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Legislative history

After the end of the period of the 2005-2010 PER (Renewable Energy Plan), in 2011 the Government of Spain approved the 2011-2020 PER. The objective of this plan is that in 2020 at least 20% of the gross final energy consumption in Spain should come from renewable sources. For this reason, Spain has a solid normative framework for renewable energies.

Until 2012, current legislation in relation to renewable energy has been devoted to its development; however, after the years of economic crisis and increasing trend of the electric sector tariff deficit, the new laws of the Government are focused on reducing the cost of these technologies within the system.

Before the Energy Reform (2012-2013), the objective of which was to decrease the tariff deficit and to give stability to the Spanish electric system, the feed in tariff (FIT) system was used in Spain. That was a legal instrument that sought to establish a special rate (reward or premium) for the energy that a renewable supplier injects to the grid and this remuneration system was well defined by the Royal Decree 661/2007[1]. In order to reduce external energy dependence, in the 1980s the development and regulation of renewable energies began, and in the 1990s the concept of "special regime" appeared for the first time, including renewable energies and cogeneration.

In 1999, the government proposed the Plan for the Promotion of Renewable Energy (PFER), which was later replaced by the 2005-2010 PER, with the objective of covering 12% of primary energy via these technologies in 2020. In addition, in 2000 actions were taken by the Government to encourage renewable energies to participate in the electric market and they could make contracts to sell energy directly to the market.

In 2004, through the adoption of the Royal Decree 436/2004[2], the remuneration system of the special regime was established, in which the renewable companies had the option of selling the energy to the distribution company at a regulated tariff or to sell the energy at market price with a participation incentive, in addition to a premium. But in 2007 the remuneration system that resulted in renewable energies reach about 43% of the country's total electricity production was definitively established.

This was governed by Royal Decree-Law 661/2007 and it maintained the double option of remuneration: on the one hand, the energy sale at regulated tariff; and on the other hand, the energy sale at market price with an economic bonus setting an upper limit and a lower limit to the total retribution, canceling the incentive for participating in the market. Before all this legislation, in addition to increasing share of renewable energy, a huge increase in costs happened for the electrical system. Therefore, the consumer tariff also increased by 63% between 2003 and 2011.

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[1] http://www.boe.es/boe/dias/2007/05/26/pdfs/A22846-22886.pdf
[2] http://www.boe.es/boe/dias/2004/03/27/pdfs/A13217-13238.pdf

In 2012, in order to solve the problem of the high tariff deficit of the electricity system, Royal Decree-Law 1/2012[3] was approved. The entry into force of that Royal Decree Law resulted in the abolition of economic incentives for the new projects of renewable power production plants, cogeneration and waste, thereby stopping investments for new facilities. In addition, Law 15/2012[4] was adopted, which establishes a tax for the production of electric energy, which charges with a tax rate of 7%, the generation activity and the injection of energy into the electric grid. Moreover, Royal Decree 661/2007 was amended, which regulated the activity of production of electric energy under special regime (renewable energies and cogeneration), eliminating the existing premiums or bonus.

In 2012 Royal Decree-Law 29/2012 was approved which corrected or removed from the economic regime the primacy for special regime installations (renewable and cogeneration) that did not fulfill the obligations required for its final registration in the pre-allocation registry.

In 2013, Order IET / 221/2013[5] was approved, which established the access tolls and the tariffs and premiums of special regime facilities. All these laws and decrees caused the wind sector to stop.

Afterwards, the Royal Decree- Law 09/2013[6] was approved and through that decree a mandate was given to the Government to approve a new legal and economic regime for the production of electrical energy from renewable sources, cogeneration and waste. Until that moment, the economic aid was given to the generators for the generated energy. Through this change of economic regime, the aids are given to companies in terms of installed capacity, and not in terms of generated energy.

The Law 24/2013[7] states that the Government may establish a specific compensation scheme to promote production from renewable energy sources, high efficiency cogeneration and waste, when there is an obligation to achieve energy objectives derived from directives or other rules of European Union law.

In order to allow renewable facilities to cover the costs necessary to compete in the market on an equal footing with other technologies and obtain a reasonable return on the project as a whole, Royal Decree 413/2014[8] was also approved.

As the Spanish government had to meet the binding targets set out in Directive 2009/28/CE of the European Council, years later the final Royal Decree 359/2017[9] was approved. This Royal Decree establishes an announcement for granting the specific remuneration regime to

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[3] http://www.boe.es/boe/dias/2012/01/28/pdfs/BOE-A-2012-1310.pdf
[4] http://www.boe.es/boe/dias/2012/12/28/pdfs/BOE-A-2012-15649.pdf
[5] http://www.boe.es/boe/dias/2013/02/16/pdfs/BOE-A-2013-1698.pdf
[6] https://www.boe.es/boe/dias/2013/07/13/pdfs/BOE-A-2013-7705.pdf
[7] https://www.boe.es/boe/dias/2013/12/27/pdfs/BOE-A-2013-13645.pdf
[8] https://www.boe.es/boe/dias/2014/06/10/pdfs/BOE-A-2014-6123.pdf
[9] https://www.boe.es/boe/dias/2017/04/01/pdfs/BOE-A-2017-3639.pdf

new facilities for the production of electric energy from renewable energy sources in the peninsular electrical system. The granting of this specific remuneration regime will be established through competitive tendering procedures. Furthermore, the assignment of specific remuneration system and the standard value of the initial investment of such installation is determined by the method of closed envelope auction with marginal system.

This chaotic historical evolution shows a clear lack of a scheme in recent years and also for the future. In a recent article's strong title in the Journal Energy, "*the cost of not doing energy planning: The Spanish energy bubble*" [10], Fueyo et al. show that "the Spanish power generation sector is facing dire problems: generation overcapacity, various tariff hikes over recent years, uncertainty over the financial viability of many power plants and a regulatory framework that lacks stability". The results of this work highlight the value of rigorous, quantitative energy planning, and the high costs of not doing it.

According to this study, and resuming our previous explanation, this situation is the consequence of the lack of energy policies and the economic crisis. A LEAP model[11] must be developed in order to obtain a good diagnostic of the situation, and to differentiate the costs of the economic crisis from the costs of the lack of planning. Fueyo et al. find that "appropriate energy planning could have reduced investments in the Spanish power sector by 2010 €28.6 billion without compromising on performance in terms of sustainability or energy security, while improving affordability". *Wind energy is not considered among these surplus investments or bubbles:* in fact, gas combined cycles and solar technologies are identified as the main bubbles.

Auctions

Nowadays, in Spain and other countries such as Netherlands, regulated tariffs are fixed by auction for onshore wind energy, but it seems that countries such as Poland or Germany will follow Spain. In the case of Spain, as it refers in the BOE (Boletín Oficial del Estado)[12], the implemented auction is an "auction for the assignment of the specific compensation arrangements to new facilities for production of electricity from renewable energy sources".

The Spanish Industry Ministry auctioned a certain volume of power, 5,000 MW in the last auction, for all renewable energy technologies such as biomass, hydraulic, photovoltaic, solar thermal systems or wind energy systems. Every company that participates in the auction should already endorsed 60,000 € for each offered MW. This guarantee will be totally or partially lost if they are finally adjudicated and do not meet some milestones imposed by the Ministry, and the deadlines for these control milestones are decided by the Ministry too.

These milestones are:

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[10] http://www.sciencedirect.com/science/article/pii/S0360544216300457

[11] Long-range Energy Alternatives Planning System, is a widely-used software tool for energy policy analysis and climate change mitigation assessment developed at the Stockholm Environment Institute. See: https://www.energycommunity.org/default.asp?action=introduction

[12] https://www.boe.es/boe/dias/2017/04/12/pdfs/BOE-A-2017-4094.pdf

1. To identify the projects where the farms will be located.
2. To have the administrative authorization for the construction (environmental impact assessment, etc.)
3. To register the installation in the RAIPEE (Registro Administrativo de Instalaciones de Producción de Energía Eléctrica, or the administrative register for electrical energy production installations).

The objective of these type of auctions is to set a low price, and this is related to the price offered by different companies to take the bid, because offering their energy cheaper shows more possibilities. This will make almost all renewable companies offer the energy at a very low price, since the costs in O&M are close to zero. In addition, it is a marginalist auction, in which bids will be ordered from cheaper to more expensive, and the last to fill the quota will be the charged by all the participants. Therefore, it seems that the auctions will end up being at zero price. Although the auction price becomes zero and the pool market price falls in the next years, the government guarantees a floor price to energy sale to make the investments profitable.

In case of a tie of offered prices, the government discriminates between technologies by equivalent hours of energy generation. In this case, the wind sector has received more hours than the photovoltaic sector, so it seems that the wind industry has a previous advantage to win the auctions; *in fact, photovoltaic companies have complained about this issue.* And if there is also a tie in price and technology, the largest packages have preference.

Site designation

After Franco dictatorship's end in Spain, the competences of land-use planning passed to the autonomous communities in 1978. They have been responsible for legislating and developing their own land-use regulations, so they all have their own law on land-use planning.

There are 17 autonomous communities in the Spanish State, and each of them has its own legislation, so the site designation of construction of wind farms is different in all of them. For example, in the sectoral land-use planning of the Basque Country[13] there is a definition and a regulation of what a wind farm is and what authorizations must obtain to install wind farms, in different type of lands, such as undeveloped lands or public and communal lands.

On the other hand, in the autonomous communities, the territory is divided into many particular areas, so the wind sector also has to deal with private ones, because the potential location often is private. That is why the wind sector has to negotiate to install the turbines in public and private areas. It must be said that there are more private areas ("latifundiums") in the central castilian steppe and in the South of Spain (Andalusia), while the land

[13]http://www.ingurumena.ejgv.euskadi.eus/contenidos/informacion/plan_energia_eolica/es_8109/adjuntos/documentoII/documentoII_c.pdf

distribution is more communalistic in the North (Navarre, Araba in Basque Country, Huesca in Aragon, etc.) because of historical reasons. These factors are essential to understand the possibilities of site designation for wind industry.

Two autonomous communities lead the use of wind energy for their needs; both have a strong national identity and their territorial structure presents communalistic roots (public lands or non-private lands[14]):

- *Navarre***.** In the last decade Navarre sustained approximately 70 percent of its electricity needs from wind farms (900-MW installed wind power in a region with 640,647 population). Navarre lacks thermal, nuclear, coal, oil, gas fields power stations, but does possess considerable wind renewable resources, which the Government of Navarre pursued to drop its external energy dependence. The strong GAMESA manufacturing company was created in this region and its fast development cannot be understood without the political intervention of Navarre government in favour of the domestic market (see section 6).

- *Galicia*. In the final years of the last decade Galicia lead Spain in wind power development amongst the autonomous regions with an average increase of more than 200 MW, succeeding Castilla La Mancha, Castile and León, Aragon and Navarre, and other autonomous regions.

In short, the wind sector like other renewable technologies, until 2010-12 increased strongly their participation in the electricity generation and this was because of the premiums. After this, and due to the problem of the tariff deficit, the premiums were frozen and the sector showed difficulties to continue installing new generators; that is why the wind sector in Spain has basically stopped for 6 years. Now, after the energy reform, the compensation system has changed, and it seems that, following the introduction of the auctions, the wind sector will start to increase again.

As mentioned before, the autonomous communities will continue to decide their land-use planning, and hence, adding the problem of the private lands, they will continue to do site designations for the construction of the wind farms according to the future objectives for different industries and factories. As wind farms present a great land-occupation at specific locations of high potential and strong visual impact in mountains that in some regions are almost sacred, the geographical identification of public lands within the limits of municipalities that are interested in the investment on wind energy could be strategical for the future.

[14] For example, in Galicia the majority of the mountains are no public, but also no-private: these territories are neighborhood councils, which establish an identity sign in the region. There are almost one million hectares of this kind, managed historically by neighbors, without the direct control of the local administration or municipalities. These co-proprietors opt for farming, livestock, or biomass extraction, and now, they have the possibility of cooperative inversion in wind energy.

Finally, future site designations for offshore wind energy must be also mentioned. The studies on offshore wind energy potential in Spain show two different areas according to recent studies by Ulazia et al. (2016, 2017, see footnotes):

- *The Bay of Biscay, from Galicia to Basque Country.* This region is characterized by its steep bathymetry within little distance from the shore and by a good capacity factor (above 0.3) that increases towards West.[15]
- *The Mediterranean and the Balearic Islands.* Here the main factor is related to the predominant wind direction is the North and the Southern regions and the main Balearic Islands (Valencia, Murcia, Ibiza and Mallorca) are protected by the bays due the geographical orientation. Therefore, the locations of high potential are the North of Menorca in the Balearic Islands, and above all Cabo Begur, the northern cape of Catalonia, in the border of the Gulf of Lion, where we can find the most energetic location in the Mediterranean for the implementation of offshore wind energy.[16]

In both cases the total wind energy potential has been estimated taking into account these three restrictions (see footnote):

- According to the European Union offshore wind farms cannot be installed nearer than 10 km from the shore. This impossibilities founded wind turbines in the Bay of Biscay, because bathymetry reaches 1000 m in a few km to the coast. In the Balearic Islands and Cabo Begur the case is not so extreme, but floating wind farms are also needed.
- Floating wind farms cannot be anchored in waters deeper than 1000 m. This establishes the exterior technical limit of floating wind farms.
- And an annual capacity factor higher than 0.20 is needed to have a competitive wind farm. This is easily fulfilled mainly in Galicia (with a great available oceanic area) and Cabo Begur (with very high average annual capacity factor of almost 0.40).

2. Grid connection regulations

To understand the grid connection regulations, it is necessary to put on the table that, as regulated in article 53 of the law 24/2013 (see footnote 7), all renewable facilities to obtain administrative authorization must have previously obtained the access permissions, and connection to the corresponding transport or distribution networks.

[15] http://www.sciencedirect.com/science/article/pii/S0306261916311205
[16] http://www.sciencedirect.com/science/article/pii/S0306261917313144

In Spain all the high voltage electricity transmission network[17] is managed by REE (Red Electríca de España), and for this reason, any electric generation facility must obtain access to the network, through this company.

According to the REE, "REE is responsible for the processing of the access and connection procedures to the transmission network for generation facilities, as well as the assessment of the acceptability of generation with connection to distribution network and significant condition in the transmission network". This process is governed by different laws, such as Law 24/2013 (see footnote 7), Royal Decree 1047/2013[18], and Royal Decree 413/2014 (see footnote 8).

In addition the REE has done studies[19] for the autonomous communities, with the objective of quantifying the renewable generation connection capacity, in order to achieve 20% of renewable generation by the year 2020.

Spain, due to its different territories, is divided into the mainland zone and the non-mainland zone, and in each area the electrical systems are unique with different regulations because of the characteristics they have:

- *Mainland system:* Centralized generation system, giving preference to the security, stability and quality of the energy supply in spite of the losses by large transmission; there are about 23,000MW installed wind power, with a participation in generation of about 18%, being the fifth country of Europe in these terms. It is a large electrical system and is interconnected with France by submarine (commissioning 2024-2025) and underground means. As pointed out above, REE is the company that manages the electric market and the one that deals with the transmission of electric energy throughout the country. In distribution, in contrast, five large companies, such as, Endesa, Iberdrola, EDP, Gas Natural Fenosa and Viesgo Energía, distribute 95% of consumption in the mainland. Recently, new companies with cooperative identity have appeared in the Market (Goiener, Som Energia, etc.) selling electricity from renewable sources.

Non-mainland system:

- *Balearic island system:* Two small and isolated subsystems (Mallorca- Menorca and Ibiza- Formentera) have been interconnected by the Romulo project[20] with the peninsula in order to provide security and stability to the electrical supply of the Balearic island system. It has 4MW of installed wind power, but as different studies show (see footnote 16), this area presents a great potential still to develop.

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[17] http://www.ree.es/es/actividades/gestor-de-la-red-y-transportista/mapas-de-la-red
[18] https://www.boe.es/boe/dias/2013/12/30/pdfs/BOE-A-2013-13766.pdf
[19] http://www.ree.es/es/actividades/gestor-de-la-red-y-transportista/acceso-a-la-red(Capacidad de conexión para generación renovable, cogeneración y residuos en el horizonte H2020)
[20] http://www.ree.es/sites/default/files/01_ACTIVIDADES/Documentos/folleto_romulo_es.pdf

- *Canary island system:* The Canary island system is composed by six small insulated electrical systems and is not interconnected with the mainland. Even so, REE is also the company that manages the transmission network of the six electrical systems. With an installed capacity of 194 MW of wind power, 394 GWh were generated at the end of 2016. In the island of El Hierro (one of those electric insulated systems) is also the globally pioneering project that tries to self-supply the island with wind energy: Gorona del Viento (see ENDESA in section 6).

Nevertheless, step by step, there are municipalities in Spain, which in the search of a change of the electrical system, or to be exact, in the development of the energy transition towards a renewable and distributed model, are taking steps for the democratization of the electrical networks with social objectives, such as the case of Hamburg. In Hamburg, the second largest city of Germany with a population of over 1.7 million people, after a referendum the city purchased the municipal electricity grid from a private consortium with the aim of the municipalization of energy services to respond better social demands related to energy.

Taking the example of Hamburg pioneering in this change, similar actions are being adopted in Barcelona or Cadiz:

- *Barcelona:* In order to improve the living conditions of citizens, from the city council, Barcelona is working for an energetically self-sufficient city because they want to move from a centralized energy production model towards a distributed energy production model, with self-sufficiency and rationalization of consumption criteria. To this end, the City Council aims to reduce the energy dependence of the city of Barcelona from abroad, and promote the presence of local and renewable generation. Among the developed actions are the studies that the City Council has done on wind potential, to develop the urban mini-wind energy in Barcelona, as well as the installation of autonomous and self-sufficient lighting or the tool that allows citizens to know the energy resource available (solar energy or mini-wind energy) on the roofs of its buildings. In addition, it is expected that in September 2018, the public marketer Barcelona Energía will be operating providing citizens with 100% renewable and local energy. As well as guaranteeing the supply to all people in situations of energy vulnerability.
- *Cadiz:* according to the INE (National Statistical Institute), the Cadiz province and capital is among the most impoverished territories of Spain. The city council avoids about 2000 power outages per year due to non-payment of families who can not afford it. Therefore, the Provincial Strategic Plan against Energy Poverty has been approved, in which the council contemplates signing agreements with energy marketers, with the objective of avoiding the cuts to the energy supply, and giving an economic background against energy poverty. Cadiz is an example of intervention of

the system of distribution and commercialization for social purposes against energy poverty, at the municipal level.

Even with these examples municipalities have little importance in the legal constitution of the Spanish state, against the case of Hamburg where the citizens could change the regulation by referendum in their territory. So to execute a system change with social objectives in Spain, bigger municipalities, cities and autonomous communities need to be added to the initiatives.

In summary, Spain has a centralized system where grid connection regulations are governed by a legislation with a high importance of the company that transports energy, but, as mentioned above, different municipalities are trying to change the centralized electrical system, towards a renewable and distributed generation system, and this can change the established regulations in the recent politically unstable future.

3. Permission procedures and environmental impact assessments

According to the Ministry of Energy of the Spanish government[21]**,** the General State Administration is the responsible of authorizing these points:

- Electric installations for the generation above 50 MW,
- Installations located over the territorial sea,
- Those of production, secondary transport and distribution that exceed the territorial scope of an Autonomous Community,
- And all the primary transport facilities, except for the specificities established for the island and non-mainland territories.

It is also important that, as described in the section 1, Spain does not present a unification of laws[22] for the wind sector, and it should be pointed out that, as with land-use regulation, each autonomous community presents its own legislation for the authorization of electricity production facilities from wind power. That is why the permission procedures are different in each of these communities. Such an example are the permission procedures of Extremadura[23] or Castile and Leon[24]. Even so, all wind farms must obtain an authorization after having performed an environmental impact assessment.

[21]http://www.minetad.gob.es/energia/electricidad/TramitacionInstalaciones/Paginas/AutorizacionInstalaciones.aspx
[22]https://www.aeeolica.org/es/sobre-la-eolica/la-eolica-en-espana/marco-normativo/normativa-autonomica/
[23] https://www.aeeolica.org/uploads/documents/Decreto%20160_2010_Extremadura.pdf
[24] http://www.agenbur.com/docftp/fi1187EE-RR_Decrt189-1997.pdf

Just to give an example on the way to obtain an authorization of electricity production facilities for wind power, in the autonomous community of Castile y Leon, different technical documentations must be presented:

- The accreditation of the applicant's legal, technical and economic capacity appropriate to the type of production to be developed.
- A proposed draft or a project drafted by a qualified technician, which reflects the technical and operational characteristics and should incorporate at least the provisions of Decree 189/1997 (see footnote 23).
- A technical feasibility study of the project.
- An installation budget and an environmental impact assessment.

Within this environmental impact assessment, as stated in the final report "Recommendations for the Environmental Assessment of Wind Farms in Andalusia" presented by the regional government of Andalusia, different aspects should be evaluated. The aspects under evaluation would be susceptible to affection of:

- Atmospherical limit layer and surface limit layer.
- Geology, topography and geomorphology.
- Meteorology and hydrological system.
- Ecosystems and ecological niche. Species inventory.
- Plant species.
- Fauna species. Avifauna and bats.
- Air quality and light quality.
- Noise pollution.
- Impact on the landscape.
- Wastes.
- Quality of life of the population and cultural heritage.

4. Social aspects

Spain has been and is nowadays one of the countries in the European Union with greater social acceptance of wind energy. For example, traditionally it shows more acceptance than countries such as Netherlands, Belgium or United Kingdom. Nonetheless, different agents, mayors, businessman and social organizations met at the headquarters of the AEE association *(Asociación Empresarial Eólica)* in the end of 2015 to discuss how to improve the social acceptance of wind power. This discussion panel was an event to broadcast WISE

Power[25], "an European project about the social acceptance of wind energy, aiming at significantly improving local engagement and support for wind turbines while enhancing local community participation in the planning and implementation of wind energy projects". It should be noted that one of the initiatives used for the acceptance of the community, as pointed out by the leader of the company *Ibereólica*, is to hold civic participation workshops or the obligation to contract local workers for the O&M of wind farms.

In relation to the socio-economical benefits, according to the guide "Energía eólica"[26] published by IDAE *(Instituto para la Diversificación y Ahorro de la Energía,* or in English *Institute for the Diversification and Saving of Energy)*[27]*,* wind energy not only contributes to the creation of a new industrial network with a high employment rate, it also contributes to the development of many rural areas of the country. Due to the not so laborious maintenance required by the wind turbines, the greatest benefits produced by a wind farm for the municipalities of the region are not usually counted in number of jobs, but directly in the amount of money received as taxes, such as, Economic Activities or Real Estate taxes, or municipal licenses, such as, Activity or Works licenses and the rental of the lands where the wind turbines are located.

Moreover, the generation of local taxes and land transfer fees can become one of the main revenues of many local entities affected by the construction of wind farms. Furthermore, the installation of wind farms improves the guarantee of supply and the electricity infrastructure of the surrounding area, and can lead to the improvement of roads and other infrastructures.

In particular, the IDAE institute describes as an example of socioeconomic benefit the municipality of Higueruela. It is located in Albacete and has a population of about 1400 inhabitants, 30 of them have direct employment thanks to the wind sector; in fact, there are more than 220 turbines installed in the town's lands, so every year the municipality wins about 500,000 €. Other examples would be La Muela, Tarifa, Muras, etc. Even so, there is an extended social feeling in the municipalities: although the sector motivates millionaire investments, the economic benefits are not enough for the people.

We should not forget the collection of corporate tax that is implicit to the economic benefit of the use of wind resources and entered into the Treasury by the production companies to revert jointly in projects of all types over the national geography.

In addition to the socio-economic benefits, as recorded in the Basque Country's "Plan Territorial Sectorial de la Energía Eólica de la CAPV[28]" territorial plan, the wind energy also presents environmental benefits in the society because wind farms are a sign of environmental sensitivity. They involve a clear action of environmental education towards the consumer, establishing a relationship between production and consumption, which is

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[25] http://wisepower-project.eu/
[26] http://www.idae.es/uploads/documentos/documentos_10374_Energia_eolica_06_2e6a15a7.pdf
[27] http://www.idae.es/en
[28]http://www.ingurumena.ejgv.euskadi.eus/contenidos/informacion/plan_energia_eolica/es_8109/adjuntos/documentoI/3-energia-eolica_c.pdf

not perceived equally with a reduced number of large plants, about which the public is largely unaware.

5. Available wind data

It is very difficult to obtain real wind data of wind farm anemometers due to the secretiveness of wind industry in Spain. This is well known for university researchers that have problems to obtain datasets for their studies. But this is a general trend in Europe, and, as far as we know, USA wind industry associations are the only ones which provide free access to wind data of farms.

Therefore, the observational data available in Spain has three main sources:

- Meteorological stations from the Spanish Association of Meteorology, AEMET. It must be taken into account that Basque Country (Euskalmet[29]) and Catalonia[30] have their own meteorological agencies. This map shows the locations of all the stations[31]. Here wind data is measured at 10 m height.
- Spanish Port Authority (Puertos del Estado)[32] has several buoys along the Spanish coast with anemometers at 3 m heights. The quality of these data has been fully evaluated by many studies and they have been used for climatic model validation and offshore wind energy potential estimation in the Cantabric Sea[33], and in the Mediterranean and Balearic Islands.[34]
- Remote sensing data of European and international satellites is also available for Spain. An interesting one is the advanced analysis given by CCMP (Cross Calibrated Multi-Platform), since it merges multiple remote sensing sources. Multi-decadal time-series of ocean surface vector wind fields from 1987 through 2016 is available. CCMP combines QuikSCAT scatterometer and other sources to obtain an 1-hourly wind dataset (U, V components) with 0.25 degree spatial resolution in the second version V2.0[35]. Updates to the CCMP V2.0 product will be made twice a year.
- ERA-Interim and now ERA5 reanalysis from the *European Centre for Medium-Range Weather Forecasts*[36] provide wind speed and direction at 10 m height 1-hourly with 15 km spatial resolution. This data can mainly be used for offshore wind energy estimations (see footnote 19, 20), since the validations in the nearest gridpoint

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[29] http://www.euskalmet.euskadi.eus/
[30] www.meteo.cat
[31] https://www.google.com/maps/d/viewer?mid=1VC0fnGmkuDHu1NKYLD_fSt6gqsU&hl=en_US&ll=36.16301788547206%2C-6.916353000000072&z=5
[32] http://www.puertos.es/en-us/oceanografia/Pages/portus.aspx
[33] http://www.sciencedirect.com/science/article/pii/S0306261916311205
[34] http://www.sciencedirect.com/science/article/pii/S0306261917313144
[35] http://www.remss.com/measurements/ccmp/
[36] https://www.ecmwf.int/

against Spanish buoy observations (see footnote 18) shows correlations of 0.9 and even better relative errors than satellite data.

- Together with reanalysis and remote sensing, simulations using climatic models such as WRF (Weather Research and Forecasting) have been used also around Spain to estimate offshore wind energy potential (see footnote 15 and 16). The authors of these studies are mentioned in the subsection 7.1.

6. Domestic industrial capacities

In order to know 'who is who' in the wind energy sector, the Spanish Wind Energy Association published a detailed report with all the involved companies[37]. The domestic industrial capacity is well distributed geographically. There are 195 centers of manufacturing in 12 of the 17 autonomous communities of Spain, and there are more than 1000 wind farms in 800 municipalities. The main Spanish association of wind energy (above mentioned AEE) is composed of more than 170 partners (see footnote 19)[38].

Resuming, there are important companies specialized in wind energy. GAMESA-SIEMENS and ACCIONA WINDPOWER are good examples:

- GAMESA-SIEMENS: Gamesa has developed, managed and sold wind farms since 2006 and is the market leader in Spain and the fourth manufacturer in the world. In 2016 Gamesa merged Siemens. It must be emphasized that it is constructing the pioneering floating wind farm in the world, "Hywind Scotland", together with the Norwegian company Statoil over UK waters.

- ACCIONA WindPower (merged with Nordex), is the wind energy section of Acciona Energy, a bigger company that works on biomass, hydro and solar energy. It also develops the design, operation and manufacture of wind turbines. In 2010 Acciona had more than 160 wind farms in almost ten countries representing over 5,000 MW. It has an important presence in USA, with an great manufacturing center in Iowa.

As examples of Spanish wind industry's diversity, these are other relevant Spanish enterprises:

- ENDESA: It is the largest electricity utility in Spain with 10 million customers. It is awarded the installation of 540 MW according to their renewable energy action. GORONA DEL VIENTO, in the island of El Hierro (Canary Islands) is a very significative project[39]. In this volcanic island with high altitudes and strong Alisio winds Endesa installed the first hydro-wind energy park in the world that is generating electricity

[37] https://www.aeeolica.org/uploads/__GUIA_2014_WEB.pdf
[38] https://www.aeeolica.org/es/sobre-aee/socios/
[39] http://www.goronadelviento.es/

from renewable sources for the entire island with a supply of 80% of the electricity consumption in some months. A crater is used as a water tank at 700 m height for the accumulation of potential energy provided by the wind turbines to obtain hydraulic energy when it is needed by the island.

- EDP-Renewables. Although EDP company is Portuguese in origin, it has an important presence in Spain. This is the first Iberian company to own significant generating and distribution in the Iberian Peninsula, and it is also present in the electricity sectors of US, Brazil and Africa. In this moment the importance of wind energy within EDP-Renewables is substancial, since the British Moray Offshore Windfarm project of this company has been awarded a 15-year Contract for Difference for the delivery of 950 MW by the UK government.
- IBERDROLA: Based on Bilbao, Basque Country, Iberdrola is a public multinational electric utility with more than 30,000 employees. It has a long experience in wind industry. One of the subsidiaries includes Scottish Power (Scotland), and together with Scottish University of Strathclyde and other institutions are in this moment working in the TLPWIND project on offshore floating wind turbines.
- NAVACEL: This company with historical roots in nautic industry fabricates tubular structures for wind energy and maritime equipment. For example, now it is fabricating towers for the mentioned HyWind Scotland project. WINDAR is another company with similar characteristics that is working also in Brazil and Mexico.
- FORESTALIA. Although at the beginning the purpose of this company was focused on Biomass energy production, in the last years it is winning the auctions of wind energy installation in Spain in a great proportion. They have obtained almost 2000 MW in the last auctions on renewable energy by the Spanish Industry Ministry, adding wind energy, photovoltaic, and biomass.
- INGETEAM-INDAR provides power converters, generators, turbine controllers, Condition Monitoring Systems (CMS), SCADA management systems and services for wind turbines up to 12 MW.
- ORITIA&BOREAS, Spin-off of the University of Granada, offers applied research on wind effects on structural systems. The objective is to satisfy the growing demand for studies on the wind effects on tall and complex shaped buildings, bridges, flexible structures, renewable energy systems and sports science. They offer a pioneering perspective in the study of the boundary layer affected by buildings and complex topographies with a special wind tunnel, proposing a competitive and/or complementary technology for the typical CFD analysis of complex terrains.

7. Institutions in the area of R&D, training and education

Research

The most important research centre in wind energy is CENER, although there are various projects and institutions that should be mentioned:

- *CENER. Centro Nacional de Energias Renovables / National Center of Renewable Energy.* In the Wind Energy department of CENER they develop research activities and provide technical advice for promoters, manufacturers, financial entities, operators, public administrations and associations, both in Spain and abroad. This department has important infrastructures:
    - Wind Turbine Test Laboratory (the only one in the world with blade test, powertrain test, nacelle test bench and nacelles assembly bench),
    - Data Processing Centre for the analysis and design of turbines. Aerodynamic and structural design and consultancy with the CENER's proper aerofoil family. They also have a composite materials laboratory and specific algorithms designed by them for control. Finally, it must be mentioned that they present extensive experience in the simulation of offshore complex dynamics.
    - Advanced methodology in resource assessment methods and farm design, prediction models for wind farms for daily and intra-daily wind farms, wind flow characterization via LIDAR. And they even have an Experimental Wind Farm for complex terrains.
- *CIEMAT (Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas).* CIEMAT is mainly developing isolated wind systems and small power turbines with a research project in the testing and the characterization of this type of technologies. They are also developing new forecasting algorithms using artificial intelligence methods that diminishes the error especially in complex terrains with 48 hours prediction horizon. They are in the project CENIT Windlider 2015 about the design of the future wind turbines and in the project UE-TRENT Hychain-Minitrans about the developing of transportation nets in the applications of hydrogen fuel, which could be an energy storage way in the future for surplus wind energy.
- *Catalonia Institute for Energy Research (IREC)* is developing a pioneering offshore wind power project: an offshore wind power test platform to act as a test laboratory before this technology can come onto the market. The name of the project is Zefir (Zephyr). The platform, which is to be located away from the Mediterranean coast, will make it possible to develop a technology which reduces the visual impact of wind farms. This scheme is one of the most important in the world with several objectives:

boost the deployment of offshore wind power in southern Europe and worldwide; the progressive reduction of costs in offshore wind farm installation; the creation of a favorable environment to develop university programs, as attraction pole in R&D; and also training for suitable profile technicians and workers, in manufacturing, installation, operation and maintenance.

- *IH CANTABRIA. The Institute of Environmental Hydraulics of Cantabria University* is working in the operational design of offshore wind farms. It is an internationally recognized institution in aspects related to ocean engineering, so their experience is remarkable in operation optimization, maintenance, error simulation or life-cycle analysis of any structure over the sea.
- *Barcelona Supercomputing Center* offers wind energy services in short-term forecasting and seasonal predictions.
- There are some research groups that are simulating climatic models obtaining not only pressure and temperature at model's gridpoints, but also wind speed and direction at different heights. For example, *EOLO (University of Basque Country)* is developing offshore wind energy potential analysis around Spain (Bay of Biscay, West Mediterranean and Balearic Islands) using WRF climatic model with data assimilation and taking into account the bathymetry of the region for the implementation of floating turbines.[40] Another example is the group of fluid mechanics at Zaragoza University, where climatic models has been used for the estimation of onshore wind energy potential in Spain[41].

Professional Training

Although there are some specialized training courses, till now the majority of the workers in the sector have come from classical electrical and mechanical engineering studies (70% of the workers in the sector have a degree), and the professional training has been developed *in situ* in the factories of the companies. These are one of the main courses/masters of specialization recently created with a clear professional training character:

- Alcala University's *Curso de Formación en Montaje y mantenimiento de Aerogeneradores y Parques Eólicos / Course on Manufacturing and Maintenance of wind turbines and wind farms.*
- UOC (Universitat Oberta de Cataluña) also offers a similar master in manufacturing and maintenance.

[40] http://www.ehu.eus/eolo/index_en.html
[41] http://onlinelibrary.wiley.com/doi/10.1002/we.392/abstract

- *Curso de Técnico de Mantenimiento de Parques Eólicos/ Technical Course on Maintenance of Wind Farms* by the above mentioned association of wind energy companies (AEE). This is the most important course with a clear professional orientation, since it has been created from the needs of the Spanish wind energy sector and the associated companies. Ex-students are working in several companies of the sector all over the world. It is a 180 hour course, in Madrid, with direct practices in real wind farms.[42]

University Studies

- *UNED. Energía Eólica: Fundamentos y Tecnología / Wind Energy: Foundations and Technology.* Postgraduate Program and Professional Development studies online.[43]
- *Universidad de Cantabria. Energía e Ingeniería Offshore / Energy and Offshore Engineering.* Postgraduate master in offshore engineering with a specialization branch in offshore wind energy.[44]
- Mater MORE (*Master on Offshore Renewable Energies* by the University of Basque Country). Not only focused on offshore wind energy, wave energy is also included. According to the quality validations of European institutions in 2018/19 it will become an european master within ERASMUS-MUNDUS. The Master program is fully presented in English and classes are presented by professors of University of Basque Country, Strathclyde University (UK), Ecole Centrale de Nantes (France) and NTNU (Norway), and professionals from the supporting companies and institutes[45].
- There are other generalistic masters on renewable energies in which the presence of wind energy is relatively important: 'Environmental Engineering and Sustainable Energy' at the Rovira y Virgili University (Tarragona)[46]; the master on renewable energies in electrical systems of the Carlos III University in Madrid[47]; or the European Master on Renewable Energies at Zaragoza University with very good valuations within the Spanish master system[48].
- Engineer School of Gipuzkoa-Eibar (University of Basque Country). 4 years Grade in Engineering of Renewable Energies, with 60 hours subject on Wind Energy in the third course and with several final degree projects in the areas of wind industry.

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[42] https://www.aeeolica.org/es/aee-divulga/curso-de-tecnico-de-mantenimiento-de-parques-eolicos/
[43] http://www2.uned.es/ing-fluidos/Postgrado-Energia-Eolica/
[44] http://www.ihcantabria.com/en/formacion/programas-de-master
[45] http://mastermore.eus/
[46] http://www.urv.cat/en/studies/master/courses/environmental-engineering/
[47]https://www.uc3m.es/ss/Satellite/Postgrado/en/Detalle/Estudio_C/1371209017723/1371219633369/Master_in_Renewable_Energy_in_Electrical_Systems
[48] http://www.fcirce.es/masters/european-renewable-energy.aspx

Pioneering studies in the Spanish State on renewable energies.[49] For example, a group of students and teachers of this university have won the last 'university challenge' of EDP-renewables, one of the main global energetic companies, with a project in urban wind energy integration for buildings[50].

8. 8. Export promotion policies

In 2013 Spain was the third exporter in the world (after Germany and Denmark) in the wind energy sector according to UN. Spain exports to more than 50 countries in the world, almost fifty percent to Europe. In 2009-2013 it obtained an annual mean exportation value of 2.200 millions €. Although USA is more and more important for the exportations, the main destination is Europe.

At the beginning of the 2010's, not only the institutions, but even the Spanish King Felipe VI mentioned these conditions of the Spanish wind energy sector with a great honour. However, as mentioned above, 2014 passed to the history not for these achievements, but for the energetic reform. The 30% of the Spanish wind power lost previous financial incentives and the fast development of the sector was paralyzed. Now, in this new legal terms, the Spanish government can change unilaterally the economical conditions every six years.

Consequently, the year 2014 established the beginning of a new stage for the wind energy sector. The promoters have to maximize the incomes and re-financiate the debt, and the companies have to live with a double accountancy. More than 400 legal remedies were presented against this retroactive law and the consequences were immediate. For example, the exportations fell 12% from 2015 to 2016, being 2015 the year of record of exportations. It seems therefore that the Spanish wind energy sector exportations have moved away from its historical maximum.

Closing the domestic market, according to AEE, "the energetic reform has brought down the globally advanced research lines and the talent in the sector that was the envy of the world". Future perspectives are not good and the main effort is focused on avoiding relocations of genuine Spanish companies. So, after the crisis, the situation has changed and the very positive perspectives of 2007 (see for example Martinez et al.[51]) have disappeared to some extent.

This critical situation opened after 2014 shows that in this moment there is no export promotion by the Spanish government for the wind energy sector. The joining between Gamesa and Siemens is a clear example of an advanced Spanish manufacturing company trying to expand its international market by means of a strong company, among other reasons, due to the autonomy lost in the domestic market. Another example about the independent work of the association of wind energy companies (AEE) with respect to the

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[49]https://www.ehu.eus/es/web/eibar
[50] http://www.edpr.com/en/news/edp-renewables-presents-university-challenge-2017
[51] http://www.sciencedirect.com/science/article/pii/S1364032105000493?via%3Dihub

lack of promotion policies by the government, is the social network campaign called 'Yes to eolics'. This campaign has almost 20,000 followers in the social media of AEE in a country of 40 million inhabitants.

In any case, due to its historically (more than 20 years) rich technological background and the talent to develop all the phases of the manufacturing process within the country, wind energy sector keeps the necessary foundations in face of the opportunities of the global market. But the sector needs:

- Regulatory changes and positive governmental export promotion policies to remove the mentioned legal uncertainty.
- Therefore, the reactivation of the domestic market to fulfill the international compromises on climatic change by 2020, since wind energy is the main renewable source for that objective also at European level.
- And to set ambitious objectives in the future to synchronize the intervention in the domestic market (with a great wind energy potential) and the exportation activities (mainly to Europe) .

The only plan that is working now is PRIE[52] ("plan for the revival of the wind industry"), in which one of the objectives is to ensure the access to international markets with competitive products and research to keep the technological vanguard. In this plan AEE has many connections with the Industry and Economy Ministry, Port Authority, etc., as it is explained in the 17th annuary of the organization.[53] It must be underlined one important advantage of this plan for the wind industry sector: *the industrial part is managed regardless of the energetic part.* In fact, AEE is one of the members of the group of 20 industrial associations that is meeting with the government to establish a strategic schema for Spanish industry. This industry/energy institutional discrimination established by the previous government is very important to keep the relative power of the wind industry with respect to the current government that is cutting the investment in renewable energies.

Logistics is very important in this objective related to exportation. They want to construct a logistic corridor between Navarre (Aoiz, where there is a test laboratory of blades) and the Port of Bilbao (Basque Country) in order to transport big elements (towers, blades…) by mega-trailers to the test site in Navarre. In this international perspective, another important port will be Ferrol (Galicia), where the normative aspects to facilitate the nautic transportation of big turbine elements have been studied. In this sense, onshore connectivity is very important for Port Authority, to follow the marine transportation by trailers and trains, and they are therefore investing the 50% of the benefits in this connectivity.

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[52] https://www.aeeolica.org/uploads/PLAN_PRIE_.pdf
[53] https://www.aeeolica.org/uploads/AEE_ANUARIO_17_web.pdf

According to the government, there are several opportunities for industrial sectors that are interconnected with the internationalization and European politics in the core:

- Financiation: European Union Juncker Plan, ICO (Initial Coin Opening), European Investment Bank.
- Internationalization instruments: ICEX (Inversion and export in Spain), COFIDES (development financiation), FIEM (Project financiations by Economy department).
- The relation with ECOFIN in the European Union.
- Innovation from CDTI ("national innovation center")
- The regulation of the domestic market and the regulation of the commercial freedom.

From the perspective of marketing, the typical international expositions where different countries show their own industrial and technical capabilities are good indicators to obtain an idea about the priority of wind energy for the Spanish government. Although, as mentioned before, its importance has diminished in the last decade, wind energy sector remains referential for the renewable energies. For example, the Spanish pavilion of *Expo Astana 2017* (an international exposition about the relation between energy and the planet) mentions "particularly wind power" as a sector with experience within renewable energies, together with solar photovoltaics and hydro[54]. In any case, it does not seem that there is a specific governmental strategy for the marketing of wind energy sector in the exterior, because it appears merged with other renewable energies.

Another issue is the own strategy of AEE association. In the Spanish Wind Power Congress organized by this association from 2015 (2017 was the third edition[55]) there is a day of the congress about the relationship with other countries. For example, in the last edition the *Ministry of Energy and Mines* of Argentina explained the "ambitious bet" of the country on wind power. We think that this kind of national congresses with invited foreign ministries and companies can contribute more effectively to the promotion of wind energy, implementing a rational strategy and identifying key issues in international markets. Similarly, in 2016 congress, the wind energy association of Mexico (AMEE) was invited, and the ceremony was inaugurated by K. Saramoni from the International Energy Agency. Apart from these facts related to foreign policy marketing and knowledge sharing, it must be underlined the clear focus on these recent congresses of AEE on Latin American markets; this is interesting given the historical and cultural relationship of Spain with these countries of Central and South America, and their underdevelopment in terms of renewable energy and wind energy implementation compared to Spain and Europe.

[54] https://www.accioncultural.es/en/spanish_pavilion_at_expo_astana_2017
[55] https://www.aeeolica.org/uploads/Programa_III_Congreso_Elico_Espaol.pdf