POLITECNICO DI TORINO

Collegio di Ingegneria Gestionale

Corso di Laurea Magistrale in Ingegneria Gestionale

Tesi di Laurea Magistrale

Innovation and incentive regulation to foster EU energy networks integration

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Anno Accademico 2019/2020

Abstract

The purposes of this thesis is to provide information and insights about the regulation and incentives systems that sustain and promote the integration of energy networks, such as electricity and gas, in the country of the European Union, while also promoting the growth of an energy market in Europe that can be sustainable in the long term. In order to provide a better focus on the incentives and regulations, in this thesis we analyse the regulations in use in Sweden, Spain, Ireland, Portugal and Switzerland; in detail it is analysed how the regulator manages the distribution and transmission system, who are the main actors involved and how governments support innovation. For those countries, it is also provided a list of projects to promote innovative technologies or approach to energy, and who are the promoters.

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Introduction

The European Commission has been progressively more interested in working toward reaching new target of eco-sustainability in recent years, and has launched different projects to assist Member State in achieving them. The importance of setting new target is due to the consequences that an unsustainable growth in population and industrial processes can have on the environment; in order to reduce the environmental impact, the European Commission has worked on the implementation of routines and processes to increase energy efficiency and the amount of energy produced using renewable sources. The main problem in increasing the share of energy produces from renewables sources in connected to the intermittence that characterizes all these sources, and that can cause problems in making intersect demand and supply, and also makes difficult the management of the high and low peaks of production; this creates the necessity of implementing a system of conversion and storage, and changing the usual way that the citizens approach with energy consumption. In this contest measures on the network system are necessary, in order to make it more flexible, reliable and interconnected with the other infrastructure that have a part in energy generation and distribution; from this needs a new approach that wants to increase the integration of the energy networks take a step, creating synergies between the technologies used. The changes in the management of the network is also going to have a big impact on the business models of the firm operating in this industry; in fact it is inevitable that a more sensitization of the customer will move the value proposition of the firm not just towards an economic saving but also towards the use of these new technologies that are have an higher sustainability. This transformation in the energy industry also raises new challenges in what should be the approach of the regulator to stimulate these changes. The first big move in this direction was made by the EU with the liberalization of the energy market, in order to increase the competition, and the unbundling of the services for generation and supply, while the services of transmission and distribution were more difficult to separate, since they create space for natural monopoly, and limiting the expansion of the firms operating would decrease the efficiency. Hence each State has specific rules to regulate this market, avoiding episodes were an excessive concentration can slow down the progress and the welfare of the citizens while giving the firms incentives to invest the transformation and the adoption of innovative technologies. The regulation that each Country establish is important since it guides both firms and consumer to adopt the attitude in line with the goals of the Country; for this reason, many regulators in the EU started to introduce new policies that reward the firms for its performance. The scope of this thesis is to provide an overview on the technological transformation of the energy sector in the EU, that will be presented in Chapter 1, a study on the different kind of incentives and regulation systems used in Chapter 2, an analysis of the regulations and projects in five Member Country.

1 The European energy sector and its changes

1.1 The role of renewable energy sources in distributed generation

The role of renewables energy sources (RES) has been increasing in the latest years, as we can see from the figure there has been a stable increase in the use of renewable sources in the EU, in fact worldwide the production of energy from sources like hydro power, geothermic power, solar, wind and biomass increased significantly to meet the new need of reducing the environmental impact while maintaining high standards of quality of service and an affordable price, in order to guarantee the success of the firms in the competitive market.

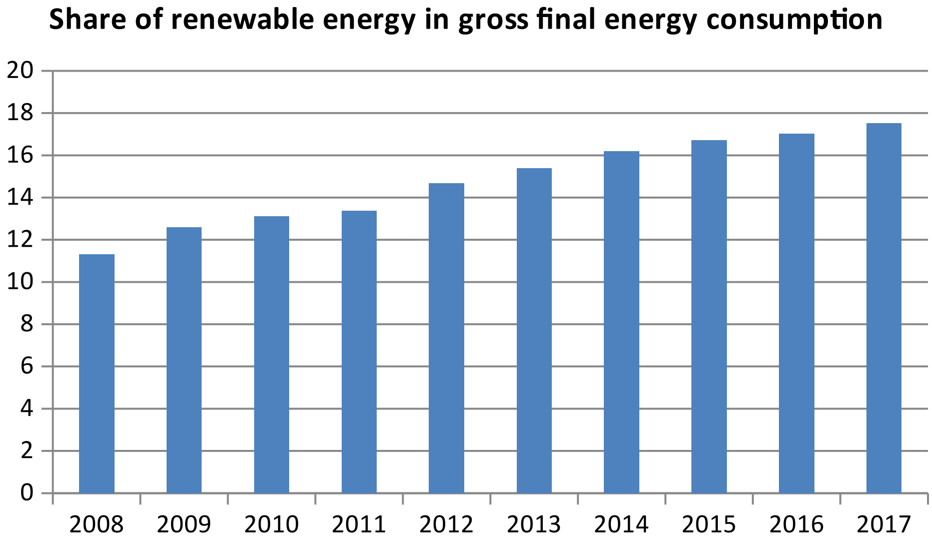


Figure 1: elaboration of data from Eurostat database

The first requirement is particularly difficult to achieve since RES are characterized by high variability and intermittency, that lead to problems of service when the demand is high and the production is low and problems of storage when the production has peak and is not met by the demand; the first case find a solution in the over sizing of the plant for energy generation, but the consequences of this measure is that there is a surplus of production that is not met by the demand, and therefore causes a waste of energy if the plant is not rightly equipped with storage systems, and for now there is limited storage in EU, in fact the average is of just 5% of installed capacity (EC Directorate-General for Energy; 2015). A successful approach to this problem is the diffusion of Energy Systems Integration (ESI), that consist in bringing together multiple firms operating in the energy sector with infrastructures that can increase the efficiency of the services while increasing reliability, reducing costs and decreasing the environmental impact (National Renewable Energy Laboratory; 2019). There are multiple conversion technologies used in ESI to create positive synergies, like the Power-to-X technologies; these technologies are used to convert the excess of energy produced into alternative products, like Power to Fuel, Power to Gas, Power to Liquid or Power to Heat; other technologies are in the Cross-vector integration, that uses different source together to deliver energy services, like Combined Heat and Power (Energy Futures Lab; 2018). Thanks to the conversion of the surplus of energy into other form that can be preserved, this system hallows to reduce the amount of over production. ESI also includes new models of structuring the grid, indeed it also refers to the integration of generators of different scale, more distributed on the territory, in what is called Distributed Generation (DG). The technologies of ESI can bring numerous benefits, like a more efficient use of the resources, the reduction of losses on the grid, the decarbonisation and a reduction of costs (Energy Futures Lab; 2018).

1.2 Benefits of the Energy Systems Integration

There are numerous benefits that act as drivers in the transition of the energy systems; they can also increase the value of the final service. Even if the importance given to each one may vary with the needs of the country in which ESI is implemented, the main benefits are:

- efficient use of resources, that has became particularly important with the increase of the industrial processes that consume a large amount of energy; this is mainly achieved thanks to the Cross-vector integration, indeed using three or more energy sources combined can lead to significant improvement in the efficiency of the generation process (Chicco and Mancarella; 2008).
- Reduction of losses, mostly caused by the production of unused heat in the operations; being able to recapture and use this heat would save up to 51% of energy (IEA; 2015).
- a reduction of emissions, thanks to both the substitution of carbon-intensive fuels with renewable sources and to the use of routines and infrastructure that require less energy to work.
- an improvement in the flexibility, reliability and resilience of the network grid; an higher flexibility is achieved thanks to the integration of interconnectors, storage implants and demand side response system (Strbac and Aunedi; 2016); reliability and resilience refer to the capacity of

the grid of facing high level of uncertainty regarding peak load or extreme weather events (Energy Futures Lab; 2018).

- a reduction in overall costs of energy; this reduction is due to two different aspects of the ESI, indeed part of the reduction is directly due to the decrease of sources needed thanks to the increase of the efficiency, while the other is obtained thanks to a better use of the existing use of infrastructure; it is estimated that a reduction is superfluous assets can generate saving up to 7% if the investment required (IEA; 2015)
- a better service provision, intended as the quality of the service offered to the customers as private citizens, communities and businesses.

1.3 Energy efficiency in the European Union

As part of the measures issued by the European Commission in 2012 as part of the Energy Efficiency Directive, the member of the EU had to reach the target of 20% energy efficiency by 2020, meaning an overall primary energy consumption of 1483 million tonnes of oil equivalent (Eurostat; 2018). The measures adopted in order to achieve this target were on reducing energy sales, increase the energy efficient renovations for buildings and adopting new strategic plans every three years. (European Commission; 2019)
The trend in the last years has showed a positive result of the plan, as in 2017 the primary energy consumption was just 5.3% over the target and showing a decreasing trend (Eurostat; 2018).

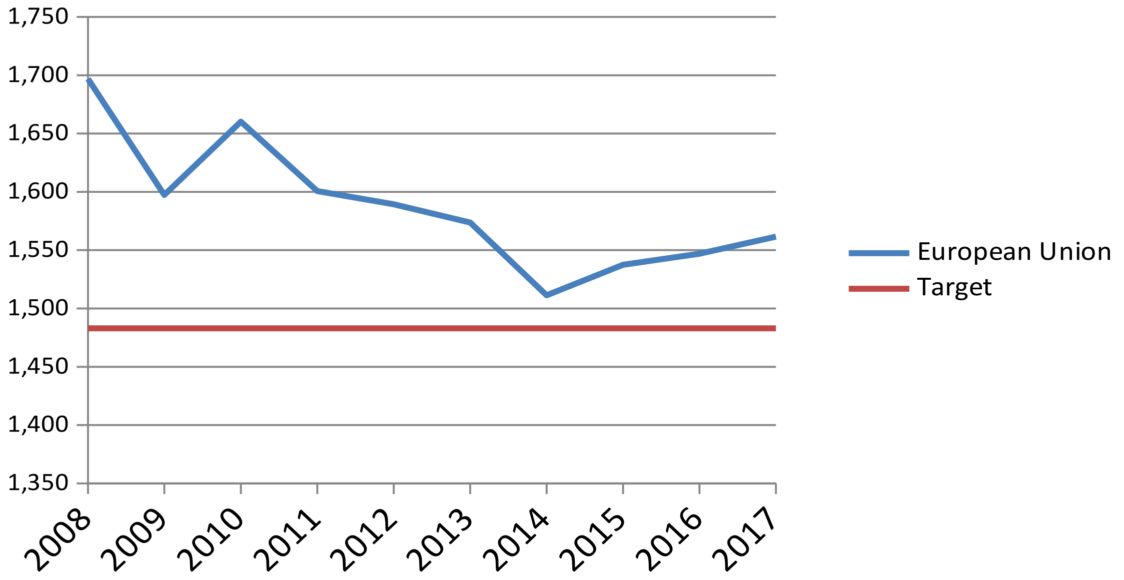


Figure 2: Elaboration of data on primary energy consumption from Eurostat

The Energy Efficiency Directive was updated in 2018, with the project "Clean energy for all Europeans package", that agreed to set the target of energy efficiency target for 2030 at 32.5% (European Commission; 2019).
In order to achieve these goals the energy efficiency technologies more used by the member State have been:

- Combined Heat and power (CHP);
- storage;
- energy conversion
- ICT systems
- Smart grids.

1.4 Combined Heat and Power CHP

The Combined Heat and power technology is a generation methodology in which the plant is used to produce electricity and heat simultaneously using the same source of energy; this systems allows to increase the energy efficiency of the plant from the 50% of plants using traditional systems up to 75% (US Department of energy; 2017).
This system can provide different benefits other than the increase in efficiency, such as decreasing costs, protecting the firm from energy price fluctuations, making the firm more competitive and increasing the energy resiliency. Other benefits of the use of cogeneration are the reduction of energy losses when the plant is near the geographical area it has to service, a reduction in carbon emission, higher flexibility in meeting the demand and the reduction of costs for the end user.
This technology has been recently improved with the Combined Cooling Heat and Power (CCHP) systems, that is capable of reducing even more the efficiency of the system by using the energy also for cooling.
The use of these technologies requires the plant to be located near the source of energy, this created the opportunity for numerous firm to be born and grow. This situation that sees a large number of plants and firms requires a better cooperation between them to increase the efficiency even further and reduce overload in the production; indeed different countries promoted the adoption of ICT systems for the communication between the firms and with the network grid.
CHP and CCHP systems have particular relevance when they are used for District Heating (DH) schemes; DH is a particular organizational form of using energy in which the same plant generates heat used by different building, thanks to this it is possible to avoid waste of heat.

Recently the development of CHP systems created the challenge of integrating renewable energy sources in the generation, the most successful RES have been geothermal energy, biomass and solar power, but there is not one optimal solution for every plant; indeed in order to reduce losses in the transportation of energy usually plants have smaller size and are built near the District they have to service, this has led every plant to have a different working environment, meaning that the availability of a renewable source may be low for some plants, while being easily used for others.
Even if it has numerous benefits, CHP technologies have seen a limited adoption due to the high barrier costs it presents to build the infrastructure for generation and connection to the network, the high requisite that the site of the plant requires in order to work efficiently and the lack in the legislation of rules to regulate these activities.

1.5 Storage systems

In order to be able to meet the demand even at peak hours, the recent solution in power plant has been an over sizing of their capacity; this however has lead to the problem of reducing waste when the demand is not high enough to absorb all of the energy produced. To avoid waste of energy different systems for storage has been developed, and they will keep growing with the increasing use of wind and solar energy and with the increase of the demand peak. Energy storage has a particular relevance when talking about making the grid more flexible, creating a better balance between demand and supply and encouraging the adoption of RES, even if for now its adoption has been limited to being mostly in form of hydro-storage, that cover 99% of energy capacity worldwide, but is possible only in some areas (European Commission Directorate; 2015). Hydro Storage System (PHS) were an optimal solution when the national grid in Member State was framed in numerous small operators and poorly interconnected, but with the progress of ICT systems and the need to have an efficient grid, other form of storage has to be deployed to cover the gap between demand and supply that the use of renewable sources creates. Storage Systems can be adopted from different actors at different size:

- Central storage in the transmission grid, at national level; it is used to balance the seasonal gap in the production and is useful for balancing markets; thanks to its large size, it is the most efficient at in the management of peak load.
- At city level, installed in the distribution grid; it is limited in capacity and can only balance daily variations.

- At household level, by end-users; it can storage a limited amount of energy and requires connections with the grid; it is useful for personal consumption and has positive impacts on customer behaviors and energy efficiency (European Commission Directorate; 2015).

Depending on the size of the storage system, different technologies are available, indeed for centralized high capacity storage the most common form of storage are thermal storage, pumped hydro, compressed air energy storage and chemical storage; for storage system installed at grid level the most common solutions are super-capacitors, hydrogen energy storage, and batteries using Lead Acid, Li-ion or Flow Batteries; finally for end user storage there is a variety of batteries available (European Commission Directorate; 2015).
Energy storage plays a key role when the share of RES in under 20%, indeed in this case the operators of the grid can face the problems connected to the intermittency of the sources, but when the share exceeds 25%, the perturbations in the grid becomes more relevant and efficient storage systems are needed.
Energy storage present also the opportunity to be integrated with other technologies, such as CHP, solar, wind and thermal production systems.
One of the main problems connected to the use of storage system is the lack of common market and regulatory issues, indeed for optimizing their use it will be necessary to establish incentives and creating a European market with balancing rules; some recommendations on this topic are:

- avoiding a system in which the DSO cannot own or operate the storage system, since the adoption of these technologies brings benefits to the DSO, that would be incentivized in investing in projects of storage to increase the flexibility and already posses data useful;
- analyzing current directives in different countries to see if they let the opportunity for the DSO to operate the storage, and what have been the consequences of this;
- increase the standardization in the network to increase the possibility of connecting the storage to the grid;
- encourage the adoption of new business models that could increase the efficiency by involving more actors (EDSO; 2017)

1.6 Energy conversion technologies

The storage of energy requires system able to convert energy into other forms that can be easily preserved and then reconverted, in order to avoid to waste the surplus of electric power. To accomplish this goal a number of technologies known as Power-to-X have been implemented, the ones with the most mature technology are:

- Electricity-to-thermal (E2T);
- Power-to-Gas (P2G) and Power-to-Hydrogen (P2H);
- Vehicle-to-Grid (V2G).

Electricity-to-thermal is used to transform the surplus of electricity generated from RES in thermal energy, that can be later used for heating or cooling purposes; the demand of thermal energy comes mostly from the final user, for this reason this conversion system is particular useful when there is small size storage installed directly by the customers. E2T has to main benefits, the fist is that it provides flexibility to the grid and the second is that it has a positive impact on the reduction of carbon emission, since it substitutes other form of heating using fossil fuels; other benefits of this system are the high efficiency and the affordable cost. The main technologies that need to be implemented in E2T systems are electric boilers and pumps. Power-to-Gas and Power-to-Hydrogen are used when the surplus of electricity is high enough to be used in processes that creates high-value products like hydrogen and methane; P2H is seen as a form of storage since hydrogen can be reconverted using fuel cells or can be combusted in power plants. The main advantage of P2G or P2H is that gas distribution systems can provide storage systems with high capacity. Future application of these technologies will see the creation of energy hubs that use simultaneously gas, wind and solar power and that can therefore provide higher efficiency. Vehicle-to-Grid uses the synergies between the production of energy from RES and the diffusion of electric vehicle (EV) and plug-in electric vehicles (PEV), indeed the batteries installed on these vehicles, when properly connected to the grid, can be used as storage systems, indeed an EV usually is connected to the charging system for at least 8 hours but the actual charging time is usually around 90 minutes, this means that for most of the time the vehicle is idle and the battery can be used as storage (Aalto University; 2015).

1.7 ICT systems and smart grids

The energy sector has seen a rapid digitalization over the last years, with the adoption and diffusion of Information and Communication Technologies (ICT), especially in the residential areas; their use is needed for other technologies such as smart metering and smart grid. ICT implementation have been proved to be an effective solution to reduce the energy intensity and increase the energy efficiency, and their use will play a key role in reducing climate change and the environmental impact of high populated areas, where the electricity consumption is higher,

indeed they will contribute at least for 50% in the 20% greenhouse gas reduction target for Member State by the end of 2020. The use of ICT will be higher in the building sector, since it is the one using 40% of final energy and can have a big impact in increasing energy efficiency and building performances; this will be possible thanks to the use of smart metering and demand response systems, but also tanks to the influence that ICT systems can have on customers behavior.
With the implementation of ICT it is possible to collect more data on the electricity use and therefore they can provide regulators and companies quantitative basis to develop future strategies, since it will be more effective to measure Energy Efficiency policies, for example one of the directive of the EU Energy efficiency Directive wants customers to have individual prices based on their consumption (World Energy Council; 2018), and a study from VaasaETT showed that this kind of pricing can reduce costs for customers of 13%.
Connected with the implementation of ICT there is the paradigm of smart grids; smart grids include all the innovative technologies such as Demand response (DR), distributed generation (DG) and distributed energy storage (DES) that are used to make the grids more connected and flexible, and that are generally called distributed energy resources (DER). DER find applications not only at the distribution level, where they are currently more applied, but also at transmission level and in the wholesale markets. Distributed generation happens when there is an high number of small generation plants that requires to be connected to the grid; the main benefit of DG is that they can be located closer to the energy sources, making easier the operation of transportation and distribution, and can also make a more efficient use of renewable sources, reducing the carbon emissions. To solve the problem of intermittency that happens when using RES, DG can be integrated with ICT to anticipate peak or overload, and, since the plants are smaller, it will be easier to manage these situations. ICT and smart grids also improve the communication between producers and consumers, that can permit better time-based pricing, which has a big impact on customers behavior. In smart grid it is also important the use of smart meters, that are devices that can collect data on the electricity use of citizens and businesses, by being installed in the buildings and being connected with the central ICT server. (IDEA; 2013).

1.8 Horizon 2020 and the PLANET Project

In order to achieve the target of reducing the emission of greenhouse gas by 20% and of increasing the share of RES used by 20% in 2020, the European Commission created the program Horizon 2020 in 2014. Horizon 2020 is a Research and Innovation program that had a total funding of almost 77€ billion available in the period from 2014 to 2020; in addition to these, the project attracted private investments. (European Commission; 2018) Among the projects financed by Horizon, there is PLANET project, born with the scope of improve tools for the optimization of energy flows, analyze possible synergies in the energy network and facilitate the integration of RES in the electricity grid. The project began in November 2017 and will finish at the end of October 2020, with a total contribution from the EU of almost €4 million, under the coordination of the Politecnico of Turin, covering the roles of general assembly and executive board, in collaboration with 10 partners in 7 countries of the European Union for technical management and dissemination exploitation management (European Commission; 2017). In the PLANET project there will be different objectives:

- an implementation of decision support system (DSS) for different actors, like utilities, regulators and companies operating in the network; the support system will use an holistic approach to guide them in the use of innovative energy conversion and storage systems, while also investigating on the advantage of combining electricity, gas and heat networks.
- increase the penetration of RES in the electricity grid, using storage and conversion technologies;
- decrease the costs of communication between the actors involved in the electrical transmission grid with district heating and gas networks.

The holistic DSS will optimize the integration of electricity, gas and heat and network, while encouraging policies makers and grid operators to invest in innovative technologies for RES integration and conversion and storage system, while analyzing different case scenarios for the best solution on the grid and management strategies.

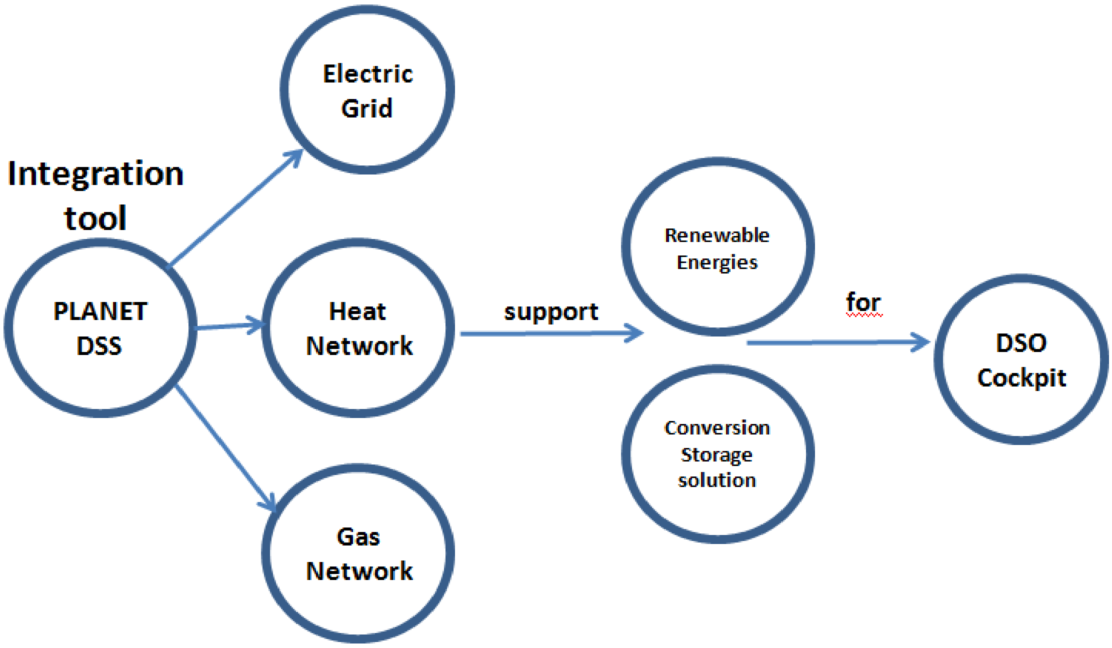


Figura 3: From project PLANET presentation

The main technologies that the project is analyzing are Power-to-Gas, Power-to-Heat, biogas, P2G and P2H in buildings; with the goals of reducing carbon emission not just on the electricity system but also on heat and gas systems (PLANET; 2018).
The project also intended to evaluate possible business models from both the point of view of the companies operating and regulator, in order to protect both interests; in particular it can be difficult to balance the need of the companies to make adequate returns and the interest of the regulators to incentivize innovation while also protecting the citizens welfare. The results of the project will be tested on two DSO, operating in the distribution of electricity, gas and heating in Italy and France; thanks to these tests, the project will also be able to conduct an analysis on how the operators can use the present infrastructures to increase the return on their capital expenses (CAPEX) under the current regulation.

1.9 The transformation of Business Models

The use of technologies that improve energy efficiency associated with the increase in the sensitization of the population about the environmental issue brought many companies in the energy sector to revisit the value proposition in their business models, and this has also been incentivized by some new regulations that promote these changes. The adoption of new business models can increase the market competitiveness of the firms, and therefore this transformation involved new companies in the market as well as incumbents that had to adapt finding way to lower their cost and increase the quality of their services. Changes in business models include:

- fulfilling the potential of the demand side
- time of use tariffs.

The first changes is an opportunity especially for small decentralized supplier, that, with the liberalization of the electricity market, can have a more important role in keeping balance between generation and demand; this better balance it is possible thank to the distribution of suppliers and thanks to ICT systems that can provide more information and forecast on the demand of electricity. In this new business model a big role will be played by demand side response (DSR) and more involvement of the customers, that can change their consumption routines to meet the capacity of the network operators; this can provide benefits to the companies, that will not have to sustain the costs of having oversized infrastructures and customers, that will benefit of a reduction of the electricity prices. The same benefits can be achieved thanks to time of use tariffs, that will be possible with the diffusion of smart meters; this technology will permit the customers to have real time data on their consumption and on the price of electricity. This system of charging customers will encourage them to increase their use of electricity when the RES are more available and to avoid times when they are scarce. (S.Hall, K. Roelich; 2016)

1.10 Innovative or green business models

It is possible to see the business model as the way the companies produces and delivers goods or services to the customers in response to the market demand, creating value that then is captured for itself and for the customers. Thanks to the implementation of new technologies and the new needs of customers, many firms had to restructure their business model in order to meet these new demands. Innovative or green business models (GBM) focus on the increase that non-technological innovations can bring to their output, from an economic and environmental view; in some cases these business models use innovative technologies, but the approach is always to put at the center of their decisions the sustainability that their use have. Even if different classification of GBM have been proposed in recent literature, it is possible to identify three main categories:

- More traditional green innovations
- coordination models for implementing synergies
- product-service systems (OECD/EC/NI; 2012).

1.10.1 Traditional green innovations

For traditional green innovation we can intend the introduction of new 'green' routines, a larger use of RES or the introduction of strategies to reduce waste. Green routines refers to the use of new materials, products or processes that reduce the environmental impact of the firms, creating not only new economic benefits to the customers, but also environmental benefits for all the citizens. A larger use of RES can be achieved in different ways, indeed beside using RES to maintain all the operations related with the production, it is possible to increase their use also in transportation and other activities in the supply chain. Strategies to reduce waste refers to the adoption of systems for a better resource management, material re-use and recycling (IDEA; 2013). In all these innovations there is a focus on the life cycle of the materials used and of the products, meaning that it is necessary to reduce the resources needed as an input to create a goods, but there is an approach with a larger view, that consider also the possibility of using the waste of one production line as an input for another, reducing the overall use of resources, that can have not only a positive impact in carbon emission and pollution, but can also be cost-saving for the firm. These innovations also go with the name of eco-innovation, that are defined by the Eco-Observatory as all the innovations that can be adopted to decrease the natural resources used while also minimizing the amount of emission across the product/service lifecycle. The adoption of eco-innovation increased in recent years especially in manufacturing and energy intensive industries, were these new technologies can have a significant positive impact also on the economic performances of the firm, indeed the most common form of eco-innovations adopted are for improving process and products creation lifecycle.

1.10.2 Coordination models for implementing synergies

Coordination models are the business models that exploit the possible synergies deriving from the cooperation of agents working closer in location or activity; thanks to this cooperation, the economic and environmental performances of the firms involved can be improved. There are two main types of coordination models, industrial symbiosis and green cities.

Industrial symbiosis refers to the coordination of companies, it can be defined as the cooperation between companies exchanging resources like waste, by-products, water and energy (Chertow; 2000); in recent years the exchange did not only included physical resources, but also services, infrastructure and utilities. The synergies are created when one of the companies produces waste that can be used by another as input, in this way both firms can benefit from this exchange, the first one because it solves the problem of the dispose of waste, and the second can get useful resources with cost-saving, by substituting alternative more

expensive inputs o by buying the same input at a more convenient price. These synergies have a positive impact on the environment since they reduce the overall use of resources consumed by the companies.
Green cities are sophisticated systems involving an high number of actors; they do not focus of one specific innovation, but involve different solutions for increasing the sustainability of high-density cities; the most common technologies involved in green cities are energy generation, ICT systems, energy storage, mobility and environment (JRC; 2018).

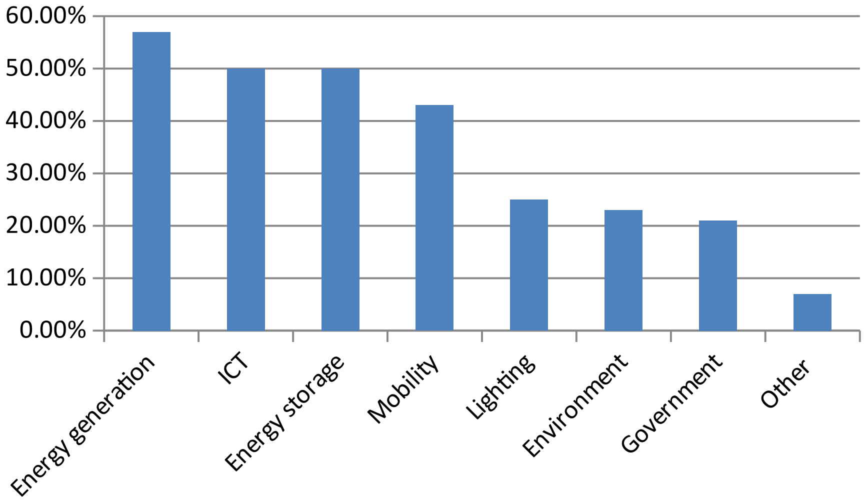


Figura 4: Share of the number of laboratories investigating in green cities technologies; JRC 2018

Green cities have been subject to a lot of innovative projects, and a study from the Joint Recent Centre in 2018 found that half of the innovation laboratories investigating on eco-innovative solutions are investigating on their potential (JRC; 2018). An important role in the development of green cities is played by the citizens, that are required to be involved by making eco-friendly decisions and adapting their behavior to the input that they receive, like decreasing their use of energy, using transportation in a more diligent way and reducing waste.
Even if they differ in terms of actors involved, both industrial symbiosis and green cities focus on the positive impact that the collaboration of multiple individuals located nearby can have on environment thanks to the sharing of resources.

1.10.3 Product-service systems

Product-service systems are systems capable of reducing the environmental impact of the production and consumption by changing the behavior of citizens and firms, pushing them through an economy more based on the service market rather than product production. In the field of GBM it is important that not all the product-service system are GBM, indeed the pure shifting from product to service that not automatically implies positive repercussion on the environment. The benefits of these models are that usually the firm can reduce the overall resources consumption by using existing infrastructure and good for more than one customer. The shift toward services also increase the possibility that the firm has to make efficiency improvements; for example by sharing their resources and capability to help the customers in making decisions good for the environment.

1.11 The role of consumers

All these transformations in the energy market are going together with the evolution of customers, that are transitioning from a passive role to a more active one, where with their behavior they can have a deep impact in the energy sector becoming 'prosumers'. Prosumers are citizens having energy resources, using and producing energy and providing storage capacity; their role will be important with the management of DES, indeed to coordinate an high number of customers connected to the grid, consuming and generating energy, ICT and smart meters will be essential to collect data to decision support systems. To encourage citizens to become prosumers it is important that the regulators create a system of tariffs, like the Feed-In-Tariffs, that can assure the consumers that the costs of having a generation or storage system will be easily re-gained in the future.

2 Regulation and investment

The different activities that take place in the electricity market have peculiar characteristics that makes them subject to different kind of market structures, indeed the operations involved in the transmission and distribution of electricity can give the opportunity for economies of scale and are also natural monopoly, on the other hand it is possible to create a competitive market for the activities of generation and supply, that will be incentivized in increasing the quality of their services by the competition.

The natural monopoly has to be maintained because the presence of many firms operating for transmission and distribution can be ineffective and uneconomic; but its presence creates the need of evaluate regulations in order to preserve customers' welfare while creating incentive to the companies having the monopoly to make investments to improve the quality of the services. Regulation presents numerous challenges also because the distinction between circumstances that make a regulated monopoly better than a competitive market is not clear, and the regulations often present some downside and is open to changes for adapting to the transformations of the sector; for this reason the regulation in many countries has a time window called "regulatory period" and at the end of it the detail of the regulation are subjected to alteration.

One of the problem connected to establish a regulation to regulate a monopoly is the inevitable lack of information and data on the market that the regulator controls, indeed in an ideal world where the regulator has perfect information on the activities of the monopolistic company, the liberalization of the market would not improve the performances (M. Armstrong; 2006); the problem is that the company has more contact with the market and its customers, and therefore will have more information that can use for its own profits.

Regulation has a main scope to guarantee a good level of welfare for customers, by avoiding that the prices are too high and there is not an appropriate amount of investments. Even if the customers are mostly concerned on prices, usually the regulators focus on investment; this is because experiences in telecommunication market has shown that missed or delayed investments can have an high welfare costs. In the past, the electricity market saw small progress in the technology used, and the incumbent firms were protected from new entrant; this situation led to small investments and a poor quality of service. For these reasons, modern legislation had a focus on incentives for investment to promote cost reduction by the separation of regulated-price setting from the costs that the firms sustain (Guthrie; 2006).

The measures helped in slowing down the increase in the price of electricity, even if it is still showing an increasing trend, as it is possible to see in the figure.

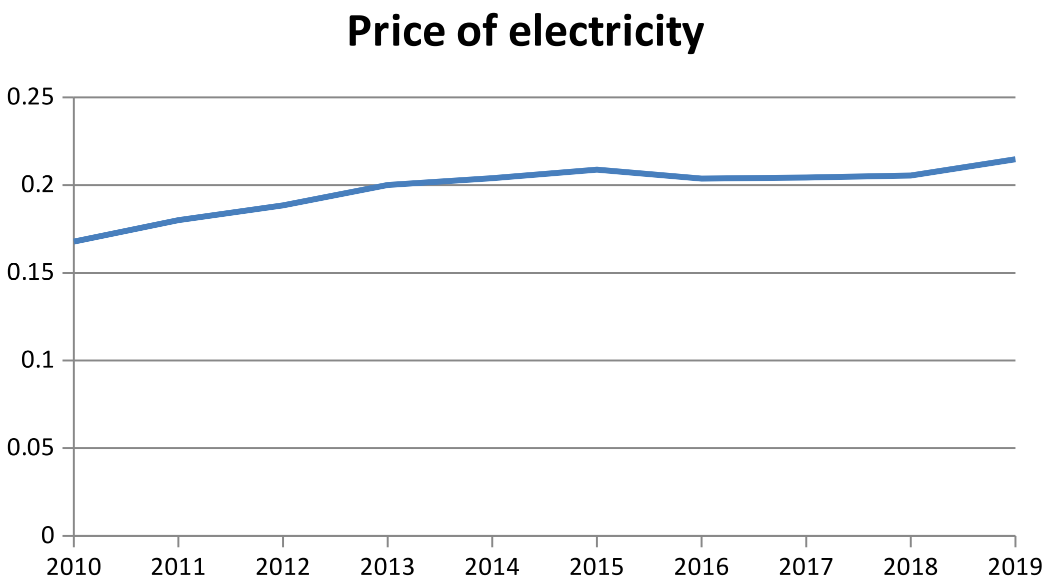


Figura 5: Elaboration of data from Eurostat DB on price (Euro/kWh)

This chapter will provide a focus on the different forms of regulation that have been adopted in the European Union and on the methodologies adopted to incentivize investments in the electricity market.

2.1 Rate of return regulation

In rate of return regulation, the regulator has the power to determine the fair price that can be charged by the monopolistic firm; the idea behind it is that the way the customers are protected from the company overcharging them taking too much advantage of its monopolistic position, while also ensuring that the stakeholders of the company would receive an appropriate return for their investment. Even if the name can be misleading, under rate of return regulation, there is not a limit on the return that the regulated firm can make, but the limit is just on the prices, in this way the firm has more incentives in reducing its costs and in operating in a more efficient way (Guthrie; 2006). At the end of the regulatory period, the regulator collects the data on the actual costs that the firm sustained to set the prices for the next regulatory period, in this way it is also possible to be sure that the firm is able to cover the investments made.
The advantages of this kind of regulation is that the prices are fair for the customers, the firm's revenues are adequate to compensate the investors, that will not earn high dividends but will have low risks, and the costs and the investments made will be covered.

On the other hand, rate of return regulation has often been criticized because the regulated firms have little incentives in making efficient investments, indeed, firms that operate under this regime have the tendency of over investing in capital without decreasing the costs of production, since all the costs sustained will be regained in the next regulatory period; this is particularly damaging for the customers, since the costs will be shifted to them.

2.2 Incentive regulation

To avoid the problem of misbehaviour from the regulated companies that the rate of return permits, there are other regulations that can be applied, so that the firms will be more prone to make efficient investment. The importance of finding an incentive system that can work without a direct intervention of the government is that in the contract between the firm and the regulator, there is asymmetric information; this is particularly difficult to solve when the regulator has to judge the cost connected to the risk of unusual project, where the firm can declare more costs than the one it actually had to sustain (European Commission; 2014). In most country the regulation went in the last years from systems like the rate of return to incentive mechanisms; the two most common are:

- price cap, in which the price level is adapted to an index resulting that takes into account the inflation and the "productivity offset";
- revenue cap, where the regulator sets the cap for the revenues that the firm is allowed to make, and then the price is set by the firm to respect that limit.

Both these methods leave the firm more independence in the operation.
Price caps was born with the idea that the regulator would face the lack of information on the decisions of the firm by setting the price to create the need for the firm to operate in the most efficient way; in other words since the firm is not able to raise the total income, the only way to make more revenues is to cut superfluous costs. Price caps regulation has also the benefits of letting the firms to choose its goals, by giving it the "menu of option", that is an offer made by the regulator of providing different reward that the firm can choose, for example one can be to reduce costs by 5 percent and keeping half of the profits o reducing cost by 10 percent and keeping all the profits (Jamison; 2007).

The prices are reviewed at the end of every regulatory period, that does not have a common length in all the countries, in order to consider the inflation rate, that reflects the increase in the costs of production that occurred in that period (it can be higher or lower than the general rate of inflation depending on how the firm is operating), and the efficiency benchmark of the other firms operating in the industry.

Revenues cap follows a similar logic to the one of the price cap, indeed the regulator decides an index, called "revenue cap index", that determine the maximum amount of the income that the firm is allowed to make in the regulatory period; this way the firm has the liberty to change prices as long as the cap is respected. This form of regulation is more suitable when the costs that the firm has to sustain do not vary very much with the quantity of product sold. Also in establishing the revenue cap index, the regulator takes into account the inflation index and the efficiency of the firm. The major downside of this mechanism is that, even if the firm is strongly incentivized to reduce costs, it is also possible that it increases the prices more than what is appropriate in a monopoly; the firm also has no benefits in seeking for new customers, since they do not have additional benefits after the cap is reached; all these problems can overall reduce customers welfare (Jamison; 2007). Since there are some cases in which the firm does not reach the number of customers needed to reach the cap, under the revenue cap regulation it is possible that the firm decides to lower the prices when the demand increases (Guthrie; 2006).

Choosing between price cap and revenue cap depends on the conditions of the market; a study on the electricity has shown that revenue caps promotes energy conservation normally, but price cap is more useful when marginal cost is large and the demand is more elastic (Campbell; 2018).

2.2.1 Increasing cost-effectiveness investments

To be able to evaluate the efficiency of the firm, the regulator, together with the efficiency at which the firm is operating, has to take into consideration the capital expenditures (CAPEX) and operating expenditures (OPEX) that the firm sustains during the regulatory period; to do so some regulators follow an ex-ante system and other an ex-post, the difference between these two mechanism is that in the first one the regulator forecast these costs and fix the legislation for the firm at the beginning of the regulatory period, while in the second system the regulator observe the actual data and then makes the adjustment needed for the firm to be in line with the contract. In the electricity network, usually the regulator does not consider the stand-alone performances of the firm, but uses benchmarking data to do a better evaluation. Most firms in the electricity market, make more consistent investment to improve the quality of the infrastructure, that can decrease the operating costs, this is especially true when the regulatory system use price-cap, since in this way the firm can increase the net profit and have more benefits in the short term period. On the other hand CAPEX require more time to generate profits, and there is the risk that the firm is not incentivized in making these investment, especially if the pay-back time is longer than the regulatory period. Capital and Operating expenditures usually are inversely proportional, meaning that when a firm sustains more operating costs, the capital expenditures will decrease, and the other way around, for example maintenance will increase OPEX but it will reduce the amount of capital expenses that will be required later. To promote both kind of investments in an effective way the regulator can follow two systems, the first one is the TOTEX-based and the second is "building block".

Under the "building blocks" approach, the regulator uses a forecast of both CAPEX and OPEX as main factor to establish the total revenue of the firm during the regulatory period; the regulator also decides the amount of revenues allowed for the firm during the regulatory period. In making this decision the revenues are calculated as a sum of different factors, called building blocks, these are the depreciation, the OPEX, the return on capital and eventually taxes and incentives. The building blocks do not have all the same influence in the revenue cap, indeed usually the return on capital reach a weight of more than 50%, while the remaining is divided between the other components; the CAPEX are taken into account, not directly, but in the calculation of the regulatory asset base (RAB), that consider the RAB of the previous regulatory period, inflation, CAPEX and depreciation (AER; 2017). The idea behind the building blocks approach is that the firm will have a cash flow with a net present value of zero, by balancing the revenues with the expenditures; but some questions on its efficiency arise because the firm is incentivized more in investing in capital expenditures, since they influence the RAB, than on OPEX that could improve the efficiency and the quality of the service of the firm. To solve this problem some countries, like the UK, implemented a solution that balance the importance of capital and operating expenditures in a solution called "TOTEX".

Total Expenditures, or TOTEX, is used not only in the electricity sector, but in all the industries that require high infrastructure assets; with this approach, the regulators want to keep the benefits of the firm investing in capital expenses without the limitation of reduced investments for improving the quality and the efficiency of the service. The main difference between totes and building blocks approach is that while in the building block capex and opex are treated in two different ways, in TOTEX the firm has an expenditure allowance to cover both; thanks to this system, total expenditures approach can overcome the unbalance between capex and opex that happens in the building block approach. The main benefits of this approach are:

- a reduction in the tendency of the firm to under invest in innovative operational solution;
- more simplicity and a reduction of the bureaucratic process that precede the permission for the firm to proceed with the investments;
- the firm is more flexible in making investments with longer payback time;

- it is easier for the regulator to analyze the data of the firm and compare them with the benchmark (Energy Network Australia; 2017).

2.2.2 Other incentive regulation

The incentives mechanism we have seen so far wanted to establish the revenue or price cap using the expenses that the firm sustained in the regulatory period, however recent evidence shows that, due to the increase in technological innovation in the electricity sector, using the inputs of the firm as the main variable is not the most efficient way to promote innovation and technological progress (European Commission; 2014). A solution adopted by a number of countries, like Italy, UK, Australia and others, is the use of "output based regulation"; the difference with input-based system, is that with an input based regulation the firm is rewarded mostly when it adopts strategy to decrease costs, while output-based approach uses the quality of supply, sustainability, efficiency, innovation and other indicators of the performances of the firm to assess the reasonable profit that the firm is allowed to make in the regulatory period. This regulation guarantees more operational freedom to the firm, since once the regulator sets the target that the firm is supposed to reach, it leaves complete autonomy to the firm in making the best decisions to achieve them; evidence has showed that when the regulator takes into consideration the actual performances of the firm, the challenges of incentivizing the firm to make the best decisions for investments, innovation and sustainability are more easily solved and that output-based systems give more incentive to the firm to improve quantity and quality of the service (Tobiasson; 2015). One downside of this mechanism is that, even if it reduce the number of ineffective investments, the firm may not be able to make the expected profits and meet the shareholders expectations when the targets set by the regulator are too high and the firm has to increase its expenditures over the reasonable limit.

2.3 Regulation and infrastructure investments

After the energy market was liberalized, many regulators focused on promoting innovation, the use of new technologies and competition between the firm; this change in the targets of the regulators was reflected in the legislation adopted, indeed until thirty years ago many regulations were based on rate-of-return, now we witness to the diffusion on incentives mechanism to promote firm's efficiency, innovation and competition. The effect of structural reforms has been proven to have influence not only in the amount but also in the kind of investments that the firms make (Griffith; 2010), for example it is observed that under the rate-of-return system the firm is not enough incentivized to make innovative investments, while regulation that take as main variables the expenditures may push the firm to make investments unbalanced between operating and capital costs. Regulation influences also the risks that the firm is willing to take, cost plus mechanisms bring low risk to the firm, for example in a rate-of-return regulation the firm is assured with a constant return without having to make investments, while a price-cap regulation is way more risky but also incentivize more the firm to make investments to reduce costs. There is also Averch-Johnson to take into consideration when evaluating the effectiveness of a regulatory system, indeed if the regulation allows a rate of return that is higher than the cost of capital, the firms will have the tendency to invest a lot more in capital, with a reduction of the efficiency of these investments.

Price cap regulation, on the other hand can be more effective in leading the firm into committing to make more investment to increase the efficiency, since lowering the cost is essential to make reasonable profit under this system, but can also have the negative effect to push the firm into reduce the quality of the services given to the customers in order to reduce costs. Even more recent regulatory policies, like incentive regulation, can lead to negative results like underinvestment.

When considering the variables to take into consideration to set the rate base, there are three conditions that should have priority:

- no windfall profits should be allowed;
- the rate base have to be positive or equal to zero before when the company is entering in the market;
- the return that the firm makes should be high enough to attract investors (Guthrie; 2006).

Using these principles, three regulatory systems have been developed, that can be more effective in incentivizing the firm in making investments and adopting new technologies, these systems use additional variables that can be added to the regulation to improve it are:

- the regulatory asset base;
- timing of the regulatory review;
- the regulator's decision making and uncertainty (Egert; 2009).

2.3.1 The Regulatory Asset Base (RAB)

The regulatory asset base is a variable used as the main parameter to establish the rate of return that the firm is allowed to make; the idea is that in regulations that calculate the rate using all assets owned by the firm, the firm may be predisposed to make too risky investment, so it is preferable that the firm propose to the regulator the investments it wants to make at the beginning of the regulatory period, and then the regulator selects those with a reasonable risk, and consider only them to calculate the rate of return. With this strategy, the regulator allows the firm to recover only the cost associated to assets that are necessary to provide the services to the customers. The decisions on which costs will be taken into consideration happens ex-ante at the beginning of the regulatory period, but other informations can be added ex-post, so that the costs of the firm that will be recovered are more similar to the actual ones. Using actual costs can however cause problems, especially if the firm is simultaneously in a competitive and non-competitive market (Braeutigam, Panzar; 1989), because the firm will be tempted to overproduce in the market where it has the monopoly, so that a share of these costs, that will be recovered, will be included in the production in the competitive market. Being subjected to this disallowance of the costs by the regulator, will make the firm more selective in choosing its investments; it will be a duty of the regulator to behave in the right way to not completely limit the willingness of the firm to invest in new projects, since a too restrictive regulation can cause the firm to invest only in small projects that do not bring enough innovation.

2.3.2 Timing of the regulatory review

The duration of the regulatory period is relevant, since if it is long enough compared to the payback time of the investments, the firm will be incentivize to make investments to reduce costs, this is because these costs will be passed to the customers in the next regulatory period if there is a rate-of-return regulation. Normally the firm will increase its investments right after the review of its cost by the regulator to maximise payoff (Egert; 2009), in this way the firm can also reduce the uncertainty of the investments. The timing of the review can be seen in function of the profitability of the firm under rate-of-return regulations, this is because if the firm's return drops under a reasonable limit, the firm will request the regulator to review the contracts, while if the returns are too high the review can be asked by the customers.

If the regulatory period is too short, the risk is the firm will not have enough time to gain from its investments and therefore it will be less incentivized into making costs-saving investments.

2.3.3 The regulator's decision making and uncertainty

Until now we have seen that the firm can take advantage of the regulatory regimes by making opportunistic decisions that may have negative consequences on the customers welfare; but there is space also for the regulators to make opportunistic decisions, for examples it may operate under the influence of public administration or politicians and set prices or the rate of return below the amount necessary for the firm to be profitable; if this happens the firm will not make investments, and the innovation will be discouraged (Egert; 2009). A study from Guthrie shows that when the firm operates under a regulation that does not guarantee consistency in time, it will make more small-size investments, since these bring less risk and it will be easier to see how the regulator reacts to them in the next regulatory period.

To avoid that the regulator is biased in establishing the regulation, in many countries the regulator is an independent body, so that it has more credibility and the firm will face less uncertainty in the relationship. Another way to reduce opportunistic behaviour by the regulator is to use ex-ante profit sharing contracts.

2.4 The effect of competition and regulation on innovation

In the last years, the electricity market in most countries has been liberalized, and the regulators are trying to determine what is the best way to promote competition in regulated industries, this indecision is due to the fact that choosing between a regulated monopoly and unregulated competition is complex and it is influenced by many factors, such as the technological advancement and the regulator's resources, that make the optimal decision not unique for all countries (Armstrong, Sappington; 2005).
The main benefits of having competition in the market are that the firms operating will be encouraged in making investments that can reduce their operating costs while also making their processes more efficient, in order to maintain or gain market share and be profitable. However, when too many firms are in competition it is easier that the innovation is reduced by phenomenon of imitation while a concentrated market can leave more profits to the monopolistic firm to invest in research and development.
The potential benefits of having a liberalized market are substantially four:

- increasing efficiency;
- stimulating innovation;
- stimulating infrastructure investments.

A deregulated market will leave the firms with more market share with extra profits, and this have a positive impact on the infrastructure investments, but the lack of incentive regulation in this kind of market have negative impact on the level of investments made to increase of efficiency and innovation. Regulations that leaves the firms with no extra profits for the improvements made in the production, like the adoption of costs saving routines, reduces the investments made by the firm; these regulations include cost-plus mechanism and rate-of-return regulation (Armstrong, Sappington; 2005). To avoid this limitation it is preferable to adopt regulations, like the price cap, that permits the firm to have more profits by investing in innovation or by reducing its operating cost.

2.5 Regulatory approaches to innovation

To the conventional regulations using cost-plus mechanisms and incentive regulation to incentivizes firms in investing in R&D activities and demonstration projects, there is the possibility of considering other variables still maintaining the same kind of approach; in this section we will see two main categories:

- input or cost based;
- output or price based.

These two mechanisms can be seen as opposite cases with regards on how they have an impact on the network innovations and how they are incentivized (Bauknecht; 2011); other differences are on the way that the regulators decides who has to bear the risks of the investments, indeed in the input system the risk is on the customers, since a bad investment will still increase the expenditures made by the firm that can therefore increase the price of its service, while in output based regulations the firm bears the risk and the innovation is promoted by providing the firm with more benefits if it reach the performances' target.

2.5.1 Input or cost-based systems

The base of cost-based mechanisms is that the regulator collect frequently the data on the costs that the firm in sustaining during the regulatory period and uses them as main variable to establish the maximum amount that the firm can charge to the customers. In this basic form, the companies will have no problems in investing high amount in innovation projects since these costs are reflected in higher tariffs on the customers, but on the other hand they will have no benefits if these projects have as main benefits a cost reduction, because in this case the regulator will decrease the amount they can charge. But this is mostly just an ideal situation, indeed in reality it often happens that the condition under which the firm is operating change during the regulatory period, and the regulator does not have enough time to collect the data and adjust the conditions of the contract in time, so that the firm may retain temporarily additional profits; in this case the firm will be more incentivized to commit time and effort to carry on innovation projects. However it is common that the regulator will use the new informations for ex-post adjustments or to set the conditions for the next regulatory period.
Usually the regulator has two options to treat the research and development costs sustained by the firm, indeed it can consider them investments and add them to the capital expenditures, and then in the RAB, or it can consider them as operating expenditures. In input based systems they are always tread as capital expenditures, the reason behind this is that they provide benefits for a period that is usually longer than the regulatory period. The downside of using input based

mechanisms is that the firms do not have incentive in adopting the most efficient way when investing, since they will have the same return.

2.5.2 Output or price based systems

The price-based systems were elaborated in order to reduce the tendency of overinvesting while being under an input based mechanisms, and currently are the most dominant kind of regulation. In these systems the regulator sets targets for the firm to be reached by the end of the regulatory period and then uses the performances of the firm as main variable to establish the reasonable return. The firm is therefore more incentivized in making efficient investment since they can gain more if the innovation bring them costs saving and a general reduction of operating expenditures. To provide the benefits to the firm that successfully reach the targets set by the regulator, there are different mechanisms: increasing the allowed revenues, increase the duration of the regulatory period or create regulatory holidays (Bauknecht; 2011).

The first method consist in letting the firm increase the price charged to the customers, so that it can retain additional profits, both to recover the costs of the investments and to create profits for the shareholders.

The second way consist in extending the duration of the regulatory period; the reason why the firm can benefit from this is that when the firm improve its process and reduces the costs, it can gain from this only until the end of the regulatory period, and then the benefits will be passed to the customers in the form of reduced price for the service. This method is not often used because it allows the firm to take advantage of the situation by starting to utilize the new technologies at the beginning of a new regulatory period even if the investments that lead to it happened before.

The last system identified by Bauknecht happen when the regulator decides to let the firm benefits from its investments by exempting it from the regulation, so it can decide how much to charge the consumers and therefore maximize the rate of return. This system has never been used for electricity services with only one firm operating, because the impact it could have on the consumers welfare would be too negligent.

3. Current situation in the EU electricity market

This chapter analyses the current situation in the EU member states. In particular the analysis will focus on the regulatory systems adopted, what the regulatory authorities are doing to promote innovation and the outcome of these incentives. For the countries analyzed it will be presented an introduction on the choice that

the regulator has make to respect the targets set by the European Union for 2020, then updated to 2030, the hierarchical organization between the regulator and other government's bodies and finally a presentation on the projects carried on in the country, with regards to who are the financing bodies.
The countries analyzed will be Sweden, Spain, Ireland, Portugal and Switzerland; to these there will also be an overview of the project conducted on a larger scale in Europe, Horizon2020, financed by the EU's funding programme.
The challenges to this study have been due to:

- the scarcity of data on some of the innovation projects, partially due to the fact that the information on the exact amount invested by private firm are not always public;
- the ambiguity concerning the innovative projects and what can be included in this definition;
- the privacy that some firms want to keep around their activity, that pushes them to not take part in market analysis, like the one conducted by the Joint Research Centre.

However, this analysis can help in providing an overview of the current situation in the electricity market in Europe and what should be the next step to achieve the ambitious targets set at the communitarian level for the next years.

3.1 Evolution of Smart Grids in Europe

The most reliable source to have an overview on the current state of the Smart Grids projects in the EU is the Joint Research Centre (JRC), that operates under the control of the European Commission, supporting the decisions taken by the EC with insightful data; one of their most recent publications, "Smart grid projects outlook 2017", was conducted in order to sustain the measures proposed in the package made by the EC "Clean energy for all Europeans", a plan made by the European Union to promote the transition from fossil fuel to clean energy. Since this package required a large use of new smart technologies in the electricity market, the JRC conducted an analysis of smart grid projects in 28 Member State, with the addition of Switzerland and Norway, other countries are considered only if they are involved in joint projects with other participants from the group, for a total of 50 countries; the data collected involved 950 projects between demonstrations and smart grid R&D, with global investments of around 5€ billion from the year 2004 to 2015. Unluckily not all the investors released complete informations on the project, so for some of these the budget information have only been estimated.
From the evolution of the numbers on the investments and number of projects over the years, we can observe that from 2005 they both showed an increasing trend until 2012, when the number of projects was 351 and the amount invested reached its peak with 936€ million invested.
The reason why the number of projects and investments started to decrease after 2012 has been associated with the choice of private investors to commit to investments with less risk, and investing in innovative projects with a low Technology Readiness Level gives more opportunity for high return but also carries high risk; another reason for the lower numbers in the last years can also be associated with the difficulties of collecting data of more recent projects.

Figura 6: Number of projects and total investments over time, from JRC "Smart Grid Projects Outlook 2017"

Regarding to the countries in which the projects take place, we can say that the investments are concentrated in France, Germany, the United Kingdom, Spain and Denmark and also that some countries started to invest in smart grid years in advance compared to the rest of the others.
It is also important to notice that these numbers do not make a distinction between demonstration projects and R&D projects, however, these two kinds of investments differ for numerosity and for effort required, indeed out of the 950 projects included in the database, 540 are on R&D and 410 are demonstrations; even if the demonstration project are only 43% of the total, they account for 3.36€ billion, making up more than 62% of the total investments, this is because the average cost for demonstration projects is 8.2€ million, compared to the less than 3€ million for R&D projects.

3.1.2 Smart Grid Laboratories

In addition to R&D projects and demonstration projects, there is also a number of laboratories in Europe studying new technologies that can be applied in the electricity sector to improve the efficiency and the share of energy produced from RES. The next figure shows the percentage of laboratories per activities, resulting from a survey done by the JRC in 2018, involving 89 laboratories across Europe and, a smaller part, from the United States.

Category	%
Generation and DER	81%
Demand Response	76%
Grid Management	73%
Storage	70%
ICT: Communication	69%
Electromobility	66%
Smart Home/Building	64%
Distribution automation	61%
Smart City	51%
AMI: Adavanced Metering Infrastructure	46%
Market	45%
Cyber Security	42%
Sustainability	33%

Figura 7: Share of laboratories per activity, from JRC

As it is possible to notice most laboratories do not focus on just one activity, this can be due to the synergies derived from implementing more than one technologies and the fact that these activities share the need for the same data as input to continue the researches.

The amount of money invested in the laboratories has a wide range; indeed some of the lab required and investment below 100k€, while the most expensive reached 5€ million; there also notable differences in the duration of these investment, with some of them having a duration of one year, with some of them lasting for over 10 years (JRC; 2018).

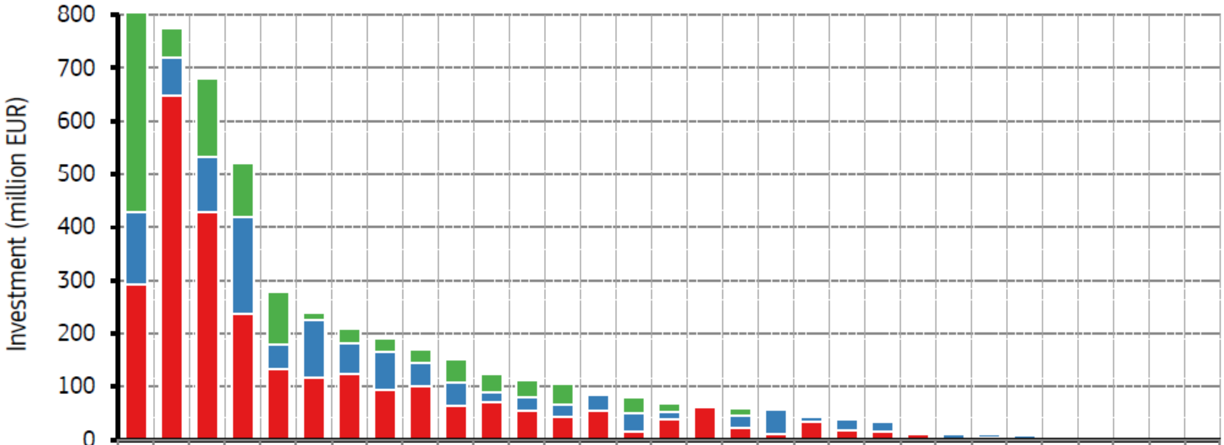
3.1.3 Overview of the investments made

In this paragraph we will furnish a deeper analysis of the investments made; the first thing to point out is that the financing sources come from three main groups, that are National Entities, the European Union and private industries, among these, the organization types that invested more are national DSOs, Universities and Technology manufacturers, that have also been the most active in terms of time effort in directing these projects.

About the countries in which the investments take places, there is an high concentration in the top three countries, that are Germany, UK and Denmark, in which take place 57% of the projects; in most of the countries the investments are mostly coming from demonstration projects, few exceptions are Denmark, Finland, Norway and Switzerland, in which the majority of the investments are from R&D projects, a reason to this is the presence in these countries of regulations that incentivize more these investments, with funding and programmes.
The projects for the development of smart grids need high investments and also involve high risks, two factors that have a negative influence on the investment decisions; for this reason, in order to promote these investments, it is crucial the role of external funding, such as incentives and private investments. The kind of project that will be developed has influence over the source of the funding; in the study by JRC it has emerged that:

- network operators are more interested in investing in projects that focus on technologies to enable the integration distributed energy sources while maintaining high level of reliability and efficiency;
- ICT developers, focus their investments in projects implementing solutions applicable in real life scenario and studying new technologies;
- public institutions focus on smart grid projects that have an high level of sustainability, reliability and are affordable.

The financing sources of the projects have been classified in three macro groups, that are national regulatory sources, private investors, and the European Commission; the group of private investors includes also the funding coming from incentives given to private from national authorities. The study revealed that, regarding the source of financing, there are notable differences between countries, due to different funding schemes, the level of access to the European funding by privates and the presence of incubators.



	DE	UK	FR	ES	DK	IT	NL	BE	SE	AT	CH	NO	FI	PT	EL	PL	LU	Non -EU	RO	CZ	SI	IE	HU	SK	LT	BG	LV	HR	CY	EE	MT
Total	809	774	680	522	279	239	209	190	171	152	123	112	106	89	78	69	61	59	58	43	42	34	16	12	10	8	7.7	6.2	4.8	3.3	2.2
National	382	54	148	104	100	14	27	25	25	44	33	31	41	4.2	28	17	0.3	13	2.4	1.3	3.8	0.9		1			0.1		0.1	0.1	0
EC	136	71	105	182	46	108	58	71	45	45	19	27	22	30	36	14	0.5	24	45	9.7	20	19	5.8	8.8	6	5.7	3.4	3.3	3	2.1	1.6
Private	291	649	428	236	133	117	124	94	101	63	71	54	43	55	14	38	60	21	10	32	18	14	10	2	4.1	2.3	4.1	2.9	1.7	1.1	0.6

Figura 8: Investments per country by source of financing, JRC

Figure 3 shows a detail of the source of financing; it is possible to notice that there is not a specific trend in the sources of fundings, meaning that there is not an optimal ratio to promote investments, indeed even if in the majority of the countries the highest source of funding is private investments, in Denmark, that is the country with most investments, the national funding constitutes the highest share. The total amount of investments shows that the majority of the funds are made by private investors, that cover 54% of the total investments, followed by financial support by the European Commission and National organization, respectively 24% and 22%. More in detail the largest investors are Distribution System Operators, Universities and technology manufacturers; for these categories there are also notable differences in how the projects are financed, indeed projects organized by DNOs have more than 70% of the financing coming from private sources, while this quota is lower for public bodies, with research centres having only 38% of the financing coming from privates.
Comparing the investments in each country its useful to have an idea on the current advancement in the research on smart grid, but it can be misleading in

terms of effort that the countries are committing to, since the quantity of fundings coming from national organizations and EC are proportioned to the dimensions of the country; for this reason another useful way to observe the data is after the normalization per capita, offered in figure 4. The differences that emerge in the ranking of numerous countries are due to the different challenges that countries with different number of citizens face when it comes to guarantee the reliability and efficiency of the grid. A notable example is offered by Luxembourg, that before the normalization was under the EU average and then, after the normalization, becomes the country that invests more.

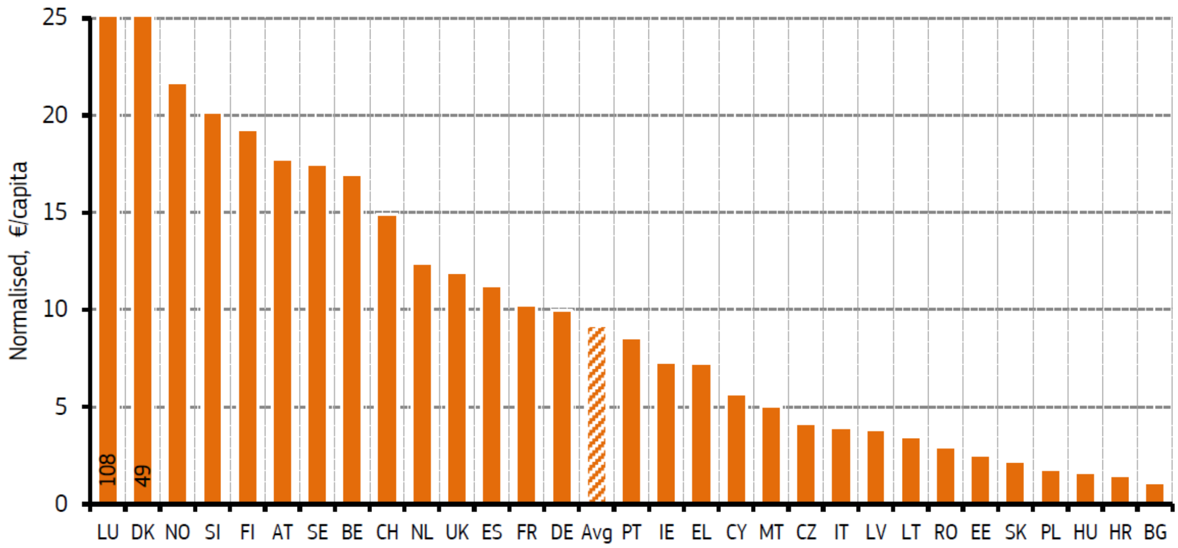


Figura 9: Investments per capita, JRC

3.2 European initiatives and programme Horizon Europe

As anticipated in Chapter 2, the European Union fixed high targets of sustainability and low environmental impact to reach in the future, one goals was to reduce greenhouse gas emissions by up to 95% in 2050 compared to 1990, to help member countries reach this target, the "Energy Roadmap 2050" was created, establishing the major points of the plan. The final outcome in the energy market wanted to increase the well-being of the population, the competitiveness, the sustainability and security of energy. As declared by the ex European Commissioner for Energy, Günther Oettinger, reaching the goals in the energy market required high investments to improve technologies that will play a key role in the future, and to attract these investments it is important to have a common European approach that can reduce the uncertainty around these new technologies. In this contest, the European Commission founded the programme Horizon 2020, in this program the EC destined a budget of €80 billion to be used to finance projects of research and Innovation over the time period from 2014 to 2020; the final and biggest tranche will be given in 2020 and it amount to €11 billion.

For these final investments, the funds will be focused on few topics, climate change and clean energy are among these crucial researches that will be covered, with overall investments of €3.7 billion; this final phase of the programme will also be used to set the new lines for the next framework programme Horizon Europe, that will start in 2021 and finish in 2027.

With Horizon Europe, the biggest difference will be the European Innovation Council, a bodies of the EU that will help the projects founded to become scalable business. This new programme have a proposed budget of €100 billion; the reason for this high budget is related to the positive outcomes of Horizon 2020, indeed the Commissioner for Research, Science and Innovation, Carlos Moedas, said that 100 euro invested in Horizon 2020 can produce an increase of 850 euro to the European GDP by 2030.

The planning of Horizon Europe will have a focus on global challenges and industrial competitiveness, and will also try to increase the participation of the European Research Area.

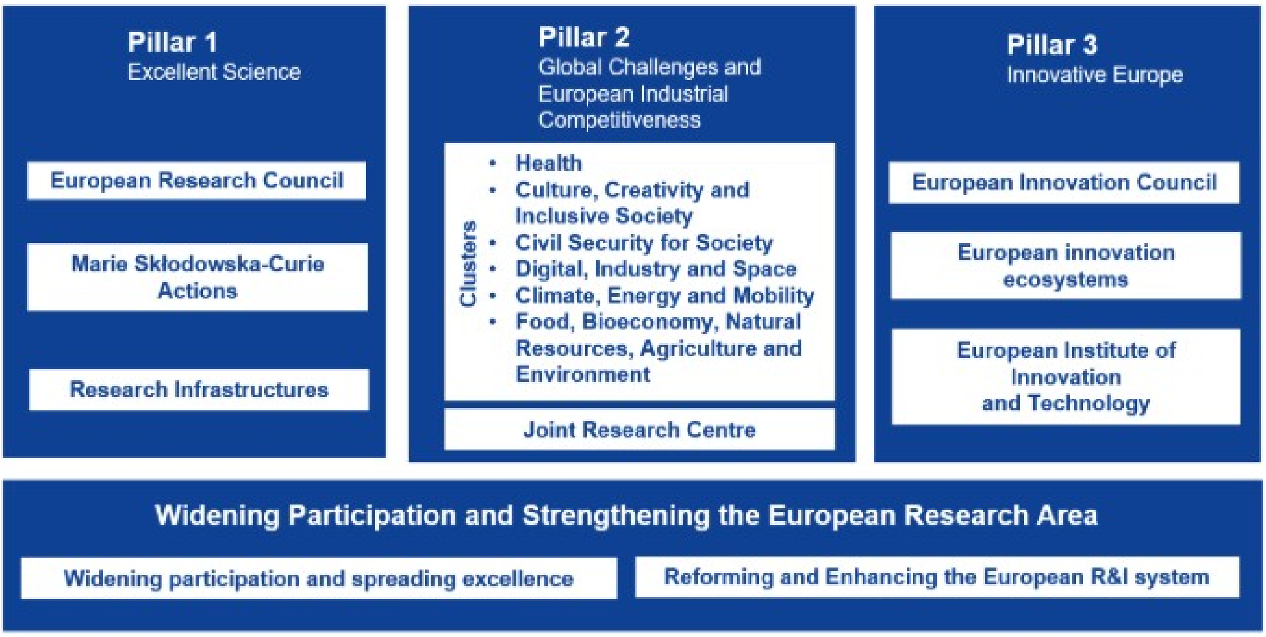


Figura 10: Preliminary structure of Horizon Europe; European Commission

In the preliminary phase of the programme, will be indentified the key areas on which investments will be focused, the missions of the projects and the areas of international cooperation.

3.3 Sweden

The framework of Energy Policy in Sweden was defined in 2016 with the Framework Agreement on Energy Policy, with this agreement the country set the goal of a zero-carbon economy by 2045 by having 100% share of renewable sources in electricity generation by 2040. The country is advanced in reaching this target , because the production of electricity has always been based on hydropower and nuclear power, which provide a combination of safety and flexibility (International Energy Agency; 2019).

Being part of the European Union, Sweden has to set his line of energy policy with those set by the EU about the principles of being sustainable, fair for the market and providing stability of supply. Nowadays, Sweden produces more than fifty percent of its energy from renewable sources, indeed, as said before, hydropower plays a big role in the production of energy, providing around 48 percent of energy; other big sources of energy are biofuels and wind power. The country also relies on nuclear power for the generation of energy (David L. Swartz; 2014).

3.3.1 The market

The process for the liberalization of the Swedish electricity market started when it was reformed in 1996; in these occasion it was established that the production of electricity was subject to competition, while the network would have still involved various monopolies. Competition in the production is expected to provide[1] customers more choice and incentive the producers in using in a more effective way their resources, while the network operations and the distribution are natural monopoly and allowing a large number of different firm work too closely would not be the best decision in efficiency and cost-benefit. (Swedish Energy Market Inspectorate; 2017).

3.3.2 Regulation

The Swedish energy market is regulated by the Swedish Energy Market Inspectorate (Ei), a regulatory body working under the authority of the Ministry of Enterprise, Energy and Communications. Its work is to superintend the energy market, that includes natural gas, electricity and district heating; and it is also responsible of the efficiency of these markets.

The national grid is operated by Svenska Kraftnät, a public company owned by the state, that works to distribute the electricity to small regional grids after having acquired it from power stations, to accomplish this, it can operate on all the national grids.

[1] All the information on the leagislation comes from David Shwartz “Energy regulation and market review”

Being under the Electricity Act2, Svenska Kraftnät, is the Distribution System Operator responsible for the correct cooperation between all the electrical plants working in the country, indeed the national DSO has to guarantee that the electric market is stable and that demand and supply are balanced. Between the responsibility of Svenska Kraftnät there is also the correct functioning of the natural gas system. In some cases the use of the national network can be given to other operators when they meet the criteria to be considered adequate; if these criteria are fulfilled, the concession can be given only to legal persons suitable. At the moment the concession to use the network has been granted only to Svenska Kraftnät and other related companies.

3.3.3 Vertical integration and unbundling

Among the principal purposes of the Electricity Act there was to set up a disjunction of the operations of transmitting and distributing electricity from those of production or generation, nevertheless it also had to take into consideration the already existing companies with high degree of vertical integration. With these scopes intent the Electricity Act established that the companies operating in the network operation could not also be involved in activities of generation and trade. Despite this legal limit, there is a case in which the network companies are allowed to generate energy, indeed they have such permission when the generation of energy is necessary to indemnify for losses that may occur in the network. The Swedish Transmission System Operators (TSO) model is applied to the trade of electricity and gas; Svenska Kraftnät is the only company on which this model is applied, because, the national grid is the only network that can be considered a 'transmission system operator', according to the Directive's definition.

3.3.4 Rates (Regulatory Framework Report)

According to the regulator, the tariffs applied to the customers for transmitting and distributing electricity have to be unbiased and impartial, to guarantee that there is as less as possible inconvenience to customers. It is important to say that on this side, the Swedish regulation changed, indeed the Electricity Act went from a system that charged tariffs using a ex-post basis to one using an ex-ante regulation that uses an income ??? revenues??? cap; the first time the cap was applied was on 1 January 2012.

Using an ex-post regulation means that the tariffs were decided and charged by the network operators before they were approved by the Swedish Energy Market Inspectorate, and then the role of the EI was to watch over them and interpose in case the tariffs were reputed not affordable.

Adopting the ex-ante regulation also had the goal to make the legislation more aligned to the directives from the European Union. With this system, the

Inspectorate decides the amount of profits that the network operator is allowed to make, usually using a time window of four years, so that there is an income cap. When the time window ends, the EI calculates the deviation from the income cap established and the actual revenues of the network operator. If the actual revenues exceed the established cap, the difference will be detracted from the cap for the next regulatory period, in the same way, any deficit will be added; there are some circumstances that allow the Energy Inspectorate to change the income cap before the end of the four years.
To establish the cap, the Inspector has to consider the costs that the network operator will sustain in the period, since they have to be fully covered, and also give the opportunity to gain a rate of return in line with the benchmark of the industry; there are other factors to be considered when fixing the cap, like the quality of the services provided by the operator.
When the cap system entered into force, the network operators applied and required what they considered a reasonable income cap; only few of the application were acknowledged by the Inspector and they were considerably lower than the rest of the applications. Numerous operators that applied and were not accepted invoked the administrative court against the decision of the Inspectorate; the administrative court judged in favour of the grid operators in most of the cases.

3.3.5 Development of renewable energy

The actual policies concerning climate and use of renewable sources for energy in Sweden started to be developed in 2009, when the Swedish parliament began to aim to new goals for the consumption of clean energy to be reached by 2020; the main target was to reach a minimum amount of 50% of energy consumed generated by renewable sources, which is a lot more than the one determined by the European Union, that is 20%. Sweden usually relied on taxation to promote the reaching of these targets; indeed, since the tax reform in 1990, the country adopted a system of "green tax exchange". This system contemplate having more taxation on energy and using these tax to reduce income tax and other action that can incentivise citizens to make more eco-friendly decisions. The guideline of the taxation system utilized in the green tax scheme is provide by the Act on Excise Duties on Energy. Sweden also utilizes incentives such as emission trading rights and electricity certificates, that are popular market-based ways to promote a more reasonable impact on the environment; the Electricity Certificates Act uses competitive market bases to encourage the generator of energy to use renewable resources.
The Swedish state created a system that uses certificates that can be traded on the market of supply of electricity by the producers; the producers earns a certificate every time it produces a megawatt hour of electricity using renewable

sources. Every producer has to have a determined number of green certificates; to reach the number imposed by the regulator he can buy them from other producers or have them from the State by producing energy from sources like geothermal power, solar power, some kind of biofuels, hydropower and other renewable sources. The certificates system creates a market demand that influence the producers to obtain green certificates to sell them and to keep them to avoid the taxation for not reaching their 'quota obligation'. The fee imposed to those that do not reach their obligation is paid by the customers, since it will be considered as a cost sustained in the period while calculating the income cap.

3.4 Projects in Sweden

3.4.1 Stockholm Royal Seaport Smart Grid

One of the main projects going on in Sweden is to develop a Green City in Stockholm; according to the definition of OECD, a green city is a system involving numerous entities that combine many innovative environmental solutions. The main goal of green cities is to promote a coordinate effort from the actors involved, to act in a more considerate way towards the environment and to reduce the impact they have on it, this can be achieved by minimising the use of waste of water, energy and mono-usage consumables, and also by reducing pollution and other kind of waste, both from industry and private. The initiatives to promote a Green Cities can be taken on a large scale from governments, but also on a smaller scale from municipal administrations; such initiatives include the financing department of Research and Development in the field of renewable energy or enforcing to respect determined standards. This is system of financing, when is not integrated with the coordination of the actors involved, is more correctly applied to classic ecological business model rather than green cities, since to promote a green cities the aspect of coordination cannot be ignored. Before going further into talking about Stockholm green city, it is important to underline the difference between industrial symbiosis and green cities, indeed these differ significantly for the target involved: the first one sees as actors only industries and on the other hand, green cities involve also individuals. (IDEA; 2013)
In Europe, in terms of actors involved and total investment, the Royal Seaport is one of the greater project for ecologic development; the entire project has been developed with the target of increasing the ecological sustainability and to reduce the environmental impact of the city, for this reason the administration of Stockholm wanted the district to be created using elevated standards, and nowadays the project is considered a good practice from other countries.
Stockholm Royal seaport wants to create a complex system that will be used for testing the possible applications of the smart grid also on bigger scale; from this

side of the project, the smart grid wants aims at guaranteeing a diminution of the losses that may occur in traditional grid and a making the power of the grid higher, so that it can better face eventually peak in the demand of electricity. One of the expected outcome of the project is to provide data that can guide the regulator to create a new set of regulation to guide the customers towards more sustainable decisions. In the project are involved 12 thousand residential houses and 35 thousand workplaces, with the goal of making them fossil fuel free by 2030 (Stockholm Royal Seaport website).
The projects involves different organizing bodies, and only one of them is a private firm; the two major organizer bodies of the project are:

- ABB (Asea Brown Boveri), a Swedish company that operates for the transmission and the distribution of electricity;
- Fortum, a Finnish state-owned company and Swedish Energy Agency.

To carry on the project there is also the support from the Swedish R&D administrator VINNOVA, the municipality of the City of Stockholm and the Clinton Climate Initiative.
Besides making the city independent from energy generated from fossil-fuel, the project also has the goal to reduce the carbon emission under 1.5 tons per capita, which is an ambitious target considering that when the project was firstly conceived the emission per capita were 4.5 tons. This project, like the other green cities, wants as well make the households more responsible for the choice they make and create active energy 'prosumers', that means that the individuals, besides consuming energy, produces it. In order for this to happen, the individuals involved in the Royal Seaport will be able to:

- install solar panels and to use them to produce electricity, the smart grid will then use the electricity for sale or will store it into local storage units.
- be more conscious of their energy consumption, by being informed of the way they use electricity and of the times of the day in which it is more convenient supply of energy produced by renewable sources.
- have charging station to charge electric cars; in this case the smart grid is able to inform the citizens of the times of the day when the electricity is less expensive and the environmental impact is less significant. Additionally the electric cars can be a substitute of the local storage unit, since the batteries can be used as power reserve for the whole district.

Other goals of the project are to collect data and other information to be used for future green cities project, understand if there are other possible concept for smart grid, create new business models and policies to increase the benefits of smart grid and prosumers. The smart grid conceived for this project also wants to be

more sustainable and reliable by reducing peak in some times of the days, as already said, this wants to be achieved by making consumers more informed.
This project was divided in more phases, it started to be implemented as a concept in 2010, with plans and studies of similar project, and then it started the phase of implementation in 2011; the study will be concluded in 2030.
The first overall budget for the project was initially 65€ million, but it was reduced to 30€ million when the planning phase was concluded; of these a total amount of 12€ million were provided by state-owned companies (the contribution of VINNOVA was 7.2 and the one from SEA was 4.8). With the use of the smart grid, it is also implemented the system of smart metering, that uses electronic devices to collects information about the consumption of electricity that can be used by the project's organizing bodies and by the individuals; this system in nowadays being promoted in all the country by the DSO. (IDEA; 2013)

3.4.2 Green and sustainable city area in Malmo

Another project carried on in Sweden for the development of smart cities is in the area of Malmo; this project sees the creation of new houses and work places that wants to be more sustainable and energy efficient. The project is founded by the Swedish state with the collaboration of E.ON company, a German energy producer with focus on renewable sources, for a total investment of 23M euro. The technologies involved in the project include the distributed heat and electricity consumption, new smart grid design and the storage of electricity. The project started in 2009 and is due to finish in 2020, with three main actors involved: the city of Malmo, E.ON and VA SUD, a Swedish company specialized in creating environmental sustainable solutions for buildings; and had the ambitious goal of making Malmo the most sustainable city by the end of 2020. To reach this goal one of the focus was on the integrate the grid for electricity, gas and heating by creating transmission systems capable of communicate (Chatziioannou; 2013).

3.4.3 Smart grid Gotland

In 2014, in the island of Gotland, began the creation of the Smart Grid Gotland project, founded by company GEAB, together with Vattenfall, ABB, Energimyndigheten, Svenska Kraftnät, Schneider Electric and KTH. The total investment was 3.56M euro, of them 1.6M were provided by SEA (Smart grid Gotland official website). To create this smart city the technologies involved will be the improvement of control nodes on the smart grid, intelligent sensors and software to provide the individuals the information to be more conscious of their energy usage. The household will be provided with real time information on their energy usage so that they can adopt behaviors to increase the usage of electricity in times of the day when the supply is higher and the price is lower, the individuals will also be guided toward being prosumers, indeed one of the objectives of the project is to increase the efficiency of renewable production by the citizens (in particular for wind power) by providing them with a better distribution system. For the project there are some measurable targets:

- Increase the hosting capacity of wind power from 195MW with 5 MW by use of load shift.
- 20% reduction of SAIDI, in the grid between substations in Källunge and Bäcks.
- Active participation of 30 industrial companies.
- Attract 2000 households to participate in a market test under market driven conditions.
- Active customer will contribute to a load shift of +/- 10%

(Chatziioannou; 2013).

3.4.4 Program for improving energy efficiency in energy-intensive industry (PFE)

Another project going on in Sweden concerns the improvement of energy efficiency for industry, in this project were involved 100 companies that agreed to a five year contract in which they accepted to provide an analysis on their energy consumption, increase the investments in energy and electricity saving measures, improve energy management system and introduce methodology for saving electricity during their activity. In return the companies did not have to sustain the EU minimum tax on electricity.

In this project the outcome was to measure the energy saving resulting from the application of new routines by the companies; the importance of this results is due to the fact that the company chosen were energy-intensive, meaning that at least 3 percent of their costs were related to use of electricity. The outcome was divided into two parts: the first refers to gross saving, intended as the efficiency improvements and energy saving derived from the new methodology adopted by the participants, the second one is the net impact, intended as the advancement in energy saving derived directly by the program, and not deriving from changes that could have taken place even without the intervention of the state.

For the gross impact, the results were above the expectation, indeed, the saving expected was 375GWh/year, while the total saving at the end of the project was 1450GWh/year. The reason behind it is that the obligation to compile report and monitor data on the electricity consumption, made the companies more responsible for their usage and therefore lead them to better improvements on the energy saving. The net impact measure has been calculated by using index to estimate the free-riding (percentage of saving that were not caused by the

program), the saving indirectly due to the intervention of the state, and the overlapping of the two effects. The net impact resulted in almost 1015 GWh/year (IDEA; 2013).
The organizing body of the project was the Swedish Energy Agency, that invested a total of 4.2€ million for planning and sustaining the project; it is also relevant consider the total investment of the companies involved, in fact they invested a total of 70.8€ M to improve their measure on electricity saving and 13€M to carry on the project (Stenqvist; 2012).

3.4.5 Project MODULIT

The Swedish Energy Agency has also launched the MODULIT project, the idea was to improve the energy storage modules, in particular the main goal of was to reduce the expenses related to the integration of electrochemical energy. The main target of the project was to study if monolithically integrate batteries could have been a better solution for the storage of energy in manufacturing industry. The project take place in the field of innovation in battery storage, a field in which over the world were invested almost 300USD billion (IEA; 2019).
For this project SEA invested 1.5€ M for a period of four years.

3.4.6 Climate Smart Process Industry

This project started in November 2018 and is carried on by VINNOVA, that plans a total investment of 1.46M euro until the end of 2021. The goal of the project is to change the process industry by making it more advanced from the side of environment impact and also to promote the reach of the target of reliability and sustainability set by the Swedish state. It also want to create more competitive energy production by increasing the efficiency and flexibility. The impact that this project is supposed to have is to reduce the emissions of carbon dioxide, to reach this target the technologies used will be focused on improving the industrial production of some of the companies involved (VINNOVA website).

Project	Description	Budget
Stockholm Royal Seaport Smart Grid (2010-2030)	The goal of the project is to create an environment to test new technologies that can be applied on the national grid, and to collect data on the behaviours of prosumers. The project will test systems to manage distributed generation, smart metering, charging station and storage systems.	30€ million Of which 12€ million from state-owned companies
Green City area in Malmo (2009-2020)	Development of a smart city from the beginning, with the creation of new houses and work places. The technologies tested are distributed heat and electricity consumption, smart grid design and energy storage	23€ million All from the Swedish government (SEA)
Smart Grid Gotland (2014-2020)	The demonstration has a focus on systems to control the flow of electricity in the nodes of the grid, ICT to collect and communicate data with consumers.	3.56€ million 1.6€ million from a state company (SEA)
Program for improving energy efficiency in energy-intensive industry (2005-2010)	Collection of data on firms regarding their energy consumption, investments in energy saving measures, and test how different incentives systems can influence their savings.	4.2€ million All from the Swedish government (SEA)
Project MODULIT (2013-2017)	Studying new energy storage modules with the goal of reducing the expenses related to the integration of electrochemical energy.	1.5€ million All from the Swedish government (SEA)
Climate Smart Process Industry (2018-2021)	Increase the reliability and sustainability of the energy consumption in Swedish industries, by changing production routines.	1.46€ million All from the Swedish government (VINNOVA)

3.5 Spain

3.5.1 Regulatory framework and policies

Spain introduced a new electrical reform in 2013, with the intentions of changing the regulation used to establish the revenues of the DSO and TSO; the reform introduced had a validity period of 6 years, a new reform is coming in 2020 and will last until 2025.

In the country there are different main actors in the energy sector, the Red Eléctrica de Espana (REE) as the only TSO and 5 different distributors with geographical distribution.

Figura 11: The DSOs in Spain; PYLON; 2018

Revenues for TSO and DSO can derive from investments, operations, maintenance and, only for the DSO, different regulatory task; for the revenues deriving from investment, operation and maintenance, the framework uses the CAPEX method and the OPEX method to establish the cap on profits. The final revenue can be augmented or increased according to their performances.
The incentives for DSO and TSO are fixed taking into consideration the reduction of grid losses, the quality of supply, and the detection of fraud; the revenues can be increased or decreased with the performance in the regulatory period.
One the regulators fixes the parameters used to calculate the revenues, these have a validity of 6 years, during which they cannot be changed or even fixed with inflation o efficiency factors; on the other hand, RAB is more flexible and it is reviewed once per year and is subjected to the new investment or depreciation.

3.5.2 Regulatory Asset Base (RAB)

The RAB policy for DSO in Spain had validity on the investment made by the distributor until the end of 2014; it used a formula based on the replacement cost, the investment made and an efficiency index, to the results are subtracted the investment made by third parties. Then there in an adjustment made to consider the part of the assets that would continue after the end of 2014.

For the TSO, the RAB method was considering the assets investment made before 1998, with an 'implicit value' method; while for the investment made during the period from 1998 to 2014, it is used the same calculation made for the DSO, but considering also the remaining regulatory asset life.
To promote cost saving operations, for assets build after 2014, RAB uses the average of the actual costs and its reference value, in this way, if the operators are capable of getting an asset at less than its reference value, they can keep part of the difference as payoff; in the same way, if they tend to spend more than the reference value they will be penalized. In some cases, like for specific assets, there may be difficulties in establishing the reference value, in these cases it will be used only the actual cost.
RAB value takes into consideration assets that have been completed, so not under construction and working capital; the revenue calculated in the RAB will be received the year after the investments have been done, for this reason the formula for RAB is (1+Rate of Return)^1,5 years (CEER; 2019).

3.5.3 Revenues for Operation and Maintenance (OPEX)

Besides the revenues from investment, the Spanish regulation also provides DSO and TSO revenues from operation and maintenance, called OPEX; the value is calculated considering the reference value of all the assets and the cost of the operations, for the way that it is calculated, the DSO/TSO have bigger incentives to keep the grid below the reference value fixed for that period.
To give incentives to keep working using assets even after their regulatory life has expired, the operations and maintenance on these receive higher revenues from OPEX. The revenues for these assets is around fifteen to thirty percent higher for the first period after the expiration (5 to 15 years) and then become 100% (CEER;2019).

3.5.4 Revenues for other regulated tasks for the DSO

There are other activities for which the DSO can receive incentives, these are:

- metering;
- client assistance;
- planning for improvement of the grid;
- revenues to compensate unplanned operating costs.

As for the other incentives, the DSO are motivated to do these operations at costs below the reference value, as the revenues are calculated using the reference value and therefore the DSO can keep the difference as additional profit.

3.6 Projects in Spain

To stay in line with the targets and goals established by the European Community, the Spanish government launched in 2011 the National Renewable Energy Action Plan, consisting in a total amount of 61 billion in all renewables technologies in the period from 2011 to 2020.
One of the major focus in Spanish projects for smart grid is related to energy storage, indeed Red Electica is promoting demonstration projects to increase the energy storage capacity to improve the smart grid; all these projects are part of the Almacena project.

3.6.1 STORE project

In 2012, Endesa Generacion, one of the DSO, launched a demonstrative project with the cooperation of industrial partners and research centers; the main goals were to investigate on the technologies for energy management, in terms on flexibility and reliability of the distribution; test the technologies that showed the most promising results; collect data useful to plan future facilities; give the regulators more reason to incentivize the investment in these technologies.

3.6.2 Almacena project

This is the first project made by the TSO and it begun in 2013; the goals were to improve the management of peak and valley hours by making a more efficient storage system in the transmission grid. The project is co-financed by the RED and the European Regional Development Fund. The battery used in this project use a lithium-ion prismatic battery, with the goal to monitor the characteristics this facilities can offer.
With this new technology, the project will also monitor and improve the communication and control system, the use of IT system and the conversion of energy.
The first phase of the project consist in installing the batteries and integrate them with the producers of renewable energy and improve the reliability of the service.
In following phases, the batteries will be used to collect data and to the impact of the technology on the efficiency of the operations, the quality of the grid service and the reliability of the system.

3.6.3 MIGRATE project

The MIGRATE project started at the beginning of 2016 with a planned duration of 4 years; the total budget over the period is 17.9 million euro, of these, 16.8 are provided by the European Union with the project 2020 Horizon (RED electrica de Espana; 2016).

The project is being carried across all Europe, and has the goal of promoting the use and development of new technologies that can improve the management of a European electricity system and the use of Power Electronics (PE). It is divided in two different phases, the first one involves generators and consumers of energy, with the purpose of stimulating new entry in the grid and making them more connected and integrated with the grid, while maintaining the same flexibility and quality of service of the distribution; the second phase as the purpose of creating new routines to monitor the transition to a high-voltage electricity system when all the customers and generators are connected to the grid.

Figura 12: Countries involved in the project; RED

The project is being developed in 5 different actions:

- proving the efficiency of the new technologies involving PE and the effect of smart metering;
- measure the flexibility of the grid with 100 percent of the consumers and generators involved connected;
- develop new system to control and guarantee stability when there is a high use of power electronics devices;

- collect data to develop new methodologies to improve the wavelength quality in new systems;
- guarantee the maintenance of the quality and reliability of the transmission during the transition to a larger use of power electronics devices.

3.6.4 ASPAS project (Automation for zone protection and control)

This project begun in 2016 and was concluded in November 2018; it was founded by Red Electrica with the collaboration of Siemens and GE. The purpose of the project is to create automation routines to control and protect the transmission grid, to improve the quality of the operations and their security. This is necessary because of the many connection that the Spain grid as with other islands and country trough submarine cable that have to work at high-voltage. When the voltage is too low, the energy passage has to be reduced in order to guarantee the stability of the system; with ASPAS the measurement of the voltage and the minimum short-circuit power can be improved, making possible to deliver more energy without the risk of damaging the functioning of the grid.
The better connection and transportation of energy from the continent to the island is particularly important since, in most of the islands like Mallorca, the price of the energy produced is higher (in Mallorca the project created saving for 250k euro every year); in addition to the economical benefit, there is also the environmental one, because the energy produced on the island often requires a larger use of carbon with consequent emissions of CO_2.

3.6.5 AMCOS project

The AMCOS project has the purpose to develop and test new prototype of batteries using advanced technologies, like ultracapacitor or Lithium-ion technology, that can speed up the charge of the capacitors connected to the grid, allowing a better management of voltage and frequency, essential for reliability and flexibility on the grid.
The organizing bodies of the projects are CDTI (Centro para al Desarrollo Tecnologico Industrial) and the European Union, as investors and founders, and the Ministry of Economy and Competitiveness; the project is being monitored and managed by the RED, the University of Las Palmas de ran Canaria and the Association of Research and Industrial Cooperation of Andalusia.
The goal of the project is to improve the electricity grid, by making possible to keep the level of security while reducing the development that the grid needs, therefore decreasing the need of new infrastructure (RED; 2016).

3.6.6 PRICE project and PERFILA project

PRICE project and PERFILA project were both born with the main focus on 'prosumers' and the use of smart meter.

The PRICE project is the main project that was carried in Spain on the creation of prosumers; it was developed until 2015 by two DSO in the area of Madrid (Iberdrola Distribucion and Union Fenosa Distribucion) with the collaboration of RED and a group of IT suppliers and R&D centers. The purpose of the project is to implement the management of the demand, to improve the integration between demand and electric vehicles and to increase the consumer's focus on better choice on the consumption of energy.
To achieve this the project will involve 2 thousand household, and will test new communications channel on them, through these channels the consumers will receive information about the price of the energy and their usage. The customers with air conditioning in their house will be provided with system to let them manage the air conditioning with cellphone application.
The expected results of the project are both to start promoting a better knowledge about the usage of electricity by the consumer with the use of smart meters and to collect data on how the household use these information and on how receiving these information can change their behavior.
The PERFILA project is organized by RED with the cooperation of the major DSO in Spain, together with the Ministry of Industry, Energy and Tourism. This project was the first in Spain to improve the technologies used for smart metering, indeed when Perfila begun, less than half of the energy could used could have been measured by the hour. The project was launched with the National Meter Replacement Plan, and it wanted to measure the change on the use of energy related to the installment of the new smart meters.

Project	Description	Budget
STORE project (started in 2012)	Investigation on technologies for energy management, testing new storage systems, collect data for the regulator to improve the current regulation.	11€ million
Almacena project (2013- Ongoing)	The project is testing new lithium-ion prismatic battery and ICT systems to improve the management of peak and valley hours.	N/A
MIGRATE project (2016-2020)	Promoting the use and development of systems for the conversion of energy to reduce grid losses, test smart metering solutions, collection of data on the flows of energy on the grid.	17.9€ million 16.81€ from Horizon 2020
ASPAS project (2016-2018)	The creation of routines to automate the detection and the adjustments of grid fallacies.	N/A
AMCOS project (2015-2018)	Test new batteries for the storage of electricity that can accelerate the speed of charging.	18€ million
PRICE and Perfila Project (2012-2015)	Both projects focus on the behaviour of prosumers; the focus is on the implementation of system to balance demand and supply during peak hours. The technologies tested will focus on ICT systems and smart metering.	N/A

3.7 Ireland

The Irish electricity market was deregulated in 2007, when in the country the Single Electricity Market (SEM)was created; the market has as regulator the Commission for Regulation of Utilities (CRU), that work together with the Utility Regulator. The market joins the electricity market of Northern Ireland and the Irish one. The purpose of creating the SEM was to make the market more efficient, reliable and sustainable in facing the demand at every time and providing energy at the more convenient cost for the customer, by establishing a wholesale market with common arrangements on all the island.
The Commission for Regulation of Utilities was founded in 1999, when it was established the Electricity Regulation Act, and its current work is to watch over the electricity market, the safeguard of customers and the overall quality of the services of distribution and transmission. CRU solves its role in over guarding the customers by solving the grievances that may rise between customers and energy company. At a first time, setting the retail price of electricity was a job of the CRU, but after 2011 this regulation ended; now CRU has to control the price, as established by the European Community in 2010 and set the cap for the revenues that can be gained by the operators.
The regulator operates in line with the policies defined in the "Green Paper on Energy Policy in Ireland", that was published by the Department of Communications, Climate Action and Environment (DCCAE) in 2014, and was updated in 2015, whit the setting of new targets for 2030. The policies have the goals of making citizens more powerful in choosing their energy behaviours, and the 'three energy pillars', that are sustainability, security of supply and competitiveness (CEER; 2019).
Given the small geographical size of the country, the legislation defined a natural monopoly that allows the conjoined management of electricity and gas, both for generation and distribution; the electricity transmission is operated by Electricity Supply Board (ESB), which is state owned, but the system is owned by EirGrid, which is also state owned.
As TSO, the responsibility of EirGrid include the management operations of the grid, such as the maintenance, the routine operation and the establishing of the policies; on the other hand, ESB has to maintain the system and to build new asset needed for the developing of the network. ESB Networks Ltd, which is owned by ESB, has the monopoly of the distribution.

3.7.1 Revenue Cap

The CRU is responsible for the determination of the revenues cap allowed for the DSO and TSO; in order to accomplish this goal, it adopts an incentive regulation

scheme over a period of 5 years with the cap setting happening ex-ante the third year of the previous period. For determining the cap, CRU takes into consideration three main element: the operational cost (OPEX), the capital cost (CAPEX) and possible depreciations of the assets.
To calculate the operational expenses, CRU conduces an analysis on the single firm over the years as an internal benchmarking, and an analysis of other firms operating in a similar field, comparable for size and revenues; in both analyses the regulator consider also what is a standard efficiency level, in order to compare the performances of the firm during the regulatory period and be able to set a bonus in case those standards are exceeded. The operational expenditure calculate in this way are confronted with the revenues proposal of the System Operator (DCCAE; 2014).
The return on capital for the system operators is based also on the investments made during that period and their efficiency, both made over its Regulatory Asset Base (RAB). which is an index that uses the value of fixed assets and future assets, that are currently being built; for the costs related to the substitution of assets the regulator uses the historic value of the assets and the inflation index.
To set the Rate of Return during the period, the value calculated before are used to establish the WACC, which is the Weighted Average Cost of Capital, that consider the cost of equity and the cost of debt. The WACC is fixed using the one of the previous year, and then it can be added a bonus to incentivize the efficiency in the regulatory period. The cost of equity is fixed using the Capital Assets Pricing Model, that consider the risk to which the assets are subjected.
During the regulatory period, the revenues cap can be subjected to modification due to new costs that may have emerged and that the SO has to sustain, these costs are managed in two different ways based on their nature. Some of them, called "Uncertain costs" are those that were not fairly expected, and for those the regulator evaluates the decision if they should be considered in the cap, case to case, this is to ensure that the system operators deal with them in the most efficient manner possible, and this would not happen if it was sure that they will be covered by the regulator. There are anyway some costs that are always covered by the cap, and these are other costs that are completely outside the control of the operator, like interest rate; for these costs the system to incentivize in managing them in the most efficient ways consist in sharing the savings between customers and SO.

3.7.2 Adjustments to the cap

Over different regulatory period, the cap fixed by the CRU may be subject to modification that are not just related to normal inflation or changes in the price of energy, but are more related to unforeseen events, in other words, the cap is fixed to reflect the expected costs that the system operators are supposed to sustain during that period, but these may not actually be the real costs sustained, so the difference between what was budgeted and what really happens is used to make adjustments to the cap for the next regulatory period. This is known as the "K-factor" and thanks to this the cap is more in line with the costs that have to be covered in that period. The cap also takes into consideration the inflation and the depreciation of the assets.

3.8 Projects in Ireland

ESB has been conducting different demonstration project with Electric Power Research Institute (EPRI), an American no-profit organization, starting from 2010; the projects are financed by ESB while the organization is conducted by both organizations.

3.8.1 Smart green circuits: ESB Networks - Smart grid demonstration project

This project started in 2010, with a duration of two years and was lead by ESB Network, with the intention of developing a circuit to connect all the independent generators across the island to the grid, while reducing losses and implementing technology related to the management of self-healing loops, increase the efficiency of the distribution and collect data on system voltages. The demonstration includes new method for the integration in the grid of new generator and electric vehicles, but also wants to conduct an analysis on the way customers approach their energy consumption and how this approach can be changed.

In the project the "smart green circuits" are intended as all the routines that can increase the reliability of the connection and of the distribution, with better collection of the data regarding the maintenance needed and the losses. The reason why EPRI started this project in Ireland is that the Irish grid, in terms of size and scale, is challenging in guaranteeing a good quality of supply in case of peak in demands; the project is being conducted in the area of Kerry, Galway, Dungloe and near Dublin.

The technologies tested in this project focus on the self healing, intended as the capability of the grid of managing critical situation and losses without any intervention; in this case, to reach this goal, there are 5 main technologies used.

The first one was focused on self healing and was applied to the Kerry area, and consist of a system capable of tracking and conducting an analysis of defects, the analysis is then communicated to the ESB in real time using GPRS, the communication arrives both on the central server and the smart phones of the employees assigned to the maintenance. The test gave good results for this technology, that was used on over 12 detections of defect; in these circumstances the system was able to seclude the flaw, so that it was possible to establish again the supply for other customers.

A second technology tested is the use of an arc suppression coil, used for increasing the safety of the grid in case there are defect of overloading that need to be carried earth without interrupting the distribution. This technology made possible cost saving for the management of the accident ad also made the detection of the defects 84% faster, with continuity of performances doubled (EPRI; 2012).

The third improvement was made by conducting an analysis of the possible saving that can be obtained by changing the transformers used in grid, indeed for the project the conventional transformers were changed with new optimized for reducing loses; this is particularly important in Ireland because there is a high number of over loaded transformers.

For the purpose of the project it was conducted a study on the improvement that can be achieved in the losses of the grid by doubling the voltage at which grid operates, in this case it went from 10kV to 20kV for more than two thousand customers. The new voltage made possible to decrease the losses of 75% and the network capacity was halved (Walsh; 2011).

The last test in this demonstration consisted in conducting a simulation on conservation voltage reduction (CVR), that showed that adopting new transformers is convenient from an economic standpoint only when there is already a need to substitute it, and it is not if the goal is just reducing the grid losses.

3.8.2 Distribution Volt-VAR control Integrated with Wind turbine Inverter Control

The second project conducted by ESB and EPRI had a focus on wind turbines, this is because Ireland has one of the greatest production of energy from this technology in Europe, and also because this technology presents difficulties regarding the necessity of operating under using the correct frequency, voltage, and reactive power requirements. (EPRI; 2012).

For the purpose of this project the case analysis had a focus on the integration of the producers utilizing wind turbines with the communication system already in use by the grid operator, and on the potential benefits that can be gained by a better integration of wind farms, since they are open for improvements on the reduction of the losses and they have a high capacity for the storage of energy.

The project was conducted on two wind farm, one in Knockawarriga and one in Tournafulla, to study how the part of grid that connects them can be improved, in

particular there was a simulation on five possible voltages at which the connection can operate.
The results showed that by maintaining the voltage fixed the hosting capacity in hosting was improved, the network losses reduced, and the transmission was also easier to manage. From the point of view of ESB it was also important to understand better what are the key factor that influences the performances of the grid, in this case the focus was on the voltage level; the analysis showed that it has an influence over the operations, but it makes more difficult to integrate the wind farm with the rest of the grid, meaning that it may be required to sustain additional costs to complete the integration.
Overall the demonstration showed that there is not a unique optimal solution of voltage to improve the benefits provided by the wind farm, since their contribution to the grid is highly related to where they operate.

3.8.3 ESB Networks Case Study on a Smart-Meter Custom Behaviour Trial

This project had a focus on the "prosumers" and analyzing how it is possible to change the behaviour of the electricity users by providing them with more information on their usage; in order to collect this information in the project were adopted new system of smart metering on almost four thousand citizens while 1100 citizens were used as benchmark. The information collected were on time-of-use (TOU), prices and quality of the service; one of the main focus was to see eventual change in the peak demand.
Six months before the project started, all the participants were provided with smart meters to collect data on their normal behaviour. The test was conducted over a period of one year, and tested four different TOU rates, and different ways of giving the customers the information on their usage (there were difference regarding the length between one report and the next and also regarding the use of monitor for each house that collected and showed real time information). Another test was conducted on the benefits that can be achieved by giving customers economic incentives for their saving in electricity usage.
In addition to citizens there are also small businesses that were testes, but in this case only two different TOU rates were tested, and also the benefits of providing the businesses with web account to monitor their usage.
The results of the test on citizens are showed in the next table:

System applied	Average result	Bi-montly bill and usage statement	Montly bill and usage statement	Bi-montly bill and usage statement and monitor	Bi-montly bill, usage statement and ffinancial incentive
Overall reduction of electricity usage	-2.50%	-1.10%	-2.70%	-3.20%	-2.90%
Reduction of electricity usage during peak time	-8.80%	-6.90%	-8.40%	-11.30%	-8.30%

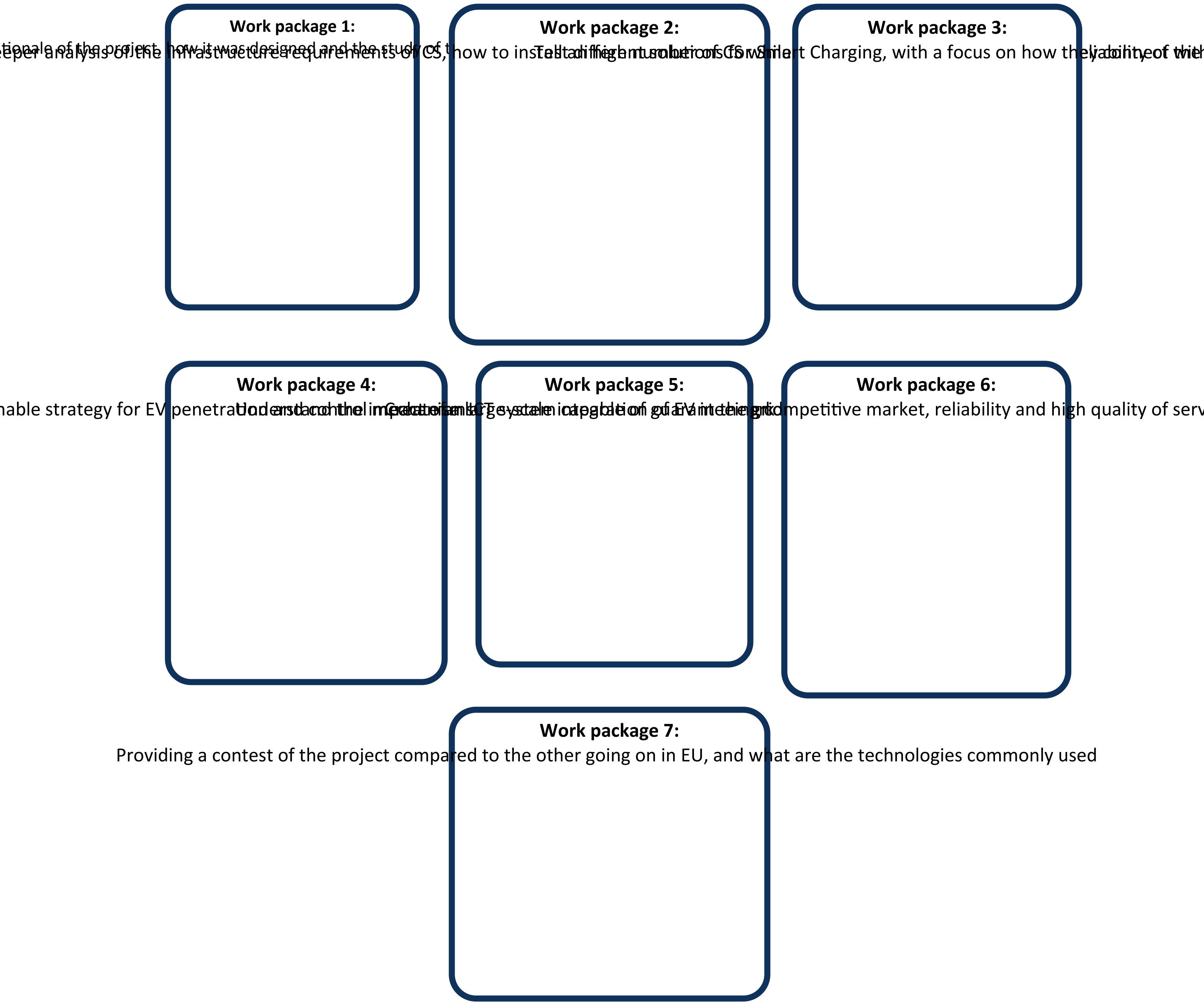
Figura 13: Elaboration of Data from the ESB report

As shown in the first column, the global results on the citizens were positive, since there was a decrease in the use of energy of 2.5%, compared to the one of the previous year, and the peak reduction was even more relevant with a decrease of 8.8%; we can also observe that the TOU tariff were not relevant in changing the behaviour, since none of them showed particular differences with the others in terms of benefits. The TOU rates that improved more significantly the use of electricity is the bi-monthly bill, combined with the in-house monitor, this is confirmed by the fact that 87% of the tested subject stated that it played a major role in shifting the use to time in which the grid is less loaded.
The results obtained on the test on small businesses were not as promising, indeed the use of electricity did not decrease, overall nor in peak times, and the web account was not used by most of the participants.
Even if the results on citizens were positive, there were some problems regarding the difficulties connected to provide daily information to the participants, this is because the wireless connection used is not suitable for a large number of users, and also the system used to collect data for every meter had some delays in giving the information to the system.

3.8.4 Electric Vehicles network integration project

This project started in 2011 until 2015, and was organized by ESB Networks, with the purposes of testing the potential benefits of improving the electric vehicles charging infrastructure, in order to request to CRU to include the costs related to these new infrastructures in the calculation of the ESB Network RAB. For the calculation of the benefits, were considered the costs related to spot the location that needed more this kind of infrastructure, the costs related to build the assets and the benefits on the Irish population.
The costs of the project were not sustained by ESB, but were included in the customers' bill as "Distribution Use of System", this was granted by the regulator

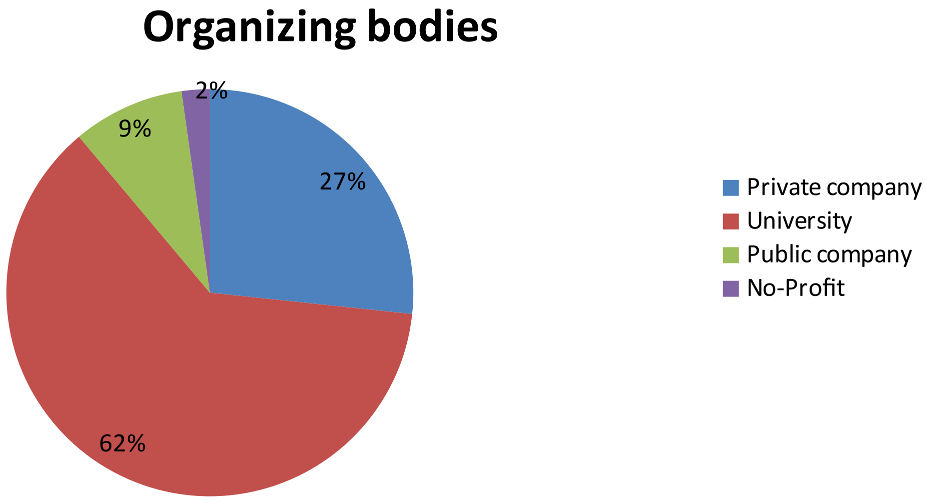
since the potential benefits of using the grid to distribute more energy, as it would happen in the case more EV charging station are connected, would decrease the price of electricity.
Before the project started, the citizens involved were given electric vehicles, since this project wanted to measure the effect that the EV will have in the future, but since the number of EV in Ireland was significantly lower than the one forecasted, there was the need to increase it in the area that were tested. There are different technologies tested in this project: ICT Systems, charging stations (CS) hardware and software and demand management strategies (ESB Network; 2018).
The project was conducted in seven work packages:



The final outcome of the project was the design of how the grid should be implemented, with focus on the connectors used, the location and type of CS and the analysis of the cost-benefits that there would be if the grid is implemented to allow the complete integration of the EV in the future; the cost expected for the implementation of the infrastructure is 350M euro, but this would be compensated over the long term since there would be a price reduction of electricity.

3.8.5 Other demonstration projects

The 10th September 2018, the minister of Communications, Climate Action and Environment granted 8M euro to sustain 45 new demonstrative projects on energy research, with different purposes, that go from clean energy to smart grid; the projects have different organizing bodies (DCCAE; 2018).



Project	Description	Budget
Smart green circuits: ESB Networks (2010-2012)	Develop new circuits for the integration of independent generators, with the adoption of new technologies for losses reduction, management of anomalies and collection of data.	2€ million
ESB case study: Distribution Volt-VAR control (2008-2012)	It carries on a case study on the integration of wind turbines with the network grid, in particular focusing on the inverter control required to adapt the voltage and decrease the losses.	N/A Financed by ESB network
ESB case study on Smart meter and custom behaviour (2008-2012)	The study involved thousands of citizens to collect data used to implement the rates and study the impact that the tariffs have on customers behaviours; during the study the TSO also tested different systems of smart metering.	N/A Financed by ESB network
Electric Vehicles network integration (2011-2015)	The project intents to test new solution for the charging of electric vehicles and the use of EV batteries as a storage system. An important part of the analysis was done on the connection of the charging station to the grid.	350€ million Sustained by customers
Aggregated demonstration projects (2018 - Ongoing)	These 45 projects, carried on mostly by universities, focus on researches on innovative solutions for clean energy and smart grids.	8€ million All provided by the government

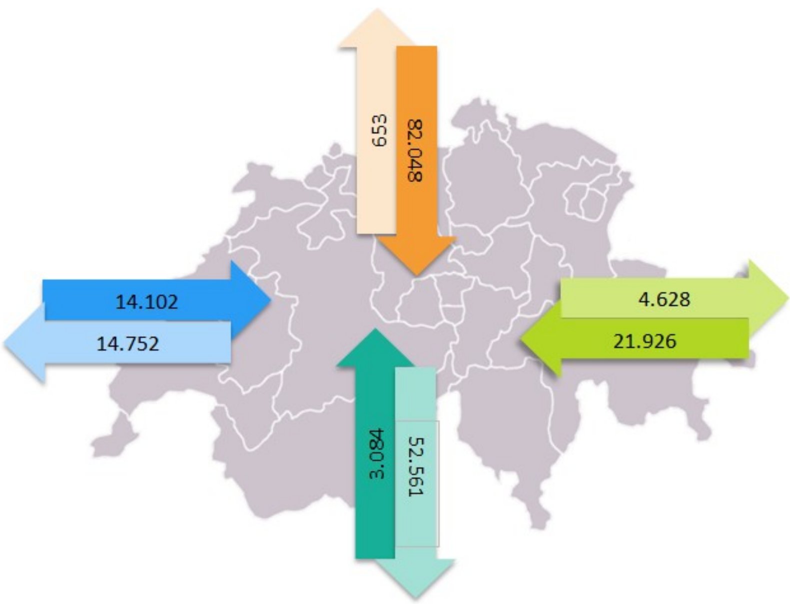
3.9 SWITZERLAND

The liberalisation of the electricity market in Switzerland started with the Federal Electricity Supply Act, in 2008; with this implementation the goal was to improve the security of the supply and to create a more competitive market, to do so the Act established the rules that the operators in the market have to observe to improve reliability and sustainability.

The liberalisation of the market in the country happened in two steps:

- from 2009, after the act was published, the citizens with an annual consume over 100 thousand kW were able to change supplier in the electricity market;
- from 2020 (programmed), the access to the market will be given also to other consumers (Scholl; 2018).

The reason that pushed the Swiss government into creating this act was the liberalisation trend that has occurred in the last decades in most of the other European country, and that could have been a threat to the local market if other companies could have had access to the customers in the country; Switzerland is indeed used as a transit to exchange energy between other countries, thanks to the central position in Europe and the high capacity of the grid (Caro; 2008). Indeed to balance the supply and demand in the country, Switzerland has continuous exchange of electricity with other countries, in particular with France, Germany and Austria to import energy when there are peaks in demand, and with Italy to export; in the Figure 1, it is possible to observe the flows of energy in MGh between Switzerland and the nearby countries (in clockwise sense: Germany, Austria, Italy and France), with the exception of Austria, the country has a negative flow, meaning that is able to export more energy than the one it imports.
In order to keep its profitable role in the European electricity market, there this the need to connect the Swiss grid to the one of nearby countries, but this also requires an alignment between the regulations in the country and those adopted in the European Union; one of the major improvement on the market was to increase the competition, the first step toward a more competitive market was indeed the federal act in 2008, since then there are already been benefits for customers with a reduction of costs of services.
The role of Switzerland as transit for energy requires major investments in the grid to improve its capacity, but until the capacity of the grid cannot support all the flows required by nearby countries and by local demand, it is necessary to regulate also the import/export



flow.

3.9.1 The regulator

The market is regulated by different authorities: the Swiss Federal Office of Energy (SFOE) and the independent regulator Federal Electricity Commission (ElCom), to these we should also consider the Competition Commission and the Federal Office for the Environment, that even if their activities do not focus on the energy and electricity market, often contribute to final decisions made.
As regulator, the role of the ElCom includes ensuring that the prices applied by the companies are not too onerous for the customers, monitoring the competition in the market and controlling the operations in the market to be sure that they are in line with the Swiss Federal Electricity Act and the Swiss Federal Energy Act, these two legislations, together with the Electricity Supply Ordinance, create the fundamentals of the Swiss regulatory framework; another important role is to

Figura 14: Flow of energy between Switzerland and other countries; data from SwissGrid

regulate disputes that may emerge between the companies operating on the grid and independent producers.
We can identify three main activities carried on by the regulator:

- monitoring the electricity tariffs;
- supervising wholesale electricity market;
- monitoring the security of the supply in all the country.

In order to carry on the first activity, the regulator has comprehensive powers in the market, and it can intervene and limit prices that are considered unfair for the customers and also intervene with a retroactive power to reduce tariffs. It also supervises the electricity tariffs for customers that consume less than 100 MWh, because they are still not able to choose their energy provider.
For its role as market supervisor, the target of ElCom is to maintain the supply of energy at a stable level of security and to detect incorrect behaviours such as unfair competition and market manipulation; to conduct this analysis and detect fallacies, ElCom collects big data on the trade of electricity. The final goal of the surveillance is to guarantee that the final user pays a air price for its consume.
Finally, monitoring the supply of electricity is the role with the highest priority for the regulator; to conduct this activity, ElCom works following the lines in the Federal Electricity Supply Act, that entrust ElCom to monitor and supervise the trends in the market to guarantee that the supply happens at the right security standard and in an economical way for the customers. Its role includes also to make decisions and plans in case that the security of supply is threatened.

3.9.2 Other actors in the market

In order to classify the other actors, beside the regulator, that operate in the market, we will consider the four main activities: generation, transmission, distribution and supply.
In the generation there are more than 80 companies operating; especially when considering the smaller one operating at a municipal or cantonal level, most of them are also owned by the Swiss government (Scholl; 2018). The largest companies in the country are: Alpiq, Axpo, BKW, Repower and Ewz.
The electricity generation is composed for hydropower systems for a share of 57%, nuclear power for 37% and 6% from renewable energy, like solar, wind power and thermal.
Considering in the renewable sources also hydropower, RES provide more than 60% of the energy consumed in the country; the reason why the hydropower provides most of the energy in the country is that the topography of the country is ideal for the construction of these king of power plant; other kind of power plants using renewable sources like solar and wind have trouble in being implemented since they are subject to a strong seasonality factor.
The transmission of energy is conducted only by the private company Swissgrid Ltd. For the transmission the grid is divided in seven level, based on the voltage at which they operate; the first one being the extra-high-voltage electricity, operating from 220kV to 380kV, has an important role because is the one directly connected to the generation plants and it is also used for the exchange of electricity with other countries; in order to minimize losses and increase efficiency, the transmission at this level is operated at the maximum voltage possible. The levels go down in voltage thanks to transformers, until reaching, the voltage of 1kV, or below, that is the level at which electricity is mostly consumed at a household level. Swissgrid is also responsible to keep the right balance between generation and demand in the transmission.
The transmission is regulated by the Electricity Transmission Lines sectoral plan, that is a document related by the Swiss Federal Office of Energy (BFE) and the Swiss Federal Office of Spatial Development. The document provides the directives for the future expansion of the transmission lines in the country, but also to manage the demand changes that may require to change the grid and to establish the best way to deliver electricity in each sector. The duties of the companies operating for the transmission of electricity are related to the maintenance of the grid, like purification and the detection of fallacies; while the costs for operating are paid for the most part by the final consumers.
For distribution and supply, in Switzerland there a lot of companies that are integrated to provide both services, indeed in the country the unbundling rules are

only applied at an ownership level on the grid. To provide the services of distribution and supply there are around 700 companies, and most of them are also the supplier of water and gas.
As anticipated, only customers with a consumption above 100MWh can choose the company to supply them electricity, all the others will have as supplier the local grid operator, that will sell electricity at the price needed to cover the cost sustained for production. The companies that want to operate as distributors or suppliers do not require any specific permit from the regulator, but they have to provide data on their costs and tariffs so that it is possible to control that the price at which they sell energy is reasonable for customers.

3.9.3 Incentives and taxes

In 2017 the Federal Energy Act was revised, and, with it, the Swiss government, committed to a long term plan, called Energy Strategy 2050; the target of this plan was to maintain the security and flexibility of the supply in the country, with the awareness that the electricity market will face new challenges connected with the new technologies adopted and the new customers' need.
Part of the plan is a consequence of the decision of the government to reduce the use of nuclear power after the Fukushima accident in 2011; the aftermath of the event and the need to improve the generation of energy in a sustainable way with limited environmental impact, made the diffusion of generation from RES one of the priority of the strategy.
The strategy is developed considering four fields that requires improvements:

- energy efficiency;
- renewable energy;
- decrease of generation from nuclear power;
- improvements in the electricity grids.

The need to improve energy efficiency derives from the need to reduce emissions, but also to the problem related to the scarcity of sources to face the increasing consume; for these reasons, Switzerland made reducing the overall consumption of energy and increasing the efficiency one of the main priorities. While carrying on the improvement of efficiency, the goal is to maintain at the same level the quality of the service. The final outcome will be a reduction of prices for customers, a decrease in importing energy from other countries and also less environmental impact.
The need of increasing the use of renewable impact refers to sources like wind and solar power, biomass, geothermal and others, but in the country there has always been an high share of RES in the production, thanks to the hydropower energy. Of the new sources, some are not already available, at least from an

economical point of view, like photovoltaic or geothermal, and will be developed in the next 30 years, while biomass, wood and ambient heat are already on the way to be used more by the citizens, since they can already provide economical benefits.
To decrease the use of nuclear energy, the government committed to prohibit the edification of new power plants, while keeping the ones already in function only until they are considered safe.
Finally, on the improvements needed by the grid, the country is making a slow but steady progress in expanding and making the grid more efficient.
In order to promote the use of renewable sources in the production of electricity, the government is using a feed-in tariff. This incentive is available for different RES, like photovoltaic, biomass, biological waste, wind energy and hydropower when it does not exceed the power limit of 10MW. The benefits are available only to companies working under the directives of Swissgrid, and they have a time window that goes from 20 to 25 years (Scholl; 2018).
For the customers there is a fee for the use of the grid, this fee is used for paying the feed-in tariff; financing consumers using systems for solar power; improvement on the grid to increase efficiency and to cover the risks of innovative projects.
To benefit more from the synergies coming from the cogeneration of heat and electricity, the government is financing researches to study how to increase the efficiency in these plants to reduce the emissions of CO2 and reduce the emissions of other dangerous gas. The high interest that the government has in implementing cogeneration technologies is connected to the fact that the potential reduction deriving from cogeneration is 25% of the actual emission of CO2 in the country, and also to the fact that cogeneration plants can provide 30% of the energy required. The high potential of this technology is also connected to the fact that until now it has not been adopted on a large scale in Switzerland, indeed of the electricity produced in the country, just around 3% of it is produced in plants using cogeneration technologies; most of these plants are using the incineration of waste products to produce electricity and heat (Scholl; 2018).

3.10 Projects in Switzerland

3.10.1 IMPROSUME

This project was born in 2010 under the organization of the organization of the Inkubator Halden AS, a Norwegian centre with a focus on projects with an impact on energy. The project, that lasted 2 years, took place not only in Switzerland but also In Norway and Denmark. This project had as main goal to study the behaviour of prosumers in order to better understand what will be their role in the emerging energy market. In particular, for this project, prosumers are not intended

just as consumer that just consume and produce energy, but it is also required that they have an active participation in the market, intended as the ability to buy and sell energy. During the project, it was conducted an analysis on the preferences that prosumers shows in their behaviour and which innovative business model was more aligned with them.
The main technology tested in IMPROVE was the smart metering, and the analysis was conducted under two point of view, the first one was to test the instruments used to collect the data and communicate them in real time to the users, the second one was testing the acceptance of them by the subject of the study, to observe which one is more capable of influencing their behaviour; the reason different methods had to be test is that in the project was involved an high number of telcom companies, and they proposed different services applicable to the smart metering, like smart home applications or mobile services. One of the most valuable output of the project was the classification of the attributes that work as drivers, in the business proposition, in order to change the behaviour of the consumers, of the six attributes tested the most important was the price per KWh, followed in order by:

- access consumption data;
- cost allocation;
- payment modality;
- flexibility of design;
- energy efficiency (Bremdal; 2013).

The total budget of the project was 160.1k euro, provided by the organizational body (Bremdal; 2013).

3.10.2 Smart Grid 2025

Smart Grid 2025 is the one of the projects developed and financed by SwissGrid. The major driver for the project has been the intend of the Swiss government to extend the possibility to choose the electricity services provider also for small scale users in the next years; this creates the need for the company to improve the quality and flexibility of the services to face the new competition that will emerge; in addition to this there is also the need to improve the capacity of the grid in order to be able to operate with more capacity as the denuclearization of the country goes on.
The plan to improve the grid will not only be about extending the actual transmission system, but also to make some technological changes, like the connection to the net of more distributor, to create a smart grid that uses forecasts and analysis of scenarios that satisfies the need of customers and producers.

3.10.3 Web2energy

This project started in 2010, with the goal of studying the new technologies that is possible to adopt to implement the net grid in Switzerland, in particular the project had three main subjects to study:

- smart metering, and how they change how consumers' relationship with the other actors in the market;
- smart energy management, in particular how to implement the grid to face an high number of prosumers;
- smart distribution automation, to increase the reliability of the grid.

For testing the smart metering systems, during the project, hundreds of citizens have been provided with this technology providing remote reading of consumptions, price variations during the day and estimation of the losses.
The smart energy management was tested on small and independent producers, the goal was to see if real time data on the demand and prices would incentivize them to improve their storage system and to sell energy when the demand was higher, in this way the intermittence nature of the renewable sources would have been compensated by the behaviours of the producers.
The smart distribution automation has as goal to introduce routines that can reduce the time needed to fix anomalies and interruption that may happen in the grid; this is particularly significant because, even if anomalies happen rarely, most of the time they are on parts of the grid operating at medium and low voltage, that is where they create more problems to the customers.
As results of the project, it was possible to elaborate ICT system capable of communicating with end users, to provide them data on their consumption and the prices that they are paying; implementing the grid to increase the integration of small distributors in the system while also changing the way they put in energy in the system and finally to create systems for the automation of the routines needed to face anomalies in the system, to reduce the time need to restore the grid to its normal functioning.

Project	Description	Budget
IMPROSUME (2010-2012)	The focus was on the behaviours of prosumers, regarding their consumption of electricity and the way in which they are connected to the grid.	160.1 k€

Smart Grid 2025 (2018- Ongoing)	The project financed by the national TSO intends to innovate the grid, by extending the length of the line and by monitoring in real time the flows of energy in the nodes, to elaborate systems to avoid congestion.	N/A
Web2energy (2010-2016)	The project studies the requirements of the smart grids, with a focus on the integration of wind and solar generation in the system. The data collected will also be used to implement new tariffs.	8€ million

3.11 PORTUGAL

3.11.1 Regulatory framework

The Portuguese energy market began to be regulated in 1999, but it was not liberalized until 2007, under the authority of the regulator Entidade Reguladora Dos Serviços Energéticos (ERSE). The regulatory framework was established under the directives of the European Union, in particular under the line of "Energy 2020", with the main targets of promoting efficiency, welfare for the citizens and increasing the amount of use of renewable energy.

In 2018 the Portuguese government established the National Plan for Energy and Climate for the period 2021 to 2030, in this plan the main goal is to reduce the GHG Emissions of 45 to 55 percent while also increasing the percentage of energy from renewables; to achieve this, Portugal will invest 21.9M euro, as declared in the National Investment Program 2030 (Pacheco; 2019).

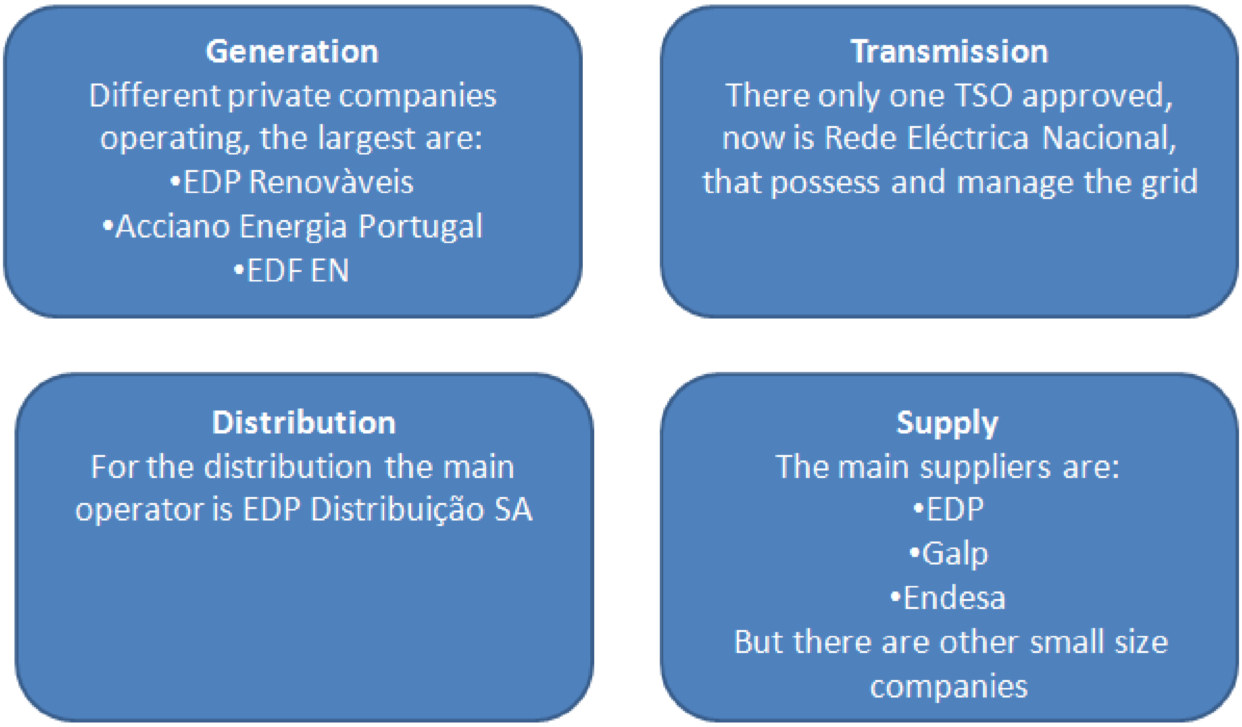
The regulator established the energy market to be liberalized, indeed to be able to operate it is necessary just the registration and receiving the concession of the government. The ability to operate on the network is obtain by respecting the key principles, that are:

- safeguard of the public interest, including the maintenance of security of supply;
- equal treatment and opportunities for all users;
- reciprocity on the use of interconnections by the entities responsible for the management of the grids to which the national electricity system is connected;
- payment of the applicable tariffs;
- implement the adequate measures aiming to prevent or minimise limitation to the transmission.

(Morais Leitão; 2019)

In the regulatory framework, the electricity market is divided in four different activities: generation, transmission at high voltage, distribution and supply, the companies operating in each of these can be seen in the next table. For transmission and distribution, ERSE declared that the services cannot be operated by the same company, so that there is the unbundling of these services.

For the operations of distribution and supply there are some particular cases for the two autonomous regions in Portugal, which are Madeira and Azores, where it is possible for the same company to operate as distributor and suppliers, and the main companies are, respectively Empresa de Electricidade da Madeira and Electricidade dos Azores.



As shown, all the companies operating in the electricity sector are private companies, the reason is that this way Portugal intends to guarantee a better liberalization of the market and is also capable to stay in line with the EU Electricity Directive, another reason is that in 2011, the country received economical assistance, from the International Monetary Fund, the European Central Bank and the European Commission, that included these obligations.
The high number of companies operating for the generation and supply of electricity is due to the fact that these activities are not rigorously regulated, and any companies can operate them after receiving the license from the regulator; to obtain the license it is sufficient to do bring to an end the contract with ERSE, that publishes the tariffs regularly.

3.11.2 The regulator

The only regulator in Portugal is the Energy Services Regulatory Authority (ERSE), which is the supervisor for both gas and electricity market. Even if it is a state-owned company, ERSE is independent from the government lines and conducts its role observing its own statute and goals, but this does not mean that it works without taking into account all the interest of the stakeholders, so it is subjected to the advice of the Advisory Board and Tariff Board, and all its decisions are published the ensure transparency, and it also do come of activities in collaboration with universities, the Council of European Energy Regulators (CEER) and the European Regulators' Group for Electricity and Gas (ERGEG).
Its main roles include:

- surveillance of the welfare of the citizens;
- Maintaining a competitive market;
- promote an appropriate use of energy, considering the environmental impact.

(ERSE; 2019)
In its role as market supervisor, ERSE manage the supply chain of electricity as if there are two different markets, indeed the production market is regulated as a wholesale market, while the trade as a retail market. In the wholesale market, the price is established by the rules of a competitive market, without rigid rules; however, there are some regulated aspects like a maximum sale price, some limit on the competition and rules to prevent the abuse of the market. The wholesale market uses a single marginal price model, in which the generators can sell at the same price of the one offered by the last supplier to meet the daily demand; in other words the generator sells at the price of the last unit sold to consumer.
At the retail level there is also a free competitive market, but the price of electricity is partly composed by tariffs that the customers have to pay that are regulated, such as the one for the use of the network. The network tariffs include costs like:

- the support to the generation of electricity from renewables sources;
- the costs that the utilities had to sustain to maintain its contractual position after the liberalization of the market;
- taxes.

Only for the activities related to the wholesale market, ERSE is affiliated with the Iberian Electricity Market (MIBEL), that is a platform created in 2006, that is used to trade energy and that calculates hourly the price of electricity as the results of the intersect between the demand and supply in Portugal and Spain; in the MIBEL market there are both organized and non-organized markets. MIBEL divides its operation in two parts, the first one concerning the spot market, which is managed by the Spanish branch, and the derivates market, managed by the Portuguese branch. With this cooperation the regulator wants to assure that all the customers pay the same price and all the sellers earn the same price for unit by defining market rules, regulate competition and establish a common regulation (Pacheco; 2019).
There are same conditions, like peak time in which the exchange of energy between Portugal and Spain is not supported by the grid, that necessitate that the market of each country is analyzed on its own (market splitting), and in these cases it is possible to observe differences in price. As regulator, ERSE wants to make these occasions happen as less as possible and to be sure that the reason they happened is not related to anti-competitiveness, and, to guarantee transparency, it publishes daily reports that show the situation of the grid.

In the electricity market the regulator is responsible for the public service and has six main targets to reach, that are assured with specific activities.

Responsibility of the regulator	Activities
Safety, regularity and quality of supply	Freedom of access to the exercising of the activities
Guarantee that the service provided is universal	No discrimination
Guarantee the connection of all clients to the networks	Equal treatment and opportunities
Protection of consumer in terms of price and tariffs	Impartiality of decisions and transparency and objectivity in rules and decisions
Promotion of the energy sefficiency and protection of the environment	Continuous exercise of supervision and monitoring
Integration of all location under the National Electricity System	Coworking with MIBEL and other external entities

Figura 15: Roles of the regulator in Portugal

3.11.3 Feed-in tariff: incentives to alternative energy sources

Being part of the European Union, the government of Portugal had to make a commitment to be in line with the EU directives that want to promote the production of energy through renewable sources, with the exclusion of large-size plants using hydropower; indeed Portugal set the goal of reaching 32% of energy used coming from renewable sources by 2030. This will be achieved by the use of economic incentives and by setting compulsory target on the minimum amount of energy that has to be produced from renewable sources. The regulation on how to calculate the incentives is included in the country's National Plan of Action for Energy Efficiency 2013 to 2016 and in the National Plan of Action for Renewable Energies 2013 to 2020 (PNAER 2020); the incentives comes from the use of feed-in tariffs applied to the production plants that respected all the requirements; that is the most important support given by the government. This decree-law also oblige the grid operator to purchase electricity produces by renewable sources from all the producers at a fixed price. The tariff is composed by two parts; the first one is the guaranteed payment rate and the second is an addition calculated by a set of formulas. Another indirect incentive given to plants producing from renewables, is the priority when they dispatch energy to the grid (RES; 2013).

Overall regulation, tariffs system and incentives

The regulation in Portugal of the activities in the supply chain of electricity, uses, for the major part, a system of incentives, like price cap and revenue-cap, for the operational expenses, while on the capital expenses the regulation uses the rate of return system. In regulating the electricity market, ERSE has three important aspects:

- applying in the calculation of the expenses, the reference cost related to the transmission that the firm had to sustain starting from the regulation period of 2009-2011;
- switching from a price cap system applied to TOTEX, to a price cap model for OPEX and a rate of return model for CAPEX in the distribution of electricity;
- using the price cap model for TOTEX in the low voltage distribution since 2018 (CEER; 2019).

As a regulator, ERSE has to establish the Tariff Code, that institutes how the system to calculate the tariffs and the limits on revenues; before the Code is approved, it has to go through a public consultation and an analysis of the Tariff Board of ERSE. In the code, all the activities are associated to a structure and a series of parameters, that are used to establish the tariff at the start of the regulatory period, that is three years. The variables are gathered when the companies send them to ERSE, by auditing activities and estimations; usually the data are about the financial statement, operational costs, depreciation and investments. To calculate the price-cap and the revenue-cap, the formula takes into account if the cost is totally under the control of the company or not, investment costs and all the operating cost decreased of the additional income; costs like the concession rents and actuarial gains are also accepted.
In order to decrease the controllable costs of the company, the regulator established an efficiency target that must be respected; this target is set up by a comparison with national and international standards.
In addition to these, the regulator set other incentives for the reduction of the losses, investments in smart grids and maintaining a high quality of the services provided for the activities related to the distribution; while for the transmission activities, the incentives are made in order to promote investment to improve the

efficiency of the network, using the reference cost, investment of this kind can be maintenance or new equipment.
[Report on Regulatory Frameworks for European Energy Networks; CEER Report]

3.11.4 Asset Base Remuneration

For calculating the remuneration, the legislation uses the weighted average cost of capital pre-taxes (WACC); for the calculation of the cost of equity of the company, it is used the Capital Asset Pricing Model (CAPM), while for the cost of debt the starting point is the risk-free rate, to which is added a bonus for the risk. Even if the WACC is calculated ex-ante, there are some deviation that may occur during the regulatory period, due to the environment in which the company is working, that may change the costs; for this reason every year there are some adjustment to take into account how the variables used in the calculations changed.
In order to evaluate the rate of the WACC for the risk-free base, the formula uses the 10y bond of Portugal, and has yearly adjustment; there are also a maximum and minimum value to reduce the volatility (see table below with indications for ROE). From the regulatory period that started in 2018, for investments that took place after 2009, there is a 0.75% of bonus if the cost of the investment is considered efficient.

	TSO	TSO
Risk-free base	1.00%	1.00%
Tax rate	31.50%	31.50%
Equity risk premium	7.66%	7.66%
Equity beta	0.58	0.63
Cost of equity (taxes excluded)	**7.94%**	**8.50%**

Figura 16: Elaboration of data from CEER; 2019

The adjustments on the revenues cap and price happen bi-yearly, and take into consideration eventual changes from the budgeted costs and the ones that the company actually had to sustain. These deviations happen with a higher frequency for activities regarding the acquiring and the sale of electricity, and for this reason the adjustments on these activities happen every year; the same goes for non-ordinary costs.
In calculating the rate of return, investments and amortizations are estimated at the beginning of the regulatory period, but they are then updated every two years using the real value.

Type of activity	Frequency of adjustment (year)
Routine activities for Revenue cap	2
Purchase and sale of electricity	1
Non-budgeted costs	1
Investment and amortizations	2

3.12 Projects in Portugal

3.12.1 InovGrid

InovGrid is a project founded in 2011 under the organization of the Portuguese DNO, EDP Distribução, with the intend of implementing the use of innovative system in the distribution grid, with the goals of creating value through energy efficiency, operations efficiency, quality of service and emerging technologies (ESOF; 2012); the three main protocols that this project wants to implement are:

- Smart Metering, with a focus on the Automated Meter Reading, in order to increase the efficiency of the grid and also to bring new benefits to the clients;
- Smart Grids, to improve the quality of the service and the efficiency of the network management systems;
- Micro generation and Distributed Generation, to face the increase of the demand of customers that want to be connected to the grid with an active role of prosumers.

(Lucio P.; 2011)

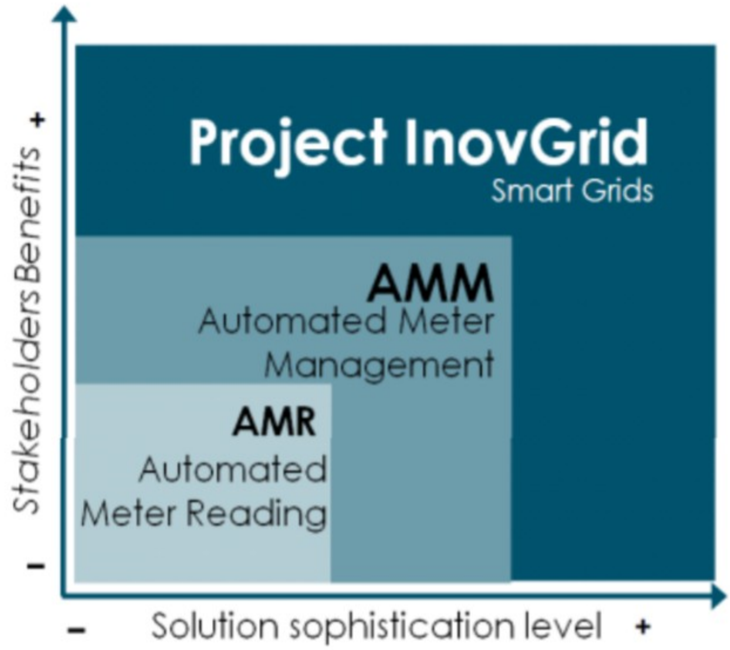


Figura 17: Benefits of InovGrid in function of the technology used, from Lucio 2011

To reach the goals of the project there are three important technologies that will be used are:

- Energy-Box
- Distribution Transformer Controllers
- Information System capable of using the informations gathered in an holistic way to make possible the communication between all the processes carried on from all the actors.

In the project the areas of the electricity market that will be improved are energy efficiency, operations efficiency, quality of service and emerging technologies (micro-generation and electric vehicle); for each of these areas there are some value drivers, that will be monitored using specific KPIs, like the reduction of the overall consumption and of the technical losses, the customer satisfaction, the increase in the integration of micro generation and other (Matos; 2012).

3.12.2 The BRIDGE initiative

The BRIDGE initiative is born in 2015 under the directives of the EC, in the framework of Horizon 2020 Smart Grid and Energy Storage Projects, that intends to create a project where innovative companies can share the progress made in the technology development and in the industrial products to increase the energy efficiency and increase the participation of customers in the market. The purpose of BRIDGE is to increase the exchange of information regarding:

- data management, in particular the use of communication infrastructure, from a technical and non-technical aspects, cybersecurity, data privacy and the way that these data are use to obtain the most significant and useful information;
- business models, to increase the adoption of innovative business models used in the projects involved, that will be used as simulation tools, to find the strength and weaknesses that each one brings, and finally to evaluate the profitability of these BM by using common metrics;
- regulations regarding the rules that the countries adopt for competition, ownership and financial conditions in energy storage;
- customer engagement and the methodologies that the projects are using to evaluating the customers, like the different kinds of segmentation that can be done, the value drivers for different segments and what leads to a change in their behaviour.

When it started, the initiative involved 36 projects in the field of Low Carbon Energy and Smart grid; in March 2019 the count of the projects raised to 44, with projects from 38 countries for a total financing of 484M euro (CIRED; 2019). Figure 1 shows the distribution of the projects involved for their field of research, with the fundings received.
The project involves different stakeholder, using the same division utilized by the organizing bodies of the project, we can distinguish seven categories:

- Consumers, this category does not include only residential citizens, but also companies and cities;
- DSOs and TSOs;
- the National Regulatory Authorities;
- associations, cooperatives and other Local Energy Communities acting as active entities in the distribution and generation of energy but with non-profit intends;
- technology providers, like for storage and ICT services;
- Energy suppliers and market operators, this category includes traders and brokers in the energy market;
- Companies active in research and innovation activities, which counts the largest number of participants, with 196 companies (BRIDGE; 2019).

Field of research	Number of projects	Fundings (M€)
Distribution Grids	10	60
Distributed Storage	7	72
Transmission Grids	4	82
Large-scale Storage	2	25
RES and H&C	2	8
Islands	6	41
TSO-DSO cooperation	2	32
Other projects	11	164

Figura 18: Overview of projects involved; from BRIDGE 2019

3.12.3 Project DOMINOES

This project was founded in 2017, with a duration of four years, with the goal of improving the technologies used for smart grids, energy system integration and storage of energy; with a budget of 3,996 M€ provided by the European Commission under the framework of Horizon 2020 (Innovation and Networks Executive Energy; 2018).
DOMINOES will be tested in a DSO environment in Evora in Portugal, but will also include tests made in a virtual power plant and a microgrid in Finland.
In improving the modern technologies, DOMINOES also has the target of decreasing the entry barriers, that are one of the biggest obstacles for increasing the competition in the energy market, with a particular focus on the generation and transmission from distributed resources and the flexibility of the networks.
The technologies that will be improved will be the systems used for demand response, grid management and peer-to-peer trading; to do so there will be a creation of new structures using ICT systems and new innovative business models; in this the participants of the project will be DSOs, that will test the systems to improve the management of the demand, with the goal of increasing the balance between demand and generation on a local scale composed mostly of energy independent communities.

3.12.4 Project SINAPSE

This project was financed by Energias De Portugal in 2014, with an overall budget of 60k€, with a duration of 3 years (ETIP; 2018). The goal of SINAPSE is to

develop a platform, active in low voltage grid, able to detect and create and automatic response for anomalies in the power grid. The benefits in the use of this new system will be a decrease in the power outage times; the optimization of responses to customers in case of energy shortage and the collection of data to further improve the management of anomalies.
The project involve also other partners, like telecommunications operators such as NOS, Vodafone and MEO, that will have benefits from this project, like an improvement in their electricity dependent activities and a reduction in the use of human labor by automating process that now depend on human intervention and also an increase in the efficiency of the operation by improving the visibility of causes of the anomalies (EDP; 2018).

3.12.5 Project PREDIS

Project PREDIS started in 2016, with a budget under 1M euro provided by the directives of Horizon 2020, and it was developed by EDP; the goal of the project is implementing the prediction capacity of the generation and consumption in the grid with a real time monitoring that uses telemetering.
The outcomes of the project are particularly relevant with the increasing use of distributed energy generation and the change in the consumption behaviors of citizens.
The main technology used for this project will be the ICT system used to collect data and conducting a predictive analysis on generation and consumption. These data will be used by the DSO, that can better understand the improvements that the grid requires to operate with more efficiency; thank to this it will be able to make more useful investments that will reduce its operating costs in the long term.

Project	Description	Budget
InovGrid (2011-Ongoing)	InovGird focuses on the automation of the technologies used in the smart grid, such as smart metering; part of the study was on micro generation and the integration of distributed generators.	N/A Financed by EDP
BRIDGE initiative (2015-Ongoing	Studying solutions for innovative business models, using data collected in different demonstration projects in all Europe. The data will also be used by local regulators to elaborate better incentives systems.	484€ million From Horizon 2020 and private investors
Project DOMINOES	Conducted by the DSSO to study	3,996€ million

(2017-2021)	energy storage systems, energy systems integration and the use of big data in smart grids. New technologies tested include demand response management, grid management routines and peer-to-peer trading.	From Horizon 2020
Project SINAPSE (2014-2017)	The project studied a platform used to identify anomalies and create routines to reduce the time to restore the grid network.	60k€ From Energias De Portugal
Project PREDIS (2016-Ongoing)	Study the prediction capacity regarding the generation and the distribution on the grid. It will also test ICT technologies to implement the predictive analysis.	1€ million From Horizon 2020

4. Conclusions

The purpose of the analysis conducted in the framework of this thesis was to collect informations on the five countries used as reference (Sweden, Spain, Ireland, Portugal and Switzerland) to understand better what is the role that national entities, like governments and regulatory bodies, have in promoting the development of energy network integration and the adoption of innovative solutions. To carry on this analysis and extrapolate the informations required, we analyzed recent policies published by governments and regulatory bodies, official websites of governments and grid operators, plus different reports on the projects that have been conducted in the countries of the analysis. In addition to these, we also took in consideration informations published on websites and reports by entities conducting analysis on a broader scale, such as the Joint Research Centre and the European Commission.

The analysis has brought the understanding of the different strategies adopted by the countries to foster innovation, and having in the study a country like Switzerland helped to a better understanding of the differences between countries in the European Union and the others, indeed it was possible to observe a common line for the goals of the four countries in the EU, in particular from the point of view of time window and specific goals regarding the share of renewable sources, while, even if it has set targets for improving the network grid and reducing the environmental impact, the national plan of Switzerland was more focused on an economic perspective, with the maintaining its position in the electricity market as the main target; the different goal that Switzerland is trying to achieve is not necessarily due to not being bonded to the targets set by the European Union, but it is more likely to be related to the fact that the country has already an high share of renewable sources in the production of energy, mostly coming from the use of hydropower plants.

The strategy adopted, and the target that the country is trying to achieve, is reflected also in the kind of projects that are being developed, indeed while the projects in the member countries are for the mostly demonstration o R&D projects focused on studying new technologies, Switzerland was lacking in this category, and most of the investments are being made to increase the capacity and the geographical area that the grid covers.

From the structure of the electricity market, it appears that in all the countries analyzed, the governments recognize the liberalization of the market as one of the best way to increase the benefits of the customers, that can therefore choose the provider more in line with its consumes, since the competition is a good incentive for the companies to keep an high quality of service while keeping low prices.

In the countries analyzed that are part of the European Union, there is the common factor that the Transmission System Operator is a monopolistic company partially state-owned, this had a good impact in the investments for innovative projects carried on, since the majority of the investments are made by the company, but there is not a strong correlation since in Portugal, there is a strong contribution of funds from the EU to finance the projects.
It is possible to see that the adoption of national plans of investments by the government had positive impact on the development of innovative projects, like in the case of Sweden and Spain, more than in countries that used as incentives only the tariffs systems.
Overall in the countries analyzed there is a common subject as focus of the projects, and Portugal was the only country in which there was a project focusing on distributed generation, but in all the European Countries there are projects for implementing storage and flexibility in the grid, that can bring in the future to a better integration of energy carries.
In the analysis conducted in this work there is not complete overview of the projects conducted in the countries, but it provided a better understanding on how the regulations and incentives systems adopted in a country can influence the investments and the projects made; this work is connected to the other analysis conducted before on other countries, and, with them, can help to help to make the right choices to face the challenges deriving from the, always more European, energy market.

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