Chapter 26
Portugal

1.0 Introduction

Due to its location, Portugal has several valuable renewable resources for electricity production. It has a high level of solar radiation, moderate wind resource, and considerable vegetable and animal biomass potential. Ocean and hydro resources are also present, mainly the latter—although its major development took place in 2006 with the construction of large hydraulic power stations. Wave energy systems are now under development; the PELAMIS project, the first of its kind, is installed and has been functioning since the beginning of 2008.

Nevertheless, Portugal still depends greatly on foreign countries for oil, gas, and coal resources, but it is taking large steps toward sustainable renewables-based electricity generation. Government and competent authorities established several measures in recent years that created incentives to install renewable energy systems and created the conditions for economic development in the energy sector.

Regarding renewable energy systems, at the end of 2008 Portugal had about 8,151 MW capacity (1), corresponding to an estimated energy production of about 23,179 GWh. This production constitutes 43.3% of national electricity demand. However, this represents a 9% decrease in production compared with 2007, largely due to the decrease hydropower production. The goals defined for 2010 and 2013—that 39% and 45%, respectively, of the national electricity demand be generated from RES—are within reach. Wind generation at the end of 2008 was about 11% of the total national electrical demand—50.6 TWh (2).

Also, use of renewable sources for micro generation of electricity is growing and as a result of legislation published at the end of 2007 (Dec. Law 363-2007, 2 November). The public in general has responded in large numbers to the initiatives and the programs that followed. By the end of 2008, 5,768 license requests had already been granted and registered on the web site of CERTIEL (3), the governing agency, corresponding to 19,772 kW of capacity. Of these registered systems, 7,137 kW are ready for inspection and about to start production (4).

2.0 Progress Toward National Objectives

During 2008, moderate steps toward accomplishment of national objectives took place. At the end of the year, renewable energy generation capacity was 8,151 MW. Hydro systems experienced a decrease in output of about 15% compared with the previous year (Figure 1). Biomass decreased slightly, whereas wind and photovoltaic (PV) systems have increased somewhat compared with the previous year. In 2008, the first PV park was connected to the electric grid. Although total PV installed capacity has grown about 60% since 2001, it is still a small part of total renewable sources (0.3% of production compared with other renewables technologies).

Table 1 Key Statistics 2008: Portugal	
Total installed wind generation	2,819 MW
New wind generation installed	694 MW
Total electrical output from wind	5.737 TWh
Wind generation as % of national electric demand	11%
Target:	3,750 MW by 2010 5,100 MW by 2013

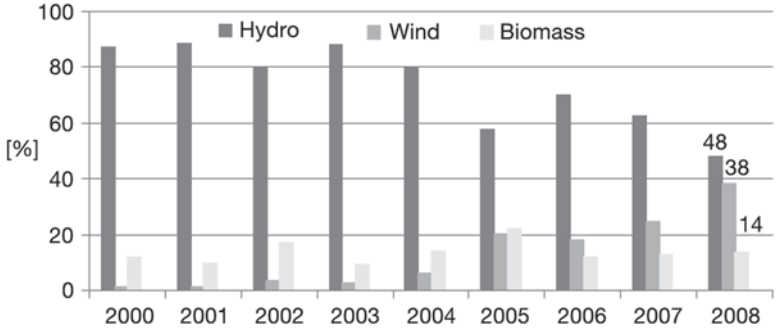

Figure 1 Evolution of the production from each renewable technology, in comparison with the overall production of renewable energy systems.

At the end of 2008, about 2,819 MW of wind energy capacity was installed, an increase of 625 MW over 2007 (Figure 2). This is a 33% increase from 2007 to 2008 (Figure 3).

Wind energy production in 2008 was 5,695 MWh in the mainland territory plus 47 MWh in the Madeira and Azores archipelagos, which together could meet about 11% of total national demand (Figure 4).

Most of the installed wind parks have capacity greater than 50 MW (Figure 5a). Figure 5b classifies wind parks in terms of production hours at full capacity.

As shown in Figure 6, the projected increase in capacity through 2010 assumes the complete fulfillment of Portugal's wind power goals under the 77/2001/EC Directive for Renewable Energies.

During 2008, the mean wind speed was above the average of the previous 10 years, representing a wind index of 1.05 for the coastal region and 1.03 for the mountainous region of mainland Portugal (Figure 7). For the Azores and Madeira archipelagos, this value is not yet available.

The increase in wind capacity occurred mostly in the northern region of the country and also in the Azores (4.5 MW). Figure 8 shows the capacity distribution by district in mainland territory.

The north of Portugal is characterized by higher values of wind energy potential. Consequently, and also due to the availability of transmission lines to collect the generated electricity, wind parks are concentrated in this region. Distribution of installed capacity is shown in Figure 9.

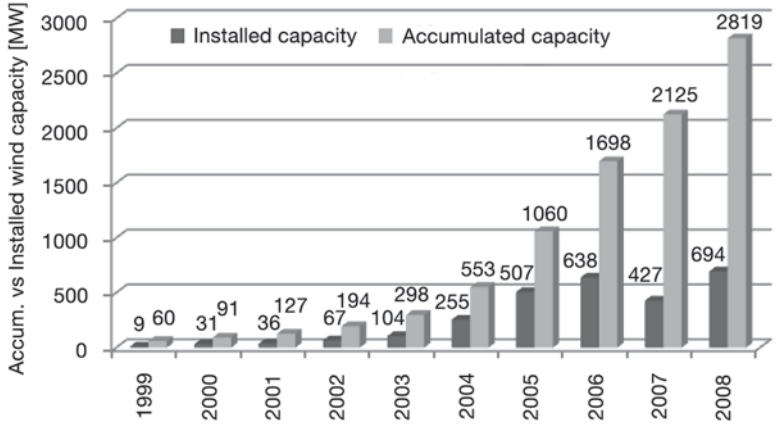

Figure 2 Installed capacity versus accumulated capacity.

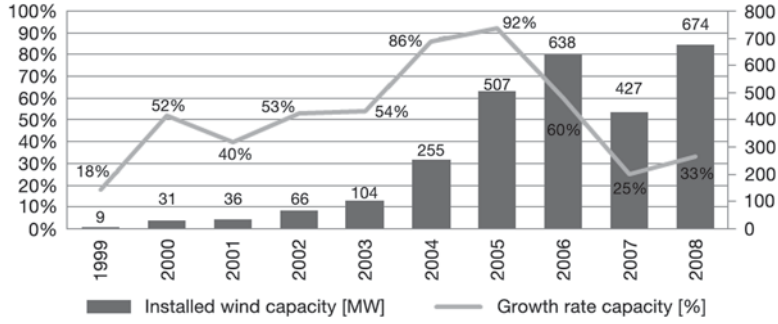

Figure 3 Installed capacity growth rate.

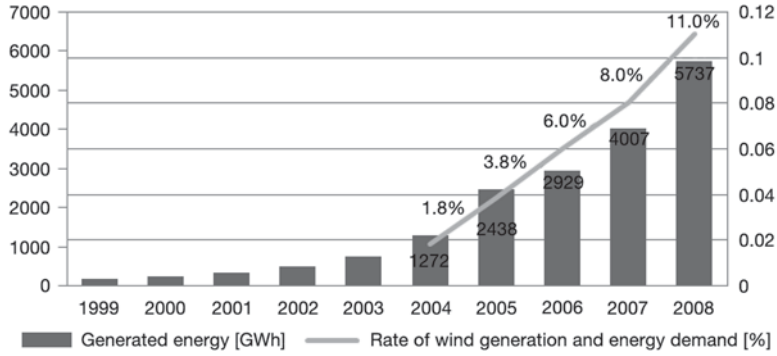

Figure 4 Wind energy generation in 2008.

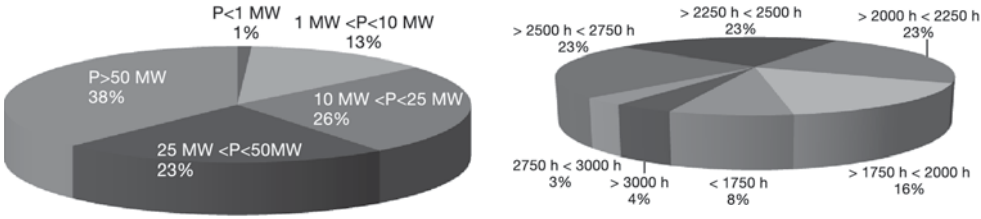

Figure 5 Wind park capacity classification (a) and classification in production hours at full capacity (b).

3.0 Benefits to National Economy

3.1 Market Characteristics

During 2008, 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 country of manufacturer. Contracted O&M is estimated to have averaged approximately 13% or 15% of the investment cost for the past decade of wind power plant operation.

Interest in the renewable energy sector is still increasing in Portugal. Several companies in this sector have been created, some of them focused on implementing microgeneration systems for domestic use. This growth has led to considerable job creation in the sector and formation of multiple opportunities to expand the sector.

During 2008, to cooperate in reaching European objectives to reduce greenhouse

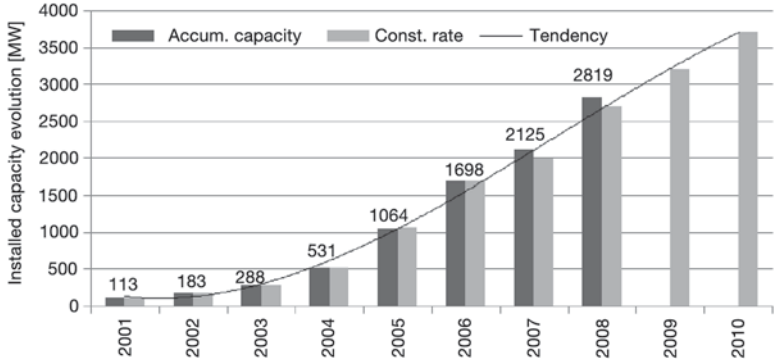

Figure 6 Installed wind capacity evolution from 2001 to 2010.

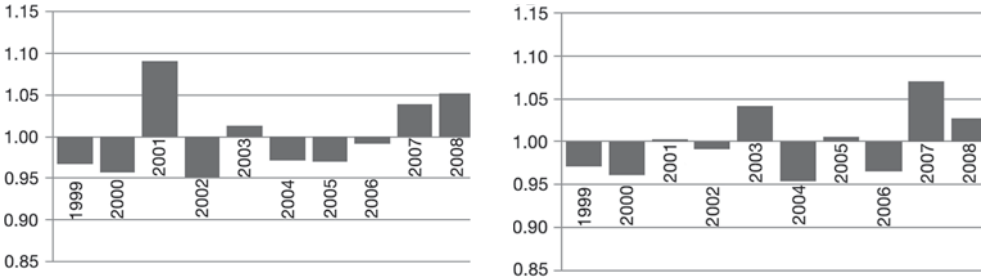

Figure 7 Wind index for (a) coastal and (b) mountainous regions of mainland Portugal.

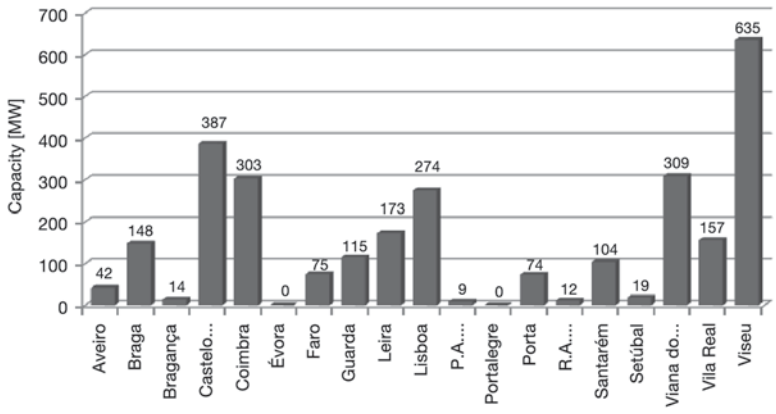

Figure 8 Installed capacity distribution by district.

gas emissions and move toward renewable energy use, the new microgeneration legislation published in 2007 (Dec. Law 363-2007, 2 November) was applied. This legislation's main objective is to simplify the licensing process for potential microproducers/consumers through Internet registration and licensing.

Application of the law began in April 2008 with the first call to register microgeneration systems. By the end of February, of the 25 MW registered, 5 MW

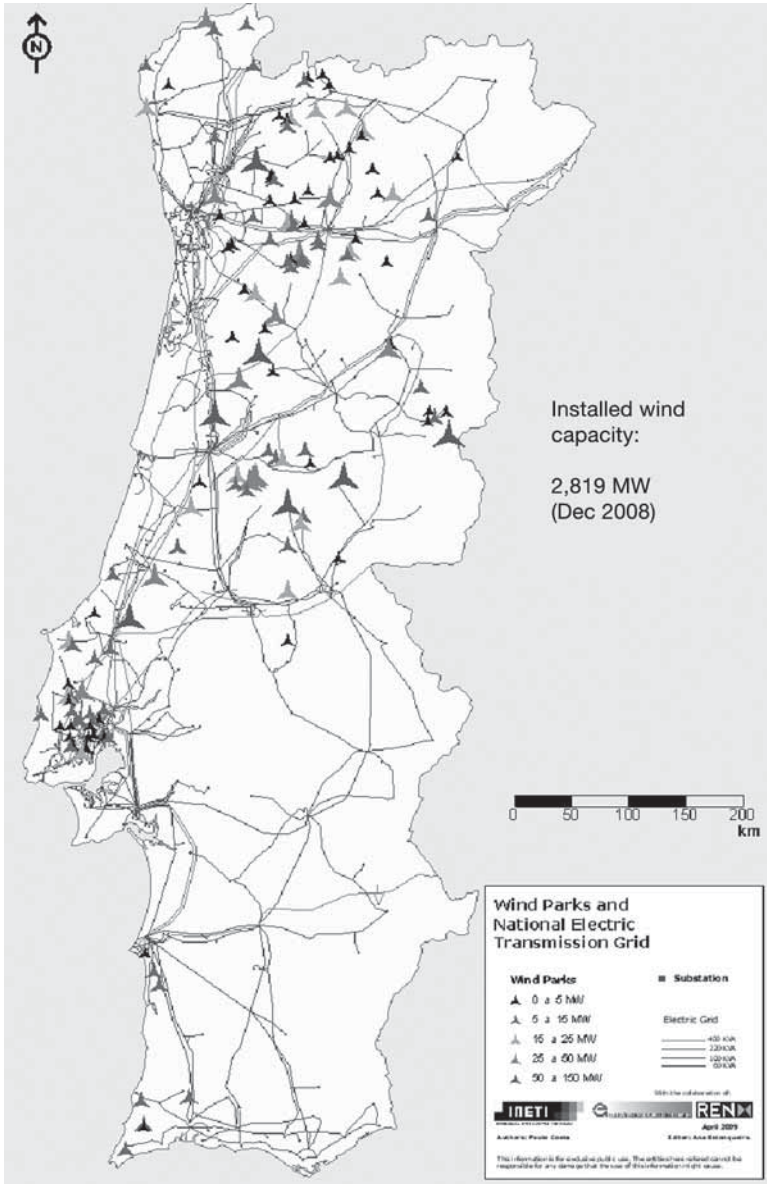

Figure 9 Wind capacity installed in mainland Portugal, showing location of wind parks and transmission network.

were already awaiting inspection. The Portuguese government's goal for 2010 is to have at least 165 MW of these small systems installed, assuming a growth rate of 20% per year.

Although application of the new legislation has been a success so far, more homeowners that have become energy producers are choosing PV over small wind turbines. This is somewhat surprising considering that the financial incentives are similar (or even better for wind) and the wind resource is quite good in some urban areas.

In the offshore wind sector in 2008, some companies examined more areas, looking for high-potential zones where offshore turbines could be used. Some companies are now conducting experiments to study the project's viability (energetic and economic).

3.2 Industrial development and operational experience

During 2008, more than 363 wind turbines were installed with an average nominal power of 1.9 MW (1). ENERCON remains the manufacturer with the largest market share in the Portuguese wind power industry. This wind turbine manufacturer, as well as Repower, produces relevant components for wind turbines in the Portuguese territory. The distribution of installed capacity by manufacturer is shown in Figure 10.

The wind power sector already plays an important role in job creation in Portugal and promises to continue to do so in coming years. This job creation has been particularly relevant in the interior regions (remote areas), since, as with most other European countries with large wind development, specialized workers for new developments, such as engineers, are becoming hard to find.

3.3 Economic details

In Portugal, 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 contract leads to the installation of turbines with high rated capacity.

The total wind farm installation costs are estimated between 1,200 and 1,400 €/kW, and annual maintenance is estimated to be between 17 and 19 million €/MW/year.

Concerning tariffs for renewable energies, in 2007 no new legislation was published regarding conventional wind parks. 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 11) for wind parks with connection permits granted before 2005.

For micro generation, and considering the new legislation being implemented there are two types of regime: general and special. In the general regime, 5.75 kW is the maximum capacity possible to install, and the tariff is equal to the cost of electricity sold under the purchasing contract. In the special regime ("additional benefits"), microproducers can install a maximum capacity of only 3.68 kW. However, to have access to these benefits, single houses must have a 2-m2 installation of solar collectors, and condominiums must have an energetic certification. The reference tariff is guaranteed for the first five years following the installation. It is defined as 650 €/MWh for the first 10 MW installed, and it decreases 5% for each additional 10 MW registered in the Registration System of Microproducers (SRM) per year (Figure 12). The amount of the reference tariff depends on the renewable energy technology used. It is 100% for solar, 70% for wind, and 30% for hydro, cogeneration, biomass, and others

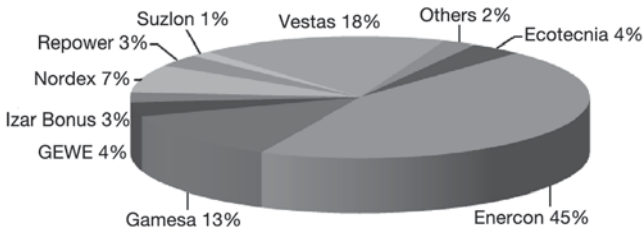

Figure 10 Distribution of installed wind capacity by manufacturer.

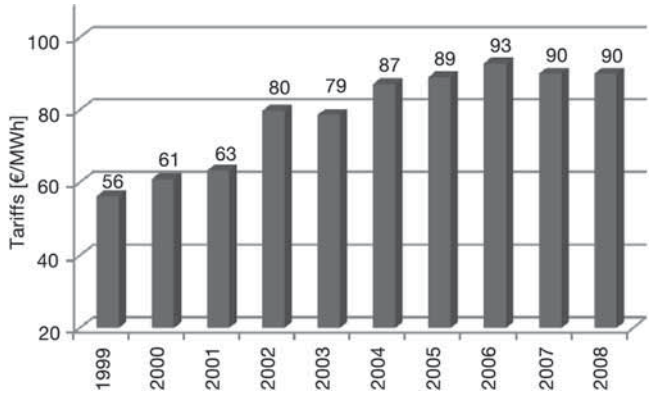

Figure 11 The TURBan 2.5-kW horizontal axis prototype, developed by INETI and installed in the Gardens of S. Bento Palace, the official residence of the Portuguese Prime Minister.

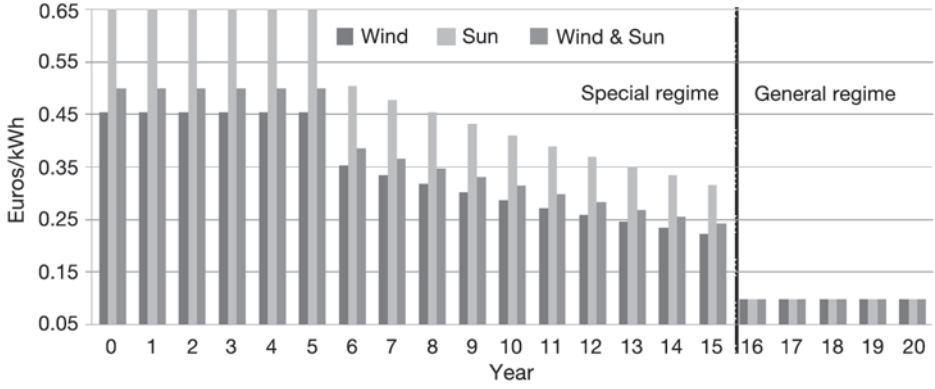

Figure 12 Tariff evolution in the project lifetime.

4.0 National Incentive Programs

During 2008, small changes in national incentive calls took place. The QREN financing program was opened in November 2008, in which several scientific and technological areas were under evaluation, including energy renewable systems. A financing call for R, D&D projects was also opened at the end of 2008 by the Portuguese Science and Technology Foundation (FCT), covering a huge variety of areas.

Several projects financed by the European Union Seventh Framework Programme (FP7) kicked off during the summer of 2008. Portuguese institutions, including Instituto Nacional de Engenharia, Tecnologia e Inovação (INETI), are participating in the five-year project NORSEWInD (Northern Seas Wind Index Database, EC FP7-2008) to run from 2008 to 2013. Another relevant governmental financing program, PRIME/MAPE, was released in 2008 with funds covering 1,533 MW of wind park capacity.

5.0 R, D&D Activities

5.1 National R, D&D Efforts

In Portugal, many R, D&D groups are housed in academic and/or research institutes and financed by research projects included in international, European, and national programs. The R, D&D

development is growing slowly with the continuing participation of wind energy developers and consultancy entities in academic projects, especially those related to doctoral and postdoctoral projects.

Wind energy R, D&D activities are mainly being developed in the regions of Oporto and Lisbon. In the north region of Portugal, the main institutes 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 most active public R, D&D organizations in wind energy research and technology is INETI, a part of the Ministry of Economy and Innovation, located in Lisbon's region and financed partially by the national government and wind energy companies (consultancy contracts).

The main R, D&D projects under way 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 (national project financed by DEMTEC (70/0201) that consists of the development of two prototypes of small and low-cost turbines for urban use) – INETI.

In 2008, Portugal achieved some milestones. It became the first country with a wave farm (the Aguçadoura Wave Farm), had several multi-megawatt photovoltaic plants installed, and had its highest increase in wind power capacity to date.

The Aguçadoura Wave Farm, the first commercial-scale farm in the world to take advantage of wave energy, is located 5 km off the coast near Póvoa de Varzim in the north of Portugal. It is composed of three PELAMIS wave energy converters. The farm was commissioned and operated during the summer and autumn of 2008, producing power and transferring it to the Portuguese national grid. This project was conceived by the Portuguese renewable energy company Enersis, which developed and financed it. In 2008, the Aguçadoura Wave Farm had an installed capacity of 2.25 MW, enough to meet the average electricity demand of more than 1,500 Portuguese homes. In its second phase the installed capacity will be increased from 2.25 MW to 21 MW using an additional 25 PELAMIS machines (Figure 13).

During 2008, Portugal also inaugurated several solar PV power plants (Figure 14). The world's third largest PV plant is near Moura, a southern Portuguese town, with an installed capacity of 46.41 MW, distributed by 2,520 azimuthal trackers, each one equipped with 104 solar panels. This plant will also include a research center..

In 2008, several wind parks were installed in Portugal, among them Europe's

Figure 13 The front of the PELAMIS machine at the Aguçadoura Wave Park with the city of Póvoa de Varzim in the background (5).

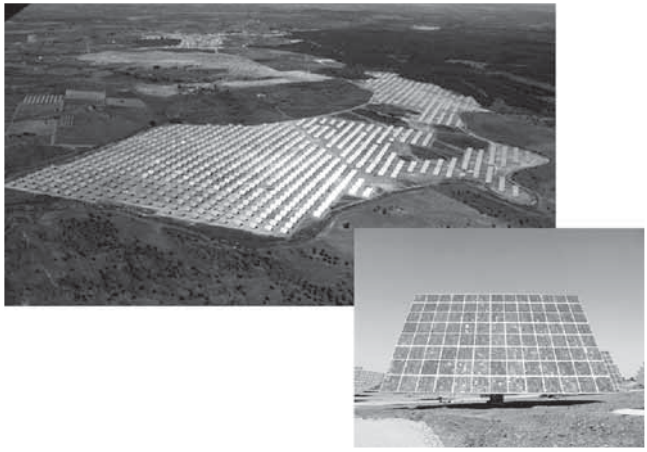

Figure 14 Solar photovoltaic central in Moura, south interior of Portugal (6).

biggest onshore wind park, installed in the northern region of Viana do Castelo. This wind farm has 120 wind turbines (Figure 15).

5.2 Collaborative research

In 2008, the TURBan project, carried out by the INETI, continued. The small wind turbine prototype with horizontal axis completed the testing phase, and industrial manufacturing for commercial launch was about to start. Portuguese manufacturers will contribute most of the components. Another small wind turbine was developed according to the second phase of the TURBan project with a vertical rotation axis (VAWT) (Figure 16). This turbine, with 2 kW of rated power, has very high performance unique in its class and is currently undergoing testing.

NORSEWInD was created to address the shortage of offshore data for the wind industry. Offshore wind is an expensive business, with a real problem in obtaining easily available high-quality datasets suitable for project decision making. This project will use new techniques to acquire physical data offshore for the wind industry. In early August 2008, the NORSEWInD project, with which INETI is involved, officially

Figure 15 Europe's biggest onshore wind park in the northern region of Viana do Castelo, Portugal. Photograph: Estela Silva/EPA.

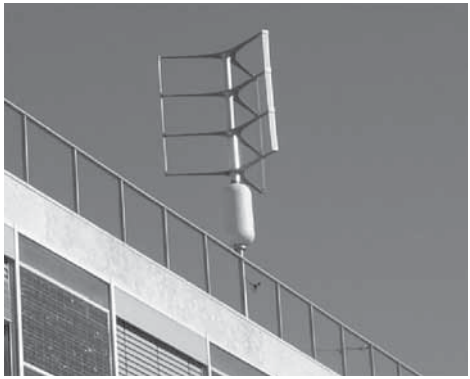

Figure 16 The TURBan 2-kW vertical-axis prototype, developed by INETI. Photograph: INETI.

kicked off. NORSEWInD is made up of 15 organizations and is financed by the European Community under the Seventh Framework Programme. The project will develop high-quality wind atlases to the North, Irish, and Baltic seas. It will use, among other data sources, the anemometer station of Berlenga Island, operated by INETI, to validate methodologies for its atlas. This project will create one of the biggest dedicated instrumentation networks to acquire wind speed data offshore.

Also, new sites for offshore measurements are already under study along the Portuguese coast using contracts with Portuguese wind energy companies.

6.0 The Next Term

During 2008, the Portuguese Wind Atlases (onshore and offshore) will be further developed and updated. The onshore atlas will incorporate detailed data at the municipality scale and apply methodologies that will be useful in several foreign countries, especially those in Africa and Eastern Europe. The offshore wind atlas project will also 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 2009.

It is expected that in 2009, offshore wind feasibility studies will begin with measurements in the sea along the Portuguese Atlantic Coast.

References:

(1) Source General Directorate for Energy and Geology (DGGE).
(2) Source National Electric Grid (REN).
(3) www.certiel.pt
(4) www.renovaveisnahora.pt/30
(5) www.eccn.edu.pt/.../Energias_Renovaveis.htm
(6) www.apea.pt/scid/webapea/defaultArticleViewOn..

Authors: Teresa Simoes, Liliana Madeira, and Ana Estanqueiro, Department of Renewable Energies, INETI. – Instituto Nacional de Engenharia, Tecnologia e Inovação, Portugal.