TÉCNICO LISBOA

Characterization of the Spanish Electricity Sector

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Y especialmente gracias a la vida por haberme dado la oportunidad de vivir esta experiencia. Estas hojas esconden muchos más aprendizajes de los que en un principio hubiese imaginado.

Viajar es marcharse de casa,

es dejar los amigos

es intentar volar

volar conociendo otras ramas

recorriendo caminos

es intentar cambiar.

Viajar es vestirse de loco

es decir “no me importa”

es querer regresar.

Regresar valorando lo poco

saboreando una copa,

es desear empezar.

Viajar es sentirse poeta,

es escribir una carta,

es querer abrazar.

Abrazar al llegar a una puerta

añorando la calma

es dejarse besar.

Viajar es volverse mundano

es conocer otra gente

es volver a empezar.

Empezar extendiendo la mano,

aprendiendo del fuerte,

es sentir soledad.

Viajar es marcharse de casa,

es vestirse de loco

diciendo todo y nada con una postal,

Es dormir en otra cama,

sentir que el tiempo es corto,

viajar es regresar.

Gabriel García Márquez

ABSTRACT

In a context of decarbonisation of the economy, the objective of this work is to analyze and to know the current Spanish electricity system, the expected future trends and to conclude if this system is adequate and sustainable both today and in the medium-long term.

To do this, we have first collected data on energy contributed to the mix and installed capacity in 2015, as well as the available power in the peaks demand of each technology in recent years.

Once exposed the composition of the electricity system with its activities regulated and released, have been presented the challenges currently facing the Spanish and European energy markets, in terms of amortization problems of the new facilities and the risk this entails future investments.

Based on the above, and taking into account the European guidelines and the state of the art of technologies: it is done an analysis of the Spanish electrical situation, the future prospects and the challenges to be faced.

The study concludes by noting that although there are no electricity supply problems today, there could be problems in the medium term, since market prices will not be able to cover the costs of future facilities, leading to investors flee to other sectors, lack of competitiveness and lack of despatchable technology in the system.

It is vitally important to carry out an audit of the electrical system to determine the real costs. Both windfall profits and windfall losses would be avoided, tending to balance the system.

Key words: Electric system, wholesale market, penetration of renewables, future trends, levelized costs of energy, windfall profits.

Num contexto de descarbonização da economia, o objectivo deste trabalho é analisar e conhecer o actual sistema eléctrico espanhol, as tendências futuras esperadas e concluir se este sistema é adequado e sustentável tanto hoje como a médio e longo prazo.

Para isso, primeiramente coletámos dados sobre a energia contribuída para o mix e a capacidade instalada em 2015, e tambem a potência disponível nos picos de demanda de cada tecnologia nos últimos anos.

Uma vez exposta a composição do sistema eléctrico com as suas actividades regulamentadas e divulgadas, foram apresentados os desafios que actualmente enfrentam os mercados energético espanhol e europeu, em termos de problemas de amortização das novas instalações e o risco que isso implica para investimentos futuros.

Com base no que precede, e tendo em conta as orientações europeias eo estado da arte das tecnologias: é feita uma análise da situação eléctrica espanhola, as perspectivas futuras e os desafios a enfrentar.

O estudo conclui salientando que, embora não haja problemas de fornecimento de electricidade hoje, poderá haver problemas a médio prazo, uma vez que os preços de mercado não serão capazes de cobrir os custos de instalações futuras, levando os investidores a fugir para outros sectores, tambem a falta de competitividade e falta de tecnologia despatchable no sistema.

É de vital importância realizar uma auditoria do sistema elétrico para determinar os custos reais. Ambos os lucros extraordinários e as perdas extraordinárias seriam evitados, tendendo a equilibrar o sistema.

Palavras - chave: Sistema elétrico, mercado atacadista, penetração de energias renováveis, tendências futuras, custos de energia nivelados, lucros extraordinários.

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LIST OF ABBREVIATIONS

REE: Red Eléctrica España

CTC: Costes de Transición a la Competencia

UNESA: Asociación Española de la Industria Eléctrica

CNMC: Comisión Nacional de los Mercados y la Competencia

PVPC: Precio Voluntario para el Pequeño Consumidor

TUR: Tarifa de Último Recurso

MIBEL: Mercado Ibérico de la Electricidad

CNE: Comisión Nacional de Energía

CCGT: Combined Cycle Gas Turbine

LCOE: Levelized cost of energy

RES: Renewable energy sources

1. INTRODUCTION

1.1. The importance of energy. The electricity

Energy plays a fundamental role in shaping the human condition. People's need for energy is essential for survival, so it is not surprising that energy production and consumption are some of the most important field of study in the society. Indeed, it has been argued that energy is the key "to the advance of civilization," concluding that quality of civilization are proportional to the quantity of energy a society uses. [1]

Energy allows us to move easily and safely around the earth through cars and planes, to transport food and goods produced anywhere in the planet. To get warm in winter when the weather is freezing and also to get cold when the summer is boiling us. Also we can cook our food and refrigerate it for consuming at another time, or having light at light in order to read whatever the human is interested in.

Why electrical energy form is important? Electrical energy plays a key role in the mix of the final energy consumption, due it is versatile in its form of generation, there are many and varied technologies that can produce it; electricity itself is clean and no contaminant; moreover it is easy to transport and distribute what allows accessibility to the most distant places.

The development of electric power has allowed a rise in the living standards of the world population. And when we make a comparison between benefits and damages caused by electric energy in our societies, we must take into account that economic and social development, technical assistance, media, literacy, access to drinking water and life expectancy are all conditioned by it. [2]

The ambition of all countries to have a more dignified life according to Western standards will lead to a brutal increase in the demand for electricity. This is expected to increase by more than 70 per cent by 2040, with China and India leading, followed by all non-OECD countries. While the countries belonging to this organization will experience a growth in demand at a lower pace.

Electricity consumption is still largely driven by GDP growth although energy efficiency improvements have contributed to decouple energy performance from economic growth. Electricity consumption decreased starting in 2008 due to the impact of the economic crisis and the subsequent sluggish recovery, as well as to energy intensity improvements. At the end of 2012, total electricity consumption was still 2.3% lower than in 2008, whereas analysts were expecting an average annual growth rate of about 2% at the time. In the future, the energy efficiency improvement in the rest of the economy is expected to increase the demand for electricity. According to the Energy Roadmap 2050, the electricity share in the final energy consumption is expected to double compared to 2005 in the decarbonisation scenarios reaching 36% - 39% of final energy demand in 2050. This reflects the increasing role played by electricity in decarbonising final demand sectors such as heating and services and in particular transport. [3]

Electricity demand in the transport sector in 2050 increases by almost a factor eight compared to 2005 under the different scenarios of the Impact Assessment of the energy efficiency review and its contribution to energy security and the 2030 Framework for climate and energy policy. This is mainly due to the electrification of road transport, in particular private cars. About 80% of private passenger transport activity is foreseen to be carried out with electrified (plug-in or pure electric) vehicles by 2050. Compared to transport, the electricity demand of households and the tertiary sector is expanding more modestly by 2050, yet markedly, mainly driven by the electrification of heating and cooling. This new usage of electricity overcomes the improvements achieved by 2050 in energy efficiency of appliances as well as the increased thermal integrity in the residential and service sectors and more rational use of energy in all sectors. By contrast, industrial electricity demand remains quite stable by 2050 compared to 2005. [3]

1.2. Concerns. Climate change and security of supply

Nowadays the two biggest concerns of any government or energy system are climate change and security of supply.

Today, fortunately, there is a growing awareness of the serious problem of global warming for present and future generations. There are demonstrated evidences over the last decades that the climate on the planet is changing and thus producing impacts detrimental to people's lives.

Going from the 1997 Kyoto Protocol to the 2016 Paris Agreement, several agreements have been discussed, signed and ratified to combat this phenomenon at the international level, limiting the temperature that the planet will reach without destroying ecosystems.

Greenhouse gas emissions and other harmful emissions are not the only negative effects of fossil fuel consumption. During the long process from oil extraction to fuel burning, there are also other practices that affect the planet, such as hydraulic fracturing or fracking. Technique widely used today and for which it has not yet been legislated against despite an infinity of geological and environmental studies that discuss its harmful effects for the planet and for the health of population.

On the other hand, the problem of the security of supply worries enormously to any government. Since, as mentioned earlier, energy is the one that moves the world and on which the whole planet depends, there is a fear of the outbreak of a conflict in any corner of the planet that compromises the supply of fossil fuels, which are the largely predominant fuels in any system in the world.

The recent tension in the Middle East, which is the region with the largest oil production in the world, and in Russia, the leading country in oil and natural gas production, gives rise to a greater concern about price fluctuations and fear of lack of supply of these fuels. Consequently, energy systems seek to alleviate this fear with energy self-sufficiency.

The solution to these two concerns explained above is undoubtedly renewable energy, which on the one hand allows good treatment of the environment and on the other hand the energy independence from third countries.

1.3. European policies

The energy policies developed by the European community have been numerous and varied. So for our study, we will refer to those that directly affect the final objective of the work.

In order to achieve a single integrated electricity market throughout the European Union, the first directive on common rules for the internal market in electricity (Directive 1996/92 / EC) was drawn up, which can be considered as the starting point of electricity markets within the European Union. The principles that have since guided the European regulation of the electricity sector have been environmental sustainability, security of supply and the introduction of competition that results in lower electricity prices for the final customer. There has been an evolution in the Member States from a regulated electricity system governed by almost obligatory planning, to a liberalized system in which agents compete in the dispatch of their plants and in the electricity supply to the final customers. To this end, a partial and progressive opening was established in which three sets of legislative measures have now been developed between 1996 and 2009 in order to achieve this objective of a common European electricity market. [4]

On other hand, in June 2009 the Climate and Energy Package entered into force committing the European Union to transform itself into a highly energy-efficient, low carbon economy over the next decade. The package includes three major objectives collectively known as the 20-20-20 targets to be achieved in 2020, these are summarized in: [5]

- To reduce EU greenhouse gas emissions by at least 20% below 1990 levels.

- To reach 20% of renewable energy in EU gross final consumption of energy.

- To increase energy efficiency by 20% (as compared to business-as-usual in 2020).

In the 2020 targets, the EU has also agreed to achieve an interconnection level of at least 10% of their installed electricity production capacity for all Member states. [3]

Moreover, in the year 2015, it is necessary to highlight the European Commission's publication of the 'Energy Union Package, which goes beyond the 20-20-20 package and defines a new strategic framework for achieving the Community's policy objectives Energy and climate change, in particular for the new specific objectives for the 2030 horizon (40% reduction in emissions compared to 1990, 27% share of renewables on final energy consumption, 27% of energy saving compared to consumption forecasts and 15% of interconnection capacity between member countries), which will require a profound transformation of the European energy system. [6]

In order to facilitate the achievement of these objectives, this new legislative package attaches great importance to increasing interconnection capacity between Member States, including a specific strategy to ensure the full integration of the internal electricity market through appropriate levels of interconnection, which requires a great and renewed political impetus at European level involving both the authorities of the connecting countries as well as the community authorities. [7]

1.4. Spanish political situation

The Spanish electricity sector has undergone a profound transformation since 1998. Until then, the Spanish electricity system was structured as a regulated system in which the government established the price of electricity, which remunerated all the costs incurred (mainly generation, transportation and distribution of electricity) to a group of electricity companies.

The approval of Law 54/1997, of 27 November, on the Electricity Sector, marked the beginning of the process of progressive liberalization of the sector through the opening of networks to third parties, the establishment of an organized market for the negotiation of energy and reduction of public intervention in the management of the system. [8]

Therefore the result today is a well differentiated electrical system in which there is a legal, accounting and functional separation between regulated activities, which are transportation and distribution, and activities in full competition, which are the generation and marketing. In the next chapter we will go into the detail of how each element of the electrical system works and the socioeconomic implications that each one of them has at present.

In order to comply with European directives, the Spanish state is currently developing the so-called Renewable Energy Plan 2011-2020. This plan includes the design of new energy scenarios and the incorporation of objectives in line with Directive 2009/28/CE of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources, which sets minimum binding targets for the European Union as a whole and for each of the Member States. Specifically, the Directive aims to achieve a minimum quota of 20% of energy from renewable sources in the final gross energy consumption of the European Union, the same target set for Spain, and a minimum share of 10% of energy from Renewable energy sources in the transport sector in each Member State by the year 2020.

It is necessary to highlight a very important feature of the current electricity system, which is the large tariff deficit that reaches today 25,000 million euros. This has its origin mainly in the photovoltaic boom (but also due to wind, cogeneration and solar thermal technologies) that took place in Spain between the years 2008 and 2013 where many megawatts were installed using technologies that were still expensive. These facilities obtained premiums out of the market so that they could amortize their facilities, which were paid by the consumers. As a result of the economic crisis and the rising rate deficit, the government decided to cut premiums to a reasonable profitability. At present, this deficit is decreasing, but it continues and will continue to be an important obstacle for the development and support to facilities new less competitive that could bring great flexibility and efficiency to the system.

It should be noted that the deficit, which has to be paid in the future by consumers, will be increased by the financial cost, which will cause an increase in future levies for their recovery. [9]

1.5. Structure of the Spanish electricity system

According to the content of Law 24/2013, the Spanish electricity system consists of the activities of: generation, transmission, distribution, energy recharging services of electric vehicles and storage batteries, marketing, the market operator performing the economic management, and the system operator (TSO) performing the technical management. These activities are described in the following order:

- Generation. Developed by electric power producers. They are natural or legal persons that have the function of generating electrical energy, and of constructing, operating and maintaining the production facilities. The production of electricity is developed under free competition, giving rise to a production market composed of a set of commercial transactions of purchase and sale of energy.

- Transmission. It is that mercantile company that has the function of transporting electric energy, as well as constructing, maintaining and maneuvering these facilities.

- Distribution. Distributors are mercantile companies or cooperative societies of consumers and users, which have the function of distributing electrical energy, as well as construct, maintain and operate distribution facilities designed to place energy at points of consumption.

- Energy recharging services for electric vehicles and storage batteries. This activity is developed by so-called cargo managers, which are mercantile companies that, as consumers, are qualified to resell electric energy for energy recharge services.

- Marketing. Los comercializadores son sociedades mercantiles o sociedades cooperativas de consumidores y usuarios, que adquieren energía para su venta a los consumidores, accediendo a las redes de transporte o distribución, a otros sujetos del sistema o realizan operaciones de intercambio internacional.

- The market operator. It is that mercantile society that has among its functions the management of the offer system of purchase and sale of electric energy in the daily market.

- The system operator. It is that mercantile society whose main function is to ensure the continuity and security of the electricity supply and the correct coordination of the production and transportation system. The system operator is the transport network manager.

- Consumers, who are the natural or legal persons who acquire energy for their own consumption.

1.6. Situation of the Spanish electricity system

Net electricity consumption in Spain was 236 TWh in 2015, an increase of 1.4% compared to 233 TWh in 2014. This growth is a recovery after four consecutive years of decline and, thus, in 2015 the level of consumption is situated in the historical values of the years 2003 and 2004. [10]

A distinction must be made between net electricity consumption and gross electricity demand, since the former is understood as the electrical energy available to the market, ie before transport and distribution. Thus, electricity demand in the year 2015 was 263 TWh and represented an increase of 1.4% over the year 2014. [11]

In terms of trends, in the last 20 years Spain's net electricity consumption has grown at an annual average rate of 2.3%, while in the last 10 years it has decreased at a rate of 0.7%. [11]

In the following two figures you can see the historical evolution of the demand for electrical energy. Figure 1 shows sharp declines in annual growth in 1969, 1973, 1979 and 1991, the first two dates most likely due to the oil crises, and the latter two probably due to the war in the Middle East: Iran-Iraq conflict and first Gulf War. More recently, and as a historical landmark, the financial crisis is unleashed in 2008, since it is the first historical decline in electricity demand in Spain.

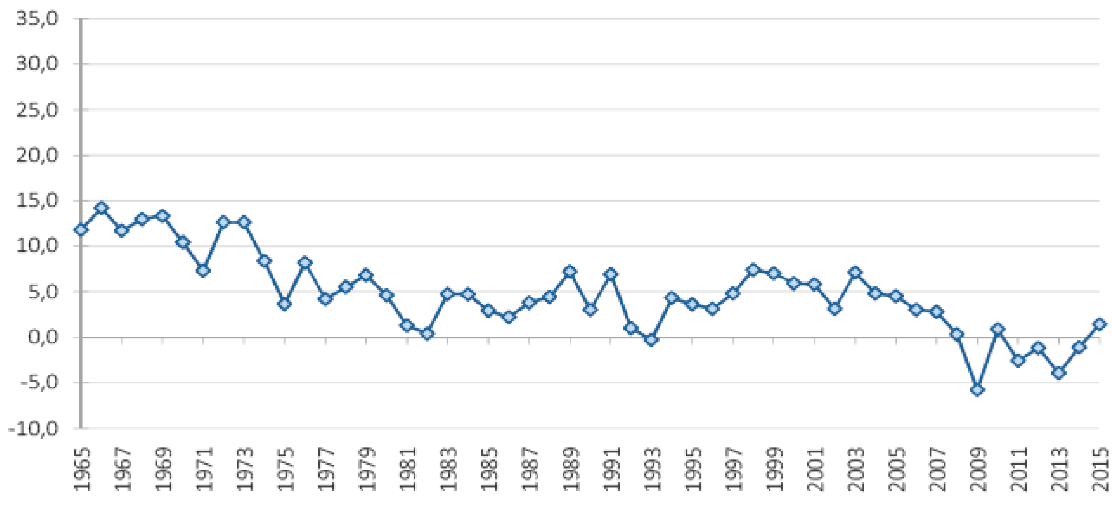

Figure 1. Annual growth of net electricity consumption in Spain (%). Source: UNESA

Figure 2 shows that, as previously mentioned, the evolution of the electric demand has always been increasing, with a greater or lesser speed, until the arrival of the financial crisis of the year 2008, where it begins to decrease . Situating in 2015 to demand levels in 2003. According to the monthly reports of Red Eléctrica Spain in relation to 2016, it seems that demand will increase slightly compared to 2015 level.

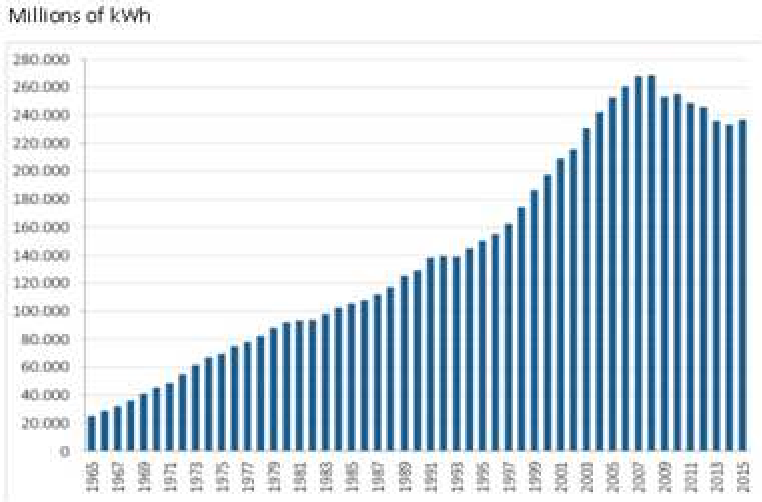

Figure 2. Evolution of net electricity consumption in Spain (Millions of kWh). Source: UNESA

The structure of electricity consumption by autonomous communities in 2015 is represented in the following table 1. It is important to note that the demand of the mainland market represents 94% of the total, i.e. 248 TWh while the extra peninsular system the remaining 6% With 15 TWh.

Comunidad Autónoma	(%)
Cataluña	17,5
Andalucia	14,2
Madrid	11,1
C.Valenciana	10,1
Galicia	7,6
Pais Vasco	6,8
Castilla- León	5,2
Castilla-La Mancha	4,4
Principado de Asturias	4,2
Aragón	3,9
Canarias	3,4
Región de Murcia	3,4
Baleares	2,3
Navarra	1,9
Cantabria	1,7
Extremadura	1,6
La Rioja	0,7
Ceuta y Melilla	0,0
TOTAL	100,0

Table 1. Structure of electricity consumption by Autonomous Communities. Source: UNESA

More information is needed to help us understand how this electrical energy is supplied in each region. Figure 3 shows very well the relationship between energy generated and consumed in each autonomous community. The areas with the most problems of self-sufficiency coincide with the most industrial areas of the Spanish territory, placing at the head of the Community of Madrid, which is barely able to supply 4% of the electric energy it consumes. The Catalan community is well supplied in the south, however the industry of the metropolitan area of Barcelona needs a lot of electrical energy to feed its factories. It is followed by the Basque Country, whose industries require a large amount of electricity, and are able to supply only 35% of the total demand in the region.

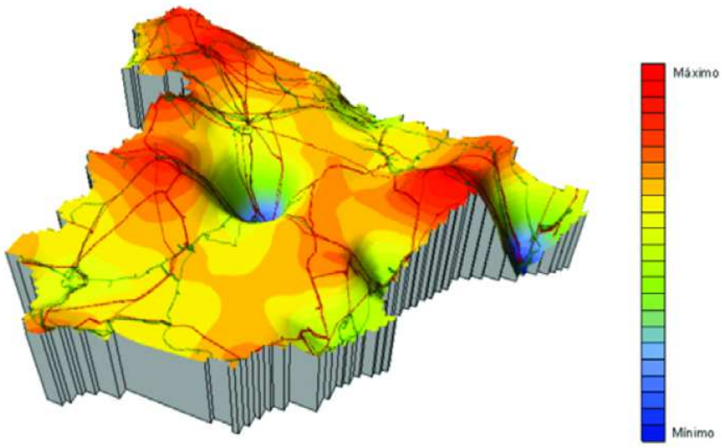

Figure 3. Self-supply of electricity. Source: REE

When conducting a study on an electrical system, it is of great importance to know the peaks in demand that occurs throughout the year, since the system must guarantee coverage at all times of the electricity demanded. With the increasing penetration of renewable energies, peaks in demand must be analyzed differently depending on the time of year when happens.

In 2015, peak demand occurred in the peninsular system on February 4 at 19:56 hours with 40,726 MW, the highest value since 2012, but far from the record annual peak of 44,876 MW in 2007, which occurred on 17 December at 19:40 hours. [10]

The generation structure of February 4 can be seen in the following figure 4 on the left, where the strong contribution of wind energy stands out.

On the other hand, the maximum peak demand in 2015 for summer months occurred on July 21 at 13.33 hours with 40,192 MW. This is the highest value since 2010, when the record high of this station was recorded, with 40,934 MW. The generation structure of July 21 can be seen in the figure 4 on the right.

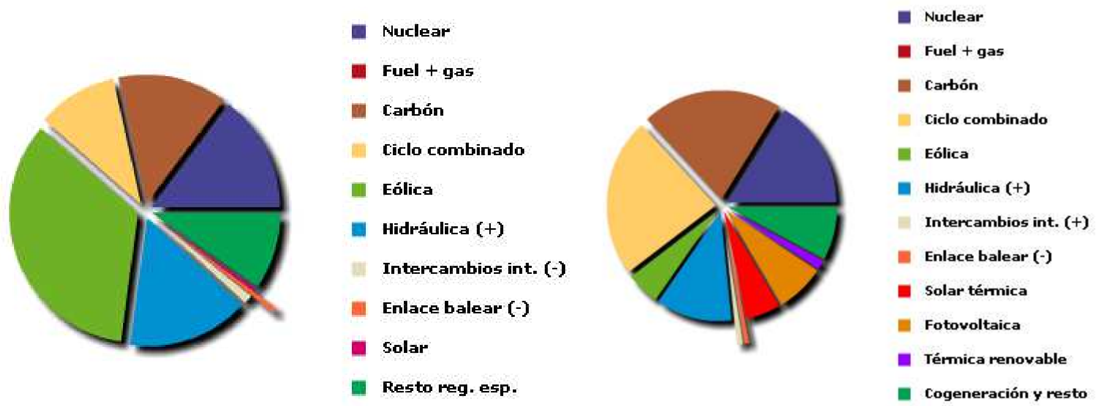

Figure 4. Structures of peak generation in winter and summer in 2015. Source: REE

We can see in the figure 4 above a great difference between the contribution to the mix of each technology, especially in the wind. Therefore, when studying and designing an electrical system, it is necessary to keep in mind what time of the year corresponds to the peak demand in question.

As can be seen in the figure, annual demand peaks were recorded in the winter months, figure 5. These maximums occur between 7:00 p.m. and 8:00 p.m.

On the other hand, it is appreciated in the figure 5 that the difference between winter and summer is not too large, around 500 MW. However, as mentioned above, it must be taken into account that the availability of certain technologies, such as hydropower or photovoltaic, vary from one station to another. This will be discussed in more depth later.

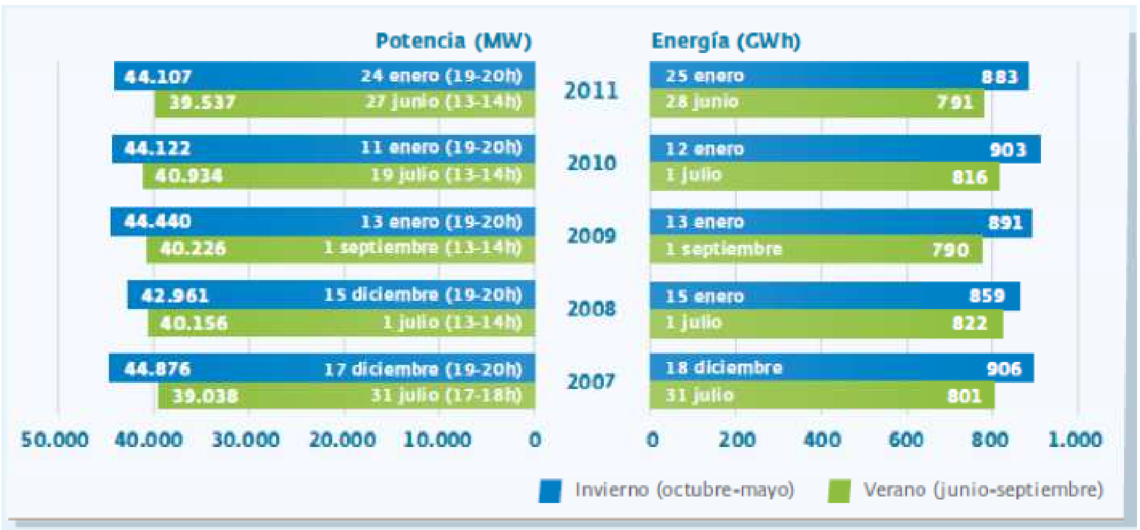

Figure 5. Peaks in demand in summer and winter. Source: REE

2. COMPOSITION OF THE SPANISH ELECTRICITY SYSTEM

2.1. Generation

The generation is a released activity and in full competence since year 1997, when the electricity market was liberalized.

2.1.1. Installed power and contribution to the mix

The electric generation field in Spain has undergone a profound transformation in the last 15 years. Installed power practically doubled from 2000 to 2015 to 107 GW, incorporating almost 30 GW of renewable power (20.5 GW wind and 7 GW solar) and 27 GW combined cycle. [12]

In the following figure 6 you can see the evolution of the peninsular installed power in recent years. As mentioned earlier, we can see the strong increase in combined cycle, wind and solar technologies. As well as the disappearance of the fuel-gas technology.

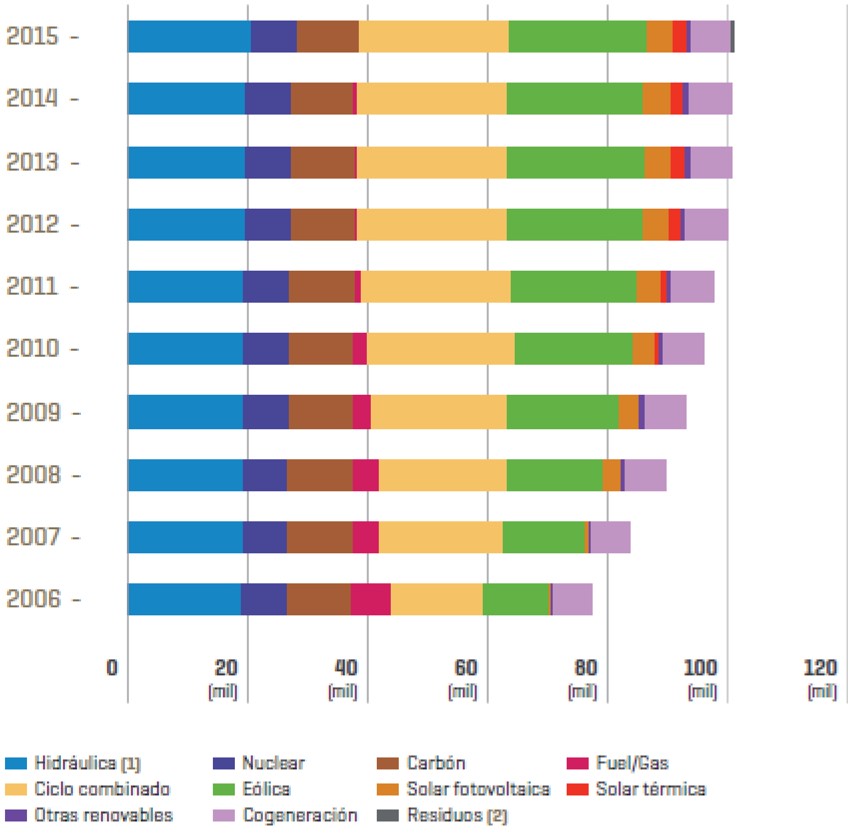

Figure 6. Evolution of the peninsular installed power. Source: REE

By 2015, the total installed capacity reached 106,247 MW, 0.5% more than in 2014, basically due to the opening of two 878 MW and 23 MW hydroelectric plants and the closure of the last central fuel-gas existing in the peninsular system of 506 MW. The figure 7 below shows the installed power of each technology.

	Sistema peninsular		Sistemas no peninsulares		Total nacional	
	MW	% 15/14	MW	% 15/14	MW	% 15/14
Hidráulica	20.352	4,6	1	0,0	20.353	4,6
Nuclear	7.573	0,0	-	-	7.573	0,0
Carbón	10.468	0,0	468	0,0	10.936	0,0
Fuel/gas	0	-100,0	2.490	0,0	2.490	-16,9
Ciclo combinado	24.948	0,0	1.722	0,0	26.670	0,0
Hidroeólica	-	-	11	0,0	11	0,0
Eólica	22.864	0,0	156	0,0	23.020	0,0
Solar fotovoltaica	4.420	0,4	244	0,3	4.664	0,4
Solar térmica	2.300	0,0	-	-	2.300	0,0
Otras renovables (1) (2)	742	-24,5	5	0,0	747	-24,4
Cogeneración (2)	6.684	-5,2	44	-63,6	6.728	-6,2
Residuos (3)	677	-	77	-	754	-
Total	**101.027**	**0,5**	**5.220**	**0,0**	**106.247**	**0,5**

Figure 7. Breakdown of installed power in 12/31/2015 Spanish electrical system. Source: REE

Mainly the peninsular system will be studied as it represents 101,027 MW of the total installed in the country, equivalent to 95%. This system is also of great interest because of its interconnections with the systems of France, Portugal and Morocco. In addition, the real-time demand curve (which has been a widely used tool in the present study) provided by REE on its website represents only the peninsular system.

The installed capacity is much higher than the historical maximum demand of 44,876 MW, which suggests that there could be an excess of power installed in the system. Even so, a detailed analysis of the situation will have to be done, since almost half of the installed technology, 48.09%, uses renewable energy as a source.

The minimum coverage, calculated as the minimum value of the ratio between the available power in the system and the peak demand by the system, had in 2015 the value of 1,37, similar to 2012, and lower than year 2014, which stood at 1,45. These variations compared to last year are basically due to the disconnection of the 2490 MW from the fuel / gas plant and the entry into operation of 936 MW hydroelectric. Even so, the value of the coefficient is quite secure, since it is calculated taking into account the most unfavorable conditions, that is, when the contribution of renewable energies is zero or very low.

If we now make a critical hypothesis, taking into account that it is at night, that there is no wind blowing and that there is no water to turbine, that is to say, considering that only conventional plants are working, with a utilization factor of 0.95, in order to be more realistic case. And taking as demanded power in the system the historical maximum of 44,876 MW, we would obtain a coverage ratio of 1.05. Therefore, we can see that by making a quick hypothesis, it becomes clear that the electrical production system is oversized if we only meet the objective of satisfying demand.

Gross generation demand was 263 TWh in 2015 and the generation structure was led by the following technologies: nuclear (21.8%), coal (20.3%), wind (19.0%) and hydropower (11%). While the participation of the combined cycle, despite the great installed power that has as seen in the previous figure, was 10.1%. The breakdown can be checked in the following figure 8.

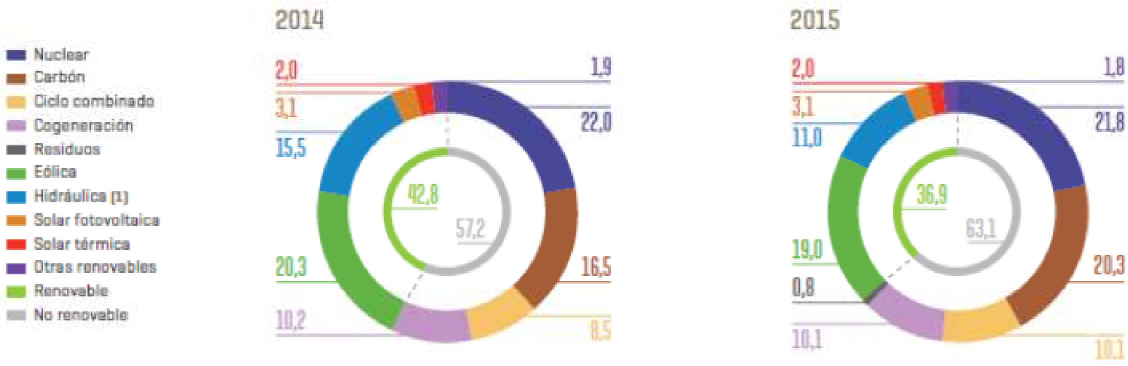

Figure 8. Annual generation structure of electrical energy in the peninsula 2014-2015. Source: REE

In the next figure 9 can be see the contribution of each technology to the two both systems and percent of variation experimented related to the previous year. Can be figure out the strong decrease in hydroelectric production, as is know is dependent of the climatic conditions, and also the decrease in windy generation. These decreases have been to be compensated by back-up dispatchable technologies: coal and combined cycle.

	Sistema peninsular		Sistemas no peninsulares		Total nacional	
	GWh	% 15/14	GWh	% 15/14	GWh	% 15/14
Hidráulica	30.815	-27,5	4	3,1	30.819	-27,5
Nuclear	54.755	-0,2	-	-	54.755	-0,2
Carbón	50.924	23,8	1.865	-14,7	52.789	21,9
Fuel/gas (2)	0	-	6.497	3,8	6.497	3,8
Ciclo combinado (3)	25.334	18,7	4.022	7,6	29.357	17,1
Hidroeólica	-	-	9	-	9	-
Eólica	47.707	-5,8	402	1,6	48.109	-5,7
Solar fotovoltaica	7.839	0,5	398	-1,9	8.236	0,3
Solar térmica	5.085	2,5	-	-	5.085	2,5
Otras renovables (4) (5)	4.615	-2,2	10	-6,7	4.625	-2,2
Cogeneración (5)	25.076	-2,0	32	-89,1	25.108	-3,0
Residuos (6)	1.886	-	311	-	2.196	-
Generación	**254.036**	**0,2**	**13.548**	**2,0**	**267.584**	**0,3**
Consumos en bombeo	-4.520	-15,2	-	-	-4.520	-15,2
Enlace Península-Baleares (7)	-1.336	2,9	1.336	2,9	0	-
Saldo intercambios internacionales (8)	-133	-96,1	-	-	-133	-96,1
Demanda (b.c.)	**248.047**	**1,8**	**14.884**	**2,0**	**262.931**	**1,9**

Figure 9. National electrical energy balance in 2015. Source: REE

2.1.2. Situation by technology

In this section will be presented the installed power of each technology and the energy produced in 2015, contrasting the data with previous years. In addition, will be shown the availability of each technology in the peak demand of year 2015. It will also discuss intrinsic and transcendent aspects of each technology concerning its relevance in the system and future prospects. All data shown below has been obtained from the REE 2015 report.

Nuclear

Nuclear power plants, as they are designed to work on baseload, i.e. they work almost at full power throughout their entire fuel cycle, provide very important network security and stability.

By 2015, installed nuclear power remains constant at 7416 MW, 7% of total installed capacity, a value that has not changed since the closure of the Santa María de Garoña power plant in 2012. Currently, there is ongoing discussion about the extension of the operation license and reopening of the plant.

In the year 2015, the 7 nuclear reactors of the Spanish territory contributed to the peninsular electrical production with 54,755 GWh, 21.8% of the total, being the technology that contributed most to the mix for the fifth consecutive year. The utilization coefficient was 97.6%, very close to the expected unit of this type of plants if they do not have to stop to change the fuel.

Therefore, must be remarked the importance of nuclear energy in Spain, which with 7% of installed capacity contributes 21.8% to electricity generation.

At the peak demand of 2015, on February 4 at 19.56 hours with 40,726 MW, the available nuclear power was 6078 MW, a value below all installed nuclear power, which leads us to believe that at that time was being carried out the work of changing fuel and maintenance of a plant. Thus, this technology with a utilization factor of 0.8 contributed to the electric mix with a 14.9%.

Regarding the maximum demand in the summer months, which was July 21 at 13.33 hours with 40,192 MW, nuclear availability was 6668 MW, with a contribution to the electric mix of 16.4% and a utilization factor of 0.88.

It can be assumed that in the two days of demand points of 2015 maintenance operations were taking place at some nuclear power plant, since the utilization factors of 0.8 and 0.88 are far from the average 0.97 of the technology throughout the year.

Operational plants have an operating license for 40 years. All began to operate in the 80's, so the license expiration is between 2021 and 2028. Probably being the extension of the life of these plants for 20 years more. This extension will depend on the future political landscape and how events around the combined cycle plants are developing.

Whether or not to build new nuclear power plants is a decision of the private sector since the end of the Nuclear Moratorium in 1997, which involved the cancellation of works and the dismantling of 7 nuclear power plants in Spain. Even so, the construction of new nuclear power plants is not foreseen in the years to come, due to the large investments that they involve and the lack of security in the political landscape.

Coal

The installed capacity of coal-fired power plants is maintained at 10,936 MW, representing 10.3% of the total capacity. This installed power is expected to decline in the years to come, as combined cycle power plants are more efficient and emit less greenhouse gases than coal, fact that is in line with Community policies.

The successive EU environmental legislation has been gradually reducing the permitted emission limits for SO2, NOx and particulate matter to conventional power generation facilities. [13]

The new Directive on Industrial Emissions (2010/75 / EU) applies more restrictive limits from 2016 for existing installations which will require them to make significant additional investments. The directive itself recognizes this difficulty and proposes flexibility measures that allow a gradual adaptation: the Transitional National Plan or the limited lifetime exemption. [13]

Spain has decided to implement a National Transitory Plan that allows it to ensure the reduction of total emissions of SO2, NOX and particulates by 60%, 70% and 40% respectively of the emissions from thermal power plants in Spain in the period 2011-2013 . The plants will be able to carry out adaptation investments before 30 June 2020 or close at the end of this period. [13]

From the 10,000 MW installed in 2016, 9,700 MW have joined to the Transitional National Plan, but only 3,560 MW (37%) have shown their interest in continuing to operate beyond 2020 with the processing of environmental permits for the realization of the necessary investments. [13]

In the year 2015, coal plants have produced an amount of electrical energy of 52,789 GWh, which is equivalent to 20.3% of the total generated. In that year, this technology increased its generation 23.8% over the previous year, which has placed it as the second source in the generation mix, increasing its participation percentage almost four points over the previous year. In addition, during the months of June, July, August, October and November, coal has been the main source of generation with a monthly participation of around 25% coinciding with the months of falling water production and with the increase of average temperature in summer months.

Thus, as expected, the coefficient of utilization of this technology increased to 61.8%, being the highest value in the last seven years.

The availability of this technology at the peak of demand was 5644 MW with a contribution to the generation structure of 13.8%. Therefore, the utilization factor was at 0.52.

On the day of maximum demand for summer months, the available power was 8599 MW with a contribution to the mix of 21.1%, being the second technology. In this way, the utilization factor of this technology was considerably up to 0.78.

Combined cycle

By 2015 the combined cycle plants in Spain represent 26,670 MW of installed capacity, which represents 25% of the total territory. All this power has been installed since 2002, according to data from Red Eléctrica Spain.

The electricity generated by this technology was 29,357 GWh, an increase of 17.1% over the previous year, with a contribution to the generation structure of 2015 of 10.1%. Being thus the fifth generation source after nuclear, coal, wind and hydraulic.

The increase in energy generated by this technology means a change in the trend after the declines suffered in the last six years. The monthly generation recorded growth during ten months and in July the biggest increase coincided with the heat wave that caused the reactivation of the production of thermal power plants. Despite this recovery, this technology continues to have a moderate weight in the generation structure, with its utilization coefficient of 12.9%.

The availability of this technology at the peak of demand was 4154 MW with a contribution to the generation structure of 10.2%. Therefore, the utilization factor was at 0.16.

On the day of maximum demand for summer months, the available power was 9735 MW with a contribution to the mix of 23.9%, being the first technology contributing. The utilization factor at this time was at a 0.37 being the annual maximum.

As mentioned above, the coefficient of utilization of these facilities is very low. In fact, in the last four years it has not surpassed 0.2 and is expected to follow this trend in the short term given the more than likely stabilization in the demand for electricity and the strong penetration of renewable energy, which despite the fall in production in 2015, have reached 37% of total demand, after the maximum historical contribution of 2014 with 43%.

In the case of combined cycle power plants, working at full power throughout the year, applying a factor of 0.95 for maintenance functions and safety aspects and taking into account that the year has 8760 hours, would obtain an energy total electric power produced per year of 221948 GWh. Therefore, only this technology would be covering 84.4% of the demand for 2015, which makes it a technology with an important importance in the electrical scenario.

Wind

The installed capacity of this technology to 2015 is 23,020 MW, representing 21.6% of the national total. This technology has experienced incredible growth in recent years, considering that in 2002 there were 4,400 MW installed, although since 2012 total wind capacity has hardly changed.

The electricity generated in 2015 was 48,109 GWh, 5.7% less than in the previous year. Even so, and for another year, it has played a key role in the electric mix, placing it in third place just behind nuclear and coal technologies, with a 19% share of the total produced.

Wind played a prominent role representing 51.4% of the peninsular renewable production. It was also the technology with the greatest peninsular contribution to the total production of electricity in February and May, representing 27.3% and 24.2% respectively.

It is necessary to emphasize the strong variability of the energy produced with the wind, in the year 2015, the wind had a participation in the generation structure that oscillated between a minimum of 2.7% on January 7, which is a critical date due to the low temperatures and high demand. By the other side, there was a maximum of 51.5% on November 21, being the technology with more weight in the generation structure of that day, reaching 70.4% coverage of demand at 4.50 hours.

La disponibilidad de esta tecnología en la punta de demanda fue de 14114 MW con una aportación a la estructura de generación del 34,5%. Por tanto, el factor de utilización se encontraba en un 0,61.

On the day of maximum demand for summer months, the available power was 2038 MW with a contribution to the 5.0% mix. The utilization factor at this time was at 0.08.

Solar

Photovoltaic solar installations maintain the growth path of more than a decade, although in the last three years a much lower rate of growth was observed than in the first years when premiums were given per kWh produced. In 2015, installed capacity grew to 4664 MW, representing 4.4% of installed capacity.

The energy produced by these facilities in the year 2015 was 8236 GWh, increasing by 0.3%, to represent 3.1% of the electric mix.

Meanwhile, solar thermal has not experienced changes in power throughout 2015, remaining constant at 2300 MW, which represents 2.2% of total installed capacity.

The energy produced by solar thermal in the national territory was 5085 GWh, a value that increased 2.5% over last year, representing 2% of the annual generation structure.

The availability of solar thermal at the peak demand was 159 MW, with a contribution to the generation structure of 0.4%. Therefore, the utilization factor was at 0.07.

On the day of maximum demand for summer months, the available photovoltaic power was 3016 MW with a contribution to the 7.4% mix. While the available solar thermal power was 2165 MW with a contribution to the mix of 5.3%. At this time, the utilization factors of each technology were 0.65 and 0.94 respectively.

Hydraulic

This technology was the pioneer in power plants in Spain in the 40's. Since then until today, the installed capacity has increased to reach 20,353 MW at the end of 2015, a power that represents 19.2% of the total installed capacity.

Hydraulic power plants have been the only type of facility with notable variations in capacity, 4.6% during 2015, as a result of the four new groups of the Muela II plant with 878 MW and 23 MW of San Pedro II plant. The Muela II is the largest pure-pumped hydroelectric power plant in Europe, which is called to play an important role in regulatory functions.

In the year 2015 the total electric energy produced was 30,819 GWh, an amount significantly lower than produced the previous year, in particular it has suffered a decrease of production of 27.5%. Thus, the contribution of this technology in the electric mix was 11%, compared to 15.5% the previous year, despite this decline continues is still the fourth largest source in the annual generation structure.

The strong decrease in hydroelectric production is due to the fact that, in hydrological terms, the year 2015 has been a dry year as a whole. The hydraulic producible[1] has been lower than the average historical value in most of the months (only February and March was above the average), which has resulted in the end of the year with a value of 18,949 GWh, 24% lower than the average annual historical value.

As a result, the hydroelectric reserves of the reservoirs were 46.6% of the total capacity at the end of the year, seventeen points below 2014 and below the average statistical value.

The availability of this technology at the peak of demand on February 4 was 6300 MW with a contribution to the generation structure of 15.4%. Therefore, the utilization factor was 0.31.

On the day of maximum demand for summer months, the available power was 4691 MW with a contribution to the 11.5% mix. The utilization factor at the moment was at 0.23.

Cogeneration

By 2015 the installed capacity of cogeneration in Spain amounts to 6,728 MW, 6.4% of the total installed capacity. This power has been reduced compared to the year 2014 by 6.2%, which is 417 MW.

The energy produced in 2015 was 25,108 GWh, down 3% from the previous year, representing 10.1% of the annual electricity mix.

The availability of this technology at the peak of demand was 3994 MW with a contribution to the generation structure of 9.8%. Therefore, the utilization factor was at 0.59.

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[1] Maximum amount of electrical energy that could have been produced in 2015 with the registered hydraulic contributions.

On the day of maximum demand for summer months, the available power was 3255 MW with a contribution to the 8.0% mix. The utilization factor at this time was at 0.48.

2.1.3. Study of contribution to peak demand

Thanks to the data obtained on the REE website, the contributions of each technology to peak demand in winter and in summer in recent years have been collected. These data allow us to know the power available at the peak demand of each technology, its utilization factor and the contributions to the mix.

Then, based on the data presented in the tables, the numbers of power provided corrected have been transformed in two graphs. On the one hand the conventional contribution of coal and combined cycle has been plotted; and on the other hand the renewable contribution of wind, hydro and solar. For a particular year, these corrected numbers are obtained as the available power of each technology divided by the maximum demanded power, in this way it is possible to have a reference when comparing the numbers from one year to another.

Nuclear technology has not been included in the study as it always works on baseload, being independent of components such as electrical demand or weather conditions. The same happens with the cogeneration technology, which has almost constant power availability throughout the year and is also independent of the elements mentioned above.

The chapter concludes with an analysis of the results obtained from tables and graphs.

Winter

Contribution to mix [%]	2008	2010	2012	2013	2014	2015	2016
Peak demand [GW]	43	44.1	43.5	39.9	38.9	40.7	38.2
Date	15-dec	11-jan	13-feb	27-feb	04-feb	04-feb	17-feb
Coal	15.7	5.5	17.2	19.3	3	13.8	14.8
Combined cycle	27.7	17.8	22.8	9.1	7.2	10.2	12.2
Hydraulic	12.9	23.9	10.6	16.1	23.8	15.4	24.7
Wind	18	22.5	20.1	21.9	32.6	34.5	15.5
Solar	0	0	0.1	0.8	0.6	0.4	1.2

Table 2. Contribution to mix in the peak demand of winter 2015. Source: Own elaboration

Power provided [MW]	2008	2010	2012	2013	2014	2015	2016
Peak demand [GW]	43	44.1	43.5	39.9	38.9	40.7	38.2
Date	15-dec	11-jan	13-feb	27-feb	04-feb	04-feb	17-feb
Coal	7026	2287	7930	7870	1174	5644	5711
Combined cycle	12348	7383	10533	3696	2818	4154	4717
Hydraulic	5744	9910	4900	6558	9334	6300	9514
Wind	8029	9358	9289	8933	12812	14114	5977
Solar	0	0	0	0	0	159	302

Table 3. Power provided to peak demand in winter 2015. Source: Own elaboration

Utilization factor [%]	2008	2010	2012	2013	2014	2015	2016	
Peak demand [GW]	43	44.1	43.5	39.9	38.9	40.7	38.2	Average
Date	15-dec	11-jan	13-feb	27-feb	04-feb	04-feb	17-feb	
Coal	61.85	20.05	71.35	70.70	10.70	53.92	59.89	49.78
Combined cycle	56.96	29.21	41.55	14.58	11.12	16.65	18.91	27.00
Hydraulic	30.89	50.56	24.71	32.97	46.91	30.96	46.74	37.68
Wind	49.60	47.84	41.09	39.10	56.08	61.73	26.14	45.94
Solar	0.00	0.00	0.00	0.00	0.00	2.35	4.46	0.00

Table 4. Utilization factor in the peak demand in winter 2015. Source: Own elaboration

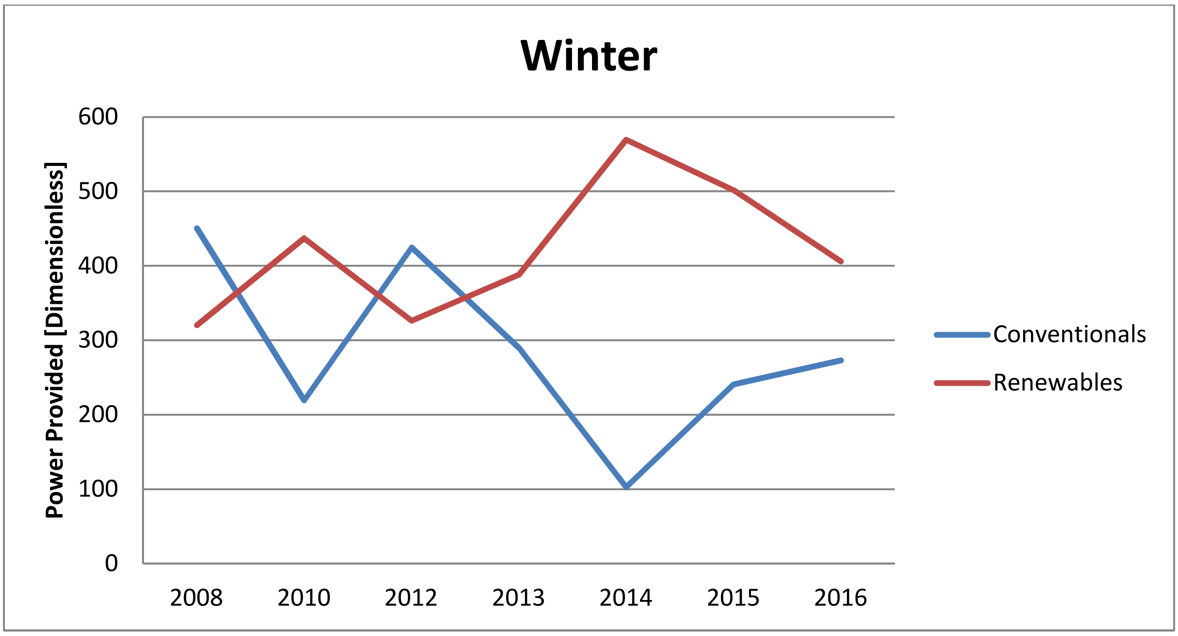

Figure 10. Provided power to peak demand during recent winters. Source: Own elaboration

Summer

Contribution to mix [%]	2008	2010	2012	2013	2014	2015	2016
Peak demand [GW]	40.1	40.9	39.2	37.4	37	40.2	40.1
Date	01-jul	19-jul	27-jun	10-jul	17-jul	21-jul	06-sep
Coal	14.2	11.3	19.6	19.2	22.1	21.1	17.1
Combined cycle	37.5	33.1	22.5	9.9	8.5	23.9	18.3
Hydraulic	17.8	16.9	12.7	19.4	11.4	11.5	14.8
Wind	3.6	1.4	7.1	6	16.9	5	2.9
Solar	6.1	7.8	12.1	12.8	13.5	12.7	12.1

Table 5. Contribution to mix in the peak demand of summer 2015. Source: Own elaboration

Power provided [MW]	2008	2010	2012	2013	2014	2015	2016
Peak demand [GW]	40.1	40.9	39.2	37.4	37	40.2	40.1
Date	01-jul	19-jul	27-jun	10-jul	17-jul	21-jul	06-sep
Coal	5821	4727	7818	7435	8540	8599	6964
Combined cycle	15367	13888	8975	3824	3290	9735	7424
Hydraulic	7284	7070	5079	7502	4390	4691	5945
Wind	1478	595	2850	2307	6500	2038	1166
Solar	2507	3109	4887	5104	5222	5181	5907

Table 6. Power provided to peak demand in summer 2015. Source: Own elaboration

Utilizacion factor [%]	2008	2010	2012	2013	2014	2015	2016	Average
Peak demand [GW]	40.1	40.9	39.2	37.4	37	40.2	40.1	
Date	01-jul	19-jul	27-jun	10-jul	17-jul	21-jul	06-sep	
Coal	51.25	41.43	70.34	66.79	77.83	82.15	73.03	66.12
Combined cycle	70.89	54.94	35.41	15.09	12.98	39.02	29.76	36.87
Hydraulic	39.17	36.07	25.62	37.72	22.06	23.05	29.21	30.41
Wind	9.13	3.04	12.61	10.10	28.45	8.91	5.10	11.05
Solar	76.71	74.24	77.93	75.91	77.62	76.60	87.27	78.04

Table 7. Utilization factor in the peak demand in summer 2015. Source: Own elaboration

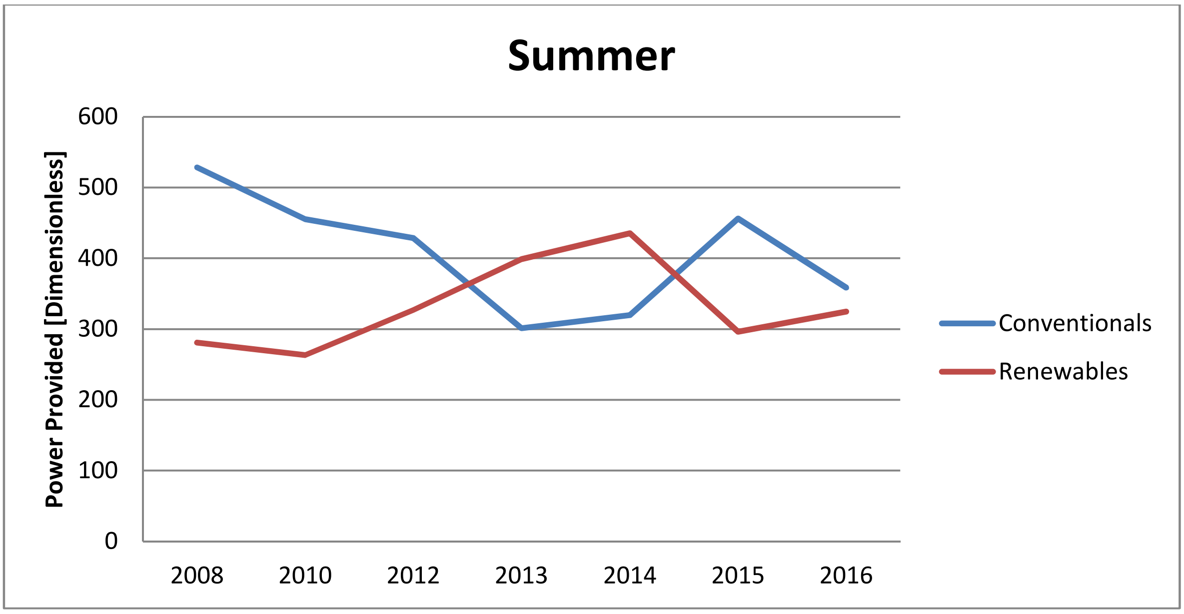

Figure 11. Provided power to peak demand during recent summers. Source: Own elaboration

Conclusions

From this study can be drawn several conclusions of great importance to know the behavior of the electrical system. In the first place, and as a determining factor, the strong variability of wind energy produced from a few years to others, both in winter and in summer, stands out. It can be seen that in two consecutive years, 2015 and 2016 winter, we have a maximum and a minimum of the utilization factor, 61.73% and 26.14%. Therefore, to ensure the electricity supply there must be technologies that produce energy in the event that wind production falls.

Continuing with the analysis of wind technology, it can be seen that the average utilization factor from summer to winter varies enormously, going from 11.05% to 45.94%.

It is interesting that solar technology is able to increase the renewable contribution at the peak of summer demand, compensating for the fall in the contribution of wind technology. The peak summer demand coincides with the time of maximum solar production, becoming a very interesting technology to guarantee the supply in these critical moments.

Regarding the hydraulic production can be seen as it varies from a few years to others strongly, as it is a technology dependent on rainfall, so this variability must also be offset by dispatchable back-up technologies.

The low participation of the technology of the combined cycle in the last four years stands out, where its utilization factor has not surpassed 20%.

It is interesting, as can be seen in both graphs, the relationship between renewable and conventional technologies, when the contribution of one increases, the one of the other decreases and vice versa.

Therefore, we can quickly conclude that conventional technologies begin to generate as the renewables are no longer available.

This correlation leads us to think that the greater the penetration of renewables is, the less need for conventional plants to produce to cover demand, since renewables will always enter the market first. This last observation will be analyzed in more depth in later chapters.

2.2. The regulated activities

From the beginning of the liberalization process, it was suggested that some of the activities of the traditional electricity and gas supply companies should continue to be regulated due to their intrinsic characteristics. Indeed, the development and operation of physical networks of cables and pipelines is subject to significant economies of scale, which makes them a natural monopoly. As a result, network companies can not and should not compete with each other by inefficiently duplicating the installations in the same area, as this would give the consumer a strong and unjustified increase in regulated costs. [14]

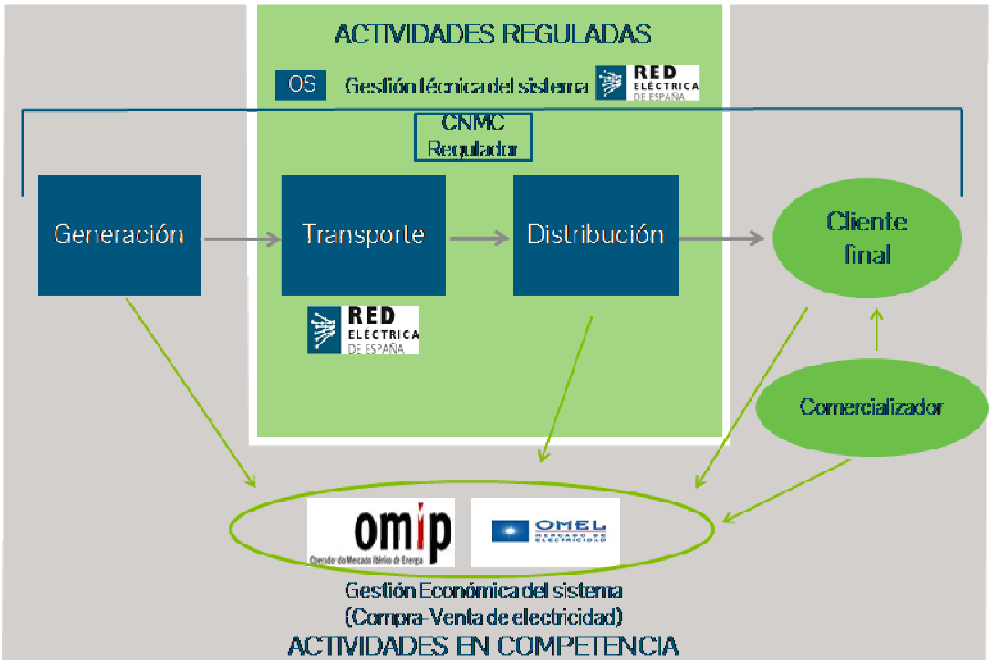

Figure 12. Separation of regulated and liberalized activities. Source: Energía y sociedad

For these reasons, in order to enable liberalization (competition in generation and marketing), free access to the networks must be guaranteed. This means that, through the payment of access fees (transparent and non-discriminatory), any generator, consumer or marketer can use the networks to transport the energy generated, consumed or commercialized. [14]

2.2.1. Transmission. System operator

Its purpose is the transmission of electric energy through the transport network, used for the purpose of supplying it to the different subjects and for the realization of international exchanges. [15]

The electricity transmission network is constituted by the primary transport network (installations with a voltage greater than or equal to 380 kV) and the secondary transport network (up to 220 kV). [15]

The transport network consists of more than 41,200 km of lines, more than 5,000 substation positions and more than 78,000 MVA of transformation capacity. These assets configure a secure and reliable network that offers high quality of service. [16]

The transport activity in Spain is governed by the model TSO (Transmission System Operator), in which the activities of operation of the system and transportation of electricity are carried out by a single agent. In this model, the operator and manager of the network is also the owner of the transport facilities. [14]

Transport network planning addresses technical and economic criteria, so that new investments can be justified by the benefits of efficient system management (increased reliability, reduction of transport losses, removal of restrictions that could generate a higher global cost of the energy supplied and efficient incorporation to the system of new generators) and the benefits derived from a safer operation that minimizes the energy not served. [16]

The remuneration of the transport activity is established administratively taking into account the costs of investment, operation and maintenance and management of the networks. The remuneration methodology seeks to cover all service delivery costs (including remuneration for invested capital) and, in turn, to encourage efficient management. Annually it is calculated as the sum of: [16]

- A term of remuneration of updated value of the investments.
- A term that allows to recover the costs of operation and maintenance.
- Incentives to the availability and efficiency of the facilities.

System operator

Red Electrica de España (REE) is the operator of the Spanish electricity system, both in the peninsula and in the island and extrapeninsular systems. The operation of the system comprises the activities necessary to guarantee such safety and continuity, as well as the proper coordination between the production system and the transmission network, ensuring that the energy produced by the generators is transported to the distribution networks with the conditions of quality required in application of current legislation. [17] [16]

The function of Red Electrica, as operator of the system, is to guarantee a balance between generation and demand in the Spanish electricity system. To do this, it forecasts electricity demand and manages real-time electricity generation and transportation facilities, making scheduled production at power plants coincide at every instant with consumer demand. If it differs, it sends the appropriate orders to the plants to adjust their productions increasing or decreasing the generation of energy so that sufficient generation margins are maintained to cope with possible losses of generation or changes in the expected consumption. [17]

In addition, Red Eléctrica manages the so-called adjustment services markets in the peninsular electricity system. These are markets through which the production schedules, freely established by the subjects in the daily market and through bilateral contracting, and later in the intraday market, are adjusted to requirements of quality, reliability and safety of the electrical system. It is understood by adjustment services or adjustment markets, the solution of technical restrictions, the allocation of complementary services and the management of diversions. [16]

2.2.2. Distribution

The distribution activity has the objetective of transmiting electrical energy from the transmission networks or, where appropriate, from other distribution networks or from the generation connected to the distribution network itself, to the points of consumption or other distribution networks in the proper conditions of quality with the ultimate purpose of supplying it to consumers. [18]

In Spain, electricity distribution installations are considered to be lines with a voltage below 220 kV which are not considered as part of the transport network and all other elements (communications, protections, control, etc.) necessary to carry out the activity properly and in terms of quality required by regulation. [19]

The distribution activity is carried out by the distributors that are Spanish, European Union or commercial companies with permanent establishment in Spain, whose function is to distribute electric energy, as well as to build, maintain and operate the distribution facilities. Also, the distributors are the managers of the distribution networks that operate. [18]

In Spain, there are 5 large distributors and more than 300 small distributors with less than 100,000 customers, who are active in the historical areas where they have been established, as can be seen in figure 13. [19]

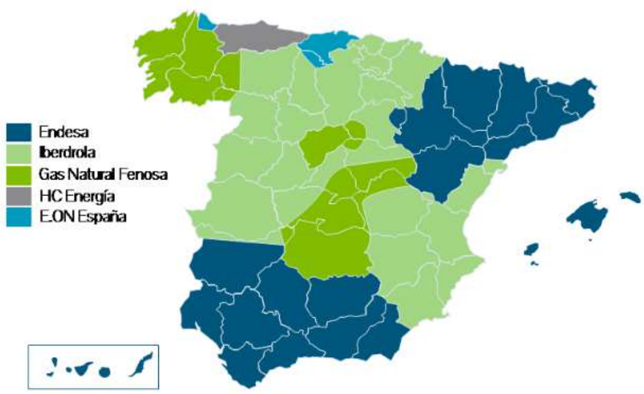

Figure 13. Map of the zones of distribution. Source: Energía y sociedad

Law 24/2013, dated December 26, of the Electricity Sector establishes that the remuneration of the distribution activity will be established in accordance with the costs necessary to build and maintain the facilities in accordance with the principle of realization of the activity at the lowest cost for the electrical system and operate the networks to ensure the supply of energy under the conditions of quality set by regulation. Given the characteristics of the distribution and the complexity of its assets (number and typology), the remuneration follows a different scheme than transportation one, so that each element of the distribution network is not valued individually. [18] [19]

2.2.3. Network access fee

The transport and distribution networks remain under a regulated scheme because they are activities that, given their intrinsic characteristics, are natural monopolies. For this reason, network costs (along with charges) are passed on to all consumers according to their characteristics, regardless of whether energy is purchased at free price or regulated price, through access fees and charges. These fees are set by the ministry of industry, energy and tourism, and must be reviewed annually, although in circumstances that significantly affect regulated costs, the ministry may make revisions with quarterly frequency. [9]

According to Article 17 of Law 54/1997 of 27 November, fees for access to the networks will be unique throughout the national territory, irrespective of the economic and geographical characteristics of the networks where the consumers are located, and will not include any type of taxes. In addition, they must be calculated together with the charges, to cover all system costs except for the cost of energy and the cost of management of the marketer. [9]

The access fees are composed of a power term (Tp) and an energy term (Te). In this way, the cost of access depends both on the power that the consumer has contracted (fixed term, because the networks must be designed to guarantee at any moment the supply of the powers that the consumers have contracted) and of the consumption one (variable term, depending on the energy consumption that has flowed through the network). The access fees in force since February 2014 are shown in table 8. [9]

Tarifas BT							
	Colectivo de aplicación	Tp [€/kW año]	Te [€/kWh]				
			Sin DH	Periodo 1	Periodo 2	Periodo 3	
2.0 A	Pc ≤ 10kW	38,043426	0,044027	-	-	-	
2.0 DHA	Pc ≤ 10kW	38,043426	-	0,062012	0,002215	-	
2.0 DHS	Pc ≤ 10kW	38,043426	-	0,062012	0,002879	0,000886	
2.1 A	10kW< P≤15kW	44,444471	0,05736	-	-	-	
2.1 DHA	10kW< P ≤ 15kW	44,444471	-	0,074568	0,013192	-	
2.1 DHS	10kW< P ≤ 15kW	44,444471	-	0,074568	0,017809	0,006596	
	Colectivo de aplicación	Tp [€/kW año]			Te [€/kWh]		
		Periodo 1	Periodo 2	Periodo 3	Periodo 1	Periodo 2	Periodo 3
3.0 A	Pc > 15kW	40,728885	24,43733	16,291555	0,018762	0,012575	0,00467
Tarifas AT							
	Colectivo de aplicación	Tp [€/kW año]			Te [€/kWh]		
		Periodo 1	Periodo 2	Periodo 3	Periodo 1	Periodo 2	Periodo 3
3.1 A	1 kV < T ≤ 36 kV	59,173468	36,490689	8,367731	0,014335	0,012754	0,007805
	Colectivo de aplicación	Tp [€/kW año]					
		Periodo 1	Periodo 2	Periodo 3	Periodo 4	Periodo 5	Periodo 6
6.1	1 kV < T ≤ 36 kV	39,139427	19,586654	14,334178	14,334178	14,334178	6,540177
6.2	36 kV < T ≤ 72,5 kV	22,158348	11,088763	8,115134	8,115134	8,115134	3,702649
6.3	72,5 kV < T ≤ 145 kV	18,916198	9,466286	6,92775	6,92775	6,92775	3,160887
6.4	T > 145 kV	13,706285	6,859077	5,019707	5,019707	5,019707	2,290315
6.5	Conexiones internacionales	13,706285	6,859077	5,019707	5,019707	5,019707	2,290315
	Colectivo de aplicación	Te [€/kWh]					
		Periodo 1	Periodo 2	Periodo 3	Periodo 4	Periodo 5	Periodo 6
6.1	1 kV < T ≤ 36 kV	0,026674	0,019921	0,010615	0,005283	0,003411	0,002137
6.2	36 kV < T ≤ 72,5 kV	0,015587	0,011641	0,006204	0,003087	0,001993	0,001247
6.3	72,5 kV < T ≤ 145 kV	0,015048	0,011237	0,005987	0,002979	0,001924	0,001206
6.4	T > 145 kV	0,008465	0,007022	0,004025	0,002285	0,001475	0,001018
6.5	Conexiones internacionales	0,008465	0,007022	0,004025	0,002285	0,001475	0,001018

Table 8. System network access fees. Source: Energía y sociedad

In addition, all of the above tariffs apply a surcharge for reactive power in case the power factor is less than 0.95 and a surcharge for excess power in case the power demanded exceeds the contracted. [9]

At the end of 2011, the government approved, by Decree 1544/2011, the application of a new fee for access to transmission and distribution networks for generation facilities, as envisaged by the Electricity Sector Law (Law 54/1997) and in the context of the measures adopted in Decree-Law 14/2010 to correct the tariff deficit. [9]

The new fee is applicable to all generation facilities, both ordinary and special, as of January 1, 2011 and has a value of 0.5 €/MWh, maximum value applicable according to European regulations. [9]

Law 24/2013, of December 26, differentiates fees from charges in order to comply with the terminology used in the European directives and the desirability of differentiating 1) the contribution payments to cover the costs of transport networks and distribution, fees, 2) of those payments related to other regulated aspects of the system, charges. [9]

Among others, the charges will cover the specific remuneration regime of the generation activity from renewable energy sources, high efficiency cogeneration and waste, remuneration of the extra cost of the production activity in the electric systems in the non-peninsular territories with additional remuneration regime, remuneration associated with the application of capacity mechanisms and annuities corresponding to the deficits of the electricity system, with their corresponding interests and adjustments. [9]

2.3. The retail market. The commercialization

According to Law 24/2013, of December 26, of the Electricity Sector, the electric energy traders are those mercantile companies or cooperative societies of consumers and users, which, by accessing the transmission or distribution networks, acquire energy for sale to consumers, to other subjects of the system or to carry out international exchange operations in the terms established by law. This activity is carried out by the trading companies on a competitive basis. [20]

These companies acquire the energy in the market of production and supply it to the final customers, who have to destine it to its own consumption. This acquisition of energy is the main added value of the marketing activity. To do this, the supply company has to forecast customer consumption (or segment of customers) and plan the acquisition of energy through different forms of contracting (daily market, forward markets or bilateral contracting). [21]

To bring energy to the consumer, trading companies make use of transport and distribution networks, by contracting and paying the access fees. The conditions of access to the networks and the prices of the corresponding fees are regulated by the administration, so that it is carried out under the same conditions for all marketers. [21]

The three main commercial processes carried out by trading companies, other than the acquisition of energy, in relation to final customers are:

- Bid: the commercialization companies elaborate offers for their clients, and they recieve them through structure of attention channels. Once the offer is accepted by the customer, it is passed to the contracting process of the electricity supply.

- Billing: the billing to consumers will be made by the marketing companies under the conditions agreed between the parties and will be made on the basis of the monthly or bi-monthly readings of the measurement equipment installed for this purpose and provided by the distributors. These readings are the responsibility of the distribution companies, in accordance with current regulations.

- After-sales service: The service to consumers established by the marketing companies must, in any case, comply with the minimum quality parameters established in the consumer and user protection legislation. Consumers will be duly advised, in a transparent and understandable manner, of any intention to modify the terms of the contract and informed of their right to terminate the contract at no cost when they receive the notice.

In the Spanish electricity sector there are three ways in which marketers can supply energy to consumers:

- Reference supply. Voluntary Price for the Small Consumer (Precio Voluntario para el pequeño consumidor in Spanish), which is a price calculated by Red Eléctrica de España, which is determined based on the hourly price of the daily and intraday markets during the period to which the billing corresponds. It is the modality that is applied by default since July 2014 if the consumer was covered by the previous Last Resort Fee (Tarifa de Último Recurso in Spanish).

- Recruitment in the liberalized market through free contracting with a marketer.

- Supply of last resort. Supply that applies to the following consumers:

- Vulnerable consumers.
- Consumers who do not meet the requirements for applying the PVPC and who temporarily do not have a supply contract in force with a free market trader.

In accordance with European regulations, marketing companies have an obligation to inform their customers about the origin of the energy supplied, as well as the environmental impacts of the different energy sources. [21]

Thus, with Directive 2001/77/CE, the accreditation of the Guarantee of Origin (Garantías de Origen in Spanish) is born, which talks about the boost of electricity produced from renewable energy sources and the need to guarantee the origin of the electricity. [22]

As regards the state level, from Directive 2001/77/CE, order ITC/1522/2007 was implemented to establish this accreditation in the state. [22]

The purpose of the Guarantee System of Origin is to ensure the publicity, management and updating of ownership and control of guarantees of origin generated on the basis of electricity produced by renewable sources or high efficiency cogeneration. [23]

Thus, the components of the final price of electricity for consumers would be those shown in the figure 14. In order to guarantee the principle of sufficiency of revenue (these must be sufficient to cover all the regulated costs of the system) and to generate efficient economic signals, access fees must be calculated by the administration as the addition of all the costs that take place in the system. [9]

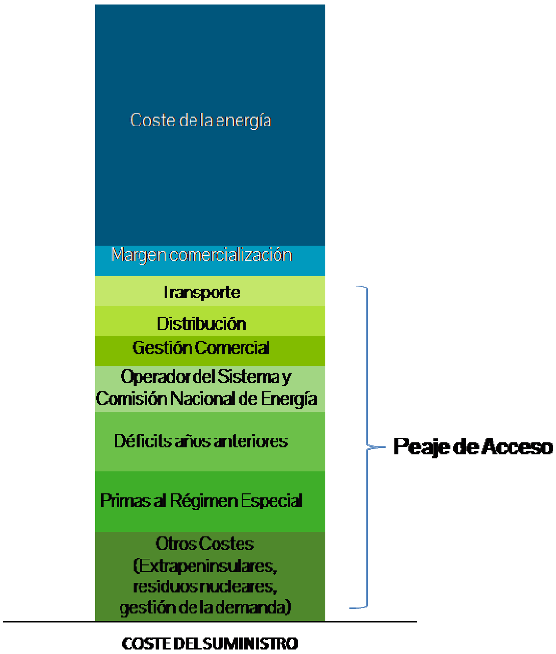

Figure 14. Structure of the cost of supply in 2013. Source: Energía y Sociedad

If the level of the access fees is insufficient to ensure coverage of these costs, a collection deficit will occur. Specifically this situation is what has been taking place in recent years as can be seen in the figure 15, giving rise to the tariff deficit currently reaching 25,000 million euros and that the government has tried to reverse cutting the premiums to the regime special. [9]

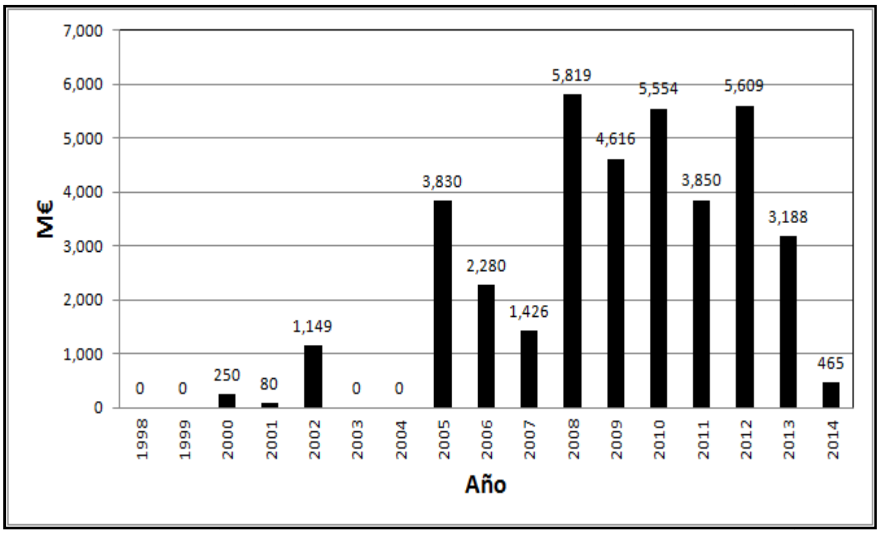

Figure 15. Annual rate deficit in millions of euros. Provisional 2014 year. Source: Energía y sociedad

2.4. The wholesale market. MIBEL

The electricity market in Spain, as in other countries, is organized in a sequence of markets in which generation and demand exchange energy and reserves for different periods. In figure 16 is represented the sequence of these markets. [24]

Before the moment the energy is generated and consumed, the agents exchange contracts with delivery periods of different duration (annual, quarterly, monthly, etc.). These transactions are carried out in so-called forward markets. [24]

Upon arrival on D-1 (a day before energy is generated and consumed), agents exchange energy for each of the hours of day D in the daily market organized by the Electric Market Operator (OMIE). In addition, within 24 hours prior to generation and consumption, agents can adjust their contractual positions by buying and selling energy in the intraday markets, also managed by the OMIE. [24]

In the very short term (from a few hours to a few minutes before generation and consumption) generators, and in some cases also demand, offer a series of services to the system in several markets organized by the System Operator). These services are necessary so that the generation exactly matches the demand at all times, thus maintaining the system in physical balance and with an adequate level of security and quality of supply. These services are three and are outlined below: [24]

- Management of technical restrictions. It allows to solve the congestions caused by the limitations of the transport network and distribution on the programming of the following day, as well as those that arise in real time.

- Management of complementary services. Within this concept of complementary services the following aspects are considered: frequency-power and voltage control system, as well as additional power reserve to be raised, necessary to guarantee quality and security of supply at all times.

- Management of diversions. It resolves, almost in real time, the mismatches between supply and demand for electricity.

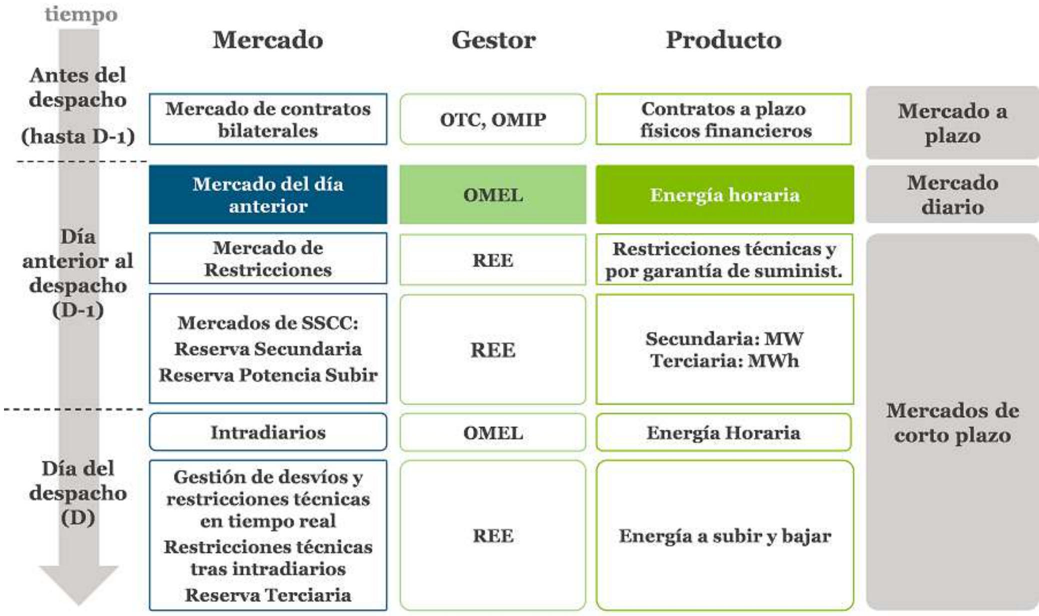

Figure 16. Sequence of markets in the Iberian electricity market (MIBEL). Source: Energía y sociedad

Participation on the spot market can be mandatory, in which case the exchange is said to have a power pool structure, Spain has this kind of market. Also the participation can be voluntary, in which case it is said to have a "power-exchange" structure. Power pools are centralized markets, usually set up by government initiative after market liberalization to facilitate competition between generators. In the power pool design, participation is mandatory: generators and and demand submit bids, from which the merit order is derived, and no trade is allowed outside the pool. The demand side is represented by a "Single Buyer" which buys all electricity from the generation sector based on a top-down estimation of demand. Hence, the market mechanism is a one-sided auction, where bids come from the supply side only. [3]

2.4.1. Daily market

The daily market is organized in accordance with the provisions of Law 54/1997 and Law 24/2013 (Law of the Electricity Sector). Its rules of operation are set out in the Rules of Operation of the Production Market. It is managed by the OMIE, a private entity whose main function is to carry out the management of the market and ensure that the procurement is carried out in conditions of transparency, objectivity and independence. [24]

Electricity prices in Europe are fixed daily (every day of the year) at 12:00 noon, for the next twenty-four hours, in what we know as the daily market. So in this market there are actually 24 different products (energy in each of the 24 hours of the next day). Schematically represented in the figure 17. [25] [24]

- Sellers (generators, importers, traders, other intermediaries) present offers to sell and buyers (traders, final consumers, exporters, traders, other intermediaries) submit offers to OMIE for each hour of the following day.

- With these offers, OMIE constructs supply and demand curves for each hour of the following day.

- The crossing of the supply and demand curves results in the market price for each hour of the following day and the matched offers are identified (sales and purchase offers that turn into firm energy delivery commitments).

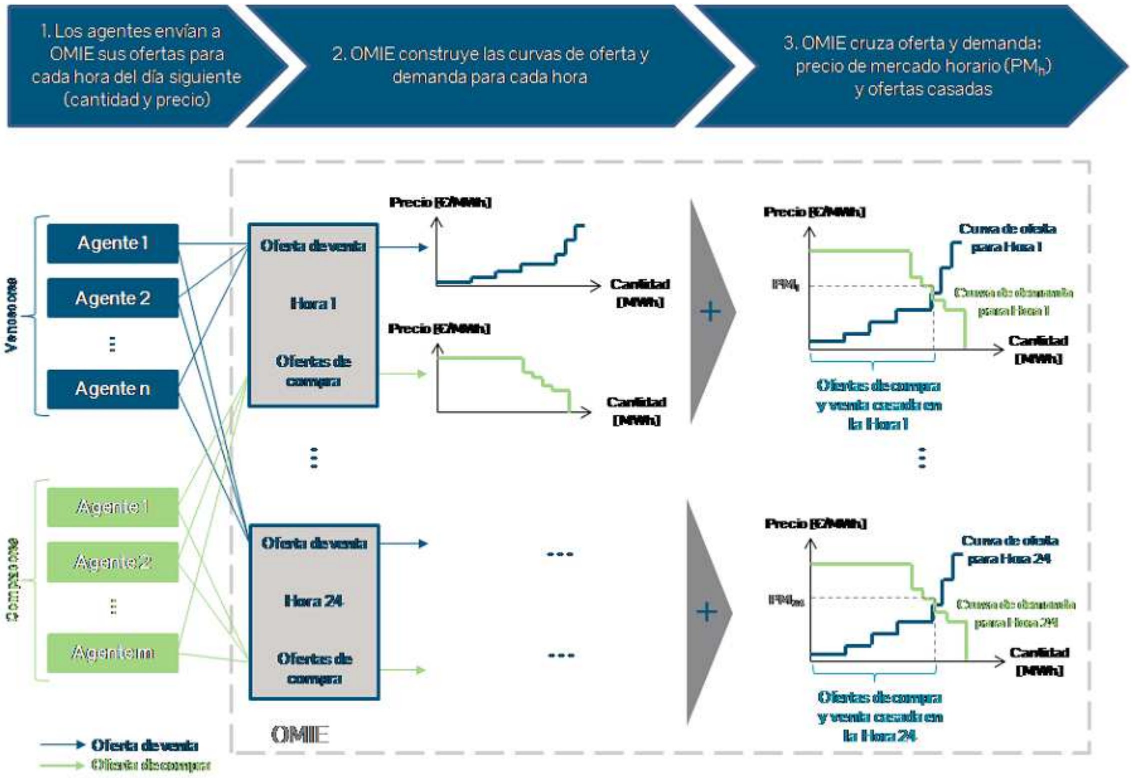

Figure 17. OMIE Daily Market Operation Scheme. Source: Energía y sociedad

In the EU a marginal model has been adopted as the model of price formation, which operates based on the algorithm approved for all European markets (EUPHEMIA). In these types of markets, the supply of a generator represents the amount of energy it is willing to sell from a certain minimum price. Thus, the competitive offers of a generator reflect: [25] [24]

- As regards quantity, the physical constraints to which its installation is subject (for example, the available power, the minimum power at which the plant is to operate to be stable and safe, the availability of fuel or stored water, the speed with which they can increase their production between one hour and the next, etc.).

- As for the price offered, this reflects the opportunity cost of generating electricity. It is important to note that opportunity cost is not the same as variable cost. Under rational and efficient behavior, generators' offers should not reflect their variable costs but those of opportunity.

The supply curve

Once the sellers have submitted their offers to the market for each of the hours of the following day, the OMIE adds them and orders them by ascending price, resulting in the market supply curve for each hour represented in the next figure 18. [24]

This curve reflects more or less clear sections or steps that correspond to offers of plants of the same technology. In view of this, it is important to point out again that the offers of the vendors reflect their opportunity costs, not their total or variable costs, hence: [24]

- Flowing hydraulic or nuclear power plants, despite their high fixed costs, appear at the bottom of the curve as their very low opportunity cost.
- The reservoir hydraulic power plants appear at the top of the curve, since their opportunity cost is very high (they have the option of reserving the water to produce in a future instant in which the market price is higher).
- Nuclear power plants, coal and combined cycle have to deal with fuel costs to produce energy. While in the first case, the fuel price is low and also its opportunity cost, the other two have to face higher fuel costs, being those in the rightmost part of the curve.

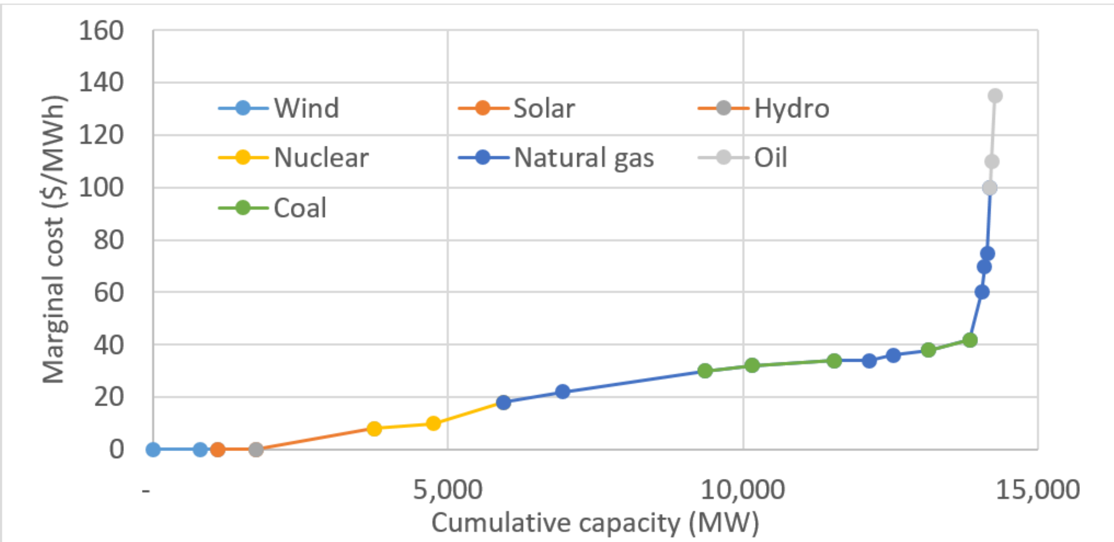

Figure 18. Typical energy supply curve. Author: Devin Hartman

The demand curve

End-users are usually classified according to the magnitude of their consumption and the purpose for which they use energy. It is often distinguished between large industrial consumers (for example, large industries - metallurgy, ceramics - or rail transport), medium-sized consumers in industrial and service sectors and, finally, small consumers connected to low tension. [24]

As in the case of the supply curve, the demand curve also has sections in which indirectly certain types of consumers are grouped, as shown in the figure 19. [24]

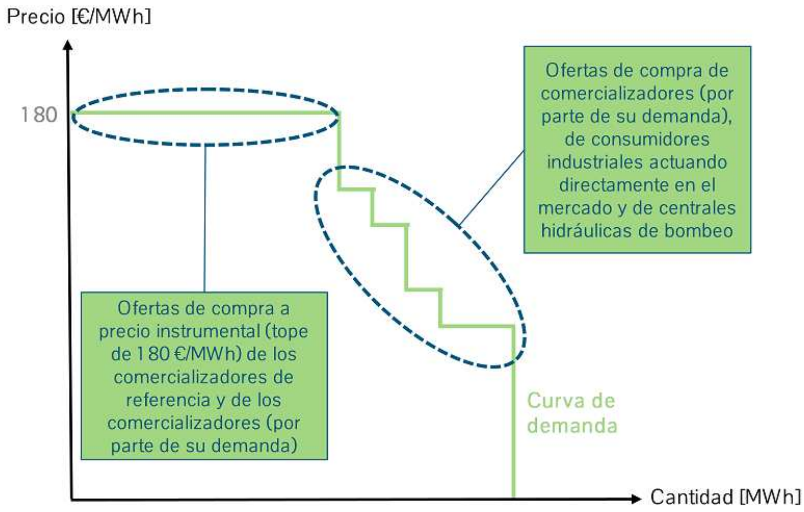

Figure 19. The electricity demand curve of the market. Source: Energía y sociedad

The crossing

The market price for the H-hour of the D-day is determined by the intersection of the market supply and demand curve for that hour. This price determines the offers of purchase and sale that are matched (what is the energy that will be finally exchanged at the market price). In every hour, all the offers of sale-purchase that are matched receive-pay the market price. [24]

The figure 20 shows an example of supply and demand matching conducted daily by OMIE for each hour of the following day. In this example, the matched energy is around 3000 MWh and the matched price is around 50 €/MWh. [24]

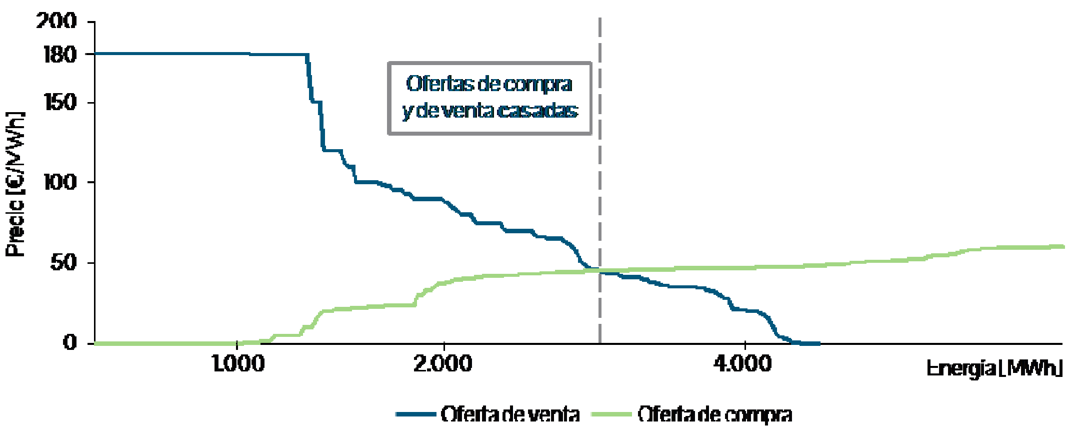

Figure 20. Crossing of demand and supply curves. Source: Energía y sociedad

Since July 2007, the daily market managed by OMIE is developed for the entire Iberian market (Spain and Portugal, peninsular). This means that in the same daily market (and intradiaries) the portuguese and Spanish production and consumption units participate. Resulting a single price for the entire Iberian system and a flow of energy between both countries. [24]

In the case of congestion in any the Spain-Portugal interconnection in any of the senses, the market-splittingis carried out, basically consisting of making two separate matches, one for Portuguese agents and another for Spanish agents, taking into account the maximum amount of energy that can be exchanged between both systems and resulting in a different price for each of the two countries. [24]

After describing the entire system from generation to consumption, we can see in the following diagram, figure 21, a summary of the economic and electricity flows that take place in the electrical system.

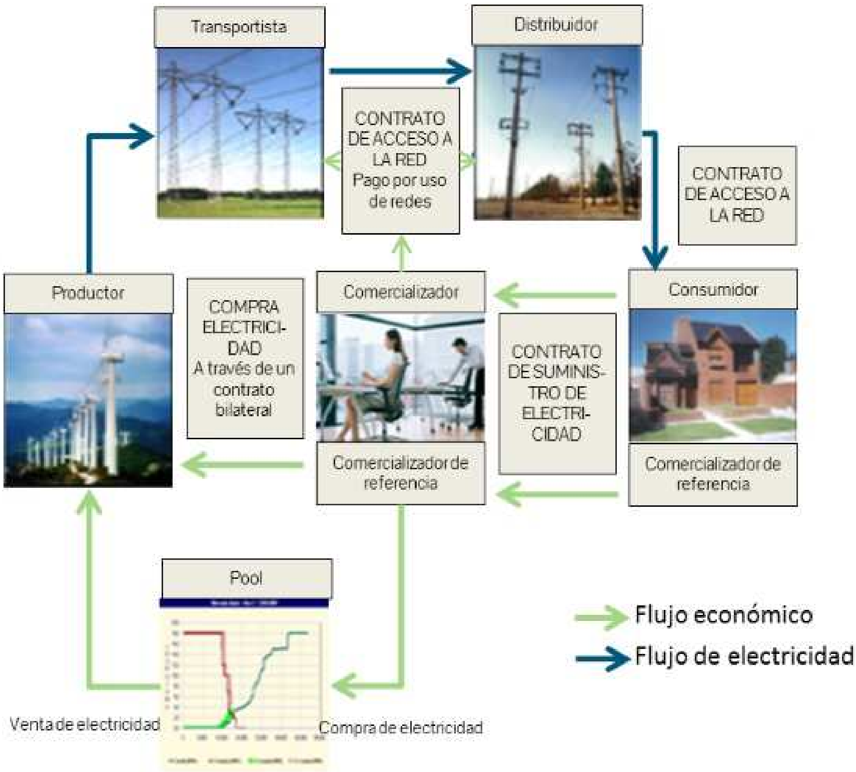

Figure 21. Scheme of the Spanish electrical system. Source: Energía y sociedad

3. INVESTMENTS IN ELECTRICITY MARKETS

Once all the involved parts of the Spanish electricity system has been described as well as the operation of the market, now must be explained the evolution and the perspectives of the market in order to predict the behavior and enable a framework that allows to reach the gols set by European Union and meet the necessities in the supply of the electricity making it affordable for the consumers and for the society in general.

The importance of the market is extremely high in the electricity sector, the markets are supposed to serve two fundamental functions: optimization of resources already in place, the current marginal design is allowing to get the minimum price of the wholesale market due to an efficient use resources; And the second function is driving investment for the future, what is the main objective to rise in the chapter, as the change in the mix generation, which is transforming in one with more low-carbon technologies, is bringing problems of trust for future investment in electricity generation.

3.1. Recent trends

In recent years, following the paths marked by the European Union with the objectives of combating climate change and achieving greater security of supply, Spain has made a strong investment in low-carbon technologies, mainly wind and solar energy, but also mention should be made of the contribution of biomass and cogeneration technologies. As these technologies were immature, they were not profitable for investors if they were not incentivized with public aid, so that thanks to this additional mechanism of remuneration outside the wholesale market could be investments economically viable and that contributed to meet the objectives imposed by Brussels.

In Spain the public support mechanism used was the called “feed-in tariff”, which is designed to accelerate investment in renewable energy technologies. It achieves this by offering long-term contracts to renewable energy producers, typically based on the cost of generation of each technology. [26]

There is no doubt that public aid to renewable energy has enabled them to enter the market and compete with the remains of technologies. But these aids that have been increasing by the great installed capacity, have resulted in an increase of the prices of the retail market as can be seen in figure 22, since the public support has been practically paid by the consumers through the charges in the electricity bill. The increasing trend can be observed for both household and industry retail price throughout the EU, even though there are considerable differences in the price level between the two types of consumers across groups of Member States.

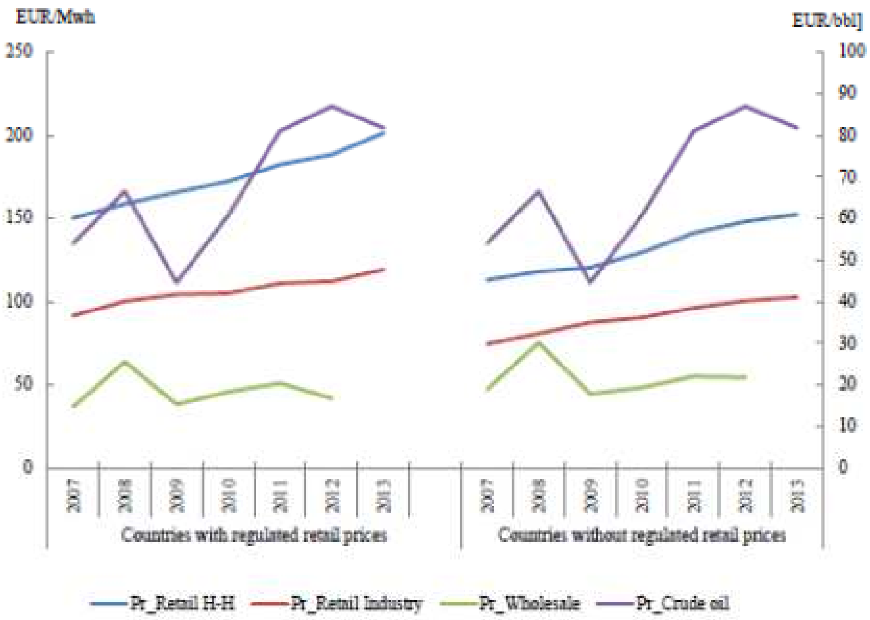

Figure 22. Average domestic and industrial retail electricity price evolution 2007-2013. SOURCE: European Commission

Making a deeper analysis in the retail electricity price through the recent years, could be seen that the reason of the increasing price is the taxes and levies aimed at renewable technologies and cogeneration. It is represented in the figure 23.

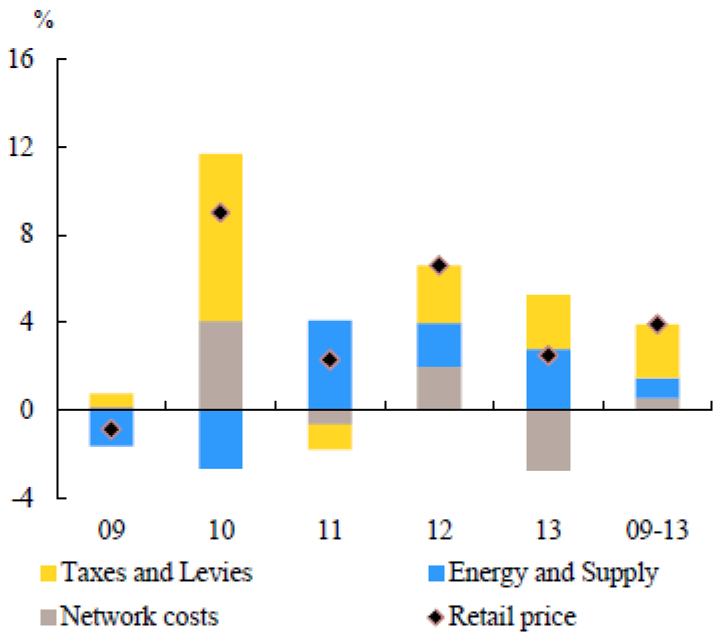

Figure 23. EU retail Price change and the contribution of the price components 2009-2013. Source: European Commission

By the other hand, wholesale electricity prices have been declining. The drop in wholesale prices is the result of many different factors, among which the evolution of energy commodity prices such as coal, gas and oil prices. After the high prices of fossil fuels of 2008, the prices of them declined making the conventional plants, which are the ones that meet the demand, have lower marginal cost and therefore lowering the price of the wholesale market. Hence, all the technologies are affected by the commodity prices as their retribution is, at the final, set by the marginal cost of gas and coal plants. [3]

Other important factors contributing to lower wholesale prices are weak demand for electricity due to the economic crisis and specially the increasing renewable generation share. As known, today conventional technologies are price makers, so with the penetration of renewable, the moments when conventional technologies are price makers will be fewer, therefore reducing the scope for these high-marginal-cost technologies to set the price. Anyway the impact of renewable generation in the wholesale market will be study more in depth later. [3]

Despite the fact that the electricity wholesale market today is sending a signal of structurally decreasing wholesale, as the figure 24 shows, the interpretation of the medium/long term effects is ambiguous, what generates uncertainty very dangerous for future investments. [3]

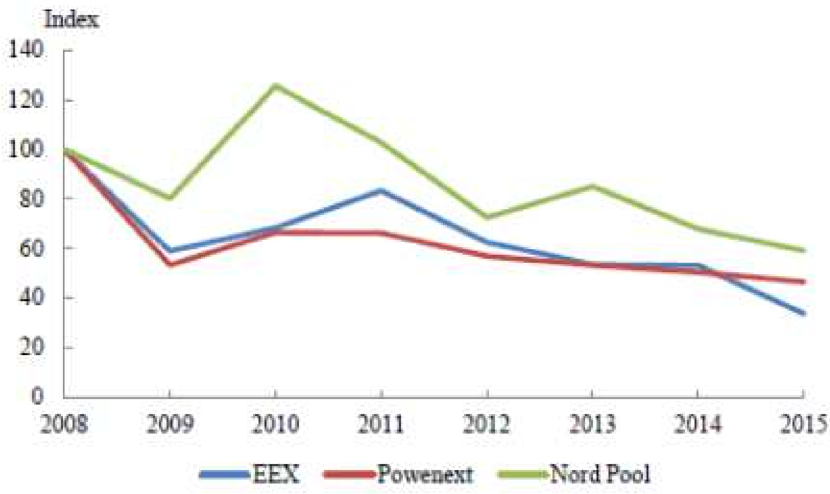

Figure 24. Electricity wholesale Price. Source: Bloomberg, Platts

3.2. Drivers in renewables and conventional technologies

As any other kind of investment, in the electricity sector, the decision of investment respond to macroeconomic conditions as general economic growth, demand evolution and financial conditions. But in this sector, the decision is also conditioned by a group of energy-specific factors as: the generation mix of the country, the wholesale prices, as well as indicator about the supply side of the market such as the reserve margin and the capacity factor of the electricity system. In addition, the decision of investment is also highly influenced by policies, they can have a sizeable when they support some technology groups in order to achieve specific objectives, in the current case supporting low-carbon technologies with public aid. [3]

There is no doubt that the main driver that made possible the development and the large increase of renewable capacity over recent years in the Spanish mix was the public support through feed-in tariffs. It reduced drastically the risk for the producers as it provides safe revenues in order to cover the investment.

This public support for renewables has been justified by the need to promote low carbon technologies at early stages of development. These technologies would otherwise not be able to compete on the market due to higher costs. Most renewable technologies remain too expensive and uncompetitive in relation to the market prices of today, even though certain are gradually becoming more mature and might compete in the current market. [3]

Public supports started in Spain when the first law of market liberalization took place in 1997, then was approved the "Special energy regime" which had the goal of supporting clean technologies in order to make them competitive in the free market. Over years this public support highly increased due to the ambitious plans carried on by the government with the "Renewable energy plan 2005-2010" and later with "Renewable energy plan 2011-2020". The result was a larger installed renewable capacity in the system in only a few years, specially photovoltaic technology which was very immature and expensive, also a result was an increased price of the retail market and a high tariff deficit[2] in the system. Consequently, due to the economic crisis and also due to reforms of support systems aimed at reducing the costs, the support given to running plants was cut to lower level of profit and the new installations will not have any kind of public support.

Now there is a broad consensus in Europe on the need to promote market-based investments without any form of support. There are already technologies that can compete in the market without support, as wind and photovoltaic technology. But by the other side, there a lot of technologies that are not competitive in the market yet, e.g. biomass, which can be very interesting as it is a dispatchable one with flexibility in the generation.

By contrast, support to conventional technologies has been much more limited, which can be explained by their level of maturity. Public support to these technologies was developed in another market framework, where they also received some comparable forms of support. [3]

According to European energy strategy, policies are addressed to descarbonization of the economy. On one hand it meant the support to low-carbon technologies and by the other side the EU emission trading scheme (ETS), which is increasing the cost of the conventional energies as coal and gas plants.

As was mentioned at the beginning of this part, the factors that determine the investment decision in the power sector can be grouped into three main categories, i.e. macro-economic, competition and energy-

[2] Tariff deficit can be defined as a shortfall of revenues in the electricity system, which arises when the tariffs for the regulated component of the retail electricity Price is set below the corresponding costs borne by the energy companies.

specific. In order to understand their role, it is useful to provide a discussion of the assumptions to their contribution. [3]

Macroeconomic factors

Higher electricity demand leads to higher investment in power generation. Economic growth is usually accompanied by higher investments. Hence it is a sign of an expanding market that businesses will want to exploit by increasing their investments in installed capacity. This indicates that demand is positively correlated with investment. In the future electricity demand is expected to be decoupled from economic growth, as a result of energy efficiency policies. [3]

Investments are negatively associated with interest rates. Power plants are capital-intensive investments, for which the cost of financing plays a substantial part. Interest rates are used in the economic literature as an indication of the cost of capital: it is expected that higher interest rates have a negative effect on investments as they make investments more expensive. [3]

A stable and transparent policy environment reduces investment risk and contributes positively to new investments. Quality of regulation is an important factor in determining the investment environment. Good regulation that removes barriers to entry generally induces new entry and investment. The better the policy environment in terms of commitment and transparency, the better the business environment and the more attractive the investment. [3]

Competition and energy-specific factors

Electricity wholesale price as a signaling device for investment. In a market, where the only commodity is energy (energy-only market) and there is no extra trade in capacity or other products, the primary income source for recovery of capital costs is the inframarginal rent generated by the difference between the clearing price and the generators' marginal costs. According to the theory of spot pricing, the optimal capacity stock is such that the price resulting from scarcity is high enough to repay the capital costs of the marginal generators when demand exceeds supply. Therefore, when prices are high, the system signals the need for new investment; hence, it is expected that higher prices are positively correlated with investment. [3]

Highly concentrated markets create significant barriers to entry that may impede new investment or expansion in electricity generation. Concentrated markets are likely to suffer from abuse of market dominance, by which the incumbent firms enjoy the ability to unilaterally raise prices by providing a less-than-optimal capacity. Therefore the market concentration has a negative impact on investments. [3]

Overcapacity reduces the motive for new investments. The reserve margin indicator is defined as the ratio between total available generation and the maximum level of electricity demand, at the time at which that demand occurs. It can be interpreted as an indicator of overcapacity in the sense that a high value implies that there is a large amount of available generation to meet peak demand. [3]

Penetration of renewable technologies induces lower incentives for new investments in conventional power plants. Renewable penetration reduces the residual demand for conventional generation, therefore reducing the size of the market they can bid on. Penetration of renewable was incentivized by support schemes, which are assumed to make investment in such technologies more attractive to investors (for example, because of more stable and higher returns) and hence to divert resources from conventional to low-carbon investment. It is expected that a higher renewable share decreases the scope for investment in conventional technologies because they increase their risk profile. In fact, the presence of renewables makes the revenue stream for conventional power plants very uncertain, whereas in their absence, conventional power plants will be operating a more predictable number of hours over the year. [3]

Additional revenues from capacity mechanisms increase the incentives for new investments. In energy only markets price caps may not allow power producers to receive the full amount of scarcity rents and to be able to recoup the fixed cost of their investment. The presence of capacity mechanisms, which act as complementary source of revenues, helps to mitigate price uncertainty and volatility caused by weather conditions and intermittent generation by providing additional sources of revenues to producers than the energy only market. [3]

4. SITUATION AND PERSPECTIVES OF THE ELECTRICITY MARKET

Both the macro-economic framework and the energy market design play an important role in driving investments in electricity generation. This part looks at price formation in electricity wholesale markets and presents the main characteristics of the sector. It also assesses the challenges posed by the increasing penetration of low carbon technologies. In the last part of the chapter, once a theoretical approach has been done, will be discuss the specific situation of the Spanish electricity system thanks to the data collected and analyzed in the chapter 2.1.3 of this work.

4.1. Price signal in electricity and design of the market

The role of the price of the wholesale market is fundamental, as prices are key drivers of investment decisions as they influence potential remuneration to investors. In well-functioning competitive markets, high prices are expected to signal the need for additional investment. For investors, it is important that prices are above the long run marginal costs so that producers can recover their fixed costs. Can be seen now why it is called price signal, due to the price sends signal to investors in order to take the decision of invest or not invest. [3]

As in any other sector, the expected remuneration is the key signal for investment, the investors need to analyze if the project is economically viable and if they will achieve profitability. In the electricity sector the remuneration come from different sources depending on the design of the market. In the case of Spain the remuneration producers can be remunerated from bilateral contracts and/or from the wholesale market; they can be remunerated from balancing services they provide; or remuneration for the availability of production capacity[3].

In the chapter 2.4.1. was explained that electricity prices on the spot market are based on the bid of the marginal unit. Therefore cheaper generation is dispatched first in the market, so that the supply function is upward sloping. The equilibrium price (the spot price) is the price of the marginal generation source needed to meet demand. Simplifying, it can be said that this is the price that all generators receive.

Here rise an interesting matter that is all the generation units with lower bids than the one which set the spot price earn an inframarginal rent equal to the difference between their bid and the bid of the last power plant in the merit. Sometimes this transform in excess profits for generator if the power plant is already amortized or in other cases cannot even cover the fixed costs of the producer in the long-term.

[3] Generation capacity refers to the procurement of the physical ability to produce electricity for long-term adequacy of the system. This is call capacity payment.

On characteristic that make electricity sector unique is the fact that electricity must be supplied at the time of demand. Therefore there is a complex task of ensuring the supply in at all the moments in the wide different scenarios, for that a long term prevision in generation must be done as storability and demand response are not developed enough for decoupling this current necessity of produce at the same time of consume.

For this reason, an important aspect of the market design is the need to keep the system reliable. Different market design exist across Europe, which can be classified under two main categories based on the products traded: in an energy only market, the only product is the power produced; whereas in the presence of a capacity market, the availability of power plants is an additional product.

In an energy-only market, the signal for investment relies on high prices that materialize in moments of excess demand (these are called scarcity prices and moments of excess demand are scarcity scenarios): whenever there is a scarcity scenario, prices are allowed to rise so that generators start earning 'scarcity rents' that are high enough to cover their fixed costs of capital and induce new investment/new entry in the market. The problem with this approach is that it may lead to high price volatility, which increases the investment risk associated to the electricity market and the uncertainty – especially for peaking plants, but also for variables renewable plants – to recuperate their investments; the possibility for prices to reach very high levels may also be used strategically by market players to abuse market power. Finally, potentially variable and high prices might not be desirable if they expose consumers, both households and industry, to unsustainable high prices. [3]

Alternatively, the market can be designed as an energy market complemented by a capacity mechanism. Capacity mechanisms are designed to support investment to fill the expected capacity gap and ensure security of supply. Typically, capacity mechanisms offer additional rewards to capacity providers, on top of income obtained by selling electricity on the market, in return for maintaining existing capacity or investing in new capacity needed to guarantee security of electricity supplies. All the relative costs associated with capacity mechanisms should be borne by consumers. [27]

Therefore we can conclude this chapter saying that the role of the price is different across market frameworks. In energy only markets, the stability of the system in terms of investments in capacity is achieved through electricity prices. When demand is in excess, prices increase to signal scarcity on the market. The high scarcity price enables the generators to cover their fixed capital costs and provide an incentive to invest so that the capacity will be able to meet market demand. In other market frameworks, the energy market is complemented by a capacity mechanism to incentivize investment to make the capacity available to meet the demand (often targeting a long term reliability standards). [3]

4.2. Ongoing transformation and challenges

The transformation of the electricity mix into low-carbon energy scenario is rising up some troubles that worried the future of the consumers, since the electricity supply and economic point of view.

From an economic perspective, low-carbon technologies can be considered as low-marginal cost technologies, they all have the same cost-structure: high fixed costs (investment) and low variable/marginal costs (operating); whereas conventional fossil fuel-based power sources have lower capital costs and higher operating costs. This has an important effect on the market outcome because as the share of low-carbon technologies increases, average spot market prices may tend to decrease and price volatility to increase, due to the variable production of the wind and photovoltaic technologies. [3]

The study “The Impact Assessment” accompanying the Communication from the European Commission “Energy Roadmap 2050” analyses policy scenarios with high penetration of low marginal cost technologies. The next table gives the out data.

	Reference Scenario		**High RES penetration**		**High nuclear penetration**	
	2010	2030	2010	2030	2010	2030
Fixed and Capital costs	58%	53%	69%	80%	65%	67%
Variable and fuel costs	42%	47%	31%	20%	35%	33%

Table 9. Electricity cost structure. Source: European Commission

According to the previous table, seems clearer for the case of Spain the high RES penetration scenario, as nuclear power will likely be finished in a decade. The expectative for 2050 is 80% of fixed and capital costs, what make us reflect about the fact that the wholesale market will not be able to properly remunerate each technology in order to cover the fixed costs due to low average spot price.

Inside the low-carbon technologies there are difference in the type of service they provide. Nuclear and hydro plants provide firm capacity, what means they can previously predict the amount of energy they will be able to deliver. Whereas wind and solar are variable or intermittent technologies which depend on the weather conditions and the outcome energy can be forecasted only in the short term. Intermittency is a technical characteristic with great impact on the requirements of the electricity infrastructure, where ancillary services are likely to play a bigger role than what they historically did. In addition, intermittency translates into an economic impact because the unpredictable amount of cheap energy on the market increases the price risk. [3]

Both the electricity price (which depends on the cost characteristic) and the increased uncertainty of revenue streams (due to intermittent energy sources) are crucial elements of the investment decision. If the average electricity price on wholesale markets is too low to cover the fixed costs together with the marginal cost of electricity production, investment is not profitable in expectation, and rational market actors will not undertake it. On the other hand, intermittency in the availability of cheap energy sources increases the variance of price: this means that the price can be low, but also very high in periods when low carbon technologies are not available. This translates into higher investment risk negatively affecting the investment decision.

For the electricity system to be reliable, most of low marginal cost units cannot serve the system alone: nuclear plants are, in general, independent from weather conditions, but they require long booting periods, while wind and solar power (variable renewable sources) are, by definition, dependent on weather conditions which are not easily predictable. This means that large scale deployment of low marginal cost units, and in particular variable renewables, challenges the reliability of the electricity system. For reliability to be maintained, they need to be complemented with other types of resources, like demand response, storage, and generation units for moments of unfavorable weather or to cope with sudden demand spikes requiring fast-responding generators, like CCGT[4] or hydro with reservoir. [3]

This means that the introduction of low carbon technologies requires flexibility resources to stay in the market (fast responding firm capacity, currently represented by conventional peaking and mid-range plants, demand response, storage, better use of interconnections and more efficient use of existing plants). With small shares of variable renewables in the system, their intermittency can be smoothed out with existing conventional capacity. But when the variable renewable share reaches higher levels (some estimates put the threshold at 20-25% back-up capacity runs for very limited amounts of time, with a consequential decrease in profitability that may force them to exit the market and/or discourages new investment. [3]

Whereas the marginal cost based pricing mechanism is widely considered as the best way to achieve efficient use of resource in the short term, its role in guiding investment is being challenged by the changing environment imposed by low carbon technologies, (intermittency, fewer hours run for peaking units and lower market prices). Depending on the techno-economical characteristics of the generation mix, price formation in a short-run, competitive market may not turn out to be functional to send long term price signals to induce investment. [3]

Over time the wholesale market will present an increasingly less attractive risk/return profile, with lower average prices and higher volatility, which will induce market concentration as larger companies can more easily bear these risks. The result will be loss of competitiveness as well as strategies by large companies to abuse the market. [3]

Therefore can be resume that the increasing share of low carbon technologies in the electricity mix is likely to lower the prices on the spot market. Under current market arrangements, this corresponds to the day ahead market. These price developments can be explained by the price formation (i.e. assuming generators bid according to their marginal costs) and the cost structure of these technologies with high fixed costs and low

[4] Combined Cycle Gas Turbine

operating costs. In such a system, there is a risk that a market price based on the operating cost of the marginal unit may not be sufficient for investors to generate sufficient revenue to cover their fixed costs. This is under the assumption that technologies with low variable costs will dominate the market and therefore regularly act as the marginal producer. [3]

This translates into a risk that the current arrangements of wholesale markets will not provide the proper incentives for long-term investment in the power generation sector. Markets are supposed to serve two functions: optimisation of resources already in place, and driving investment for the future. Whereas the electricity market serves the first function well, it is not clear whether the current electricity market design will be sufficient to convey the right long term investment signals in a system dominated by low-carbon technologies with low operating costs. However, a proper market framework is important to make these investments happen. [3]

4.3. Presentation of the Spanish case

This section presents the current electrical panorama of the Spanish system and how it is expected to go on due to the policies marked by the European Union as well as the behavior of the market and the state of the art of technologies. The section ends up deepening in a current topic of the Spanish society, the over remuneration of the historical power plants.

The future of coal-fired power plants will be strongly conditioned by the National Transitional Plan, approved by the government in 2013 and based on Directive 2010/75/EU on industrial emissions, which imposes strong demands to reduce their emissions of polluting gases. For this, Spanish coal plants would have to face heavy investments in the incorporation of denitrification and desulphurisation plants. [28] [29]

Plants that do not carry out adaptation investments can continue to operate until June 30, 2020, but could operate until the end of 2023 with a limit of hours if requested. [29]

According to an EDP report, "only 37% of the installed capacity of coal-fired power plants in Spain (3,560 MW) has shown its interest in continuing to operate beyond the year 2020". This percentage refers to plants that have carried out the necessary environmental process by the moment. [13]

It is expected that all the thermal power plants that consume national coal fuel will close due to the high price of this type of fuel. However, those that use import one are considering to undertake the high investments to adapt to the regulations. Also it has to be taken into account that they will not have any type of aid from the public administration.

If the hypothesis of the aforementioned EDP report was fulfilled, there would be a decrease in the installed capacity in 7376 MW, which would result in a very important dispatchable power loss in the Spanish generating system.

It is important to note that according to the total decarbonisation objectives of the European Union road map, these emission requirements set by the directive for 2020 will not be the last or the most demanding, and are expected to harden in the next decade, which leads one to think that it will pull back many facilities in the decision to make these large investments.

Regarding to nuclear energy, the current political framework is not encouraging in terms of extending the life of the nuclear power plants in operation. Most political parties are calling for the closure of the plants when they reach 40 years of operation, so that the seven reactors currently operating would close between 2021 and 2028. [30]

In fact was already discussed in the congress of the deputies at the beginning of the year 2016 the proposal rose by the opposition in which the nuclear blackout is demanded when the plants achieve the 40 years of operation. Almost with full support from the chamber, it is expected that by the end of the 2020 legislature, and with a view to the next elections, most parties will be in favor of the nuclear blackout. [31]

This closure would mean a reduction in the installed capacity of 7573 MW, an amount that does not seem very high in comparison with the total capacity, but knowing that these work with a utilization factor close to unity, represents a drastic reduction of energy produced annually , Which stood at 54,755 GWh, representing 20.8% of the annual demand for 2015. It should be noted that nuclear energy has been the technology that contributed most to the mix since 2011, according to REE data.

These types of plants, which use a low carbon technology, working on base are providing an instantaneous amount of energy to the system high and practically constant throughout the year, since the fuel change stops are designed not to coincide with each other. So an important challenge arises, since one has less protagonist in the system able to compensate the intermittency of the renewable energies.

As intermittent renewable technology par excellence in Spain is wind power, which despite its annual contribution to the system is high, was 54708 GWh (20.95% of the mix) in 2013 and 48109 GWh (18.29% Of the mix) in 2015, the problem is the variability that it has over the years, over the months and throughout the same day, which makes it unsafe for the stability of the system especially in peak demand. So it is strictly necessary that they are backed up at all times by dispatchable technologies.

To make clear the strong variability experienced by this technology, we will analyze the results of the study carried out in chapter 2.1.3. The utilization factor at peak demand fell from 61.73% in 2015 (historical high) to 26.25% in 2016 (historical low). In addition, the average utilization factor at the peak demand in the summer and winter months also vary enormously, from 11.05% to 45.94%. These unpredictable differences must be solved with dispatchable ones, fast-response technologies that can cope with instantaneous wind power outages.

It is an interesting fact that according to the load curve of the summer months, the peak demand of the day coincides with the moment of maximum solar power producible, given that it is hottest time and refrigeration equipment are working more. So at peak demand, this technology could contribute to the generation mix an important part, in fact in the last 5 years its contribution to the peak of demand has been higher than 12%.

Spain, according to the targets set by the EU for 2020, must be achieved a final renewable energy consumption of 20%, so there is necessity of investing in this type of technologies, currently reaches 17.5%. In fact, in the first quarter of 2017 an auction of 3000 MW will be carried out, which will surely be distributed by wind and photovoltaic for being more competitive. In addition, 500 MW of wind and 200 MW of biomass were tendered in early 2016. [32]

These renewable megawatts to be installed will be the first that will not receive premiums, since in January 2012 the moratorium was declared to collect premiums. This moratorium is in line with the trend of other European countries, which claim that consumers do not have to bear the costs of renewable facilities that have increased the light bill. Therefore, from now on, the necessary increase of the renewable quota will be independent of premiums and the facilities will be remunerated only through the market. [33]

At the same time, the hydroelectric sector is oriented above all to achieve greater efficiency, improving the performance of the facilities in operation. The proposals are aimed at the rehabilitation, modernization, improvement or expansion of existing plants. Since most of the attractive and exploitable hydrographic basins for the installation of a plant are already occupied. [34]

So this hydroelectric technology is not called to be a major player in future. If by way of regulators, since reversible power plants have a great capacity of response both when generating and when pumping.

As we know the intermittent production must be supported by technology dispatchable at all times, such as combined cycle, reservoir hydroelectric or biomass. The despatchable technology by excellence in the Spanish electrical system is the combined cycle with 26,670 MW installed.

The cogeneration technology, which had a significant development thanks to the premiums they received over the years, has now been frozen. As can be seen in the electricity system reports of recent years, this technology contributes to the generation mix at around 10% per year and has a contribution of about 25,000 GWh per year, divided steadily over the months and days, so it can be considered a base technology with 2900 MW.

Today, with the demand of the system, the combined cycle alone, assuming a factor of utilization of the unit, could satisfy 88.8% of total demand. Therefore we have a coverage index more than enough, specifically 1,37.

If we go further, assuming that all the assumptions discussed above are met, the combined cycle could back up over the next decade the increasing share of renewable technology without problem, in a scenario where demand of electric power would slowly increase due to economic growth but above all by the transformation in the transport sector that will affect Europe and Spain, where the electric car will be introduced to meet the objectives set by the EU.

From 2030, where there would be no nuclear power or coal, and demand will have increased substantially by the replacement of the electric car by the internal combustion car, combined cycle power does not seem sufficient to guarantee the level of stability and security of supply in the system. The installed capacity of biomass today is only 754 MW, it is still an expensive technology to compete in the market.

Due to the fact that in recent years the utilization factor of the combined cycle plants has not exceeded 20%, several were considering closing their facilities as they are having problems in the amortization of their facilities. Given the decrease in coal and nuclear power in the coming years, these facilities must remain available, and here comes the important role of capacity payments to these types of plants, in order to obtain incomes to amortize their facilities and do not try to leave the market.

It is true that right now and in the next decade, according to the announced hypotheses, there should be no electricity supply problems. But from the year 2030 new investments will be necessary if the stability of the grid and continuous supply is wanted to be guaranteed. As discussed in section 4.1. this market design, in which the spot price is the signal that is sent to investors to make investment decisions, will not help the installation of new megawatts of conventional technology, because with a penetration of renewable energy so high, according to the EU target for 2030 renewable energy should represent 37% of final energy consumption, the hours at which conventional power plants will operate will be low and the market price will also be low, increasing investors' risk to amortize its facilities.

It is therefore a major challenge for the Spanish electricity system, and for the rest of the EU countries, which will have to face the problem of investment in conventional technologies in the long term, if they want to ensure a quality electricity supply to the future generations.

In spite of having cut public aid, investment in renewable technologies continues to increase, especially wind and solar technologies, which have reached a point of technological maturity that makes them competitive in the wholesale market with other technologies.

Defining the concept, the levelised cost of energy is a measure of a power source which attempts to compare different methods of electricity generation on a consistent basis. It is an economic assessment of the average total cost to build and operate a power-generating asset over its lifetime divided by the total energy output of the asset over that lifetime. The LCOE can also be regarded as the minimum cost at which electricity must be sold in order to break-even over the lifetime of the project. LCOE has three basic cost components: [35] [36]

– Fixed costs, such as initial investment.

– Variable costs, such as operations and maintenance (O&M) and fuel.

– Financing costs, such as cost of debt and cost of capital.

The idea of levelized cost of energy is a very useful tool for comparing unit costs of different technologies during their economic life. They correspond to the cost of an investor assuming the certainty of the costs of production and stability in the prices. In other words, the discount rates used in the LCOE reflect the return of capital to an investor in the absence of technological or market-specific risks. As these specific markets and technological risks often exist, there is a difference between LCOE and actual financial costs for an investor operating in a real electricity market with its specific uncertainties. For the same reason, the LCOE are also closer to the real costs of investment in electricity production regulated by a monopoly with guaranteed loans and regulated prices than to the real costs of investing in competitive markets with variable prices. [36]

As can be seen in the table 10, the levelized costs of large-scale photovoltaic solar and onshore wind energy are low, which makes it evident that these technologies can already compete in the market without public subsidies. However, waste and biomass technologies, which are renewable technologies called to supply base energy to supplement the intermittency of the others, are not yet at a point in their learning curve that allows them to compete in the market, and without public subsides does not appear to be a leading technology in the coming years, unless the government auctions a reserved space for this technology. [37]

Wind-onshore and PV technologies, as can be seen in the table 10, have reached a maturity point such that they are already more competitive than combined cycle technology. It is expected that this cost gap will continue to increase as carbon emission taxes will increase in order to eradicate polluting technologies from the market and achieve the 100% renewable target by mid-century.

Technology	**LCOE [Euro/MWh]**		
	3%	7%	10%
PV – residential rooftop	91,07	124,87	154,92
PV – large, ground-mounted	79,34	100,52	120,18
Thermal (CSP) – no storage	244,11	319,23	394,34
Wind onshore	73,23	94,88	110,79
Biomass turbine	138,02	159,61	175,57
Solid waste incineration	203,74	262,89	309,83
CHP gas turbine	24,41	32,86	37,56
CCGT	94,30	99,01	103,73

Table 10. Levelized costs of energy for generating plants in Spain in 2015. Source: International Energy Agency

The levelized costs of nuclear technology have not been included in the table as it is almost certainly expected that there will be no new investments in this technology in the near future.

The wholesale market prices in recent years are represented in the following figure 25:

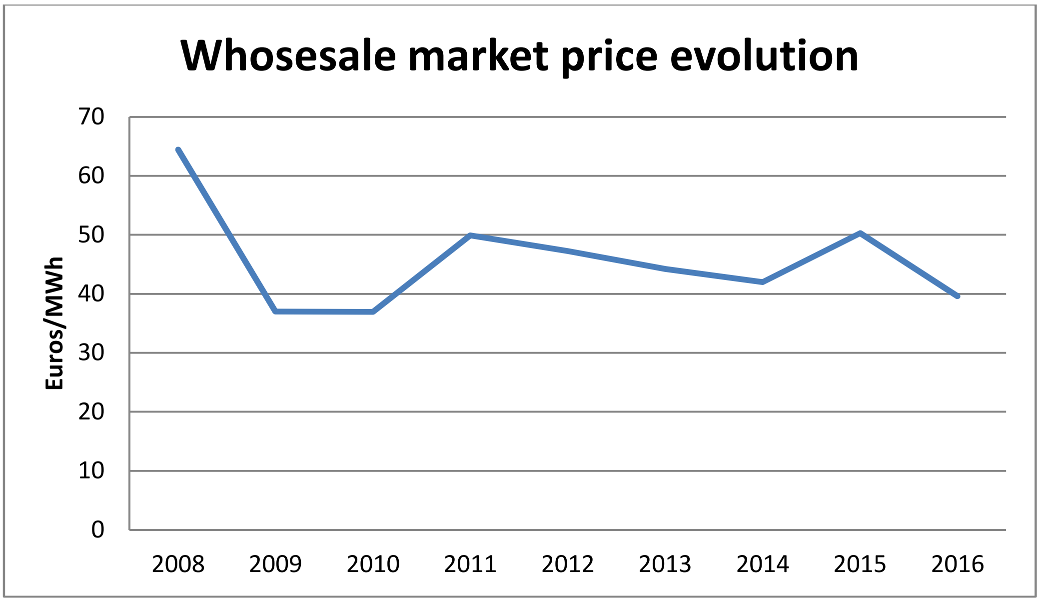

Figure 25. Wholesale market prices in the recent years. Source: OMIE

Prices have been plotted since the financial crisis of 2008, where there was a great increase in the prices of fossil fuels, with consequent rise in wholesale market prices. In addition, as mentioned earlier the demand from this year began to decline. Therefore, the prices of these last years are the most faithful when analyzing the reality of the market and the remuneration that the producers are currently having.

The average wholesale market price in these years is 43.4 €/MWh. Comparing to the levelized costs of the previous table, is easily noted that the prices are not sufficient to cover the costs of a new generating facility.

4.3.1. The case of historical power plants

The case of the historical power plants in Spain, which are the large hydro and nuclear plants that were built before the liberalization of the market in 1997, is a current political and social issue. Several experts have been claiming for years that these plants are having over remunerations or in the economic slang wind fall profits of the electricity sector, since 2006. This situation in a context of constant increases in light prices to consumers and with a huge tariff deficit is giving much to speak today.

To explain this situation, we will use the intervention of the expert Jorge Fabra Utray [5], who in summer of 2015 declared to the supreme court alleging what will be exposed.

[5] Jorge Fabra Bucay is a former Government Delegate in the Exploitation of the Electricity System, a former director of Babcox & Wilcox and Endesa, former president of Red Eléctrica España, a former adviser to the National Energy Commission and currently chair of the Board of Directors of " Economists facing the Crisis "association of which he was co-founder.

“In 1997, the government agreed with the companies of UNESA the Protocol for the establishment of a New Regulation of the National Electrical System, which agreed to implement the marginal system of fixing prices by which all generation plants would collect the price of the last plant which completes the coverage of electricity demand. That is, the highest price offered in the hourly auctions carried out every 24 hours”. [38]

“The Protocol also established the compensation to historical power plants, via the so-called Transition to Competition Costs (CTC), for the losses estimated to be caused by the new regulatory system to the investments corresponding to those historical plants. The Protocol and its connection with the Electricity Sector Law 54/97 are proof that companies and the government were aware that, companies being remunerated by the two channels (via tariff and via the market In excess of the estimated price), the agreed compensation (CTC's for 8,664 million euros) and also with market prices above 36 MWh and other regulated remuneration supplements, the investments to which we refer were already recovered”. [38]

“The National Energy Commission (CNE), in a report dated December 2, 2009, (...), concludes that the CTC's collected between December 1997 and June 2006 by the electricity companies that signed the Protocol were 10,187.20 million of euros, at net present value at 31 December 1997, what means 1,523.60 million above and more than the authorized ceiling of 8,664 million”. [38]

"The CNE report clearly shows that the advantageous position of the nuclear and hydroelectric technologies that provide them, with the current market design, a high remuneration, is not a position or competitive advantage that can be legitimized by the markets. The nuclear moratorium and the inexistence (in significant terms) of new economically exploitable hydroelectric basins, determine the lack of freedom of entry in these technological segments so that new entrants cannot dispute the benefits. Consequently, there is no possibility of real competition with these technologies, which leaves them out of the market”. [38]

In its report it shows the accounts of the profitability that these historical centers has been able to have in the 10 years:

1- The average producible energy of hydroelectric plants is 30,007,000 MWh; considering that its remaining production costs are, under generous assumptions, around 11 € MWh, and that its revenues have been between 53 and 66 euros MWh, the whole of these plants would be experiencing annually, from June 2005 to present, unexpected profits between 1.275 and 1.670 million euros per year. [38]

2- The average producible energy of nuclear power plants is 59,888,000 MWh; considering that their remaining production costs are around € 22 million MWh, under generous assumptions, and their revenues have been between € 40 and € 50 per MWh, all these plants would be experiencing from June 2005 to the present, unexpected benefits between 1.078 and 1.692 million euros per year. [38]

“In summary, since June 2005, the date of recovery of CTCs, nuclear and hydroelectric plants have generated inesperated incomes (windfall profits in the economic literature), which have been - according to the moderate hypotheses mentioned above - between 2.335 and 3.361 million per year. That is to say, in 10 years these unexpected revenues have reached an order of magnitude similar to the tariff deficit - 30,000 million euros - that today represents the financial imbalance which has justified the set of norms emitted under the Electrical Reform, without any of these rules having not only not analyzed, nor even made mention of this issue". [38]

5. ANALYSIS OF THE SITUATION AND ROADMAP

In order to meet the objectives set by the EU in terms of decarbonisation of the economy and energy independence, to guarantee the electricity supply to consumers and to achieve electricity prices that induce wealth creation and not poverty, must be rethinked whether the current system tends to the aforementioned or on the contrary we are increasingly moving away from this goal.

Firstly, the wholesale market was created with the idea of competitiveness between technologies, in order to promote the efficiency and the optimal use of resources. Must be remained that the market is a marginal one, where the producers bid depending on the marginal cost of each technology. Therefore in this scenario, where low-marginal cost technologies are struggling against high-marginal cost technology make no sense this kind of market, as is impossible an effective competitiveness between these disparate technologies. The result is that these essential conventional technologies will be out of the market.

With the current trend, if a market redesign is not carried out, it will be dominated by low-carbon technologies and the spot price will fall sharply, which will result in no facility, either renewable or conventional, to amortize its assets. In addition, with the high penetration of renewables prices will fluctuate enormously with the consequent uncertainty for the investors. Therefore, given this uncertain scenario of volatile and low prices, it will be difficult for investors to install new capacity, they will flee to markets where they can secure profits.

All this leads us to think that the design of the wholesale market is outdated and will not be able to meet the needs of the future times. Therefore, a redesign of the market will have to be made according to the scenario that is being experienced in the European Union, where a growing penetration of renewable technologies is giving place to unexpected changes and creating challenges that will have to be faced to guarantee an optimal electrical supply.

The new market design should aim to ensure that all the technologies involved in the generation mix are remunerated so that they can amortize their facilities in the long term and have all the same profitability, which must be reasonable. This would result in a fair and balanced retribution system where there would be no windfall profits or windfall looses for any technology.

This could lead us to think that the efficiency that the current market gives, in which the technologies that have the least marginal cost enter into market. So this could be arranged through auctions, where for example 500 MW of biomass power is taken out. And therefore, the investors who present their projects with lower cost, more efficient, are those that are awarded the permits. This new installation would be remunerated according to its costs, which are lower than the other proposals, thus promoting competitiveness and producing energy at a lower cost to consumers.

The fact of remunerating the technologies according to their costs, must also be for the facilities that are already in operation. As we know, this is already taking place for renewables, which are being paid in a fixed way, receiving out of the market through charges in the light bill the amount needed to amortize the facilities.

However, in the case of the historic power plants, nuclears and large hydroelectrics, as mentioned in section 4.3.1, they have been getting over remunerations from the electricity market for years, where the spot price is well above their costs. Therefore, and as several political parties and the scientific community have been claiming for a long time, these technologies should make public their costs through an audit so as to cut off the windfall profits they are having, and also be assigned a fixed remuneration which allows them to have a reasonable and fair income from the operation of their plants. [39]

The previous measures would save in the over remuneration to the historical power plants and could be invested in other parts of the electric system, being traduced ultimately in a lower cost of the light bill to the consumers, which in Spain is one of the most expensive of the European Union. They could be used to tackle the tariff deficit, which is a huge concern nowadays and could also be used in capacity payments.

Regarding the remunerations to coal and natural gas power plants, they are having problems to amortize their costs, especially the last ones that take less time in the system, they are working during the year with a very low utilization factor. As discussed in section 4.3, combined cycle power plants are called to be the protagonist back-up plants in a future scenario. Therefore if it is desired they are not dismantled, the capacity payments play a very important role, so that facilities will be amortizated despite the few hours of annual production they have.

There is an extensive bibliography about new and more efficient market designs that adapt to the upcoming situation of high penetration of renewables, but it is not the objective of this study to analyze which option is the most feasible for an adequate sustainability and optimization of the system. The following bibliographies help those interested to delve deeper into this topic of redesigning electric markets in Europe. [40] [41] [42]

The roadmap that Spain should follow to face the challenges of this new reality goes through several paths, such as the design of a generation mix that minimizes the impact on the light bill and ensure security of supply. Spain is a country rich in sun, has one of the highest average annual radiation in Europe, and it is quite high in most of the country. In addition it is also rich in wind resources, given the great extension of coast with strong and constant winds.

That said, a new legislation regarding self-consumption is almost mandatory, in which the famous "sun tax", imposed on solar photovoltaic energy production must be repealed. So we should move towards a new regulation that encourages production and self-consumption with renewable energies, not penalizing or putting up barriers as it is today. As a first positive effect, it would be possible to reduce the need to produce energy in large power plants, take advantage of the value of solar radiation in the country and create wealth and employment in this sector. [43]

An adequate interconnection plan is also needed within the same country, so that in each region electricity would be generated using the most economical resource and then flow to other areas through the transmission lines. Going further, and as one of the main objectives of the EU, an European interconnection would allow the cooperation and coordination of different regions and optimize resources globally.

In addition, we must not forget the need for investigation and development of new renewable technologies that are not competitive today. We are talking about those that harness geothermal, marine and biomass energy. Each source has its specific characteristics, they provide flexibility and versatility in power generation, which reduces dependence on specific technologies, increases resource efficiency and enhance security of supply.

It is necessary to mention the importance and prominence of new players that are going to revolutionize the next decades such as smart grids, distributed generation and the participation of citizens in the system through the electric car and other forms of demand response. That will ultimately break the rules of the game and open the possibilities of supplying electricity from new perspectives, always tending to efficiency and optimization of resources.

Ultimately, as an mandatory necessity, the political-legislative framework, as well as the scientific community, must be aware that these new technologies today are a pervasive reality in society and therefore must respond with proactivity, conscience, lucidity and flexibility, in order to align policies with progress and development that improve the lives of citizens.

6. CONCLUSIONS

Nowadays, and in the short term, there are no problems of electricity supply to consumers. The Spanish generators can cope with existing demand, as it has a minimum coverage ratio of 1,37.

In the coming years, in order to comply with European directives, investments are only expected in renewable energies. Especially photovoltaic and wind as they are the cheapest, but also in biomass and waste.

In Spain today, the levelized costs of photovoltaic and wind energy are lower than those of the combined cycle. These renewable technologies are perfectly competitive, so facilities for production and self-consumption should be promoted.

Despite the high penetration of renewable energies and the extraordinary peninsular interconnection, despatchable conventional technologies have an unquestionable and fundamental role to ensure the electricity supply in both valley and peak hours.

Over the next decade, after the expected closure of nuclear power plants and most coal plants, as well as an expected increase in electricity demand, the system could have problems with despatchable generation technologies.

It is of vital importance, thinking in the medium-long term, to keep the combined cycle power plants open, which will be the main despatchable technologies. So capacity payments will play a key role.

Because average spot prices tend to fall due to increasing renewable penetration, there will be problems in future investments, as the plants will not get enough revenues to amortize the facilities. This fact is especially concerned with investment in despatchable technology.

Another effect of high renewable penetration is the volatility of prices caused, creating a scenario of doubts and risks for investors. This fact raises barriers to competitiveness and tends to domination from oligopolies, the only ones capable of dealing in a more uncertain atmosphere.

So we can conclude that the current market system is outdated as it will not be able to generate enough revenue for existing facilities, create competitiveness and provide clear price signals for new investments.

A new market design becomes necessary, one that tends to remunerate each technology based on its energy production costs. This requires a complete, clear and transparent information on the activity of all generators. This new design would avoid both windfall profits and windfall losses for generators, and would result in a cheaper price for electricity for consumers

At present, the high light prices in Spain, largely due to public support for renewables and cogeneration, could be offset by an audit of the system that would allow us to known the actual generation, transport and distribution costs and then remunerate them in a fair way. The windfall profits of the historical power plants and other ones could relieve the light bill.

With a long-term future perspective, note the growing role of smart grids, which will gradually transform electricity generation model, going from a centralized to a decentralized one, where consumers will acquire importance within the system, also acting as generators. This will bring about a radical change in the way the system is currently set up.

Lastly, I must emphasize that in order to face the current and future challenges, a flexible political attitude is needed for getting adapted to present times and anticipates future events. Also a lucid political attitude is needed, which is aware of reality, in order to know strengths and opportunities to make the most of them; as well as the weaknesses and threats that could prejudice. A proactive attitude is also fundamental, with the aim of taking creative and bold initiatives that generate improvements and progress.

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