metering systems could be configured within home, so that the utility delegates decision making to the user and the home network. Such devolved and decentralized systems offer a contrast to producer-led systems where centralized control of applications keeps a tighter grip on user activity.

   As illustrated in Fig. X, the user-led TDP raises the possibility of new producer-user relationships in which the user exerts more influence over the services they receive, and can use the informational capacities of the smart meter to devise their own home energy efficiency and conservation regimes.

The challenge of re-asserting environmental functionalities into TDPs is only partly of a technological issue; support for the installation of environmental applications across TDPs also requires a powerful shift in the regulatory and institutional frameworks. The challenge for public policy is to ensure that these evident environmental opportunities are not foreclosed as utility competition develops. In particular, a context needs to be created in which "dominant social interests", such as utilities, manufacturers and communications companies, can be supplemented with the "missing voices" of regulators and user groups like environmental and community organizations.

This would allow more open debate and investigate the diversity of environmental applications which could realistically be built into each TDP, such a coalition of interest could focus on three substantive areas: first, utility regulation has to find ways of accelerating environmental action. The regulatory and institutional framework has to widen its agenda to raise the importance of environmental objectives when the utilities are setting technical priorities within the development of TDPs. The challenge for regulation is to strengthen the links between utilities' commercial objectives and environmental policy. For instance, rewarding utility resource savings would help raise the visibility of currently marginalized environmental applications in smart-metering developments. Regulators can also provide support for new resource suppliers who have different reasons from traditional utilities for entering the marketplace. For example, environmentally motivated suppliers have announced their intention to enter in energy markets and hope to encourage demand-side management by balancing prices with environmental and social objectives. This might provide opportunities to extend the configurations of metering technologies in new and beneficial ways (Langley, 1997).

Second, groups responsible for formulating technical standards in metering should consider the importance of creating different contexts for environmental action, and continue their support for open standards. Smart metering is still undergoing a rapid rate of development. Any attempts to harmonize or set definitive design protocols at this stage must be viewed with caution, as overly prescriptive standardization could foreclose the emergence of new TDPs with a high level of environmental functionality, such as the emerging user-led TDP.

In the end, the importance of modular design processes needs to be maintained for the promotion of environmental applications. It is important to avoid the development of TDPs which prematurely “lock” users into particular relations with their utilities, without fully assessing user needs. Manufacturing groups must ensure that unexploited technical capabilities can be easily upgraded and activated to meet the changing needs of users. As more research is undertaken, new user requirements for environmental functions might emerge and systems must be able to respond to these new service opportunities (Marvin et al.,1999).

1.3.3 Actors involved in the systems

Although there are different configurations of smart metering structure, the actors involved in the implementation and management of the system are the same. The most important stakeholders of the whole smart metering value chain are distribution system operators (DSO), meter operators, meter manufacturers, technology suppliers, system integrators, policymakers and technical bodies.

This framework of actors is obviously wider than the "dumb" meter value chain; the innovative technology has indeed introduced a number of new roles and interest for the original operators, and created a wide range of competing groups with different objectives. Marvin et al. (1999) shows how each of these interest groups has particular institutional roles and diverse objectives, including economic and environmental efficiency, commercial competitiveness, technical competence and social welfare; in Figure 23 the relationships between the different actors and the role of smart meter as a "gateway" between producers and consumers are represented.

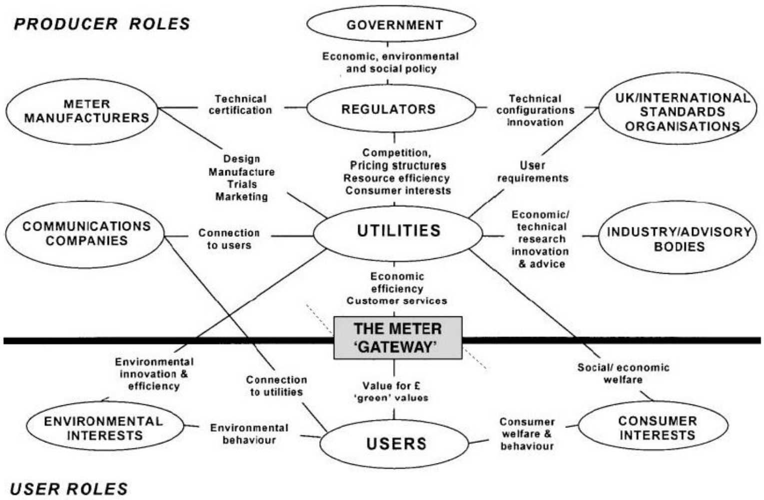


Figure 23 - Shaping metering - roles of key interest groups

The old configuration of the metering system of energy consumption was developed in a different context; generally an actor had a monopoly on the total energy supply, and had no desire to improve different aspects of the system. Today new commercial opportunities have accelerated the emergence of smarter metering, encouraging manufacturers to design systems which improve network efficiency and extend new value-added services, such as controlling security devices, home energy services and account management systems (McNicholas, 1997). All the electricity utilities have actively participated in trials of smart metering systems. At the same time, the metering industry is operating within an uncertain economic context characterized by mergers, new international entrants and restructuring of the utilities sector (Clarke, 1997).

Managing the phases of installation of smart meters is an important problem from the point of view of supply chain: in the "smart metering implementation program" developed by the Ofgem, the office of gas and electricity markets in Great Britain, it is stated that the current electricity metering supply chains has a number of layers of delivery and ultimately are reliant on meter installers. The meter installer may be provided from a range of sources, including being an employee of a meter operator, a contractor to the meter operator or contracted through a third party. Discussions with stakeholders suggest that meter operators would like to retain a reasonably consistent and predictable level of resourcing throughout the rollout.

This is due to a number of factors, including:

- Achieving maximum value from the costs of training meter installers;
- Being able to contract for installers over a longer timeframe and achieve reasonable rates;
- Avoiding peaks in workload that require overtime costs, travel costs or short-term contracts;
- Developing consistency and quality in delivery through resource retention.

Other stakeholders, in particular the Health and Safety Executive, have expressed concerns that plans that create a specific peak in resource volumes could have a detrimental effect on quality and safety.

Despite this variety of actors, which tend to specialize their skills to the growth of technological and system complexity, some studies show a possibility for cooperation between them. Romer et al. (2012) suggests that stakeholders seriously consider the potential of new collaborations because a lot of synergies can be reached. Also in his work Romer identifies the important stakeholders for smart meter implementation: the distribution system operators, the private and commercial end users that could have own electricity production, the electricity retailers, the metering service providers, the private and public utilities and telecommunications companies. In addition to this, actors are mentioned a series of stakeholders that usually are not considered: the automotive industry (owing to an expected increase in electric vehicle penetration), energy wholesale market traders, energy exchange and traders, responsible organizations for balancing groups, and electronic component manufacturers. This increase in the number of actors involved indicates, once again, how the energy system, with the advent of smart meters, has become more complex.

1.4 Benefits of Smart Metering

Sometimes new technologies arouse great interest because of their use; this happens because they present the best features compared to previous technologies or because they lead to new meanings and innovative experiences. Van Gerwen (2006) argued that Smart meters appear to be the biggest innovative development of the last years, this is because this technology is able to cause at the same time, new technical potentialities and new experiences.

The European Commission itself has recognized as the smart metering “mark a new development on the path towards greater consumer empowerment, greater integration of renewable energy sources into the grid and higher energy efficiency and make a considerable contribution to reducing greenhouse gas emissions and to job creation and technological development in the Union”.

Thus the benefits of a smart metering system include a lot of aspects and it becomes difficult to identify all of them; in the literature they are often presented by some classifications; this can cause some overlap between classes, but it allows a greater comprehension of the description.

1.4.1 Nature of the Benefit

The first difference between the benefits is their relation with the electricity savings; when a smart metering system is implemented, it is possible to consider which benefits are related to the energy savings and which are related to the increase of service for the customers or energy suppliers.

The ability to real-time measure the energy consumption helps the suppliers to manage more efficiently the loads, deciding whether to increase or decrease the flow of electricity; but the use of smart meters is seen as a key component of the low-carbon economy. Through the modernization of the electricity grid and the implementation of smart components it is possible to reduce 5% to 10% the home energy use, with considerable economic savings, and studies suggest that smart meters could save million tonnes of CO_2 emissions.

Another important advantage is the opportunity for smart meters to interface with the systems of distributed generation, such as renewable energy sources, and decentralized systems of energy storage: because of their fluctuating nature, renewable energy sources could complicate the balancing of demand and supply. The risk of grid instabilities may cause damage to electronic devices and power outages, which eventually lead to deadweight losses.

At the beginning the problems arising from fluctuating feed-in can be solved by increasing demand elasticity or decoupling generation and consumption, but through the use of smart meters it is easier face these problems (Romer et al., 2012).

In addition to the benefits of lower energy consumption there are many advantages "non-energy related"; the use of a smart meter involves an added value for the customer and the utility which can better manage the supply of energy. Knowing in real time the failures of the grid, for example, can reverse the trend where the utility gets outage information by the customer, which call the utility; smart meters instead tell the utility that the power is out and the utility can call the customer first. There are potentials for on-selling related energy management services in the increases of knowledge about the end-customers consumption behavior; it represents an opportunity to develop new services aimed at helping the customers become more energy efficient (Houseman, 2005).

The research literature shows that in-home displays are one of the devices that most helps to change the end-customers consumption behavior; through them enough new feedback information are sent to interested users, on real-time, to help them understanding and managing better their electricity, achieving savings in the range of 5–15% (Darby, 2006) or, in a more recent review, of 7% on average for customers buying on credit and twice when combined with prepayment (Faruqui et al., 2010). There is also some evidence that displays have an enduring impact even if only used for short periods, through changed habits and investment in efficiency measures (Darby, 2006; Rossini, 2009).

1.4.2 Parties involved

As seen above, a smart metering system involves a lot of subjects, consumers utilities and society as a whole, and each of them could have many benefit from it. It's important to distinguish the benefits for different groups of actors, because these differences explain many of the problems in the promotion of this new technology. Vasconcelos in one of his studies make a wide description of the benefits, splitting them between the following actors: energy suppliers, distribution system operators, metering companies and consumers, and finally he highlight the impact for the social interest.

From the suppliers side, smart meters offer the possibility of the new "pricing options": the time-of-use rate options (TOU). A better knowledge on the consumption pattern of individual customers gives suppliers the opportunity to target them with customized contracts. These contracts may offer different electricity price that applicable at different time of the day (Hartway et al., 1999). The change in the process of reading meters, became automatic, naturally increases the speed of the process.

In addition to the operational benefits, the management of the bill has significant improvements: there are fewer bill complaints due to more accurate billing; this leads to a reduction of back-office costs in terms of customers service center and to less re-issued bills. Finally, there remain fewer bad debts because there is no longer any need to gain access to premise.

With smart meters suppliers know the real consumption of their clients, instead of standard average profiles; this enables suppliers to optimize wholesale power purchases and thus make a better portfolio management. On the other hand, aggregating a critical mass of demand responsive customers enables suppliers to further reduce wholesale energy cost and even, if they so wish, to participate in balancing and reserve markets, earning extra profits.

In principle, when the metering market was liberalized and suppliers had the freedom to offer customers different metering solution, the potential benefits for suppliers was higher since there was more scope for differentiation (Vasconcelos, 2008).

At the level of distribution system operators (DSO), smart metering enables better information on the low voltage distribution network, offering a range of potential savings to distribution operators. System-wide benefits derive from optimizing distribution operations, a better reliability and the ways in which smart metering support outage detection and reduction of restoration times, thus improving quality of service. Smart meters can enhance the operation of SCADA system (Depuru et al., 2011b). In addition smart meter system provides several benefits such as efficient power system control and monitoring, operational decisions are then taken timely to minimize outages and losses (Mahmood et al., 2008).

The main benefits recognized by researchers are: identification of fault locations, faster restoration time, service quality improvements and improved detection of network losses and theft are.

For the metering companies the key operational savings come from reduced meter reading cost and other ways in which smart meter technology replaces labour costs. Benefits also result from improved process and fewer errors in meter management. Smart meters also allow low frequent meter reads and improve meter reading accuracy, thus reducing meter disputes.

Operational savings also derive from remote signal dispensing with the need for physical visit to premises to activate/deactivate and remote maintenance which does not require the customer's presence. It is possible to use the smart metering for the better management of bad debts through remote reduction of the available power, followed by remote disconnection if the customer doesn't pay.

For the consumers the implementation of smart meters in their homes means more choices about price and service, less intrusion and more information to manage consumption, cost and other decisions. It means also higher reliability, better power quality, and more prompt, more accurate billing . In addition, smart meter will help keep down utility costs, and therefore electricity prices.

Society benefits from smart metering in many ways. One way is through improved efficiency in energy delivery and use, producing a favorable environmental impact (Vasconcelos, 2008). Furthermore it can accelerate the use of distributed generation, which can in turn encourage the use of green energy sources, and it is likely that emissions trading will be enabled by smart meter's detailed measurement and recording capabilities.

A major benefit of smart metering is its facilitation of demand response and innovative energy tariffs: as mentioned previously the TOU rate option can allow a lot of advantages and can be profitable for all the subjects involved (Hartway et al., 1999). During a period of high energy demand, a small reduction in demand produces a relatively large reduction in the market price of electricity and reduced demand can avoid rolling blackouts (Romer et al., 2012).

In a study Romer et al. addressing the issue of decentralized energy storage technology to enable the above, mentioned "distributed generation": the "prosumers", producers and consumers of electricity, become increasingly important actors in flow of energy management and the use of a smart metering system, thanks to its characteristics, help to address this problem. Romer identifies the most important stakeholders in a smart meter implementation and the diverse effects and impacts that it has on distinct stakeholders. In Figure 24 are allocated private costs (displayed as grey boxes) and benefits (displayed as white boxes) to the various players. For an higher comprehension, the table does not distinguish between private and commercial end users with or without own electricity generation facility.

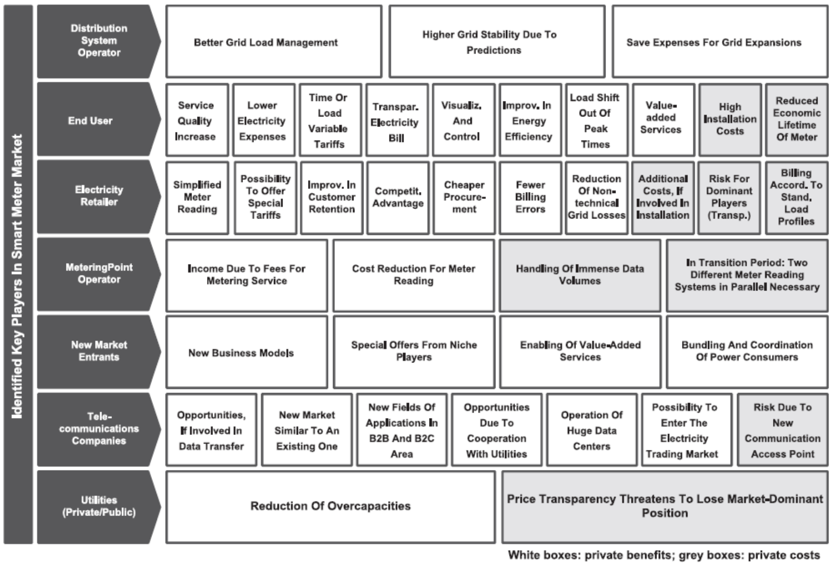


Figure 24 - Key stakeholders in the smart meter market and their private costs and benefits

1.4.3 Timing of the benefits

It's possible to assess the benefits arising from the use of smart meters even from a temporal point of view: there are some benefits recordable in the short term and others that appear in the time.

Joung and his team of work have carried out a study for assessing demand response and smart metering impacts on long-term electricity market prices; their claim that, up until now, the benefits of smart meter implementation, which can only be realized through consumer demand response to price signal, have been mainly assessed or measured in the context of near-term effects such as hourly market price decreases and daily peak load reduction (U.S. Department of Energy, 2006). The impacts of demand response resource, and the implementation of smart meter, in terms of long-term market prices, however, have not been tackled much in analytical ways. Only conceptual and qualitative approaches have been made in assessing benefits of smart meter implementations. However, as the applications of these new technologies to the deregulated electricity markets will have long-term impacts on market competitiveness and system reliability, a proper analytical framework for long-term market equilibrium and system reliability considering demand response resources is essential to assess the sustainable long-term impacts of smart meter implementation (Joung et al., 2013). The study results show that the more price responsive demand side resources are present in the market, the more competitive the long-term electricity market becomes and the more reliable the system becomes.

1.5 Overview on Smart Metering projects

1.5.1 Project-based approach

Traditionally, as stated by Zhang and Nuttal in their research, the electricity Distribution Systems Operators (DSOs) are the dominant meter operators for domestic meter points. They have a license obligation to provide metering services to all meter points, upon the request of the electricity suppliers; DSOs own and manage the meter assets and also charge electricity suppliers for metering services (Zhang et al., 2011). So that, they are the primarily responsible for the Smart Meter promotion and diffusion. Due to the initiative of some DSOs, many projects of Smart Metering are started in the early years of the 21st century.

The project implementation process, as argued by Pinto and Slevin, is complex and usually requiring simultaneous attention to a wide variety of human, budgetary, and technical variables. In addition, projects are often initiated in the context of a turbulent, unpredictable, and dynamic environment. This is exactly the scenario in which the DSOs have to implement the smart meter; the project approach, however, allows to overcome these difficulties and achieve the success in the smart meter implementation through a set of factors under the project manager's control (Pinto et al., 1987).

In 2008, less than 4% of the global installed base of 1.5 billion electricity meters were smart. In four years by 2012 smart meter penetration has grown to over 18 %. It is expected to continue to grow and it is projected to exceed 55% by 2020. That's nearly 1 billion smart meters worldwide (Zeiss, 2012). Smart metering implementation is a theme with high relevance on international energy agendas; a variety of proposals and a differentiated level of implementation have to be highlighted in an international overview of smart metering deployment.

1.5.2 Smart metering progress in the World

Out of the Europe, the main regions in which smart metering projects are developed are: United States, Canada, Australia and more recently China; in these countries,

although with different reasons, the use of intelligent solutions is a necessity as well as a strategic choice (see Figure 25).
United States, with 60 smart metering projects ongoing or already completed, are the regions with the largest number of installations, today there are commitments in place to install nearly 80 million smart meters by 2019. The requirement for a demand response policy and smart meter deployment was first raised in California in the last years of utility crisis, the main driver for introducing AMI in this region is to increase the reliability of electricity supply through the reduction of consumer peak demand. California has a summer peak demand for power during approximately 50 to 100 hours per year, this peak is mainly due to the increasing use of air conditioners. The main energy agencies of California saw demand response as an important mechanism to decrease this peak; all three major California utilities developed their own plans to implement AMI systems to all residential customers (Van Gerwen, 2006). The development and installation of advanced meters and communications infrastructure represented some of the largest AMI deployments in the world and it is now further stimulated from the $4.5 billion federal economic package, allocated for research related to smart grids (Benzi et al., 2011); more recently also the Obama administration has allocated a grant of $3.4 billion for energy grid modernization to emphasize the strategic importance of the smart energy solutions.
In Canada the projects ongoing or already completed are 57, similar to the USA case, but their dimensions are smaller, with only 4 million of smart meters installed by 2015. In Ontario, the most populous region of Canada, the electricity demand peaks were the driver for smart metering implementation (Ofgm, 2006); energy conservation and demand side management have become important goals within the energy policy of the region. The Ontario Energy Board has proposed basic smart metering functions and some minimal technical standards. Each DSO is free to develop its own smart metering framework.
Even in Victoria, Australia, increasing summer electricity demand peaks by air conditioning caused extra investments on low use plants; introduction of smart meters to customers was seen as a mechanism to link wholesale and retail markets. The government changed legislation as instigated by the Essential Service Commission of Victoria; installation is started in 2006 for dedicated categories and the Essential

Services Commission of Victoria has rolled out a timetable to install 1 million smart meters by 2013. (Van Gerwen, 2006).

Developing countries like China and India are looking toward smart grids and smart metering as crucial technologies to cope with an efficient management of energy distribution and control in overcrowded areas. China plans to invest $490 billion in grid upgrades by 2020, including about $90 billion in smart metering technology; the State Grid Corporation of China (SGCC) has just announced it will install over 300 million smart meters by the end of 2015. As of 2011, SGCC has installed 36 million smart meters.

Figure 25 - Diffusion of smart metering project around the world

1.5.3 Smart metering progress across Europe

In Europe, a relevant role is played by regulatory authorities and government agencies; over the years some general directives were taken by the European Union (EU) and thus they were transmitted and implemented in many single states. The European Union has shown the way for “realise these energy savings and thus help the Community to reduce its dependence on energy imports”, through the European Directive 32/2006 on end-user energy efficiency services (DIRECTIVE 2006/32/EC, 2006). Afterwards, with the Directive 2009/72/EC European Union requires Member States to proceed with the rollout of at least 80 % of smart meters in their territory by 2020 (EC 2012, EU 2009). Significant investments have already been mobilised and a few countries have already proceeded to full smart metering rollout. A conservative estimate is that at least € 5 billion have been spent to date on smart metering pilots and rollouts. (Giordano et al., 2012).

Even if the international agencies themselves stimulate the use of energy efficient technologies, the smart metering installations are usually led by DSOs/utilities. In many case the decision to start with a smart metering project (o metti decisions oppure metti is taken) is taken by these electricity operators and they manage all the phases of the project. The DSOs' role in smart metering implementation is central in many European country, except in UK where the projects are led by energy retailers, and in Bulgaria where they are led by a telecom company. the size of the projects too varies widely among the different states, from a few hundred to a few tens of thousands of meters installed for each project (Giordano et al., 2012).

Among other European and international countries, Italy deserves a special mention since it was the first European country to adopt smart metering technology and, with more than 30 million smart meters installed, it covers more than 80% of households and it leads the deployment of smart metering devices in the world.

Enel, the largest Italian utility, introduced smart meters already in 2001 through the "Telegestore project". Before deregulation of the energy market, ENEL made the in-company investment decision to introduce smart meters as first utility worldwide. The main reasons for ENEL were the expected savings or revenues in the purchasing and logistics areas, in the operations field, customer services and revenue protection, in order to avoid fraud. The regulator or government or other market parties had any or only marginal influence on requirements Enel had to fulfil. Regarding the type of meter or the communication infrastructure, Enel was left totally free. ENEL has chosen a smart electricity meter that communicates through PLC to the nearest substation. Then , centralised control rooms read the data through GSM. By the end of 2005, Enel has 27 million smart meters installed, 24 million meters of which are being remotely managed and bimonthly read.

In Sweden first studies into smart metering were carried out in 2001. Some companies had already pilot projects, but the government foresaw opportunities for energy savings and it wanted to exploit the potential benefits. By a bill passed in 2003, the government obligated the grid companies to a monthly meter reading for all electricity users by 2009 and thus it stimulated the introduction of smart metering; in July 2010, Sweden became the first European nation to reach 100% smart meter rollout for all energy customers (Zeiss, 2012).

In the Netherlands, the government proposed a nationwide introduction of AMR after having conducted a detailed cost-benefit analysis (Van Gerwen et al., 2005); For example in 2007, it was planned that all 7 million households of the country should have a smart meter by 2013. In 2009 the Dutch government had to back down after consumer groups raised fears about data privacy; nevertheless the diffusion of smart technologies has continued and currently they are starting projects of roll out. Today many residential customers have a smart meter in their home, while the commercial and industrial customers are still exclude from these technologies (Scott, 2011).

Like Sweden and Netherlands, other northern Europe nations show increasing attention to the smart technology: Finland and Norway are planning to introduce legislation for smart meter implementation by 2014; in Denmark smart meter deployment is happening rapidly without any government or regulatory intervention. The need to change the old meter system, which caused an enhance of complaints and operational costs , has forced the Northern Ireland to install a new smart metering system. The introduction of the 'Liberty 'Credit Management' keypad meter' has started since 2000. By 2005, some 155.000 meters have been installed, covering 22% of customers. Since 2005 trials too have been undertaken in new customer services. These focus on pricing, offering different rates in specific periods, and indicate reduction of energy use by customers(Van Gerwen et al., 2006).

Malta and Finland will complete their smart metering rollout by 2013. Finland is installing 5.1 million meters for a total investment in the range of € 600-900 million. Malta is about to complete the installation of around 250 thousand meters for a total investment of € 86.5 million (Giordano et al., 2012).

Other countries have given the go-ahead for smart metering rollouts. For example, France will install 35 million meters by 2017, the UK will install 56 million by 2019, Spain will install 28 million by 2018. In September 2010, the French government decreed that 95% of French homes will have smart meters by 2016.

In the UK, regulator Ofgem has recently been exploring the potential of smart meters, the government has released a £ 11.7 billion implementation plan to install 53 million smart meters for gas and electricity use in every home between 2014 and 2020.

Considering the Member States of the European Union which, at this date, have already committed themselves to, or shown strong interest in, a full smart metering rollout, it can be estimate that the total investment in smart metering will be at least € 30 billion by 2020, for a total of at least 170-180 million smart meters installed. The level of investment and the number of installed meters is bound to grow as other Member States take official steps (Giordano et al., 2012).

1.5.4 Policy intervention

If the DSOs are the primarily responsible for the Smart Meter's implementation and diffusion, other actors can contribute to facilitate and promote the use of this innovative technology. It was already seen the role played by regulatory authorities and government agencies: they usually define general directives for the smart meters adoption (in terms of timing and entity extent installation) and they deliver the funds to facilitate investments in a technology which is still uncertain and expensive. The characteristic of uncertainty in technology diffusion raises the strategic issue of what policies the government and European policy makers should introduce to boost the rollout of smart meters in energy market; lessons from international experience (e.g., Italy, Sweden, and California) suggest that introducing smart metering in the context of monopoly provision can be a very successful strategy, but the best way to disseminate this technology still remains a matter of debate and research.

The diffusion and adoption of innovations have been an important field of research for decades, focusing on product and process innovation as major sources of creative destruction. A wide variety of theoretical models and conceptual frameworks for analysis have been developed to examine the drivers of diffusion and explain adoption (Geroski, 2000); the literature on policy diffusion of smart meters is smaller and pretty recent, but some theoretical model and conceptual frameworks for analysis have been developed in last years. For analyze the policy makers' influence, Rixen et al. tested different policies and their effects on speed and level of Smart Meter adoption. The tested interventions are: Market liberalization, information policies, and monetary grants.

In their research the objective- goal was identify the primary adoption drivers for effective and efficient policy design. Effectiveness was measured via diffusion speed and level, instead efficiency via cost and welfare impacts.

Simulation results underline that one policy does not fit in all situations, but that best suited intervention depends on the regulator's objective. Market liberalization is a dominant strategy. Intensifying competition is an effective and efficient adoption driver, while closed markets primarily favour the monopolist. Information policies typically accelerate adoption whereas monetary grants boost both speed and level. Policy makers must not underestimate synergies across inducements as well as supply and endogenous demand to keep control over policy costs (Rixen et al., 2012).

Another relevant model for the evaluation of the government's policies on promoting Smart Metering is the one proposed by Zhang and Nuttal for the UK energy market. UK policies for promoting smart metering stated that between 2008 and 2010 any household requesting a Smart Meter could get one free of charge. The key issue raised by this policy is: who pays for this device? Based on this issue, they broke down the policy into three dimensions: 1- the government subsidizes; 2- the electricity suppliers pay for SM; 3- DSOs pay for SM. Under the three strategies, the next issue is how best to roll out SM. If the government subsidizes SM, these devices can be rolled out in either the context of monopoly or the context of competition; if electricity suppliers pay for SM and they are responsible for rolling them out, they will be rolled out in the context of competition; if DSOs pay for SM and they are responsible for rolling them out, they will be rolled out in the context of monopoly. Therefore, Zhang's model of market game simulates the scenarios of these policy options, as shown in Figure 26.

The model developed by the authors helps to understand the dynamics of smart metering technology diffusion under the different policy options, but it also highlights as any configuration is always better than the other.

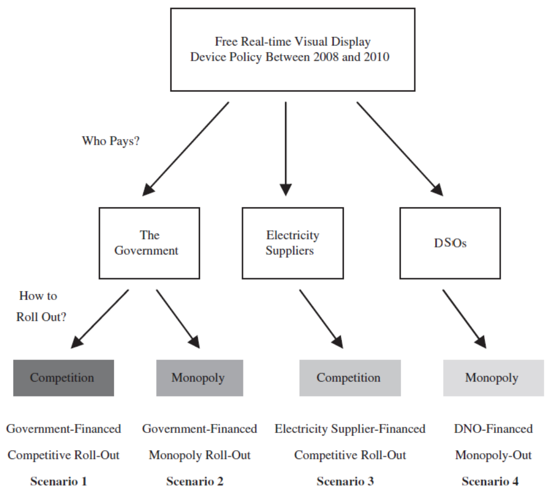


Figure 26 - Policy options

1.4 Drivers for Smart Metering implementation

As seen above there are different ways to carry out a smart metering project; it often depends on the country specific characteristics and on the policies chosen by the national governments; on the other hand there are some elements, common among regions, that promote the smart meter implementation. Potential benefits of wide smart meter diffusion have been mentioned previously, but the main driving factors that lead the DSOs to start a different smart metering projects and influence have not yet been thoroughly investigated. In literature there are not studies focused on the drivers for the smart meters implementation, but an initial identification of these factors has been done taking into account the projects already developed. Feedbacks from different smart metering projects already completed, or in phase of rollout, are presented in the firsts Deliverables of the Meter-ON projects. The identified driving forces have been classified into 5 categories: economic, technical, regulatory, social and related to new requirements and functionalities.

1.4.1 Economic

The economic benefits are obviously one of the main elements, if not the first, that make the use of new technologies more interesting for the DSOs. In fact one of the main drivers for the adoption of smart meters is that they are now cheaper than ever; in Europe the price per meter has dropped in the last years (Huseman, 2005) and continues to decrease.

In addition to the lower meter’s costs a substantial reduction in operating costs due to the change in contracted power and in connection and disconnection management is possible. The energy distributors can reduce their billing operation costs due to more accurate consumption measurements and consequently also the call-center care costs due to fewer calls related to inaccurate billing.

From the maintenance point of view, many costs are avoided because the breakdown caused by the overcharge are reduced and thus the site visits are avoided.

The ability to predict more accurately the consumption by the DSO permits to reduce the electricity technical losses: the peak loads are managed better through the voltage control and therefore greater efficiency is pursued in energy consumption. Finally there is also reduction in commercial losses: distributors are able to detect energy theft and false bills

1.4.2 Technical

Dealing with a new technology, as aforementioned , the smart meter introduces a lot of new features that constitute a strong driver for the operators: first of all the functionalities of the smart metering infrastructure make faster, remote and accurate operations possible. These new functionalities allow an improvement in the commercial and technical services, thus the DSO ability to increase its market share. In addition the smart meters fully support the liberalization of the energy market by providing the required infrastructure and TOU tariff that incentives the customer to consume energy in off-peak period.

The smart meters therefore represent a strong tool in order to maximize the value of DSO's metering infrastructure in terms of efficiency, maintenance and monitoring of energy flows and assets. Finally, another important result enabled by the new meters is the integration of higher proportion of renewables into energy mix: being able to handle two-way electricity flows, the risk of network's overloading is reduced and to dissipate the energy produced by the renewable sources is avoided.

1.4.3 Regulatory

In addition to the economic and technical drivers, there are regulations and directives that became driving factors for energy distributors; they must comply with these regulations but above all they try to take advantage from these rules through a proactive interpretation of their role.

The regulatory requirements for smart metering infrastructure is seen as the main driver for the uptake of a rollout program. Directives taking into consideration for the development of the different projects are listed below:

- Directive 2009/72/EC: concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC.
- European Directive 20-20-20: it sets three key objectives for 2020:
    - A 20% reduction in EU greenhouse gas emissions from 1990 levels;
    - Raising the share of EU energy consumption produced from renewable resources to 20%;
    - A 20% improvement in the EU's energy efficiency.
- Directive 2012/27/EC: European Directive on Energy Efficiency; on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC

In many cases the DSOs have realised a cost-benefits analysis before starting the project development; if this kind of analysis has a positive outcome it will become a strong driver able to start a smart metering rollout.

1.4.4 Social

In the social field there are two main aspects that encourage the DSOs to implement smart metering solutions: the first refers to the reduction of greenhouse gas emissions and a more energy efficiency use; the second refers to the role of the consumers that become progressively active in energy management and consumption.

The opportunities to saving 20% of the currently electricity consumption and the reduction of carbon emissions are important benefits for the society as a whole, but the DSO's main interest is to comply with regulations and promote their "green" image towards the customers in order to increase its market share and customers' loyalty.

In particular, consumers' trust in their utility company can be seen as a driver for the smart meter acceptance. If the consumer has a high level of trust in his provider, the introduction of the smart meter will be seen as another benefit which the company wishes to introduce to improve even better the offered services. In addition, smart meters overall can play a central role in consumer empowerment. As deployments go forward the consumer becomes awarer of the topic and his possible benefits.

1.4.5 New value-added functionalities

The last category of drivers refers to the new solution or service that the Utilities can implement to improve their offer: new services, markets and products are enabled by the new meters.

First of all, the integration of multi-metering solutions facilitate the Utilities' operations and reduce their costs; but above all it simplifies the relationships with the customers, reducing the number of interactions and increasing the frequency of consumption data delivery.

The ability to better integrate the renewable energy sources leads to a synergy between the smart meters and renewables' markets: they influence positively each other and the new meter can contribute to the diffusion of green technologies. In addition, due to a wide diffusion of the projects, it will increase the use of the tools connected to the new meters, like in-home display and communication systems, and their markets will be growing.

Finally, integrate new services in the power grid seems to become possible: for example it will increase the ability to charge lots of electric vehicles and thus it will enhance the spread of electric mobility, with additional revenues for energy distributors.

1.5 Barriers to the adoption of Smart Metering technology

The implementation of a smart metering system allows a better management of the energy electricity flow, as previously described a wide range of players are benefiting from their use; despite these advantages, however, the adoption of this new technology is not totally free of issues and challenges. The DSO must overcome a number of difficulties which, directly or indirectly, to impede his work and seems to make less advantageous the use of smart meters.

The barriers that have prevented smart metering technology from taking off in the energy consumer market can be summarized in three aspects: economic, technical and regulatory (Zhang et al., 2007).

1.5.1 Economic

As they are based on advanced technologies, smart meters inevitably cost more than conventional meters, and although their price has dropped in the last years remains higher than the old meters (Houseman, 2005). In some simulations Leite et al. consider that an electronic meter capable of measuring active energy can be purchased for about 15,00 $; for other smaller components and workmanship for exchange, it is considered an amount of about 8,00 $ per meter. Thus the meter will be installed at the total cost of 25,00 $. In the case of smart meter implementation, the costs are composed by three parts: the installation of the meter, the deployment of telecommunication infrastructure and Operation and Maintenance (O&M) costs of this system; this package would lead to an increase in the cost of the meter, for an estimated total cost of the new meter around 130,00 $, including installation costs (Leite et al., 2011).

The high investment problem is more important for those DSO that in the last years have systematically replaced the older electromechanical meters with new, but not "smart", meters. This situations would leave millions of dollars in stranded investments and require extensive changes to existing billing and customer information systems. In addition, the amount of load that could be reduced by relatively low-use, and residential customers may not provide sufficient benefits or savings that would justify the expenses associated with meter replacements (Soergel, 2010). Therefore, high absolute cost of replacement of existing conventional meters with smart meters remains a significant economic barrier and this investment has to be realized as a function proportional to the projected increase in the energy demand and portion of the distributed generation (Hallberg, 2010).

Another factors that can make it difficult for a DSO to switch to a smart metering system are the incentive schemes in the various countries; in the USA, for example, utility companies receive incentives for selling more electricity, which might not drive them to encourage their customers to conserve energy (Vojdani, 2008).

1.5.2 Technical

Although smart metering technology is already available, there are many issues that must be resolved in order to facilitate a wider dissemination of this technology.

First of all the deployment of a communication network, essential for the efficient use of smart technology, in some localities might be difficult due to terrestrial difficulties; lack of proper infrastructure for synchronizing this new technology with the existing ones might interrupt the introduction of smart meters (Depuru et al., 2011b).

Operation of a smart meter system involves a huge quantity of data transfer between a smart meter and the server located at the base station; this continuous transmission of data in real-time might arise some questions and problems in several customers. The data, in fact, might also reveal the information about presence of people at their residence, when they were present, and what appliances are in use. In view of this, some customers might be unwilling to communicate their energy consumption data.

The privacy and security in use of the data collected through the smart meters are concerns for the utility that must to interface with customers (Laicane et al., 2013), for this reason the industry is currently working closely with governments and consumer groups to address meter security. Technical specifications continue to evolve, while new or revised security and data privacy mandates may be introduced; the European Commission, in its recommendations, highlights the importance to "find appropriate technical and legal solutions which safeguard protection of personal data as a fundamental right under Article 8 of the Charter of Fundamental Rights of the European Union and Article 16 of the Treaty on the Functioning of the European Union".

Fundamentally, it would be an issue about the choice of parameters to be transmitted and administrator authentication to access that information (Bennett, 2008).

The lack of standardization of types of smart meters can create risk for energy suppliers: a consumer installing a smart meter from one energy supplier may switch to another energy supplier because its new smart meters appear to offer more advanced services (Zhang et al., 2007). Additionally, the lack of standardization of smart metering technology means that large number of smart meters of different types will work under different communication protocols. Currently, this issue remains a big technical challenge for energy suppliers (Vasey, 2007). The standardization of smart meter technology can overcome this technical barrier and enable energy suppliers to boost the deployment of smart meters in large scale.

If the lack of standardization facilitates customers to switch to another energy supplier, the great diversity between the protocols used may favor the lock-in effect. The lock-in effect is a very interesting phenomenon in marketing; it describes a state of an evolving market in which consumers prefer one of two or more competing products and that this preference persists for a long time beyond what would be economically rational (Gilbert et al., 2000). The lock-in effect in the adoption of smart metering technology could be a non-trivial problem for DSO because they would not have an incentive to improve their products and to provide new services; indeed, empirical observations from the energy market show a typical lock-in effect that exists between the major electricity suppliers (Zhang et al., 2007).

1.5.3 Regulatory

With the current regulatory framework, in many countries, most of the energy meters remain assets of the energy suppliers; for this reason one of the prime focus of the regulator has been the development of metering competition in the energy market. Some studies suggests that metering competition would advance the interests of consumers by offering more choices, encouraging technological innovation and reducing costs for both consumers and energy suppliers (Ofgem, 2006). For this reason the competition cannot be achieved only through the meter's standardization, the electricity network operators, in fact, are reluctant to risk developing innovative services, especially those that can render their current assets obsolete; instead, it is necessary a balanced system of rules, to prevent the emergence of a single solution on one side and encourage innovation on the other.

The European union is interested to identify which regulatory framework facilitates better the smart meters dissemination, in order on one hand to promote the interests of the Utilities and on the other hand increase the benefits to the final consumers.

Chapter 2 – Patterns identification

2.1 Meter-ON project

Smart metering has the potential to enable customers to have better control over their energy consumption, helps them to adjust their behaviour and ultimately reduce their energy bills. For this reasons, smart meters are considered the core element in the development of smart grids: the innovation led by smart metering paves the way to the provision of innovative services, enabling the active participation of end customers to the electricity market, smart charging of electric vehicles and supporting smart integration of distributed generation.

As above descripted, there are many projects of Smart Metering in developing; the worldwide opinion seems to approve their diffusion and the expectations regarding their use are high. Many of this projects are in rollout phase or will be in the coming months, but some aspect of their operation are still not clear.

First of all it is not sure which are the real benefits of their implementation, with some uncertainty on the amount and the beneficiaries, but above all there are many doubts about the best ways how to develop these projects. In many countries Distribution System Operators (DSOs) and Metering Operators are the entities responsible for the metering services, for this reason became important to know how a DSO operate and what mechanisms work inside.

So that, the European Union has decided to study how Smart Metering project work, their mechanisms and their characteristic elements, to steer the implementation of this solution and make greater clarity in the smart-metering community. With these objectives, the "Meter-On project" was launched by a Consortium led by the European Distribution System Operators for Smart Grid, including 12 leading DSOs and association throughout the European Union (Figure 27).

Figure 27 - The Meter-On project Consortium

The goal of Meter-On will be to provide to any stakeholder an open information platform with clear recommendation on how to tackle the technical barriers and the regulatory obstacle endangering the uptake of smart metering technologies and solutions in Europe. The project's results will be disseminate in the community, involving stakeholder of the whole smart metering value chain: Distribution System Operators, meter operators, meter manufacturer, technology suppliers, policy makers and technical bodies.

2.2 Panel composition

The work starts from the identification of the key elements that, from the DSO's point of view, have relevance in a smart metering project development, focusing on the rollout projects.

In order to draw concrete conclusions and not to be a purely theoretical exercise, a Panel of experts in the energy market sector was formed; the Panel comprises stakeholders that being relevant for the project work are not part of the project consortium: Panel's members are delegates of research agencies, Distribution System Operators and academic institutions (see Annex 1).

Leveraging on the expertise and experiences of members within the panel, a thorough analysis of the characteristics of a smart metering project was carried out and a set of influencing factors has been identified. The goal was to identify a subset of variables which convey the most relevant part of the information, thus reducing the complexity of the project analysis.

2.3 Variables identifications

The outcome of their research is a list of 41 variables (see Annex 2) which address the most relevant aspects that influence the results and the success of a smart metering project; variables are separated in 5 different sections, the sections A, B, C, D and E allow to cover all the different aspects of a smart metering projects.

Each section of variables specifies a particular aspect of the project:

- Variables A (Table 1, Annex 2) summarise the "General information" on electricity smart metering project; they indicate the number of customers involved, the scale and the timing of the project.
- Variables B (Table 2, Annex 2) indicate "Technological" characteristics of the project; they focus the attention on the different technologies involved in smart meters. In particular, communication technologies, used for the communication of the meters with possible data concentrators or data repeaters, as well as with the back-end system; local communication technologies and metrological

technologies (as far as gas and heat utilities are concerned). In addition, the adopted approaches to tackle cyber security and privacy of the data.

- Variables C (Table 3, Annex 2) indicate the "Quantitative" characteristics of the project; they focus the attention on the financing mechanisms, cost-benefits and make-or-buy approach adopted by the company. The objective is point out the financing mechanisms, the contracts the joint ventures and, whether is possible, the economical drivers (e.g., opportunity costs).
- Variables D (Table 4, Annex 2) indicate the "Qualitative" characteristics of the project; they focus the attention on regulatory & legal framework in place in each country and in Europe to outline the framework conditions and their impact on the development of the project. In addition, User Acceptance and Customer Involvement is assessed for the project, indicating how final customers have been involved and whether possible customer empowering devices such as home displays or active demand systems were accepted or rejected by final customers.
- Variables E (Table 5, Annex 2) indicate the "Advanced Topics" of the project; they focuses on the possible applications of smart meters as a pillar of the smart grid. These variables underline how the smart meter and Automated Metering Infrastructures can be used for metering of electric vehicle charging points, devices for empowering customers in demand response actions and, finally multi-metering, i.e., systems collecting metrological information for different utilities exploiting all possible synergies.

2.4 Variables evaluation

As seen in Annex 2, a scale of values has been assigned to each variable in order to quantify them and provide the overall picture of the smart metering environment. The scale adopted varies from case to case in relation to the variable type: generally, for the continuous variables, a value on a scale from 1 to 4 is assigned, meaning:

- 1 – low
- 2 – medium low
- 3 – medium high
- 4 – high

on the contrary, for the binomial variables are used the extremes of the above scale.

Variable A1, for example, indicates the "number of customers served by the DSO" and it is a continuous variable; it assume the value "1" if the number of clients served is less than 1 Million, “2” if it is from 1 to 5 Million, “3” if it is from 5 to 10 Million, “4” if they are more than 10 Million. Variable A6, instead, indicates the “type of customers” involved in the project; it is a binomial variable and thus assume the value “1” if are involved only residential customers and “4” if are also involved industrial and commercial customers.

2.5 Interests and Controllability by stakeholders’ viewpoint

As shown previously, a series of actors are involved into a smart metering project, at different way and level; therefore to include all the relevant players, maintaining a reasonable number of actors, a list of 6 stakeholders was compiled (see Annex 3).

The stakeholders identified include regulators at international and national level, actors involved in the electricity market as distributors or technology producers and institutions that are close to the consumers’ needs.

It is clear that stakeholders play different roles in the promotion of a smart metering project and consequently show interest and degrees of control different from each other: to clarify their role and ability to influence the characteristics of the project, the relationship among the 6 stakeholder and the 41 variables used to describe the project are been evaluated in terms of “Relevance” and “Controllability”.

With “Relevance” refers to the importance which a specific element, represented by a variable, assume for an actor and the interest that it shows in order to achieve a good results in the project for that item. To evaluate the “Relevance” a scale of values ranging from 1 to 4 has been adopted, meaning:

- 1 – low relevance
- 2 – medium low relevance
- 3 – medium high relevance
- 4 – high relevance

With “Controllability” refers to the stakeholder’s ability to influence a specific element of the project (represented by a variable); stakeholders can improve or reduce the amount and the impact of the different variables, thus they influence the performance of the whole project through their choice and actions.

Also to evaluate the level of “Controllability” of an actor on a specific variable, a scale of values ranging from 1 to 4 has been adopted, meaning:

- 1 – low controllability
- 2 – medium low controllability

- 3 – medium high controllability
- 4 – high controllability

Evaluation of the variables was carried out comparing with the members of the Panel and levels of "Relevance" and "Controllability" were identified through n-cycles of improvement (see respectively Annex 4 and Annex 5).

2.6 Relationship Matrix

Among the 41 variables (described in Annex 2) previously descripted it is possible to identify a cause and effect relationship for each interaction. The variables have been arranged on rows and columns to obtain a rectangular matrix and facilitate the visual representation of the strongest relationships. To each correspondence between the variables has been assigned a value on a scale from 1 to 4 meaning:

- 1 – low
- 2 – medium low
- 3 – medium high
- 4 – high

In the case where there is no relationship between the assessed row and the column, the value "0" is assigned. If the relationship exist but it is negative, the above scale of values is still observed by adding a sign "-" in front of the value considered.

From the cross topic examination of each variable; different types of relationships have emerged: from very strong ones with relationship level of "4" or very weak ones with level of "1" and even non-existing relationships with "0".

To facilitate the reading of the table, in the *relationship matrix* (Annex 6) are shown only the strongest relationships among the variables ("1") and are signed by not relevant ("NR") the other relationships.

2.7 Patterns description

2.7.1 Methods and criteria

Considering that each variable is linked to one or more other variables, there are a number of chains of subsequent links among relevant variables later call "patterns". Considering all levels of relationship among the variables a very high number of patterns may be identified so that the analysis would become unmanageable; hence, a set of criteria is listed to reduce the number of these patterns.

The only patterns under consideration are the ones:

- Leading to a variable having level of interest “4” at least for 1 stakeholder (see Annex 3);
- Only patterns including only links characterized by strongest relationships (“4”);
- Including at least 1 variable controllable at the highest level (“4”) by at least 1 of the stakeholder (see Annex 3).

Under the application of these criteria 50 relevant patterns (Table 2) have been identified; releasing one or more constraints is scientifically possible but it would imply an enormous increase in the number of patterns.

2.7.2 Identifications and description

In Table 2 the list of the *relevant patterns* with their composing variables are presented, whereas the full description of the patterns are reported in Annex 7. The 50 patterns allow taking into account most of the variables used to study the projects; in fact 13 variables out of 41 are not included in the patterns. To further study their role, it is sufficient removing some of the constraints described above.

Among the patterns identified, the variables categories involved are in order of importance: A (project characteristics) with 35 patterns that contain a variable from this group, B (technical features) with 28 patterns, C-EF (economic-financial features) with 23 patterns, D2 (user acceptance) with 11 patterns, D1 (regulations) with 10 patterns, E (advanced functionalities and multi-metering) with 4 patterns and C-SP (supply chains features) with only 1 pattern. The most frequently variable is A6 that represent the “Type of customers” and appears in 27 patterns; then the variable 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 variables B4 and D11 represent the “Type of elaborated data” and “Status of obligation to implement smart metering” 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.

#	Pattern	#	Pattern	#	Pattern
1	A3 → A4	18	A1 → A4 → C-EF2	35	D11 → D14
2	A1 → A4 → A5	19	A3 → A4 → C-EF2	36	A6 → B4 → D21
3	A3 → A5	20	A6 → B1 → C-EF2	37	C-SP1 → D21
4	A3 → A4 → A5	21	A6 → B2 → C-EF2	38	D11 → D21
5	A6 → B1	22	A6 → B4 → C-EF2	39	D11 → D23 → D21

6	A6 → B2	23	A6 → B4 → B2 → C-EF2	40	D11 → D24 → D21
7	A6 → B1 → B6 → B2	24	A6 → B1 → B6 → B2 → C-EF2	41	A6 → B4 → D22
8	A6 → B4 → B2	25	A6 → B1 → B6 → B5 → C-EF2	42	B3 → D22
9	A6 → B4	26	A1 → A4 → C-EF3	43	D11 → D22
10	A6 → B1 → B6 → B5	27	A3 → A4 → C-EF3	44	D11 → D23 → D22
11	A6 → B1 → B6	28	A6 → C-EF3	45	D25 → D22
12	A6 → B1 → C-EF1	29	A6 → B1 → C-EF3	46	D11 → D23
13	A6 → B2 → C-EF1	30	A6 → B1 → B6 → B2 → C-EF3	47	D13 → E1
14	A6 → B4 → C-EF1	31	A6 → B2 → C-EF3	48	E2 → E4
15	B3 → C-EF1	32	A6 → B4 → C-EF3	49	A6 → B1 → B6 → B5 → E5
16	A6 → B1 → B6 → B2 → C-EF1	33	A6 → B4 → B2 → C-EF3	50	D11 → D14 → E5
17	A6 → B4 → B2 → C-EF1	34	D11 (→) C-EF6		

Table 2 - Relevant Patterns

The criteria used to construct the patterns include the presence of stakeholders with high control and interest; stakeholders taken into consideration are EU policy makers, National Regulatory Authority, Government, Distribution System Operator, technology providers and customers; each of them are involved in the patterns in different ways.

The Distribution System Operator, as seen in Figure 28, is the most interested player with 38 patterns out of 50 under its attention; it can also control 33 patterns especially through the variables B, C-EF and D. A high involvement of the DSO confirms its leading role in a smart metering project.

The National Regulatory Authority follows the DSO in the ranking of patterns interest. NRA has 20 patterns out of 50 that end with a variable of its attention but, as seen in Figure 29, it is the player that has most control on the patterns. In fact, especially through the variables B and D1, the NRA can control 58 patterns out of 50 and this shows how the controllability of the project is greater at the local level rather than at the international one.

The other regulatory players have less control but, above all, less interest on the patterns. The EU policy makers can control 14 patterns out of 50 and they show interest for 10 of them; in 9 cases they control the variable D11 that indicates the “Mandate on Smart Metering”, while in 2 cases they control the variable B5 that indicates the “Compliance with standards”. The 10 patterns for which the EU policy makers show interest mainly include the variable C-EF3 that indicates the “Countrywide benefits”, the variable D23 that indicates the “Opt out option implications” and the variable E4 that defines the scale of deployment foreseen for each advanced solution. The Government can control 11 patterns out of 50, with high recurrence of the variables D11 and D23, but it show interest for only 7 patterns; 5 of them refer to the variable C-EF3 that indicates the “Countrywide benefits”, the benefits for the whole society.

Instead the Technology providers and the Customers do not have control levers on the patterns identified, but show a quite high level of interest.

Technology providers show attention for 15 patterns mainly through the variables B, C-EF and E; in particular 7 patterns refer to the variable C-EF2 that indicates the “Business benefits”. In addition Customers show attention for 17 patterns, mainly through the variables C-EF and D2; in particular 5 patterns refer to the variable C-EF1 that indicates the “Customers benefits”, 5 refer to the variable D21 that indicates the initiatives dedicated by the utility to improve consumer involvement and acceptance and 5 refer to the variable D22 that indicates the initiative inside the utility to adapt their current CS with the focus on SM.

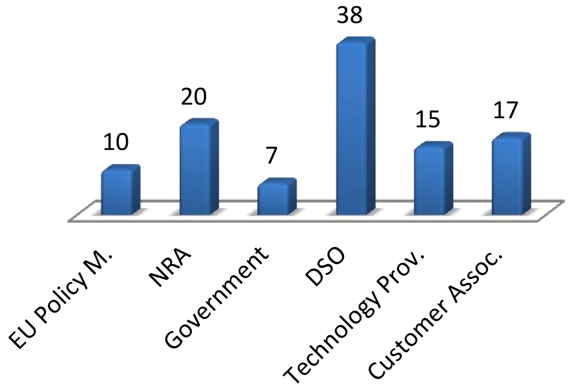


Figure 28 - Relevance for the stakeholders (out of 50 patterns)

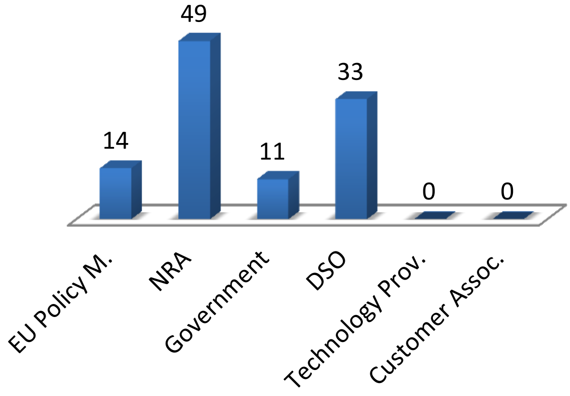


Figure 29 - Controlling stakeholders (out of 50 patterns)

2.7.3 Interested stakeholders’ view point

It is possible to study with more detail the interest shown by each actor for the patterns previously identified. The possibility to control by oneself, with other, or not to control a pattern of own interest is analysed below.

2.7.3.1 EU Policy Makers

The EU policy makers show interest for 13 patterns out of 50; 4 of these patterns are directly controlled by the EU policy makers with other actors (Table 3) while the remaining 9 are controlled only by the other actors (Table 4).

In the following tables are listed the patterns of interest to the EU policy makers, the controlling actors (see Annex 3) are indicated for each of them.

#	Pattern	NRA	Gov.	DSO
1	D11 → D14	X	X	

2	D11 → D23	X	X	
3	D13 → E1	X	X	
4	E2 → E4	X	X	

Table 3 - Patterns of interest to the EU Policy Makers, under their control

#	Pattern	NRA	Gov.	DSO
1	A6 → B1 → B6	X		X
2	A1 → A4 → C-EF3	X		X
3	A3 → A4 → C-EF3	X		X
4	A6 → C-EF3	X		
5	A6 → B1 → C-EF3	X		X
6	A6 → B1 → B6 → B2 → C-EF3	X		X
7	A6 → B2 → C-EF3	X		X
8	A6 → B4 → C-EF3	X		X
9	A6 → B4 → B2 → C-EF3	X		X

Table 4 - Patterns of interest to the EU Policy Makers, out of their control

There are not patterns under the only control of the EU Policy Makers, this highlights the need of collaboration between EU Policy Makers and other actors, especially with the national bodies. The National Regulatory Authority is the most controllers together the EU Policy Makers followed by the Government; they control most of the variables D1 and A, while the section E is only under the NRA's control. The status of obligation to implement smart metering in a particular country (variable D11) it's a strong lever in the hands of EU Policy Makers, with which to influence the set of minimum functionalities set in a specific country (variables D14) and the ability for customers to refuse the smart meter implementation (variable D23).

It is interesting how the DSO controls the patterns alternatively to the Government; it even exceeds the Government if the EU Policy Makers cannot control the pattern. The DSO has high control mainly on the sections A and B, with high impact on an economic-financial feature like the countrywide benefits (variables C-EF3). The type of customers (variable A6) involved in the project and the type of communication technology chosen for the smart meters (variable B1) are elements that impact in many patterns and influence technological and economic items.

Technology Providers and Customers Association never can control patterns under the EU Policy Makers' interest.

2.7.3.2 National Regulatory Authority

The National Regulatory Authority show interest for 23 patterns out of 50; 2 of these patterns are directly controlled by the National Regulatory Authority without other actors (Table 5) while the remaining 21 patterns are controlled together other actors (Table 6).

In the following tables are listed the patterns of interest to the National Regulatory Authority, the controlling actors (see Annex 3) are indicated for each of them.

#	Pattern
1	A6 → B4
2	B3 → C-EF1

Table 5 - Patterns of interest to the National Regulatory Authority, under only its control

#	Pattern	EU	Gov.	DSO
1	A1 → A4 → A5			X
2	A3 → A5			X
3	A3 → A4 → A5			X
4	A6 → B1 → B6			X
5	A6 → B1 → C-EF1			X
6	A6 → B2 → C-EF1			X
7	A6 → B4 → C-EF1			X
8	A6 → B1 → B6 → B2 → C-EF1			X
9	A6 → B4 → B2 → C-EF1			X
10	A1 → A4 → C-EF2			X
11	A3 → A4 → C-EF2			X
12	A6 → B1 → C-EF2			X
13	A6 → B2 → C-EF2			X
14	A6 → B4 → C-EF2			X
15	A6 → B4 → B2 → C-EF2			X
16	A6 → B1 → B6 → B2 → C-EF2			X
17	A6 → B1 → B6 → B5 → C-EF2	X		X
18	D11 (→) C-EF6	X	X	
19	D11 → D23	X	X	
20	D13 → E1	X	X	
21	E2 → E4	X	X	

Table 6 - Patterns of interest to the National Regulatory Authority, under its control

The 2 patterns under the only control of National Regulatory Authority allow to influence the type of data elaborated (variable B4) and the customers benefits (variable C-EF1), through respectively the type of customers involved in the project (variables A6) and the type and number of communication interfaces present in the meters (variable B3). This highlights the ability of NRA to intervene directly on the technological aspects and the needs of consumers.

The National Regulatory Authority can control 18 patterns together other actors; Table 6 shows how the controllability of the project is greater at the local level rather than at the international one. The DSO controls the majority of these patterns and through the section B and it has high impact on the economic-financial features (variables C-EF). Government and EU Policy Makers can influence the source of financial support for the project, if private or public (variable C-EF6) and thus the typology of market actors who are beneficiaries of the implemented solution (variable E1); the levers used are the status of obligation to implement smart metering (variable D11) and the type of "unbundling" adopted in the country (variable D13).

Technology Providers and Customers Association never can control patterns under the National Regulatory Authority's interest.

2.7.3.3 Government

The Government shows interest for 10 patterns out of 50; the Government directly controls 2 of these patterns with other actors (Table 7) while the remaining 8 are only controlled by the other actors (Table 8).

In the following tables are listed the patterns of interest to the Government, the controlling actors (see Annex 3) are indicated for each of them.

#	Pattern	EU	NRA	DSO
1	D13 → E1	X	X	
2	E2 → E4	X	X	

Table 7 - Patterns of interest to the Government, under its control

#	Pattern	EU	NRA	DSO
1	A1 → A4 → C-EF3		X	X
2	A3 → A4 → C-EF3		X	X
3	A6 → C-EF3		X	
4	A6 → B1 → C-EF3		X	X
5	A6 → B1 → B6 → B2 → C-EF3		X	X
6	A6 → B2 → C-EF3		X	X
7	A6 → B4 → C-EF3		X	X
8	A6 → B4 → B2 → C-EF3		X	X

Table 8 - Patterns of interest to the Government, out of its control

EU Policy Makers and National Regulatory Authority share the control of all the patterns under the Government's influence, this highlights the need of collaboration between Government and other regulatory actors.

The National Regulatory Authority is the most controllers; through the section A and B (project dimension and technology features) they influence the variable C-EF3 that indicates the benefits for the whole society, including also non-monetized benefits.

The DSO controls only the pattern out of the Government's control, pointing out their complementarity; DSO has high control on the variable A and B, with high impact on the economic-financial features (variables C-EF).

EU Policy Makers instead show, in this case, greater interest to promote either the advanced functionalities (section E) and the economic-financial features (section C-EF), underlining its main interest for the development and dissemination of advanced solutions.

Technology Providers and Customers Association never can control patterns under the Government's interest.

2.7.3.4 Distribution System Operator

The Distribution System Operator shows interest for 42 patterns out of 50; only 1 of these patterns is directly controlled by the Distribution System Operator without other actors (Table 9), 21 patterns are controlled together other actors (Table 10) and 16 patterns are out of its control (Table 11).

In the following tables are listed the patterns of interest to the Distribution System Operator, the controlling actors (see Annex 3) are indicated for each of them.

#	Pattern
1	C-SP1 → D21

Table 9 - Pattern of interest to the Distribution System Operator, under only its control

#	Pattern	EU	NRA	Gov.
1	A3 → A4		X	
2	A1 → A4 → A5		X	
3	A3 → A5		X	
4	A3 → A4 → A5		X	
5	A6 → B1 → B6 → B2		X	
6	A6 → B4 → B2		X	
7	A6 → B1 → B6 → B5		X	
8	A6 → B1 → B6		X	
9	A6 → B1 → C-EF1		X	
10	A6 → B2 → C-EF1		X	
11	A6 → B4 → C-EF1		X	
12	A6 → B1 → B6 → B2 → C-EF1		X	
13	A6 → B4 → B2 → C-EF1		X	
14	A1 → A4 → C-EF2		X	
15	A3 → A4 → C-EF2		X	
16	A6 → B1 → C-EF2		X	
17	A6 → B2 → C-EF2		X	
18	A6 → B4 → C-EF2		X	

19	A6 → B4 → B2 → C-EF2		X	
20	A6 → B1 → B6 → B2 → C-EF2		X	
21	A6 → B1 → B6 → B5 → C-EF2	X	X	
22	A6 → B4 → D21		X	
23	A6 → B4 → D22		X	
24	D25 → D22	X	X	
25	A6 → B1 → B6 → B5 → E5	X	X	

Table 10 - Patterns of interest to the Distribution System Operator, under its control

#	Pattern	EU	NRA	Gov.
1	A6 → B1		X	
2	A6 → B2		X	
3	A6 → B4		X	
4	B3 → C-EF1		X	
5	D11 (→) C-EF6	X	X	X
6	D11 → D14	X	X	X
7	D11 → D21	X	X	X
8	D11 → D23 → D21	X	X	X
9	D11 → D24 → D21	X	X	X
10	B3 → D22		X	
11	D11 → D22	X	X	X
12	D11 → D23 → D22	X	X	X
13	D11 → D23	X	X	X
14	D13 → E1	X	X	X
15	E2 → E4	X	X	X
16	D11 → D14 → E5	X	X	X

Table 11 - Patterns of interest to the Distribution System Operator, out of its control

Distribution System Operator can promote the involvement of the customers in the project development and their acceptance to the new meters through the supply chain configuration, in particular, adopting a high level of proximity to the end users in terms of number of final activities performed by the DSO itself (variable C-SP1).

The National Regulatory Authority can control almost all the patterns that are under the DSO's interest, this underline the importance of collaboration between DSO and NRA in defining the characteristics of the projects. The NRA's ability to establish the type of customers (variable A6) and the DSO's control on some technological aspects (variables B1, B2 and B4) allow, together, to achieve good results in terms of data security (variable B6) and benefits for customers and utility (variables C-EF1 and C-EF2).

EU Policy Makers can influence many aspects of the project through the definition of standards (variable B5) and the obligation for the countries to implement the smart metering solution (variable D11). In particular are influenced the users acceptance for smart meter technology (variables D21 and D22) and the scenario for the dissemination of advanced solutions (section E).

The Government controls many patterns together the EU Policy Makers, but especially those are outside the DSO's control; through the variables D1 (regulations) it influences the customers involvement (variables D2), the implementation of advanced functionalities (section E) and finally the main sources of financing for the project, if they are mainly public or private (variable C-EF6).

Technology Providers and Customers Association never can control patterns under the Government's interest.

2.7.3.5 Technology Providers

The Technology Providers show interest for 17 patterns out of 50; they control none of these patterns. The 15 patterns are only controlled by the other actors (Table 12).

In the following tables are listed the patterns of interest to the Technology Providers, the controlling actors (see Annex 3) are indicated for each of them.

#	Pattern	EU	NRA	Gov.	DSO
1	A3 → A4		X		X
2	A6 → B1		X		
3	A6 → B2		X		
4	A6 → B1 → B6 → B2		X		X
5	A6 → B4 → B2		X		X
6	A1 → A4 → C-EF2		X		X
7	A3 → A4 → C-EF2		X		X
8	A6 → B1 → C-EF2		X		X
9	A6 → B2 → C-EF2		X		X
10	A6 → B4 → C-EF2		X		X
11	A6 → B4 → B2 → C-EF2		X		X
12	A6 → B1 → B6 → B2 → C-EF2		X		X
13	A6 → B1 → B6 → B5 → C-EF2	X	X		X
14	D11 → D14	X	X	X	
15	E2 → E4	X	X	X	
16	A6 → B1 → B6 → B5 → E5	X	X		X
17	D11 → D14 → E5	X	X	X	

Table 12 - Patterns of interest to the Technology Providers, out of their control

Among the patterns under the Technology Providers' interest, there is high attention to enhancing the benefits for the utility (variable C-EF2) following by the attention to the technological features (section B).

The EU Policy Makers have little influence on the pattern of interest for Technology Providers, on the contrary the National Regulatory Authority controls all these patterns. Government, such as the EU Policy Makers, controls some variables D1 and influences mainly the advanced functionalities of the smart meters (section E).

The Distribution System Operator is obviously in high connection with the Technology Providers' interests; DSO have control over the majority of the patterns and the collaboration between the two stakeholders is certainly good result.

Customers Associations never can control patterns under the Technology Providers' interest.

2.7.3.6 Customers Association

They control none of these patterns. The 18 patterns are only controlled by other actors (Table 13).

In the following tables are listed the patterns of interest to the Customers Association, the controlling actors (see Annex 3) are indicated for each of them.

#	Pattern	EU	NRA	Gov.	DSO
1	A6 → B1 → B6		X		X
2	A6 → B1 → C-EF1		X		X
3	A6 → B2 → C-EF1		X		X
4	A6 → B4 → C-EF1		X		X
5	B3 → C-EF1		X		
6	A6 → B1 → B6 → B2 → C-EF1		X		X
7	A6 → B4 → B2 → C-EF1		X		X
8	A6 → B4 → D21		X		X
9	C-SP1 → D21				X
10	D11 → D21	X	X	X	
11	D11 → D23 → D21	X	X	X	
12	D11 → D24 → D21	X	X	X	
13	A6 → B4 → D22		X		X
14	D25 → D22	X	X		X
15	B3 → D22		X		
16	D11 → D22	X	X	X	
17	D11 → D23 → D22	X	X	X	
18	D11 → D23	X	X	X	

Table 13 - Patterns of interest to the Customers Association, out of their control

The efforts of consumers association to increase the data security level (variable B6) allow facilitating the initiatives to improve consumer's involvement and acceptance.

The interest of consumers (expressed by the variables D21, D22 and D23) is always under the control of National Regulatory Authority and Distribution System Operator, for this reason it is important to increase the awareness of stakeholders on the needs of consumers. EU Policy Makers and Government have control on fewer patterns than NRA and specular to the DSO; regulation of international standards (variable B5) and the obligation to implement smart metering in a particular country (variable D11) are respectively their main levers.

The Technology Providers do not control patterns of interest for the Customers Association.

Chapter 3 – Cases Interpretation

3.1 Single case analysis

After the identification of all relevant patterns that describe the work of a smart metering project, a study on twelve initiatives by European Distribution System Operator (listed in Annex 8) is carried out; projects information have been collected through a detailed survey (see an example in Annex 9). The survey addresses the most relevant topics on every considered smart meter project, including also contextual information, e.g. regarding regulatory framework, in force laws, information on the initiatives carried out to improve customer acceptance and ongoing smart grids development. The questions proposed in the survey allow to cover technological, qualitative, quantitative and smart grids related topic issues.

The information gathered through the surveys are exploited to assign values to the 41 variables used for the project's description (see Annex 2); each variable takes a specific value for each Distribution System Operator involved in the study. In Annex 10 are shown the information extracted from the surveys.

The values obtained allow to identify which patterns are confirmed and which are not for each study project: a pattern is confirmed if all the links that compose it are confirmed, only one link that does not work makes the whole pattern "unconfirmed".

A questionnaire was prepared for each Distribution System Operator, in this document have been included links that do not work in their specific case study and a set of questions were annexed in order to gather more information on their development (see an example in Annex 11). The questionnaire allow to better understand which choices or contextual factors explain why the link does not work and to identify which actors, on the participants' perception, can enable the link through their intervention.

The information obtained from the surveys and the insights provided by the questionnaires allow to realise a "single case analysis" for each project. During the single case analysis were identified the contextual elements and the DSO's choices that facilitate the work of the patterns and that influence their on-going development.

For each Distribution System Operator a brief interpretation of the case will be presented below, and for each of them it is indicated which elements hinder the pattern to work and which may foster its compliance.

3.1.1 EDP Distribuição

EDP coordinates Project InovGrid, which entails a large-scale smart grid demonstration project; the first stage of EDP smart meter project has started in Q4 2007 and it was finished in Q4 2011, while the second stage has started in Q4 2011 and it is still ongoing (about 5%). It involves 30000 customers in the first stage and 100000 customers in the second stage, 99% of which are residential and 1% commercial, that correspond at 1.5% of the total customer of EDP.

To date, in the EDP case, 23 patterns out of 50 work, while 26 of which are not confirmed. Among the unconfirmed patterns probably 19 will work within a short time and 7 have features that in this specific case, on the participants' perception, will not work (Figure 30). 1 pattern remains excluded from the study, the information gathered from the previous analysis are not sufficient to evaluate its trueness.

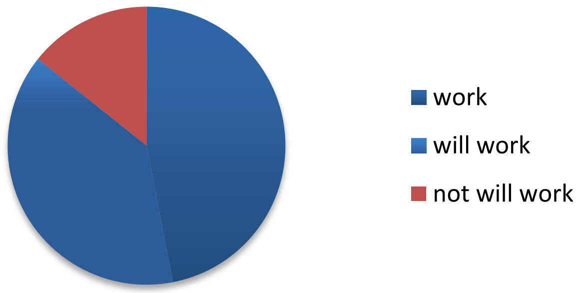


Figure 30 – EDP case

In Table 14 the patterns that already work are listed. These patterns show how the project is largely under the regulator's control; in fact, National Regulatory Authority can control 20 patterns; 3 of them with the support of EU policy makers and Government.

#	Pattern	#	Pattern	#	Pattern
1	A3 → A4	9	B3 → C-EF1	17	A6 → B4 → D21
2	A6 → B1	10	A6 → B4 → B2 → C-EF1	18	C-SP1 → D21
3	A6 → B2	11	A6 → B1 → C-EF2	19	D11 → D24 → D21
4	A6 → B4 → B2	12	A6 → B2 → C-EF2	20	A6 → B4 → D22
5	A6 → B4	13	A6 → B4 → C-EF2	21	B3 → D22
6	A6 → B1 → C-EF1	14	A6 → B4 → B2 → C-EF2	22	D11 → D23
7	A6 → B2 → C-EF1	15	A3 → A4 → C-EF3	23	D13 → E1
8	A6 → B4 → C-EF1	16	D11 (→) C-EF6		

Table 14 - Patterns that already work in EDP case

The choices made in the development phase of the project, the technology adopted and the management of the supply chain enable many patterns in EDP case; they mainly show relationships between technological aspects (variables B) and general features of the project (variables A). For example, the impact of the customers involved in the project (variable A6) on the type of elaborated data by the meters (variable B4) is very high and frequent. Many of the patterns in Table 14 lead to significant results in terms of economic and financial performance (variables C-EF), user acceptance (variables D2) and advanced functionality (variables E).

In Table 15 the patterns that currently do not work, but that probably may work in the future are listed and in Table 15 the patterns that hardly will work are shown.

#	Pattern	#	Pattern	#	Pattern
1	A1 → A4 → A5	8	A1 → A4 → C-EF2	15	D11 → D23 → D21
2	A3 → A5	9	A3 → A4 → C-EF2	16	D11 → D22
3	A3 → A4 → A5	10	A6 → B1 → B6 → B2 → C-EF2	17	D11 → D23 → D22
4	A6 → B1 → B6 → B2	11	A6 → B1 → B6 → B5 → C-EF2	18	A6 → B1 → B6 → B5 → E5
5	A6 → B1 → B6 → B5	12	A1 → A4 → C-EF3	19	D11 → D14 → E5
6	A6 → B1 → B6	13	D11 → D14		
7	A6 → B1 → B6 → B2 → C-EF1	14	D11 → D21		

Table 15 - Patterns that will work in EDP case

#	Pattern	#	Pattern	#	Pattern
1	A6 → C-EF3	4	A6 → B2 → C-EF3	7	D25 → D22
2	A6 → B1 → C-EF3	5	A6 → B4 → C-EF3		
3	A6 → B1 → B6 → B2 → C-EF3	6	A6 → B4 → B2 → C-EF3		

Table 16 - Patterns that will not work in EDP case

The Project InvoGrid is still in the demonstration phase, development and testing steps lasted a little more time than expected and this causes many of the patterns' failures; some regulation aspects and technology solutions have yet to be assessed or may change in the short term. On the one hand the "Data security" level (represented by variables B6) are currently low because the chosen technology was not ready to use encryption in all data communication; this lack of technological performance may compromise the relationship between DSO and customers, and limit their satisfaction. On the other hand, from the meters' functionality point of view, EDP approach surpasses the "Minimum functionalities requested" by EU Directives (represented by variable D14) and therefore anticipates the EU recommendations. Finally "Opt out options" (variable D23) are still not available at the time of the project implementation, even if the customers' will to opt out option was respected during the project, with an opt out rate below 0,3%. The opt out option will much probably be addressed along with the decision to start the rollout.

The information regarding the countrywide benefits (variable C-EF3) are scarce and difficult to find, for this reason it is not still clear how the patterns in Table 16 do not work; there is an exception for the pattern number 7, it indicates how EDP not expects impact of the project on vulnerable or special need customers is different from other customers. Nevertheless, there are some specific functionalities in their solution to highlight, in both the smart meter and the central system, if the client is vulnerable or has special needs.

Therefore the contextual factors that mainly hamper the work of the patterns are:

- the inadequacy of technological solutions for the security and privacy of data;
- the lack of EU directives about the meters' functionality;
- the non-adoption of opt-out options at the time of the project implementation.

The actors who mainly hamper the work of the patterns are the Technology Providers, the National Regulatory Authority and the Government; they often do not provide technological solutions or clear regulations for the DSO.

The actors who mainly foster the work of the patterns are the Technology Providers, the customers associations, the DSO the National Regulatory Authority and Government:

- NRA, Government and DSO have to setting clear well defined and rigorous requirements regarding data and communication security; Government also should give a mandate to rollout smart meters, starting date and time frame;
- Technology providers have to making technology and products available, optimizing the delivery period;
- customers associations should exert pressure to modify regulations about data privacy and opt out options, increasing cooperation with regulators.

Since the project is in demonstration phase, some information are still partial, for this reason some patterns that include these variables do not work or are even "undefined" (see Table 17).

#	Pattern
1	E2 → E4

Table 17 - Undefined patterns in EDP case

In conclusion, the EDP case shows how, within a short time, the project will achieve good results. Regulators should deal with the lack of regulation with more rapidity, Technology Providers should improve the performance of some components and consumer associations should be encouraged to collaborate with the smart meter operators. This collaboration will bring benefits for both stakeholders and will increase the chances of success of the smart metering project.

3.1.2 Endesa

The Endesa smart meter project has started in 2008 and it's expected to finish mass deployment in 2018. It is currently the largest on-going smart metering rollout in Europe. It involves about 13.000.000 customers, 84% of which are residential. Since 2011 the mass rollout is ongoing and over 3.500.000 smart meters have been installed already.

To date, in Endesa case, 34 patterns out of 50 work; among the unconfirmed patterns probably 10 will work within a short time and the remaining 5 have features that in this specific case, on the participants' perception, will not work (Figure 31). 1 pattern remains excluded from the study, the information gathered from the previous analysis are not sufficient to evaluate its trueness.

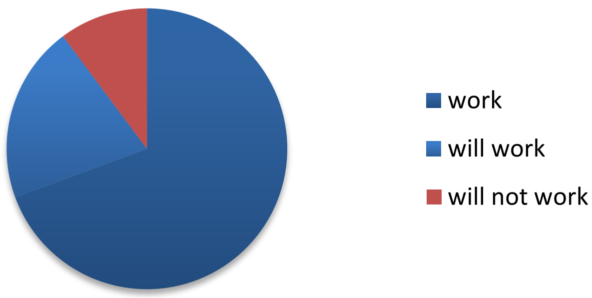


Figure 31 – Endesa case

In Table 18 the patterns that already work are listed. These patterns show how the project is fully under the regulator's control; in fact, National Regulatory Authority can control all the confirmed patterns, 6 of them with the support of EU policy makers and 5 of them with the support of Government. In this case also the DSO shows to have some control on the project development: it can control 23 patterns out of the 34 identified.

#	Pattern	#	Pattern	#	Pattern
1	A3 → A4	13	A6 → B2 → C-EF1	25	A6 → B4 → B2 → C-EF3
2	A1 → A4 → A5	14	A6 → B4 → C-EF1	26	D11 → D14
3	A3 → A5	15	B3 → C-EF1	27	A6 → B4 → D21
4	A3 → A4 → A5	16	A6 → B1 → B6 → B2 → C-EF1	28	D11 → D21
5	A6 → B1	17	A6 → B4 → B2 → C-EF1	29	A6 → B4 → D22
6	A6 → B2	18	A1 → A4 → C-EF3	30	B3 → D22
7	A6 → B1 → B6 → B2	19	A3 → A4 → C-EF3	31	D11 → D22
8	A6 → B4 → B2	20	A6 → C-EF3	32	D13 → E1
9	A6 → B4	21	A6 → B1 → C-EF3	33	A6 → B1 → B6 → B5 → E5
10	A6 → B1 → B6 → B5	22	A6 → B1 → B6 → B2 → C-EF3	34	D11 → D14 → E5
11	A6 → B1 → B6	23	A6 → B2 → C-EF3		
12	A6 → B1 → C-EF1	24	A6 → B4 → C-EF3		

Table 18 - Patterns that already work in Endesa case

During the project development, Endesa had a great attention to the technological features, current and future; through the compliance with standards and the use of advanced technologies (variables B1, B2, B4, and E5) good financial results and the customer satisfaction have been achieved. In particular, the customers' benefits (variable C-EF1) and the countrywide benefits (variable C-EF3) are quite high and the obligation to install smart meter (variable D11) facilitates the utility's initiatives in their diffusion (variables D21 and D22).

In Table 19 the patterns that currently do not work, but that probably may work in the future are listed and in Table 20 the patterns that hardly will work.

#	Pattern	#	Pattern	#	Pattern
1	A1 → A4 → C-EF2	5	A6 → B4 → C-EF2	9	D11 (→) C-EF6
2	A3 → A4 → C-EF2	6	A6 → B4 → B2 → C-EF2	10	D11 → D24 → D21
3	A6 → B1 → C-EF2	7	A6 → B1 → B6 → B2 → C-EF2		
4	A6 → B2 → C-EF2	8	A6 → B1 → B6 → B5 → C-EF2		

Table 19 - Patterns that will work in Endesa case

#	Pattern	#	Pattern	#	Pattern
1	C-SP1 → D21	3	D11 → D23 → D22	5	D11 → D23
2	D11 → D23 → D21	4	D25 → D22		

Table 20 - Patterns that will not work in Endesa case

Even if many of the adopted technological features (like the variables B1, B2, B4 and B5) have a positive impact on the benefits for the Utility because they reduce the meter's unit cost, In the smart metering project carried out by Endesa, the "business benefits" (variable C-EF2) are low and this causes the failure of many patterns. Economic benefits represent an important part of the total business benefits for Endesa, but in Spain the NRA does not consider all the cost incurred by the DSO and it does not allow to achieve good financial performance. To increase the DSO's benefits, NRA should consider all the costs and promote a fair distribution among the players.

In addition, due to the economic crisis, there are few public funds for the smart metering development (variable C-EF6); Government should make available new ways of public financing to support the DSO.

Moreover, from the analysis of the project, it can be seen that Spanish regulators and Government are not promoting initiatives to involve the customers into the smart metering diffusion (variable D24).

In Spain opt out (variable D23) is not an option for the customers and the "vulnerable customers" (variable D25) represent a small percentage of the total number of customer, for these reason it is likely that the patterns in Table 20 will not work.

The contextual factors that mainly hamper the work of the patterns are:

- low number of vulnerable customers;
- the lack of public financial founds due to the economic crisis.

The actors who mainly hamper the work of the patterns are the National Regulatory Authority and the Government: NRA does not consider all the costs occurred during the project by the DSO; Government does not provide funds for advanced solutions deployment.

NRA and Government can also foster the work of the patterns through new ways of public financial support and new initiatives to educate the customers; in addition, NRA should consider all the project costs and promote a fair distribution of them among the players.

The objectives are:

- implementation of new ways of public financial support;
- changing the regulatory framework, in order to involve customer issues and make them an active part of the system;
- promoting a business model to achieve a fair distribution of the costs among the players.

Since the project is in a demonstration phase, information is still partial; for this reason a pattern that includes these variables does not work or it is even "undefined" (see Table 21).

#	Pattern
1	E2 → E4

Table 21 - Undefined patterns in Endesa case

In conclusion, within a short time the project will get good results. With the changes proposed above, Endesa should also achieve good economic results and the Regulators should remedy to the lack of public financing and initiatives to educate the customers. These changes will bring benefits for both stakeholders and increase the chances of success of the smart metering project.

3.1.3 Enel Distributie Muntenia

The Enel Muntenia smart meter project has started in 01/02/2009 and it was finished in 30/06/2009. It involves 864 customers, 93% of which are residential, that correspond at 100% of the total customer of Enel Muntenia. Enel Smart Meters have been installed in a central and compact area of Bucharest (capital of Romania) with the main purpose to test Enel Smart Meters functionalities and AMM system; in case of rollout it's foreseen that 2.6 million smart meters will be installed between 2013 and 2022, 80% of which until 2020.

To date, in the Enel Muntenia case, 37 patterns out of 50 work, while 4 of which are not confirmed. All patterns that still do not work, on the participants' perception, will work within a short time (Figure 32). 9 patterns remain excluded from the study, the information gathered from the previous analysis are not sufficient to evaluate its trueness.

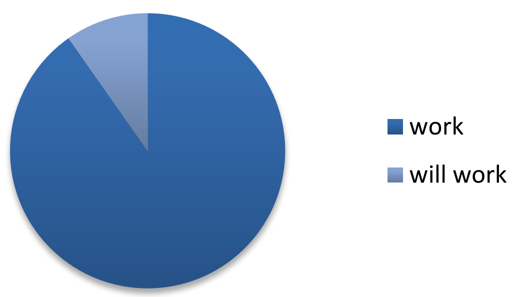


Figure 32 – Muntenia case

In Table 22 the patterns that already work are listed. These patterns show how the project is largely under the regulator's control; in fact, National Regulatory Authority can control 36 patterns, 12 of them with the support of EU policy makers and 9 of them with the support of Government. In this case also the DSO shows to have some control on the project development: it can control 25 patterns out of the 37 identified.

#	Pattern	#	Pattern	#	Pattern
1	A3 → A4	14	A6 → B1 → B6 → B2 → C-EF1	27	C-SP1 → D21
2	A1 → A4 → A5	15	A6 → B4 → B2 → C-EF1	28	D11 → D21
3	A3 → A4 → A5	16	A1 → A4 → C-EF2	29	D11 → D23 → D21
4	A6 → B1	17	A3 → A4 → C-EF2	30	A6 → B4 → D22
5	A6 → B2	18	A6 → B1 → C-EF2	31	D11 → D22
6	A6 → B1 → B6 → B2	19	A6 → B2 → C-EF2	32	D11 → D23 → D22
7	A6 → B4 → B2	20	A6 → B4 → C-EF2	33	D25 → D22
8	A6 → B4	21	A6 → B4 → B2 → C-EF2	34	D11 → D23
9	A6 → B1 → B6 → B5	22	A6 → B1 → B6 → B2 → C-EF2	35	D13 → E1
10	A6 → B1 → B6	23	A6 → B1 → B6 → B5 → C-EF2	36	A6 → B1 → B6 → B5 → E5
11	A6 → B1 → C-EF1	24	D11 (→) C-EF6	37	D11 → D14 → E5
12	A6 → B2 → C-EF1	25	D11 → D14		
13	A6 → B4 → C-EF1	26	A6 → B4 → D21		

Table 22 - Patterns that already work in Muntenia case

In the Enel Muntenia case there is great attention to the technological features, current and future; through the compliance with standards and the use of advanced technologies (variables B1, B2, B4, and E5) are been achieved good financial results and the customer satisfaction. In particular, the customers' benefits (variable C-EF1) and the business benefits (variable C-EF2) are quite high and the obligation to install smart meter (variable D11) facilitates the utility's initiatives for their diffusion (variables D21 and D22). Moreover, in many patterns emerges that the involvement of high number of customers, both residential and industrials, facilitates the use of systems with a high level of data security (variable B6).

In Table 23 the patterns that currently do not work, but that probably may work in the future are listed.

#	Pattern	#	Pattern
1	A3 → A5	3	D11 → D24 → D21
2	B3 → C-EF1	4	B3 → D22

Table 23 - Patterns that will work in Muntenia case

The project duration (variable A5) was shorter than expected because the DSO has decided to purchase the smart metering solution to test their use and minimize the risks; NRA could enforce an implementation time frame longer than necessary with the aim to minimize the impact in distribution tariff. Being the smart meter a new appliance for the energy markets, market conditions and regulations do not create demand for advanced smart metering functionalities (variable B3), including the set of interfaces with the client. It is foreseen an increase in the complexity of the interfaces as soon as smart meter become a commodity as all other home appliances. The lack of preparation of the market for smart meter utilization lead to low client responsiveness to NRA effort in smart metering. If the client has no conditions or reason for exploit smart meter benefits then information campaign and support are not enough to obtain solid integration of smart meter into the market. By accelerating the energy market modernization these obstacles will be overcome.

The project size is very small, for this reason it is difficult to estimate the benefits for the whole society (variable C-EF3) and consequently some patterns that include this variable are still "undefined" (see Table 24).

#	Pattern	#	Pattern	#	Pattern
1	A1 → A4 → C-EF3	4	A6 → B1 → C-EF3	7	A6 → B4 → C-EF3
2	A3 → A4 → C-EF3	5	A6 → B1 → B6 → B2 → C-EF3	8	A6 → B4 → B2 → C-EF3
3	A6 → C-EF3	6	A6 → B2 → C-EF3	9	E2 → E4

Table 24 - Undefined patterns in Muntenia case

In conclusion, the Enel Muntenia case shows how, within a short time, the project will achieve good results. Regulators should deal the lack of regulation with more rapidity, Technology Providers should improve the performance of some components and consumer associations should be encouraged to collaborate with the smart meter operators. This collaboration will bring benefits for both stakeholders and increase the chances of success of the smart metering project.

3.1.4 ENEL

In the second half of the 90's Enel Distribuzione launched a project named Telegestore, aimed at building a comprehensive Automated Metering Infrastructure for its entire customer base (over 30 million LV customers). The implementation phase started in 2001 and finished in 2006; Telegestore is now a system made of 32 million electronic meters, more than 350,000 data concentrators and some thousands of meters in selected secondary substations, fully dedicated to energy service applications.

To date, in the ENEL case, 12 patterns out of 50 work, while 23 of which are not confirmed. Among the unconfirmed patterns probably 2 will work within a short time and 21 have features that in this specific case, on the participants' perception, will not work (Figure 33). 15 patterns remain excluded from the study, the information gathered from the previous analysis are not sufficient to evaluate their trueness.

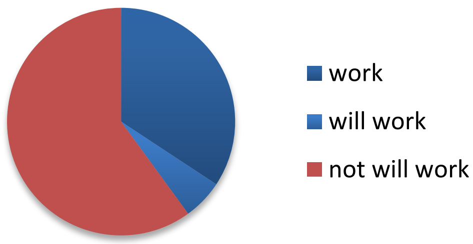


Figure 33 – ENEL case

In Table 25 are listed the patterns that already work.

#	Pattern	#	Pattern	#	Pattern
1	A3 → A4	5	A1 → A4 → C-EF2	9	D11 → D21
2	A1 → A4 → A5	6	A3 → A4 → C-EF2	10	D25 → D22
3	A3 → A5	7	D11 → D14	11	D13 → E1
4	A3 → A4 → A5	8	C-SP1 → D21	12	D11 → D14 → E5

Table 25 - Patterns that already work in ENEL case

Enel is the largest Italian DSO and this allowed to involve in the project a high number of customers (variable A4); the duration of the project (variable A5) was high even if not excessive, in 5 years 32 million of smart meters have been installed.

The Telegestore project has enabled Enel to achieve good technological results, monetary and non-monetary benefits (variable C-EF2); the Italian DSO has developed a system with a high set of functionalities (variable D14) and whole compliance with technology requirements for advanced solutions (variable E5). Being one of the first smart metering projects, Enel has dedicated many initiatives to improve consumer involvement and acceptance for the new technology (variable D21).

In Table 26 the patterns that currently don't work are listed, but that probably may work in the future and in Table 27 the patterns that don't work.

#	Pattern	#	Pattern
1	B3 → D22	2	D11 → D22

Table 26 - Patterns that will work in ENEL case

#	Pattern	#	Pattern	#	Pattern
1	A6 → B1	8	A6 → B1 → C-EF2	15	A6 → B4 → D21
2	A6 → B2	9	A6 → B2 → C-EF2	16	D11 → D23 → D21

3	A6 → B1 → B6 → B2	10	A6 → B4 → C-EF2	17	D11 → D24 → D21
4	A6 → B4 → B2	11	A6 → B4 → B2 → C-EF2	18	A6 → B4 → D22
5	A6 → B4	12	A6 → B1 → B6 → B2 → C-EF2	19	D11 → D23 → D22
6	A6 → B1 → B6 → B5	13	A6 → B1 → B6 → B5 → C-EF2	20	D11 → D23
7	A6 → B1 → B6	14	D11 (→) C-EF6	21	A6 → B1 → B6 → B5 → E5

Table 27 - Patterns that do not work in ENEL case

The Telegestore system is the result of a voluntary strategic choice of Enel Distribuzione and the project rollout started before the roll out mandate. Many patterns do not work for specific choices made at the beginning of the project: first, Enel decided to involve only residential customers (variable A6) although the technology and communication solutions implemented are able to support commercial and industrial customers; second, opt out option for the costumers (variable D23) has not been considered; finally, the source of funding (variable C-EF6) has been 100% private from Enel and the investment has been recognized in RAB and recovered in tariff.

In addition, there are some contextual factors that disable the work of some patterns: in Italy the involvement of AEEG, the National Regulatory Authority, in customer issues has not been considered (variable D24) and the metering rollout started before the roll out mandate. For example, since the beginning Enel carried out some actions to adapt their customers service with the new systems (variable D22), but these initiatives have been increased only after the full roll out.

Enel has achieved good financial performance due to the smart meters implementation, but quantify the other sources of benefits has not yet been possible. The patterns that refer to the customers' benefits (variable C-EF1) and to the countrywide benefits (variable C-EF3) are still "undefined" (see Table 28).

#	Pattern	#	Pattern	#	Pattern
1	A6 → B1 → C-EF1	6	A6 → B4 → B2 → C-EF1	11	A6 → B1 → B6 → B2 → C-EF3
2	A6 → B2 → C-EF1	7	A1 → A4 → C-EF3	12	A6 → B2 → C-EF3
3	A6 → B4 → C-EF1	8	A3 → A4 → C-EF3	13	A6 → B4 → C-EF3
4	B3 → C-EF1	9	A6 → C-EF3	14	A6 → B4 → B2 → C-EF3
5	A6 → B1 → B6 → B2 → C-EF1	10	A6 → B1 → C-EF3	15	E2 → E4

Table 28 - Undefined patterns in ENEL case

The main driving force behind the decision to implement Automated Metering Infrastructure by Enel was the improvement of the commercial and technical services quality, while at the same time achieving a reduction of operational costs and losses (both technical and not technical). These goals seem to have been achieved, even if the project was done in very particular conditions; Telegestore was a gamble, but Enel won the challenge because it is still the frontrunner smart metering application in the international context.

2.1.5 Enexis BV

The ENEXIS Smart Metering Project has started on January 2011 and it's expected to finish the deployment in 2020. At current time it involves about 240.000 customers, 95% of which are residential and 5% commercial. In case of rollout, it is foreseen that 2.600.000 meters will be installed by 2020.

To date, in the ENEXIS case, 24 patterns out of 50 work; among the remaining patterns, 3 have features that in this specific case, on the participants' perception, will not work even in a future (Figure 34) and 23 remain excluded from the study because the information gathered from the previous analysis are not sufficient to evaluate their trueness.

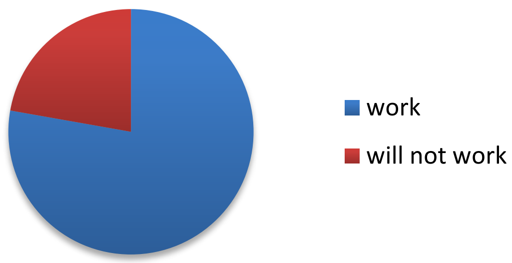


Figure 34 – Enexis case

In Table 29 the patterns that already work are listed. These patterns show how the project is largely under the regulator's control; in fact, National Regulatory Authority can control 20 out of 21 patterns, some of them with also the support of EU policy makers (12 patterns) and Government (10 patterns).

#	Pattern	#	Pattern	#	Pattern
1	A3 → A5	9	D11 (→) C-EF6	17	B3 → D22
2	A6 → B1	10	D11 → D14	18	D11 → D22
3	A6 → B2	11	A6 → B4 → D21	19	D11 → D23 → D22
4	A6 → B1 → B6 → B2	12	C-SP1 → D21	20	D25 → D22
5	A6 → B4 → B2	13	D11 → D21	21	D11 → D23
6	A6 → B4	14	D11 → D23 → D21	22	D13 → E1
7	A6 → B1 → B6 → B5	15	D11 → D24 → D21	23	A6 → B1 → B6 → B5 → E5
8	A6 → B1 → B6	16	A6 → B4 → D22	24	D11 → D14 → E5

Table 29 - Patterns that already work in Enexis case

The technological features of the meters are well developed in the Enexis case: communication technology (variable B1), upper layer protocols (variable B2) and mechanism for data security (variable B6) are suitable for advanced function and this allows to achieve excellent performances in the project. As mentioned above the control of regulatory bodies on the project is pretty high, the status of obligation to implement smart metering in a particular country (variable D11) is the initial element of many patterns. They lead to the definition of a set of minimum functionalities for the meters' operation (variable D14) or, in many cases, to enhance the relationships between DSO and customers, increasing their satisfaction. For example the initiatives by utility to improve consumer's involvement and acceptance (variable D21), the initiatives dedicated to adapt the current Customer Service employees to the Smart Metering topic (variable D22) and finally the preparation of opt out option for those customers that do not want to adopt the new technology (variable D23) increased. In order to define the amount of training, the utility must also consider the presence of socially vulnerable customers (variable D25), this allows to realize more comprehensive training programs.

In addition it is highlighted that depending on the conditions of the rollout (mandate wise) private investment can be very low or very high (variable C-EF6).

In Table 30 the patterns that hardly will work are listed.

#	Pattern	#	Pattern	#	Pattern
1	A3 → A4	2	A1 → A4 → A5	3	A3 → A4 → A5

Table 30 - Patterns that will not work in Enexis case

All the patterns not confirmed refer to the number of customers involved in the project (variable A4); this point is in disagreement with other characteristics of the project. The DSO in the Netherlands have a fixed number of customers; for this reason, even if Enexis has a monopoly in managing the electricity and gas grid, their total amount of customers cannot overcame a specific number.

Since the project is still in progress, information is partial or unavailable; for this reason many patterns include variables that have unknown value and therefore it makes the patterns "undefined". These patterns are reported in Table 31.

#	Pattern	#	Pattern	#	Pattern
1	A6 → B1 → C-EF1	9	A6 → B1 → C-EF2	17	A6 → C-EF3
2	A6 → B2 → C-EF1	10	A6 → B2 → C-EF2	18	A6 → B1 → C-EF3
3	A6 → B4 → C-EF1	11	A6 → B4 → C-EF2	19	A6 → B1 → B6 → B2 → C-EF3

4	B3 → C-EF1	12	A6 → B4 → B2 → C-EF2	20	A6 → B2 → C-EF3
5	A6 → B1 → B6 → B2 → C-EF1	13	A6 → B1 → B6 → B2 → C-EF2	21	A6 → B4 → C-EF3
6	A6 → B4 → B2 → C-EF1	14	A6 → B1 → B6 → B5 → C-EF2	22	A6 → B4 → B2 → C-EF3
7	A1 → A4 → C-EF2	15	A1 → A4 → C-EF3	23	E2 → E4
8	A3 → A4 → C-EF2	16	A3 → A4 → C-EF3		

Table 31 - Undefined patterns in Enexis case

The lack of information mainly concerns to the economic and financial aspects, in particular the customers benefits (variable C-EF1), the business benefits (variable C-EF2) and the countrywide benefits (variable C-EF3). Obtaining complete information on these topics will permit to assess the patterns in Table 31 and to have a more detailed description of the project developed by Enexis.

In conclusion, the Enexis case shows how, with the information currently available, the project will achieve good results; it will probably be able to successfully implement a smart metering projects on large scale, with advanced technology solutions, and satisfying the needs of consumers, despite the limitation to the DSO on the number of clients served.

3.1.6 ERDF

The Electricité Réseau Distribution France (ERDF) has started the “Linky project” for the smart meter implementation; the project has started in 2007 and it’s expected to finish the deployment by 2020. At the moment it involves about 300.000 customers, 90% of which are residential. It’s foreseen that in 2020 there are 35.000.000 meters installed, that correspond at 100% of the total customer of ERDF. The Linky project is the pilot test project prior to massive rollout.

To date, in the ERDF case, work 19 patterns out of 50; among the other patterns 2 have features that in this specific case, on the participants’ perception, will not work (Figure 35). 29 patterns remains excluded from the study: the information gathered from the previous analysis are not sufficient to evaluate their trueness.

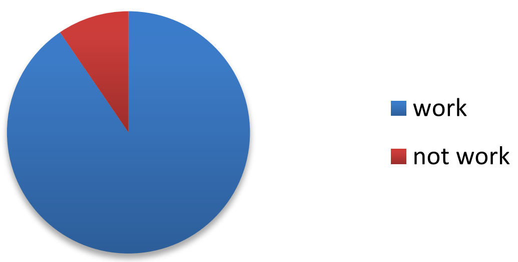


Figure 35 – ERDF case

In Table 32 are listed the patterns that already work. These patterns show how the project is largely under the regulator's control; in fact, National Regulatory Authority can control 18 out of 19 confirmed patterns, 6 of them with the support of EU policy makers and 5 with the support of Government. In this case also the DSO shows to have some control on the project development: it can control 11 patterns out of the 19 identified.

#	Pattern	#	Pattern	#	Pattern
1	A3 → A4	8	A6 → B4 → B2	15	D11 → D21
2	A1 → A4 → A5	9	A6 → B4	16	D11 → D24 → D21
3	A3 → A5	10	A6 → B1 → B6 → B5	17	D13 → E1
4	A3 → A4 → A5	11	A6 → B1 → B6	18	A6 → B1 → B6 → B5 → E5
5	A6 → B1	12	D11 → D14	19	D11 → D14 → E5
6	A6 → B2	13	A6 → B4 → D21		
7	A6 → B1 → B6 → B2	14	C-SP1 → D21		

Table 32 - Patterns that already work in ERFD case

The patterns that already work in ERDF case show as the decisions about the structure of the project, like the scale the number and type of customers involved (variables A3, A4 and A6 respectively), impacts significantly on the technological aspects (variables B). Some aspects of the regulation (represented by variables D11) lead to increase the number of initiatives developed by the utility to ensure the acceptance of the project by the user (variables D2). Finally there is a lot of attention to the development of advanced solutions: technology and regulatory solutions guarantee a high compliance of the existing smart metering solutions with technology requirements for advanced solutions (variable E5).

In conclusion, many of the patterns in Table 32 lead to significant results in terms of technological solutions (variables B), user acceptance (variables D2) and advanced functionality (variables E). About the relationship between utility and customers, there are many initiatives inside the utility to adapt their current Customer Service with the smart meter implementation.

In Table 33 are listed the patterns that hardly will work.

#	Pattern	#	Pattern
1	D11 → D23 → D21	2	D11 → D23

Table 33 - Patterns that will not work in ERFD case

The patterns do not work in the ERDF case due to the lack of "opt out options" for the customers (variable D23). No opt out option, in fact, has been neither evoked neither discussed in France.

NRA and Government have decided for a deployment at no costs for the customers and this has been pivotal to exclude opt out option.

Theoretically, customer associations could propose the introduction of this solution. But they have not done it so far.

Since the project is in advanced stage but have not yet achieved the full roll out, information is partial or unavailable; for this reason many patterns include variables that have unknown value and therefore make the patterns "undefined". These patterns are reported in Table 34.

#	Pattern	#	Pattern	#	Pattern
1	A6 → B1 → C-EF1	11	A6 → B4 → C-EF2	21	A6 → B4 → C-EF3
2	A6 → B2 → C-EF1	12	A6 → B4 → B2 → C-EF2	22	A6 → B4 → B2 → C-EF3
3	A6 → B4 → C-EF1	13	A6 → B1 → B6 → B2 → C-EF2	23	D11 (→) C-EF6
4	B3 → C-EF1	14	A6 → B1 → B6 → B5 → C-EF2	24	A6 → B4 → D22
5	A6 → B1 → B6 → B2 → C-EF1	15	A1 → A4 → C-EF3	25	B3 → D22
6	A6 → B4 → B2 → C-EF1	16	A3 → A4 → C-EF3	26	D11 → D22
7	A1 → A4 → C-EF2	17	A6 → C-EF3	27	D11 → D23 → D22
8	A3 → A4 → C-EF2	18	A6 → B1 → C-EF3	28	D25 → D22
9	A6 → B1 → C-EF2	19	A6 → B1 → B6 → B2 → C-EF3	29	E2 → E4
10	A6 → B2 → C-EF2	20	A6 → B2 → C-EF3		

Table 34 - Undefined patterns in ERFD case

The lack of information mainly concerns the economic and financial aspects, in particular the customers benefits (variable C-EF1), the business benefits (variable C-EF2) and the countrywide benefits (variable C-EF3); in addition, it was not possible to gather information about the dedicated initiatives, inside the utility, to adapt their Customer Service with the smart meter implementation (variable D22). Obtaining complete information on these topics will become possible to assess the patterns in Table 34 and have a more detailed description of the project developed by The Electricité Réseau Distribution France.

In conclusion, the ERDF case shows how, with the information currently available, the project will achieve good results; it will probably be able to successfully implement a smart metering projects on large scale, with advanced technology solutions and satisfying the needs of consumers.

2.1.7 EVN AG

EVN, an Austrian energy service company, coordinates Smart Metering HH IND project which entails a R&D and Pilot Test project; it's started in November 2008 and it's finished February 2012, is then 100% completed.

The project has involved 460 customers, including residential and industrial, seeing an installation of 300 electricity meters (160 additional PLC meters in another pilot test project) and 30 gas meters.

To date, in the EVN case, work 16 patterns out of 50; among the unconfirmed patterns probably 28 will work within a short time and the remaining 5 have features that in this specific case, on the participants' perception, will not work (Figure 36).

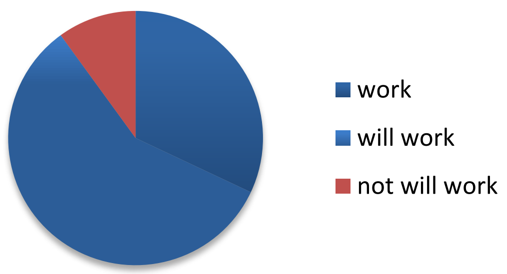


Figure 36 – EVN case

In Table 35 the patterns that already work are listed. These patterns show how the project is largely under the regulator's control; in fact, National Regulatory Authority can control all the confirmed patterns; 7 of them with the support of EU policy makers and Government. The DSO, however, can control 6 of the confirmed patterns.

#	Pattern	#	Pattern	#	Pattern
1	A3 → A4	7	A1 → A4 → C-EF3	13	D11 → D23 → D22
2	A3 → A5	8	A3 → A4 → C-EF3	14	D11 → D23
3	A6 → B1	9	D11 → D14	15	E2 → E4
4	A6 → B2	10	D11 → D23 → D21	16	D11 → D14 → E5
5	A1 → A4 → C-EF2	11	B3 → D22		
6	A3 → A4 → C-EF2	12	D11 → D22		

Table 35 - Patterns that already work in EVN case

The patterns that already work in EVN case show as the decisions about the structure of the project, like the scale the number and type of customers involved (variables A3, A4 and A6 respectively), impacts significantly on the project's economical results, in terms of utility and countrywide benefits (variables C-EF2 and C-EF3), and on the technological aspects (variables B). Some aspects of the regulation (represented by variables D11) lead to set the minimum functionalities requested for the meters' operation and to a high number of initiatives to ensure the acceptance of the project by the user (variables D21 and D22). Finally there is a lot of attention to the development of advanced solutions: more public money (variable E2) make easier to deploy bigger advanced projects (variable E4) and is guaranteed a high compliance of the existing smart metering solutions with technology requirements for advanced solutions (variable E5) through the regulation.

In Table 36 the patterns that currently do not work, but that probably may work in the future are listed and in Table 37 the patterns that hardly will work are shown.

#	Pattern	#	Pattern	#	Pattern
1	A1 → A4 → A5	11	B3 → C-EF1	21	A6 → B1 → C-EF3
2	A3 → A4 → A5	12	A6 → B1 → B6 → B2 → C-EF1	22	A6 → B4 → C-EF3
3	A6 → B1 → B6 → B2	13	A6 → B4 → B2 → C-EF1	23	D11 (→) C-EF6
4	A6 → B4 → B2	14	A6 → B1 → C-EF2	24	A6 → B4 → D21
5	A6 → B4	15	A6 → B2 → C-EF2	25	C-SP1 → D21
6	A6 → B1 → B6 → B5	16	A6 → B4 → C-EF2	26	D11 → D21
7	A6 → B1 → B6	17	A6 → B4 → B2 → C-EF2	27	D11 → D24 → D21
8	A6 → B1 → C-EF1	18	A6 → B1 → B6 → B2 → C-EF2	28	A6 → B4 → D22
9	A6 → B2 → C-EF1	19	A6 → B1 → B6 → B5 → C-EF2	29	A6 → B1 → B6 → B5 → E5
10	A6 → B4 → C-EF1	20	A6 → C-EF3		

Table 36 - Patterns that will work in EVN case

#	Pattern	#	Pattern	#	Pattern
1	A6 → B1 → B6 → B2 → C-EF3	3	A6 → B4 → B2 → C-EF3	5	D13 → E1
2	A6 → B2 → C-EF3	4	D25 → D22		

Table 37 - Patterns that will not work in EVN case

The objective of EVN is to test the smart metering technology, for this reason many phases of the project were made slowly and also were used inadequate hardware; the small size of the project, with only 460 customers involved, causing the failure of many patterns. Mainly are not confirmed many relationships between variables that describe the technological characteristics, and variables that indicate the economic and financial characteristics of the project; the "customer benefits" (C-EF1), the "Business benefits" (C-EF2) and the "Countrywide benefits" (C-EF3) are still not quantifiable. Other aspects are explained by the decision of EVN to stay very close to customers, providing the whole spectrum of service, and supporting the full costs of technology implementation; this tendency inevitably will change when the project dimension will increase. Finally the lack of certain rules in the project's development and management is due to the earliness of the project developed by EVN, in a short time these gaps will be certainly covered.

On the contrary the relationship between the variable D13 and the variable E1, that indicate respectively what type of "Unbundling" has been adopted and the actors "Beneficiaries" of each advanced solution, will not work even in the future. The energy market in Austria is fully unbundled but the implementation of smart metering, either as field-test or as rollout implementation will bring beneficiaries more for the deregulated entities like the customers and the energy suppliers; for the DSO, which have the metering competence, it is a zero-sum situation. The most expensive hardware and installation will be paid by the customer.

In addition EVN sees no need to take care of social vulnerability (variable D25), it thinks that this has to be done by the social security and administration of the government.

Therefore the contextual factors that mainly hamper the work of the patterns are:

the lack of proven smart metering technology solutions;

the DSO's decision to implement advanced solutions, without financial support from the customers or the regulator;

- the lack of clear and defined rules for the smart metering implementation;
- the NRA's decision to not allow to raise the energy tariff because of this technological progress.

The actors who mainly hamper the work of the patterns are the Technology Providers, the National Regulatory Authority and the DSO.

The actors who mainly foster the work of the patterns are the Technology Providers and the National Regulatory Authority:

- NRA has to setting clear, well defined and rigorous requirements regarding data and communication security; it also has to prepare and run a massive communications program towards smart metering implementation in Austria;
- Technology providers have to making technology and products available, optimizing the delivery period.

In the future, with the experience gained and adequate support by NRA and Technology Providers, EVN will probably be able to successfully implement a smart metering project on large scale.

3.1.8 Fortum AMM

The full scale rollout of smart meters to all Fortum Finland grid area was started in November 2007 and it's expected to finish deployment in March 2014. At current time it involves about 583.000 residential customers, 98% of their total customers.

To date, in the Fortum case, work 31 patterns out of 50 while 10 are not confirmed. Among the unconfirmed patterns probably 9 will work within a short time while the remaining has features that in this specific case, on the participants' perception, will not work (Figure 37). 9 patterns remain excluded from the study, the information gathered from the previous analysis are not sufficient to evaluate their trueness.

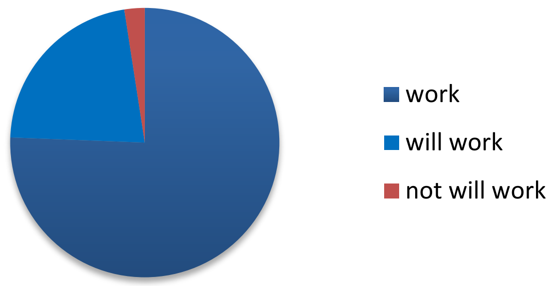


Figure 37 - Fortum

In Table 38 the patterns that already work are listed. These patterns show how the project is largely under the regulator's control; in fact, National Regulatory Authority can control 30 out of 31 confirmed patterns, 11 of them with the support of EU policy makers and 9 with the support of Government. The DSO, however, can control 17 of the confirmed patterns.

#	Pattern	#	Pattern	#	Pattern
1	A3 → A5	12	B3 → C-EF1	23	A6 → B4 → D22
2	A6 → B1	13	A6 → B1 → B6 → B2 → C-EF1	24	B3 → D22
3	A6 → B2	14	A6 → B4 → B2 → C-EF1	25	D11 → D22
4	A6 → B1 → B6 → B2	15	A1 → A4 → C-EF2	26	D11 → D23 → D22
5	A6 → B4 → B2	16	A3 → A4 → C-EF2	27	D25 → D22
6	A6 → B4	17	D11 (→) C-EF6	28	D11 → D23
7	A6 → B1 → B6 → B5	18	D11 → D14	29	D13 → E1
8	A6 → B1 → B6	19	A6 → B4 → D21	30	A6 → B1 → B6 → B5 → E5
9	A6 → B1 → C-EF1	20	C-SP1 → D21	31	D11 → D14 → E5
10	A6 → B2 → C-EF1	21	D11 → D21		
11	A6 → B4 → C-EF1	22	D11 → D23 → D21		

Table 38 - Patterns that already work in Fortum case

The patterns that already work in Fortum case show as the decisions about the structure of the project, like the scale the number and type of customers involved (variables A3, A4 and A6 respectively), impacts significantly on the project's economical results, in terms of customers and utility benefits (variables C-EF1 and C-EF2) and on the technological aspects (variables B). Some aspects of the regulation (represented by variables D11) lead to set the minimum functionalities requested for the meters' operation and to a high number of initiatives to ensure the acceptance of the project by the user (variables D21 and D22). Finally, the last two patterns show how is guaranteed a high compliance of the existing smart metering solutions with technology requirements for advanced solutions (variable E5) through the regulation.

In Table 39 the patterns that currently do not work, but that probably may work in the future are listed and in Table 40 the pattern that hardly will work are shown.

#	Pattern	#	Pattern	#	Pattern
1	A3 → A4	4	A6 → B1 → C-EF2	7	A6 → B4 → B2 → C-EF2
2	A1 → A4 → A5	5	A6 → B2 → C-EF2	8	A6 → B1 → B6 → B2 → C-EF2
3	A3 → A4 → A5	6	A6 → B4 → C-EF2	9	A6 → B1 → B6 → B5 → C-EF2

Table 39 - Patterns that will work in Fortum case

#	Pattern
1	D11 → D24 → D21

Table 40 - Patterns that will not work in Fortum case

Fortum is the biggest DSO company in Finland, but still they have "only" about 600.000 customers; it must therefore attributable to "country reasons" the failure of the first 3 patterns in Table 39, they show how the number of customers involved (variable A4) is not in agreement with the scale of the project (variable A3). In addition the duration of the project (variable A5) in Fortum case is very high in relation to the number of customers involved, this is the result of a specific Fortum's decision that considered unwise to install meters more quickly.

The other unconfirmed patterns refer to the relationship between technological features (variables B) and the business benefits (variable C-EF2). To date, given that the project is not yet completed, are not possible to measure fully the benefits to the company; at first the benefits seemed to be very low, in relation to technologies installed, but over the months their estimate has grown and will probably reach high levels.

The pattern that probably will not work even in the future (see Table 40) refers to the NRA involvement in creating awareness on the smart metering implementation; in Fortum case, in fact, DSO has performed the implementation by itself.

Therefore the contextual factors that mainly hamper the work of the patterns are:

- the limited number of customers served by the DSO;
- the provisional measure of the benefits for the utility in carrying out the project;
- the limited NRA involvement in creating awareness on the smart meters implementation;

The actor who mainly hampers the work of the patterns is the National Regulatory Authority. The actor who mainly foster the work of the patterns are the National Regulatory Authority:

- NRA must increase its efforts to raise awareness and consent of the consumer to the new smart technology.

Since the project is in advanced stage but have not yet achieved the full roll out, some information are partial or unavailable, for this reason many patterns include variables that have unknown value and therefore make the patterns “undefined”. These patterns are reported in Table 41.

#	Pattern	#	Pattern	#	Pattern
1	A1 → A4 → C-EF3	4	A6 → B1 → C-EF3	7	A6 → B4 → C-EF3
2	A3 → A4 → C-EF3	5	A6 → B1 → B6 → B2 → C-EF3	8	A6 → B4 → B2 → C-EF3
3	A6 → C-EF3	6	A6 → B2 → C-EF3	9	E2 → E4

Table 41 - Undefined patterns in Fortum case

The lack of information mainly concerns the economic and financial aspects, in particular the assessment of the countrywide benefits (variable C-EF3). Obtaining complete information on these topics will become possible to assess the patterns in Table 41 and have a more detailed description of the project developed by Fortum. In addition information about the nature of the incentives that enable the deployment of advanced solutions (variable E2) is not available; in fact, more public money (variable E2) should theoretically make easier to deploy bigger advanced projects (variable E4).

In the future, with the experience gained and adequate support by NRA, Fortum will probably be able to successfully implement a smart metering project on large scale.

3.1.9 Gas Natural Fenosa

The Gas Natural Fenosa smart metering project started in 2011 and its deployment is expected to finish in 2018. At current time, it involves about 3.600.000 customers, 100% of which are residential. In case of rollout, it is foreseen that 3.600.000 meters will be installed by 2018.

To date, in the GNF case, 26 out of 50 patterns work; among the unconfirmed patterns, probably 19 will work within a short time and the remaining 5 have features that in this specific case, on the participants' perception, will not work (Figure 38).

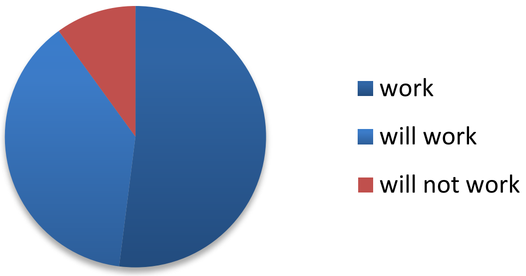


Figure 38 – GNF case

In Table 42 the working patterns are listed. These patterns show how the project is largely under the regulator's control; in fact, National Regulatory Authority can control 25 out of 26 confirmed patterns, 6 of them with the support of EU policy makers and 5 with the support of Government. In this case also the DSO shows to have some control on the project development: it can control 16 patterns out of the 26 identified.

#	Pattern	#	Pattern	#	Pattern
1	A3 → A5	10	A6 → B4 → C-EF2	19	A6 → B4 → D21
2	A6 → B1	11	A6 → B4 → B2 → C-EF2	20	C-SP1 → D21
3	A6 → B2	12	A1 → A4 → C-EF3	21	D11 → D21
4	A6 → B4 → B2	13	A6 → C-EF3	22	A6 → B4 → D22
5	A6 → B4	14	A6 → B1 → C-EF3	23	D11 → D22
6	B3 → C-EF1	15	A6 → B2 → C-EF3	24	D25 → D22
7	A1 → A4 → C-EF2	16	A6 → B4 → C-EF3	25	D13 → E1
8	A6 → B1 → C-EF2	17	A6 → B4 → B2 → C-EF3	26	D11 → D14 → E5
9	A6 → B2 → C-EF2	18	D11 → D14		

Table 42 - Patterns that already work in GNF case

In the GNF case there is great attention to the technological features, current and future; through the compliance with standards and the use of advanced technologies (variables B1, B2, B4, and E5), good financial results and customer satisfaction have been achieved. In particular, business benefits (variable C-EF2) and countrywide benefits (variable C-EF3) are quite high and the obligation to install smart meters (variable D11) leads to utility's initiatives for their diffusion (variables D21 and D22).

In Table 43 patterns that currently do not work but probably may work in the future are listed, and in Table 44 the patterns that hardly will work are also listed.

#	Pattern	#	Pattern	#	Pattern
1	A6 → B1 → B6 → B2	8	A6 → B4 → B2 → C-EF1	15	B3 → D22
2	A6 → B1 → B6 → B5	9	A6 → B1 → B6 → B2 → C-EF2	16	D11 → D23 → D22
3	A6 → B1 → B6	10	A6 → B1 → B6 → B5 → C-EF2	17	D11 → D23
4	A6 → B1 → C-EF1	11	A6 → B1 → B6 → B2 → C-EF3	18	E2 → E4
5	A6 → B2 → C-EF1	12	D11 (→) C-EF6	19	A6 → B1 → B6 → B5 → E5
6	A6 → B4 → C-EF1	13	D11 → D23 → D21		
7	A6 → B1 → B6 → B2 → C-EF1	14	D11 → D24 → D21		

Table 43 - Patterns that will work in GNF case

#	Pattern	#	Pattern	#	Pattern
1	A3 → A4	3	A3 → A4 → A5	5	A3 → A4 → C-EF
2	A1 → A4 → A5	4	A3 → A4 → C-EF2		

Table 44 - Patterns that will not work in GNF case

From the analysis of GNF case, it emerges that one of the most problematic topics is the variable B6, the "Data security level". It appears in 8 of the unconfirmed patterns and by itself, it leads to the failure of 7 of them; so far, high data security level is not included but there is work in progress regarding this issue in standardization bodies and internally in GNF. Another significant impact comes from the variables from section "C-EF", that indicates economic-financial features: currently, there is no regulation that provides economic retribution for new advanced services and thus the customer benefits are low (variable C-EF1); in addition there is no public financing for DSOs to perform the change of the old meters. Finally, another problematic topic is the lack of "Opt out option" for the customers (variable D23); 3 patterns do not work because currently there is no obligation regarding opt-out in Spain.

The patterns that definitely will not work even in future in GNF case refer to the number of customers involved in the project (variable A4): it is in disagreement with the other characteristics of the project. Gas Natural Fenosa is a medium-sized DSO and their maximum deployment is 3.7 million customers.

The contextual factors that mainly hamper the work of the patterns are:

- the lack of regulation regarding the financial compensation to DSO for the cost of Smart Grid/Smart Home services (there is not business model in present regulation);
- the non-involvement of NRA or Government in Customer acceptance and involvement regarding smart metering;
- regulatory issues in general.

The actors who mainly hamper the work of the patterns are the National Regulatory Authority and the Government; they often do not provide funds for advanced solutions deployment. On other hand, the Government´s and NRA´s tendency is a higher protection for Residential customers in comparison with C&I ones.

The actors who could mainly foster the work of the patterns are the customers associations besides the already mentioned National Regulatory Authority and Government. The customers associations should exert pressure to modify regulations and increase cooperation with regulators.

The objectives are:

- enhancing level of security regarding data privacy;
- facilitating the development of real-time data;
- changing the regulatory framework, in order to involve customer issues and make them an active part of the system;
- promoting a business model regarding the services associated to additional interfaces.

In conclusion, the GNF case shows how, within a short time, the project will achieve good results. Regulators should deal the lack of regulation with more rapidity and consumer associations should be encouraged to collaborate with the smart meter operators. This collaboration will bring benefits for both stakeholders and take the most of success of the smart metering deployment.

3.1.10 Iberdrola

The Iberdrola Castellon smart meter project has started in 2011 and it has finished deployment in 2012. At current time it involves about 98.151 customers, 90% of which are residential. In case of rollout, it is foreseen that by 2018 10 million meters will be installed. The Castellon project was the initial demonstration project prior to massive rollout.

To date, in the Iberdrola case, work 15 patterns out of 50; among the unconfirmed patterns probably 2 will work within a short time and 5 have features that in this specific case, on the participants' perception, will not work (Figure 39). 28 patterns remains excluded from the study: the information gathered from the previous analysis are not sufficient to evaluate their trueness.

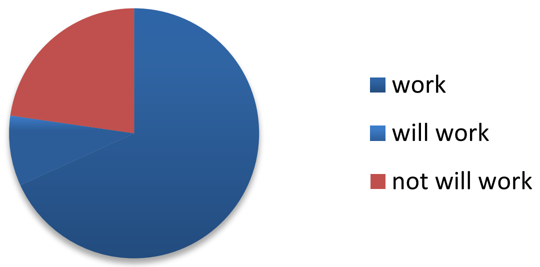


Figure 39 – Iberdrola case

In Table 45 the patterns that already work are listed. These patterns show how the project is largely under the regulator's control; in fact, National Regulatory Authority can control all the 15 patterns; 5 of them with the support of EU policy makers and 4 with the support of Government. In this case also the DSO shows to have some control on the project development: it can control 8 patterns out of the 15 identified.

#	Pattern	#	Pattern	#	Pattern
1	A3 → A4	6	A6 → B2	11	A6 → B4 → D22
2	A1 → A4 → A5	7	A6 → B4 → B2	12	D11 → D22
3	A3 → A5	8	A6 → B4	13	D25 → D22
4	A3 → A4 → A5	9	D11 → D14	14	D13 → E1
5	A6 → B1	10	A6 → B4 → D21	15	D11 → D14 → E5

Table 45 - Patterns that already work in Iberdrola case

The choices made in the development phase of the project, the technology adopted and the management of the supply chain allow at many of the patterns to work in Iberdrola case; they mainly show relationships between technological aspects (variables B) and general features of the project (variables A). The impact, for example, of the customers involved in the project (variable A6) on the type of elaborated data by the meters (variable B4) is very high and frequent. Many of the patterns in Table 45 lead to significant results in terms of technological solutions (variables B), user acceptance (variables D2) and advanced functionality (variables E). About the relationship between utility and customers, there are many initiatives inside the utility to adapt their current Customer Service with the smart meter implementation.

In Table 46 the patterns that currently do not work, but that probably may work in the future are listed and in Table 47 the patterns that hardly will work are shown.

#	Pattern	#	Pattern
1	D11 → D24 → D21	2	B3 → D22

Table 46 - Patterns that will work in Iberdrola case

#	Pattern	#	Pattern	#	Pattern
1	D11 (→) C-EF6	3	D11 → D23 → D21	5	D11 → D23
2	C-SP1 → D21	4	D11 → D23 → D22		

Table 47 - Patterns that will not work in Iberdrola case

The Castellon Project has achieved excellent levels of technological performance with the exception of the number and type of interfaces installed in the meters (variable B3). Obviously the types and number of interfaces could have been a strategic decision of Iberdrola in order to take advantage of economy and market scales, as well as of regulatory scenarios; the NRA and Technology Providers, however, have not adequately supported the DSO during the first phase of the project: if regulatory and economy scenarios were clearer maybe more developed interfaces would have been chosen.

The lack of NRA's intervention is also shown in relation to the marketing and customer involvement Initiatives by the utility. Iberdrola has decided, at its own risk, to start some successful activity to improve consumer involvement and acceptance of the new meters; NRA, instead, has decided not to involve strongly with supporting massive implementation.

When the NRA will involve highly with the smart meter deployment probably there will be a greater awareness of the smart metering project.

Many patterns do not work in the Iberdrola case due to the lack of "opt out options" for the customers (variable D23). Opt out option is not available in Spain, and with near a 35% rollout completed it seems difficult that this changes, but initiatives for improve the customers involvement or the Customer Service adaptation are already being performed with Iberdrola's high efforts.

Other patterns that do not work in the Castellon Project refers to the source of financial support for the project (variable C-EF6) and the number of final activities, of the supply chain, performed by the DSO itself (variable C-SP1). About the financial support are used exclusively private funds: it is not a choice of Iberdrola, but the only way to progress on the roll out in Spain was private funding.

Therefore the contextual factors that mainly hamper the work of the patterns are:

- the difficulty of reaching prices and economy scales due to the Technology Providers' dimension;
- the NRA/Government criteria about the financial support;
- the non-adoption of opt-out options at the time of the project implementation.

The actors who mainly hamper the work of the patterns are the National Regulatory Authority and the Government; they often do not provide technological solutions or clear regulations for the DSO.

The actors who mainly foster the work of the patterns are the Technology Providers, the National Regulatory Authority and Government:

- NRA, and Government have to setting clear, well-defined and rigorous requirements regarding technological features; in addition a NRA's higher involvement to create awareness of projects would be needed. Finally, should change the NRA/Government criteria to increase public financial support;
- Technology providers have to making technology and products available with better prices and economy scales.

Since the project is in advanced stage but have not yet achieved the full roll out, information is partial or unavailable; for this reason many patterns include variables that have unknown value and therefore make the patterns "undefined". These patterns are reported in Table 48.

#	Pattern	#	Pattern	#	Pattern
1	A6 → B1 → B6 → B2	11	A3 → A4 → C-EF2	21	A6 → B1 → C-EF3
2	A6 → B1 → B6 → B5	12	A6 → B1 → C-EF2	22	A6 → B1 → B6 → B2 → C-EF3
3	A6 → B1 → B6	13	A6 → B2 → C-EF2	23	A6 → B2 → C-EF3
4	A6 → B1 → C-EF1	14	A6 → B4 → C-EF2	24	A6 → B4 → C-EF3
5	A6 → B2 → C-EF1	15	A6 → B4 → B2 → C-EF2	25	A6 → B4 → B2 → C-EF3
6	A6 → B4 → C-EF1	16	A6 → B1 → B6 → B2 → C-EF2	26	D11 → D21
7	B3 → C-EF1	17	A6 → B1 → B6 → B5 → C-EF2	27	E2 → E4
8	A6 → B1 → B6 → B2 → C-EF1	18	A1 → A4 → C-EF3	28	A6 → B1 → B6 → B5 → E5
9	A6 → B4 → B2 → C-EF1	19	A3 → A4 → C-EF3		
10	A1 → A4 → C-EF2	20	A6 → C-EF3		

Table 48 - Undefined patterns in Iberdrola case

The lack of information mainly concerns the economic and financial aspects, in particular the customers' benefits (variable C-EF1), the business benefits (variable C-EF2) and the countrywide benefits (variable C-EF3). Obtaining complete information on these topics will become possible to assess the patterns in Table 48 and have a more detailed description of the project developed by Iberdrola.

In conclusion, the Iberdrola case shows how, with the information currently available, the project will achieve good results; it will probably be able to successfully implement a smart metering projects on large scale, with advanced technology solutions and satisfying the needs of consumers, despite some deficiencies on the part of regulatory bodies.

3.1.11 Liander

The Liander smart metering project has started on January 2012 and it has finished at the end of 2013. It is a rollout that involves a number of residential customers in the range of 225000-275000, with an equal number of smart meters. In this small-scale roll out, concentrators are not used because until now only GPRS communication is used.

To date, in the Liander case, 14 patterns out of 50 work, while 20 of which are not confirmed. Among the unconfirmed patterns probably 7 will work within a short time and 13 have features that in this specific case, on the participants' perception, will not work (Figure 40). 16 patterns remain excluded from the study, the information gathered from the previous analysis are not sufficient to evaluate their trueness.

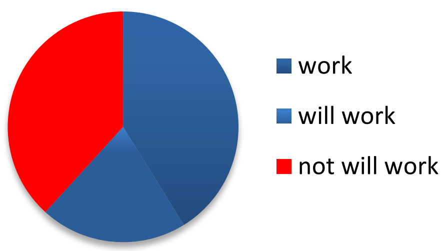


Figure 40 – Liander case

In Table 49 the patterns that already work are listed. These patterns show how the project is largely under the regulator's control; in fact, National Regulatory Authority can control 13 patterns; 10 of them with the support of EU policy makers and Government.

#	Pattern	#	Pattern	#	Pattern
1	A3 → A5	6	D11 → D23 → D21	11	D25 → D22
2	A1 → A4 → C-EF2	7	D11 → D24 → D21	12	D11 → D23
3	D11 → D14	8	B3 → D22	13	D13 → E1
4	C-SP1 → D21	9	D11 → D22	14	D11 → D14 → E5
5	D11 → D21	10	D11 → D23 → D22		

Table 49 - Patterns that already work in Liander case

The choices made in the initial phase of the project, the technology adopted and the initiatives developed by the DSO enable many patterns in Liander case; they mainly show that the higher the mandate level (variable D11) the more marketing initiatives are expected to involve the customer (variable D21) and the more adaptation of customer services is expected (variable D22).

The involvement of the customers is also facilitated by a high level of proximity of the DSO to the end user (variable C-SP1); in Netherland the attentions to the vulnerable customers (variable D25) is high and opt out options (variable D23) are granted to the customers.

In Table 50 the patterns that currently do not work, but that probably may work in the future are listed and in Table 51 the patterns that hardly will work are shown.

#	Pattern	#	Pattern	#	Pattern
1	A6 → B1	4	A6 → B1 → B6	7	A6 → B1 → B6 → B5 → E5
2	A6 → B1 → B6 → B2	5	A6 → B1 → C-EF2		
3	A6 → B1 → B6 → B5	6	A6 → B1 → B6 → B5 → C-EF2		

Table 50 - Patterns that will work in Liander case

#	Pattern	#	Pattern	#	Pattern
1	A3 → A4	6	A6 → B4	11	A6 → B1 → B6 → B2 → C-EF2
2	A1 → A4 → A5	7	A3 → A4 → C-EF2	12	A6 → B4 → D21
3	A3 → A4 → A5	8	A6 → B2 → C-EF2	13	A6 → B4 → D22
4	A6 → B2	9	A6 → B4 → C-EF2		
5	A6 → B4 → B2	10	A6 → B4 → B2 → C-EF2		

Table 51 - Patterns that will not work in Liander case

The decision to involve only residential customers in the start of the rollout do not prevent the development of solutions with high level of performance; Liander has decided to install meters with communication technologies suitable for advanced function and this solutions will help it when the industrial customers will be introduced in the project.

In Netherlands the DSOs have stable number of customers and the monopoly in their own areas; this market configuration do not promote large scale projects and lead to low number of customers involved in each project. in addition, the low number of customers prevents the achievement of economies of scale for the meters implementation; the DSO have the needs to reduce the costs of smart meters, therefore it has adopted equipment with total compliance with international standards (variable B5). In this way it will be able to increase its benefits, which now appear to be very low.

Therefore the contextual factors that mainly hamper the work of the patterns are:

- the lack of industrial customers involvement;
- the low number of customers involved because of the market structure;
- the high unit cost of the smart meters.

To overcame this obstacles:

- DSO needs to expand as much as possible the number of customers participating in the project;
- Regulators should facilitate the implementation of large projects, it allows DSOs to reduce costs;
- Technology providers must increase efforts to reduce the cost of components and allow for greater dissemination of smart technologies.

Information is still partial; for this reason some patterns that include these variables do not work or are even "undefined" (see Table 52).

#	Pattern	#	Pattern	#	Pattern
1	A6 → B1 → C-EF1	7	A1 → A4 → C-EF3	13	A6 → B4 → C-EF3
2	A6 → B2 → C-EF1	8	A3 → A4 → C-EF3	14	A6 → B4 → B2 → C-EF3
3	A6 → B4 → C-EF1	9	A6 → C-EF3	15	D11 (→) C-EF6
4	B3 → C-EF1	10	A6 → B1 → C-EF3	16	E2 → E4
5	A6 → B1 → B6 → B2 → C-EF1	11	A6 → B1 → B6 → B2 → C-EF3		
6	A6 → B4 → B2 → C-EF1	12	A6 → B2 → C-EF3		

Table 52 - Undefined patterns in Liander case

In conclusion, the Liander case shows how, within a short time, the project will achieve good results. To achieve better performance, Technology Providers should improve the performance of some components and consumer associations should be encouraged to collaborate with the smart meter operators. This collaboration will bring benefits for both stakeholders and will increase the chances of success of the smart metering project.

3.1.12 Stromnetz

The Stromnez smart meter project is currently in R&D phase. It started in 2009 and 2012 it finished planning phase. At the beginning of the 2013 the project started the pilot test with 500 household involved. It is planned to start a mass testing in 2014, and involving 400.000 customers by the 2020. Energie Steiermark is about to finish its planning phase at the middle of 2013. It can be stated that Energie Steiermark will act as supplier and service provider, Stromnetz Steiermark as a distribution system operator.

To date, in Stromnetz case, 18 patterns out of 50 work, while 4 of which are not confirmed. All the unconfirmed patterns probably will work within a short time (Figure 41). 28 patterns remain excluded from the study, the information gathered from the previous analysis are not sufficient to evaluate their trueness.

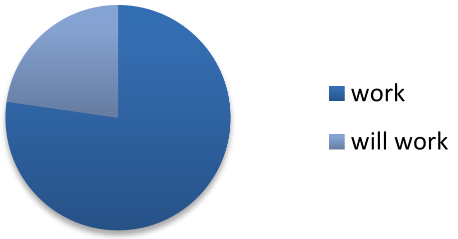


Figure 41 - Stromnetz case

In Table 53 the patterns that already work are listed. These patterns show how the project is largely under the regulator's control; in fact, National Regulatory Authority can control all the patterns; 6 of them with the support of EU policy makers and Government.

#	Pattern	#	Pattern	#	Pattern
1	A3 → A4	7	A6 → B4	13	D11 → D23 → D21
2	A3 → A5	8	A6 → B1 → B6 → B5	14	A6 → B4 → D22
3	A6 → B1	9	A6 → B1 → B6	15	B3 → D22
4	A6 → B2	10	D11 → D14	16	D11 → D22
5	A6 → B1 → B6 → B2	11	A6 → B4 → D21	17	D11 → D23 → D22
6	A6 → B4 → B2	12	D11 → D21	18	D11 → D23

Table 53 - Patterns that already work in Stromnetz case

The involvement of both residential and industrial customers leads the DSO to install meters with high level of performance: the type of communication technology adopted (variable B1) and the type of protocol used to send the data (variable B2) are suitable for advanced function. The patterns that already work show that the high mandate level (variable D11) leads to many marketing initiatives to involve the customers (variable D21) and to the adaptation of customer services with the focus on smart meters (variable D22).

The high attention to customers' needs is confirmed by the allowed opt out options to customers (variable D23) and to the DSO's efforts to achieve a high security level in the data transmission (variable B6).

In Table 54 the patterns that currently do not work, but that probably may work in the future are listed.

#	Pattern	#	Pattern
1	A1 → A4 → A5	3	D11 → D24 → D21
2	A3 → A4 → A5	4	D25 → D22

Table 54 - Patterns that will work in Stromnetz case

The duration of the project is high compared to the number of clients involved in the project; the planning of the project was conservative in order to better manage the systems development and testing. The number of clients involved in the meters implementation will increase when the mass testing will start: 400.000 customers will be involved by the 2020.

In Austria there is no actions regarding customer involvement from the National Regulatory Authority (variable D24), it has still not been involved in creating awareness on the smart meters implementation. In addition, Stromnetz sees no need to take care of social vulnerability (variable D25).

Therefore the contextual factors that mainly hamper the work of the patterns are:

- the DSO's decision to involve low number of customers to better manage the initial phase of the project;
- the lack of clear and defined legal framework for the smart metering implementation.

The actor who mainly foster the work of the patterns is the National Regulatory Authority:

- NRA has to setting clear, well-defined and rigorous requirements regarding the involvement of the customers in the project development; it has to prepare and run a massive communications program towards smart metering implementation in Austria.

Since it is a pilot project, information is still partial; for this reason many patterns that include these variables do not work or are even "undefined" (see Table 55).

#	Pattern	#	Pattern	#	Pattern
1	A6 → B1 → C-EF1	11	A6 → B4 → C-EF2	21	A6 → B4 → C-EF3

2	A6 → B2 → C-EF1	12	A6 → B4 → B2 → C-EF2	22	A6 → B4 → B2 → C-EF3
3	A6 → B4 → C-EF1	13	A6 → B1 → B6 → B2 → C-EF2	23	D11 (→) C-EF6
4	B3 → C-EF1	14	A6 → B1 → B6 → B5 → C-EF2	24	C-SP1 → D21
5	A6 → B1 → B6 → B2 → C-EF1	15	A1 → A4 → C-EF3	25	D13 → E1
6	A6 → B4 → B2 → C-EF1	16	A3 → A4 → C-EF3	26	E2 → E4
7	A1 → A4 → C-EF2	17	A6 → C-EF3	27	A6 → B1 → B6 → B5 → E5
8	A3 → A4 → C-EF2	18	A6 → B1 → C-EF3	28	D11 → D14 → E5
9	A6 → B1 → C-EF2	19	A6 → B1 → B6 → B2 → C-EF3		
10	A6 → B2 → C-EF2	20	A6 → B2 → C-EF3		

Table 55 - Undefined patterns in Stromnetz case

In the future, with the experience gained and adequate support by NRA, Stromnetz will probably be able to successfully implement a smart metering project on large scale.

3.2 Cross case analysis

The single case analysis shows that in most of the considered European countries there is a plan for the development and implementation of smart metering systems. In many countries these systems are already being rolled out or are in an advanced testing phase, confirming the fact that these systems are universally recognized as the main block for the development of smart-grid.

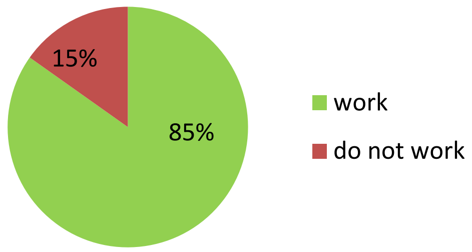
During the single case analysis were identified the contextual elements and the DSO's choices that facilitate the work of the patterns and that influence their on-going development. The "confirmed" or "not confirmed" patterns were identified for each project.

A comparison among the twelve cases study and a cross analysis of the patterns' performance allow to highlight which elements more influence the project, which hamper their development and which foster the smart meters diffusion.

3.2.1 Patterns validation

The percentages of patterns that correctly predict the performance of a project are shown in Figure 42; a high number of confirmed patterns (green section in Figure) shows the validity of the model.

Some processes have a longer time to realization and currently they are not still confirmed; to date the percentage of confirmed patterns is lower (see Figure 43). If some conditions will be respected, the inertia of the projects leads to the confirmation of these patterns in a short time.



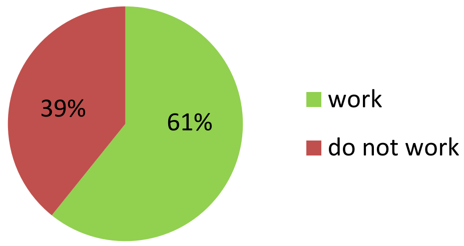


Figure 42 - Future percentage of patterns' work

Figure 43- Currently percentage of patterns' work

The majority of the patterns have been confirmed in the twelve cases previously studied: 60% of them confirm the theoretical model while the remaining ones introduce elements of difference. A quarter of the patterns (24%) are still in progress and it is foreseen that they will work in near future; this evolving scenario underlines a still unclear understanding of the dynamics that drive a smart metering project and indicates the needs to identify the guidelines that should be followed to improve their performance.

3.2.2 Interested stakeholders' view point

A cross analysis has been performed among the projects; the analysis was divided by interested stakeholders' viewpoint. Elements that allow the functioning of the patterns are studied for each stakeholders; a comparison between the different projects was realized to identify the possible levers, which may be used to enhance the success of a smart metering project.

3.2.2.1 EU Policy Makers

The EU policy makers show interest for 13 patterns out of 50; in the following Figures the patterns of interest for the EU policy makers are listed and the outcomes of the previous cases study are shown. Green side refers to the patterns that work in all the project analysed, red side to the patterns that do not work.

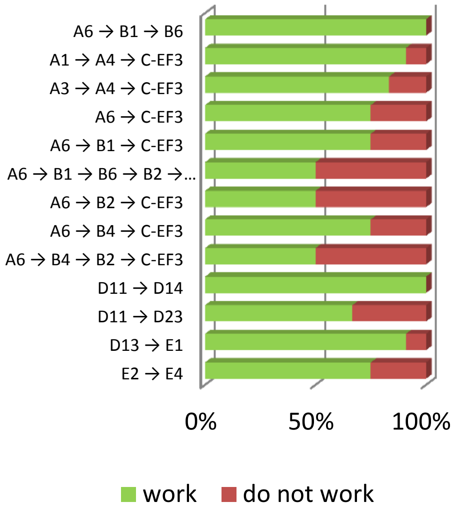


Figure 44 - Future work of the patterns – interest to the EU Policy Makers

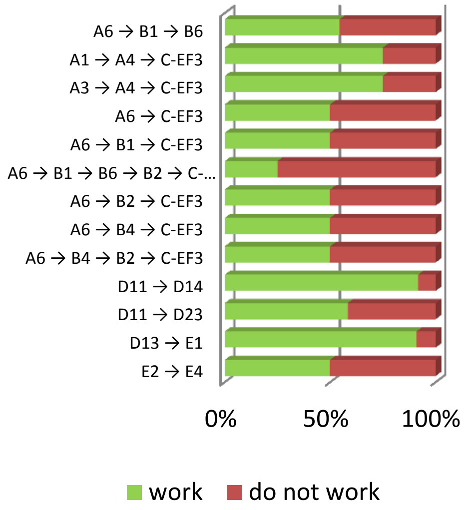


Figure 45 - Currently work of the patterns – interest to the EU Policy Makers

Figure 44 shows the outcomes expected when the project is in full rollout; some projects need more time to reach these theoretical results and have addressed some difficulties in their initial phase (see Figure 45). The patterns will work within a short time, on the participants' perception.

Almost all patterns are confirmed in the majority of the studied projects and someone in all of the cases. The purpose of the European policy makers to improve the security in the data communication and increase the benefits for the whole of society may be enabled by numerous elements.

The typology of customers involved in the project is a relevant element in the smart metering contest; DSOs can involve in the meters implementation only residential customers or also industrial clients. Implementation has never been addressed only to the industrial customers.

The majority of the DSOs has involved both the type of customers and decide to implement solutions with high level of performance; in fact, are required many different functionalities to fulfil the customers' needs. On the contrary, Enel in Italy and Liander in Netherlands have involved only residential customers in the project; however the result is not changed and the DSOs have obtained good performance from the meter installed. In the initial phase of the project development instead, many DSOs have involved only residential customers, introducing the industrial only in a second time.

The involvement of high number of consumers and both residential and industrial customers in a smart metering project allows to reach good results both in term of worldwide benefits and in data security communication: the wide diffusion of smart equipment facilitate the energy saving and the reduction of pollution; DSOs prefer to adopt a unique security technology for all customers in order to reduce costs and accelerate their development.

Regulators and DSOs are interested to implement mechanism to control the data transmission, but at the beginning they have faced many issues to implement security technology for the data transmission (see Figure 45).

The level of obligation to implement a smart metering project obviously force the DSOs to comply with certain directives; from the beginning the DSOs have setting functionalities in accordance to the EU directives and even in EDP case the meters' functionalities surpassed the "minimum functionalities requested". In many projects, the opt out option for the customers has not been granted and also is not taken into account their future implementation. To introduce opt out option, the customer associations should put pressure on the regulatory bodies and the regulatory framework has to change.

EU Policy Makers have to promote the involvement of the greatest number of customers in the smart metering project; this increases both the security of data transmission and the benefits for the whole society.

3.2.2.2 National Regulatory Authority

The National Regulatory Authority shows interest for 23 patterns out of 50; some of which have already been described in the previous paragraph. In the following Figures are listed the patterns of interest for the National Regulatory Authority and are shown the outcomes of the previous cases study. Green side refers to the patterns that work into the project analysed, red side to the patterns that do not work.

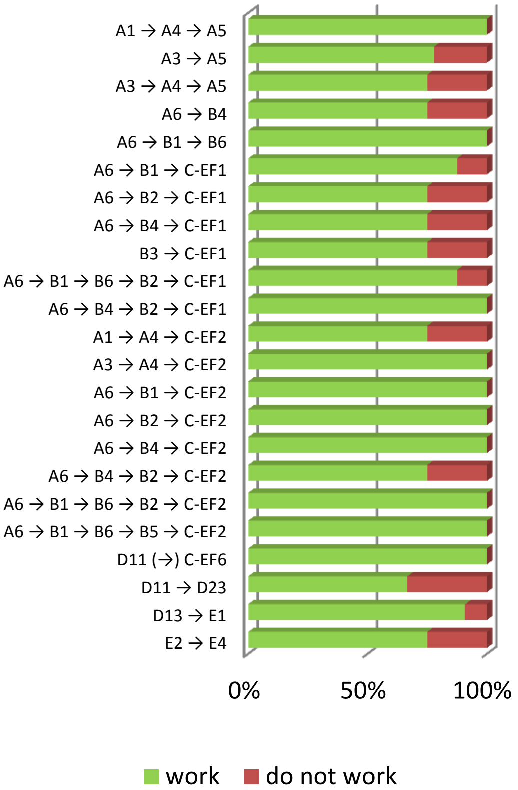


Figure 46 - Future work of the patterns – interest to the NRA

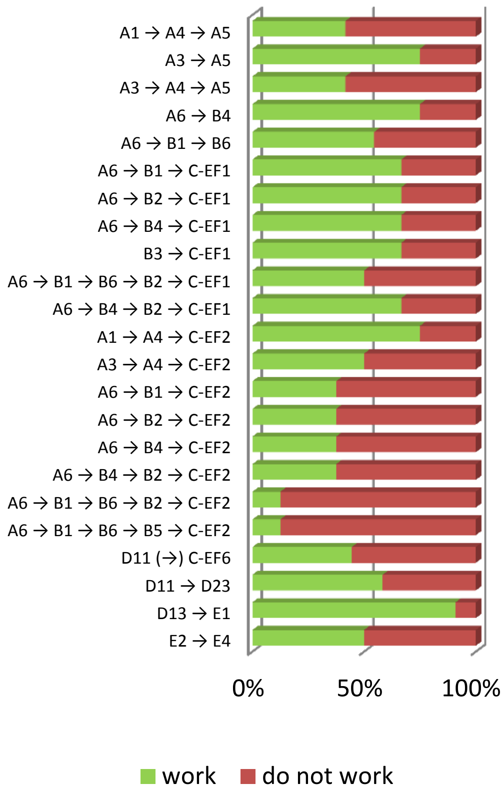


Figure 47 - Currently work of the patterns – interest to the NRA

The interest of National Regulatory Authority refers mainly to the benefits for the utility and the customers, its objective is to disseminate the smart technology in own country for increase the utility's revenues and customers' involvement.

National Regulatory Authority in interested to a large diffusion of the meters, but also to accelerate the timing of their implementation; experiences by the studied project confirm that greater the number of customers involved in the project, the longer the duration of the meters implementation (Figure 46).

In some cases the DSOs have carried out pilot or demonstration projects to test technological and organizational solutions and thus reduce the timing of subsequent development; even in a second time they started the roll out phase. Development times, however, are not decreased and DSOs had several problems.

DSOs have performed products and systems testing steps before starting the projects, but technology providers are often not ready to deliver adequate technology for the utility's needs (Figure 47).

On the other hand NRA tries to minimize the impact of the new products in energy tariff and in some cases it enforces an implementation time frame longer than necessary.

Therefore, NRA and Government have to collaborate to plan the start of the mass rollout early enough to reach the target in 2020 and avoid delays, but also they have to ensure better quality checks of the hardware supplier and accelerate smart metering development through liberalization and modern market tools.

The type of customers involved in the project emerges as relevance from the analysis of the patterns; in the previous paragraph their influence on the worldwide benefits has been in depth analysed, but in Figure 46, it is shown how the type of customers influences also the benefits for utilities and customers. The high involvement of customers leads the DSOs to develop and install meters with advanced functionalities e.g., advanced communication technology and protocol to send the data, high number of interfaces and sophisticated measures. The use of technology with high performances and functionalities improves the services received by clients and enables the utilities a better control over energy consumption and a reduction in costs.

In many cases, the benefits for the utility are too low during the first stage of the projects and many patterns that describe it result unconfirmed (see Figure 47); often the reason of this issues is the lack of adequate return on investment. In Spain, for example, in GNF and Endesa cases the regulation does not contribute economically to the development of advanced solution; NRA, in particular, does not consider all the costs incurred by the utilities.

Increase revenues for the DSOs, through public incentives or by charging more money to the customer, means to increase both utility and customer benefits; more financial capabilities allow to develop advanced technology and thus increase the service for the clients (see Figure 46).

Therefore the contextual factors that mainly hamper the work of the patterns are:

- the DSO’s decision to involve low number of customers to better manage the initial phase of the project;
- the lack of clear and defined legal framework for the smart metering implementation;
- the NRA criteria about the financial support.

The actors who mainly can foster the work of the patterns are NRA and Government, they should:

- implement new ways of public financial support;
- change the regulatory framework, in order to involve customer issues and make them an active part of the system;
- promote a business model to achieve a fair distribution of the costs among the players.

3.2.2.3 Government

The Government shows interest for 10 patterns out of 50; all of which have already been analysed in the paragraph refers to the European community, but it is possible find some differences between the role of the regulatory bodies. In the following Figures the patterns of interest for the Government are listed and the outcomes of the previous cases study are shown. Green side refers to the patterns that work into the project analysed, red side to the patterns that do not work.

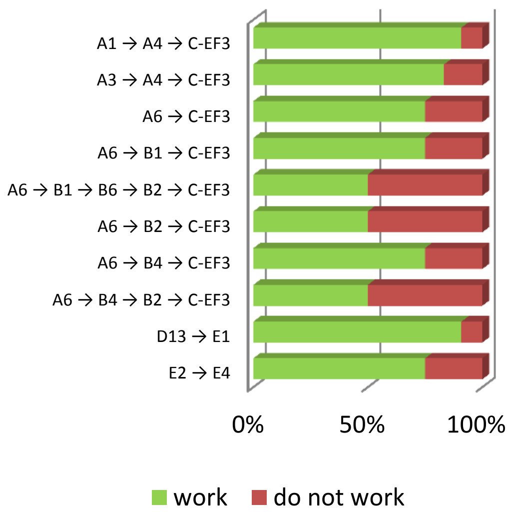


Figure 48 - Future work of the patterns – interest to the Government

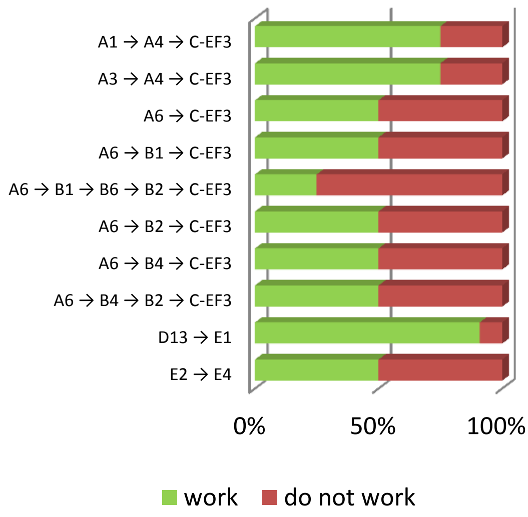


Figure 49 - Currently work of the patterns – interest to the Government

The objective of the Governments is to disseminate smart technologies in their country, preserving the interest of the whole society.

The involvement of high number of customers and both residential and industrial clients allows to achieve optimal performances in data security communication and to reduce the emission of CO2 (see Figure 48). Moreover, the project studied shown that thanks to a high level of obligation to implement the smart metering technology in the countries, a set of minimum functionalities were provided to the meters. A high level of government mandate facilitates the respect of the requirements of customers, like the introduction of opt out options for the clients. To date many states e.g., Italy, Spain, France, do not provide the ability for customers to refuse the smart meter implementation, but if there were a regulatory change in these states and the customers associations had pressured to modify regulations and increase cooperation with regulators, the benefits for customers will increase.

In all the states that have launched a smart metering project a high level of market unbundling has been adopted; in all of them, with the exception for the Austria, the implementation of smart metering will bring beneficiaries more for the regulated actors. In Austria, instead, the implementation of smart metering will bring beneficiaries more for the deregulated entities like the customers and the energy suppliers; for EVN, the Austrian DSO, smart metering implementation it is a zero-sum investment because the more expensive hardware and installation will be paid by the customers in the grid tariff, without any gain to the DSO.

To date, many projects do not have a high level of security in the data transmission (see figure 49) because it is not perceived as necessary by the DSOs; the increasing of the customers' number involved in to the projects makes the issue of security more relevant for both DSOs and Governments. Therefore Governments have to setting clear and rigorous requirements regarding data and communication security.

3.2.2.4 Distribution System Operator

The Distribution System Operator shows interest for 42 patterns out of 50; many of which have already been analysed in the previous paragraphs, but now it is also considered the DSOs' interest for the whole technology characteristic and the new initiatives developed for the meters implementation. In the following Figures the patterns of interest for the Distribution System Operators are listed and the outcomes of the previous cases study are shown. Green side refers to the patterns that work into the project analysed, red side to the patterns that do not work.

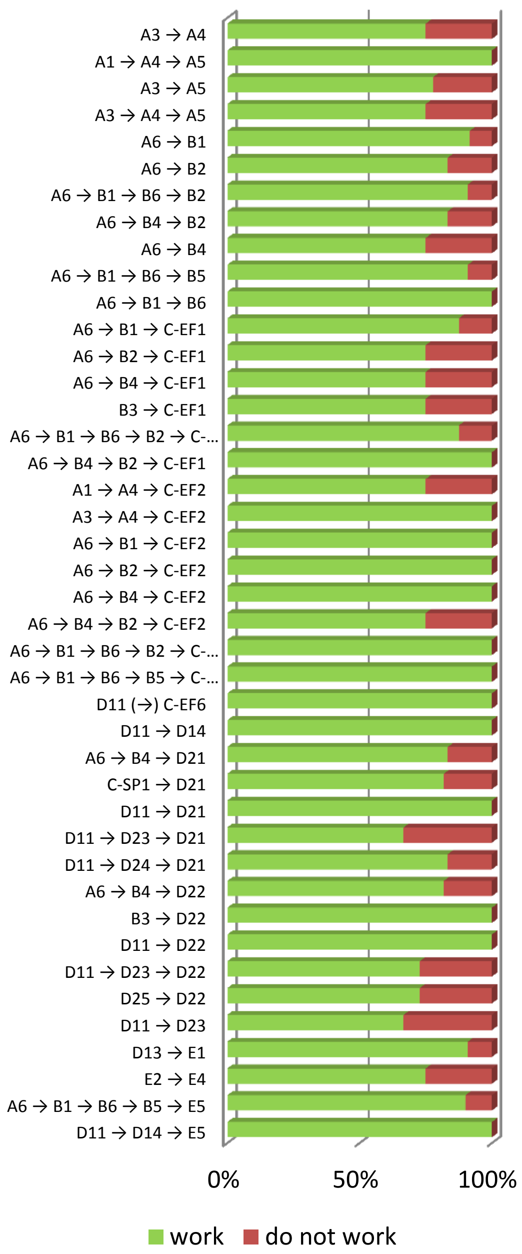


Figure 50 - Future work of the patterns – interest to the DSO

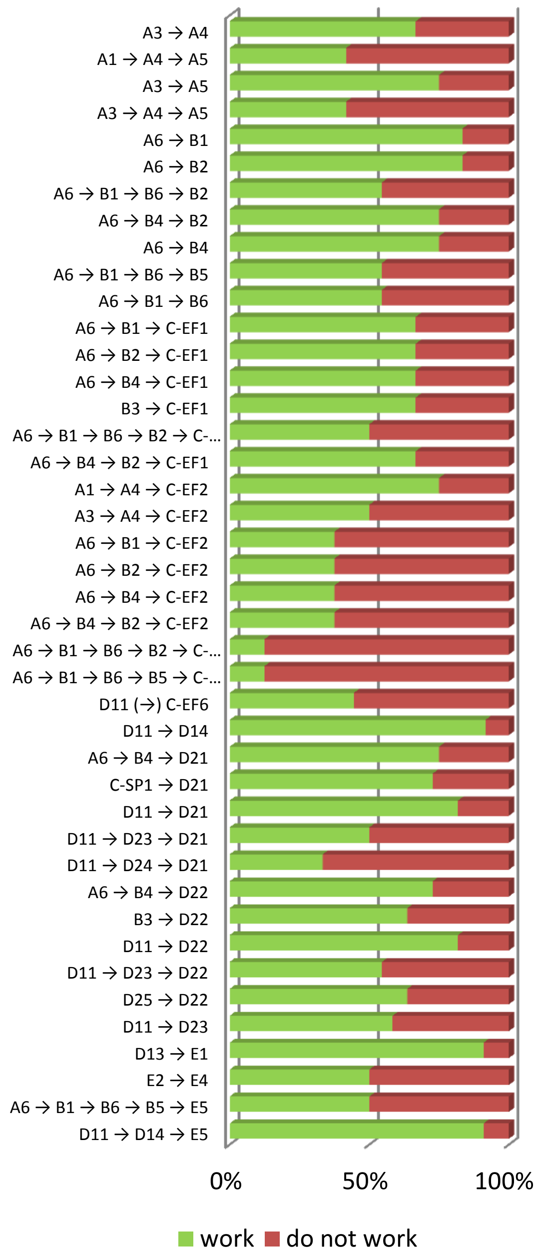


Figure 51 - Currently work of the patterns – interest to the DSO

Results presented in Figure 50 confirms the influence that customer's type has on the benefits for the DSOs: to extend the meters implementation to all potential customers allows the DSO to reduce the costs per unit implemented and to achieve synergies in to the communication technologies installed and protocol used to send the data. The need to satisfy the requirements of different type of customers force the DSOs to install equipment with the highest level of performance, in order to fulfil the customers with the highest needs. In addition, the DSOs can exploit the high performance of the equipment installed also to offer new services and opportunities to the other customers. The installation of the new smart technologies causes issues both for the utility and the customers, due to the innovative contents of the smart meters. For this reason, DSOs have to carry out some initiatives to improve consumer involvement in to the projects and to adapt their current customers service with the focus on smart meters.

The studied projects shown that many elements lead to an increase of the initiatives developed by the utilities; obviously the involvement of many customers, with different characteristics, forces the DSOs to increase their efforts; but also the government's intervention through high levels of obligations and a specific supply chain configuration can promote the initiatives of the utility.

To date, many DSOs find it difficult to financially support investment in new meters and to achieve good financial benefits (see Figure 51).

In many project DSOs have decide to encrypt the data in all the communication with standard algorithm, this ensures a high level of security. In some cases the DSOs were not able to perform high levels of data security from the beginning: EDP in Portugal, GNF in Spain and EVN in Austria have had some issues at the beginning of the project. The chosen technology did not support encrypted data communication so far or not proved to work properly (Figure 51). When technology providers will solve this problem and develop adequate solutions, DSOs will be able to use it in large scale.

Therefore the contextual factors that mainly hamper the work of the patterns are:

- the immaturity of technological solutions for the security and privacy of data;
- the lack of EU directives about the meters' functionality;
- the non-adoption of opt-out options at the time of the project implementation;
- the non-involvement of NRA and Government in customer issues regarding smart metering adoption.

The actors who mainly hamper the work of the patterns are the Technology Providers, the National Regulatory Authority and the Government; they often do not provide technological solutions or clear regulations for the DSO.

The actors who mainly foster the work of the patterns are the Technology Providers, the customers associations, the DSO the National Regulatory Authority and Government:

- NRA, Government and DSO have to setting clear well defined and rigorous requirements regarding data and communication security; Government also should give a mandate to rollout smart meters, starting date and time frame;
- implementation of new ways of public financial support;
- Technology providers have to making technology and products available, optimizing the delivery period;
- customer associations should exert pressure to modify regulations about data privacy and opt out options, increasing cooperation with regulators.

3.2.2.5 Technology Providers

The Technology Providers show interest for 17 patterns out of 50; all of which have already been analysed in the previous paragraphs, but there are some specific elements that refer to technology issues. In the following Figures the patterns of interest for the Technology Providers are listed and the outcomes of the previous cases study are shown. Green side refers to the patterns that work into the project analysed, red side to the patterns that do not work.

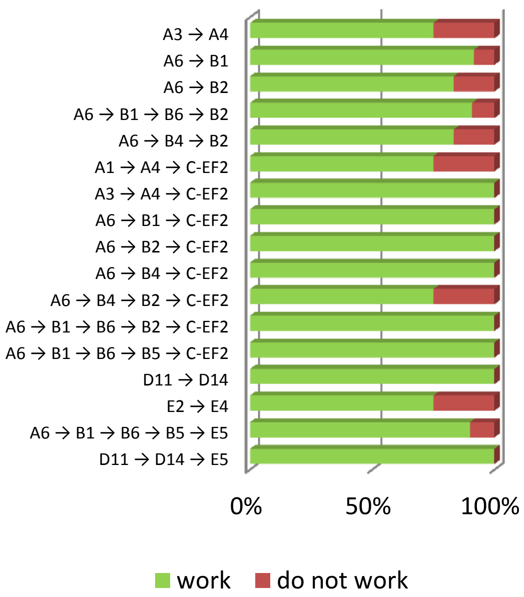


Figure 52 - Future work of the patterns – interest to the Technology providers

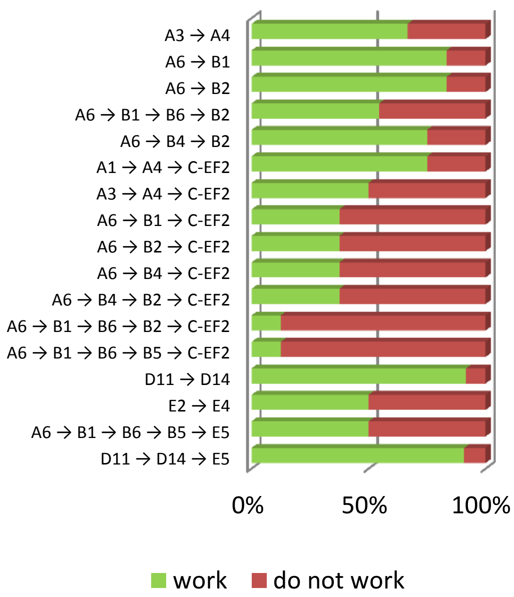


Figure 53 - Currently work of the patterns – interest to the Technology providers

The goal of the Technology Providers is to develop innovative solutions for the energy utilities; a wide dissemination of advanced meters ensures high revenues for producers and good performance in to the energy management (variable C-EF2).

The involvement of both residential and industrial customers forces the DSOs to implement complex technologies; Technology Providers thus have to satisfy the needs of the DSO and provide them adequate equipment.

In addition, Technology Providers are interested in making meters with high level of compliance with technology requirements for advanced solutions; this avoids the need to change the equipment within a short time.

All studied projects show that the patterns work very well: involve different types of customers will bring high benefits for businesses (Figure 52). Some difficulties have appeared in the early stages of the projects, Technology Providers have been slow to develop technologies appropriate to the needs of the DSO and then the projects have been slowed; in addition some Technology Providers have low dimension and this causes difficulties of reaching prices and economy scales. The benefits for the Technology Providers were initially low (Figure 53).

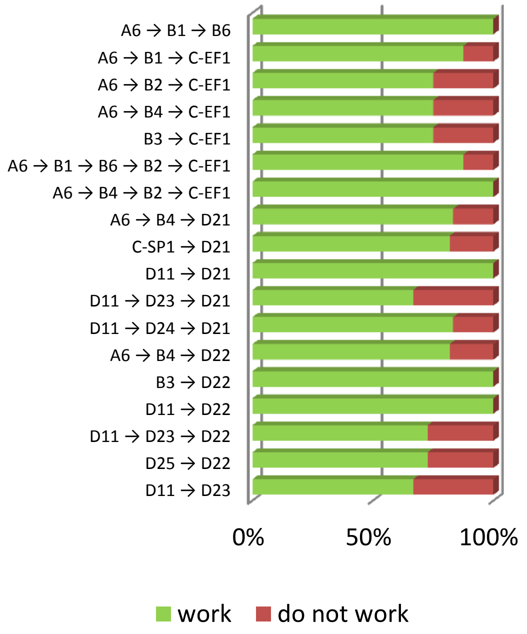
Therefore to foster the work of the patterns Technology Providers have to:

- make technology and products available, optimizing the delivery period;
- increase efforts to reduce the cost of components and then the price per meter.

Large Technology Providers are facilitated to achieve economies of scale; Regulators should promote the increase of their dimension. Standardization increases economies of scale and reduces costs in long-term.

3.2.2.6 Customers Association

The Customers Association show interest for 18 patterns out of 50; all of which have already been analysed in the previous paragraphs, but there are some specific elements that refer to customers service issues. In the following Figures the patterns of interest for the Customers Associations are listed and the outcomes of the previous cases study are shown. Green side refers to the patterns that work into the project analysed, red side to the patterns that do not work.



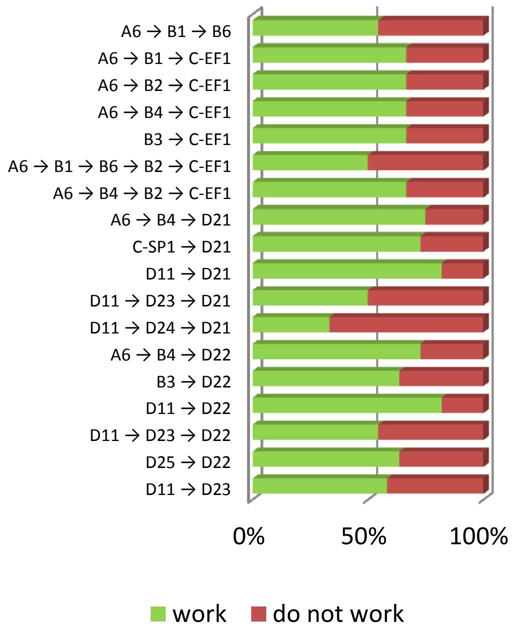


Figure 54 - Future work of the patterns – interest to the Customers associations

Figure 55 - Currently work of the patterns – interest to the Customers associations

The goal of the customers associations is to safeguard the interests of the consumers; they work to increase the benefits for the energy consumers and to ensure their adequate involvement in the projects development (Figure 54).

The projects show high level of benefit to the customers, both residential and industrial: through the diffusion of smart technologies they can reduce their energy consumption and so their energy bill. In addition to the consumption cuts, customers associations control the level of services provided to customers; the willingness of DSOs to dedicate initiatives to improve consumer acceptance changes between projects. These initiatives are very useful to disseminate the “smart meter concept” in public opinion.

Many projects have included initiatives to raise customer awareness on the smart meter technology; information campaigns and demonstrations have been used to educate customers about the new features of the meters. Some DSOs have also provided an updating course for their customer service, the employees training is needed to provide adequate support to customers on new technologies.

The involvement of customers is facilitated by many contextual elements and by some specific choices in the regulatory. The degree of proximity of the DSO to the end user, in terms of quantity of the final activities performed by the DSO itself, it is a relevant element: the higher level of proximity to the end user, the higher level of customer related initiatives is expected. Many DSOs have performed the majority of the activities directly to the customers and this has led to a large number of activities aimed at customer engagement.

On the contrary, many national Governments have not paid attention to initiatives to increase customer involvement and acceptance to the new technologies and this has hampered, directly or indirectly, their realization (Figure 55). Governments should pay attention on some specific issues like the management of the vulnerable customers and the opt out options granted to consumers; the DSOs' initiatives will increase accordingly. In addition the installation of technologies with high complexity, in terms of number of interfaces and communication systems, forces the DSOs to provide initiatives to train both their employees and their client. Therefore the customers associations should exert pressure to modify regulations about data management and services for the customers; is necessary to increase collaboration between regulators and customers associations.

Chapter 4 – Drawing guidelines

The comparison between the theoretical work of the project and the interpretation of the real cases, shown in the previous Chapters, has underlined the existence of some elements that repeatedly affect the projects development and results. The interest of the European union is to highlight these common elements and to define a set of recommendation to solve the problems, increasing the benefits for the whole society.

Therefore this chapter contains a set of guidelines for rolling out smart metering. The transition towards smart metering involves several actors of the value chain; for this reason, a complete identification of the guidelines should take into account all the stakeholders: EU Policy Makers, National Regulation Agency, energy suppliers, Customer bodies, Customers, local authorities and media.

4.1 EU Policy Makers

Concerning the interest of EU Policy Makers, the main guidelines can be summarised as follows:

- National Governments need to define clear and shared rules on the minimum functionalities to be included in the smart meters; a set of common rules, in accordance with EU Directives, provide the best way toward which direct regulatory, economical and technical efforts and so facilitates the projects implementation and the technology development around the country.
- Carry out the market unbundling is an opportunity for the stakeholders to increase the benefits for the regulated actors. This market configuration should be performed although it is not the result of an obligation of regulators.
- The amount of customers involved into the smart meters implementation is a relevant issue. Distribution System Operators should involve a high number of customers, possibly from both the residential segment that industry segment, to achieve considerable benefits for the whole society.
- The development of smart metering system is a complex process; it is advisable for the Distribution System Operators to carry out a large-scale experiment before a massive rollout. In this way the number of clients enhances from the beginning and the benefits increase.
- The promotion of standardization increases the benefits for all the stakeholders.

4.2 National Regulatory Authority

Concerning the interest of the National Regulatory Authority, the main guidelines can be summarised as follows:

- a new business model to achieve a fair distribution of the costs among the players is needed; increasing the public financial support to the Distribution System Operators the smart metering deployment scale will increase.
- National Regulatory Authority should enforce an implementation time frame longer than necessary to minimize the impact of the new products in energy tariff. In this way the Distribution System Operators can complete depreciation of the traditional meters and defer loses generated by dismantling investments not fully depreciated.
- The development of smart metering system is a long process. It is advisable to carry out a demonstration project to test technological, management and organizational solutions before a massive rollout, so the timing of subsequent development is reduced.
- Regulators have to ensure systems to better quality checks of the hardware supplier; they can accelerate smart metering development and overcame delays due to technological issues, through liberalization and modern market tools.

4.3 Government

Concerning the interest of Governments, the main guidelines can be summarised as follows:

- There is often a tendency common to the various governments to better protect the interests of residential customers in comparison with C&I ones. Governments should establish rules to involve both residential and industrial customers; expanding the scenario of customer involvement leads to an increase of benefits for the whole community.
- NRA, Government and DSO should collaborate to setting clear well-defined and rigorous requirements regarding data and communication security. Common rules and shared goals increase the possibility to improve the performance of the systems.
- The proper planning of the phases of a project is an important aspect for its success, in particular for dissemination projects of innovative technologies. Government should plan with high detail the starting date and the time frame in

which to complete the installation of the meters. Detailed planning reduces the unexpected events and allows involving more customers; therefore it will increase the economic, technological and social benefits.

- Adequate financing and business model are necessary for enhancing smart metering.

4.4 Distribution System Operator

Concerning the interest of Distribution System Operator, the main guidelines can be summarised as follows:

- The availability of high-performance technologies is a crucial element for the success of the projects. The research stimulation through economic incentives and the obligation to provide the meters with minimum functionality are good ways to ensure adequate performance.
- The quality and performance of the communication technologies are key factors for the success of a smart meter system. The implementation of communication technologies suitable for advanced functionalities of the meters has demonstrated to be the best option to access the smart meters.
- Internal training and large scale pilots are the most direct solution to manage the new systems and to provide adequate support to customers.
- Equipment that are not robust enough to achieve a high level of performance or have technology maturity issues shall not be installed in large number. There is a considerable difference between equipment that satisfy all the specs and equipment that are ready to be installed in the field.

4.5 Technology Providers

Concerning the interest of Technology Providers, the main guidelines can be summarised as follows:

- A pilot project that involves low percentage of total customers is an excellent opportunity for a technical validation of such a complex system, including interoperable components (both meters and concentrators). In particular, involving in the first stage only a specific type of customer allows technology providers to focus on particular issues, easier to solve. Synergies and lower costs of production can be achieved at a later stage involving all types of customers.

- Providing a high level of security in data communication is a great effort for the Distribution System Operators; the implementation of communication technologies with advanced mechanism to transmit the data helps manufactures to develop systems to encrypt the information. Focus on the development of communication technology helps to improve security standards for data transmission.
- Smart meters are a first step towards the smart management of the whole energy system; the implementation, by Distribution System Operators, of smart metering solutions with many functionalities and high security levels makes easier the future compliances with the standards for Smart Grids solutions and the technical requirements for advanced solutions. Difficulties for technology providers will therefore be reduced.
- Regulators, with high level of mandate, should specify the set of minimum functionalities requested for a smart meter, it will influence future high level of compliance with tech requirements for advanced solutions.
- The involvement and cooperation of technology providers in standardization groups is key for enhancing interoperability

4.6 Customers Association

Concerning the interest of Customers Association, the main guidelines can be summarised as follows:

- Regulators should change the regulatory framework, in order to better involve customers into the development phases and make them an active part of the system; customers' satisfaction is a relevant issue for the success of the implementation projects of new technologies. Opt out and collaboration are thus opportunities that should be introduced to enhance the role of the clients.
- The customers need to be informed and educated about Smart Metering features; engaging the customers is a must in obtaining success. It is important to invest time and money to communicate the project features to the customers (context, benefits, constrains) before the deployment, but avoid misguided expectations. It is important to be ready for customers' complaint management challenge.
- Customer involvement depends on many factors such as: country and scale of the project, strategy adopted to address the customers (active or passive),

Regulator role between customers and DSO; therefore the customers associations should exert pressure to modify regulations about data management and services for the customers; it is necessary to increase collaboration between regulators and customers associations.

Chapter 5 – Conclusions and future research

Smart meter is a technology in rapid dissemination, it is becoming an essential instrument in the energy demand management system and many initiatives to install it have been undertaken. A better understanding of how a smart metering project work has been achieved through the study developed in this thesis; considering the Distribution System Operator as the main actor of the energy distribution system, the dynamics that characterize a rollout project have been identified. A scheme of fifty patterns has been realised to describe the interactions among the project's features and highlight the ability of the stakeholders to act on the project's dynamics. Theoretical relationships that make up the patterns were tested through the study of twelve European projects of smart meter implementation, and patterns have showed to explain correctly the projects' development: the 85 percent of the tested patterns were confirmed by the analysis of the projects.

The new information obtained by modelling the work of the projects allow the Distribution System Operators to improve the knowledge of their systems and understand which are the problems that affected their projects; in this way they can learn from past mistakes and better manage their future initiatives. In addition, the study of unconfirmed patterns allowed to highlight the reasons that hamper the projects' development and to identify twenty-five guidelines for rolling out the smart metering projects.

These guidelines represent a fundamental knowledge base for the European policy makers because they want to standardize the new meters' implementation and reduce the country differences.

The twenty-five guidelines will be useful to:

- complete the projects still in the implementation phase, ensuring the achievement of excellent results;

- increase the dissemination of smart meters with new projects in the European countries; these projects will be able to prevent the recurrence of operation problems;
- implement large-scale projects. Dissemination projects of innovative technologies have similar characteristics to the smart metering projects; therefore follow the same dynamics.

To deepen the work of this master thesis, future research should be addressed at the smart metering topic and the model realised to study the work of the smart metering projects could be improved.

A better description of the work dynamics of a project could be achieved by changing the criteria with which the patterns were identified: considering all levels of relationships among the variables used to describe the projects, a very high number of patterns may be identified. The unique consideration of the strong links results in the loss of many potentially relevant information for the project description. In addition, the analysis could be extended to other projects in order to enhance the validity of the drawn guidelines and identify new recommendations.

Extending the study to the energy smart metering projects developed in other countries not already analysed will be the first step to improve the analysis: Eandis in Belgium and EDF in Hungary, for example, have recently launched initiatives to install the new meters in their regions. Moreover, analyse the smart metering projects in those countries that do not operate in according to the DSO's logic but that present different systems of energy distribution and management would be useful.

Future researches will include the study of projects that include different types of meters: gas and water fields have a lot of features in common with the energy sectors, but the use of the new-smart technologies is still low.

Finally, the scheme of patterns can be tested on plans for the dissemination of generally mass product; if the results will be positive, the identified guidelines could be extended also on these projects and a list of recommendations should be defined in order to facilitate the widespread dissemination of any new technologies.

References

Aitken A., DSM: A European overview, *Metering International* 1996.

AMI White Paper, Advanced metering infrastructure, *National Energy Technology Laboratory for the U.S. Department of Energy Office of Electricity Delivery and Energy Reliability*, February 2008.

Anderson W., White V., Exploring the Functionality of Real-time Home Energy Displays, *Report to the Energy Saving Trust. Centre for Sustainable Energy*, 2009.

Asif M., Aamir M., Irfan A.M., Design and Implementation of AMR Smart Grid System. *IEEE Electrical Power and Energy Conference* 2008.

Bates B., Prepayment from a first world perspective, *Metering International* 1996.

Bennett C., Highfill D., Networking AMI smart meters. *IEEE Energy Conference*, 2008.

Benzi F., Bassi E., Frosini L., Electricity Smart Meters Interfacing the Households, *IEEE transactions on industrial electronics* 2011.

Billewicz K., Probabilistic method detection of illegal power consumption in low tension, *Przeglad Elektrotechniczny*, 2008.

Brasek C., Urban utilities warm up to the idea of wireless automatic meter reading. *Computer Control Eng.*, 2005

Choi M., Ju S., Lim Y., Design of integrated meter reading system based on power line communication. *IEEE International Symp. Power Line Communication*, 2008.

Clarke C., War games, *Utility Week* 1997.

Cleveland F.M., Cyber security issues for advanced metering infrastructure. *IEEE Power and Energy Society General Meeting – Conversion and Delivery of Electrical Energy*, 2008.

Climate Group, Smart 2020: Enabling the Low Carbon Economy in the Information Age, *Report by The Climate Group on behalf of the Global Sustainability Initiative*, 2008.

Cowburn J., Electricity prepayment systems, *Power Engineering Journal* 1996.

Craig A. D., Moore P. M., Long, C. D. Experience with a high speed MV/LV power line communications system for remote metering, load control and network automation. *Eighth International Conference on Metering Apparatus and Tariffs for Electricity Supply, Institution of Electrical Engineers*, 1996

Darby S., The Effectiveness of Feedback on Energy Consumption. A Review for DEFRA of the Literature on Metering, Billing and Direct Displays, *Environmental Change Institute*, 2006.

Darby S., Smart metering: what potential for householder engagement?, *Building Research & Information* 2010.

Depuru S.S., Wang I., Devabhaktuni V., Smart meters for power grid: Challenges, issues, advantages and status, *Renewable and Sustainable Energy Reviews* 2011a.

Depuru S.S., Wang I., Devabhaktuni V., Electricity theft: overview, issues, prevention and a smart meter based approach to control theft, *Energy Policy* 2011b.

Dick A. J., AMR systems: What do users want?, *Draft of article for the UKAMRA Newsletter* 1996.

EPRI IntelliGrid, Application Guidelines: Metering and Consumer Systems, 2005.

European Commission, Recommendation for the Roll-out of Smart Metering Systems (2012/148/EU) , 2012.

Faruqui A., Harris D., Hledik R., Unlocking the €53 billion savings from smart meters in the EU: how increasing the adoption of dynamic tariffs could make or break the EU's smart grid investment, *Energy Policy* 2010.

Formby R., Evaluation of communications to meet customer/utility requirements for DSM and related functions, 1996.

Garrett P., Hanging onto your customers, *Utility Week* 1995.

Geroski P.A., Models of technology diffusion, *Research Policy*, 2000

Gilbert N., Terna P., How to build and use agent-based models in social science, *Mind and Society*, 2000.

Guy S., Marvin S., Pathways to `smarter' utility meters: The socio-technical shaping of new metering technologies, *Computers, Environment and Urban Systems* 1995.

Hallberg P., Smart grids and networks of the future, E*urelectric views*, 2010.

Hart DG., Using AMI to realize the smart grid. In: Proc. IEEE Power and Energy, Society General Meeting, *Conversion and Delivery of Electrical Energy* 2008.

Hartway R., Price S., Woo C.K., Smart meter, customer choice and profitable time-of-use rate option, *Energy* 1999.

Houseman D., Smart metering: the holy grail of demand-side energy management?, *Refocus* 2005

International Energy Outlook, 2011.

Joung M., Kim J., Assessing demand response and smart metering impacts on long-term electricity market prices and system reliability, *Applied Energy* 2013.

Giorndano V., Meletiou A., Mengolini A., Smart Grid projects in Europe: Lessons learned and current developments, *JRC Scientific and policy reports* 2012 update.

Laicane I., Blumberga A., Rosa M., Blumberga D., Assessment of changes in households' electricity consumption, *Agronomy Research* 2013.

Langley Q., Reverse tactics, *Utility Week* 1997.

Lascelles D., Adonis A., Highways into your home: The coming revolution in domestic technology, *The Financial Times* 1995.

Lasciandare A., Garotta S., Veroni F., Experimental field trials of a utility AMR power line communication system analyzing channel effects and error correction methods. *11th IEEE International Symposium on Power Line Communications and its Applications*, 2007.

Leite D.R.V., Lamin H., de Albuquerque J.M.C., Camargo I.M.T., Regulatory Impact Analysis of Smart Meters Implementation in Brazil, *IEEE* 2011.

Mahmood A., Aamir M., Anis M.I., Design and implementation of AMR smart grid system. In: Proc. *IEEE Canada Electric Power Conference*, 2008.

Marvin S., Guy S., Smart metering technologies and privatised utilities, *Local Economy*, 1997.

Marvin S., Chappels H., Guy S., Pathways of smart metering development: shaping environmental innovation, *Computers, Environment and Urban Systems*, 1999.

McNicholas M., Remote control, *Utility Week*, 1997.

Meter-ON project's Deliverables; be accessed on web site: www.meter-on.eu /project-progress-results/official-project-deliverables

Ofgm, What is a smart meter?, *Ofgem* 2006.

Oksa P., Soini M., Sydanheimo L., Kivikoski M., Considerations of using power line communication in the AMR system. *IEEE, International Power Line Communication*, 2006

Pinto K., Slevin P., Critical Success Factors in Effective Project implementation, *Project management handbook* 1987.

Rao N.M., Narayanan R., Vasudevamurthy B.R, Das S.K., Performance requirements of present-day distribution transformers for Smart Grid, *IEEE Innovative Smart Grid Technologie*s, 2013

Rixen M., Weigand J., Agent-based simulation of policy induced diffusion of Smart Meters, *Technological Forecasting & Social Change* 2013.

Romer B., Reichhart P., Kranz J., Arnold P., The role of smart metering and decentralized electricity storage for smart grids: The importance of positive externalities, *Energy Policy* 2012.

Rossini G., Hydro One: in-home real time display. Customer feedback from a 30,000 unit deployment. Presentation given at the *Home Energy Displays Conference* 2009.

Selga J., Zaballos A., Corral G., Vives J., Lessons learned from wireless sensor networks with application to AMR and PLC. *IEEE International Symp. Power Line Communication*, 2007.

Soergel S., An Economic Smart Metering Pilot Implementation Usinf Standards-Based Protocols, *IEEE Innovative Technologies for an Efficient and Reliable Electricity Supply (CITRES)* 2010.

Stansell J., New electricity meters will give consumers full information on how they use energy, *Sunday Times* 1993.

Tan H., Lee H., Mok V., Automatic power meter reading system using GSM network. *IEEE International Power Eng. Conf.*, 2007.

U.S. Department of Energy, 2006

U.S. National Energy Technology Laboratory, 2008

Gerwen R.J.F., Jaarsma S., Koenis F., Cost Benefit Analysis for Smart Metering, *Metering International* 2005.

Gerwen R.J.F., Jaarsma S., Wilhite R., Smart Metering, *Distributed Generation* 2006.

Vasconcelos J., Survey of Regulatory and Technological Development Concerning Smart Metering in the EU Electricity Market, *Policy Paper*, 2008.

Vasey, G. M., SMART metering - Requires SMART technology, *Issue Alert* 2007.

Vojdani A., Smart integration. *IEEE Power & Energy Magazine November* 2008.

Walawalkar R., Fernands S., Thakur N., Chevva K.R., Evolution and current status of demand, *Energy*, 2010.

Wang, H., Schulz, N.N. (2006). Using AMR data for load estimation for distribution system analysis, *Electric Power Systems Research*, 2006.

Warwick R., A novel solution for the domestic de-regulated electricity market. In Proceedings of the Eighth International Conference on Metering Apparatus and Tariffs for Electrical Supply. *Institution of Electrical Engineers, Conference Publication* 1996.

Wasnarat A., Tipsuwan Y., A power efficient algorithm for data gathering from wireless water meter networks. *IEEE International Conf. Industrial Informatics*, 2006.

Whiteman M. F., Applications of distribution automation and demand side management in AMR systems. In Proceedings of the Eighth International Conference on Metering Apparatus and Tariffs for Electrical Supply. *Institution of Electrical Engineers, Conference Publication* 1996.

Wood G., Newborough M., Energy-use information transfer for intelligent homes: enabling energy conservation with central and local displays. *Energy and Buildings*, 2007.

Woolner L., Hannon T., Demand side management-latest developments in tele-technology. In Proceedings of the Eighth International Conference on Metering Apparatus and Tariffs for Electrical Supply. *Institution of Electrical Engineers, Conference Publication* 1996.

Zeiss G., Report projects 55% smart meter penetration worldwide by 2020, *Between the Poles*, 2012.

Zhang T., Nuttal W. J., Agent-based simulation of consumer purchase decision-making and the decoy effect. *Journal of Business Research* 2007.

Zhang T., Nuttal W. J., Evaluating government's policies on promoting smart metering diffusion in retail electricity markets via agent-based simulation, *Journal of Product Innovation Management* 2011.

Annex 1 – Panel of experts

The Panel is composed by experts from the following associations:

- ESMIG: Industry Association
- EDSO members (not third parties to project): Distribution System Operators
- AIT: Technology Institute
- SM – CG (CEN – CENELEC): Standardisation Committee
- IEC: Standardisation Committee
- G3: Technological Consortium
- Meters and More: Technological Consortium
- GEODE: European DSO Association
- GSE: Government body
- CEER: European Regulator
- BEUC: European Consumer Association

Annex 2 – List of variables

List of variables (including definition, link with real data, scales applied)

In the following tables, a list of 41 variables will be presented separated into different sections, the variables sections: A, B, C, D or E.

A scale has been assigned for each variable (which varies from case to case) in order to quantify each one of them, thus providing the overall picture of the smart metering environment.

Section A			
	Variable name	**Definition**	**Scale**
S	**A1 Nª customers served by the DSO**	Number of customers served by the DSO within the national boundaries	1: <=1 Million 2: From 1 Million to <= 5 Million 3: From 5 Million to <= 10 Million 4: More than 10 Million
S	**A2 Decision power of the DSO**	Power decision of the company carrying out the project within and outside the national boundaries	1: Presence within national boundaries 2: Presence in more than one country 3: first DSO (in terms of % of national customers served) + Presence in more than one country 4: first DSO (in terms of % of national customers served) + Market share > 50% + Presence in more than one country
S	**A3 Project Scale**	An indication of the type of the project (is it a R&D, pilot, demonstration project or a rollout program?)	1. R&D 2. Pilot 3. Demonstration 4. Roll out
T	**A4 Number of customers involved in the project**	A measurement of the "size" of the project. The metric proposed is the number of customers involved in the project	Low: <=1 Million Medium: From 1 Million to <= 10 Million High: More than 10 Million
T	**A5 Duration**	Interval from the start of the project execution until the moment the project is completed	Low: <= 1 year Medium: From 1 Year to <= 5 Years High: More than 5 years
T	**A6 Type of customers**	Indication of which customers are involved in a project: residential customers, commercial and industrial customers (C&I) or both	1. Residential 2. Commercial and industrial 3. Residential + Commercial and Industrial

Table 1 – Section A variables

Section B			
	Variable name	**Definition**	**Scale**
S	**B1 Type of communication technology (for each communication path)**	It refers to the type of communication technology used for the interfaces between the meters and the other smart metering devices, in particular, with this variable we refer to the lower layers (media layers) of the OSI stack. So we mean what type of technical solution is used to physically send the information (e.g. GPRS, PLC, optical fibre, etc.).	Low: not appropriate Medium: appropriate High: very appropriate

S	**B2 Type of upper layer protocol (for each communication path)**	With this variable we refer to the upper layer (host layers) of the OSI stack. So, it means the protocol used to send data, the way in which data are formatted, encrypted and converted in packets and the managing of who can transmit data at a certain time and for how long.	Low: not appropriate Medium: appropriate High: very appropriate (Send 8-bit string for an information of 1 byte is not appropriate, whilst send a 64-bit string is a waste of bandwidth)
S	**B3 Type and number of interfaces**	How many interfaces - and their type - are present in the meter to communicate to the customer (e.g. display, optical output, serial port, ZigBee, etc.) and to communicate with the concentrator (e.g. PLC, WiFi or ZigBee modem, etc.).	Low: only basic interface (display, and communication with concentrator) Medium: possibility to add an external display (In-Home-Display) High: possibility to interface the smart meter with the domestic system (via serial communication, ZigBee, etc.)
T	**B4 Elaborated data**	The indirect measures (e.g. active power, reactive power, frequency, energy etc., (with a specified time granularity)) that are performed from the meter starting from the direct measure of voltage and current.	Low: only basic elaboration (Voltage, current, instantaneous power and energy) Medium: frequency and RMS values High: 4-quadrants measure
T	**B5 Compliance with standards**	Compliance with international standard. We mean if the parts of a meter (HW, SW, communication, etc.) are compliant or not to the related international standards.	Low: no compliance Medium: some parts are compliant High: all parts are compliant
T	**B6 Data security level**	The issues involved in data security and the way in which them are ensured.	Low (1): only the basic mechanism provided by the used protocol are implemented. High (4): data are encrypted in all the communication with standard algorithm.

Table 2 – Section B variables

Section C			
	Variable name	**Definition**	**Scale**
S	**C-EF1 Customer benefits**	Benefits for the end customers. It includes also non-monetized benefits	This variable represents a part of "total benefit = consumer + business + countrywide". Considering 33.3% the average point if the three benefits were equally distributed among the possible beneficiaries and. Furthermore, assuming 50% enough to consider its weight significant, the following rank seems appropriate: from 0% to 25% is low; from 25.01% to 50% is medium and from 50.01% to 100 is high.
S	**C-EF2 Business benefits**	Benefits for the utility carrying out the project. It includes also non-monetized benefits	This variable represents a part of "total benefit = consumer + business + countrywide". Considering 33.3% the average point if the three benefits were equally distributed among the possible beneficiaries and. Furthermore, assuming 50% enough to consider its weight significant, the following rank seems appropriate: from 0% to 25% is low; from 25.01% to 50% is medium and from 50.01% to 100 is high.
S	**C-EF3 Countrywide benefits**	Benefits for the whole society. It includes also non-monetized benefits	This variable represents a part of "total benefit = consumer + business + countrywide". Considering 33.3% the average point if the three benefits were equally distributed among the possible beneficiaries and. Furthermore, assuming 50% enough to consider its weight significant, the following rank seems appropriate: from 0% to 25% is low; from 25.01% to 50% is medium and from 50.01% to 100 is high.

S	**C-EF4 Degree of Feasibility**	An acronym to assess the project's creation of value, let us identify projects in terms of financial opportunity. As the weighted average cost of capital is the expected average future cost of funds, whereas internal rate of return is an investment analysis technique useful to decide whether a project should be followed through, the delta between IRR and WACC, is intended as a proxy of the investment acceptance	if DOF<0 then "not desirable"; if DOF close to 0 then "somehow acceptable"; if DOF>0 it is "opportune"
T	**C-EF5 Cost Distribution**	This variable embeds the three typologies of costs as stated in the questionnaire.	Being this variable a "sum" of shares that add to 100% it is not directly measurable using a ordered measure unit. However, in the majority of cases "in premises costs" play a remarkable role, thus we can use it as anchor where a) low means "in premises costs up to 50%"; b) medium stands for "50,01% < In premises costs <75%" and c) high if " in premises costs > 75,01%.
T	**C-EF6 Source of financial support**	Projects need financing from various sources, in some combination of equity and debt. The ratios of these different contributions depend on a set of conditions; this variable clarify the main sources of financing	This variable basically splits source of financial support in a) private b) public. A benchmark can be created using "Private" as reference. Thus we create three intervals: a) "low" is private share is from 0% to 33,3%, "medium" if the private contribution lies between 33.4% to 66.66% and high from 66.67 to 100%.
S	**C-SP1 Proximity to end user**	Degree of proximity of the DSO to the end user, in terms of quantity of the final activities (of the SC) performed by the DSO itself. This variable refers to the number of activities directly experienced by the end users (out of the three: Installation, Maintenance, Data management), actually performed by the DSOs.	Three levels: High (3 out of the Installation, Maintenance, Data management activities performed internally); Medium (2 out of 3); Low (up to 1 activity)
S	**C-SP2 Level of integration**	Amount of Supply Chain activities performed by the DSO out of the total (that is, out of the six: Manufacturing & Assembly, Logistics, Installation, Maintenance, Data communication, Data management).	Three levels: High (5-6 out of all the 6 activities of the Supply Chain performed internally); Medium (3-4 out of 6); Low (up to 2 activity)
T	**C-SP3 Within Group acquisition**	Existence of acquisitions from suppliers belonging to the DSO group.	It is a variable referred to each activity of the Supply Chain. It is a binary variable: Yes (existence of Within-Group acquisitions)/Not. At an aggregate level, we take the activities not performed only by the DSO: if more than half are supplied within-group, the level of the variable is HIGH; if not, is LOW.
T	**C-SP4 Number of suppliers**	Number of suppliers to supply each of the activities outsourced (typically, contrasting 1 supplier vs. more than 1 supplier).	It is a variable referred to each activity of the Supply Chain. 3 possible levels: SINGLE (1 supplier), DOUBLE (2 suppliers), MULTIPLE (more than 2 suppliers). At an aggregate level, we take the activities not performed only by the DSO: if the majority of the cases is SINGLE+DOUBLE, the level of the variable is LOW; if not, is HIGH.

T	**C-SP5 Exclusiveness of supplier**	Exclusiveness of Supply (supplier-side) in terms of number (if any) of DSO competitors supplied by the DSO suppliers for each of the activities outsourced (typically, contrasting suppliers supplying only to the DSO vs. suppliers supplying also competitors of the DSO).	It is a variable referred to each activity of the Supply Chain. It is a binary variable: Yes (the suppliers do NOT supply other DSOs)/Not. At an aggregate level, we take the activities not performed only by the DSO: if the majority of the cases are YES, the level of the variable is HIGH; if not, is LOW.
T	**C-SP6 buyer supplier relationship**	Kind of Buyer-Supplier Relationship, in terms primarily of duration (thus effort, trust, commitment, possibly integration, …) of the relationship set-up with the supplier(s) for each of the activities outsourced (typically, ranging from short-term to long-term relationship).	It is a variable referred to each activity of the Supply Chain. 2 possible levels (of the duration of the Buyer-Supplier Relationship): Long-Term, Short (or Medium) Term. At an aggregate level, we take the activities not performed only by the DSO: if the majority of the cases are Long-Term, the level of the variable is HIGH; if not, is LOW.

Table 3 – Section C variables

Section D			
	Variable name	**Definition**	**Scale**
S	**D11 Mandate on Smart Metering**	Status of obligation to implement Smart Metering in a particular country What are the legal conditions related to SM deployment?	Low: obligation does not exist Medium: there is no specific obligation, but the respective country has SM rollout High: obligation exists
S	**D12 Country CBA Status**	Has the CBA been performed Y/N/not YET? What is the overall result? Positive or Negative?	Low: negative CBA Medium: CBA not performed/no info High: positive CBA
T	**D13 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.)?	Low: not unbundled Medium: partly unbundled High: unbundling done as per EU directives
T	**D14 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)	Low: some of the minimum functionalities have been implemented Medium: only minimum set of functionalities implemented High: minimum set of functionalities and more have been implemented in the SM deployment
T	**D15 Tariff Schemes**	How tariffs are set ('Bundled' pricing is where the charges that make up the rates are shown as a combined rate on the bill. 'Unbundled' pricing is when the network charges are split out from the energy charges.)	Low: basic tariff schemes/no info provided. Medium: some tariff schemes and some info provided High: detailed tariff schemes and relevant info provided
S	**D21 Marketing and Customer Involvement Initiatives**	Has the utility dedicated initiatives to improve consumer involvement and acceptance? How is the feedback on this?	Low: no initiatives or no information provided on them Medium: some initiatives High: many initiatives/projects to ensure SM awareness
T	**D22 Customer Service Adaptation**	Has the Customer Service employees been trained on the Smart Metering topic? Is there a dedicated initiative inside the utility to adapt their current CS with the focus on SM?	Low: no initiatives or no information Medium: some references that CS adaptation is considered High: dedicated projects on adjusting CS
T	**D23 Opt out option implications**	Is there the opt-out option? How is opt-out cases handled? If no opt-out what is the feedback on this?	Low: opt out not available Medium: the opt out is still under discussion High: opt out is available
T	**D24 NRA involvement in customer issues related to SM**	Is the NRA involved in creating awareness on the SM implementation? To focus in the discussion on the connection between NRA involvement supporting the utility and on how a better the collaboration can be achieved	Low: no involvement or no information Medium: some references on this High: clear initiatives from the NRA on this

T	**D25 Vulnerable customers**	This refers to the socially vulnerable customers (health - special needs, life support; economic). Has the utility considered this issue in their project?	Low: no references/no information Medium: some references on this High: the info provided clearly specifies the vulnerable customer and there are initiatives related to them
	D26 Privacy level	It refers to the issues related to privacy and data security and the way in which they are ensured.	Low (1): No customer authorization is required High (4): Authorization is always required

Table 4 – Section D variables

Section E			
	Variable name	**Definition**	**Scale**
S	**E1 Beneficiaries**	This variable describes the list of market agents who are beneficiaries of each advanced solution. This list is ordered by benefit preference.	Low: the beneficiaries are more on the side of non-regulated market Medium: the beneficiaries are equally divided in regulated and non-regulated markets High: the beneficiaries are more on the side of regulated market
S	**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 (i.e. funding, renting of devices, regulated cost of service)	Low: no incentives Medium: local/pilot incentives High: countrywide incentives
T	**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)	Low: no role Medium: partial involvement High: whole involvement
T	**E4 Deployment Scale**	This variable defines the degree or scale of the deployment foreseen for each advanced function.	Pilot Test 500 < x < 2.000 meters Demonstration 2.000 < x < 200.000 meters Roll Out > 200.000 meters
T	**E5 Compliance with tech requirements**	Compliance of existing smart metering solution with technology requirements for advanced solutions. This variable identifies the degree of existing gap between the smart metering solution capabilities and the advanced solution needs (i.e. real time requirements, data processing and transmission needs)	Low: no compliance Medium: partial compliance High: complete compliance
T	**E6 Openness of the advanced solution**	This variable describes the degree of standardization of each advanced solution (standardized versus proprietary solution), with a special focal point on communication interfaces and protocols.	Low: proprietary solution Medium: in process of standardization High: standardized solution

Table 5 – Section D variables

Annex 3 – List of stakeholders

- EU Policy makers
- National Regulatory Authority
- Government
- Distribution System Operator
- Technology providers
- Customers Association

Annex 4 – Relevance of the variables for the stakeholders

Relevance	EU Policy Makers	NRA	Government	DSO	Technology providers	Customer Associations
A1 Nª customers served DSO	1	1	1	4	4	1
A2 Decision power DSO	1	1	1	4	2	1
A3 Project scale	3	4	4	4	4	4
A4 Number of customers involved in the project	2	3	1	4	4	1
A5 Duration	3	4	1	4	3	2
A6 Type of customers	1	3	1	4	4	3
B1 Type of comm tech	1	2	1	4	4	2
B2 Type of upper layer protocol	3	3	1	4	4	3
B3 Number and type of interfaces	3	3	1	4	4	4
B4 Elaborated data	1	4	2	4	3	3
B5 Compliance with standards	3	3	1	4	3	3
B6 Data security level	4	4	3	4	3	4
C-EF1 Customer benefits	3	4	3	4	2	4
C-EF2 Business benefits	3	4	2	4	4	1
C-EF3 Countrywide benefits	4	2	4	2	2	3
C-EF4 Degree of Feasibility	3	3	2	4	2	2
C-EF5 Cost Distribution	2	3	2	4	2	2
C-EF6 Source of financial support	2	4	3	4	2	2
C-SP1 Proximity to end user	1	1	1	1	1	3
C-SP2 Level of integration	1	1	1	1	1	1
C-SP3 Within Group acquisition	1	1	1	1	1	1
C-SP4 Number of suppliers	1	1	1	1	1	1
C-SP5 Exclusiveness of supplier	1	1	1	1	1	1
C-SP6 buyer supplier relationship	1	1	1	1	1	1
D11 Mandate	4	4	2	4	2	4
D12 Country CBA status	2	3	1	3	1	2
D13 Unbundling	4	3	2	4	1	2
D14 Min, functs.	4	3	1	4	4	1
D15 Tariff schemes	2	2	1	4	3	2
D21 MKt and cust. Initiatives	2	2	1	4	1	4
D22 Customer Service adaptation	1	1	1	4	2	4
D23 Opt put implications	4	4	2	4	3	4
D24 NRA involvement	2	3	2	2	1	3
D25 Vulnerable customers	2	3	3	2	1	3
D26 Privacy level	4	4	1	4	3	4
E1 Beneficiaries	4	4	4	4	1	3
E2 Incentives	3	4	4	4	2	2
E3 DSO role	4	4	4	4	1	1
E4 Depl. Scale	4	4	4	4	4	3
E5 Compliance with tech requirements	2	2	2	4	4	3
E6 Openness of the advanced solution	3	3	3	3	4	3

Annex 5 – Degree of stakeholders' controllability

Controllability	EU Policy Makers	NRA	Government	DSO	Technology providers	Customer Associations
A1 Nª customers served DSO	1	1	1	1	1	1
A2 Decision power DSO	1	1	1	1	1	1
A3 Project scale	2	4	2	4	1	1
A4 Number of customers involved in the project	1	4	1	4	1	3
A5 Duration	3	4	1	3	1	1
A6 Type of customers	1	4	1	3	1	1
B1 Type of comm tech	1	2	1	4	3	1
B2 Type of upper layer protocol	3	3	1	4	3	1
B3 Number and type of interfaces	3	4	1	3	3	2
B4 Elaborated data	3	4	1	4	2	3
B5 Compliance with standards	4	4	1	4	3	3
B6 Data security level	3	4	1	4	3	1
C-EF1 Customer benefits	1	4	1	4	2	1
C-EF2 Business benefits	2	4	1	3	2	1
C-EF3 Countrywide benefits	4	4	4	1	1	1
C-EF4 Degree of Feasibility	1	4	2	3	3	1
C-EF5 Cost Distribution	2	2	2	4	3	1
C-EF6 Source of financial support	1	4	4	3	1	2
C-SP1 Proximity to end user	1	1	1	4	1	1
C-SP2 Level of integration	1	1	1	4	1	1
C-SP3 Within Group acquisition	1	1	2	4	1	1
C-SP4 Number of suppliers	1	1	1	3	1	1
C-SP5 Exclusiveness of supplier	1	1	1	3	1	1
C-SP6 buyer supplier relationship	1	1	1	3	1	1
D11 Mandate	4	4	4	1	1	1
D12 Country CBA status	2	3	2	1	1	1
D13 Unbundling	4	4	4	1	1	1
D14 Min, functs.	3	4	2	1	1	1
D15 Tariff schemes	1	3	1	3	1	1
D21 MKt and cust. Initiatives	1	2	1	4	1	4
D22 Customer Service adaptation	1	1	1	4	1	4
D23 Opt put implications	3	4	4	1	1	2
D24 NRA involvement	1	4	3	1	1	3
D25 Vulnerable customers	4	4	1	4	1	3
D26 Privacy level	3	4	1	4	3	4
E1 Beneficiaries	1	4	4	1	1	1
E2 Incentives	4	4	4	1	1	1
E3 DSO role	4	4	4	2	1	1
E4 Depl. Scale	3	4	3	3	2	4
E5 Compliance with tech requirements	3	3	3	4	4	2
E6 Openness of the advanced solution	3	3	3	3	4	1

Annex 6 – Relationship Matrix

METER-ON – Relationship Matrix	A1 Nª customers served DSO	A2 Decision power DSO	A3 Project scale	the project	A5 Duration	A6 Type of customers	B1 Type of comm tech	B2 Type of upper layer protocol	B3 Number and type of interfaces	B4 Elaborated data	B5 Compliance with standards	B6 Data security level	C-EF1 Customer benefits	C-EF2 Business benefits	C-EF3 Countrywide benefits	C-EF4 Degree of Feasibility	C-EF5 Cost Distribution	C-EF6 Source of financial support	C-SP1 Proximity to end user	C-SP2 Level of integration	C-SP3 Within Group acquisition	C-SP4 Number of suppliers	C-SP5 Exclusiveness of supplier	C-SP6 buyer supplier relationship	D11 Mandate	D12 Country CBA status	D13 Unbundling	D14 Min, functs.	D15 Tariff schemes	D21 MKt and cust. Initiatives	D22 Customer Service adaptation	D23 Opt put implications	D24 NRA involvement	D25 Vulnerable customers	D26 Privacy level	E1 Beneficiaries	E2 Incentives	E3 DSO role	E4 Depl. Scale	E5 Compliance with tech requirements	E6 Openness of the advanced solution
A1 Nª customers served DSO	-	1	NR	1	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
A2 Decision power DSO	NR	-	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
A3 Project scale	NR	NR	-	1	1	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
A4 Number of customers involved in the project	NR	NR	NR	-	1	NR	NR	NR	NR	NR	NR	NR	NR	1	1	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
A5 Duration	NR	NR	NR	NR	-	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
A6 Type of customers	NR	NR	NR	NR	NR	-	1	1	NR	1	NR	NR	NR	NR	1	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
B1 Type of comm tech	NR	NR	NR	NR	NR	NR	-	NR	NR	NR	NR	1	1	1	1	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
B2 Type of upper layer protocol	NR	NR	NR	NR	NR	NR	NR	-	NR	NR	NR	NR	1	1	1	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
B3 Number and type of interfaces	NR	NR	NR	NR	NR	NR	NR	NR	-	NR	NR	NR	1	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	1	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
B4 Elaborated data	NR	NR	NR	NR	NR	NR	NR	1	NR	-	NR	NR	1	1	1	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	1	1	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
B5 Compliance with standards	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	-	NR	NR	1	NR	NR	NR	NR	NR	NR	NR	NR	1	1	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	1	NR
B6 Data security level	NR	NR	NR	NR	NR	NR	NR	1	NR	NR	1	-	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
C-EF1 Customer benefits	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	-	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
C-EF2 Business benefits	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	-	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
C-EF3 Countrywide benefits	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	-	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR

C-EF4 Degree of Feasibility	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	-	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
C-EF5 Cost Distribution	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	-	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
C-EF6 Source of financial support	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	-	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR		NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
C-SP1 Proximity to end user	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	-	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	1	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
C-SP2 Level of integration	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	-	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
C-SP3 Within Group acquisition	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	-	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
C-SP4 Number of suppliers	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	-	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
C-SP5 Exclusiveness of supplier	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	-	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
C-SP6 buyer supplier relationship	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	-	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
D11 Mandate	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	-1	NR	NR	NR	NR	NR	NR	-	NR	NR	1	NR	1	1	1	1	NR	NR	NR	NR	NR	NR	NR	NR
D12 Country CBA status	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	-	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
D13 Unbundling	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	1	NR	NR	NR	NR	-	NR	NR	NR	NR	NR	NR	NR	NR	1	NR	NR	NR	NR	NR
D14 Min, functs.	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	-	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	1	NR
D15 Tariff schemes	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	-	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
D21 MKt and cust. Initiatives	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	-	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
D22 Customer Service adaptation	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	-	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
D23 Opt put implications	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	1	1	-	NR	NR	NR	NR	NR	NR	NR	NR	NR
D24 NRA involvement	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	1	NR	NR	-	NR	NR	NR	NR	NR	NR	NR	NR
D25 Vulnerable customers	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	1	NR	NR	-	NR	NR	NR	NR	NR	NR	NR
D26 Privacy level	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	-	NR	NR	NR	NR	NR	NR
E1 Beneficiaries	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	-	NR	NR	NR	NR	NR
E2 Incentives	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	-	NR	1	NR	NR
E3 DSO role	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	-	NR	NR	NR
E4 Depl. Scale	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	-	NR	NR
E5 Compliance with tech requirements	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	-	NR
E6 Openness of the advanced solution	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	-

Annex 7 – Patterns description

#	Pattern	Description
1	A3 → A4	The higher the value of project scale, the greater the number of customers involved in the project.
2	A1 → A4 → A5	The greater the number of customers served by the DSO, the greater the number of customers involved in the project; so the higher the number of customers involved, the longer the duration of the project.
3	A3 → A5	The higher the value of the project scale, the longer the time to complete the project.
4	A3 → A4 → A5	The higher the value of project scale, the greater the number of customers involved in the project; so the higher the number of customers involved, the longer the duration of the project.
5	A6 → B1	In case c&i are considered in the project more advanced functions should be offered by the communication technology.
6	A6 → B2	In case c&i are considered in the project more advanced functions should be offered by the upper layers protocol.
7	A6 → B1 → B6 → B2	In case c&i are considered in the project more advanced functions should be offered by the communication technology; in case of technologies suitable for advanced functions, higher data security level is achieved, so higher level of data security implies to choose an upper layer protocol suitable for advanced functions.
8	A6 → B4 → B2	In case c&i are considered in the project more elaborated data should be offered, so there are some type of elaborated data that can be given only by an advanced upper layers protocol.
9	A6 → B4	In case c&i are considered in the project more elaborated data should be offered.
10	A6 → B1 → B6 → B5	in case c&i are considered in the project more advanced functions should be offered by the communication technology; in case of technologies suitable for 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	A6 → B1 → B6	In case c&i are considered in the project more advanced functions should be offered by the communication technology; in case of technologies suitable for advanced functions, higher data security level is achieved.
12	A6 → B1 → C-EF1	In case c&i are considered in the project more advanced functions should be offered by the communication technology; in case of technologies suitable for advanced functions higher business benefits are achieved: loss reductions, less operation managements, quality of supply.
13	A6 → B2 → C-EF1	In case c&i are considered in the project more advanced functions should be offered by the upper layers protocol; so the higher is the value of

		advanced functions the greater number customer benefits are given: savings, awareness, quality of supply, quality of the service.
14	A6 → B4 → C-EF1	In case c&i are considered in the project more elaborated data should be offered, so the higher the value of elaborated data: the greater number of customer benefits are given: savings, awareness, quality of supply, quality of the service.
15	B3 → C-EF1	The higher the number of interfaces, the greater number of services are offered to the customers.
16	A6 → B1 → B6 → B2 → C-EF1	In case c&i are considered in the project more advanced functions should be offered by the communication technology; in case of technologies suitable for advanced functions, higher data security level is achieved, so higher level of data security implies to choose an upper layer protocol suitable for advanced functions; the higher is the value of advanced functions; the greater number customer benefits are given: savings, awareness, quality of supply, quality of the service.
17	A6 → B4 → B2 → C-EF1	In case c&i are considered in the project more elaborated data should be offered; there are 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 greater number customer benefits are given: savings, awareness, quality of supply, quality of the service.
18	A1 → A4 → C-EF2	The greater the number of customers served by the DSO, the greater the number of customers involved in the project; so the higher the number of customers involved, the better economy of scale.
19	A3 → A4 → C-EF2	The higher the value of 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.
20	A6 → B1 → C-EF2	In case c&i are considered in the project more advanced functions should be offered by the communication technology; in case of technologies suitable for advanced functions; the greater customer benefits are given: savings, awareness, quality of supply, quality of the service.
21	A6 → B2 → C-EF2	In case c&i are considered in the project more advanced functions should be offered by the upper layers protocol; so the higher is the value of advance functions the higher business benefits: loss reductions, less operation managements, quality of supply.
22	A6 → B4 → C-EF2	In case c&i are considered in the project more elaborated data should be offered; so the higher the value of elaborated data; the higher business benefits: loss reductions, less operation management, quality of supply.
23	A6 → B4 → B2 → C-EF2	In case c&i are considered in the project more elaborated data should be offered; there are some type of elaborated data that can be given only by an advanced upper layers protocol, so the higher is the value of advance functions the higher business

		benefits: loss reductions, less operation managements, quality of supply.
24	A6 → B1 → B6 → B2 → C-EF2	In case c&i are considered in the project more advanced functions should be offered by the communication technology; in case of technologies suitable for advanced functions, higher data security level is achieved, so higher level of data security implies to choose an upper layer protocol suitable for advanced functions; the higher is the value of advance functions the higher business benefits: loss reductions, less operation managements, quality of supply.
25	A6 → B1 → B6 → B5 → C-EF2	In case c&i are considered in the project more advanced functions should be offered by the communication technology; in case of technologies suitable for 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.
26	A1 → A4 → C-EF3	The greater the number of customers served by the DSO, the greater the number of customers involved in the project, so the higher the number of customers involved, the greater number of energy efficiency initiatives and emissions reductions.
27	A3 → A4 → C-EF3	The higher the value of project scale, the greater the number of customers involved in the project; so the higher the number of customers involved, the greater number of energy efficiency initiatives and emissions reductions.
28	A6 → C-EF3	In case c&i are considered in the project more countrywide benefits in terms of C02 reductions.
29	A6 → B1 → C-EF3	In case c&i are considered in the project more advanced functions should be offered by the communication technology, so in case of technologies suitable for advanced functions; the greater number of countrywide benefits: CO2 reductions, energy efficiency.
30	A6 → B1 → B6 → B2 → C-EF3	In case c&i are considered in the project more advanced functions should be offered by the communication technology; in case of technologies suitable for advanced functions, higher data security level is achieved; higher level of data security implies to choose an upper layer protocol suitable for advanced functions, so the higher is the value of advanced functions; the greater number of country-wide benefits: CO2 reductions, energy efficiency.
31	A6 → B2 → C-EF3	in case c&i are considered in the project more advanced functions should be offered by the upper layers protocol, so the higher is the value of advanced functions; the greater number of country-wide benefits: CO2 reductions, energy efficiency.
32	A6 → B4 → C-EF3	in case c&i are considered in the project more elaborated data should be offered, so the higher the value of elaborated data; the higher country wide benefit: CO2 reductions, energy efficiency.

33	A6 → B4 → B2 → C-EF3	in case c&i are considered in the project more elaborated data should be offered; there are 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 greater number of country-wide benefits: CO2 reductions, energy efficiency.
34	D11 (→) C-EF6	Depending on the conditions of the rollout (mandate wise) private investment can be very low of very high.
35	D11 → D14	The higher the level of mandate available the higher the level of correlation with minimum functionalities specified (the link between national mandate and integration of min functionalities given by the EU).
36	A6 → B4 → D21	In case c&i are considered in the project more elaborated data should be offered, so the higher level of elaborated data the higher the level of customer related initiatives (expected in order to increase acceptance and understanding).
37	C-SP1 → D21	The higher level of proximity to the end user the higher level of customer related initiatives is expected.
38	D11 → D21	The higher the mandate level the more marketing initiatives are expected to involve the customer.
39	D11 → D23 → D21	The mandate of a roll out refers implicitly to the opt out options/implications, so if opt-out available the DSO should have in place initiatives to convince the customers of the benefits of the SM.
40	D11 → D24 → D21	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 DSO one's and vice versa.
41	A6 → B4 → D22	In case c&i are considered in the project more elaborated data should be offered, so the higher the level of elaborated data the higher the level of customer services adaptation (this is expected in order to create comprehensive services for the customer).
42	B3 → D22	The higher the level of B3 the more customer services need to be developed.
43	D11 → D22	The higher the mandate level the more adaptation of customer services is expected.
44	D11 → D23 → D22	The mandate of a roll out refers implicitly to the opt out options/implications, so if opt-out available the DSO needs to have in place a well-adapted customer service in order to cope with possible inquiries.
45	D25 → D22	The higher attentions to the vulnerable customers the higher efforts to train the Customer Service employees.
46	D11 → D23	The mandate of a roll out refers implicitly to the opt out options/implications.
47	D13 → E1	The type and level of unbundling adopted delineates the type of beneficiaries in the MS.
48	E2 → E4	More public money, make easier to deploy bigger projects.
49	A6 → B1 → B6 → B5 → E5	In case c&i are considered in the project more advanced functions should be offered by the

		communication technology; in case of technologies suitable for advanced functions, higher data security level is achieved; so to reach a high data security level implies to be compliance with the corresponding standards; SM solutions compliance with the standards make easier the compliance with the standards for Smart Grids solutions and the compliance with technical requirements.
50	D11 → D14 → E5	The higher the level of mandate available the higher the level of correlation with minimum functionalities specified (the link between national mandate and integration of min functionalities given by the EU), so high implementation(specification) of minimum requirements will influence future high level of compliance with tech requirements for advanced solutions.

Annex 8 – List of Distribution System Operators

1. EDP Distribuição (Portugal)
2. Endesa (Spain)
3. Enel Distributie Muntenia (Romania)
4. ENEL (Italy)
5. Enexis BV (Netherlands)
6. ERDF (France)
7. EVN AG (Austria)
8. Fortum AMM (Finland)
9. Gas Natural Fenosa (Spain)
10. Iberdrola (Spain)
11. Liander (Netherlands)
12. Stromnetz (Austria)

Annex 9 – Survey for data collection

Part A : General Information on electricity smart metering project				
A.1 Project Name				
A.2 Contact person				
A.3 Leading company				
A.4 Project Start Date and End Date				
A.5 Project Location				
A.6 Project Scale	R&D ☐	Pilot Test ☐	Demonstration ☐	Roll Out ☒
A.7 Number of meters installed				
A.8 Number of concentrators installed				
A.9 Status of the project (%)				
A.10 Number of customers involved in the project and percentage of total customers served by the leading company				

A.11 Type of customers involved	☒ Residential % of total Customers: __	☐ Commercial and Industrial % of total Customers: __
A.12 Brief Description of the electricity smart metering project (Please also specify which are the actors involved, i.e. suppliers, distribution system operators, service providers, etc.)	•	
A.13 In case of rollout, number of meters to be installed and deadline		

Part B : Technological Analysis	

B.1 Grid information **In case of roll out, please provide information on the characteristics of the whole grid operated by the company, otherwise please consider the characteristics of the portion of the grid where the R&D/pilot/demonstration (electricity smart metering) project is carried out.**		
Yearly energy distributed (TWh)		
HV,MV and LV voltage levels		

Number of HV/MV substations;			
Number of MV/LV substations;			
Total Number of MV/LV power transformers			
Maximum number of power transformers per MV/LV secondary substation			
Number of Points of Delivery (POD) connected to low voltage network;			
Number of Points of Delivery (POD) connected to medium voltage network;			
LV Underground and Overhead Km lines			
MV Underground and Overhead Km lines			
Maximum number of POD connected at MV/LV substation			
Average number of POD connected at MV/LV substation			
Average residential contractual power (KW)			
Types of residential meters installed	Single Phase ☒	Polyphase ☒	
Percentage of single phase – three phase meters connected to low voltage network			
Average residential yearly consumption (KWh)			

B.2 General information on electricity smart metering solutions

B2.1 Please describe the architecture of your remote electricity metering solution (High Voltage level)

B2.2 Please describe the architecture of your remote electricity metering solution (Medium voltage level)	
B2.3 Please describe the architecture of your remote electricity metering solution (Low Voltage level)	
B2.4 Please describe the main features of the components of your remote electricity metering solution (Medium Voltage level)	
B2.5 Main features of the components of your remote electricity metering solution (Low Voltage level).	
B2.5.1 Please provide a description of data collector features: **a. How many meters can it manage?** **b. Where is it installed?;** **c. Which kind of communication interfaces are available on data collector?** **d. How is remote synchronization of clock managed? (UTC, GPS,….);** **e. Please describe the mechanism of sending of the alarms to central system. In particular:** - **Which is the alarm mechanism enabled ? Push or pull mechanism ?** - **How much time is needed to get the alarm to the central system?** **f. Concentrator self consumption (W)** **g. Is it interoperable with phase-to-phase and phase-to-neutral systems?**	
B2.5.2 Please provide a description of communication technologies used between main components of system. (e.g. PLC, RF, GSM, GPRS, WI-FI …). In particular the description must contain the following points: **a. What is the achieved reliability of each communication technology?** **b. What sources have been detected that disturb each communication technology?** **c. How are disturbances detected?** **d. How are disturbances mitigated?** **e. Which precautions are taken to solve disturbances on the long term?** **f. What are the associated costs with these precautions?**	

B2.5.3 Please provide a brief description of communication protocol used between main components of system (In particular, is your smart meter solution implementing IP communication?	
B2.5.4 What is the meter reading success rate (monthly active positive register and Q1 register) ? What are the main reasons for unsuccessful readings?	
B2.5.5 What is the success rate of load profile acquisition? (active positive register and Q1 register)	
B2.5.6 What is the success rate of contract management operations ? (average value for each kind of contract management operation)	
B.2.5.7 Which is the amount of data requested in each reading operation (how many energy registers are read, how many channels does the load profile have etc. …)?	
B.2.5.8 How often are data being retrieved from the meters during normal operation?	
B.2.5.9 Data recovery mechanisms involved	

<table>
<tr><td colspan="3"></td><td></td></tr>
<tr><td colspan="4">B3 Information on electricity smart meters</td></tr>
<tr><td colspan="4">B3.1 Please provide information on the main features of low voltage <u>single phase</u> meters (for each typology of meter installed)</td></tr>
<tr><td>Meter average life (Years)</td><td colspan="2"></td><td></td></tr>
<tr><td>Temperature range operation (°C)</td><td colspan="2"></td><td></td></tr>
<tr><td>Voltage Reference (V)</td><td colspan="2"></td><td></td></tr>
<tr><td>Operating frequency range (Hz)</td><td colspan="2"></td><td></td></tr>
<tr><td>Current range operation (direct insertion) (A)
(Please consider minimum, reference and maximum currents)</td><td colspan="2"></td><td></td></tr>
<tr><td>Meter self-consumption (W, VA)</td><td>In case of active communication:</td><td>In case communication is not active:</td><td></td></tr>
<tr><td>Percentage of time in which active communication takes place (averaged over year)</td><td colspan="2"></td><td></td></tr>
<tr><td colspan="4">Please briefly describe the compliance of meter components to international standards</td></tr>
<tr><td colspan="3">The Meter measures energy in all four quadrants both for active and reactive power (A+, A- , R+L, R+C, R-L, R-C).
The Energy measurement (active and reactive energy) has been designed and implemented according to the following International Standards:
IEC/CEI EN 62052-11; EN 62053-21, IEC/CEI EN 62053-23, MID EN 50470-1 and MID EN 50470-3
In particular:
- Active energy accuracy class is “C” for MID (equivalent to Class 0,5 of IEC). Anyway, the meters are manufactured according to class “B” of MID</td><td></td></tr>
</table>

- Reactive energy accuracy class is “2” according to IEC		
Maximum programmable transmission baud rate and baud rate used (Bound)		
Has the meter any electrically protective device? (e.g. short circuit , overcurrent, overvoltage…)		
Does the meter include an internal switchgear? **If so :** - **What kind of switchgear is implemented? (relay, breaker..)** - **Is the switchgear accessible from external? If not accessible please describe the rearmament mechanisms** - **Indicate the international standard to which the switchgear complies.** - **Indicate the maximum cut-off current;** - **Indicate the number of cutting poles;**		
What kind of backup power supply is available (for time keeping purposes) in the meter?		
General description of display interface (including the information of whether or not the display is alphanumeric)		
B3.2 Please provide information on the main functionalities of low voltage <u>single phase</u> meters (for each typology of meter installed		
Frequency for reading rate (daily, monthly, bimonthly, yearly…)		
Does the meter record the maximum power of consumption?		
Which are the instantaneous measurement values available in the meter?		
Is the active energy measurement bi-directional?		

Is the reactive energy measurement detected in 4 quadrants?		
How many types of load profile are recorded?		
Is the load profile configuration changeable (including both integration period and measurements recorded)?		
Does the meter record a network frequency profile?		
Does the meter record a voltage profile?		
What kind of billing profiles are available? (daily, monthly…)		
How many annual tariff programs can be programmed?		
How many weekly tariff programs can be programmed for each annual program?		
How many daily tariff programs can be programmed for each weekly tariff programs?		
How many daily tariff intervals can be programmed?		
How many load profile sampling options are available ?		
Does the meter record the max and min value of power factor? (specify the period of reference);		
Does the meter record the current imbalance? (specify the period of reference, daily, weekly...)		
Does the meter record the RMS voltage for single phase? (specify the period of reference, daily, weekly...)		
Is it possible to remotely synchronize the clock/calendar?		
Is the real time clock compliant with any international standard ?		
Which is the minimum accuracy of Real Time Clock?		
Is it possible to remotely manage supplying contracts? (available power threshold, disconnection..)		
Is it possible to locally manage supply contracts ?		

Does the meter support load control? If so: - **Is it possible to remotely manage a load reduction?** - **Please describe the tripping curve algorithm** - **Please describe the available reconnection mechanisms**		
Does the meter record events (event log)? Which are the monitored parameters? How is information accessed ?		
Does the meter record information about power outages and quality of supply?		
Does the meter have any demand management feature implemented? If so, please describe it.		
Does the meter have any prepayment management implemented? If so, please describe it.		
How many local interfaces are available ? For which purposes ? (e.g. local access interface for field operations, Home Area Network Interface to connect in-house devices, …). **For each interface, please indicate the main features (e.g. baudrate, frequency band and compliance with international standard)**		
General description of display interface (including the information of whether or not the display is alphanumeric)		
Is it possible to remotely program the information on the display?		
Is possible to remotely download (both application and communication) firmware?		
How is remote synchronization of Clock/calendar managed? (UTC, GPS,….)		
Does the meter have any fraud detection mechanism implemented (meter cover open detection, neutral current detection …)?		
Please describe the mechanism of sending of the fraud alarms to central system		
Please describe how the meter is acknowledged by central system when it's installed in the field (e.g. Plug&Play..)		

What kind of installation modes are possible? (e.g. socket, DIN and indoor or outdoor…)			
B4 Information on electricity smart meters			
B4.1 Please provide information on the main features of low voltage <u>three phase</u> meters (for each typology of meter installed)			
Meter average life (Years)			
Temperature range operation (°C)			
Voltage Reference (V)			
Operating frequency range (Hz)			
Current range operation (direct insertion) (A)			
In case of indirect insertion, how is the current ratio stored in the data systems? (e.g. in the meter, in central system…)			
Meter self-consumption (W,VA)	In case of active communication:	In case communication is not active:	
Please briefly describe the compliance of meter components to international standards			
Percentage of time in which active communication takes place (Averaged over year)			
Maximum programmable transmission baud rate and baud rate used (Bound)			

Has the meter any electrically protective device (e.g. short circuit, overcurrent, overvoltage…)		
Does the meter include an internal switchgear? **If so :** - **What kind of switchgear is implemented? (relay, breaker..)** - **Is the switchgear accessible from external? If not accessible please describe the rearmament mechanisms** - **Indicate the international standard to which the switchgear complies.** - **Indicate the maximum cut-off current;** - **Indicate the number of cutting poles**		
What kind of backup supply is available (for time keeping purposes) in the meter ?		
General description of display interface (including the information of whether or not the display is alphanumeric)		
B4.2 Please provide information on the main functionalities of low voltage <u>three phase</u> meters (for each typology of meter installed)		
Frequency for reading rate (daily, monthly, bimonthly, yearly…)		
Does the meter record the maximum power of consumption?		
Which are the instantaneous measurement values available in the meter?		
Is the active energy measurement bi-directional?		
Is the reactive energy measurement detected in 4 quadrants?		
How many types of load profiles are recorded?		
Is the load profile configuration changeable (including both integration period and measurements recorded)?		
Does the meter record a network frequency profile?		
Does the meter record a voltage profile?		

What kind of billing profiles are available? (daily, monthly…)		
How many annual tariff programs can be programmed?		
How many weekly tariff programs can be programmed for each annual program?		
How many daily tariff programs can be programmed for each weekly tariff programs?		
How many daily tariff intervals can be programmed?		
How many load profile sampling options are available ?		
Does the meter record the max and min value of power factor? (specify the period of reference);		
Does the meter record the current imbalance? (specify the period of reference, daily, weekly...)		
Does the meter record the RMS voltage for single phase? (specify the period of reference, daily, weekly...)		
Is it possible to remotely synchronize the clock/calendar?		
Is the real time clock compliant with any international standard ?		
Which is the minimum accuracy of Real Time Clock?		
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Is it possible to locally manage supplying contracts ?		
Does the meter support load control? If so: - Is it possible to remotely manage a load reduction? - Please describe the tripping curve algorithm - Please describe the available reconnection mechanisms		
Does the meter record events (event log)? Which are the monitored parameters? How is information accessed ?		

Does the meter record information about power outages and quality of supply?		
Does the meter have any demand management feature implemented? If so, please describe it.		
Does the meter have any prepayment management implemented? If so, please describe it.		
How many local interfaces are available ? For which purposes ? (e.g. local access interface for field operations, Home Area Network Interface to connect in-house devices, …). For each interface, please indicate the main features (e.g. baud rate, frequency band and compliance with international standard)		
General description of display interface (including the information of whether or not the display is alphanumeric)		
Is it possible to remotely program the information on the display?		
Is possible to remotely download (both application communication) firmware?		
How is remote synchronization of Clock/calendar managed? (UTC, GPS,….)		
Does the meter have any fraud detection mechanism implemented (meter cover open detection, neutral current detection …)?		
Please describe the mechanism of sending of the fraud alarms to central system		
Please describe how the meter is acknowledged by central system when it's installed in the field (e.g. Plug&Play..)		
What kind of installation modes are possible? (e.g. socket, DIN and indoor o outdoor…)		
B5 Cyber security		
Please provide information on the security policy of your electricity smart metering solution (Low Voltage level)		

<table>
<tr><td colspan="2">B5.1 Please provide a brief description of how the smart meters support access to data, manage access rights and on demand access</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">B5.2 Please provide a brief description of how the data collectors support access to data, manage access rights and on demand access</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">B5.3 For each component of the smart metering system, is the identification of the source (for all data communications on all of its communication interfaces) unambiguous?</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">B5.4 For each component of the smart metering system please describe how data is accessed (In read and write mode);</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">B5.5 For each component of the smart metering system please describe the criteria used for the user identification and logging</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">B5.6 Is data transmission (AMM – data collectors – meters) protected against not authorized users?</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">B5.7 Is the system able to manage access rights for each of its components ?</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">B5.8 For each component of smart metering, is integrity of all the messages exchanged ensured?</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">B5.9 For each component of smart metering, are data exchanges protected against replay attacks?</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">B5.10 For each components of smart metering, are the cryptography algorithms standardized? If so , please specify which standards are used</td></tr>
<tr><td></td><td></td></tr>
</table>

B5.11 For each component of smart metering, are security events logged?		
B5.12 For each component of smart metering, are equipment alarms events sent automatically or on demand?		
B5.13 Is the firmware upgrade ensured in a secure way? (for data collectors and meters)		
B5.14 Is encryption performed in the system? In which parts of it ? (e.g. data storage, communication channel etc.)		
B6 Privacy		
Please provide information on the privacy policy of your electricity smart metering solution (Low Voltage level)		
B6.1 For each components of smart metering, is confidentiality of critical data preserved in all data exchanges ?		
B6.2 Is customer authorization needed to collect specific data from the meter? Who is in charge of requesting customer authorization ? (e.g. DSO, metering operator, supplier …)		
Part C : Quantitative Analysis		
C.1 Financial information **Please answer every question in "2012 real money" (€)**		
C1.1 Total Project Budget (€)		
C1.2 % of private investment		
C1.3 Private investment source		

C1.4 % of public funding		
C1.5 Public Funding Source		
C 1.6 Type of public funding source (e.g. credit facility, grant etc.)		
C1.7 Payback period (years)		
C1.8 Internal Return Rate (%)		
C1.9 Net Present Value (€), and base year (year)		
C1.10 Discount Rate (%), and related time period (years)		
C1.11 Project WACC (%)		

C2 Cost-Benefit Analysis

Please provide in column (A) the actual costs and benefits of the completed project; in column (B) (if your project is NOT a rollout already) the forecasted costs and benefits of the future full rollout.

C2.1 Costs

	COLUMN A Completed Project	**COLUMN B Full rollout**	
Total costs (€)			

C2.1.1 Detailed Costs (please also specify, for each component, which is the actor incurring the cost)					**COLUMN A Completed Project**	**COLUMN B Full rollout**	
In premise costs	Meters (€)	Energy supplier ☐	DSO ☒	Other (please specify) ☐			
	Installation of Meters (€)	Energy		Other			

		supplier ☐	DSO ☒	(please specify) ☐			
	Operation and maintenance of meters (€/year)	Energy supplier ☐	DSO ☐	Other (please specify) ☐			
	Communications equipment in premise (if applicable; e.g. WAN communication module) (€)	Energy supplier ☐	DSO ☐	Other (please specify) ☐			
	In Home Displays (if applicable)	Energy supplier ☐	DSO ☐	Other (please specify) ☐			
Field devices costs (if applicable)	Data collectors (€)	Energy supplier ☐	DSO ☒	Other (please specify) ☐			
	Installation of data collectors (€)	Energy supplier ☐	DSO ☒	Other (please specify) ☐			
	Operation and maintenance of data collectors (€/year)	Energy supplier ☐	DSO ☐	Other (please specify) ☐			
Data Communication infrastructure	Capex (€)	Energy supplier ☐	DSO ☐	Other (please specify) ☐			
	Opex (€/year)	Energy supplier ☐	DSO ☐	Other (please specify) ☐			

Other Costs	Energy (€/year) (Consumed by smart metering assets)	Energy supplier ☐	DSO ☐	Other (please specify) ☐			
	Disposal (€)	Energy supplier ☐	DSO ☐	Other (please specify) ☐			
	Pavement reading inefficiency (€/year annual average) (Inefficiency effect of having to manually read a decreasing number of basic meters as the rollout of smart meters progresses)	Energy supplier ☐	DSO ☐	Other (please specify) ☐			
	Marketing (€/year annual average)	Energy supplier ☐	DSO ☐	Other (please specify) ☐			
	Legal costs (€/year annual average)	Energy supplier ☐	DSO ☐	Other (please specify) ☐			
	Organizational costs (e.g. data protection, ongoing regulation, assurance, accreditation, tendering) (€/year annual average)	Energy supplier ☐	DSO ☐	Other (please specify) ☐			
	Stranding costs (costs incurred when a meter is taken out of service before the end of its expected economic life) (€)	Energy supplier ☐	DSO ☐	Other (please specify) ☐			

Other Costs (please specify other cost elements if not included in the list; if Capex in (€), if Opex in (€/year))	**The remaining 5% corresponds to costs associated with IT system development, R&D costs and other expenses.**	Energy supplier ☐	DSO ☐	Other (please specify) ☐			
	…	Energy supplier ☐	DSO ☐	Other (please specify) ☐			
	…	Energy supplier ☐	DSO ☐	Other (please specify) ☐			
C2.2 Benefits **Note: if numbers cannot be provided please provide a qualitative indication of the benefits in asterisks:** ***negligible benefits** **** good benefits** ***** very high benefits**					**COLUMN A Completed Project**	**COLUMN B Full rollout**	
				Total Benefits (€)			
C2.2.1 Detailed benefits (If needed, please specify the beneficiary)					**COLUMN A Completed Project**	**COLUMN B Full rollout**	
Consumer Benefits	Energy Savings (€/year)						
	Energy Savings (gross annual reduction in demand, % per year)						
	Peak load transfer (€/year)						
Business Benefits	Reduction of meter reading and operations cost (reading, billing, customer care) (€/year)	Energy supplier ☐	DSO ☐	Other (please specify) ☐			
	Reduction of operations and maintenance cost (assets and	Energy supplier	DSO	Other (please			

	equipment breakdowns) (€/year)	☐	☐	specify) ☐			
	Deferred generation capacity investments (€)	Energy supplier ☐	DSO ☐	Other (please specify) ☐			
	Deferred transmission capacity investments (€)	Energy supplier ☐	DSO ☐	Other (please specify) ☐			
	Deferred distribution capacity investments (€)	Energy supplier ☐	DSO ☐	Other (please specify) ☐			
	Reduction in electricity technical losses (€/year)	Energy supplier ☐	DSO ☐	Other (please specify) ☐			
	Reduction in commercial losses (thefts, frauds, …) (€/year)	Energy supplier ☐	DSO ☐	Other (please specify) ☐			
	Reduction in outage times (thefts, frauds, …) (€/year)	Energy supplier ☐	DSO ☐	Other (please specify) ☐			
Country-wide benefits	Global CO2 reduction (Ton CO2 and € if applicable)	Energy supplier ☐	DSO ☐	Society ☐			
	EU Emission Trading Scheme from energy reduction (€) (if applicable)	Energy supplier ☐	DSO ☐	Other (please specify) ☐			
	EU Emission Trading Scheme from application of Time Of Use tariffs (€) (if applicable)	Energy supplier	DSO	Other (please specify)			

		☐	☐	☐			
Other benefits (Please specify other benefit elements if not included in the list)	…	Energy supplier ☐	DSO ☐	Other (please specify) ☐			

C.3 Make-or-buy and Development Process Analysis: Actors involved in the supply chain

C3.1 Please indicate who performed, in the project, the activities listed below and what is the cost per unit

Supply chain	Your company	Companies belonging to your Group	Other suppliers	Cost per unit (€) Optional
Manufacturing and assembly	☐	☐ If so, 1) How many are they? 2) Do they also supply other competitors? (Yes/No)	☒ If so, 1) How many are they? Do they also supply other competitors? Long term relations?	
Logistics	☒	☐ If so, 1) How many are they? 2) Do they also supply other competitors? (Yes/No)	☐ If so, 1) How many are they? 2) Do they also supply other competitors? (Yes/No) 3) Long term relations? (Yes/No)	

Installation	☐	☐ If so, 1) How many are they? 2) Do they also supply other competitors? (Yes/No)	☒ If so, 1) How many are they? 2) Do they also supply other competitors? (Yes/No) 3) Long term relations? (Yes/No)	
Maintenance	☒	☐ If so, 1) How many are they? 2) Do they also supply other competitors? (Yes/No)	☐ If so, 1) How many are they? 2) Do they also supply other competitors? (Yes/No) 3) Long term relations? (Yes/No)	
Data Communication	☐	☐ If so, 1) How many are they? 2) Do they also supply other competitors? (Yes/No)	☒ If so, 1) How many are they? **1** 2) Do they also supply other competitors? (Yes/No) 3) Long term relations? (Yes/No)	
Data Management	☒	☐ If so, 1) How many are they? 2) Do they also supply other competitors? (Yes/No)	☐ If so, 1) How many are they? 2) Do they also supply other competitors? (Yes/No) 3) Long term relations? (Yes/No)	
C3.2 In the case of a full rollout, please indicate who would perform, in the project, the activities listed below and what would be the cost per unit				

Supply chain	Your company	Companies belonging to your Group	Other suppliers	
Manufacturing and assembly	☐	☐ If so, 3) How many are they? 4) Do they also supply other competitors? (Yes/No)	☐ If so, 2) How many are they? 3) Do they also supply other competitors? (Yes/No) 4) Long term relations? (Yes/No)	
Logistics	☐	☐ If so, 3) How many are they? 4) Do they also supply other competitors? (Yes/No)	☐ If so, 4) How many are they? 5) Do they also supply other competitors? (Yes/No) 6) Long term relations? (Yes/No)	
Installation	☐	☐ If so, 3) How many are they? 4) Do they also supply other competitors? (Yes/No)	☐ If so, 4) How many are they? 5) Do they also supply other competitors? (Yes/No) 6) Long term relations? (Yes/No)	
Maintenance	☐	☐ If so, 3) How many are they? 4) Do they also supply other competitors? (Yes/No)	☐ If so, 4) How many are they? 5) Do they also supply other competitors? (Yes/No) 6) Long term relations? (Yes/No)	
Data Communication	☐	☐ If so, 3) How many are they? 4) Do they also supply other	☐ If so, 4) How many are they? 5) Do they also supply other competitors? (Yes/No)	

		competitors? (Yes/No)	6) Long term relations? (Yes/No)	
Data Management	☐	☐ If so, 3) How many are they? 4) Do they also supply other competitors? (Yes/No)	☐ If so, 4) How many are they? 5) Do they also supply other competitors? (Yes/No) 6) Long term relations? (Yes/No)	

Part D : Qualitative Analysis

D1. Regulatory and legal framework Analysis

D1.1 Status of unbundling to comply with 2009/72/EC repealing Directive 2003/54/EC

Before liberalization came in power in 1999 with the Legislative Decree n. 79/99, the whole electricity market was under the monopoly of a single vertically integrated and state-owned company, while nowadays energy production, transmission, distribution and retail are under the responsibility of distinct actors (i.e. producers, TSO, DSOs, suppliers).
Terna is the unique transmission system operator in Italy.
143 DSOs operate the electricity distribution networks in Italy. Enel Distribuzione is the first national distribution system operator, covering the 86% of Italy's electricity demand.
Regarding the supply structure, according to the abovementioned decree, customers can choose their supplier on the free market, at liberalized prices. Domestic and small business customers can stay in the regulated market where the price is determined by the National Regulatory Authority (AEEG), based of the price paid by the Single Buyer in the wholesale market.
Approximately 200 suppliers sell energy in the free market to the end customers.

D1.2 Please select the functionalities provided by your electricity smart metering solution in line with the common minimum functional requirements included in the "Commission Recommendations of 9.3.2012 on preparations for the rollout of smart metering systems".
web link:

For the customer	Provide Readings directly to the customer and any third party		

	designated by the consumer	☒ (Provide any comment if needed – Max 100 Words)	
	Update the readings referred to in point (a) frequently enough to allow the information to be used to achieve energy savings	☒ (Provide any comment if needed – Max 100 Words)	
For the metering operator	Allow remote reading of meters by the operator	☒ (Provide any comment if needed – Max 100 Words)	
	Provide two way communication between the smart metering system and external networks for maintenance and control of the metering system	☒ (Provide any comment if needed – Max 100 Words)	
	Allow readings to be taken frequently enough for the information to be used for network planning	☒ (Provide any comment if needed – Max 100 Words)	
For commercial aspects of energy supply	Support Advanced tariff systems	☒ (Provide any comment if needed – Max 100 Words)	
	Allow Remote on/off control of the supply and/or flow or power limitation	☒ (Provide any comment if needed – Max 100 Words)	
For security and data protection	Provide secure data communications	☒ (Provide any comment if needed – Max 100 Words)	
	Fraud prevention and detection	☒ (Provide any comment if needed – Max 100 Words)	

For Distributed generation	Provide Import/export and reactive metering	☒ (Provide any comment if needed – Max 100 Words)	
D1.3 Please describe the commercial and technical quality standards set by the National Regulatory Authority (NRA)			
-			
D1.4 Please describe electricity metering tariff schemes in place allowing cost recovery of metering service (both in case of metering service for consumers and "prosumers")			
D1.5 Please describe the National Cost Benefit Analysis performed by NRA on electricity smart metering roll out, main results and indicate the web link to public information			
D1.6 Please describe the national mandatory obligations on the installation and commissioning of electricity smart metering			
D1.7 Status of national electricity smart metering implementation (% of electricity customers provided with smart meters)			
D1.8 Please describe the electricity market structure (Who is responsible for meter installation, meter maintenance, meter reading, meter data management; who is the owner of the meter, who owns the meter data)			
D2. User Acceptance and Customer Involvement Analysis			
D2.1 Describe the company initiatives carried out to improve consumers involvement and understand consumers perception regarding smart meters usage			

D2.2 Describe the initiatives carried out (by your company/the national regulatory authority, customer associations etc.) to understand which are the consumers priorities regarding smart meters (functionalities, cost effectiveness, smartness of the solutions, privacy issues, etc.)	
D2.3 Describe if surveys/tests regarding the provision of empowering devices (In Home displays or active demand systems) have been carried out and describe the main results.	
D2.4 Please indicate if National Authority monitors customer satisfaction regarding smart metering service (e.g. customer care services, ease of use of smart meters and meter display)	
D2.5 Please indicate if and how vulnerable customers and those with special needs have been taken into consideration. (please indicate if reports are available)	
D2.6 Please indicate if you have plans to adapt/ have adapted your Customer Service accordingly to the smart metering deployment. (please indicate if reports are available on this)	
D2.7 Please indicate if there are customers who, in spite of mandatory obligations, want to opt out, and how your company is handling/is going to handle those cases	
Part E : Advanced Topics	
E1. Impact of electricity smart metering on distribution network operation	

E1.1 Please describe what is the impact of smart metering deployment on distribution management system. (e.g. use of load profiles to improve network calculations)				
E1.2 Please describe what is the impact of smart metering deployment on network planning				
E1.3 Please describe what is the impact of smart metering deployment on network maintenance				
E1.4 Please describe what is the contribution of smart metering to the reduction of technical and non technical energy losses				
E1.5 Please describe which is the impact of smart metering on quality of supply				
E2. Smart Metering at the core of the EV charging infrastructure				
E2.1 Is your smart metering solution dealing with innovative services for EV charging ? Y/N **If so, please select and describe below the enabled services:**				
Smart Charging ☒	Vehicle to Grid services ☐	Vehicle to Home services ☐	Other ☐	
E3. Smart metering in support of distributed generation				
E3.1 Describe the metering technical configurations used to measure energy produced by producers/prosumers.				

Who are the actors involved and responsible for metering ?	
E4. Electricity smart metering solution enabling demand response	
E4.1 Considering your smart metering solution, please provide a list of smart meter features which enable demand response functionalities (e.g. Display on board, type of parameters displayed, Interval metering for residential/industrial consumers, overload alarm)	
E4.2 Has your company developed innovative solutions which leverage on smart metering infrastructure to promote energy efficiency/active participation of end consumers/demand response ?	
E4.3 Which customer interfaces can be used to get access to the meter data (web interface, TV, smartphones, dedicated displays, personal computer, entertainment equipment)	
E4.4 Has your company conducted market tests to evaluate the potential impact of the solutions on the consumer awareness/customer acceptance ? How many customers are involved ? what are the main results ?	
E4.5 Please provide a brief description of ongoing national/European demand response/active demand projects your company is involved in. If available, please provide also a web link to the project site	

E4.6 Please provide an overview of the regulatory framework and the initiatives carried out by NRA to promote demand response (including the application of Time Of Use Tariffs, and modification of market structure to promote the participation of the demand side)	
E5. Other advanced metering solutions (heat, water, gas) **Please answer to the following questions for each solution (heat, water, gas) developed by your company**	
E5.1 Please describe the main features and functionalities of your remote advanced metering solution. Is your solution leveraging on existing electricity smart metering infrastructure ?	
E5.2 Based on your metering infrastructure model , who is the responsible for : - **Meter manufacturing** - **Meter installation and maintenance** - **Meter reading** - **Communication devices (e.g. concentrators) manufacturing, installation and maintenance** - **Central system management** - **Data management**	

E5.3 Is your company carrying out pilots/ demonstration projects/ roll out plans ? If so, please indicate the number of smart meters installed/to be installed.	
E5.4 Has the NRA evaluated a cost benefit analysis for metering / multi metering solution ? If public information is available, please indicate a web link	
E5.5 Has the NRA defined a minimum set of functionalities to be provided ?	
E5.6 Has the NRA set a deadline for the meters full roll out ?	
E5.7 Does your advanced metering solution include the provision of value added services (e.g. provision of smart devices for the visualization of meter data)	

Annex 10 – Projects evaluation

VARIABLES	PORTUGAL – EDP	SPAIN – Endesa	ITALY – ENEL	ROMANIA – ENEL	NETHERLANDS – Enexis BV	FRANCE – ERDF	AUSTRIA – EVN	FINLAND – Fortum	SPAIN – GNF	SPAIN – Iberdrola	NETHERLANDS – Liander	AUSTRIA – Stromnetz
A1 Nª customers served DSO	3	4	4	2	2	4	1	1	2	4	2	1
A2 Decision power DSO	4	3	4	1	1	4	2	2	2	2	1	1
A3 Project scale	2	4	4	3	4	4	2	4	4	4	4	1
A4 Number of customers	1	4	4	2	2	4	1	1	2	4	2	1
A5 Duration	4	4	3	1	4	4	3	4	4	4	4	4
A6 Type of customers	4	4	1	4	4	4	4	1	4	4	1	4
B1 Type of comm tech	4	4	4	4	4	4	4	4	4	4	4	4
B2 Type of upper layer protocol	4	4	4	4	4	4	4	4	4	4	4	4
B3 Number and type of	4	4	4	1	4	4	4	4	1	1	4	4
B4 Elaborated data	4	4	4	4	4	4	1	4	4	4	4	4
B5 Compliance with standards	4	4	4	4	4	4	4	4	4	4	4	4
B6 Data security level	1	4	4	4	4	4	1	4	1	NA	4	4
C-EF1 Customer benefits	3	2	NA	3	NA	NA	1	3	2	NA	NA	NA
C-EF2 Business benefits	3	2	3	3	NA	NA	1	1	3	NA	1	NA
C-EF3 Countrywide benefits	1	2	NA	NA	NA	NA	1	NA	2	NA	NA	NA
C-EF4 Degree of Feasibility	NA	3	NA	4	NA	4	1	NA	2	NA	NA	NA
C-EF5 Cost Distribution	3	3	4	4	NA	NA	2	4	4	NA	4	NA
C-EF6 Source of financial support	4	4	4	4	1	NA	4	1	4	4	NA	NA
C-SP1 Proximity to end user	3	2	3	3	4	4	4	1	4	2	4	NA
C-SP2 Level of integration	3	2	3	3	4	4	4	1	4	2	3	NA
C-SP3 Within Group acquisition	1	1	1	4	1	NA	1	1	1	1	1	NA
C-SP4 Number of suppliers	4	4	1	4	NA	4	1	1	4	4	4	NA
C-SP5 Exclusiveness of supplier	4	1	1	1	NA	NA	4	1	1	1	1	NA
C-SP6 buyer supplier relationship	4	4	1	4	NA	NA	4	4	1	4	4	NA
D11 Mandate	2	4	4	2	3	4	4	4	4	4	3	4
D12 Country CBA status	4	3	3	4	4	4	4	4	3	NA	4	4
D13 Unbundling	4	4	4	3	4	4	4	3	4	4	4	3
D14 Min, functs.	4	4	4	3	4	4	4	4	4	4	4	4
D15 Tariff schemes	2	4	2	4	4	4	1	4	1	1	4	1
D21 MKt and cust. Initiatives	4	4	4	3	4	4	2	4	3	4	4	3
D22 Customer Service adaptation	4	4	1	3	3	NA	3	3	3	3	3	3
D23 Opt put implications	2	1	1	2	4	1	3	3	1	1	4	3
D24 NRA involvement	3	1	2	1	4	4	1	1	1	1	4	1
D25 Vulnerable customers	1	1	2	4	4	4	1	4	2	4	4	1
D26 Privacy level	1	4	4	4	4	4	4	4	1	4	4	4
E1 Beneficiaries	4	4	4	4	4	3	1	4	4	4	4	NA
E2 Incentives	NA	NA	NA	NA	NA	NA	1	NA	1	NA	NA	NA
E3 DSO role	3	3	4	4	4	4	2	3	4	3	3	NA
E4 Depl. Scale	1	1	4	4	4	4	1	1	4	4	4	NA
E5 Compliance with tech	3	3	4	3	4	4	4	3	3	4	4	NA
E6 Openness of the advanced	4	3	4	4	4	4	3	NA	4	4	3	NA

Annex 11 – Questionnaire

<table>
<tr><th>Link</th><th colspan="6">Answers & Comments</th></tr>
<tr><td rowspan="2">A6 → B1</td><td colspan="6">Link Description</td></tr>
<tr><td colspan="6">The variable A6 indicates the “Type of customers” involved in the project, it should impact positively the variable B1 that indicates the “Type of communication technology” for each communication path; with this variable we mean what type of technical solution is used to physically send the information.</td></tr>
<tr><td rowspan="2">As it stands the link does not work; do you think that it will work in the future? If yes, when?</td><td colspan="3">☐ YES</td><td colspan="3">☐ NO</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td>Which choices, during design, didn't allow the link to work?</td><td colspan="6"></td></tr>
<tr><td>Which choices, during implementation, didn't allow the link to work?</td><td colspan="6"></td></tr>
<tr><td>Which factors, within your organization, explain why the link does not work?</td><td colspan="6"></td></tr>
<tr><td>Which factors, external to your organization, explain why the link does not work?</td><td colspan="6"></td></tr>
<tr><td rowspan="2">Which actors disable the link? Why?</td><td>☐ EU Policy Makers</td><td>☐ NRA</td><td>☐ Government</td><td>☐ DSO</td><td>☐ Technology Providers</td><td>☐ Customers Associations</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td rowspan="2">Which actors (would) enable the link? Why?</td><td>☐ EU Policy Makers</td><td>☐ NRA</td><td>☐ Government</td><td>☐ DSO</td><td>☐ Technology Providers</td><td>☐ Customers Associations</td></tr>
<tr><td colspan="6"></td></tr>
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