



1.0 Introduction

The installed wind capacity in Spain on 1 January 2007 was 11,615 MW, according to data from the wind-power observatory of the Spanish Wind Energy Association (AEE) and the Association of Producers of Renewable Energies (APPA) (1). During 2006, an additional 1,587 MW were put into operation, which represents an annual growth of 15.8%. This growth rate is similar to the growth rate in 2005. The Spanish wind sector has maintained annual growth rates above 1,500 MW during the past five years making it an important and consolidated industrial activity.

The figures show very clearly the solid contribution of wind energy in Spain. Growth in 2006 was lower than expected and slightly inferior to the rates described in the Plan of Renewable Energies (PER 2005-2010) (2), which expects to reach 20,000 MW connected to network by 2010. Possible reasons to explain this lower growth rate include problems with the connection of wind farms to the electrical grid caused by delays in the construction of electrical infrastructures such as transport lines and high voltage substations.

Spain has not yet experienced the lack of major components (gearboxes, electric generators, blades, and so on) that the wind sector suffers on a global level. This is because many companies in Spain are both wind turbine manufacturers and wind farm developers.

In 2006, annual electricity demand in Spain was 3.6% more than in 2005 (after corrections due

to seasonal effects). Installed electrical power had a net growth of 4,213 MW, which assumes an increase in the capacity of the system of 5.7% from 2005 to 2006. This increase comes exclusively from combined-cycle power plants with natural gas and from wind energy. Figure 1 shows the generation of electricity in Spain during 2006. Electricity produced by wind farms met almost 9% of the total electrical demand in Spain.

It is important to note the increase in exports of wind generators during 2006. Spanish-made wind turbines totaling more than 1,200 MW of generating capacity were installed in wind farms in the Australia, China, France, United States, and other countries.

2.0 Progress toward national objectives

The current objectives for 2010 for the promotion of renewable energy sources are gathered in Spain's PER 2005-2010. This plan is a revision of the previous one which was revised in 2002. The aim of this revision is to maintain the commitment to use renewable sources to meet at least 12% of total energy use by 2010, while incorporating other indicative targets (29.4% of electricity to be generated from renewable sources and 5.75% of transport fuel needs to be met by biofuels).

The plan was revised for several reasons. First, primary energy consumption and energy intensity have grown more quickly than was expected. This fact alone makes it necessary to increase the growth in renewable energy sources to achieve the 12% tar-

Table 1 Key Statistics 2006: Spain

Total installed wind generation	11,615 MW
New wind generation installed	1,567 MW
Total electrical output from wind	23.372 TWh
Wind generation as % of national electric demand	9%
Target:	20,155 MW by 2010

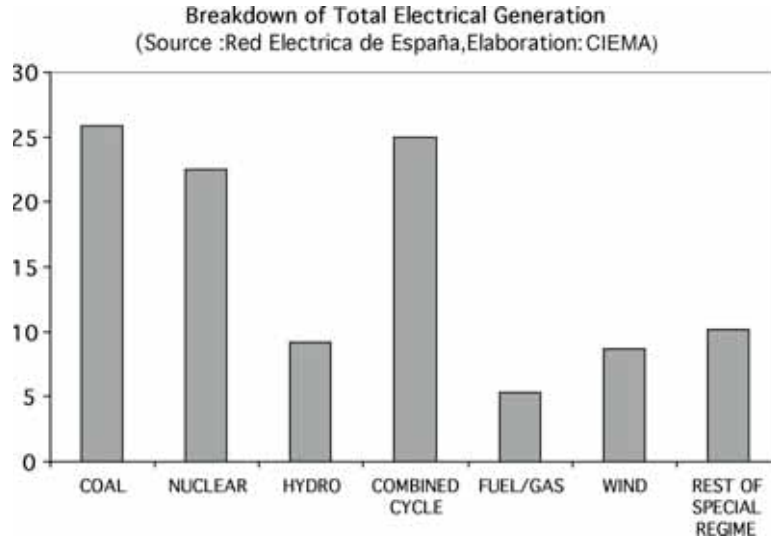


Figure 1 Wind energy and other generation sources for 2006.

get for 2010. Following the approval of the previous plan, two further indicative targets have been set. The new plan also needs to take these into account.

Wind energy is the area that has developed most rapidly and is supported by a range of business initiatives in the market. In line with the general targets of the plan, the new objective for the wind energy sector is an increase in power output of 12,000 MW between 2005 and 2010. This implies ending the decade with a total installed potential of 20,155 MW. In Figure 2, the installed power in Spain is shown, along with the objectives related in the PER.

The increase of installed wind power in Spain during 2006 was lower than expected and slightly below the increase called for by the PER. During the first half of 2006, 913 MW were installed; during the second half of the year, which usually registers

a higher increase in installations, fewer installations were completed for a total for 2006 of 1,587 MW. In some cases, grid connection problems delayed installation of the wind plants, which usually occurs in the later months of the year, to the first term of 2007. Completion of the new electrical infrastructure and the new procedure for connecting wind turbines to the grid will allow Spain to regain, during the coming years, a level of growth that will fulfill the PER targets.

Alongside the plans of the central administration, the various autonomous regions have elaborated their own objectives to achieve by 2010 (Table 2). These objectives of the autonomous regions almost double the national target.

Most of the autonomous regions (which have the responsibility for regulation of wind installations) have planned a total installed capacity of about

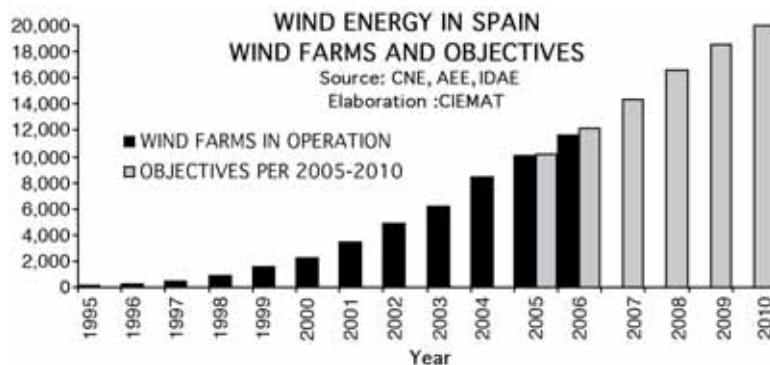


Figure 2 Wind energy in Spain: Wind farms in operation and PER objectives for the year 2010.

**Table 2 National and autonomous-region targets for wind energy at 2010**

Autonomous Region	Year	Regional Target (MW)	National Target (MW)
Andalucía	2010	4,000	2,200
Aragón	2012	4,000	2,400
Asturias	2010	900	450
Baleares	2015	75	50
Canarias	2011	893	630
Cantabria	2010	300	300
Castilla y León	2010	6,700	2,700
Castilla - La Mancha	2011	4,450	2,600
Cataluña	2010	3,000	1,000
Extremadura	2010	225	225
Galicia	2010	6,300	3,400
Madrid	2010	50	50
Murcia	2012	850	400
Navarra	2011	1,530	1,400
La Rioja	2011	660	500
Comunidad Valenciana	2010	2,359	1,600
País Vasco	2019	624	250
TOTAL		36,916 MW	20,155 MW

39,000 MW by 2010 through 2012. Taking this situation into account, there is an open discussion to define new targets and describe adequate infrastructures to achieve them.

The total amount of electricity generated by wind energy was 23,372 GWh, about 9% of the total electricity demand in 2006, according to the data from Red Electrica de España, the Spanish transmission system operator, (3). These values make wind power the fifth largest electricity generation technology in Spain after coal, nuclear energy, natural gas, and hydropower. The monthly electricity generated by wind is shown in Figure 3.

The year 2006 was less windy than previous years, and the average equivalent hours of full production were fewer than 2,000 hours for the total wind farms in Spain. Together with the lower price of wind-generated electricity during 2006, this implies an important reduction of the benefits of the sector during the year. Nevertheless, the sector remains very active and in continuous growth. On some occasions, wind-generated electricity in Spain has covered more than 25% of total electricity demand.

The maximum hourly production by wind energy of 8,140 MW took place on 8 December 2006. A full 31% total electricity production at that particular moment was supplied by wind energy. The maximum peak demand during the year took place on 30 January 2006 when the total power produced was 42,100 MW. At this time, wind energy supplied about 8% of the total.

Wind power helped decrease fossil fuel imports, achieving savings of more than 730 million € in 2006, mainly due to the reduction in purchases of natural gas and coal. In addition, the Spanish economy saved around 18 million tonnes of CO₂ and did not have to purchase emission permits that would otherwise have been required in 2006. This represents nearly 360 million € of savings, assuming a price of 20 €/tonne of CO₂ emissions.

Wind power is presently the renewable energy that makes the greatest contribution to the energy supply in the country (around 76% of the total renewables contribution comes from wind). Wind-sector analysts are optimistic that Spanish wind energy targets will be met.

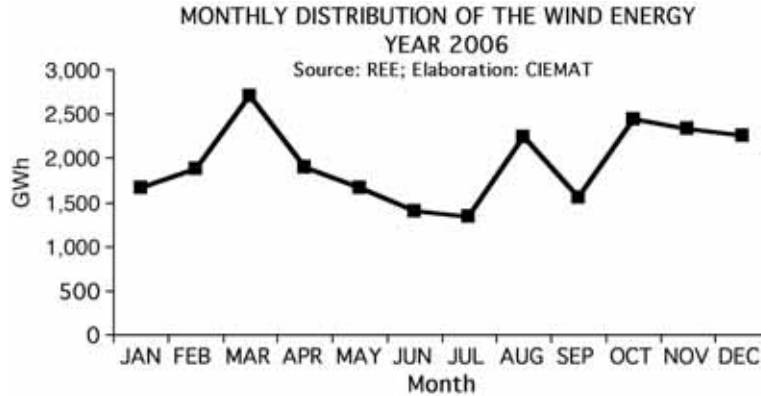


Figure 3 Electricity generated by wind, monthly distribution.

3.0 Benefits to national economy

3.1 Market characteristics

Wind power development and promotion is a well-established activity in Spain. The fact that 11,600 MW are in operation shows the experience and maturity of the sector.

So far, wind farm promotion is carried out by very big entities: utilities, finance companies, civil engineering firms, and industrial developers. There is a strong tendency to consolidate activities among the big promoters of wind farms in Spain; big companies accumulate the main wind farms, and big developers purchase the smaller ones. This process was particularly important for 2006, as remarkable financial operations have taken place in the wind business.

An important new development has been the increasing interest in the foreign market. During 2006, about 1,200 MW of wind turbines “made in Spain” have been installed in wind farms in the United States, China, Australia, and France, among other countries. Following this tendency, Spanish wind developers have begun to promote strategies for establishing even more wind installations in foreign countries.

The distribution of wind installations in Spain is shown in Figure 4.

Galicia, in northwest Spain, has the most installed wind power, with a total of 2,600 MW, including an increase of 233 MW in 2006. Castilla La Mancha is second with 2,310 MW (including an increase of 293 MW in 2006). Castilla León in central Spain has an important amount of wind energy—2,120 MW, including an additional 309 MW during 2006. In relative terms, the most spectacular

growth occurred in Valencia in the Mediterranean region, where a new 280-MW wind farm means an increase in capacity of 1,300% from the previous year. Growth rates for Andalucía and Cataluña were 57% and 36%, respectively.

Figure 5 shows the market share of wind farm developers at the end of 2006.

Regarding ownership of installed wind power in Spain, the main utility (Iberdrola) maintains the leading position with a total value of 30.7% of the total wind generating capacity. Acciona has the second position with 17.5% of the wind farms, followed by Neo Energía with 8.4%, Endesa (another big utility) with 7.5%, Eufer with 3.4%, Gas Natural with 3.2%, Enerfin with 2.9%, and others. As mentioned previously, the tendency toward mergers of Spanish wind farms is increasing. It is important to note the financial operations performed by Neo Energía in 2006; it has taken ownership of the wind farms of the smallest promoters DESA and CEASA.

The international nature of the sector can be appreciated in Spain; big foreign investment groups have acquired Spanish wind farms. Their interest is yet more proof of the success of the development of the wind energy.

3.2 Industrial development and operational experience

Regarding manufacturers, Gamesa and its subsidiary company Made (60.4%) remains the leader of the sector in Spain and has a dominant position in the total market. Vestas (which has mainly models from the old Neg-Micon company) is also present in the Spanish market, with a share of 13% of the total capacity. The Spanish manufacturer Ecotecnia maintains represents 8.3% of the total installations.

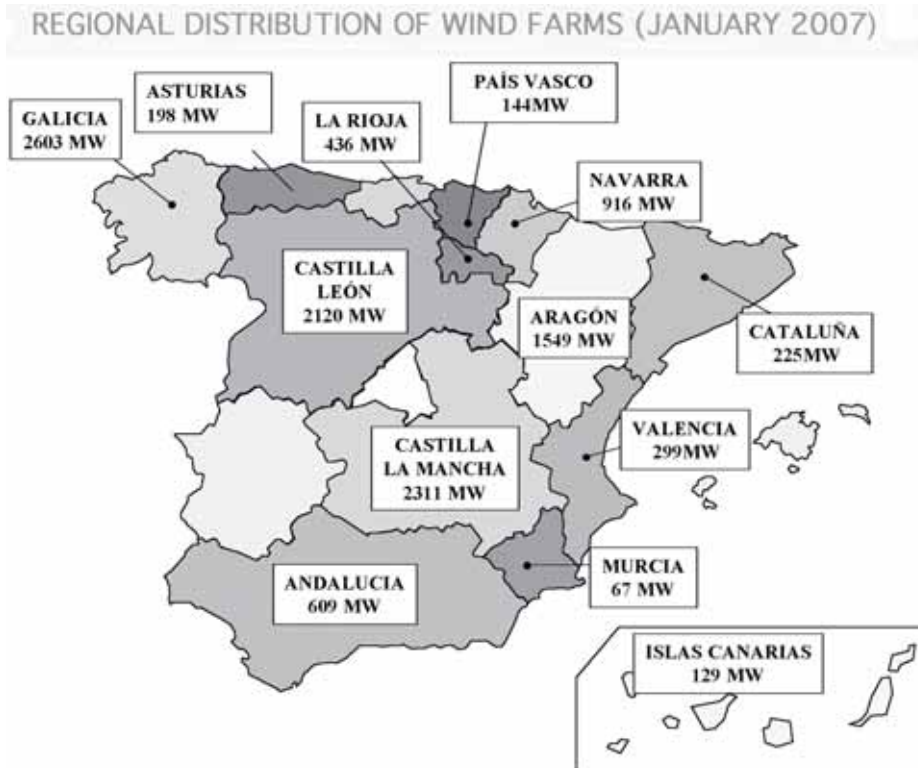


Figure 4 Regional distribution of wind farms.

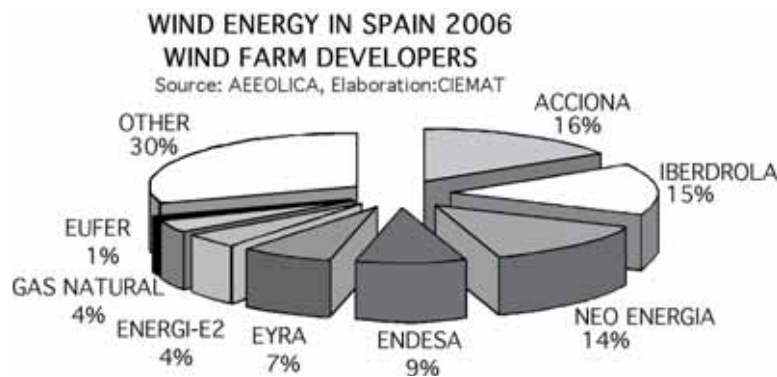


Figure 5 Regional distribution of wind farms.

General Electric (6.6%), Acciona (4.4%), and Navantia-Siemens (4.0%) are also present in the market (Figure 6).

It is important to note the merger of two new manufacturers: Acciona Wind Power, which is part of the Acciona group, one of the major developers of wind farms in Spain, and Mtorres, a company with

activity in the aeronautical field. Mtorres has a 1.7-MW upwind, direct-drive, multi-pole generator, that is pitch regulated.

New wind turbines installed in Spain are becoming larger. The average size during 2006 was about 1.4 MW; during 2005, it was around 1.3 MW; and during 2004, it was a little higher than 1 MW.

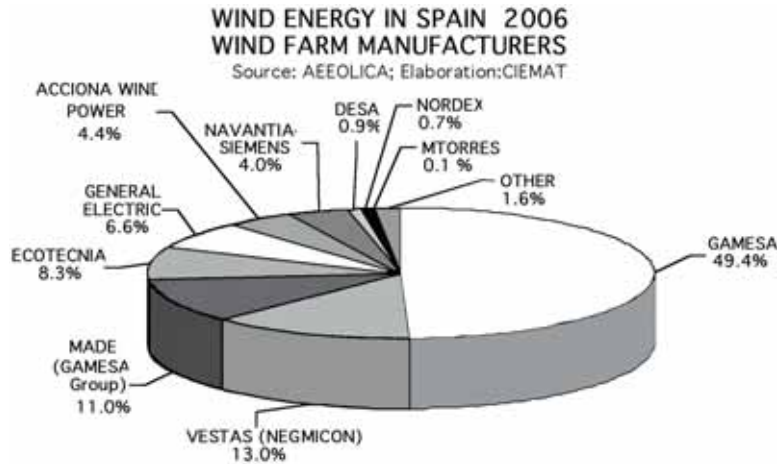


Figure 6 Wind turbine manufacturers represented in Spain.

In Figure 7, the increase in wind turbine size over the years is shown.

3.3 Economic details

A study by AEE and APPA shows the tendency of wind turbines to increase in cost. The increase in size of wind turbines (in fact, the new installations use machines over 2 MW of rated power), the increase in the price of raw materials, the lack of major components, and the excess in demand have combined to increase the cost of wind energy. The average cost during 2006 was about 1,110 €/kW. The forecast of operation costs for the new wind farms and the estimates of production are also part of the study. Study results are shown in Table 3.

4.0 National incentive program

The promotion of renewable energies has been a stable national policy for several years. All political parties have similar policies regarding support of renewable energies.

The main tools within this policy at a national level are:

- A payment and support mechanism enshrined by the parliament through Electric Act 54 /1997: Producers of renewable energy 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.

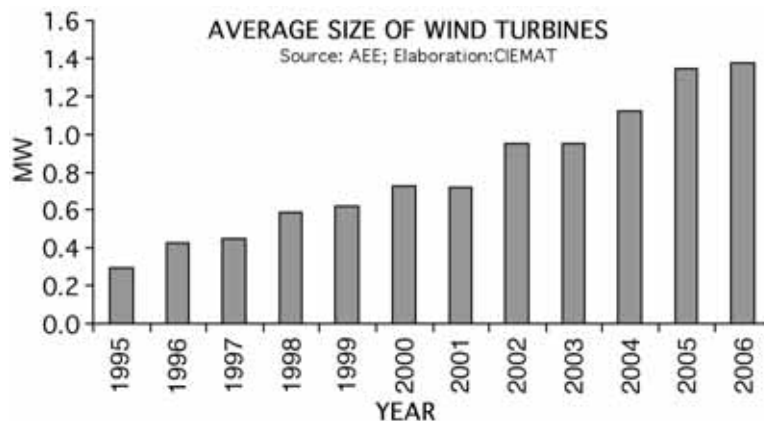


Figure 7 Average size of wind turbines installed in Spain since 1995.



Figure 8 Carballeira Wind Farm in Spain.

Table 3 Evolution of installation costs and electricity production of wind farms in Spain								
Parameters	Unit	2004	2005	2006	2007	2008	2009	2010
Average Size of Wind	MW	35	35	35	35	35	35	35
Equivalent hours	hours	2241	2297	2271	2245	2200	2150	2100
Yearly variation	%		2.50%	-1.13%	-1.14%	-2.00%	-2.27%	-2.33%
Total Cost	X1000€/MW	1005	1057	1110	1175.10	1233.41	1290.50	1350.55
Yearly variation	%		5.17%	5.01%	5.86%	4.96%	4.63%	4.65%
Exploitation and manage, costs	€/MWh	15.72	16.58	18.20	18.61	19.10	19.64	20.19
Yearly variation	%		5.47%	9.77%	2.25%	2.63%	2.83%	2.80%

Source: AEE, APPA. The position of Spanish wind sector in the modification of the RD436/2004



Figure 9 Faladiora Wind Farm in Spain.

- The Renewable Energy Plan, including mid-term objectives for each technology (PER 2005–2010).

Royal Decree 436/2004, which regulates the price of electricity from renewable sources in Spain, has been a very useful instrument for the development and consolidation of wind energy in Spain. The law allows electricity generated by wind farms access to the electricity market. Remuneration to wind farms consists of the market price plus a bonus established as a percentage of the named “average reference tariff” (an indicator related to the total cost of the overall electrical system).

The increasing price of electricity in Spain has caused the remuneration to wind farm operators directed by this procedure to reach high values in 2005 and 2006. For instance, the average price received by wind farm operators that used the market option in 2006 was 91 €/MWh. The benefits of wind investment have been remarkably high.

In mid-2006, Spanish authorities began to write new draft rules concerning renewable energy sources (wind energy in particular) in order to limit the price received by wind farm operators. The general rules of the draft establish a maximum value to be paid to the wind farm owners when the electricity price is excessively high, and a minimum value as a guaranteed compensation when the price is low. The law’s intent is to guarantee sufficient profit for

wind energy investment without a significant increase in the total cost of the electrical system.

An example of the prices obtained according to the new draft is described in Table 4. For instance, in the case of a wind farm that produces more than 5 MW during the first five years of its operation, the maximum price to be paid to the developer would be 84.7 €/MWh, and the minimum value would be 67.7 €/MWh. Table 4 shows a complete description of the payments.

The new draft rules contain the first mention in Spain of wind energy in offshore wind farms. The draft rules define a bonus of 84.7 €/MWh over the market price and specify that the maximum price to be paid will never exceed 164 €/MWh. No minimum level is defined. Although the wind energy sector has had an overall positive reaction to this regulation, it has expressed the opinion that the payments are not enough to start the offshore market in Spain. Actually, the discussion between the authorities and the industrial sector is still going on. The main criteria used for the development and administration of the rules is to guarantee sufficient remuneration to permit fulfillment of the PER targets in the Renewable Energy Plan (PER 2005–2010).

5.0 R, D&D activities

The Renewable Energy Plan (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 Spanish manufacturers is to make efforts leading toward the following goals:

- Development of advanced systems to control the quality of the power fed into the grid, in particular optimizing how wind farms behave regarding perturbations on the grid
- Development of wind turbines with unit power outputs of more than 2 MW and the incorporation of new materials
- Adaptation of high-capacity wind turbines to the more demanding technical requirements of offshore applications
- Implementation of demonstration offshore wind farms.

The National Energy Program for Scientific Research, Development and Technological Innovation (2004 to 2007) centralized Spanish R&D projects in the energy sector. The target areas defined



Table 4 New draft for the payment of the electricity generated by wind

		< 5 MW		> 5 MW		
			2007		2007	2008
			€/MWh		€/MWh	€/MWh
Tariff	First 15 years	73.10	First 5 years	73.10	74	
	Rest of the life	61.20	Year 6 - year 15	66.20	67	
			Rest of the life	61.20	62	
Bonus	First 15 years	17.40	First 5 years	17.40	17	
	Rest of the life	5.50	Year 6 - year 15	10.50	10	
			Rest of the life	5.50	5	
Maximum level	First 15 years	89.10	First 5 years	84.70	86	
	Rest of the life	77.20	Year 6 - year 15	77.80	79	
			Rest of the life	72.80	74	
Minimum level	First 15 years	70.20	First 5 years	67.70	69	
	Rest of the life	58.30	Year 6 - year 15	60.80	62	
			Rest of the life	55.80	56	
Absolute lower level		52.80		50.30	51	
Maximum value		71.70		67.30	68	

in the plan for wind energy projects included such topics as these:

- Development of infrastructure and tools for design of new wind turbines
- Improvement of efficiency, availability, reliability, maintenance, and security of operation
- Integration into the electric system
- Design of wind turbines for special sites
- Development of new technologies and systems for the environmental integration of wind energy systems.

Inside of a broadly defined program to improve the technological capabilities of Spain, new strategic lines have been defined, and one of them is the Strategic National Consortiums for Technological Research. The main objective is to increase co-operation between the public sector and the private sector. To do that, a budget for 50% support is specified to start extensive industrial research lines. Participating private and public research groups must sign contractual agreements to maintain at least four years of co-operation.

For wind energy, an initiative called Windlifter 2015 has been started. According to this proposal, the Spanish manufacturers Gamesa and Ecotecnia are undertaking an industrial research project aimed at keeping Spain at the forefront of wind technology. The expected budget is around 40 million €. Research objectives include a better understanding of

large wind turbine design and shortening the time needed to bring new products to the market.

As part of this research, Windlifter 2015 aims to produce a comprehensive simulation of a large wind turbine. This model will be validated and fine-tuned by testing complete wind turbine and critical components (generators, gearboxes, converters, housings, yaw systems, and so on) with a power rating of 5 MW. This will allow extrapolating proven performance data to outputs in excess of 10 MW. Universities and research and technological centers are involved in the initiative. The Spanish Wind Energy Association estimates that 90 million € will be spent by the wind sector (including both public and private research groups) in R&D activities.

During the last call for proposals at the end of 2006, a new consortium called for the development of technological research in the field of the offshore application of the wind energy. The proposal, called Eolia, was presented by the company Acciona Energía. Its main focus is the study of wind technology for deep-water application. A decision about the project will be made in 2007.

In the field of small wind turbines, a national strategic project was approved. The project, called Minieólica, includes all the companies involved in the sector—small wind turbine manufacturers, technological centers, and so forth. The main aims of the proposal are:



Figure 10 Installation of wind turbine blade.

- Creation of specific R&D programs for small wind turbines
- Implementation of a certification system useful for small wind turbines
- Establishment of demonstration projects
- Definition of support mechanisms.

The created network called Reoltec (Spanish Technological Wind Sector Network) continues the activities started in 2005. The initiative is promoted by AEE, and its main objective is to maintain the positioning of the national industry through the reinforcement of technological knowledge and the selective diffusion of results and experiences. A work plan that covers short-term (2005 to 2007) and medium-term (2007 to 2010) strategies has been issued.

The main research challenges for wind energy in Spain are to reduce the cost of wind-generated electricity, increase the availability of wind turbines, and, in general, increase wind turbine size

and redesign wind turbines for special conditions (for example, offshore, extreme climate, and weak electrical networks).

6.0 Next term

The Spanish wind power industry is a solid, established sector. Over the past four years, average installed generating capacity has grown by about 1,500 MW/yr. The objective of Spain's PER for wind power is to reach 20,155 MW of total capacity by the end of 2010. The total objective for the regional plans is more than 39,000 MW (nearly double the national objective) for the years 2010 to 2012. The national legislative framework, regional regulations, and the maturity and competitiveness of the technology used have made it possible to achieve these targets.

Two important steps must be taken to guarantee the fulfillment of wind energy objectives. First,



Figure 11 Transport of wind turbine nacelle.



Figure 12 Factory for wind turbine blades. Gamesa.



Figure 13 Test site for small wind turbines on a snowy day.

a study of the alternatives is called for in order to increase wind-power penetration in the electricity system in a way that is compatible with the system's security. Second, it is essential that the current legislative framework be retained without substantial changes between now and 2010.

Progress on offshore projects has been slow. During 2006, there were two positive advances—definition by the authorities of the content of the environmental impact study for offshore application and a special mention of offshore wind farms in the new draft rules for the electricity tariffs.

During 2006, only a few discrepancies occurred in connection with the stated objectives of the Spanish PER. Nevertheless, it is necessary to be alert to guarantee fulfillment of the plan's objectives.

7.0 References

- (1) Spanish Wind Energy Association (Asociación Empresarial Eólica), www.aecolica.org; Spanish Association of Renewable Energy Sources Producers (Asociación de Productores de Energías Renovables), www.appa.es.
- (2) Spanish Renewable Energy Plan 2005–2010, Madrid, August 2005. Instituto para la Diversificación y Ahorro de la Energía (IDAE).
- (3) Red Eléctrica de España (Spanish Electricity System). Spanish Transmission System Operator advance report for the year 2006, www.ree.es.

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