POLITECNICO DI TORINO

Corso di Laurea Magistrale

in Ingegneria Gestionale

Tesi di Laurea Magistrale

THE IMPACT OF THE NATIONAL REGULATORY POLICIES ON SMART GRID ADVANCEMENT IN EUROPE

Alessandra Colombelli
Liliana Proskuryakova

Ilaria Billò

Anno Accademico 2019/2020

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List of Abbreviations

AAEGSI: Autorità per l'Energia Elettrica, il Gas e il Sistema Idrico

AMI: Advanced Metering Infrastructure

CAPEX: Capital Expenditure

CBA: Cost-Benefit Analysis

CEER: Council of European Energy Regulators

CRE: Commission de Régulation de l'Energie

D&D: Demonstration & Deployment

DE: Germany

DER: Distributed Energy Resources

DR: Demand Response

DSO: Distributor System Operator

EEGI: European Electricity Grid Initiative

ES: Spain

EU: European Union

FRA: France

ICT: Information and Communication Technologies

IoT: Internet of Things

ITA: Italy

LCCC: Low Carbon Contracts Company

MINCOTUR: Ministerio de Industria, Comercio y Turismo

NEBEF: Notification d'Echange de Blocs d'Effacement

NER: National Energy Regulator

NIC: Network Innovation Competition

OFGEM: Office of Gas and Electricity Markets

OPEX: Operating Expenditure

R&D: Research & Development

RES: Renewable Energy Sources

ROR: Rate of Return

SEDC: Smart Energy Demand Coalition

SG: Smart Grid

ToU: Time of Use

UK: United Kingdom

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Summary

The development of electricity smart grids at national level is one of the most discussed topics in Europe nowadays: the need of a transition towards a decarbonized economy, the depletion of non-renewable sources of energy and the need of urgent actions to combat the impact of climate change have indeed given this topic more and more relevance. Due to this, the smart grid field and specifically the distribution level of it results the one that is requiring the highest level of investments in Europe.

Furthermore, many empirical papers have widely recognized that national regulation plays a key role in the development of smart grids, that without a stable regulatory framework able to spur its deployment, would not have reason to exist.

The main task of this work is to explore the impact of the national regulatory frameworks on the development of smart grids. The work is implemented by firstly providing an overview about the type of regulatory frameworks for distribution system operators implemented in Europe over the last decades. After that, a policy analysis about the smart grid related policies implemented at national level will be undertaken: thirdly, through a qualitative comparative analysis the results achieved in the previous phases will be interlinked, with the purpose of understanding if a specific connection exists between the adopted regulatory framework and the smart distribution development.

The results of such analysis can help understanding the effectiveness of the different regulatory frameworks that might be chosen by national regulators, identifying potential strengths and weaknesses of the diverse models for spurring risky and uncertain activities like those related to smart grid.

Introduction

The deployment of smart grid technologies, namely the electricity networks that can intelligently integrate the actions of all users connected to it, on a national level is one of the most relevant challenges faced by the European countries in the last decades. Indeed, it forms an integral part of the so-called "future green challenge".

Although a unique definition has not been recognized yet, this intelligent grid for electricity distribution has been designed with the aim to add a communication and control network to the classical distribution system, in order to monitor and optimize the energy flows, avoid electricity waste and redirecting energy surpluses in real time condition. However, lot of challenges, opportunities and benefits are linked to this project. In this context, it is possible to identify the main features that characterize the new grid, in comparison with the existing one. Starting from the major potential benefits that the new electricity grid could create, it is important to mention one of the main features of the projected network, namely the shift from a unidirectional flow of energy into a bidirectional one. Since the project of the smart grid provides for a bidirectional flow of both energy and information, the overall process of control and management of the grid will result more reliable, secure and efficient. Another pillar of the new grid is characterized by the integration of RES (Renewable Energy Sources): this choice has been made in order to address one of the most relevant environmental and social challenges of the last decades, that is the combination of the climate change issue together with the depletion of energy sources (Cambini et al., 2016). It implies that energy will be produced from DER (Distributed Energy Resources), that will be added to the classic centralized production system, able to introduce some advantages such as a better matching between energy demand and supply.

Another common pattern is the so-called "electrification of the transport sector", that is becoming a trend worldwide. Specifically, the smart grid program includes the "vehicle-to-grid" concept, according to which the energy stored in specific electric vehicles' battery can flow through the grid in order to solve some actual problems, like interruption and shortage issues. Finally, the last widely recognized element will be the new role of the consumers, that is likely to become a more active actor in the production and distribution management process: in particular, the "prosumer" figure is supposed to become a reality soon, since the final customers are going to have the opportunity to generate the energy that then they will consume and to sell the additional amount of it to the electrical utilities. Therefore, the final customers will be empowered by a higher degree of responsibility and awareness, since they will be able to have more control over their energy bills and consequently save money on them.

Talking about the potential issues and challenges to cope with, it is important to clarify that the introduction of RES into the electricity system also provide a minor degree of predictability, that these sources are commonly characterized by.

Furthermore, all these new elements are likely to introduce some issues to hold in consideration, especially those related to cyber security and consumers' data protection. In fact, the big amount of information that is likely to flow through the grid and then to be processed, will create a big and relevant concern among customers.

For all the previous presented elements, it is generally accepted that national regulation plays a key role in the development of smart grids.

According to a study (Grajek & Roller, 2009), a stable regulatory scheme that includes a mechanism capable of stimulating investment is necessary, especially for the high capital expenditures required in the process of communication between the grid and the clients. A previous study has identified the cost as one of the main obstacles for the transformation of the current electricity system into a smarter one and this gives to regulation an even more crucial role in setting up a favorable framework that fosters these investments (Marques et al., 2014).

In particular, two kinds of necessary investments can be identified: the ones related to the infrastructure part and the ones related to the information system. For what concern the former, they are necessary in order to update the current system through the introduction of new sensors, controllers and devices, while for the latter, it is required the creation from the beginning of a new information system able to collect, store and analyze the data, through the use of advanced software and communication technologies. Another point which the authors focus on, is the responsibility of regulators in ensuring a stable and effective regulatory framework that provokes minimal distortions into the economic environment and minimal monopoly rents.

The relevance of this concern makes the national regulation an important and actual subject of study and analysis. Some authors (Di Santo et al., 2015) analyze the main barriers in the depletion of the new grid, underlining the necessity of an intervention by national regulators: in particular, some programs that are able to stimulate and increase the final customer's engagement and awareness of the new communication technologies are required, as well as policies that are able to cope with the issue related to cyber-security and privacy violation. Finally, if from one side the integration of new technologies is supposed to take benefits from the overall management process, from another point of view the great speed at which the technological progress is evolving nowadays introduces another factor to address, namely the risk of a fast-technological obsolescence.

Furthermore, differently from the last two decades, in recent years several regulators have modified their policies to ensure that the new forms of investment required by the smart grid development are reflected in the regulated tariffs, while some other regulators are keeping considering the development projects in the same way as the other costs, without providing suitable incentives (Cambini et al., 2016) . Then, one of the most crucial challenges the regulators have to cope with is the realization of a new system, characterized by a high level of supply quality and reliability, by facing at the same time the problem of integrating energy from intermittent energy sources (Lin et al., 2013).

Although several studies have been recently published in order to underline the importance of national regulatory policies on smart grid advancement in Europe, very little attention has been given to the comparative analysis of the different policies implemented at national level. Due to this reason, the main objective of my study is to examine the impact that the various national regulatory frameworks adopted in Europe currently have on the development of smart grid; the study is aimed at answering the following research questions:

- What are the differences and similarities in the adopted regulatory schemes across the main European countries?
- Which are the most advanced European countries in the deployment process of Smart Grid?
- Is it possible to find a connection between this advancement and the adopted regulatory approach?

Indeed, not all the European countries share the same market features; they widely differ for various factors, such as for the DSOs' concentration, the regulatory adopted mechanism or for the mechanism that the State has decided to implement to stimulate innovation. These market factors can have an influence on Smart Grid investments at national level.

In order to accomplish this work, the study will be organized according to the following research tasks: firstly, an overview about the type of regulatory framework for DSOs implemented in Europe over the last decades will be provided, analyzing how the selected

European countries have developed and updated them through the years, adjusting them to the necessity of developing a new electricity grid.

Secondly, specific analysis over the development projects implemented at national level by the different countries will be undertaken, by considering the different goals that each chosen country has decided to set, paving the way to the smart grid development.

Thirdly, the last research task of this work is about exploring the results obtained in the two previous phases, with the purpose of understanding if a specific connection exists between the adopted regulatory framework and the smart distribution development.

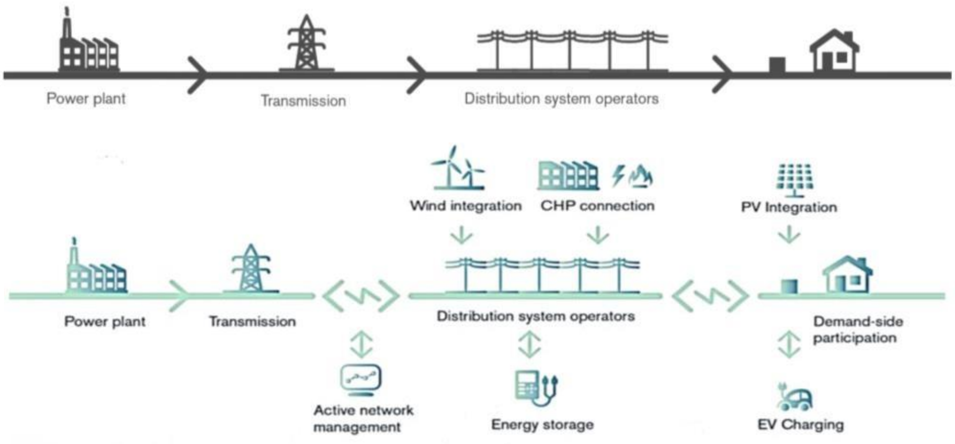
The choice of Europe is dictated by the energy targets (the so called 20-20-20 targets) set by the European Union (EU) member state leaders in 2007 and to be attained by 2020, including the reduction of its greenhouse gas emissions by 20% compared to 1990 levels, the production of 20% of the total energy from RES and the 20% increase in energy efficiency and by the strategic role that the deployment of the Smart Grid, and consequently of a smart regulatory policy, has in this sense. These targets have been widely achieved at European level, even though some countries have contributed more than others. Indeed, the overall European objective has been translated into specific binding national targets, chosen according to the initial capacity of each member state to generate energy from renewable sources and to the expected potential in increasing this production.

In addition to this, the focus on Europe has been made by considering the specific European Smart grid targets: indeed, the European Union aims to replace at least 80% of electricity meters with smart meters by 2020. These are devices that give the consumers the opportunity to adapt their energy usage according to different energy process through the day, allowing them to consume more during lower price periods and save money on their energy bills.

Moreover, the study is going to be focused on the reforms aiming at developing the Smart Grid system at the distribution level: indeed, the total investments in the deployment of smart grid in Europe has been estimated in the range of €600 billion between 2014 and 2035; nevertheless, the bulk of the forecast amount is allocated to the development of the distribution network (Cambini et al., 2016).

Indeed, the so-called DSOs, responsible of the management of the energy distribution network, have the core responsibility to secure a high level of supply and quality of the service, despite the further connection of RES, naturally characterized by a high level of variability, to our electricity network (Figure 1)

Figure 1: DSOs' role respectively in the current and smart grid



Source**:** European Energy Forum, 2018

Furthermore, it is important to consider the role that DSOs will play along the entire supply chain. They are likely to become the major actors along the chain (Ruester et al., 2014) , by providing a more efficient and active distribution system management service. Finally, it is important to remember that DSOs are regulated entities (natural monopolies) and for this reason a national regulation that balances their benefits with the capital costs is required.

1. Literature review

The relationship between the regulatory framework of EU countries and the development of smart grid has been subject of great debate in the last decades. This chapter provides an overview of the literature that has already covered this topic and it is organized as follows: the first chapter is devoted to explain how smart grid technologies' integration could help to address some important social challenges, laying the basis on the relevance of a stable and consistent regulation system.

The second paragraph introduces some smart grid technologies and programs that could be implemented at distribution level and that result to be the first drivers of the development and upgrading of the actual electricity grid at national level.

Finally, the last paragraph presents an overview of smart grid deployment and its regulation alike in Europe, by focusing on the distribution level.

1.1 Social return of Smart Grid

Some increasingly relevant questions about the dependence on fossil fuels and their impact on environmental constraints, such as about the ageing assets that characterize the actual grid and the consequences on its reliability and safety, are nowadays raising (Clastres, 2011): innovative smart grid technologies can be the key to answers such questions. As it has been said in the previous chapter, in the context of electricity network, smart grid technologies are represented by communicating instruments that have the potential of transmitting data about the network's status in real time, allowing to balance supply and demand in an easier way; however, these particular instruments are also likely to play the role of encouraging the elaboration and further application of some social policies.

Besides, the integration of consumers in the electricity production system has also consequences on the social environment: in fact, they are likely to enhance savings, especially by reducing the peaks in demand, and making them become one of the potential tools to reduce greenhouse gas emissions.

But smart grid technologies are not only supposed to help achieving goals at environmental level: for instance, the integration of renewable resources into the grid, together with a well-functioning energy storage system, would enhance a decrease in the level of power loss, that is actually very high on the current network. Then, the opportunity of using customers personal consumption data, can help to predict demand in a more accurate way, consequently optimizing the use of production resources. Finally,

smart grid could reduce failures and outages, thanks to the rapid provided access of information.
Another analysis (Alahakoon, 2016) also addresses this concern: by focusing on the benefits that could be distributed to the various stakeholders, the study puts its attention on smart meters, key element of smart grid, which big potential lies in data acquisition and analysis. Specifically, the availability of this big amount of data can be beneficial for both customers and retailers: in the first case, through smart meter devices users would be able to review their energy usage and adapt it to reduce energy costs. Besides, they can be used to improve the demand-response process: indeed, the final customers could be able to handle their level of consumption according to period of high/low demand, and consequently high/low pricing and so on, allowing a more stable level of supply. For instance, it would help diminishing the level of energy consumption during peak hours and thus, reduce the greenhouse gases emissions. The challenge in this case, would rely in enhancing customers' awareness of the real benefits that can be reached through the use of smart meters.
Furthermore, the presence of such a number of data can lead to some benefits also for the retailers; in particular they could start using it in order to build a higher level of customer loyalty, by analyzing customers' consumption, needs, requirements and characteristics.
The idea that smart grid can be exploited to fulfill individuals social needs can be easily seen also in its main goals (Phuangpornpitak & Tia, 2013): enhancing customer participation in the electricity production process and creating an environment in which the utilities and the final users influence each other. Final users would have a direct impact on the grid thanks to the possibility to add energy through renewable resources, while in the other sense, utilities can influence customers, by improving the reliability level of the grid: specifically, a tool that results particularly useful in this sense, is the introduction of demand-response programs, that have the role of improving the level of awareness of the final users about their consumption. For what concern the influence of customers on the grid, between the available renewable resources at first place we can find hydroelectric power, that today represents 83% of the total; wind power has always been an attractive option, thanks to the decentralized presence of wind in several zones, while biomass, that could represent a viable and long-run solution for the grid electrification, is for now inefficient.
Coming back to the direct benefits that can be fulfil through the implementation of an intelligent grid, it must be noted that the enhancement of power quality and reliability

level, would also lead to the opportunity to reduce outages for the users and other related issues. On the other side, a more active presence of customers, would allow to reduce peaks in demand and so, indirectly, also the emissions of greenhouse gases.

1.2 Smart technologies and related programs

This chapter of the literature review has been designed to offer an overview about the most relevant technologies and related programs influencing the deployment of smart grid at its distribution level. It is organized into four sub-chapters: the first one explains the nature of Smart Grid as potential application of the concept of Internet of Things (IoT) in the real world; each of the following ones is aimed to present a brief depiction of a specific smart appliance or program that is likely to bring some changes in the actual grid, shaping the shift from the current one to the grid of the future.

1.2.1 Smart Grid and Internet of Things

Digital Transformation concept is gaining increasingly importance nowadays, since various digital trends are likely to have a strong impact on the business environment of both big and small companies. In this context, one of the major trends is the so-called IoT.

Internet of Things can be described as an autonomous system that allows to connect a big number of objects (number that according to updated statistics is likely to increase by 30% per annum by 2035) and to monitor and control devices, through modern technologies in cyber space (J. Lin et al., 2017). The key element of Internet of Things, namely the characteristic that makes it so relevant, is the interconnection of devices: what is clear today is that no only objects can be connected in this way, but also data, information, behaviors and so on. The objective of this new way of connecting and inspecting things is to offer more reliable and secure services, that is exactly the aim that the electricity smart distribution has. Indeed, the integration of RES and DER, the introduction of electric vehicles, but also the design of smart meters has the potential of making the interaction between customers and suppliers more efficient, by improving the resources utilization of the grid and reducing costs and interruptions of the provided service.

Specifically, the key features that belongs to the “IoT world” and that have a direct application in the smart distribution system are the establishment of a bidirectional communication flow between final consumers and electricity providers, an higher degree of interaction between them supported by a wireless communication linkage and finally a big amount of information flowing through the grid.

1.2.2 Smart meters

Smart meters are smart devices able to record the electricity consumption levels of the final consumers and automatically send the data to the energy supplier that will monitor and bill it. Although it might appear that these devices have just an impact at consumption level, their usage actually creates a strong spillover effect at distribution level: indeed, they have the ability of making final consumers more aware of their own energy consumption levels, making them change their energy consumption habits according for example to the different electricity prices over the day. This effect can be noticed on the distribution system management process, facilitating the supply-demand balance from DSOs.

Smart meters support two-way communication between customers and electricity providers and constitute the main smart appliances supporting the intelligent distribution system (Luthra et al., 2014).

The role of smart meters can be easily identified into the broader concept of “smart home”, mainly characterized by a high degree of interaction between all the grid operators. In this context, smart meters serve as an interface between the consumer and the electricity utilities (Di Santo et al., 2015), through which the utilities can decide whether or not sending the final customer control signs, suggesting to decrease or increase their electricity consumptions: the nature of these signs depends on the overall level of electricity consumption among all the final consumers involved in the process.

Together with telecommunication technologies, smart meters can help to spur the development of Advanced Metering Infrastructure (AMI), that, in contrast to the old one, gives the opportunity to automatically read the meters’ data and send it to the other communication side. Through this innovative infrastructure it is also possible to better detect the grid failures (in a stand-alone way too) and consequently to respond to them switching to the best solution available: anyway, as pointed in Di Santo et al. analysis, this process is today still at its early stages of deployment.

Although there are several benefits for the usage and implementation of smart meters, some issues and challenges related to them have been analyzed: the first and most relevant one is the huge required investment for both the installation and maintenance phase. It is besides important to note that the benefits derived from a smart metering system can be exploited only when several devices are integrated into the network (Depuru et al., 2011).

Furthermore, the integration of communication technologies can bring some difficulties in some particular zones, due to terrestrial characteristics. Finally, the usage of smart meters and the big amount of data and information they are likely to spread through the grid draw some privacy and security issues out, making the final consumers more difficult to persuade in their usage.
Moreover, form the analysis of the existent literature it is possible to claim that smart metering is the area in which the biggest results have been achieved in Europe.

1.2.3 Demand response programs

Related to the above-mentioned smart metering implementation programs, another type of policies widely discussed in the literature are those related to the implementation of demand response (DR). The main purpose of these programs is to stimulate the final consumers change the power consumption of their electricity utilities with the aim to better balance the equilibrium between electricity demand and supply and consequently reduce the electricity demand peak value and related supply interruptions (Torriti et al., 2010). The customers might benefit from these programs for both their intention in reducing electricity bills and avoiding blackouts: this makes easy to understand the current relationship with smart meters and the importance of a two-way communication flow they are able to provide to both consumers and energy suppliers.
At level of energy utilities, it has been claimed that the development of smart grids required high investment levels specifically at the beginning of the upgrading phase: one of the major benefits of DR is to postpone the need for these upgrades. Indeed, its capability of enhancing the reliability of the distribution system and, in the long-run, lowering the electricity peak demand reduces the need for capital and plant investments and postpones the need for network upgrades (Siano, 2014).
Although the underlying principle of every demand response program is the same, three different examples of them have been described in the literature: the rate-based one, the incentive-based one and the demand reduction bids (Di Santo et al., 2015). In the first one the price of energy consumption varies over the time, so that customers would have higher energy bills during peak hours and would benefit from a more convenient price during off-peak hours. The incentive-based DR programs stipulate a reward for the customers when they reduce their consumption levels: sometimes the program administrator can have a certain level of control over the customer's energy-using equipment. Finally, the demand reduction bids refer to those programs that require that the final consumers

indicate to the utility a disposal to reduce their load on periods of high electricity prices in exchange to monetary benefits. The bids usually consist of the consumer's available demand reduction capacity and the requested cost.

1.2.4 Renewable energy technologies

The renewable energy sources (RES), also known as alternative energy sources, are becoming significantly relevant during the last few decades, due to the increasingly higher worldwide energy demand, but also for the implications deriving from the climate change, one of the major issues faced by the international community during the current century. For this reason, their importance is noted also in the Smart Grid deployment process: the usage of RES has been estimated in the range of about 50% of total energy coverage by 2040 (Phuangpornpitak & Tia, 2013).

Anyway, the usage of RES in the electricity grid leads to both benefits and challenges to cope with. On one side, they are inexhaustible, sustainable and provoke a minimal environmental impact: therefore, their usage might help facing the fossil fuels depletion and the reduction of greenhouse gas emissions. On the other side, in the context of Smart Grid, they have the important potential of improving the reliability of energy distribution system, providing for rapid remediation of electricity shortages or sudden interruptions of the distribution service. Anyway, this raises some essential matters related to the deployment of DER integration into the actual grid, like the huge amount of investments required in the short period in order to upgrade the actual grid, by preparing it with the necessary ICT (Information and Communication Technology) infrastructure.

Diverse types of renewables exist. Talking about the solar power, nowadays it results the most abundant form of renewable energy and the most exploited one. Solar photovoltaic systems are indeed widely used today, both for domestic and commercial cases and the practice of link them to the centralized electricity system is already in use: the major issue presented by photovoltaic systems is the necessity of large surface area for small amount of energy generation. In the second place, it is possible to find wind power, second to solar systems for installed capacity: the most important benefit deriving from this type of renewable is its pollution free characteristic. The exploitation of this kind of energy takes place through the usage of wind turbines to connect the energy available in wind into electricity or mechanical power (Panwar et al., 2011).

Talking about the negative sides, due to high intermittency and unpredictability that characterize RES, the integration of these into the grid leads to some relevant challenges that have to be hold into account: first of all, if on one side the have the potential of increase the reliability of the supply system, on the other one some precautional measures should be taken to make the electricity system keep staying stable. Indeed, the flow of additional sources of energy towards the centralized grid can cause either a positive or negative effect (Ruester et al., 2014): for instance, the injection of power in times when there is already an excess of supply (and so an imbalance between demand and supply) can bring to an even wore (more imbalanced) situation. On the other side, the injection of additional power when there is a shortage of supply and a related excess of electricity demand, can lead to a better balancing between the two.

Finally, even if RES seems to be an optimal answer to all the aforementioned issues that are characterizing our days, it is important to consider that in different geographical locations diverse types of renewables could be exploited.

1.3 Smart Grid regulation

As previously mentioned, the distribution system is likely to become more and more complex, due to the integration of various communication technologies that are going to be introduced into the grid. Focusing on the distribution level of Smart Grid, many studies in the existent literature have underlined the DSOs' nature of regulated entities. They in fact are natural monopolies: a natural monopoly usually arises when the fixed required costs are much higher than the variable ones and consequently the average costs decrease with the production volume, making sure that one single entity can supply the demanded quantity of product or service at a lower price than two or more entities. For this reason, a regulatory intervention is needed in order to avoid a potential situation in which the firms decide to set abnormally high prices and consequently gain abnormally high monopoly rents, which could have a high impact on the social welfare.

Furthermore, n the Smart Grid context, the necessity of intervention from regulatory authorities comes from the huge amount of required investments and the lack of financial resources (Luthra, 2014): indeed, even though through the smart grid deployment some important goals at both environmental and societal levels might be achieved, these could result a lack reason to invest so many resources in an activity characterized by a very long payback period and an high level of risk and uncertainty. Starting from this consideration, it is clear that some updated regulatory frameworks are needed in order to cope with the new challenges imposed by Smart Grid. In fact, the traditional regulatory schemes might provide effective incentives to enhance productivity efficiency, but they do not provide any kind of premium or stimulus for facing the uncertainty characterizing these types of investment. In addition to that, Crispim et al. (2014), pointed out that the role of the regulators should be extended to trying to minimize the private rents that could emerge from Smart Grid development, with the broad purpose to improve the overall social welfare.

All the aforementioned causes emphasize the existent linkage between a new and stable regulatory framework and the development of Smart Grid at national level, even though some activities can be seen even at European Union level.

Several programs have indeed been developed (Crispim et al., 2014): examples are the *7th Framework Programme* that has, among various aims, the purpose to join forces across different member states for the cooperative development of Smart Grid solutions, *Horizon 2020,* run from 2014 to 2020, that set approximately € 5.9 billion to enhance Smart Grid projects development across Europe and the *European Electricity Grid Initiative (EEGI),* that proposed a nine-year research and development program to encourage the deployment of the European Union's smart electricity networks. Moreover, in 2013 the European Parliament proposed and approved the Guidelines of the EU energy infrastructure package, a legislative package intended to increase the credibility of Smart Grid projects and reduce the administrative redundancies: The package offered also a funding of € 5.1 billion across European countries.

The programs and activities set up at European level are thought in order to define the constraints and boundaries within which each single country is then free to shape its own path toward Smart Grid development.

Different markets and regulatory factors can be identified across diverse European countries and they should be hold into account; indeed, these factors might have an impact on the smart grid national investment decisions and on the ideal conditions to stimulate innovation. Some of the characteristics that have been taken into consideration in already delivered studies are the DSOs' concentration (that can be high, medium or low according to the number of DSOs operating the same zone), the regulatory mechanism chosen by the regulator and the potential presence of some sorts of innovation-stimulus mechanism, specifically thought for spurring these kinds of high risky and uncertain activities. Different values of these features across different countries show how the same purpose can be pursued with different strategic tools.

Moving toward another important pillar of this theme, it is important to underline that regulators are likely to face some issues while trying to delineate the afore-mentioned updated regulatory framework.

In this context, Marques et al. (2014) provided an important overview of both the main concepts and features characterizing smart grid development and the most relevant challenges the regulators have to cope with. One of the main obstacles for the actual deployment of a more intelligent grid in Europe has been identified in the required costs; according to the authors, the greater element that differentiates the actual grid with the smart one is technology and in particular the usage of software and other communication devices, that have to power of changing the incentives of the network companies to invest into the sector. For this reason, in the paper it is underlined the necessity of an incentive mechanism able to stimulate the investments in smart grid development as well as the "conventional" investments able to stimulate an increasing performance and efficiency of the grid. Besides, the role of regulators is to provide such incentives by contextually provoking minimal distortion in the economy and minimal economical rents. Now, shifting our attention to the main challenges, it is possible to say that they are constituted by two main problems: the so-called "adverse selection" problem and the "hazard" one. The first refers to the lack of information gained by the regulators with regard to firms' cost, while the second one refers to the difficulties met in trying to decrease the firms' cost level.

For what concern the former, it comes up when one between the "buyer" and the "seller" of a product or service has information that the second one does not have: in this case it can explained with the fact that the regulators cannot be fully aware of the real firms' cost function and the related economical rents they are going to gain. The latter, instead, is a problem concerning the regulators' effort in decreasing cost level. The two issues are related to each other as it will be subsequently explained: this makes the reader understand that the regulatory effort required for the Smart Grid development progress is very hard.

To overcome these issues and to improve and spur the national investments on Smart Grid development programs different types of regulatory mechanisms have been analyzed in the existent literature.

In the study of the above-mentioned Marques et al. for example, the two possible mechanisms considered are the cost-plus model and the incentive-based regulation, each of them proposed in order to trying to overcome the above presented issues. The cost-based model implies the calculation of the average cost of production born by electricity companies and then the addition of an amount that constitutes the normal level of rate of return a firm should expect to earn: the price is then set accordingly. The main problem of this scheme is the lack of incentives for electricity companies in keeping low costs, since it is easy to see how, according to this mechanism, to higher costs correspond higher prices, resulting in economical inefficiencies. For this reason, if it might be considered a useful instrument to overcome the "adverse selection" problem, it lays the basis for the "hazard" one. Anyway, it results a good tool to promote investments in the network. On the opposite side, under pure-incentive regulation the price level is fixed by regulator and not reviewed, so that the firms have an incentive to decrease their operational costs and therefore to increase the efficiency level, but they keep all the gains due to these costs reduction: as it is been said that the regulators is not completely aware of the real cost function of the firms, an higher price level might be decided. For this reason, in the context of Smart Grid, characterized by multiple uncertainties on new technologies development and investor response, the regulator may finally opt for a hybrid approach, that is basically a mix of the aforementioned ones.

2. Methodology and Approach

The methodology of this work is divided into three sections: specifically, each portion is aimed to answering one of the three research questions of the study.

The three research methods that will be implemented are a document analysis (to analyze the existing similarities and differences among the chosen regulatory approaches), a policy analysis (aimed to identify the progress and the reached results in the Smart Grid deployment at national level) and finally a qualitative comparative policies analysis (aimed to finding the interlinkage between the results obtained in the two previous phases, in order to understand if a specific connection exists between the adopted regulatory framework and the smart distribution development).

The chosen methodology has been designed in order to examine the potential impact that the regulatory approach chosen by a country has over the deployment of Smart Grid.

Before starting with the first research method, the first section of this chapter is dedicated to the country selection: in particular, it is meant to explain the criteria used for the choice of the five countries on which the analysis is further implemented and to give an overview about their main characteristics.

Besides, each section of the chapter gives a picture about the data gathered at each phase of the methodology and the sources this data come from.

2.1 Selection of countries

This paragraph is dedicated to the explanation of the criteria used to choose the five European countries on which the above-mentioned analysis will be developed. The choice of Europe is linked to the fact that today the sector that is requiring the greatest value of investment in Europe is the energetic one: specific targets for the development of Smart Grid have in fact been imposed at European level and subsequently outlined individually for each member state of the European Union.

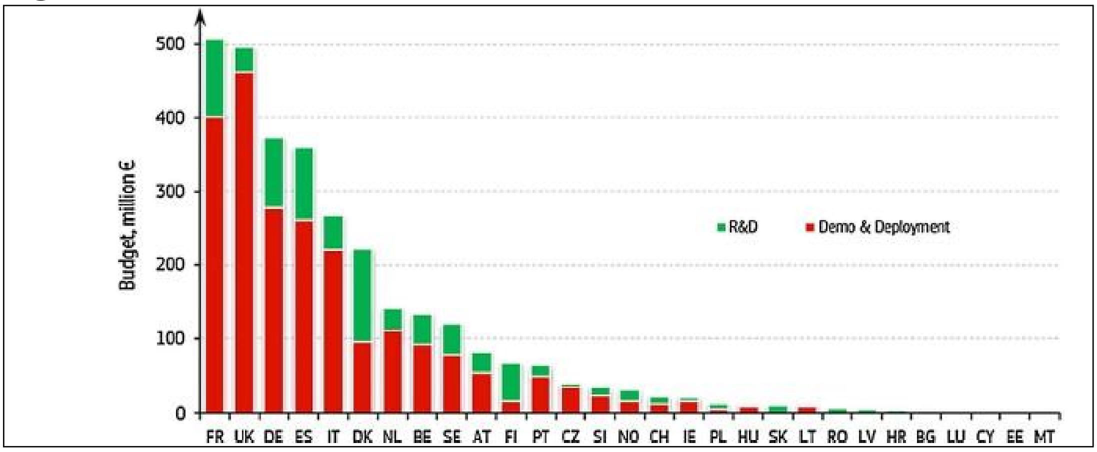
Nevertheless, not all member countries can say that they have reached the same levels of development in the Smart Grid context. The five chosen countries are those that have invested the most in the development of the smart grid at the distribution level: in order to apply this criterion and make the subsequent choice, the considered data is the level of investment of each individual country in deployment/implementation related projects.

In order to accomplish the selection, the data provided by the Joint Research Centre of the European Commission were used: specifically, this data belongs to the “Smart Grid project database” owned by the aforementioned institution.

This center collects and analyses projects at both national and international level related to the development of the smart grid in terms of numbers, countries, duration, collaboration and investments. The center has also provided four reports since 2011 (in 2011, 2013, 2014 and 2017), all with the intention of offering a snapshot of the results achieved by the various involved countries and what still needs to be implemented, including future goals. The countries analyzed are all 28 members of the European Union with the addition of Norway and Switzerland.

The selected of countries has been based on the assumption that if there are no policies in place, national grid cannot develop; basing on this hypothesis, the choice fell on the countries that have been more involved in development and demonstration (D&D) projects, because, intuitively, they are those which have already developed a national regulatory framework related to the Smart Grid implementation. Two main variables have been taken into account for the selection: the first one is the number of total projects, sum of Research and Development (R&D) and D&D projects, per country, while the second one is the Smart Grid investment value (considering both R&D and D&D projects) per stage development and country. The two reports used to undertake the choice have been the 2014 one and the 2017 one. The former, that bases its analysis on more than 450 European Smart Grid projects, shows that the five countries that until 2014 most invested in Smart Grid related deployment projects were France (FRA), United Kingdom (UK), Germany (DE), Spain (ES) and Italy (ITA) (see Figure 2).

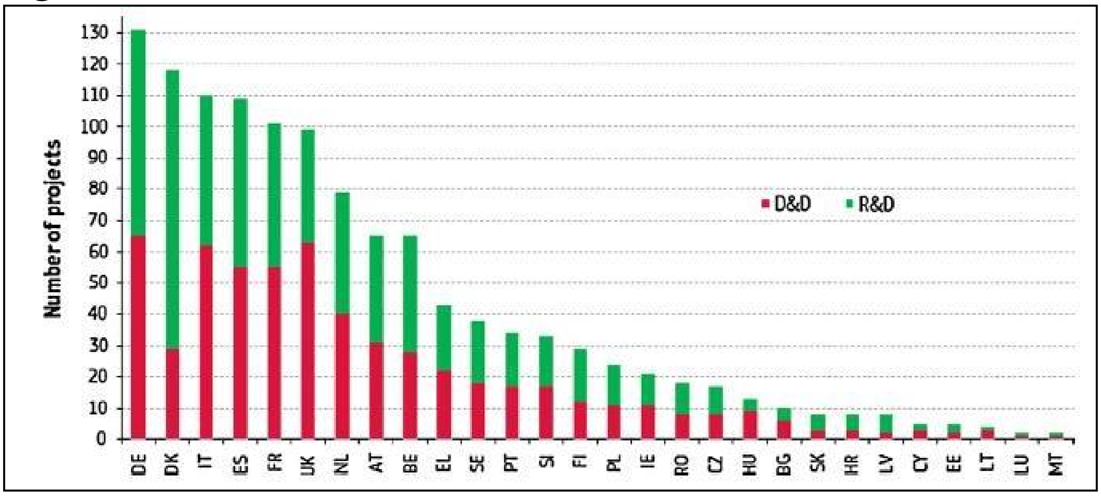
Figure 2: Smart grid investment per stage of development and country



Source: Joint Research Centre of the European Commission, 2014

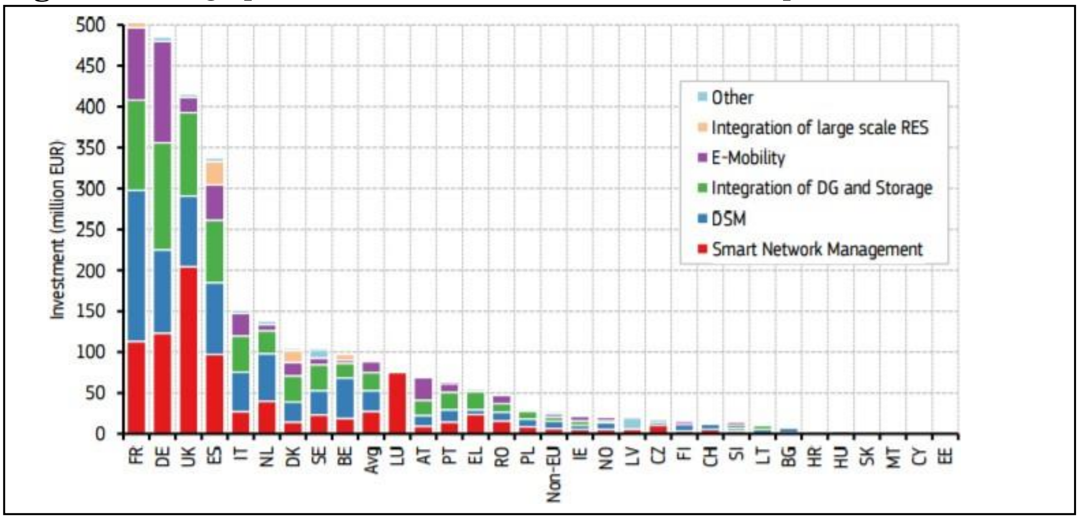
This report also shows that the same aforementioned countries are those that undertook the biggest number of Deployment projects until 2014 (see Figure 3).

Figure 3: Number of projects per country



Source: Joint Research Centre of the European Commission, 2014

Figure 4: Geographical distribution of investment in the implementation sites



Source: Joint Research Centre of the European Commission, 2017

Now moving to the latter, namely the report published by the center in 2017, as it can be seen in Figure 4, France, Germany, United Kingdom, Spain and Italy result the five countries that most invested in the Smart Grid related implementation projects. For the above-mentioned reasons, these are the five countries selected to implement the analysis of this work.

2.2 Document analysis

As mentioned in the previous chapters, among the main goals of the study there is that of making a comparison between the adopted regulations at national level in the five previously selected European countries. Specifically, this first stage of the methodology aims to identifying the main differences and similarities in the implemented regulatory framework. For this purpose, the chosen research method is the document analysis.

Document analysis is a systematic procedures for reviewing or evaluating documents, both printed or electronic: it is usually implemented to fulfil several purposes, such as describing trends or patters or relating different sources of information to the message they provide: for this reason it results the most adequate one to undertake this first stage of methodology.

Although it is often used in combination with other qualitative research methods as a means of triangulation, it can be also used as a stand-alone one (Bowen, 2009). The decision of undertaking a document analysis to implement the first phase of the analysis relies firstly on the type of research question ("What?") this first phase will try to answer to; furthermore, according to Bowen (2009), it results an affordable method when the purpose of the study is to identify similarities, differences and general patterns, making it perfectly matching with the first research question of this work.

In order to develop the analysis, the first task is the research and further collection of relevant articles about the regulatory framework for DSOs adopted by the regulator of each selected country. After that, the documents are critically analyzed by identifying the data relevant for the work: then, the selected information are organizing in different categories in order to make the comparison process ready to be undertaken. The categories into with the information will be split are the following one: the type of regulatory mechanism chosen, the potential existence of innovation mechanism that can stimulate the undertaking of risky smart grid development activities, the regulatory period that characterizes each mechanism and the number of times the selected countries have shifted from one mechanism to another.

The first category has been designed to underline the potential differences in the nature of the regulatory mechanisms, highlighting the diverse options available related on the nature of the regulation itself.

The second category has been conceived to differentiate the various nations according to their potential adoption of further options that have the opportunity of enhancing the deployment of Smart Grid: according to Cambini et al. (2016), it is a key enabler of SG investments. The regulatory period is added since to longer regulatory periods correspond lower risks of losing the return on the invested capital for DSOs and consequently it should lead to a higher propensity to invest.

Finally, the fourth category aims to identifying the stability of the national regulatory frameworks over the years: indeed, according to Eurelectric (the Union of the Electricity Industry in Europe) this factor can have a big impact on the results gained from the further related Smart Grid policies.

2.3 Document Analysis Data sources

The data gathered for undertaking the aforementioned document analysis come from a broad range of sources: first of all, one Eurelectric report has been considered (Eurelectric, 2014) as well as a report provided by the Council of European Energy Regulators (CEER, 2019). Then data from a consulting company (Ernst & Young, 2013) have been collected: all the aforementioned gained data has been used in order to validate the data gathered by the annual reports of European national energy regulators (NERs), first data source for the document analysis. Finally, some studies already presented in the literature have been further analyzed in order to provide an overview about the different types of regulatory frameworks that can be implemented at national level.

2.4 Policy analysis

The second phase of the methodology is constituted by a policy analysis: this stage includes the selection of the main policies implemented at national level in each selected country and related to the smart distribution grid deployment.

In order to accomplish this task, the analysis is undertaken through the study of the policies taken in place by each country with the purpose to underline their progress. Therefore, according to Montgomery (1987), "*Policy analysis is intended to be an aid to rational decision making, which is the act of choosing among alternatives according to a logical criterion*": the purpose of this kind of analysis is to assess the implementation of a policy that aims to address specific societal problems, issues or concerns. For this reason, it results to perfectly fit to this methodology phase.

The policies that will be collected and further analyzed are those which result to be related to the two fields that turn out to mostly affect the initial development of a smart distribution electricity system at national level, according to the results of the previous literature review section. Hence, the two selected fields are the following: “Smart metering implementation policies” and “Renewable energy sources integration policies”. For what concern the former ones, the policies that will be taken into account are those related to the rollout strategy of smart meters through the country and the subsequent demand response programs that have been implemented thanks to the deployment of such devices, able to make the consumers more aware of their electricity consumption levels and more able to act over their electricity consumption habits.

The collected policies will be systematically analyzed by considering each phase of the policy cycle that includes the agenda setting (from which different policy goals and objectives further emerge), the policy formulation (that specific in detail each phase of the policy, the main actors and stakeholders involved, the roles and responsibilities and their division among the players), the policy implementation (that defines the implementation phases of the policy) and finally the policy evaluation (through which it is possible to control, monitoring and evaluate the policy progress). In order to classify the information in a systemic way using the above-mentioned approach, the analysis of the collected data will take place through a specific coding frame created in order to organize the overall information into categories: “vision and objectives”, “strategy development”, “implementation phase” and “outcomes evaluation”. In this way the comparison between the implemented policies and the gained results will be immediately visualized. Starting from this point, both the implicit and explicit demand response programs running at national levels will be presented.

With regard to the second type of policies, those related to the integration of renewable energy sources to the centralized grid, an overview of the existent supporting schemes for the purpose will be provided. After having laid this basis, the analysis carries on through a comparison between the policies that have been designed by every single regulator to spur the integration of these kind of sources to the grid.

This phase of the research methodology has been developed in order to answer the second research question of the study (Which are the most advanced European countries in the deployment process of Smart Grid?).

2.5 Policy analysis Data sources

The data gained to accomplish this phase of the methodology came from a wide range of sources, according to the different considered fields.

The information about the smart meter implementation strategy developed by the selected countries have been gained through the official documents provided by “Ofgem”, the English government regulator for gas and electricity markets, by “Enel”, the Italian national energy agency, by the “Federal Ministry of Justice and Consumer Protection”, that operates in Germany, by “Électricité de France”, the largest producer of electricity in France and by “Red Electrica de España”, the biggest TSO in the Spanish electricity market, aiming to manage the high voltage transmission grid.

The data gathered to gained information about the implicit and explicit demand response programs implemented in Europe and specifically in the countries under analysis come from range of reports provided by the “Smart Energy Demand Coalition” (SEDC), a European business association dedicated to the study of both implicit and explicit demand-side solutions in the European electricity market.

Finally, with regard to the active projects related to the integration of renewable energy sources into the grid, the analysis relied on the information provided by the “RES Legal Europe”, a database devoted to the delivery of data about the available supporting schemes for the introduction of RES and the policies for energy from renewable sources in the electricity industry.

2.6 Comparative policy analysis

The third and last phase of the research method implemented in the paper is constituted by a qualitative comparative policy analysis aimed to finding the interlinkages between the main results obtained in the two previous phases, in order to understand if a specific connection exists between the adopted regulatory framework and the smart distribution development.

This stage has the objective to answer the third and last research question of the study (Is it possible to find a connection between this advancement and the adopted regulatory approach?).

The analysis will be implemented through a specific matrix analysis, made of rows and columns. Each row represents different type of regulatory framework, while each column indicates the potential presence of an innovation stimulus mechanism able to spur the deployment of smart grid.

Each intersection of the table will then be filled with the outcomes gained at national level thanks to the previously analysed smart-grid related policies, including the share of electricity smart meters in the total electricity meters (and relative decrease in energy bills

deriving from the implementation of the deployment programs and demand response projects); the share of energy coming from renewable sources consumption on the total amount of energy consumed (and relative CO_2 emission levels).
In this way, it is possible to visualize which of the adopted regulatory approaches have a positive impact on the development of smart grid and which of them are not able to spur its deployment at national level.

3. Findings

This section has been designed in order to present the findings resulting from the implementation of the above-mentioned research methodology. It is divided into three chapters, according to the three different described steps and they aim to provide a plausible answer to the research questions of the work: each section corresponds to a research question of the study.
The aforementioned results will be commented in the final chapter of the work.

3.1 Document analysis results

This first chapter of Findings aims to present the results gained from the implementation of the first research method, that is Document Analysis.
The chapter is organized by firstly providing a wide explanation of the existent regulatory approach for DSOs, explaining their features and the differences among all of them and providing a wide overview of the electricity distribution market in Europe. Then, a deeper analysis has been made for each country under analysis, in order to underline the regulatory choices, they have made through the year, especially those related to the development of Smart Grid at national level. Finally, the above-mentioned information is systematically summarized through the use of categories that are able to point out the main analogies and differences between the various nations.

3.1.1 Regulatory frameworks

Over the last decades two natures of regulatory frameworks result to have been implemented in Europe: the so-called "Cost-plus" regulatory method and the "Incentive-based" one.
The first type takes shape in a particular type of scheme, the Rate of Return.
Following the ROR scheme, the regulator defines a limit level to the rate of return on investment a regulated company might gain: this level is set as ratio between the Net

Profit and the Investment Level of a company, by basing the value on those of the last period.

$$ROR = \frac{R - wl}{K} \leq \rho$$

When R stands for Total Revenues, l is the labor factors (proxy of the variable costs), w is the proxy of the unit cost of input factors and K stands for the total level of invested capital. Starting from this and implementing the reverse formula, the regulator then sets the total revenues or the maximum allowed price the regulated entity can stipulate. The method is based on a hearing process: it means then when the rate of return results ex post higher than the maximum allowed level "ρ", then the regulator reduces the price and vice versa, when it results lower than "ρ", he increases the maximum allowed price.

The method presents both some positive and negative features: starting from the formers, the related risk is very low and it means that the likelihood of gaining the returns on the invested capital is quite high: for this reason, there is no incentive in decreasing the quality of the offered services or goods. On the contrary, the quality investments are spurring: it leads to a negative side of this scheme, since no incentive in reducing costs are provided by this method, so that the productive efficiency is not enhanced. Indeed, the formula says that if the regulated firm increase its variable costs also the related revenues will increase: this can be summarized by saying that under this scheme, firms are brought to overinvest, especially when the ρ level results to be higher than the ROR.

The second aforementioned framework takes shape in the "price cap" scheme: through this method the regulator defines, for a designed period of time, a limit to the growth of prices of a set of goods or services provided by the regulated firm.

$$P_t = (1 + RPI_t - X) * P_{t-1}$$

When P_t is the price at time "t", RPI_t stands for the retail price index at time "t" (a proxy of the inflation rate and so of the prices rise) and X stands for expected productivity gains (the portion of revenues the regulator designs to pass to the final consumer). If the regulated firm manages to increasing its productivity levels at a higher rate than X it realizes a profit (for this reason it is talked about "Beating the X").

Actually, the situation is less immediate than the one just described: in fact, P_t and P_{t-1} do not represent the prices of a single good or service but an average of the prices of a certain set of goods or services weighted on consumption levels of final consumers. For this reason, this is known to be a regulatory framework in which the state delegates the companies to set individual prices independently (with just an average price constraint placed by the regulator).

Talking about the main pros and cons of this scheme, it is possible to recognize that the incentive-based mechanisms have the potential to decrease the OPEX characterizing the regulated firm and so the relative potential of spurring the achievement of higher levels of productive efficiency. Then, the fact that it is the firm itself to define every single price of good or service makes this method to be much less costly from the point of view of regulators' administrative costs.

On the other hand, it also provides some incentives to decrease the costs related to the quality level of the provided goods or services, since the only investments that result to be spurred by price-cap regulation are those that can be immediately monetized, while those in risky and uncertain activities such as Smart Grid related projects result not to be incentivized at all. Finally, among the negative sides it has to be recognized that the regulated firm risks to go bankrupt if the expected productivity gains ("X" factor) is too high.

Furthermore, two subsequent studies in the literature have pointed out the different impact that these two methods have had on the electricity utilities' investments through the years: the first findings result to be confirmed by the further analysis, so that investment is higher under incentive regulation and lower under cost-plus regulation and investments seem to be mostly driven by the WACC than by the "X" factor (Abrardi et al., 2018; Cambini & Rondi, 2010).

Anyway, these two methods have not been chosen indistinctly by the national European regulators: indeed, one decisive factor in the shift from the former to the latter was the waves of liberalization that characterized the energy sector across the late 90s, with the purpose of decrease the barriers, restrictions and rigidities occurring in the related market (Ernst & Young, 2013): all the national energy (gas and electricity) utilities were privatized and the new resulting companies became monopolist ones in a liberalized market, so that regulating these firms became an urgent task to perform.

Besides, in order to overcome the issues related to these two frameworks, some countries have recently decided to implement a so-called "hybrid" method that could converge the qualities of incentive-based and cost-plus regulation and minimize their limits: the aim was to provide a regulatory framework able to spurring a decrease in high levels of OPEX that characterize the energy utilities and by delivering at the same time the right stimulus to undertake risky and uncertain investments (Abrardi et al., 2018). Finally, more recently, the single and different objectives of the European level in the electricity distribution sector have converged towards new quality targets that have the purpose of ensuring electricity DSOs do not reduce their costs by decreasing the performance quality of the provide service (Ernst & Young, 2013): for this reason, in this context some quality stimulus in terms of either financial incentives or penalties have been included into the various national regulatory frameworks.

3.1.2 Overview of national regulation in EU countries

In France the authority responsible to regulate the electricity market is CRE (Commission de Régulation de l'Energie): it sets up the prices for the utilization and distribution in electricity national grids. The industry is dominated by a single DSO, which owns more than 95% of the total network, followed by six others DSOs operating another 4% and finally hundreds of players having an almost imperceptible impact on the market. CRE opted for a shift from the previously implemented RoR mechanism to a pure price-cap in 2009, almost ten years later in comparison to the other countries under analysis: the price tariffs were equal for all the existing DSOs, despite the diversity in size. This regulatory framework is still working nowadays, but some financial incentives have been recently provided to help companies bearing the costs related to research and development Smart Grid projects and to spur their efficiency.

The regulatory period is currently fixed at four years.

Now, shifting the attention to the second country under analysis, in Germany the first implemented regulatory method resulted to be a cost-plus mechanism. It started to work in 2005 and remain stable until 2008: like the aforementioned France, also German national regulator "Bundesnetzagentur" opted for a shift in 2009, designing a pure incentive-based framework to regulate the electricity DSOs. The electricity market is characterized by more than 900 operating DSOs, most of which controlled by vertically integrated utilities that control both the transmission and the distribution activities of the market. The "cap" to maximum prices that a German DSO can charge is set by considering the total expenditures (TOTEX) borne by electricity utilities during the previous regulatory period. The efficiency benchmarking ("X" factor) involves assessing the operators' individual costs against the services they provide and determining each operator's cost efficiency compared to the other operators.

The current regulatory period is set to four years.
The electricity distribution industry in Italy is instead made of five big companies (DSOs) that control the entire market.
Following the waves of liberalization characterizing the European electricity sector and in particular the distribution field, Italy switched in 2000 from a RoR mechanism to an incentive-based one, resulting a mix between a revenue and a price-cap scheme. Anyway, it has not resulted the only changing for the country: less than ten years later, in 2009, the at that time Italian regulator AEEGSI (Autorità per l'Energia Elettrica, il Gas e il Sistema Idrico) decided to implement a shift from a pure incentive-based approach to a hybrid solution for electric distributors. The RoR method was chosen to regulate CAPEX, while a price-cap mechanism has been used for OPEX. Besides, the regulatory period shifted from four to six years: it resulted a positive feature for DSOs management, since having the prices' levels fixed for a longer period allows to better predict the future revenues and so it leads to a lower risk level for the regulated companies.
In the specific context of Smart Grid, the Italian regulator some incentives have been introduced for spurring the smart grid development at national level: specifically, an extra WACC mechanism applies. It works as an incentive for demonstration projects related to Smart Grid activities, allowing a 2% premium over the weighted average cost of capital (Crispim et al., 2014).
Let's consider Spain: the electricity distribution market in Spain is characterized by five large DSOs acting like natural monopolies on the various regions and owning more than 90% of the system revenues and hundreds of small DSOs, with a very little impact on the market. With regard to the more recent types of regulatory implemented to control these natural monopolies, the Spanish regulator MINCOTUR (Ministerio de Industria, Comercio y Turismo) shifted in 1998 from a pure cost-plus mechanism to an incentive-based one following the wave of liberalization that occurred in Europe. More precisely, it firstly opted for a pure incentive-based mechanism until 2012, and then shifted to a hybrid approach that combines the features of price-cap and RoR: DSOs receive revenues for investments (CAPEX), OPEX and other regulatory tasks. In addition to this they receive specific incentives that can result in awards or penalties (increased or decreased revenues depending on their performance): these kinds of incentives are output-based.
The previous regulatory period was defined of four years and then being extended to six years after the electrical reform of 2013.

The last country to analyze is United Kingdom: between 1990 and 1995 the electricity utilities of the country started to be privatized and acted like natural monopolies (few companies dominate the market) in a liberalized environment. United Kingdom was the first among the selected European countries to adopt (in the late 80s) an incentive-based approach for the regulation of electricity distribution actors, since its regulator OFGEM (Office of Gas and Electricity Markets), responsible of setting and control prices, was the first in noting the failures of cost-plus regulation, opening the way for the further shift of the other countries. After this, in 2008, the first changings in OFGEM mentality started to occur, given the risk-aversion that was starting to characterized the electricity utilities regulated with a price-cap mechanism, that resulted in insufficient investments in infrastructure upgrading and innovative projects undertaking. Indeed, those were the years characterized by the raise of the government's environmental goals and the Climate Change Act, that set an 80% reduction in greenhouse gas emissions and the necessity of creating a more reliable, secure and efficient electricity distribution network. For this reason, from April 2015 electricity DSOs are regulated via a new output-based model, called RIIO, built upon the previous price-cap method, but more focus on the opportunity of heavily investing in risky projects, like those related to Smart Grid deployment, when the return on the invested capital is not sure to be gained. It has been defined as a new type of regulatory mechanism: its acronym stands for "Revenues + Incentives + Innovation + Output". Additionally, the UK national regulator decided to "adjust the revenues" of DSOs by providing a funding scheme called Network Innovation Competition (NIC), able to incentivize the implementation of Smart Grid solutions and applicable to electricity distribution entities only.
With regard to the regulatory period, under the previous pure incentive-based price-cap it was set of five years, while under the RIIO model it has been extended to eight years.

3.1.1 Final scheme

In order to better analyze the differences and similarities of the above-mentioned selected countries for what concern the type of regulated mechanism chosen by each of them at national level, the gained information has been organized into the following categories (see Table 1).

Table 1: Regulatory frameworks implemented at national level

Country	Type of regulatory framework (current)	Regulatory period (years)	Innovation-spur incentive	Number of changes over the years
France	Incentive-based	Four	/	RoR until 2008 Incentive based since 2009
Germany	Incentive-based	Four	/	RoR in the period 2005-2008 Incentive based since 2009
Italy	Hybrid	Six	Extra-WACC	RoR until 1999 Incentive based until 2008 Hybrid since 2009
Spain	Hybrid	Six	/	RoR until 1998 Incentive based until 2011 Hybrid since 2012
United Kingdom	Output-based	Eight	Adjusted-revenues	RoR until late 80s Incentive based until 2014 Output based since 2015

Source: the author

Summarizing the results achieved in this section, it is possible to notice that United Kingdom was the first country in Europe shifting from a pure cost-plus mechanism to an incentive-based: the wave of liberalization characterizing the electricity market has then spurred this shift, that occurred at the beginning of the century both for Italy and Spain. Germany and France result to have accomplished it ten years later. An additional shift has been implemented for the first three mentioned countries, but if Italy and Spain opted for a hybrid scheme able to combine the benefits of the two pure mechanisms, United Kingdom adopted in 2015 a completely new type of scheme (called output-based), specifically designed to spur the deployment of risky and uncertain activities like those related to Smart Grid. No country is actually implemented a pure cost-plus mechanism. Finally, Italy and United Kingdom result to be the only countries providing an additional innovation-spur incentive: the former is provided in the way of "extra-WACC", while the latter in the way of "adjusted-revenues".

3.2 Policy analysis results

This section is devoted to the presentation of the findings regarding the second part of the methodology. The choice of focusing on three smart grid related features (smart meters' deployment, demand response and RES integration into the grid) has been made since several empirical studies in the literature consider them to be the three key drivers able to incentivize the shift from the current situation to a more dynamic concept of grid (Crispim et al., 2014).

After having presented the directives imposed at European level over the deployment of smart meters in each member country, an overview about the specific deployment strategy implemented at national level is provided: this overview has been designed in a way to make the comparison between the policies as clear and immediate as possible. It is possible to find the implemented framework adopted for the realization of the comparison in the Appendix of this paper. The second part of the chapter is devoted to the presentation of the main results achieved at national level by the five selected countries in the field of demand response programs: even in this case the paragraph has been structured so that the comparison can be undertaken in an easy way by the reader. Finally, the last section of the chapter is related to the programs implemented by the chosen nations in the field of renewable energy sources integration to the centralized national electric grid.

3.2.1 Smart meters related directives at European level

Smart meters have from the outset been one of the main players in the Smart Grid development strategy at national level in Europe. However, this development has been driven by specific directives, implemented in order to provide guidelines to individual member states of the European Union for the implementation of these devices.

Both the 20/20/20 targets and those specifically related to the development of the Smart Grid contain provisions in this regard: specifically, the goal set by the Union to provide at least a percentage of 80% of the consumers with new "intelligent" devices with cutting-edge functionality is of particular relevance.

After the exit of a European directive in 2009 (Directive on the internal markets 2009/72/EC) that introduced a new Act based on the “Third Internal Market Package”, member states were asked to carry out a cost-benefit analysis (CBA) aimed at predicting whether a mass implementation strategy for these devices could bring a positive net benefit to the country under analysis. Furthermore, the guidelines on how to undertake these analyses have been provided by the European Union itself.

In the majority of cases these analyses were successful, leading the countries to develop specific implementation strategies. In particular, in 2014 thirteen states carried out a road map for a complete introduction of smart meters in the country, while for five others the analysis reproduced a negative result. Across the five selected countries of this study, only German CBA provided with a negative outcome, claiming that a mass deployment of smart electricity meters would have resulted economically irrational for the most part of German customers.

Talking about the results achieved at European level through the years, data show that at the beginning of 2014 the percentage of old meters substituted by smart devices was of 22% and that in 2019 the rate has increased, by almost reaching a percentage of 60%.

3.2.2 Smart meters rollout in EU countries

Through this section it will be provided a detailed overview on the smart meters’ implementation programs organized in France, Germany, Italy, Spain and United Kingdom over the last two decades: the policies are, except for the case of Germany, all designed to provide residential customers smart electricity meters able to spread a higher level of awareness and accuracy with regard to electricity consumptions. The data gained from the analysis of these policies has been categorized through a specific coding frame, including the following categories: Vision and Objectives, Strategy Development,

Implementation Phase and Outcomes. In this way, the similarities and differences about the diverse policies can be easily identified. The table summarizing the coding frame along with the related data can be found in the Appendix of this paper.
Here the categorized information will be presented in a textual form, providing the most relevant findings that came up from the analysis.
Let’s start with the case of Italy: unlike the other countries under analysis, Italy began experimenting with remote control systems for electricity meters as early as the late 1990s. For this reason, when the liberation of the energy market took place, Enel Distribuzione (now e-distribution) decided to launch an innovative project called "Telegestore". The Telegestore system was an innovative system designed to remotely read and manage the customers of electric energy on the low voltage network: the main high-level objectives of the project were to increase the transparency of the process of realization of electricity tariffs and meter reading through an invoicing process based on up-to-date meter management, the reduction of mistakes in energy consumption reading and the consequent increase in customer satisfaction and finally an increase in the level of automation of the consumption data collection process. As for the installation strategy of the new devices, it included the creation of a remote automatic metering system using the low-voltage distribution network as data support. Starting from this point, it was planned to replace 30 million intelligent electronic meters equipped with an electronic communication device at residential level in order to improve the relationship that the utility had with customers, making it flexible, transparent and easier to manage. After an initial testing-pilot phase, in 2001 the deployment stage began, the project was consolidated in 2003 and in 2005 the full deployment was reached, making Italy the first European country to be involved in such a successful project. Anyway, the technical lifespan of these meters and of the relative communication equipment is usually about 10-15 years. For this reason, Enel Distribuzione, that changed its name in e-distribuzione, decided to launch another autonomous project, starting in 2017: the “Open meter” one. The objectives of this new project basically involved the replacement of the first-generation smart meters with new devices, able to respond to the future challenges of the digitalization world and to the requirements set at European level in 2009: they included an enhancement in customers’ experience, the introduction of smart network sensors enabling real time quality of service monitoring and identification of network faults. The implementation strategy foresaw the installation of 41 million new electricity meters, 32

of which would replace first generation meters. With a planned investment of 4.3 billion euros, the implementation period was set at 15 years starting in 2017.
Another active country in replacing the old electricity meters was Spain: the vision that led to the development of this project was the idea that all Spanish households could have a clear control and subsequent modification of their consumption levels and that these levels could be read automatically from a central office without the need of human intervention. The involved actor in the design and subsequent implementation of this strategy was "Red Electrica de Espana", the major Spanish electricity TSO. In order to spur the country's transition to a de-carbonized economy based on the exploitation of renewable energies, Spain has imposed the installation of 30 million smart meters with the objective of spurring a future mass rolling-out of electric vehicles and the realization of demand response programs able to enhance the reliability of the distribution system. Even in this case, the political decision that set the rollout of smart meters occurred before the coming out of the European directive: indeed, this was set at national level in 2007, making the rollout strategy began in 2008. Only one implementation phase was carried out: all householders saw their energy meters replaced with smart meters by the end of 2018. For this reason, it is possible to say that this goal was successfully achieved; anyway, the purpose of spur and support further smart grid-related programmes like demand response ones failed. The deployment itself cannot be considered a full success, since lot of "hardware" has been installed but the rules for the software to exploit the infrastructure have not been set yet.
Now shifting the attention to United Kingdom, the rollout of smart electricity meters has been seen by the country as a strategy to sustain a shift towards a low-carbon economy, as well as for reducing the greenhouse gas emission of the nation and finally to ensure a more affordable, reliable and secure energy distribution to customers. Differently than the previous two cases, the rollout strategy was designed in UK after the implementation of the Directive at European level in 2009. Trough the installation of these intelligent devices, UK designed to increase the use of renewable energy sources and spur the development of related demand-side management policies in order to reduce peak demand levels, exactly as Spain had previously proposed. The objectives of the implementation strategy were to install smart electricity meters in over 26 million domestic sites by 2020. Two different stages have been implemented: the first one was called “Foundation Stage” and began in April 2011. This first period has been used by the UK Government in order to work with the industry sector, the final consumer groups

and other involved stakeholders to establish all the required technical foundation to start the following mass roll-out phase. The second implementation phase was indeed called "Mass roll-out Stage" and started in late 2014; based on the results obtained in the previous step, the strategy foresaw that the largest number of smart meters would be installed during this phase. However, it did not go as planned. The overall objective designed at the beginning of the program was not reached at the end of 2019 (15.3 million operational smart meters installed vs 26 million targeted). For this reason, the UK Government decided to design a new regulatory framework to ensure that the roll-out stage can go on beyond 2020, as long as all the domestic will be provided by these devices: now the objective is to reach the end of the installation for the end of 2024.
Now talking about France, the overall objective of its deployment strategy set a 95% digital meter deployment by 2020, following the directives set at European level, like UK. The strategy was set in 2015, later in comparison to the other countries because of a first CBA analysis that claimed that such installation would have been almost financially neutral for the country: it was just thanks to a second scenario that showed a positive outcome that the regulator decided to design this policy. The main objectives of the implementation strategy were to install a 35 million national smart meters, decreasing the percentage of distribution network losses and meter reading cost, creating a smart meter architecture able to minimize the human interventions and reaching an almost real-time gathering and transfer of energy consumption data for balancing the production and consumption levels and enhance the reliability of the grid. After an initial pilot program running from 2009 to 2011 in the French zones around Lyon and Loire Valley, the first rollout phase started in 2013 and involved the rollout of 3 million Linky (this is the name of the French smart meters) meters all over the France. The second implementation phase was designed to occur between 2014 and 2022 and included a mass rollout strategy until 2022: state of the art at the end of 2019 showed that just 7 million Linky meters were installed in France, making thinking that the rollout speed has not been sufficiently high to reach the aforementioned goal for the end of 2022.
Germany deserves a separate speech in this regard: indeed, as previously mentioned, it took a long time before a first proposal about the implementation of smart meters in Germany was put on the table. A first negative CBA performed by the consulting company "Ernst & Young" in 2013 made Germany not follow the European directive and design a personalized and limited national smart meter strategy. For this reason, the program implied that starting from 2017 just the largest electricity consumers will be

provided with smart meters: it means that most of the German householders is not going to receive such devices, since their average consumption level is too low to make them being included in the program. The implementation period has been established between 2017 and 2020 and has included the installation of just little more than 7 million intelligent meters so far.

Summarizing the findings, it is possible to note that just one country out of five decided not to follow the directives provided at national level in 2009, while all the others conducted a CBA that resulted to have a positive outcome. Then two countries, Spain and Italy, have reached the goal imposed at European level (a penetration of 80% of smart electricity meters by 2020) before the due date: indeed, they have both reached a penetration rate higher than 99%. France and United Kingdom have extended their mass rollout period over the date indicated at European level, by respectively imposed a penetration target of 95% and 100% by 2021 and 2024, since the rollout speed resulted too low for both the nations. Finally, Germany decided to implement a stand-alone implementation strategy that excludes the small residential customers, making it to be the only country across those considered not to have followed the directive imposed at European level and making it to be the only country not to be engaged in any program able to provide smart meters to households.

3.2.3 Demand response programs in EU countries

Demand response is nowadays considered a strategic tool in the energy markets, able to spur the reaching of a balance between energy supply and demand, since to higher unbalances usually correspond higher energy prices against final consumers. The new climate objectives imposed at European level, including the increasing integration of renewable energy sources to the central grid makes this concern even more urgent to perform, since it is widely recognized that these kinds of sources are characterized by high levels of intermittency. Through demand response it is possible to achieve an efficient electricity system: the deployment of smart meters is linked to the development of demand response programs, since a better understanding and awareness over the electricity consumption levels is considered the first required step to involve customers in these types of projects. Even in this case, the householders resulted to be the most targeted category.

Anyway, two different types of demand response programs can be identified: the explicit one and the implicit one. Explicit demand response, also known as incentive-based programs, are those in which consumers receive an economic incentive to switch their energy consumption habits upon requests: in this case customers can benefit of the schemes either individually or in an aggregated form. Implicit demand response refers to programs also known as price-based ones, in which consumers react to the range of different electricity market prices over the day. It is important to notice that the two programs are not a replacement for one another but that a mutual usage of them is required in order to exploit their synergies and obtain better results.

Although there was an increase of interest in enabling both explicit and implicit demand response in Europe, in order to set out complete programs more stable, accurate and precise regulatory framework have to be developed. In particular, talking about explicit demand response, it is clear to notice the lack of regulation for what concern the role of aggregators: aggregators are those players that enable consumers to trade into the market, by aggregating their small loads into a bigger one and trading it as a single resource: indeed, final consumers often do not possess the means to trade independently in the market. The role of aggregator can be played by electricity retailers or by independent actors.

Now let’s shift the attention to the single countries under analysis: starting from Spain, what can be noticed about this nation is its advanced position in implicit demand response schemes in comparison with the level achieved by the other biggest European countries. Dividing the hours of the day between “supervalley”, “valley” and “peak”, different electricity prices are provided during the day, spurring the shift in consuming electricity during the off-peak hours. Furthermore, just for the small customers that hire an average power up to 10 kW, a dynamic Time of Use (ToU) scheme that involves 24 different prices for each hour of the day is applied. Different is the Spanish situation regarding explicit demand response programmes: in fact, the only programme in force at national level is the so-called "Interruptible Load Programme", limited to the benefit of large industrial consumers. Aggregation is not permitted in any of the key market (Balancing

Market[1], Wholesale Market[2] and Ancillary Services[3]), making the participation of single consumers harder to perform for the difficult-to-meet requirements.

Italy has a different background, but it presents several analogies with the previous country: until 2017, in Italy the only explicit demand response program in action is the so-called "Interruptible Load" one and, as well as in Spain, it has always been open just to large industrial consumers. Lot of regulatory barriers actually have hampered the deployment of new explicit demand response programs through the years and between them stands out the fact that aggregation is not allowed in any of the key electricity markets: it implies that, even if the wholesale market and the ancillary services are theoretically open to demand response resources, the technical thresholds are often not met by single little consumers that are not able to participate and trade in them. Anyway, recently a great innovation in the field has been brought by "Enel X", the Enel Group business line, that launched a pilot program aimed at opening the entry on the balancing electricity market by residential sites equipped with energy storage for photovoltaic panels: Enel X is acting as an aggregator and the project has been implemented in some provinces of North Italy. It is the first program that permits to distributed household resources to give their contribute in the supply of flexibility to the electricity network, a feature that until now was dedicated to large customers only. If the program was successful, it could lead to the entrance of other aggregators in the market and to the future participation of many small consumers. For what concern the consumers' reaction to price signals, all the low-voltage consumers in Italy are obligately exposed to static ToU tariffs, whether they do not decide to independently choose a supplier in the market.

United Kingdom has been one of the first country in Europe in opening several of its electricity markets to demand-side participation: anyway, evidence shows some lacks in the regulatory frameworks of these activities, so that the resulting outcomes are not as

[1] Balancing market (also called real time market) refers to a single period market in which it is possible to trade in order to balance the consumption and production level of electricity immediately before the deliver of energy to final consumers.

[2] Wholesale market refers the general electricity market in which the exchange of energy between generators and resellers occur. The price is usually determined through an auction.

[3] Ancillary Services refer to a broad range of services provided in order to maintain the electricity grid-s stability and reliability. For example, in case of a electricity shortage, ancillary services help restore the distribution of energy as quickly as possible.

effective as designed. For example, differently form the other nations, aggregation is allowed in most of the electricity market, but the lack of standardized processes make the participation of aggregators almost null. Similar to the previous cases, even though some explicit demand response programs have been inserted in some of the key markets, they result not attractive and suitable for small final customers since their requirements are challenging to meet. Anyway, from the point of view of the distributive electricity network, United Kingdom has been the only nation so far in having five out of its six DSOs running in demand response pilot projects that could lead to innovative features. For what concern implicit demand response, the final consumers are submitted to specific distribution tariffs made of a fixed charge and a variable component based on their energy consumption. The first ToU tariff in Europe has been introduced in United Kingdom: it is a dynamic scheme called "Agile Octopus", in place since 2018 in which prices reacts according to the changes in the wholesale market. It replaced the previous static tariff that just offered to smart meters customers a cheaper charge during weekday nights.

Germany can be defined the country that, among the five selected ones, has characterized by the highest level of barriers that hamper the deployment of explicit demand response programs: indeed, most of its electricity markets are closed to demand response and aggregation and even in those that allow it, the lack of standardized processes, rules and responsibilities makes the participation of consumers very difficult to occur, making its situation very similar to that in UK. Specifically, Balancing Market, Ancillary Services and the Wholesale Market are all theoretically open to explicit demand response and aggregation but in practice the lack of specific framework does not permit the development of effective progresses in the field. Regarding the distributive electricity network, network fees are designed in a way that results of spurring a flat consumption pattern, instead that flexible consumption habits, not involving final consumers in understanding the benefits that a variable and flexible consumption levels could have on their energy savings and on the reliability of the distributive grid. Implicit demand response in Germany is realized through two different pricing schemes: the former is a peak tariff running during the day, while the latter can be defined as an off-peak tariff that takes place during the night hours. The scheme was widely recognized obsolete, especially for the increasing interest in the integration of renewable generation sources that are making the German electricity system more and more decentralized.

France is the most advanced in the deployment of explicit demand response programs across Europe; since 2003 large industrial consumers can participate as demand-side resources providers in the Balancing Market, while from 2007 the first pilot projects aimed at integrating smaller residential loads started to be run. The most relevant program is called NEBEF (Notification d'Echange de Blocs d'Effacement), a mechanism that allows small loads to directly trade into the wholesale market without the need of an aggregated entity. It means that the requirements to enter the market are easy to be met by final consumers, differently from the previously presented nations.

ToU tariffs are also available: in particular, France also results to be the most advanced country in Europe for the development of dynamic price schemes. It has been one of the pioneers of ToU pricing programs, since as early as in the late sixties both industrial and residential customers were exposed to this type of tariffs. Nowadays, it is the only nation across the ones under analysis having implemented a critical peak pricing tariff with its "Tempo" program introduced in the market at the beginning of the century.

3.2.4 RES integration policies in EU countries

The liberalization of the electricity market that occurred in Europe introduced some changes in the industry structure: specifically, a shift from a concentrated environment characterized by few oligopolistic players to a market composed of lot of small decentralized players occurred. Simultaneously, RES technologies linked to the production of green renewable electricity started to grow, making, often, changing the role of the final consumers in that of prosumer, an individual able to produce and consume energy at the same time. The consequences of this shift have been an unbundled electricity market in which generation, transmission and distribution activities are undertaken independently.

Besides, some issues and challenges have also raised up, such as the need of standardized frameworks, rules and roles that could define how the communication between the different involved actors must take shape.

In this section the findings related to the different supporting schemes for the integration of renewable decentralized energy into the national grid implemented in Italy, France, Spain, Germany and United Kingdom, as well as their policies (that resulted to be really poor so far).

Starting talking about Italy, the two main support schemes for the integration of renewable energies still in force today are a net-metering scheme ("Scambio sul Posto") and a premium tariff ("Ritiro Dedicato"): the former is a particular form of on-site self-consumption that makes it possible to compensate the electricity produced and fed into the grid at a certain time with the energy furtherly withdrawn and consumed. The net-metering tariff is instead a premium tariff, which acts as a simplified mode available to producers for the marketing of electricity produced and fed into the grid.

The two tariffs cannot be exploited together. Apart for these, some tax credits are allowed for photovoltaic and wind energy plants (reduced VAT of 10%). With regard to the connection of their plant to the central electricity grid, grid operators are obliged by law to provide a connection contract to third parties and to expand the grid, whether it resulted necessary, for the integration of the plant. In addition, there is a priority rule allowing priority connection to plants producing renewable energy.

Considering the French panorama, the analysis shows that until 2015 the main support mechanism for investment in decentralized renewable energy plants was a feed-in tariff (a kind of supporting tool that implies the realization of a long-term contract that provides a higher and fixed price compared to the market one and that acts as an incentive for investing in renewables). With the advent of the Act of Energy Transition for Green Growth in 2015, the previous scheme was replaced with a new mechanism (premium tariff one): in fact, a greater exposure of renewable energy to market competition was required at European level. The new tariff, called "Mécanisme de compensation" allocates a premium tariff to renewable electricity producers, which is added to the market price to ensure that the costs for installation and future connection of the system are covered. Besides, France organized diverse tenders across the years for the construction of RES plants in order to achieve the objectives set by the “Programmation Pluriannuelle des Investissements”. Finally, grid operators are obliged to conclude agreements for the connection of energy plants to the centralized grid (but no priority rule runs for RES technologies).

Similarly to France, the two main schemes implemented at national level in Germany are a feed-in tariff and a premium tariff: differently from the previous context, however, the first tariff applies to renewable energy producers that own small plants (up to 100KW of power), while the second scheme applies to all the producers of electricity from renewable sources, regardless the size of the plant and it results the main support mechanism at national level from 2014. Anyway, the element that differentiates the German context from other European countries is the possibility for those who want to open a RES plant to take advantage of a series of loans at advantageous conditions: loans specifically designed to spur the integration of offshore wind energy (including financial packages to support companies that invest in this kind of energy), loans for renewable energy storage, specifically designed for both people that want to invest in new solar energy storage units or in PV panels integrated with a solar storage unit and finally loans for electricity producers who wants to invest in RES plants. RES plant operators are authorized to connect their plants to the central electricity grid; usually the grid operator that is obliged to make the agreement is the closest grid operator to the plant in question, but whether it results economically more favorable, a grid operator further away may also be obliged. Even in this case the priority rule for RES plants applies.

Since 2014, a single support scheme for the integration of renewable energies has been in place in Spain; it is called Specific Remuneration Regimen and applies to new RES plants that are installed in the Spanish mainland. More than a support mechanism, it could be defined as a complementary remuneration scheme that makes RES technologies able to compete in the electricity market. Contrary to other countries, this scheme is only valid for solar and wind energy. The analogy with other countries lies in the obligation of grid operators both to enter into contracts with small decentralized producers and to expand the grid if needed: in addition, priority connection is guaranteed to RES plants.

In United Kingdom the production of electricity by RES is supported by a bunch of feed-in tariff, contracts for difference and tax mechanisms. The first type of tariff aims to develop and support the installation of small RES plants (up to 5 MW of power) and eligible technologies are in this case wind, solar, biogas and hydro energy. Contracts for difference work as private agreements between RES productors and a third party, represented by a government own firm, the Low Carbon Contracts Company (LCCC): it has resulted the only supporting scheme running in UK and applicable to every kind of technologies since 2014. Its functioning implies that the generator is paid by the government the difference between two prices, a "strike" one, that reflects the cost in investing in a low carbon technology, and a "reference" one, that reflects the price of the average price market of electricity. The objective is to reduce the exposition of such producers to the volatility of electricity prices. Finally, it is provided an exemption on the payment of a tax on fossil fuels, that usually applies on traditional energy technologies. As in the previous case, also in United Kingdom plant operators result entitled to ask for the connection of their plants to the national electricity grid and this obligation applies against grid operators even in case it is required a reinforcement or expansion of the grid itself: anyway, electricity from renewable sources are not given priority.

To summarize, the premium tariffs result to be the most used tool to incentivize the installation and further integration of renewable plants; all the country implemented such tariffs, except for United Kingdom that is still adopting a feed.in one. Feed-in tariff resulted to be the second most used mean of support, implemented in UK, France (even though it has been increasingly replaced by a premium mechanism) and Germany for supporting small-size plants. Other mechanisms of support have also been tax incentives, tenders and loans provided at favorable conditions. Finally, the priority for the integration of RES plants in comparison to electricity coming from traditional technologies is provided just in Italy and Germany.

Now, shifting the attention to the policies developed at national level, it is easy to see that they are all still in a pilot phase or that none of these has a specific objective in terms of increasing the amount of renewable energy injected into the grid.

Specifically, every selected country has implemented some training and certification programmes aimed to provide those who wishes to install a RES plant a professional qualification to implement this task, so to meet the European and in some cases international standards. Besides, they are also used as mean to ensure a high degree of quality in the installation of the plant itself.

In public-building field, the only two countries that are actually taking some actions to spur the decrease of greenhouse gas emissions and the integration of RES into the national grids are France and Italy: Italy is engaged with a national program called "Grenelle Building Plan" (Plan Batissement Grenelle) aimed to reach a decrease of greenhouse gas emissions of 50% by 2018. This is linked to a need of an increase in the usage of renewable energy sources: for this reason, the plan implies that all the new buildings realized in France reach a balance between their non-RES consumption and withdrawal from the grid and their RES production by the end of 2020, making mandatory the need of installing new RES plants linked to these buildings. With regard to Italy, all the new buildings and the buildings that go through major refurbishment processes are obliged to take the usage of RES integration into consideration and to provide for the installation of such plants whenever it resulted feasible.

Talking about the main results achieved in this field, in 2018 the share of the consumption of energy coming from renewable sources on the total energy consumption at national level has been about 17% for all the selected country, except for United Kingdom that has stopped at 11% (the relative data can be seen in Table 2). Even though, United Kingdom resulted to be the country with the highest increase, having augmented this share by 65% in 2013 in comparison to 2009 levels and by 230% in 2018 in comparison to 2009 levels (shifting from 3,3% to 11%): indeed, it started with the much smaller initial share of RES consumption in 2009, in comparison with the other countries. The relative data can be seen in Table 3.

Table 2: Share of energy consumption from RES/Total national energy consumption

Country/Year	2009	2013	2019
FR	12,216%	14,043%	16,593%
DE	10,87%	13,766%	16,481%
ITA	12,775%	16,741%	17,775%
ES	12,963%	14,043%	17,453%
UK	3,342%	5,498%	11,017%

Source: Eurostat

Table 3: Variation in the share of RES consumption through the years

Country/Period	2009-2013	2013-2019	2009-2019
FR	+14,96%	+18,16%	+35,83%
DE	+26,64%	+29,72%	+51,62%
ITA	+31,05%	+6,18%	+39,14%
ES	+8,33%	+24,28%	+34,64%
UK	+64,51%	+100,38%	+229,65%

Source: the author

3.3 Comparative policy analysis results

The analysis that has be implemented is a qualitative comparative analysis: in this section the relative findings are presented.

The aim of the study has been to explore the potential existence of a correspondence between the regulatory approach adopted by the analyzed countries and the results achieved with regard to the deployment of Smart Grid at national level.

The previous chapters were devoted to the policies related to the rollout of smart meter devices across the various nations with the relative design of demand response programs, as well as the support schemes and incentives related to the integration of RES into the national electricity grid. The main objective of the first policies is to make the final customers (both at commercial and residential levels) more aware of the electricity prices they are subjected to in order to decrease the final energy consumption and the relative energy bills. The latter type of policies is instead finalized to an increase in the energy production and further consumption of electricity coming from RES in order to guide the single countries toward a decarbonized economy and to a relative decrease in their CO_2 emission levels. Due to this reason the following matrix (designed to accomplish the above-mentioned analysis) aims to provide a linkage between the main results achieved and the in effect regulatory frameworks.

Table 4: Comparative analysis

<table>
<tr><th>Type of regulatory framework / Presence of innovation stimulus mechanism</th><th>YES</th><th>NO</th></tr>
<tr><td rowspan="2">Incentive-based</td><td rowspan="2">/</td><td>DE:
<table>
<tr><td>SMART METERS PENETRATION 2019 (%)</td><td>15</td></tr>
<tr><td>VARIATION IN THE ENERGY BILLS (2009-2019; %)</td><td>4,1</td></tr>
<tr><td>VARIATION IN THE ENERGY BILLS (2013-2019; %)</td><td>-0,59</td></tr>
<tr><td>SHARE OF RES (2019; %)</td><td>16,481</td></tr>
<tr><td>CO2 EMISSIONS (2019, Mt)</td><td>777,51</td></tr>
</table></td></tr>
<tr><td>FRA:
<table>
<tr><td>SMART METERS PENETRATION 2019 (%)</td><td>19</td></tr>
<tr><td>VARIATION IN THE ENERGY BILLS (2009-2019; %)</td><td>36,9</td></tr>
<tr><td>VARIATION IN THE ENERGY BILLS (2013-2019; %)</td><td>6,52</td></tr>
<tr><td>SHARE OF RES (2019; %)</td><td>16,593</td></tr>
<tr><td>CO2 EMISSIONS (2019, Mt)</td><td>305</td></tr>
</table></td></tr>
<tr><td>Output-based</td><td>UK:
<table>
<tr><td>SMART METERS PENETRATION 2019 (%)</td><td>25</td></tr>
<tr><td>VARIATION IN THE ENERGY BILLS (2009-2019; %)</td><td>9,5</td></tr>
<tr><td>VARIATION IN THE ENERGY BILLS (2013-2019; %)</td><td>-0,52</td></tr>
<tr><td>SHARE OF RES (2019; %)</td><td>11,017</td></tr>
<tr><td>CO2 EMISSIONS (2019, Mt)</td><td>377,06</td></tr>
</table></td><td>/</td></tr>
</table>

Hybrid	ITA:		ES:	
	SMART METERS PENETRATION 2019 (%)	>99	SMART METERS PENETRATION 2019 (%)	>99
	VARIATION IN THE ENERGY BILLS (2009-2019; %)	-7,7	VARIATION IN THE ENERGY BILLS (2009-2019; %)	20,1
	VARIATION IN THE ENERGY BILLS (2013-2019; %)	-6,14	VARIATION IN THE ENERGY BILLS (2013-2019; %)	0,94
	SHARE OF RES (2019; %)	17,775	SHARE OF RES (2019; %)	17,453
	CO2 EMISSIONS (2019, Mt)	326,144	CO2 EMISSIONS (2019, Mt)	308,84

Source: the author

With regard to smart meters deployment, it is possible to notice that the best outcomes in the penetration rate have been achieved by Italy and Spain: the in effect regulatory scheme of both the countries is a hybrid mechanism aimed to treat in a different way OPEX and CAPEX. Anyway, it is possible to underline that, while Italy has also implemented an effective communication plan with its customers, spreading awareness of the benefits of smart metering processes, Spain failed under this point of view. Indeed, Italy has reached the highest decrease in its energy bills, thanks to its consumers' reduction in the electricity consumption levels. In this case, the innovation-stimulus mechanism added in the framework (extra WACC provided for Smart Grid related projects) has worked effectively. On the other side Spain, despite having reached a similar result in the penetration rate of smart meters, has not managed to persuade its final consumers effectively into changing their energy consumption habits: besides, both explicit and implicit demand response programs are still in the first phase of their deployment, so that the total energy bills of the country has raised up by 20,1% through the years.

Germany and France resulted the two countries lagging far behind the others in the deployment of smart meters: they have both implemented an incentive-based mechanism since 2009, without providing any form of innovation stimulus mechanism able to spur the investments in risky and uncertain activities. It results to be the least effective mechanism form this analysis. With the smallest rate of smart meters penetration rate, they both experimented an increase in their energy bills in comparison to 2009 level (year of the European directive about smart meters rollout), even though during the last five years France has greatly diminished this increase. Finally, there is UK, the only across the analyzed countries that has recently set up an output-based mechanism specifically designed to support high risky activities like the projects related to Smart Grid deployment: anyway, this framework became available just in 2015 and has not paid off yet. Indeed, UK resulted in a smart meters' penetration rate of just 25% against its goal of 100%. With regard to its energy bills, UK suffered an increase of 9,5% in comparison to 2009 levels, even though during the last five years this increase has become a decrease (-0,52%) that could be related to a better management of the electricity consumption and to a development of the smart metering system for its final consumers.

Discussion and Conclusion

The aim of this work is to understand which are the approach adopted by five main European countries in order to regulate the electricity distribution system operators and to understand if this choice has a direct impact on the results obtained at national level with regard to the deployment of smart grid. The analysis has involved France, Germany, Italy, Spain and United Kingdom.

Relatively to the first research question of the study ("What are the differences and similarities in the adopted regulatory schemes across the main European countries?") some conclusions can be drown: specifically, no country still has a RoR-type regulatory scheme in place (typical of pure cost-plus mechanisms), although this was the preferred scheme before the liberalization of energy markets in Europe. This scheme is obsolete because it does not lead to production efficiency. Countries such as Germany and France have thus decided to overcome the problem by moving to a pure incentive-based regulatory scheme (such as the aforementioned price-cap): despite this, it still has negative characteristics such as its low propensity to push regulated companies to invest in uncertain projects such as the Smart Grid. For this reason, United Kingdom has opted for a completely new type of mechanism, output-based, more focused on the opportunity of heavily investing in risky projects. On the contrary, Spain and Italy have opted for a regulatory scheme called hybrid and aimed at minimizing defects and maximizing the values of the two pure schemes presented above. In addition, only two out of the five countries concerned have added a mechanism to the basic regulatory framework to encourage the development of innovative projects: the United Kingdom has introduced this mechanism in the form of "Adjusted Revenues", while Italy has done so in the form of an "extra-WACC", provided just for innovative and risky projects. Finally, the basic regulatory period is four years (Germany and France), while Spain and Italy have extended it to six years, in order to make it easier for regulated companies to forecast future revenues and to provide even more incentives for such companies to invest. United Kingdom has even extended it to eight years.

Relatively to the second research question of the work ("Which are the most advanced European countries in the deployment process of Smart Grid?") it has been analyzed the state of the art of the five selected countries with regard to the rollout of smart meters in households, demand response programs and RES integration policies. This choice has been made by because several empirical studies in the literature consider them to be the three key drivers able to incentivize the shift from the current situation to a more dynamic concept of grid. With regard to the first category, only Italy and Spain have achieved their targets for the penetration rate of smart electricity meters over the country. United Kingdom and France, stopping at a penetration rate of just 25% and 19% respectively, still lagging far behind the first two cases. Finally, Germany, the only European country considered to have abandoned the European directive on the deployment of smart electricity meters and the only one to have adopted a strategy of its own, has not yet put in place any strategy to provide smart meters to final householder consumers.

On the other hand, considering the results obtained in the field of 'explicit demand response', it can be seen that two out of the five countries considered are still totally unprepared, also from a regulatory point of view, for the spread of these types of programmes, since all their key markets are closed to both aggregation and demand-side resources. Germany is in an intermediate situation, since it has its electricity markets partially open to demand response resources and aggregation but lags far behind for what concern the regulatory framework and standards to exploit these sources. Lastly, France and the United Kingdom are the two countries most prepared to develop these types of programmes, since they both have a broad range of markets open to demand-side participation. France can also benefit from detailed framework and standards.

Finally, talking about the main outcomes achieved in the field of RES integration, evidence show how the situation among the countries is almost the same, having all reached a similar level in the share of energy consumption from RES: the supporting schemes are indeed basically the same for all the involved countries and the policies related to the integration of this kind of sources to the grid are all at pilot stage.

Thirdly, in order to answer the last research question of the work (Is it possible to find a connection between this advancement and the adopted regulatory approach?) the study has led to the following results: the o findings seems to suggest a positive relationship between a hybrid regulatory mechanism accompanied by a support incentive and the benefits deriving from the implementation of smart meters on a national scale. One the contrary, the least effective mechanism results to be the incentive-based one adopted by France and Germany.

The situation regarding a possible relationship between the regulatory framework in the different countries and electricity production from RES sources is different. In fact, although the various countries have implemented different regulatory schemes over the years, the policies for the integration of electricity from RES sources have been almost the same at national level. This situation is also reflected in the percentage of RES energy consumed by the considered nations, which results to be at the same level for all the analyzed countries in 2019, starting from a similar initial value in 2009.

Talking about the limitation of the study, in the future the proposed method can be expanded by considering other smart grid related technologies and policies. For example, the study can be extended by considering the “vehicle-to-grid” programs. Furthermore, the analysis concentrated on five selected countries, specifically those that resulted to be more involved in development and demonstration (D&D) projects, so those that had already developed a national regulatory framework related to the Smart Grid implementation. For this reason, the analysis can be repeated by considering the countries that, on the contrary result to be less advanced in this process.

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Appendix

Table 5: Policy analysis framework

Country	VISION AND OBJECTIVES	STRATEGY DEVELOPMENT	IMPLEMENTATION PHASE	OUTCOMES EVALUATION
France	-reaching a 95% digital meter penetration by 2020; -minimize the human intervention in metering billing and collection of data.	Involved actors: ERDF, biggest French electricity DSO; Strategy objectives: -reach a 35 million national rollout of smart meters in France; -decrease the percentage of distribution network losses (25%) and meter reading costs (5%); -reaching a real-time gathering and transfer of energy usage information for balancing the production and consumption levels; -faster intervention and localization of outages. Time period: 2015-2022; Investment: € 5 billion.	Pilot phase: from 2009 to 2011, testing of the Linky information system in Lyon and Loire Valley; First phase: from 2013 to 2016, initial rollout of 43 million smart meters in households; Second phase: From 2016 to 2020, mass roll-out of about 25 million smart meters.	State of the art: at the end of 2019, just 7 million smart meters are installed in France (correspondin g to a 19% penetration rate). The proposed outcome has not been reached.
Germany	No policies in place for households.	/	/	/
Italy	From Telegestore project: -reaching a higher level of transparency with customers; -Introducing billing schemes based on up-to-date meters reading; From Open Meter project: -replacement of the previous installed meters; -manage more comprehensiv	From Telegestore project: Involved actors: E-distribuzione, biggest Italian electricity DSO. Strategy objectives: -development of a remote automatic metering management system which used the low-voltage distribution grid as a data carrier; -provide 30 million of customers with intelligent electronic meters with an external electronic communication device; Time period: 2001-2005; Investment: € 5 billion. From Open meter project: Involved actors: E-distribuzione, biggest Italian electricity DSO.	Pilot phase: -testing phase aimed to recreate the typical environment of the noise existing on the electricity network (more than 1,000 meters connected with 3,000 electronic appliances commonly in use in households). First implementation phase: -from 2000 to 2001, initial rollout of a remote metering management system which used the low-voltage distribution grid as a data carrier. Phase designed in order to test the new models of the system	State of the art: the proposed outcome has been successfully reached with a smart meters' penetration higher than 99% in households at the end of 2019.

	e and detailed information to support the activities of national electric companies; -reaching a 100% smart meter penetration by 2020.	Strategy objectives: -rollout of second-generation meters, including the installation of 41 million smart meters, of which 32 million replacing the previous installed ones; -designing and implementing an effective metering system able to match the energy-efficiency standards set at European level. Time period: 2017-2020 Investment: € 4,3 billion.	(meters and concentrators). Second implementation phase: From 2001 to 2006, mass rollout of 30 million meters. From Open meter project: Single implementation phase: -from 2017-2020, replacement of first-generation smart meters over a four-year period.	
Spain	-reaching a 100% smart meter penetration by 2018; -enhance the accuracy of meter-reading activities; -enable the further development of demand response programs and integration of RES technologies.	Involved actors: Red Electrica de Espana, Spanish electricity TSO Strategy objectives: -install 30 million smart meters (to all Spanish household customers); -opportunity of benefiting from real rather than estimated consumption readings; -passing from seeing the distribution activity as an infrastructure activity to a customer-oriented activity. Time period: 2008-2018; Investment: € 2 billion.	Unique implementation phase: -from 2008 to 2018 mass rollout phase of approximately 30 million smart meters.	State of the art: the proposed outcome has been successfully reached with a smart meters' penetration higher than 99% in households at the end of 2018. The goal of spurring and support further smart grid-related programmes like demand response ones failed.
United Kingdom	-reaching an 80% smart meter penetration by 2020; -provide consumers with more awareness, visibility and control over their energy	Involved actors: Department for Business, Energy and Industrial Strategy (BEIS), Office of Gas and Electricity Markets (Ofgem). Strategy objectives: -install 53 million smart electricity and gas meters to over 26 million domestic and smaller business sites;	First implementation phase: from 2011 to 2014, called "Foundation Stage"; it has been used in order to work with the industry sector, the final consumer groups and other involved stakeholders to establish all the required technical foundation to start the following mass	State of the art: at the end of 2019, just 15,3 million smart meters are installed in UK (correspondin g to a 25% penetration rate).

	consumption and related energy bills; -spur the use of renewable energy and development of related demand-side management policies in order to reduce peak demand's levels.	-ensure an efficient roll-out and optimizing the consumer installation experience; Time period: 2010-2020	roll-out phase. A significant number of smart meters were installed during this stage. Second implementation phase: 2014-2020, called "Mass roll-out Stage"; most of the final customers received the smart meters during this stage.	The proposed outcome has not been reached. For this reason, the UK Government decided to design a new regulatory framework to ensure that the roll-out stage can go on beyond 2020, as long as all the domestic sites will be provided by these devices. The new framework will stay valid until 2024.

Source: the author