Chapter 25
Portugal

1.0 Introduction

Portugal has its most valuable energy asset in renewable energy resources. It is one of the countries of Europe with a high level of sun radiation, considerable vegetable and animal biomass potential, and a good wind resource. Portugal also has available hydro resources and possibilities for ocean energy (when that technology reaches maturity). Although Portugal still depends largely on foreign countries for oil, gas, and coal, especially for the transportation sector, in recent years the country has taken a clear path towards a sustainable, renewable-based, electricity generation. The energy contribution and the investments in the renewable energies are becoming more relevant every year as a strategically sector for the development of the country's economy.

By the end of 2007, Portugal had installed 7,409 MW (1) of renewable-based power plants. That capacity has generated an estimated 18, 207 GWh (2) during 2007. Renewable sources have contributed an estimated 36.4% of the total electricity demand, one of the highest percentages in Europe. The goals defined for 2010 and 2013 of 39% and 45% of the national electricity demand generated from RES, respectively are within reach.

In 2007, fewer wind parks were installed than in previous years. However, the second phase of the public call for grid connection of wind power capacity, started in 2005 was concluded in August 2007. As a result, 400 MW were added to the 1,200 MW attributed in 2006. It is expected that wind energy capacity growth will increase again in the next few years.

2.0 Progress Toward National Objectives

The wind and hydro resources are considered the most valuable energy resources in Portugal, and the ones that will have a higher contribution to the national and European targets, both for 2010 and 2020. Until 2006, the successive Portuguese governments set up ambitious targets stating that 5,100 MW of wind capacity should be installed in Portugal by 2013 (RCM 169/2005). If this elevated goal is achieved, the Portuguese electrical sector will be among the top three power systems in the world with a high wind energy penetration (approximately 20% of total consumption).

The high wind energy penetration forecast will require careful design of the Portuguese system. This will be especially important because of the peripheral location of Portugal and the much less interconnected network relative to the central European countries.

With that in mind, the Portuguese government sponsored studies which indicated that added reversible hydropower capacity would not only contribute to the national renewable energies goals, but would also enable easy wind power integration (Figure 1 and 2). In Portugal there is currently 4,945 MW of hydropower capacity. To fulfill the 2020 targets another 2,055 MW are needed to total 7,000 MW. At least 5,354 MW of hydropower capacity are needed by 2011. The study - "Plano Nacional de Barragens de Elevado Potencial Hidroelélictrico (PNBEPH)" - was published in September 2007 by the Portuguese Government and resulted in the definition of ten new hydroelectric power plants for deployment. These are Almourol,

Table 1 Key Statistics 2007: Portugal	
Total installed wind generation	2,125 MW
New wind generation installed	427 MW
Total electrical output from wind	4.036 TWh
Wind generation as % of national electric demand	8%
Target:	3,750 MW by 2010 5,100 MW by 2013

Alvito, Daivões e Foz Tua, Fridão Girabolhos e Gouvães e Padroselos, Pinhosão e Vidago) totaling approximately 1,100 MW and having an estimated yearly production of 1,630 GWh/y. It is of notice that seven of them with installed capacity of 807 MW will be reversible.

The hydroelectric power plants already in the project or construction phase are: Picote II with 231 MW; Bemposta in Douro river with 409 MW; Ribeiradio in Vouga river with 70 MW; Baixo Sabor in Sabor river with 170 MW (reversible); and Alqueva II in Guadiana river with 260 MW. This later is of special notice since two reversible groups to support the high wind penetration and having a pumping equivalent capacity of 2,110 MW will be available in 2011.

Figures 1 and 2 illustrate the natural compatibility between the wind generation - that will exceed the consumption both in wet and dry windy days in 2011 - and the reversible hydro power stations. With these new hydropower stations, Portugal is preparing for the penetration close to 20% expected in 2013.

In 2007, the amount of new wind capacity installed in Portugal was slightly lower than in previous years. According to the national Directorate for Energy and Geology (DGEG), 427 MW of capacity, corresponding to a growth rate of 25%, was installed and commissioned during 2007. By the end of 2007, 2,108 MW were installed in mainland Portugal, and 17 MW were installed in the archipelagos of Madeira and Azores. These values correspond to 2,125 MW

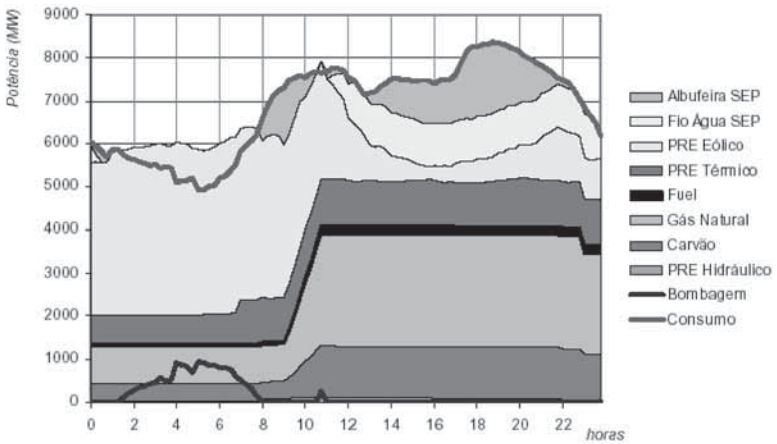

Figure 1 Scenario of generation profile for a dry windy day in 2011.

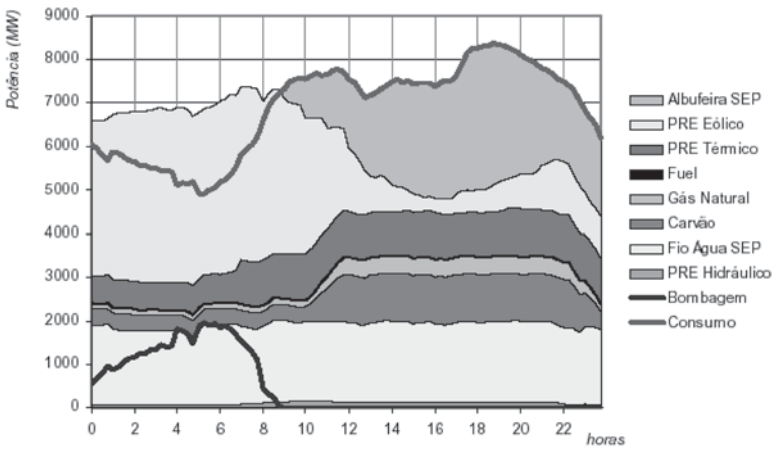

Figure 2 Scenario of generation profile for a wet windy day in 2011.

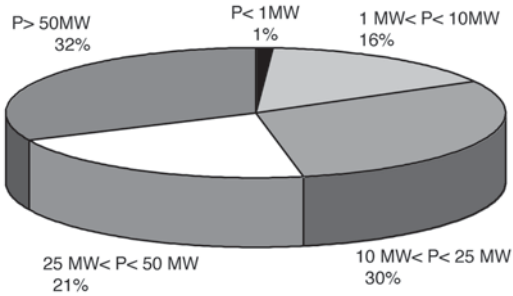

Figure 3 Wind parks capacity classification.

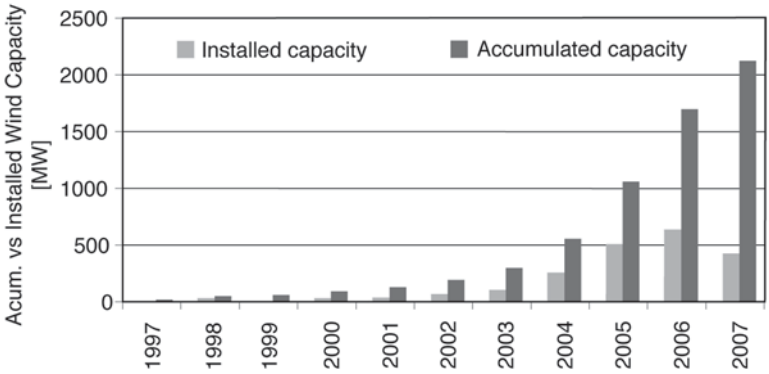

Figure 4 Accumulated vs. installed wind capacity.

in the whole territory, representing already 56% of the 2010 goal.

The wind parks installed in 2007 are characterized by large nominal power – 32% of them being above 50 MW, as shown in Figure 3. The wind capacity installed and accumulated is presented in Figure 4.

The electric energy generated from the wind capacity installed through the end of 2007, was 4,036 MWh. That represented, approximately, 8% of the national demand, the highest energy penetration experienced by the country so far. Figure 5 depicts the wind capacity installation trend through 2010 that will fulfill the Portuguese wind power goals under the 77/2001/EC Directive for Renewable Energies. Figure 6 shows the wind energy generation until the end of 2007.

Assuming an annual rate of capacity growth of approximately 20% through 2010, and grid capacity allocated for wind park development, there is not much doubt that the goals established for this sector will be achieved.

The wind capacity is not evenly distributed in the Portuguese mainland territory. By analyzing Figure 7, one can see that the northern and coastal areas have more wind parks. This is because of the wind potential of these areas and also due to the availability of the transmission lines to collect the generated energy.

3.0 Benefits to National Economy

3.1 Market characteristics

During 2007, the unit cost of wind turbines was estimated to be in the range of 950 to 1,110 €/kW. Cost depends on the turbines' characteristics and/or the origin country of manufacturer. Contracted O&M has averaged approximately 13% or 15% of the investment cost, for the last decade of the wind power plant operation.

A new line of manufacturers is now entering the wind energy market and there is growing interest by developers to invest in other "niches" of this renewable energy sector. One of these is the micro-turbines market for the urban and built environment which has gained interest with the publication of new legislation at the end of 2007 (Dec. Law 363-2007, 2nd November). This Dec.-Law regulates the capacity of domestic renewable projects to connect to the electric grid, as well as the tariffs that apply to each renewable source. The legislation has as

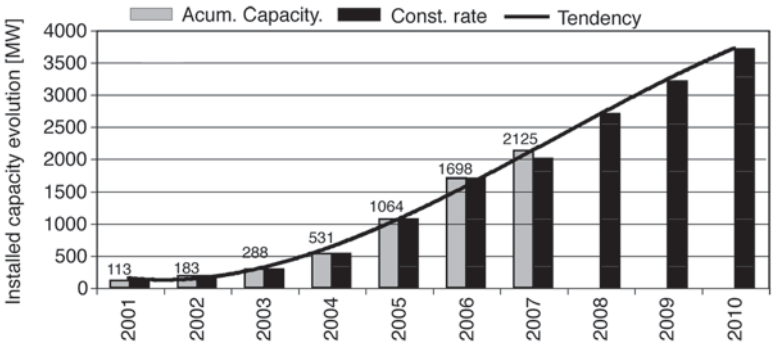

Figure 5 Wind capacity trend (2001-2010).

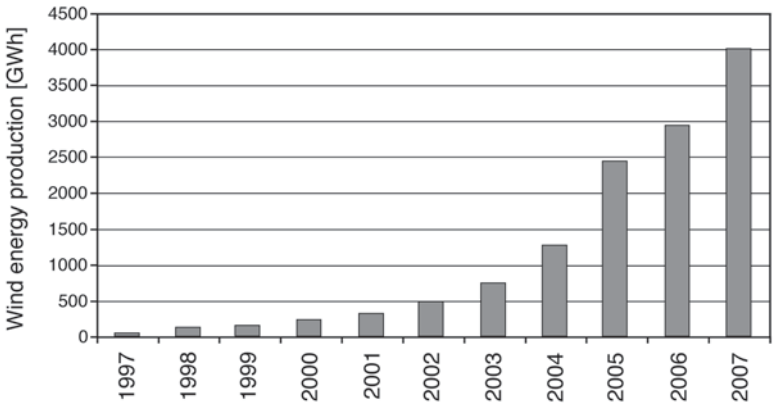

Figure 6 Wind energy production.

main objective to simplify the licensing process for potential producers/consumers by using Internet registration and licensing. This Dec.-Law has several positives aspects while it encourages the public in general to become an electricity producer, it simplifies the permitting process and contributes to unloading both the distribution and transmission grids.

Since Portugal is part of the Iberian Peninsula, the economic relevance of the sea is very high. It is thus natural to think of offshore wind development as the next step for the wind energy sector in this country. In 2007, a few developers and utilities started to investigate the feasibility (energetic and economic) of performing measurement campaigns and installing offshore wind parks. Some demonstration projects, both national and European, are about to start, mainly in the area of wind resource assessment, detailed bathymetry, and sea bed characterizations.

3.2 Industrial development and operational experience

During 2007, more than 200 wind turbines were installed, with average nominal power of 2.6 MW (source DGEG). The distribution in the Portuguese market of the different manufacturers was not as varied as in the previous year. The largest share was attributed to ENERCON, the first wind turbine manufacturer to set up an organization and produce relevant components of wind turbines in this country. This new industrial capability of the country is an outcome of the public call opened in July 2005, where gaining access to the transmission network was dependent on (among other factors) the investment and creation of jobs in deprived regions. The distribution of installed capacity by the manufacturer is shown in Figure 8.

Early in 2007, a national project to develop a small wind turbine was started. In this project the turbine design was developed by the

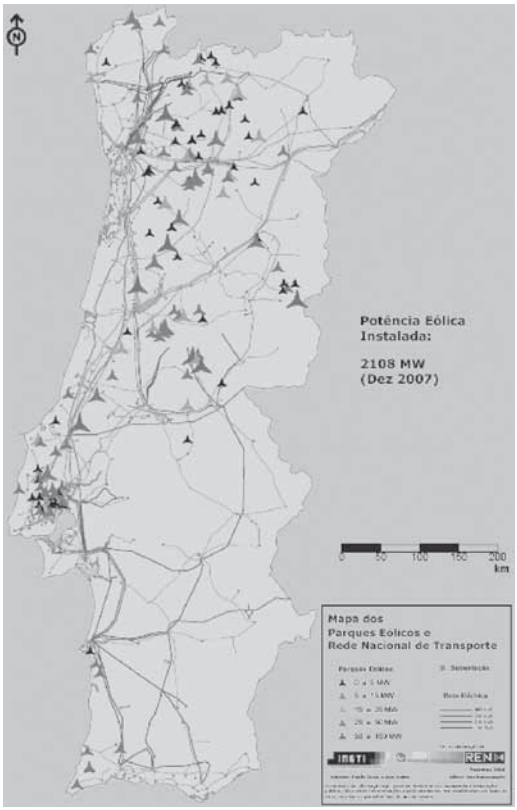

Figure 7 Wind capacity installed in mainland Portugal with the wind parks' location and the transmission network.

National Institute for Engineering, Technology and Innovation I.P. (INETI) and the manufacture of the components was contributed by the Portuguese industry. This project named TUR-Ban is the result of the national government policy and strategy to encourage the micro-generation of electricity by renewable sources in Portugal, the already mentioned Dec.-Law nº363/2007.

Another result of the public call for wind capacity was the strong interest showed by some foreign industries to establish production facilities in Portugal in the near future. In November 2007, a technological complex from the German company Enercon GmbH began activity in Viana do Castelo, (Figure 9) a city in the northern part of Portugal. This complex manufactures most of the wind turbine's components, both for the national market and for export. The complex also integrates with other Portuguese companies already established in the wind sector, namely the high-quality tower manufacturers and the specialized construction and electrical components companies.

Also during 2007, wind energy international consultancy companies and wind energy developers, as Garrad Hassan and Partners and Airtricity have started their activity in Portugal.

All the existing and planned facilities, both in the industrial and the consultancy sector, will benefit from experienced Portuguese workers, because wind power has been a relevant sector

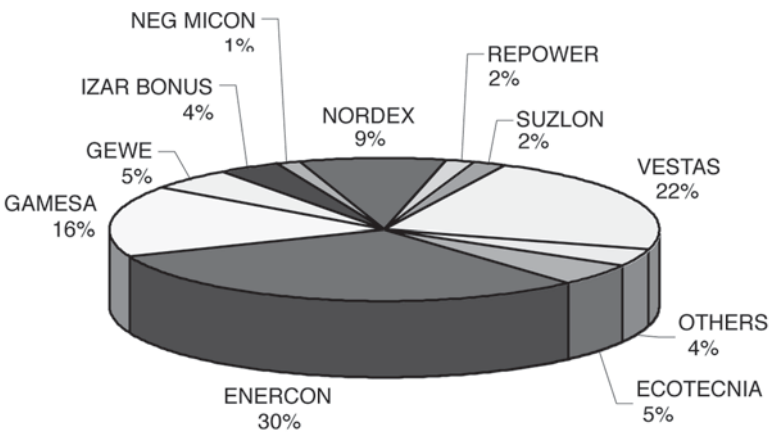

Figure 8 Distribution of the installed wind capacity by manufacturer.

in the economy for a number of years. These facilities promise continued job creation in interior remote areas. As has already been reported in most European countries with large wind development, specialized workers such as engineers for new developments are becoming hard to find.

3.3 Economic details

In Portugal, the environmental regulators are very rigid about wind energy, and prefer large wind turbines (> 1,500 MW) over the smaller ones. Also the very complex orography that characterizes mainland Portugal and the fact that most of the suitable sites for wind energy exploitation are already taken and/or under project leads to the installation of turbines with high rated capacity.

The total wind farm installation costs are estimated to be between 1200 to 1400 €/kW, and annual maintenance is about 15% of annual income.

Concerning renewable energies tariffs, in 2007 no new legislation was published regarding conventional wind parks. The Dec. Law 33 – A/05, is used to define which tariffs to apply in the operating projects. Also the price for energy remains unchanged since 2006 (Figure 10), for wind parks with connection permits granted before 2005.

For micro-generation, the actual tariff for wind energy production established in the recent legislation is 455 €/MWh, corresponding to 70% of the overall tariff (650 €/MWh) applicable to PV systems.

4.0 National Incentive Programs

During 2007, a call in the form of a QREN program was opened on 15 November with the final date for participants to present their projects at the end of February 2008. This program was not specifically directed to the wind energy sector, but during this year was the only national program to support R,D&D in Portugal. Besides this, a call in the European Union Seventh Framework Programme (FP7) was opened for the wind energy sector. Portuguese institutions are participating in relevant projects namely the five-year project Norsewind (EC FP7-2008) to run from 2008 to 2013 where INETI is participating. Another relevant governmental financing program, PRIME/MAPE, was released in 2007 with funds covering 110 wind energy projects.

Figure 9 Technological complex in Viana do Castelo.

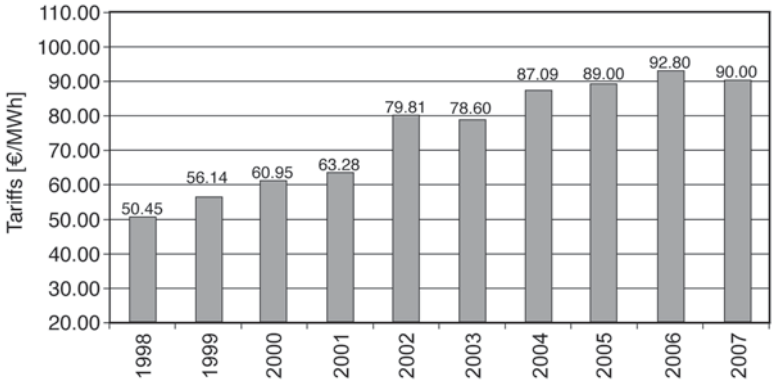

Figure 10 Evolution of wind energy tariffs in the period 1998–2007.

5.0 R, D&D Activities

5.1 National R, D&D efforts

In Portugal, the R, D&D activities related to wind energy are located mostly in Lisbon and Oporto. In 2007, Oporto gained the Garrad Hassan group, a consultancy company with some activity in the wind energy market and in R, D&D. The majority of R,D&D groups are in academic and/or research institutes. Most of this work is financed by their own research projects, which are usually included in international, European, and national programs, as the mentioned above. Wind energy developers and consultancy entities also participate in academic projects mainly in those concerning doctoral and postdoctoral projects, contributing to R, D&D development in a small way.

INETI, a part of the Ministry of Economy and Innovation, is one of the most active public R, D&D organizations in wind energy research and technology. Its activities are partially financed by the national government and by wind energy companies (consultancy contracts).

In the north of Portugal, the main institutes dedicated to R, D&D are the Faculty of Engineering of the University of Porto (FEUP) through the Research Centre for Wind Energy and Atmospheric Flows (RCWEAF) and the associated laboratory INESC-Porto (Computers and Systems Engineering Institute of Porto), which is part of the research network established by the Portuguese Foundation for Science and Technology (FCT).

The main R, D&D projects underway in Portugal include the following:

- ANEMOS plus (EC) – INESC Porto:
- Cup anemometer correlation with wind satellite data for offshore purposes (input to NORSEWind, EC FP7-2008) – INETI;
- Applying research on the use of hydro storage as regulation for excess wind production; – INESC Porto;
- Remote control of wind park clusters using DSO by TSO request – Several wind energy developers;
- Using wind turbine as FACTS – INESC Porto;
- TURBan 2.5-kW small wind turbine project. A national project financed by DEMTEC (70/0201) that consists in the development of two prototypes of small and low-cost turbines for urban use – INETI.

5.2 Collaborative research

In the TURBan project, a prototype small (2.5-kW) wind turbine with horizontal axis is in the test phase. This turbine has a 2.3-m rotor diameter and is designed for a 10 to 15 m high tower (Figure 11).

Also the wind offshore atlas project is under way. Its offshore measurement campaign has been going on in Berlenga Island, since November 2006. New sites for offshore measurements are also under study along the Portuguese coast.

6.0 The Next Term

During 2008, the Portuguese Wind Atlases (Onshore and Offshore) will be further developed and updated. The Portuguese Wind Atlas

Figure 11 The TURBan 2.5-kW horizontal axis prototype, developed by INETI and installed in the Gardens of S. Bento Palace, the official residence of the Portuguese Prime Minister.

(onshore) will incorporate detailed data at the municipality scale and apply methodology applicable to several foreign countries, especially from Africa and Eastern Europe. Also the offshore wind atlas project will be continued. It will include the data obtained in the measurements campaign of 2007 and will study new methodologies for offshore resource assessment.

The urban wind energy sector is now a high priority, representing a new business opportunity for the wind energy sector. This opportunity demands new methodologies for urban wind resource assessment. It also requires continued development of simple methods to reliably estimate wind energy production in very complex terrain. These are good prospects for R, D&D during 2008.

It is expected that 2008 will be the year when the offshore wind feasibility studies will begin with measurements over the sea along the Portuguese Atlantic coast.

References:

(1) Source General Directorate for Geology and Energy (DGGE).

(2) Source REN – Rede Eléctrica Nacional.

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