UNIVERSIDADE DA BEIRA INTERIOR - FACULDADE DE ENGENHARIA

ELECTRICAL ENGINEERING FINAL PROJECT.

RELATION OF THE PRICES OF THE MIBEL WITH THE WIND POWER GENERATION.

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Introduction

This report will try to address as a main objective the relationship between wind power generation and the daily prices of the MIBEL. The purpose of this detailed introduction is to discover the reader a previous context to further analysis to be displayed. In addition, to understand the existence of a common market between Spain and Portugal. We can identify and know the function of each of the players in this market. For this there is a first larger part with the justification and goals of the project. Then we find the explanation of technical and environmental problems, reason we decided to address this issue. And last but not least, throw the sight backwards to the Spanish legislation about electricity markets for the last thirty years. The process will be treated since the central were part of the Spanish State to be liberalized.

FUSTIFICATION AND GOALS.

The principles on which this project is based is rooted in a popular theme about the ecological and economic unsustainability of our society and the culture therein. Conceived as an analysis that tries to generate a rigorous and informed discourse to address these issues from a position that combines the creditworthiness of the scientific method to social consciousness.

The purpose of this report is twofold. On the one hand I want to give objectively the keys necessary to understand how the MIBEL works. To do this, we start with an introduction to basic concepts of an electrical system, where also review the previous process of the liberalization, *Marco Legal Estable*. At the end of the chapter we will outline both components: the regulated and the market one.

The second objective is to provide a particular view on the electricity market as a framework to manage the electricity sector, focusing on the relationship between the prices variation in the MIBEL with wind power generation. To do this, with the help of the information provided to us e.SIOS (Sistema de Información del Operador del Sistema) and another web sites, I have elaborated graphics with different features and comparisons that allow an easier understanding.

PROBLEM

To this day it seems unquestionable that the energy plays a fundamental role in our society. In particular, electricity is gaining more ground in everyday life, representing a significant portion of final energy consumption we do. If in addition we consider the versatility of this form of energy (can be transported almost instantaneously, can be generated from a variety of sources), it is foreseeable that in a long/medium stage term the scarcity of fossil resources.

The management of an electrical system, understood as it formed by all participants and infrastructure involved in the generation-transport-consumption cycle represents a multidisciplinary challenge. On the one hand there is the technical problem, the generation and consumption of electricity must be balanced at all times. There is an economic dimension, since it is necessary to establish frameworks and mechanisms to reward generators and establish real prices to consumers.

Finally, there are the environmental considerations: power generation today involves the consumption of fossil fuels, the generation of radioactive waste, the emission of greenhouse gases and toxic substances, consumption of raw materials and water and the use of the land among others. It seems clear that in a world with finite resources, cannot be planned an electrical system apart from these considerations.

BACKGROUND: HISTORICAL EVOLUTION OF ELECTRICITY SECTOR

STUDYING DURING THE MARCO LEGAL ESTABLE (MLE)

It is known as Marco Legal Estable the set of rules and laws that regulated the Spanish electricity sector from 1988 to 1997. This regulation was based on the premise that the electricity sector is a strategic element for national development and that electricity should be considered a basic right, to which all citizens have access. Therefore, it was essentially a framework regulated by the state, which took responsibility for organizing and planning the sector.

The MLE is created with the goal of, as its name suggests, provide a stable framework for all stakeholders. Such stability is embodied in ensure the companies acceptable benefits and recover their long term investments and transparently establish rates to consumers in terms of minimum cost.

The situation of each of the agents within the MLE depended on their activity:

In generation the most characteristic was the use of the term ‘standard cost’, by which, annually, the Ministry of Industry and Energy recognized the electrical companies the generation cost associated to each type of source (differentiating even concrete centrals in some cases). This cost mainly included investment costs in facilities, operation, maintenance and fuel. With the payment of such costs, power companies ensured the long-term depreciation of facilities and a range of annual benefits by the activity performed. On the other hand, the State reserved the right to encourage more one technology than another to set the generation mix through revisions of the standard costs.

NUCLEAR	
Nuclear antigua	51373
Vandellós I	112214
Almaraz I y II	134400
Cofrentes, Ascó I y II	180000
Vandellós II	229312
Trillo	252243
NATIONAL/IMPORTED COAL	
Nuclear antigua	47694
Nuclear moderna	90000
LIGNITE	
Lignito pardo	117000
Lignito negro antigua	55643
Lignito negro moderna	105000
Lecho fluido a presión (Escatrón 5)	186673
FUEL/GAS	
Fuel-Oil antigua	32993
Fuel-Gas antigua	39592
Fuel-Oil moderna	54841
Fuel-Gas moderna	65809

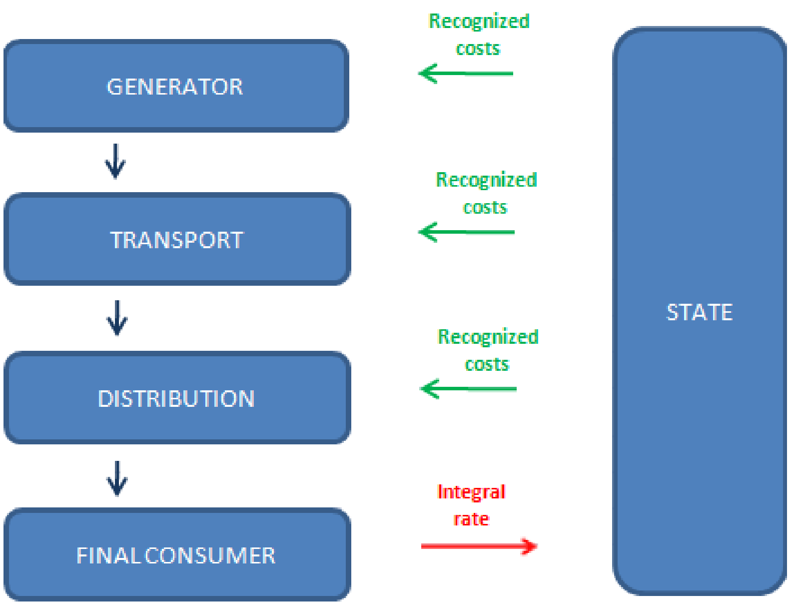
Standard base investment per kW installed as technology in the MLE of 1982 in pesetas.

The main change introduced by MLE in the transport was the nationalization of the network of high voltage transmission. Before the MLE, the peninsula was fragmented into poorly connected regions where different power companies had created their own self-supply network. With the nationalization started one philosophy of combined export of the electricity system in all the country. Transportation becomes therefore in a natural monopoly, the most efficient is that exists only one responsible company. Red Electrica Española (REE) is created.

Distribution networks continued to belong to electricity companies, responsibles for carrying out the distribution and marketing in regions where traditionally were operating. In the same way as in the generation, they were recognized annually costs associated with this activity to ensure maintenance of distribution networks.

Marketing during the MLE determines the price that consumers have to pay electricity through the concept of Tarifa Integral. The central idea is simple, was to group the expected total costs of the electricity system and dividing by the estimated demand for that year. The costs included were the following:

- Standard costs of generation and distribution activities, based on the estimated demand.
- REE costs for transport activity.
- Costs associated with deviations between estimated demand and actual demand in previous years.
- Other costs, such as basic stock of uranium, second part of the nuclear fuel cycle, research and development programs, nuclear moratorium, aid to the coal (from 1995), additional cost of extrapeninsular system, ...



Scheme of the main players in the MLE. Blue arrows indicate electricity flows. Red and green ones indicate cash flows.

In this way, the electrical system could be understood as a closed chain in which consumers assumed the entire system costs with prices regulated by the Administration, prices which in turn ensured the power companies recover investment and other costs previously recognized by the state. This state presence in all links of the chain gave the state a full capacity to plan the country's energy policies in the short, medium and long term.

HISTORICAL SUMMARY OF FIGURES DURING THE MLE.

The MLE is heir to a peculiar situation. In the decade before the start, and as a result of the energy crises of the 70s, the National Energy Plans focused on enhancing the diversification of generating capacity to reduce dependence on oil. Was carried out an accelerated plan of coal power plants, hydroelectric plants and the implementation of most of the current nuclear fleet plan. In addition, was designed a framework for the Special Regimes for which distributors were required to purchase the energy produced under this scheme at a price fixed by the Ministry.However, the forecast consumption trends were too high, so that at the beginning of MLE the generation park was oversized.

So much so, that throughout the period that lasted the MLE installed capacity increased from 41,415 MW (in 1988) to 43,280 MW (in 1997)that is to say, an increase of only 4, 5% in 9 years (less than 0,5% per year) to meet a demand that evolved to 3,2% annually.

During MLE occurred the takeoff (in terms of energy produced) of Regime Special, it passes to cover 1% of demand in 1988 to 10% in 1997. Although the distributors were required to buy the energy at a high price, these costs were recognized within the standard costs. However it was feared that this progressive increase energy involves an excessive increase of the 'Tarifa Integral'. That is why in 1994 a new remuneration framework for reducing the cost of acquisition of the Special Regime.
To conclude and as a summary of the economic aspect, we noted that the electricity tariff grew throughout the period of the MLE at a rate of 2.8% annually, while inflation was on 4, 8%. That is, the real cost of the electricity tariff down at a rate of 2% annually.

PROCESS OF LIBERALIZATION OF THE ELECTRICITY SECTOR.

Law 54/1997 on the Electricity Sector in Spain begins the process of liberalization of the electricity sector in order to redefine the areas of activity of those involved (government, businesses and consumers). This law explicitly eliminates the notion of power as a public service and introduce free market mechanisms to manage part of the decisions with antique frame (MLE) corresponded to the State.

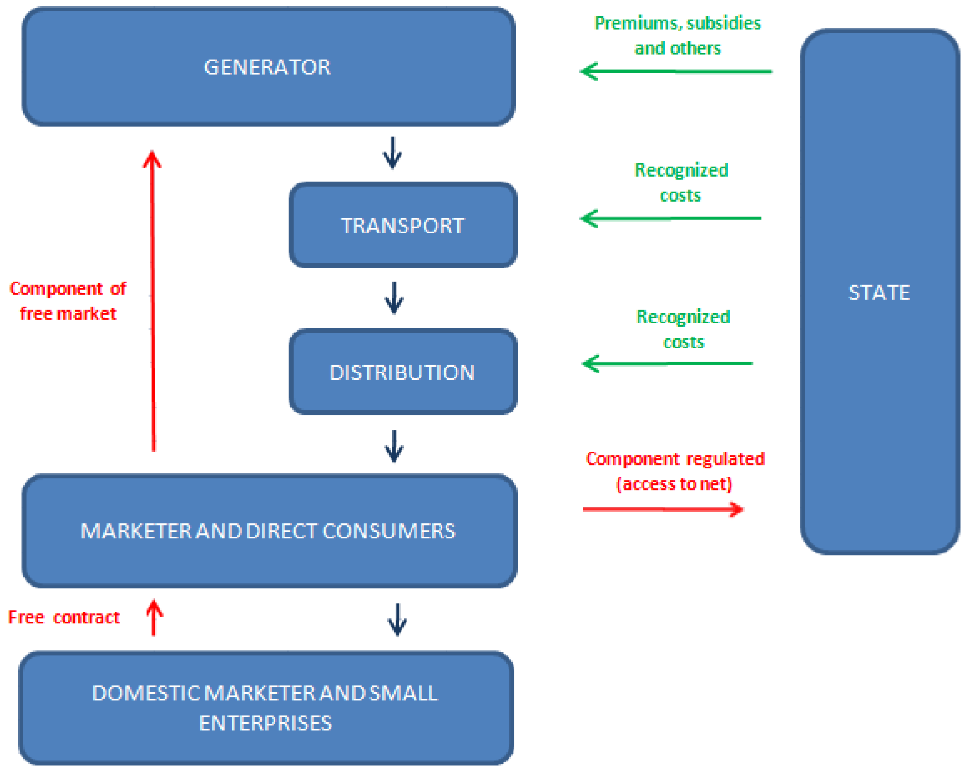
The process of liberalization of electricity markets is driven in the framework of the European Union. The idea is that from basic principles (price liberalization and deregulation of generation and consumption activities), each country develops its own process so that the different experiences allow progress towards common energy markets.

In the mention law is designed a new framework for each of the four activities that make up the electrical system (generation, transmission, distribution and consumption), and the rhythm at which must be implanted in each of them, so that in 2009 the process is completed. The basic idea is to differentiate an area where state regulation (those related to maintenance of electrical networks: transport and distribution) and another whose management is transferred to market mechanisms (generation and supply). In particular:

Installation capacity is liberalized in generation. This implies that a certain company decides, based on their expectations of market what type of technology and how much installed to generate electricity. In addition, the remuneration associated to the activity of generating no longer regulated and passes defined by market mechanisms.

Transport and distribution remain regulated activities. Is consolidated REE's role as sole transmission and operator of the system. The distribution continues to make the same distribution companies, which are unlinked marketing.

Consumer prices are liberalized and the figure of the marketing of electricity is created. Organizationally, the acquisition of energy is carried out in two markets: the retail market, where domestic consumers and small businesses sign a free contract with one of the marketer companies which are competing in conditions of free competition and the wholesale market, in which traders and big direct consumers buying electricity from generators through market mechanisms, in addition to paying a fee that will allow access to the electricity grid, referred to here as regulated component. It is seen, therefore, that the traders perform a role of "administrative mediator" between the generation side and the small consumer, acting as a buyer in the wholesale market and selling in the retail market.



Scheme of the main players in the liberalized market. Blue arrows indicate electricity flows. Red and green ones indicate cash flows.

The outline of the new liberalized framework it shares with the previous stable legal framework the idea that consumers are the final costs covering the entire electrical system with paying their bills. The difference now is that the cost of a kilowatt-hour includes two components, which are obtained separately:

The component regulated oriented to cover the costs of the system (transmission and distribution) and cover other incentives even State competition (incentives to availability, premiums under the Special Regime, incentives to indigenous coal, costs of transition to competition, ...) .

The market component, which is the subject of this study, obtained by market mechanisms between producers and consumers of the wholesale market (traders and direct consumers) on a competitive regime. It is important to note that domestic consumers and small businesses pay the marketer hired as a free contract that pays both components plus the profit margin of the trading itself. Since this margin depends on the agreement in principle reached, the data are not homogeneous, and in this study we omit them, but to consider them, it should be included in the component market. Moreover, in the current situation, most small consumers are benefiting from the 'Tarifa de Último Recurso', the market component is determined by another mechanism.

Development.

Because of the above introduction we have set a framework on which we can support our ideas and start the investigation. However, to understand the interactions of actors through the aforementioned mechanisms is important to understand how the Iberian Electricity Market works. Then we will have a brief explanation of key concepts to understanding the further analysis. This test will try to demonstrate a relationship between the variable onshore wind generation and the price of MIBEL.

ANALYSIS OF THE MARKET COMPONENT OF THE ELECTRICAL PRICE.

In this part of the development are described the mechanisms by which producers and consumers agree on a price and a quantity of energy exchange, thus generating the market price component of electricity.

These markets consist of a series of procedures for the exchange of information between producers and consumers so that those producers willing to produce at the lowest price cater to those consumers willing to pay; all under the main constraint of an electrical system already mentioned: generation and consumption must be adjusted at all times.

Participants in these markets are on one hand the actors involved in these markets are known as market units, and basically distinguishes between producers and qualified consumers. It can also be a qualified consumer who goes to a wholesale market to purchase energy is typically a marketer or a large direct consumer. The traders then formalize contracts with small consumers, households and businesses, to resell the electricity purchased, thus obtaining a profit for the role of intermediaries. In this way is generated a retail market where final consumers have the choice that marketer that offers more advantageous contracts.

There are several markets and therefore several mechanisms by which producers and consumers can agree on a certain price for a certain amount of energy.

- Unorganized Markets: are bilateral contracts which have stable prices and quantities, agreeing a producer and a consumer of its own accord for a period of time (eg six months).

- Iberian Energy Market (MIBEL), where Spanish and Portuguese agents come to the market. The MIBEL turn comprises:

- Market installment or futures market, organized by the Portuguese pole (OMIP), where are auctioned stable long term contracts.

- Daily and intraday production markets (spot market), organized by the Spanish pole (OMEL). They are schedules markets where prices and quantities for each and every hour of the year are decided.

Another set of markets targeted REE managed to organize last minute adjustments to ensure the instantaneous equilibrium between generation and consumption: ancillary services markets, solving technical constraints, deviation management, etc.
In the Iberian Peninsula, most electricity is managed in the spot market (daily and intraday markets), where a large number of participants (producers and consumers) come to make their offers and finalize the price of electricity for each hour . For their interest and relevance in determining the price, the rest of the chapter focuses on explaining these markets.

THE DAILY MARKET.

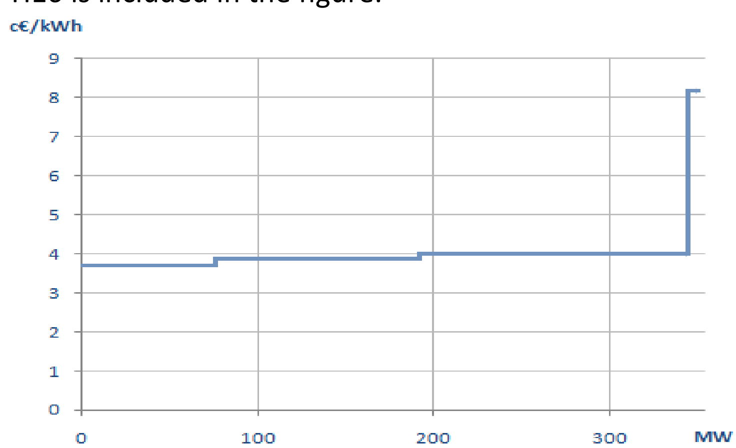
The aim of the daily market is to define the price and quantities of energy that producers will pour into the grid and consumers will absorb it for a certain hour. This market is held every day, so around 14 hours of the day D-1 a price of electricity is set(common for all participants) for each of the 24 hours of the day D and also what producer will produce and how much each of those hours.

Perhaps the simplest to understand how these numbers are reached either illustrate with actual data for any given day, for example, on May 15, which we will call on day D. Consider the case of a thermal power plant.

Making offers.

As generating unit, you must perform before 10 h day D-1 its 24 bids for 24 hours of the day D, designated by H 01, H 02, ..., H 24. An offer is a growing curve which link power and prices at which it is willing to produce at that particular hour. For example, the bid is made for the time center H16 is included in the figure.

MW	c€/kWh
75	3,75
191	3,91
344,2	4
350	8,17



Offer for sale of a thermal power station for 16 H in May 15.

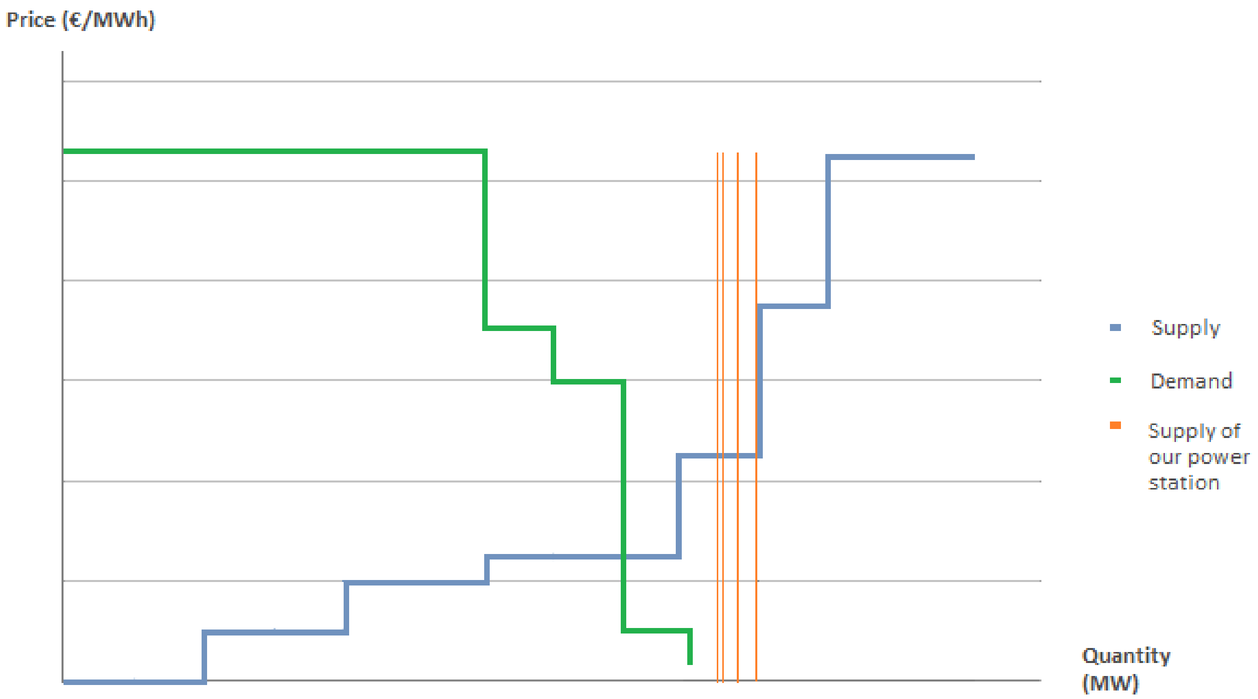
The reading of this offer in this plant, for the hour and the day mentioned implies the willingness to produce a power level of 75 MW at a price of 3.75 c€/kWh; at a level of 191 MW if the price was 3.91 c€/kWh; and so on, up to a level of 350 MW if the price reached the 8.17 c€/kWh.

All generation units make their own bids for each hour. Similarly, consumers make purchase offers in decreasing price bands, which read as follows, ‘I am willing to purchase a certain amount of energy at a given price, but if the price is lower, I am willing to acquire even more power ".

The cassation.

After 10 h day D-1 OMEL has received all offers of producers and consumers.

What then does is generating, for each hour, the curves aggregate supply and demand ordering by sections of low to high, all offers generation and sections from highest to lowest all bids. The figure below shows the aggregate curves obtained for the case of the H 16. The position in which were the four sections of the offer made by the central object of study is highlighted.



Aggregate supply and demand curves for H 16 hours of May 15, 2011. Vertical stripes indicate all four sections of the offer made by the thermal power plant.

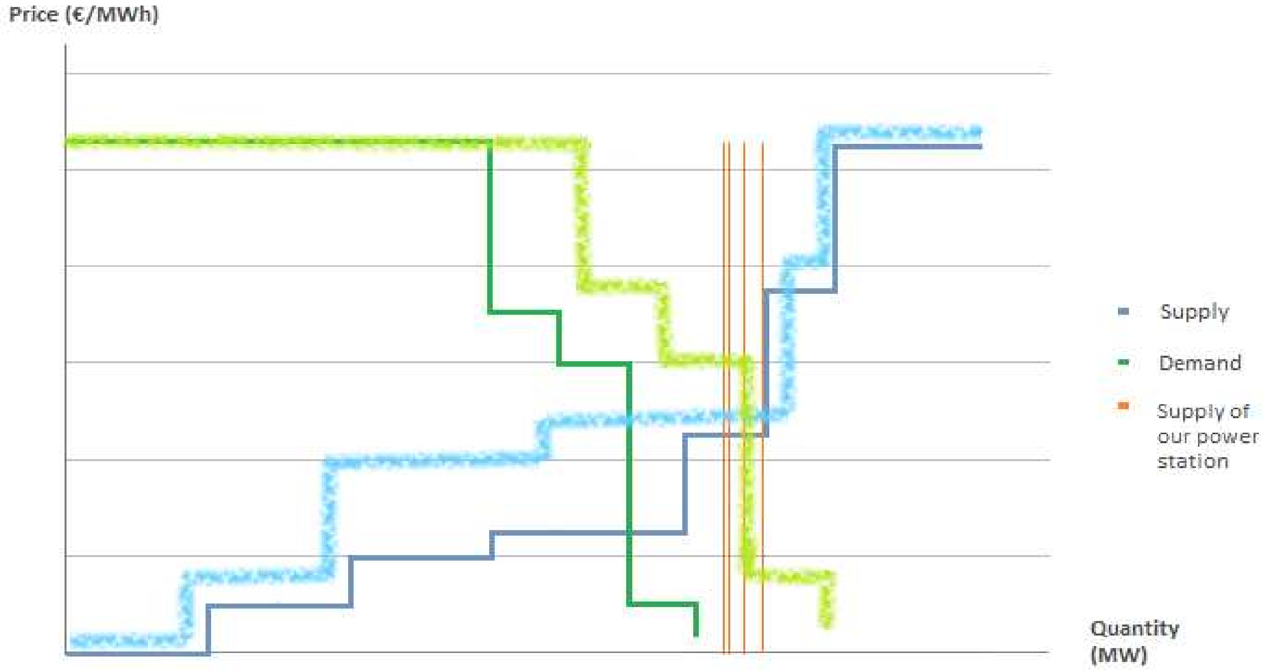
In theory, the cutting of these curves indicates the amount of energy and agreed as the price of cassation. Specifically, sections of the curves "married" (those who are to the left of the range price) indicate to each unit the power level which must generate or consume during that particular time. Therefore, in principle our unity should not pour power to the grid during H 16 hour, since he has not married any portion of its offer for this hour.

However, these curves should be changed often for two reasons.

- If the interconnection capacity between Spain and Portugal is exceeded, there is what is called decoupling of markets and the markets of both countries are resolved separately, providing matching different prices in each country. We omit the details of this procedure, but for practical purposes involves a rightward shift of the demand curve.

- Hourly offers made by generators, explained in the previous section, sometimes accompanied by complex conditions. These allow the vendor to impose conditions on several hours at a time. For example, the load gradient restriction allows a certain center no case sections of their bids involving gradients in the power generated higher than a given threshold, due to technical limitations. Another commonly used is the minimum income condition, whereby a generator imposes a minimum level of total income to get in 24 hours a day; not being attained its offer generation of this day retire. As a result of incorporating the complex offers appeal, the aggregate supply curve a certain time is shortened, retreating to the left.

Except incidents, around 11 hours a day D-1 these modified curves are abtained, which, now determine the final outcome of the daily market, indicating for each hour how much will have to generate each producer, how can consume each consumer price obtained to which the exchange occurs. The following figure shows these modified curves for H 16, where you can see the new price of cassation, the new intersection of new lines of supply and demand, and the new exchange volume. We highlight the first three tranches of the offer made by our center who have married after considering the modifications.



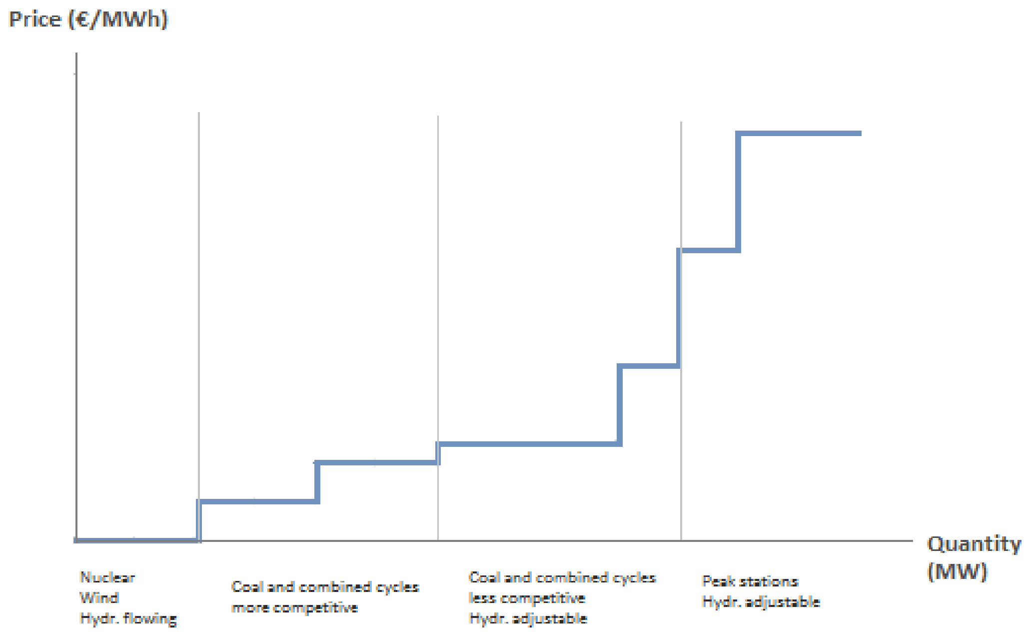
Aggregate supply and demand corrected curves after taking into account the decoupling of markets and complex conditions, time H 16, May 15. Vertical stripes indicate all the sections married the offer made by the thermal power plant.

Therefore, this unit has agreed to be producing 191 MW during H 16 the next day in exchange for purchasing a receivable. Proceeds from the central to the daily market (H 16) = 191 MW * 1 h * marginal system price in c€/kWh.

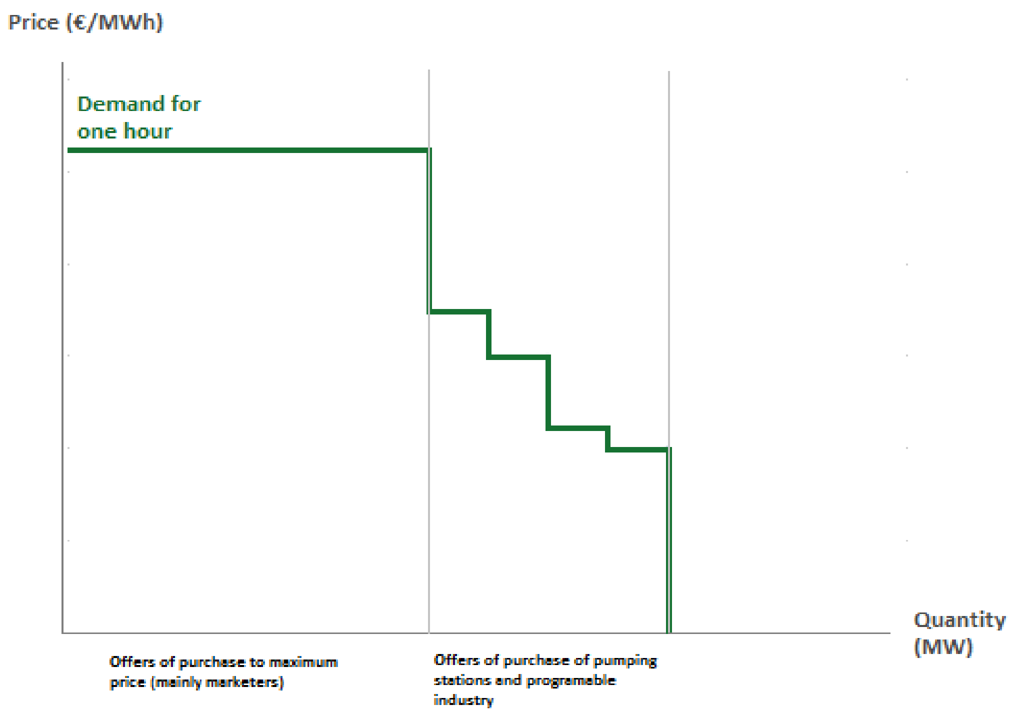
It is important to note that all producing units tendered at a lower price than the price of cassation, all of them are remunerated at the same price, it is what is known as marginal system. Similarly, although at a higher price tendered consumers, ultimately pay the price kWh appeal. An alternative to this method is that the units paid or received each bid price it, it is called 'pay as bid system'.

Typically at what prices each technology offer?

Consider a pair of curves aggregate supply and demand. As mentioned, all tenders received are divided into sections which are ordered, so it is possible to find stretches of offering technology virtually anywhere on the curve. However, on average, typical areas are like next representation.



Typical position generating technologies in the aggregate supply curve.



Typical position of consumers technologies in the aggregate supply curve.

Why wind power plants "offer a price of zero"?

The answer to this question has to do with a more general question, based on what criteria are designed generating unit prices of their bids? In principle, it may seem that the design of a curve reflects the costs of generation of the technology involved, so below that price it is not profitable generated by many factors: the fuel costs, the costs of starting and stopping, … .However, the real reason to set prices in offers is the opportunity cost, broader concept that encompasses production costs and other considerations and factors.

Think of a hydroelectric plant with prey. If, due to heavy rains, reserves at the limit of their capacity and must evacuate water, the plant will bid at a very low price so as to ensure sell-appeal. Conversely, if the level of reserves is very low, then it will bid a very high price to ensure that only wastes water in exchange for a big pay, so you can afford not to produce while waiting for a future state price high appeal. Mentioned these two extremes, in most cases the central design their offers based on a strategy of maximum benefits, given all the factors that affect, the level of reserves that have the reservoir, prediction rainy .. . In other words, expectations about future possibilities determines the current price below which refuses to generate.

Clearly, each technology evaluates differently its opportunity cost. Hydropower plants are heavily conditioned by the weather and the capacity of the reservoir, but not the cost of fuel because water to receive free. Thermal power plants must evaluate the price of their fuel, the capacity of stock, forecasting the trend of these prices and the cost of starting and stopping involved a large turbine.

In the case of a wind farm, fuel is the wind, which is free, but cannot be stored for another time. Therefore, if you have the opportunity to create a situation favorable wind, it does not do not increase the possibility of higher benefits in the future, since neither saves fuel and can store it for a later occasion. That said, if the weather forecast for the next day at the site of the park provides a level of generation of multi-megawatt, this park will bid a price zero for that power to ensure the appeal. It is recalled that despite offering to zero, the price of pay is common to all and equal to the highest price appeal to be established on marginal system. This bid strategy is also common in photovoltaic plants and river power for the same reasons.

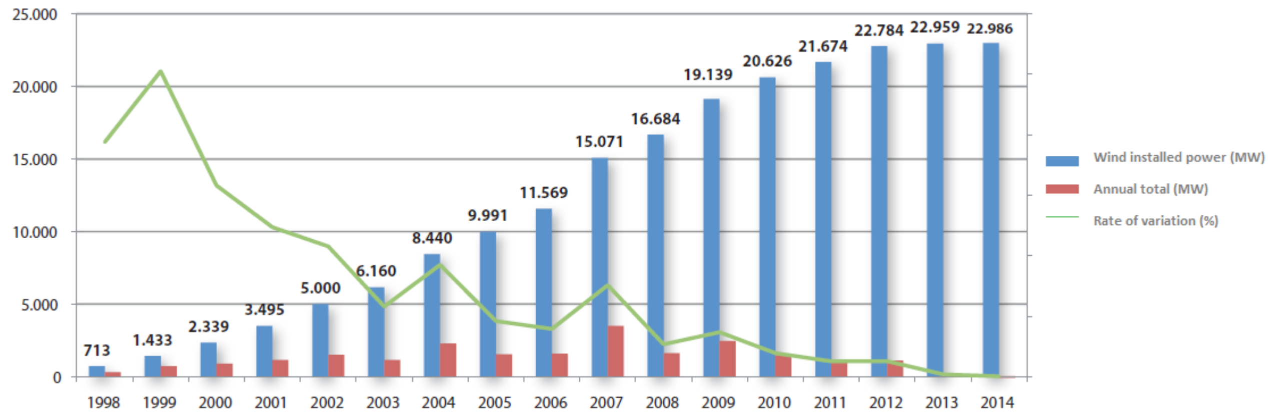
Considering as an example the different initial and maintenance costs of these technologies, is therefore clarified that the offer price that make generating units in the daily market does not have to do merely with the cost of the technology itself, if not with greater or less versatility that each technology provides to develop a strategy for maximum benefits in a free market context.

STATICALLY ANALYSIS OF THE RESULTS OBTAINED.

At this point of the report, from the collection of information we have previously done, we are going to make a compilation and analysis of data. Will link multiple variants as temporary (decomposing at yearly, daily or even hours intervals), those relating to wind power generation (examining its record maximum and minimum observing the responses to these changes) and of course comparing this with the final market price. To further an analogy of the numbers we will do two tests, first one decomposing Spain and another identical for Portugal. As noted above, the purpose of this project and in particular of this section is to see if there is a correlation between the price of Iberian Electricity Market and the Iberian wind generation.

It seems natural to start this study detailing the evolution of wind power installation is concerned over recent years, we have started from Spanish data but the growing trend also applies to Portugal. Each year the Spanish Wind Energy Association publishes a yearbook summary of all changes, history, news, ... that have happened throughout the year in the sector. Logically thinking, every year a greater or lesser extent the installation of new wind farms is more (this increasing trend has been reduced dramatically in recent years due to the Energy Reform of 2012, with a final growth with values close to +0.12 %).

Therefore, as a general rule, each year typically exceeded the previous historical records, this is great news because it implies a continued increase in consumption of renewable energy. Because of this continued increase, our analysis will focus on data collected from January 2014 to March or April 2016, so that the difference between installed power not decompensate the study.



Evolution of annual installed wind power and rate of change in Spain (1998-2014).

STUDY OF PEAK VALUES.

Below we have made a compilation of the maximum, minimum and average values for each year. In this table we will see a double classification; first data are intervals between hours and the other are periods of days. With this second have to be more careful because the database for both is the same, as a result indicates that the daily data taken is the sum of the data of the 24 hours per day. And it is known that grouping lost detail of the sample and therefore the information is lost or dims.

We started in Spain and its division into hours. In it we will find the maximum and minimum for years, both in wind generation and Spot market price. We have also obtained the average of all samples.

	Price(€/MW)	Date and time
Maximum 2014	113,92	2014-03-27 T19:00
Maximum 2015	85,05	2015-01-07 T10:00
Maximum 2016	66,71	2016-01-19 T19:00
Minimum 2014	0,00	2014-01-01 T05:00
Minimum 2015	4,00	2015-01-31 T03:00
Minimum 2016	2,30	2016-01-10 T06:00
Average 2014	42,17	
Average 2015	50,32	
Average 2016	30,60*	

	Generation(MW)	Date and time
Maximum 2014	16413,24	2014-01-27 T13:00
Maximum 2015	17212,60	2015-01-29 T19:00
Maximum 2016	17390,06	2016-01-11 T13:00
Minimum 2014	97,39	2014-04-16 T10:00
Minimum 2015	143,90	2015-07-20 T11:00
Minimum 2016	273,13	2016-01-25 T23:00
Average 2014	5775,90	
Average 2015	5446,22	
Average 2016	7725,35*	

Maximum, minimum and average values of wind production and price MIBEL for hours in Spain. (2014-2016).

The first idea that we have to take into account when considering the above graph is that the relationship between the parameters price and generation are inversely proportional, that is to say, ideally the maximum generation of 2015 should correspond to the minimum price of 2015. I have tried to capture the idea on the table by coloring the same color parameters relative to each other.

It is of significant importance to see (*) as in 2016 the average generation obtained the highest generation and the lowest price. This leaves a slight residue of the relationship between generation and price but also this is because only have information until March, which means winter, when is usually given the highest concentration of generation. Later we will see this behavior more thoroughly in an analysis by stations.

We do the same but this time looking at daily intervals.

	Price(€/MWh)	Date
Maximum 2014	71,06	10/10/2014
Maximum 2015	66,41	02/12/2015
Maximum 2016	53,07	20/01/2016
Minimum 2014	0,48	09/02/2014
Minimum 2015	16,35	22/02/2015
Minimum 2016	5,79	27/02/2016
Average 2014	42,96	
Average 2015	49,84	
Average 2016	28,63*	

	Generation(MWh)	Date
Maximum 2014	347714,57	25/03/2014
Maximum 2015	352679,33	30/01/2015
Maximum 2016	365360,88	12/02/2016
Minimum 2014	9177,25	29/09/2014
Minimum 2015	17206,30	11/11/2015
Minimum 2016	40156,77	17/03/2016
Average 2014	135278,50	
Average 2015	135775,31	
Average 2016	161611,37*	

Maximum, minimum and average values of wind production and price MIBEL for days in Spain (2014-2016).

These panels we can draw several conclusions a priori. The first and most obvious, if we look at the first table, the case of maximum generating / minimum price (shaded in pink) shows that all cases occur in January. It seems hard to believe that there is no relationship occurring both in the same month for several consecutive years.

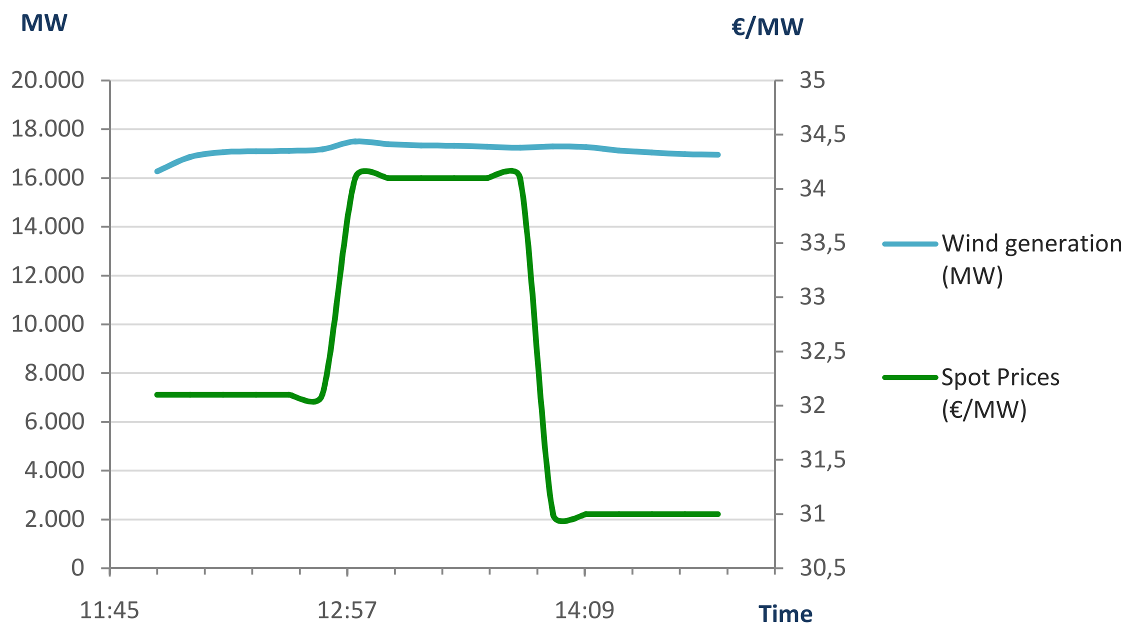
In the second table, the data is attenuated by making the average as mentioned before, we can still appreciate same trend. The interval data is maintained in the winter season in the months of January, February and March. On the other hand the relationship between minimum generation/ maximum price (shaded in yellow) presents no feature to draw conclusions. The months in which it develops are totally random at first sight.

This study links two factors but, like any other aspect of any sector to be analyzed depends on many more factors. This makes a not linear relationship and conclusions are not obtained at the first glance. So it is not mandatory that day with maximum wind generation have to be the day with the minimum price of electricity and vice versa. At the auction interfere more factors than the wind. One of these factors is the energy demand.Today the maximum consumption of summer and winter are evenly matched, because if we make great use of heating in winter, recently the use of air conditioning has soared.

The trend that older generation days have been days of winter has been a repetitive event in recent years and therefore coincide with days of heavy electricity demand, this makes entering the most expensive energy auction. The other major factor is the offer that other generation plants based on the resources of that day. This issue is discussed further in the analysis per stations, as previously idea raised.

By this we want to explain that displaying a graph that exact moment where the peak wind power, or even close to the event period is given, we will not see a clear downward deviation of price. On the contrary, we can appreciate it if we draw this trend in longer periods of time.

Due to the introduction of new plants each year, the record production becomes overcome in 2016 as it was advertised. We represent the price against the generation of the 11 January, 2016, maximum historical instant. We can see what we have already talked earlier: there is not an inverse relationship between the two curves. Recall that the price of the offers are constant in hours intervals, in this case 34.1 € / MW held for all the H 13. For the same reason we lose the relationship between the two lines.

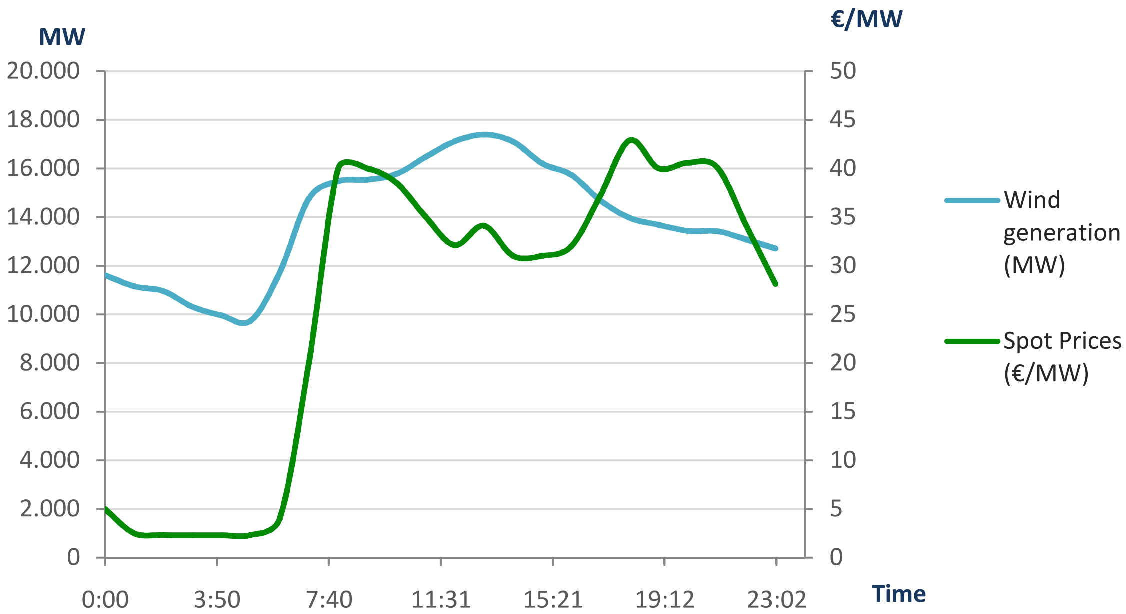


Curves of wind production and Spot price in the highest instant time in Spain (12 - 15h.).

Wind gen. (MW)	Price (€/MW)	Time	Wind gen. (MW)	Price (€/MW)	Time
16.266,00	32,1	12:00	17.321,00	34,1	13:30
16.858,00	32,1	12:10	17.277,00	34,1	13:40
17.054,00	32,1	12:20	17.245,00	34,1	13:50
17.097,00	32,1	12:30	17.288,00	31	14:00
17.110,00	32,1	12:40	17.260,00	31	14:10
17.181,00	32,1	12:50	17.126,00	31	14:20
17.499,00	34,1	13:00	17.037,00	31	14:30
17.387,00	34,1	13:10	16.973,00	31	14:40
17.330,00	34,1	13:20	16.956,00	31	14:50

Table with wind output and price in the highest instant time in Spain (12 - 15h.).

We expand the range full day to see if we can do with a better perception the relationship between variables. In this case the range of the abscissa has passed comprise a range of twenty four hours, the full day.

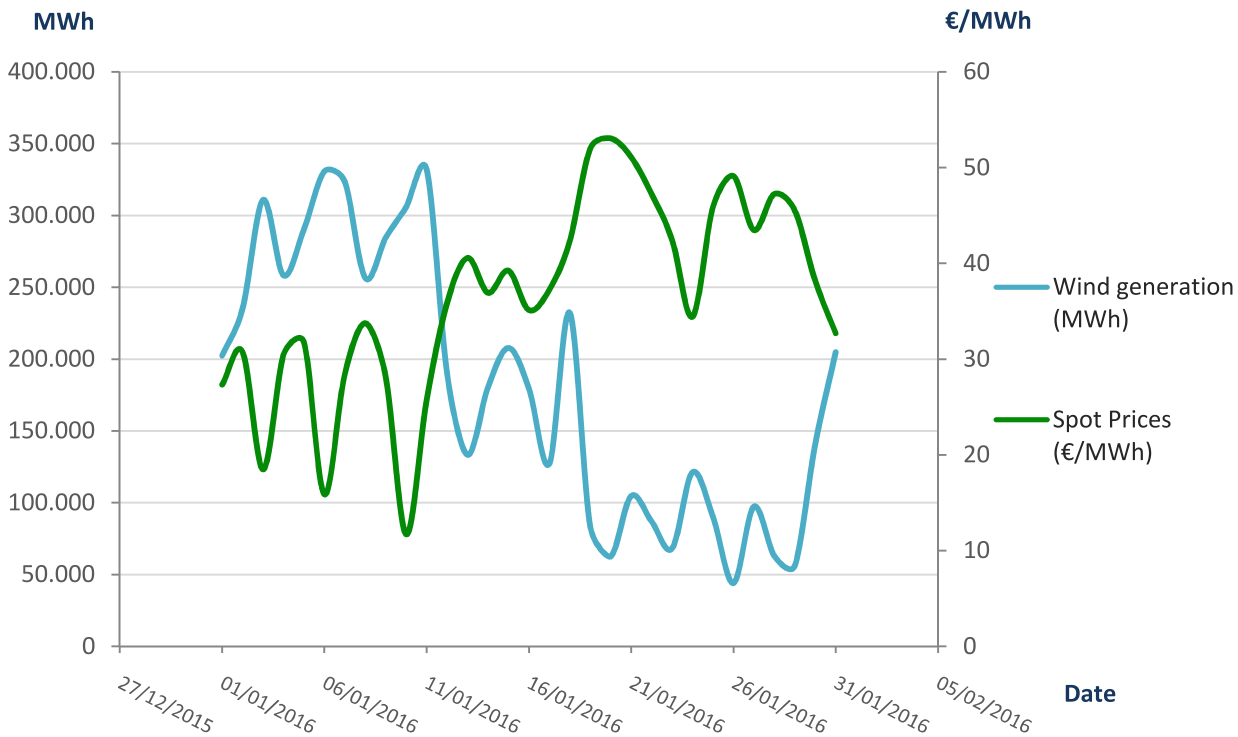


Curves of wind output and price in the highest instant time in Spain (00 - 23h).

Wind gen. (MW)	Price (€/MW)	Time	Wind gen. (MW)	Price (€/MW)	Time
11.619,80	5	0:00	17.108,52	32,1	12:00
11.155,52	2,5	1:00	17.390,06	34,1	13:00
10.962,43	2,33	2:00	17.101,57	31	14:00
10.312,09	2,3	3:00	16.202,01	31	15:00
9.950,63	2,3	4:00	15.730,51	32	16:00
9.732,64	2,33	5:00	14.676,87	37,21	17:00
11.720,87	4	6:00	13.967,28	42,88	18:00
14.762,61	20	7:00	13.686,05	40	19:00
15.472,75	40	8:00	13.428,06	40,59	20:00
15.539,23	40	9:00	13.420,26	40,1	21:00
15.774,33	38,5	10:00	13.070,57	34,1	22:00
16.470,96	35,01	11:00	12.700,97	28,1	23:00

Table with wind output and price in the highest instant time in Spain (00 -23h)

No doubt this time we can draw more conclusions of the graphic, but also without having a definite trend on which to rely. So we decided to again increase the range of values of the time variable, this time we will represent the entire month of February.



Curves of wind output and price in the highest instant time in Spain (January 2016)

Wind gen. (MWh)	Price (€/MWh)	Date	Wind gen. (MWh)	Price (€/MWh)	Date
202.523,84	27,33	01/01/2016	179.538,30	35,13	16/01/2016
235.420,27	30,73	02/01/2016	127.332,39	37,26	17/01/2016
310.858,83	18,48	03/01/2016	232.271,92	42,39	18/01/2016
258.328,04	30,46	04/01/2016	83.407,81	52,02	19/01/2016
290.415,16	31,77	05/01/2016	62.605,55	53,07	20/01/2016
330.775,18	15,88	06/01/2016	104.750,83	51,11	21/01/2016
323.350,28	28,45	07/01/2016	86.923,99	47,24	22/01/2016
256.490,56	33,76	08/01/2016	68.237,16	42,46	23/01/2016
284.639,33	28,13	09/01/2016	121.282,77	34,44	24/01/2016
306.026,34	11,7	10/01/2016	90.233,41	45,91	25/01/2016
331.956,65	25,73	11/01/2016	44.065,65	49,14	26/01/2016
189.892,32	35,88	12/01/2016	97.392,37	43,49	27/01/2016
133.408,84	40,58	13/01/2016	62.963,97	47,26	28/01/2016
180.370,77	36,93	14/01/2016	56.304,83	45,52	29/01/2016
207.838,57	39,25	15/01/2016	140.693,90	38,17	30/01/2016
			204.917,54	32,7	31/01/2016

Table with wind output and price in the highest instant time in Spain (January 2016)

Finally now it seems that the arrangement of the two curves will reflect an tangible increasingly relationship. We see that there are two critical points. The first corresponds to the day 26 with minimal wind generation and "casually" also the day with highest prices in January with 49.14 €/MWh. On the opposite side, on 11 January we have the maximum generation and the third lowest price in the month. The price that day fell by 48% over the maximum price, and when compared to the value of one day before the decline is 75%. This creates an inevitable and trivial relationship between the two concepts. Plus this not only happens in the maximum and minimum points, a reverse oscillation is also observed throughout the range covered by the graph.

Now we shall proceed to do the same analysis, but this time with Portugal. In this part of the analysis we will find only very small differences with those obtained for Spain, hence the argument that there is a common Iberian market. Prices are always identical except when there is a saturation in the connections between the two countries, an exceptional occurrence. The curious thing about the realization of this project based on the Iberian Electricity Market is that we can contrast our idea by two cases. At first, studying Spain, price and generation were variable values. By contrast, in this case the prices will be virtually constant while the above values of wind generation in Portugal have no relationship with the Spanish.

Before beginning the analysis is important to note that the database of wind generation in Portugal obtained through the transparency.entsoe.eu website has certain days when there is no record of wind activity, we can imagine that due to technical problems. There may be some deviations, so we have decided not to calculate annual averages.

As in the Spanish case, we must give importance to detail (**), in 2014 there is no record of generation in the database until the 10th of December. This implies that the peak values are indicated in the table can have discrepancies with the real one.

As previously, we started with the classification by hours of the maximum and minimum of each year. And then, the daily ranking.

	Price(€/MW)	Date and time
Maximum 2014	110,00	2014-02-17 T21:00
Maximum 2015	85,05	2015-01-07 T10:00
Maximum 2016	66,00	2016-01-20 T19:00
Minimum 2014	0,00	2014-01-01 T05:00
Minimum 2015	4,00	2015-02-01 T03:00
Minimum 2016	0,00	2016-02-14 T08:00

	Generation(MW)	Date and time
Maximum 2014	3854,00**	2014-12-29 T10:00
Maximum 2015	4056,00	2015-09-16 T02:00
Maximum 2016	4252,00	2016-02-13 T19:00
Minimum 2014	75,00	2014-12-24 T14:00
Minimum 2015	35,00	2015-03-11 T13:00
Minimum 2016	62,00	2016-04-01 T14:00

Maximum and minimum values of wind output and price MIBEL per hours in Portugal (2014-2016).

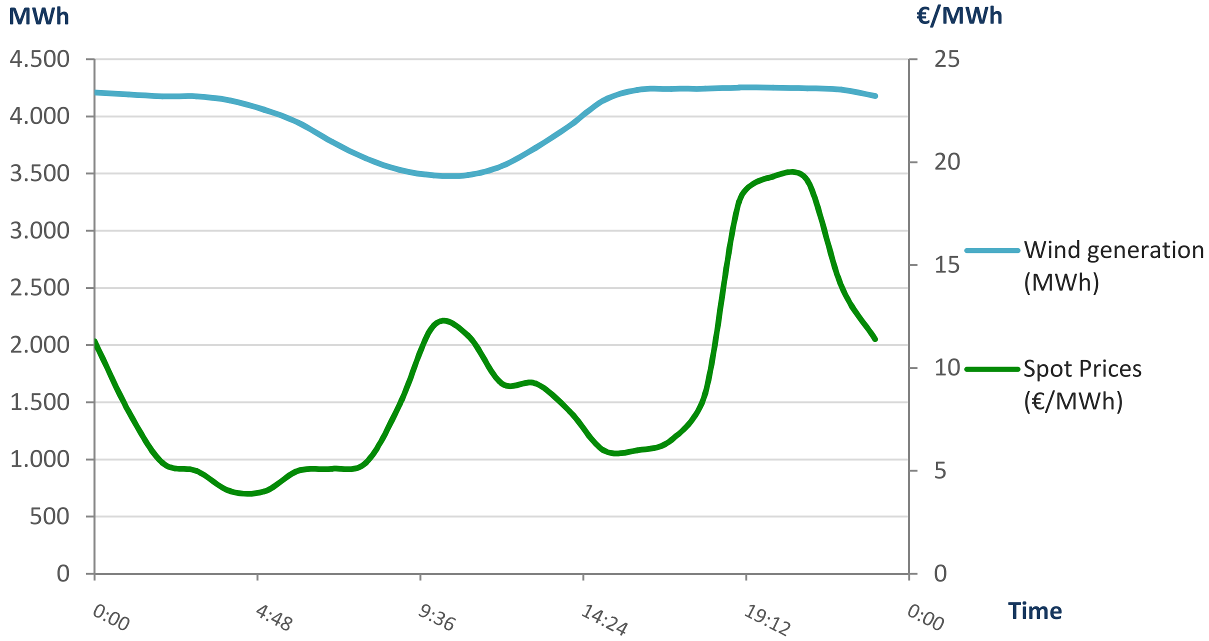
	Price(€/MWh)	Date
Maximum 2014	71,06	10/10/2014
Maximum 2015	67,12	02/12/2015
Maximum 2016	53,07	20/01/2016
Minimum 2014	0,48	09/02/2014
Minimum 2015	16,47	22/02/2015
Minimum 2016	5,70	14/02/2016

	Generation(MWh)	Date
Maximum 2014	83485,00	29/12/2014
Maximum 2015	95087,00	30/01/2015
Maximum 2016	97763,00	07/01/2016
Minimum 2014	4797,00	24/12/2014
Minimum 2015	2845,00	11/03/2015
Minimum 2016	4017,00	26/01/2016

Maximum and minimum values of wind output and price MIBEL per days in Portugal (2014-2016).

In these panels we cannot extract as much information as the Spanish case, because the database is intermittent and sometimes fails to complete entire year. The most illustrative year is 2015 and it is the only year that it is complete. If you look at their results are very similar to the trend that marked the Spanish, being January the month with the days of maximum generation. As for the price, as we noted earlier there is hardly any difference if compared with the Spanish table.

The next step is to represent in time ranges increasingly higher wind generation curves versus demand. Portuguese data base does not have measurements every 10 minutes as in the previous case represent. So we will skip the first graph which represents only the maximum point generation since it is hardly representative. This time we opted to show on February 13, 2016, maximum historical instantaneous Portuguese. Directly we will draw the daily period and see the possible conclusions.

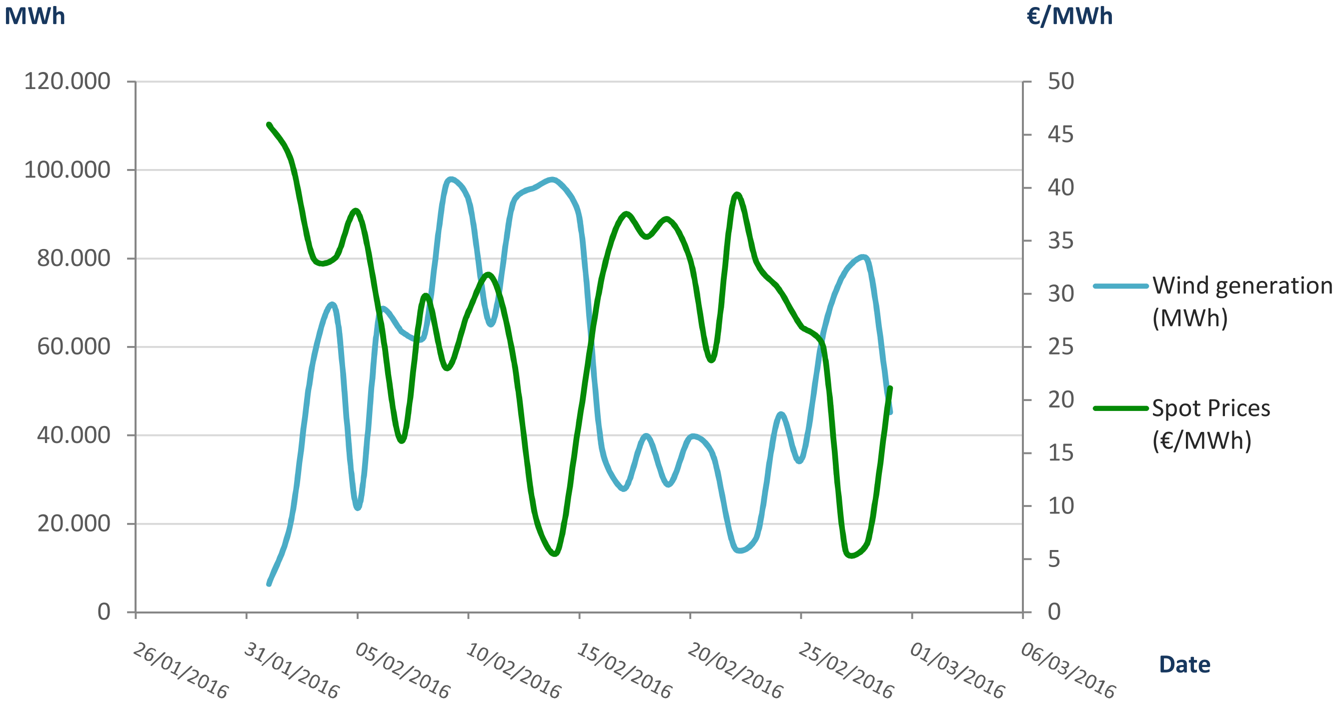


Curves of wind output and price in the highest instant time in Portugal (00-23 h.)

Wind gen. (MW)	Price (€/MW)	Time	Wind gen. (MW)	Price (€/MW)	Time
4208	11,3	0:00	3565	9,25	12:00
4192	7,9	1:00	3726	9,25	13:00
4175	5,4	2:00	3917	7,9	14:00
4176	5	3:00	4139	6	15:00
4138	4,01	4:00	4232	6	16:00
4058	4	5:00	4241	6,5	17:00
3947	5	6:00	4242	8,77	18:00
3777	5,1	7:00	4252	18,1	19:00
3633	5,4	8:00	4250	19,3	20:00
3533	8,25	9:00	4246	19,1	21:00
3484	12,07	10:00	4234	14	22:00
3487	11,59	11:00	4179	11,39	23:00

Table with wind output and price in the highest instant time in Portugal (00-23 h.)

As in the previous case you cannot extract any information representing only one period of 24 hours. We will expand the range to February entirely to see if we can do with a better perception the relationship between variables.



Curves of wind output and price in the highest instant time in Portugal (March 2016)

Wind gen. (MWh)	Price (€/MWh)	Date	Wind gen. (MWh)	Price (€/MWh)	Date
6339	45,95	01/02/2016	89110	18,17	15/02/2016
20661	42,56	02/02/2016	37348	31,44	16/02/2016
56946	33,38	03/02/2016	27821	37,43	17/02/2016
68528	33,4	04/02/2016	39862	35,36	18/02/2016
23500	37,71	05/02/2016	28799	37,01	19/02/2016
67800	27,87	06/02/2016	39584	33,13	20/02/2016
63372	16,15	07/02/2016	35729	23,82	21/02/2016
62472	29,72	08/02/2016	14504	39,14	22/02/2016
96855	22,99	09/02/2016	17275	32,89	23/02/2016
93223	28,35	10/02/2016	44451	30,42	24/02/2016
65034	31,7	11/02/2016	34487	26,92	25/02/2016
92420	24,22	12/02/2016	63274	24,9	26/02/2016
96031	9,19	13/02/2016	77171	5,79	27/02/2016
97431	5,7	14/02/2016	79404	6,68	28/02/2016
			45183	21,11	29/02/2016

Table with wind output and price in the highest instant time in Portugal (March 2016)

We distinguish the higher price point is day 1 with a value of 45.95 €/MWh coinciding with the day of the month less generated. This price drops to 88% on day 13. No doubt, we are getting achieve the objective of this analysis. Clearly we distinguished an inverse relationship between the two curves shown.

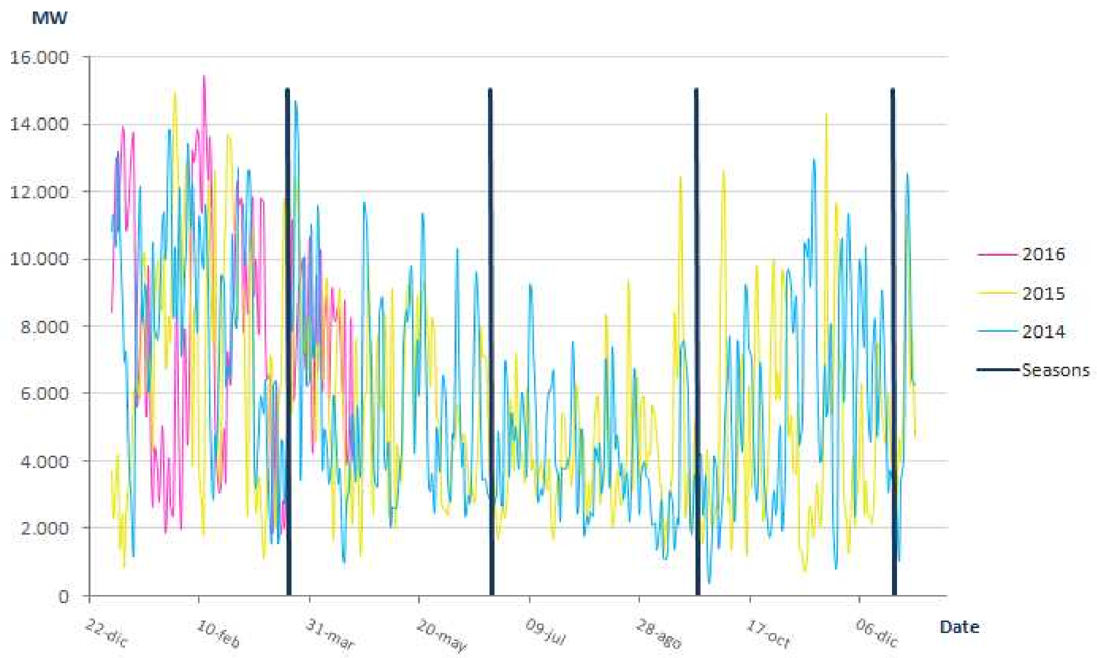
It seems logical that if all classifications we have raised have obtained a similar response to the latter, we face the fact that wind power and Spot market prices are closely linked.

SEASONS STUDY: GENERATION, PRICE AND DEMAND.

Since the Spanish database is larger and easier to work from now I'll just do the study with it. In this part of the analysis we will clear all the unknowns raised in the previous point: what profile has annual electricity demand? why winter months are those with a lower price ?, ...

To do this, the most intuitive way to visualize this information is to overlap the generation of the years 2014, 2015 and 2016. We will see if every year is different or not, and in the case that be similar what pattern adopted.

With deviation margins, as it is completely tolerable, there is a tendency that defines wind power production over the years. We can see that in the winter season is where you get the maximum values, lie the minimum remained virtually constant throughout the year. It is also important to note as the minimum generations are given from the late spring to late summer. This will have a big influence on prices during June, July and August. We see it in the following representation of the price of MIBEL.



Curves of wind production in Spain during the years 2014, 2015 and 2016 separate in seasons.

Curves of MIBEL price in Spain during the years 2014, 2015 and 2016 separate in seasons.

If we look at the two graphs simultaneously we see that one is the opposite reflection of the other. Another litmus test to confirm our theory that wind electricity production generates lower prices in the MIBEL. In the later study by years we will see more detail of this relationship.

As explained at the beginning of the project, these two variables are affected by many more factors. The most decisive, electricity demand. If there is a lot of demand, offers plants with higher prices also enter in the auction and this increase the final price of that day MIBEL price.

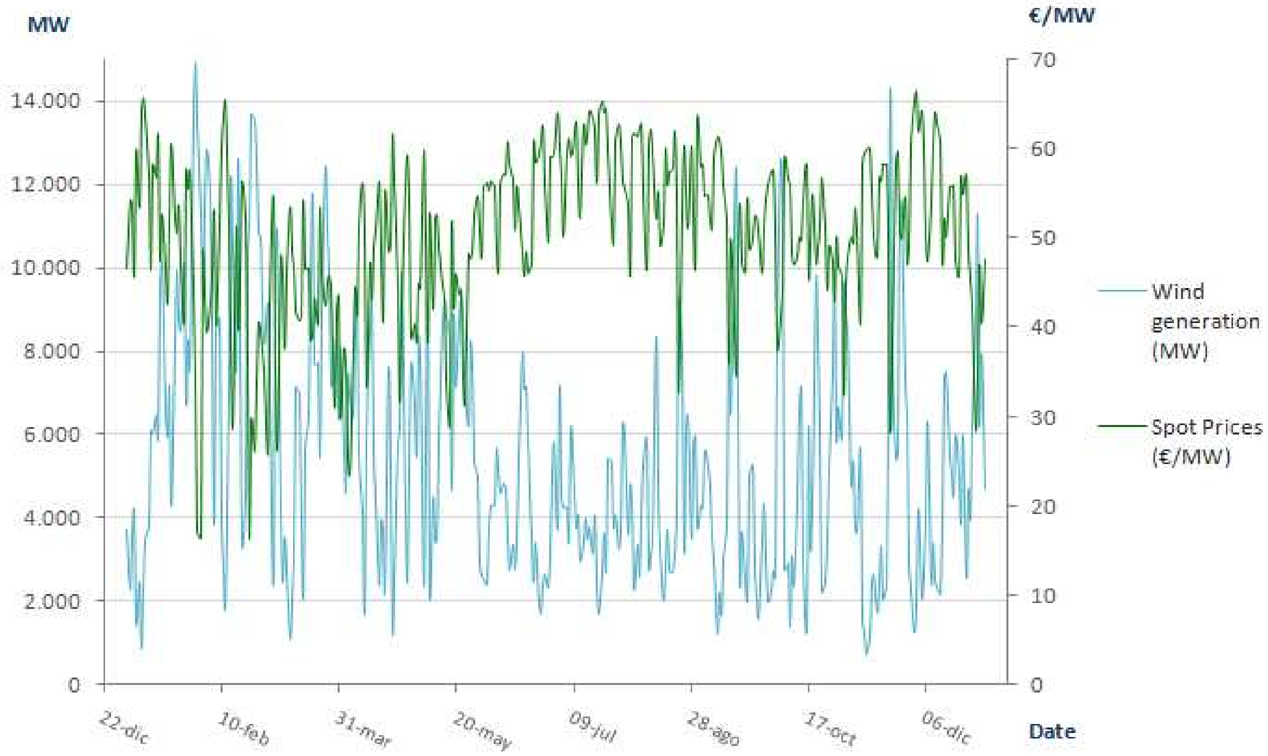
This is what causes the highest prices in summer months. In addition to that wind generation decreases to 50% over the winter months, we must add that numerous publications show that in recent years energy spending the summer months has equaled the winter. Which leaves these months in a very unfavorable situation.

Curves of demand in Spain during the years 2014, 2015 and 2016 separate in seasons.

ANNUAL STUDY.

This chapter is the product result of all previous analyzes. Here we will focus and simplify all information previously seen in three graphs, one for each year. In each representation we will associate generation and price views in earlier points.

Curves of wind production and MIBEL price in Spain during 2014.



Curves of wind production and MIBEL price in Spain during 2015.

Curves of wind production and MIBEL price in Spain during 2016.

By embedding this trend over a range of 365 days, except in 2016 that are about 110 values, we note the obvious connection between our samples. There is an opposite connection between the two ones. In general we can assign 8000 MW to the central representation point. Every time one of the variables exceeds a value close to the central one (8000MW approximately) other variable drops below that value and vice versa.

Conclusions and Reflections.

After attending all the studies in the previous chapter it seems inevitable that wind generation influences the daily MIBEL prices in a decisive way. Many articles have been published regarding this subject. Here is an example taken yearbook published by the Electricity Wind Energy Association.

The year closed with an arithmetic average daily market price of 42.13 € / MWh, 4.81% lower than the end of 2013 (from 44.26 €/MWh). Without wind, it would have been 18,96 € (31%) higher and you have located at 61.09 €. In terms schedules, daily market price has reached minimum of 0€/MWh for 177 hours a year, all before the publication of the Energy Reform.

In the months of January, February, March and April, the average price of the Iberian market was below the average of major European countries. During the other months it was above. The effect of wind on prices looks great in 2014, which has been a very clear difference between the first and second semester. In the first, in which more wind blew, the wind was the first system technology, with a production of 28.7 TWh. The average daily electricity market price stood at 33.06 euros / MWh, 11.31% below the same period last year. By contrast, in the second half was down wind generation (was 21.7TWh) and coal was the first system technology. This resulted, despite the falling prices of fossil fuels, the average daily market price go up to 51.02 € /MWh, a very similar to last year's level of 51.12 € /MWh.

This statement opens a wide range of debates and opinions. One of the main is whether it is worth promoting raw renewable energy, specifically wind production.

Personally, I feel that once the electricity market has been liberalized, premiums become the mechanism to economically valorize their advantages of some energy sources, so that the market itself encourages their development. It is obvious that renewable energy provides significant advantages to the electrical system and collaborates in achieving objectives that would be more than desirable.

First, its impact on the environment is reduced and so is its lower emissions of greenhouse gases and other pollutants, which on compliance with the Kyoto Protocol, other international treaties such as the Convention on Transboundary Air Pollution and Long Distance Geneva, and other commitments with the European Union, as the directives on air quality or the National Emission Ceilings. Secondly, the use of renewable energy avoids having to resort to the already scarce fossil resources of our country and can increase our energy sovereignty. In addition, renewable energies allow distributed generation close to consumption points and, therefore increasing efficiency of the system by reducing losses in the transport of electricity. As all these aspects are not included in the cost of energy production and as producers whom finally sell their energy will be determined by the liberalized electricity market, how to enhance the development of these energy available it is the establishment of a premium system which put them in a more competitive place in the electricity market situation.

Meanwhile, give up electrical system with state governance and move to a liberalized system where the advantages of renewable energy are internalized by premiums is not entirely equivalent. First, premiums must be perfectly designed to achieve your goal without showing counterproductive mechanisms, such as the one that hit photovoltaic energy. But also, premiums have been heavily criticized from some sectors that they consider undesirable state intervention in the free electricity market, without thinking that maybe this is an internalization of advantages. As a result premiums have been very discredited and are often accused of being solely responsible for the increase in electricity prices or increased tariff deficit. These accusations overlook the savings resulting from decreased energy costs caused by the fact that premiums move to the right the supply curve in the market, making the price range less. There are reports that estimate that the savings caused by this displacement of the curve is more or less in the same order as the premiums they get.

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