# Chapter 26
# Spain

## 1.0 Introduction

Wind energy installations in Spain reached a new record during 2007. Capacity installed in 2007 was 3,522 MW, twice the 1,524 MW installed in 2006. The capacity installed in 2007 is even greater than the previous record during the year 2004. The growth of wind power in Spain in 2007 has been the second largest in the world market.

By January 2008, the total capacity was 15,145 MW according to the Wind Power Observatory that includes the data supplied by promoters and manufacturers (1).

In relative terms the new capacity put into the system during the last year means a growth of 30% of the total capacity, in comparison with the 18% corresponding to the year 2005 or the 16% during the year 2006. This strong performance is a key step to achieve the objectives of the Spanish Renewable Energies Plan (PER) which expects to reach 20,155 MW of wind energy at the end of 2010 (2).

One explanation for this strong growth is the new favorable regulations for wind farms put in operation before 2008. For instance, after 2008 wind farms must satisfy the new grid code PO.12.3 referring the behavior of wind turbines during voltage drops.

The Spanish demand for electric power reached 260,838 GWh, which represents a growth of 4% over 2006. Wind energy met 10% of this demand and was the fourth largest contributing technology in the generation system, besting hydropower (9% of demand). The other contributors to the system were coal power plants (25% of demand), natural gas (24%), and nuclear energy (20%) (3). Figure 1 shows the structure of the electricity system in Spain during 2007.

During 2007, the demand for power and energy reached new highs in Spain and wind energy made significant contributions to supply. The average hourly demand for power rose to 45 GW on December 18, and on that day wind energy supplied up to 6 GW. On several occasions wind energy has covered 30% of the hourly demand, and for several days supplied more than 20% of the daily demand for electricity. For instance, on March 19, wind energy supplied a record 23.2% of the demand for the day.

Wind energy in Spain has also emerged as a driving force for industrial development. In 2007, investment was more than 5,000 million €, and around 50% of the Spanish wind energy equipment production is dedicated to the export market. Jobs resulting from wind power reached 45,000 in 2007. Of this total, direct jobs in operation and maintenance of wind farms, manufacturing, assembly, research, and development is estimated at more than 18,000, while indirect jobs linked mainly to components is estimated to be more than 27,000.

Finally it is important to point out the important efforts of the industrial sector and the system operators to implement the new grid code. (P.O.12.3). Due to their coordinated efforts, the impact of wind energy on system operation is smaller than expected. The regulation systems have been able to regulate and optimize system management with very low costs.

## 2.0 Progress Toward National Objectives

The present objectives for 2010 for the promotion of renewable energies are contained in the Plan of Renewable Energies (PER) 2005-2010 "Spanish Renewable Energy Plan" (2). This plan is a revision of the previous one (the last revision was completed in 2002). The aim of

| Table 1 Key Statistics 2007: Spain | |
|---|---|
| Total installed wind generation | 15,145 MW |
| New wind generation installed | 3,522 MW |
| Total electrical output from wind | 27.026 TWh |
| Wind generation as % of national electric demand | 9.8% |
| Target: | 20,155 MW by 2010 |

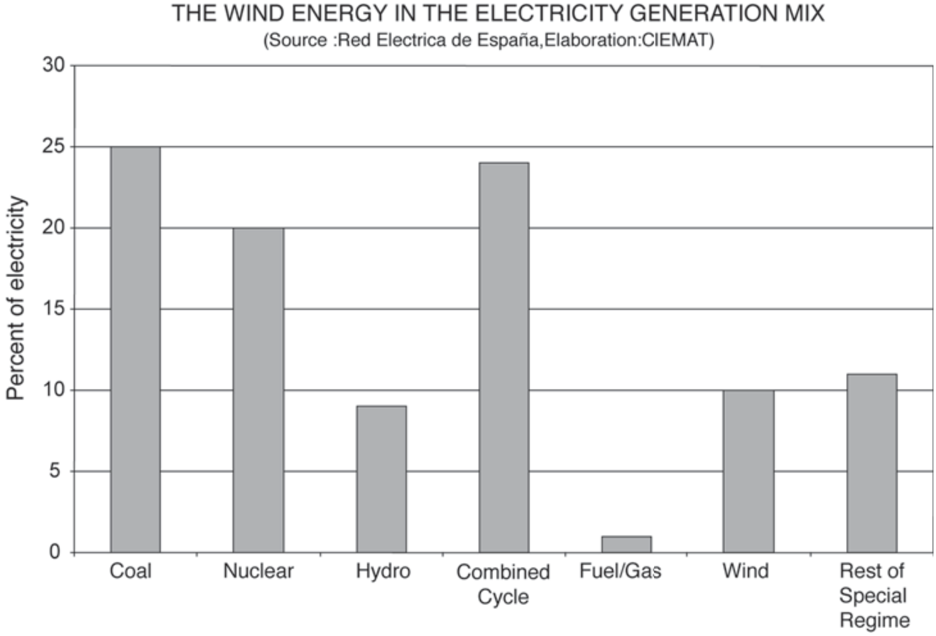


Figure 1 The electricity generation system in Spain, 2007.

this revision was to maintain the commitment to meet at least 12% of total energy use from renewable sources by 2010. It also incorporates other indicative targets (29.4% of electricity generated from renewable sources and 5.75% of transport fuel from biofuels).

For the wind energy sector, the PER objective implies reaching a capacity of 20,155 MW by the end of 2010. With the new 3,522 MW installed in 2007, an important step was taken to achieve the objectives of the PER. In fact, growth of only 1,700 MW per year will meet the final objective. Developers, manufacturers, and auxiliary firms consider the 20,155 MW target well within reach. Figure 2 shows the annual cumulative wind capacity according to the PER 2005-2010.

The strength of the wind energy sector and its continuous growth has created the expectation of new targets for the next term. There is a consensus to fix a new target of 40,000 MW for 2020. The power installed in Spain during 2007 implies a growth rate of 30% as shown in Figure 3. Several factors have contributed to the accomplishments and expectations.

The majority of the Autonomous Regions (that have the responsibility for regulating wind installations) have plans which imply reaching 39,000 MW between 2010 and 2020. The main reasons considered by the local governments are related to energy pacification, local resource use, industrial development, and job creation in their zones.

The industrial sector participating in the Asociación Empresarial Eólica AEE (The Spanish Wind Energy Association) has established a new objective of 40,000 MW for 2020. It is conducting studies and developing strategies to reach that goal.

Finally, the management and planning of the new Spanish target is designed to fulfill the new European Union objectives established during 2007 — 20% of the primary energy with renewables by 2020. Due to the solidity of the sector, it is likely that an important amount of the renewable objective will be covered by wind energy.

Electrical generation capacity nationwide reached over 92 GW at the end of 2007, with over 10% growth compared to 2006. Combined cycle and wind power are the technologies that contributed the most to this growth of total capacity. With the new installed wind power in 2007, there are more than 16,000 turbines operating in Spain. They are grouped in 672 wind farms. The average size of an installed wind farm in 2007 was 26.4 MW.

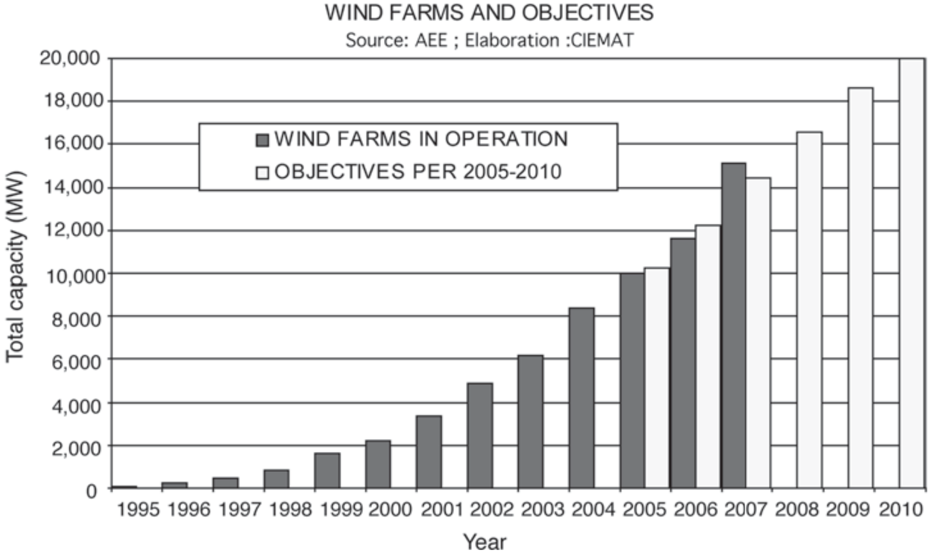


Figure 2 Wind farms in operation and objectives for 2010.

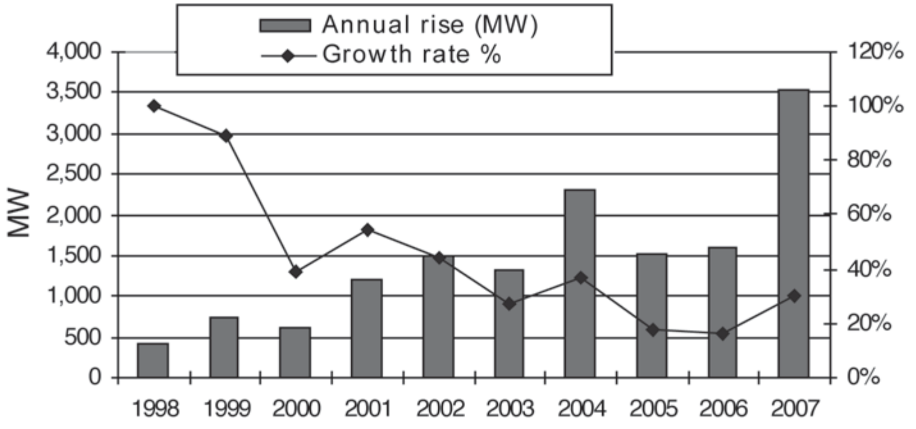


Figure 3 Annual growth of wind power.

Wind energy is present in fifteen of the seventeen Autonomous Communities, and Castilla La Mancha has the most installed power among them. Figure 4 shows traditional windmills still operating in La Mancha. Only two Autonomous Communities have not yet installed wind power, however they have advanced projects and regulation to start wind energy activities. It should be noted that unlike many other countries with significant wind development, Spain has increased its distribution throughout the country. Table 2 and Figure 5 show wind energy developments by regions and the annual growth.

In absolute terms, Andalucia and Castilla La Mancha are the regions where more capacity was installed in 2007, with 853 MW and 850 MW respectively. In percentages, the largest growth was in Andalucia with growth of 140% and total capacity reached 1,459 MW. Castilla La Mancha has the most capacity with 3,131 MW total and 37% growth, overcoming Galicia where more than 2,900 MW are operating and growth was 12.6%. Castilla y Leon increased to 2,818 MW and grew 32%. Aragon now has more than 1,700 MW.

Wind power has lowered $CO_2$ emissions by about 18 million tons just during 2007.

Figure 4 Old wind mill in La Mancha.

Furthermore, wind generation has saved up to 50 million tons of conventional fuels. It is estimated that more than 127 million tons of $CO_2$ emissions will be avoided over the 2005–2010 period thanks to wind energy generation in Spain. The new National Plan of Assignations 2008–2012 will mean wind generation will save more than 400 million €, assuming emission rights price of 20 € per ton.

## 3.0 Benefits to National Economy

### 3.1 Market characteristics

The number of installations during 2007 demonstrates the maturity of the wind industry, which has been able to increase despite worldwide difficulties with the supply of wind turbines and components. Installing and operating wind plants to cover 10% of the Spanish electrical demand implies a huge activity for the promoters and manufacturers.

In 2007, there was a tendency to consolidate holdings. The largest companies have accumulated the farms they put into the network and some companies are being acquired by others. Nevertheless new agents also appeared in the Spanish market as promoters and manufacturers.

Wind farm promoters are mostly utilities, civil works companies, and venture capital organizations. The large Spanish utility Iberdrola had the largest growth in capacity in 2007, increasing its wind generation by more than 670 MW and reaching a total of 4,245 MW. Acciona Wind Power (a company which began with civil works activity) is the second largest promoter with 2,678 MW in operation in Spain and a growth of 676 MW during 2007. The utility

| Table 2 Wind Power Growth by Regions | | | | |
|---|---|---|---|---|
| Autonomous Community | Total 01/01/2007 MW | Installed 2007 MW | Total 01/01/2008 MW | Growth 2007/2006 % |
| Castilla-La Mancha | 2,281.46 | 849.90 | 3,131.36 | 37.25% |
| Galicia | 2,619.64 | 332.05 | 2,951.69 | 12.68% |
| Castilla y León | 2,122.91 | 695.76 | 2,818.67 | 32.77% |
| Aragón | 1,532.44 | 191.10 | 1,723.54 | 12.47% |
| Andalucía | 606.56 | 853.15 | 1,459.71 | 140.65% |
| Navarra | 916.36 | 21.00 | 937.36 | 2.29% |
| Comunidad Valenciana | 333.99 | 256.95 | 590.94 | 76.93% |
| La Rioja | 436.62 | 10.00 | 446.62 | 2.29% |
| Cataluña | 225.30 | 122.14 | 347.44 | 54.21% |
| Asturias | 198.86 | 79.10 | 277.96 | 39.78% |
| País Vasco | 144.27 | 8.50 | 152.77 | 5.89% |
| Murcia | 67.72 | 84.59 | 152.31 | 124.91% |
| Canarias | 133.24 | 0 | 133.24 | 0% |
| Cantabria | 0 | 17.85 | 17.85 | 0% |
| Baleares | 3.65 | 0 | 3.65 | 0% |
| TOTAL | 11,623.01 | 3,522.09 | 15,145.10 | 30.3% |
| Source: AEE; Elaboration CIEMAT | | | | |

company Endesa through its subsidiary company ECYR is next with a total capacity of 1,267 MW, and 347 of them have been installed during the last twelve months. The largest percentage growth, 58%, goes to Neo Energia, a company with a strong presence of the main utility from Portugal. The company has installed 447 MW, for a grand total of 1,223 MW. Olivento (a company with participation from Australian societies) grew by 56% with a total of 150 MW in Spain. Eufer (with participation of the utility Union Fenosa) grew more than 50% by adding 198 MW to reach total capacity of 594 MW. Figure 6 shows the distribution of wind energy promoters in Spain.

Several other organizations have installed wind power capacity during 2007. For instance, Forlasa, a group of companies operating in the dairy meat and beverage sectors, now operates 3% of the wind power capacity; Medwind has 1.6% of the total; Eolia has 1.3%; and Eolica De Navarra has 1.2%.

It is worth mentioning the development work of Gamesa, which processes, builds, and hands over each year many wind farms to other companies. It does not show in statistics of owners. Gamesa delivered more than thirteen wind farms to its clients in 2007, equaling 329 MW and making the company one of the main developers of wind projects.

Spanish companies also have important activities in the international market. Iberdrola, for instance, is an important global wind promoter, with a strong presence in the markets of Ireland and the United Kingdom. Acciona also has an important international activity; it just began operating a new factory in the United States (the fourth factory in operation after two factories in Spain and one in China). The company recently commissioned the Tatanka wind farm in the United States with a total capacity of 180 MW.

### 3.2 Industrial development and operational experience

The important growth of wind power capacity during 2007 reveals an open market, with a larger presence of new providers, until now missing in Spain; but that has not affected the dominance of the main manufacturers. For

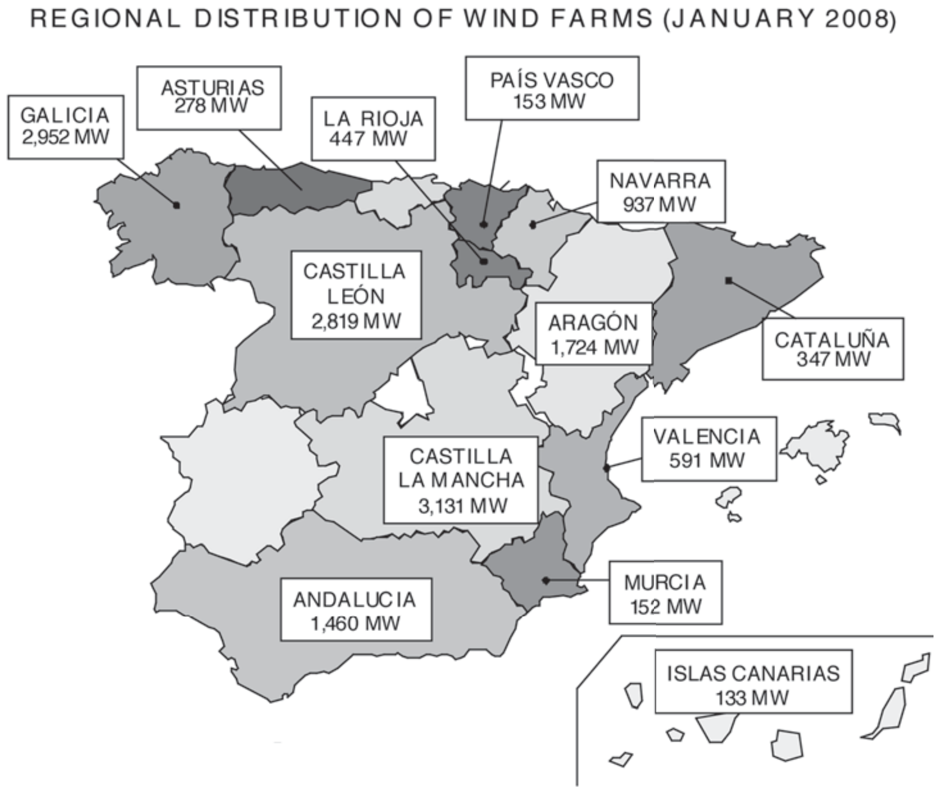


Figure 5 Regional distribution of wind farms.

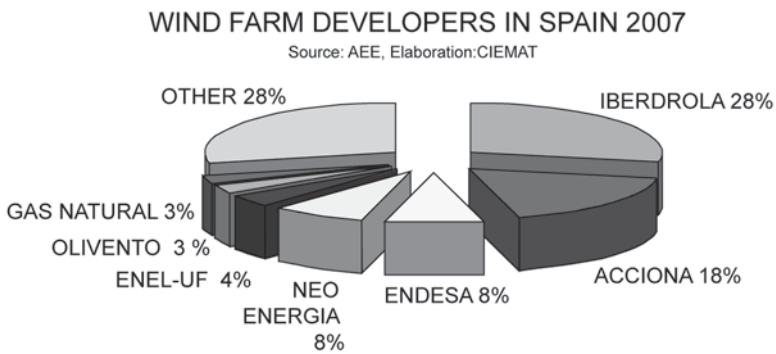


Figure 6 Installed wind capacity in 2007 by developer.

example, Gamesa installed 57% of the new capacity (including the subsidiary company MADE) in Spain, according to the Wind Power Observatory from the AEE. In 2007, Gamesa put 1,670 MW into operation compared with 700 MW in 2006, which consolidates its leadership among manufacturers. This important growth came in a year of consolidation of foreign markets that demanded a choice for export, while local production of machinery and spare parts was consolidated as well (Figure 7).

The second largest manufacturer considering installed capacity in 2007 was Vestas, with almost 700 MW. This is more than three times the capacity installed in 2006 by Vestas. This demonstrates the company's keen interest in the Mediterranean markets, and particularly in Spain. This interest is further supported by the announcement of plans to build a blade factory in central Spain with a total capacity of more than 1,000 MW per year. This will bring about 500 new direct jobs.

Acciona has also experienced important growth, with more than 670 MW put into operation last year (more than double that of 2006) for a total capacity of 1,240 MW in Spain. Acciona began with experience in the operation and maintenance of wind farms and is now one of the manufacturers with a major international image.

Ecotecnia installed around 150 MW during 2007, and it has 1,100 MW in operation in Spain. Ecotecnia is part of the French group Alstom.

Siemens through an agreement with the Spanish company Navantia put in 149 MW for a total capacity of 600 MW.

GE installed more than 100 MW for a total capacity of 890 MW, and Enercon installed 68 MW in 2007, an increase of 180%.

Figure 8 shows a modern Spanish wind farm.

The number of wind turbines in Spain increased by more than 2,200 in 2007, and the total number turbines is 16,000 units. Most of the new generation installed (42%) have a rated power of 2 MW. The rest are rated at 1.5 MW (26%) and 850 kW (16%).

The average size of a wind turbine installed in 2007 was 1.6 MW. The total electricity generated by the wind farms was over 27,000 GWh, and the equivalent hours at rated power were slightly higher than 2,000 hours for all of the wind farms. Wind turbines operating in Spain show important seasonal behavior as shown in Figure 9.

### 3.3. Economic details

The increasing use of large wind turbines (2 MW of nominal power), the increasing of prices of raw materials, the shortage of main components, and the excess demand for wind turbines have increased the prices for wind generators. The average cost per kilowatt installed during 2007 in Spain was around 1,250 €/kW.

## 4.0 National Incentive Programs

The promotion of renewable energies has been a stable national policy for several years. All political parties have kept similar policies regarding support to renewable energies. The main tools within this policy at a national level are:

- A payment and support mechanism enacted by the Parliament through Electric Act 54 /1997: Producers of renewable energy sources are entitled to connect their facilities and transfer the power to the system through the distribution or transmission grid. Producers of renewable energy are entitled to receive remuneration in return.
- The Renewable Energy Plan including mid-term objectives for each technology (PER 2005-2010), and the tariff scheme are guaranteed until the fulfillment of targets.
- The Royal Decree 661/2007 regulates the price of electricity from renewable sources in Spain. The new regulation is in force since June 2007. Wind farm

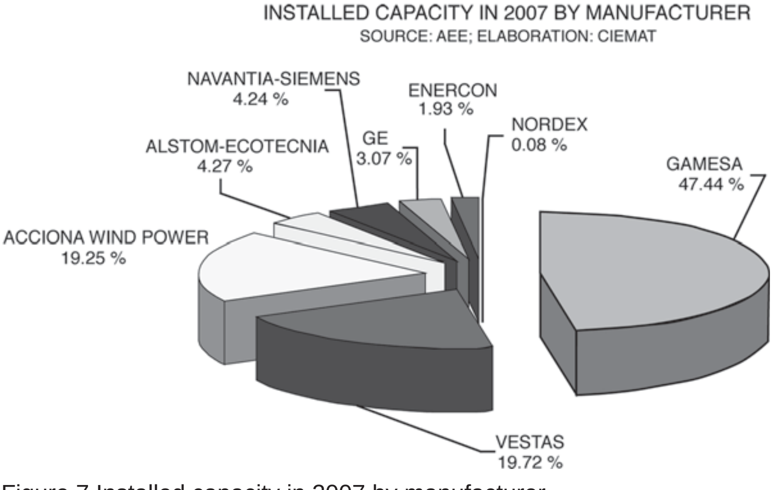


Figure 7 Installed capacity in 2007 by manufacturer.

Figure 8 Photo of a characteristic Spanish wind farm in Galicia (NW Spain).

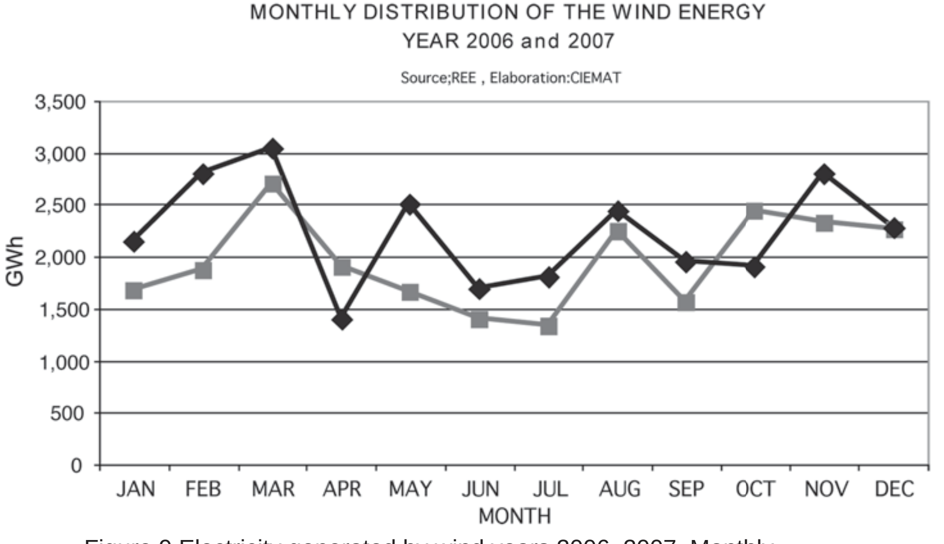


Figure 9 Electricity generated by wind years 2006–2007. Monthly distribution.

installations governed by previous regulations (RD 436/2004) have until January 2009 to decide whether they will continue to follow RD 436 or choose the new RD 661/2007.

To facilitate the integration of wind energy into the grid, supplemental incentives are based on technical considerations: reactive power and voltage dips (only for the existing wind farms, after January 2008 it is mandatory to satisfy the Grid Code PO.12.3).

The payments for electricity generated by wind farms in Spain is based on a feed-in scheme. The owners of wind farms have two options: a regulated tariff scheme or a market option. In the regulated tariff scheme, the payment for electricity generated by a wind farm is independent of the size of the installation and the year of start up. For 2008, the value is 75.68 €/MWh and the update is based on the Retail Price Index minus an adjustment factor. For the market option, the payment is calculated as the market price of electricity, plus a premium, plus a supplement, and minus the cost of deviations from energy forecasting. There is a lower limit in order to guarantee the economic viability of the installations and an upper limit (floor and cap). For instance, the values for 2008 are: reference premium 30.27 €/MWh, lower limit 73.66 €/MWh and upper limit 87.79 €/MWh. The price of wind electricity versus the market price is shown in Figure 10. The feed-in scheme will be valid until fulfillment of the PER objectives in 2010 (20,155 MW). An additional 2,000 MW are considered for repowering wind farms built before December 2001, and an extra bonus of 7 €/MWh is considered.

For offshore installations, only the market option is available with a maximum premium of 84.3 €/MWh over the market price and the maximum price to be paid (cap) will never exceed 164 €/MWh. No lower limit is defined. A new regulation for offshore wind energy is defined in the new RD 1028/2007 published in August 2007. It established the administrative procedure for processing requests for power generation installation authorizations in Spanish waters. Several off-shore wind farm projects are at the initial design and basic engineering stage off the South and East coasts of Spain. They add up to a total of 2,000 MW.

The market price of electricity in Spain during the years 2006 and 2007 is shown in Figure 11.

## 5.0 R, D&D Activities

The PER 2005–2010 makes an exhaustive analysis of the technological innovation required to achieve its objectives. In the case of wind energy, the priority for the Spanish manufacturers is to make efforts leading towards the following goals:

- Develop advanced systems to control the quality of the power fed into the grid,
- Develop wind turbines with unit power outputs of more than 2 MW,
- Adapt high-capacity wind turbines to the more demanding technical requirements of offshore applications, and
- Implement demonstrations of offshore wind farms.

One of the instruments to increase the R&D activities is the CENIT Program carried out from the Center for Industrial Technological Development (CDTI) from the Ministry of Industry and Energy. The CENIT Program is a Spanish government project aimed at increasing investment in R&D for both public and private initiatives over the next few years, with the objective of reaching 2% of GPD. The program started in 2006 and so far there are two approved projects: Windlider 2015 and Eolia.

Windlider 2015 is an industrial research project led by Spanish turbine manufacturers Gamesa and Ecotecnia. Its objective is to keep Spain at the cutting edge of wind power technology. Specifically, the project involves the design of new high-power machinery. Windlider 2015 has received a 13-million-€ grant, almost half of the 28.5 million € estimated total investment required. The project's objectives are the following:

- Improve the design process of future turbines, reducing 'time to market' and increasing maturity of the first series, considered vital to leading the market as of 2012;
- Boost Spanish-owned enabling technologies;
- Create a holistic simulation model that reproduces as faithfully as possible the behavior of future turbines and determines the

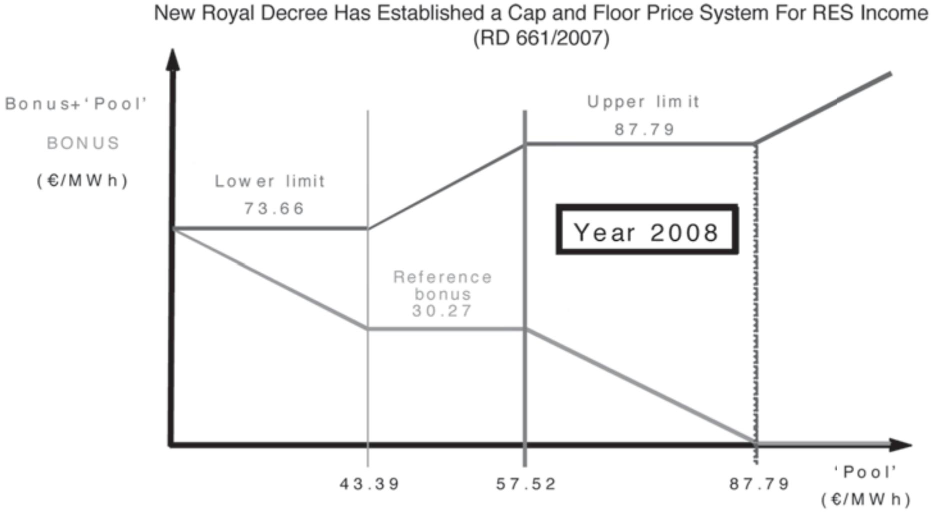


Figure 10 New regulations for the payment of electricity from wind plants.

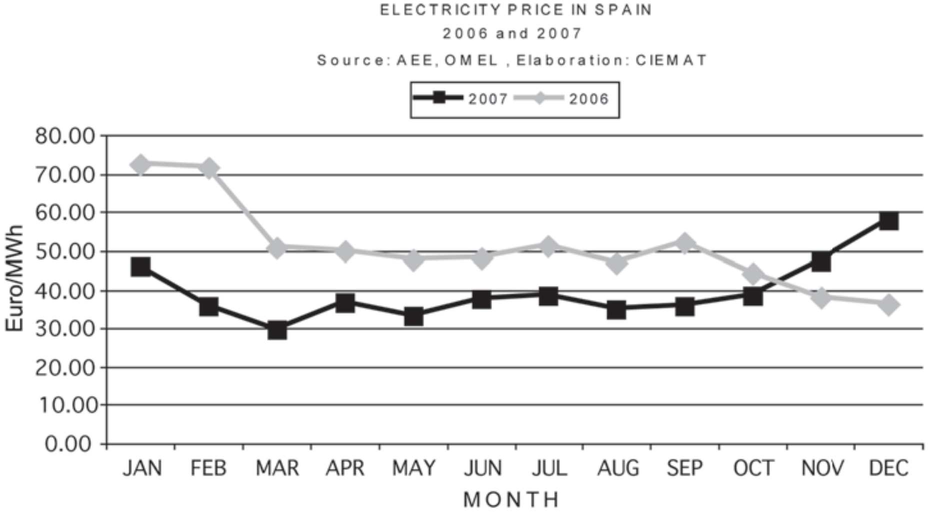


Figure 11 Electricity prices in Spain, 2006 and 2007.

effect of new configurations, new enabling technologies, and other factors on turbine performance;

• Deploy several mid-sized technological-scientific infrastructures in Spain that permit experimentation in scales up to 5 MW with complete turbine prototypes and critical components (generators, gearboxes, converter, chassis yaw, etc.).

Another R&D project is Eolia, a consortium of 16 companies led by Acciona Energia. The project has been approved by the CDTI for a 16.7 million € grant, over half the overall 33.9 million € requirement. Eolia includes 25 research centers and 7 private companies sub-contracted by the consortium. Its objective is to develop technologies enabling deployment of offshore wind plants in deep waters (over 40 m). The project's research activities integrate a series of technologies, including energy (wind power and other electricity technologies) aquiculture, desalination, construction, and naval technologies.

The Program for the Promotion of Technical Research (PROFIT) is an instrument through which the government makes calls for proposals for publicly-funded projects aimed at encouraging companies and other entities to adopt research and technology development activities. The program is in line with the objective established in the National Plan of Scientific Research, Development and Technological Innovation 2004–2007, in the part dedicated to promotion of technological research. The National R&D and Innovation Plan 2004–2007 set a series of objectives aimed at contributing to the general development of the science-technology-company relations. The energy objectives of PROFIT are:

- To use R&D to guarantee economically viable and environmentally friendly energy supply, based on efficiency and quality criteria, employing conventional energy sources and introducing technologies to optimize their use and
- To facilitate scientific and technologic resources contributing to the efficient and competitive deployment of renewable and emerging energy technologies, together with their improved integration within the electricity system.

During 2007 the following projects were approved.

- Hydrogen storage pilot system for regulating feed-in of wind power generation,
- Manufacturing processes optimization for laminated rims,
- Advanced control systems and automatic turbine tower cleaning systems design,
- Nanotechnology applications to improve wind plant yields,
- Lighter-weight turbine components development based on component design, improved materials, and new molding techniques,
- Floating wind-hydraulic hybrid platform for a sustainable solution to water and energy demand,
- Prefabricated concrete tower development and specific manufacturing and assembly processes for large turbines,
- Systems development for designing, manufacturing, and installing prefabricated concrete turbine towers,
- Data acquisition methods at sea for off-shore wind power viability study,
- Mixed wind power system development with both grid connection and connection to an electrolyzer for producing and storing hydrogen for use in a combustion motor grid-connected generator,
- Anti-ice systems development for conventional turbine blades in existing wind plants,
- Socio-economic implications of off-shore wind development along the Spanish coasts,
- Distributed micro-generation based on renewables and smart demand management,
- Off-shore wind power resources evaluation and prediction,
- Systems of reactive current injection for special electricity regime (Regimen Especial) generators.

The PSE Projects are Strategic National Consortiums for Technological Research lead by the industrial sector. In the field of wind energy, a project called Minieolica is developing to promote the Spanish small wind energy sector (new developments up to 100-kW wind turbines). The project is organized in three main areas:

- Product development supporting manufacturers to develop new products. New designs will cover the needs of the market in the power range between 20 kW and 100 kW;
- Technical development breaking technological barriers and advancing the technological development in key areas for small wind turbines (SWTs);
- Infrastructure development activating and supporting the SWT sector. The objective of this area is the promotion, dissemination, sensitization, and information collection for the SWT sector.

An important role in the coordination and definition of the Spanish R&D activities in wind energy it is carried out by the Wind Power Technological Platform Reoltec. Reoltec was created with the support of the Spanish Ministry of Education and Science to define priorities, as well as the procedures for optimizing the acquisition of the forecasted results.

## 6.0 The Next Term

The expectations for the Spanish wind energy industry for 2008 are very high. It is likely that by the end of the year, 17,000 MW of total capacity will be installed. This amount represents 85% of the objectives defined in PER 2005–2010 that established a target of 20,550 MW by the end of 2010. When the target is reached, a revision of the tariff scheme will be in order.

The electricity prices will be increasing during the next year and could exceed 70 €/MWh (especially if the decreasing contribution of hydropower to the system continues).

During 2008, increased installation costs are expected. The global wind energy market and the shortage of components and materials could influence this.

One of the main challenges for the industry during the next year is to complete the regulations for the Grid Code. Grid management has been reformed and every wind farm is assigned to a control centre, which makes the feed-in more transparent.

With joint effort between the system operators and the wind energy sector, wind parks will continue to increase their contribution to meeting electrical demand.

A new Renewable Energy Plan is being studied by the Authorities in order to include the objectives of the European Union for the year 2020. A realistic estimate for wind energy in Spain would say that 40,000 MW of onshore and 5,000 MW of offshore wind capacity could be operating by 2020, providing close to 30% of Spain's electricity.

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