32 Portugal

1.0 Overview

In 2014, the wind energy sector achieved a maturity status within the Portuguese power system. While it still experienced some additional capacity deployment (222 MW), after 15 years of intense deployment Portugal reached 4, 953 MW of installed wind power capacity by the end of 2014. Wind power represents 25% (considering only mainland Portugal) of the total operational capacity and 42% of renewable energy capacity in the country [1, 2]. In 2014, Portuguese wind parks produced 12.1 TWh maintaining a wind energy contribution of 24% of the annually electricity consumption. This high wind penetration was influenced by the favorable wind conditions observed in the first three months of the year over central and northern regions of mainland Portugal that also correspond to the largest concentration of installed wind capacity [1].

The electricity generation from renewable energy sources in 2014 reached 65% of the national consumption, which is a new record in Portugal [1, 2]. The individual renewable contribution in Portugal was similar to the previous year, where hydropower production represented the highest contribution with 33% of the electrical demand. The high contribution from the endogenous resources enabled Portugal to reduce to 1.8% the dependency on foreign energy for meeting consumption, decreasing more than 4% when compared to the previous year [2].

Due to the energy efficiency measures implemented in the latest years and also to economic stalling, electricity consumption in Portugal was 50.3 TWh in Portugal, which corresponds to a slight reduction of 0.3% with respect to 2013 [1, 2]. Figure 1 depicts the yearly contribution of each technology in the Portuguese energy mix, the imports/exports and the consumption index in the period between 2008 and 2014. From Figure 1 it is possible to verify that the dependence on fossil fuels to balance the demand is less than 40% for the second consecutive year. This dependency is essentially supplied by the coal since it is the cheapest fossil fuel for generating electricity, although higher levels of pollutants are released into the atmosphere when compared to natural gas.

On 3 March 2014 the wind power generation reached the penetration of 64% on an average daily basis. The highest daily wind energy production was also registered on this day with 88.4 GWh. The highest wind instantaneous penetration was observed on 28 December with 89%—which is slightly below the previous instantaneous record of 93% observed on 13 November 2011. Despite these high values, no technical problems were reported during these periods by the Portuguese transmission system operator.

2.0 National Objectives and Progress

2.1 National targets

The targets for installed capacity currently in place were established in April 2013 by the Portuguese government through the National Renewable Energy Action Plan (NREAP) 2013–2020 [3]. Regarding wind power, this action plan sets the need to reach an installed minimum capacity of 5,300 MW by 2020. This value is divided into 5,273 MW installed on land (where 400 MW correspond to expanding the capacity of current wind parks—"overcapacity") and 27 MW offshore.

2.2 Progress

During 2014, a net capacity of 222 MW was added, which represents an installed capacity growth of 5% with respect to the

An instantaneous wind penetration on 28 December was 89%—with no technical problems by the Portuguese transmission system operator.

Table 1. Key National Statistics 2014: Portugal	
Total (net) installed wind capacity	4,953 MW
New wind capacity installed	222 MW
Total electrical output from wind	12.1 TWh
Wind generation as percent of national electric demand	24%
Average national capacity factor	28%
Target:	Land-based: 5,273 MW Offshore: 27 MW by 2020

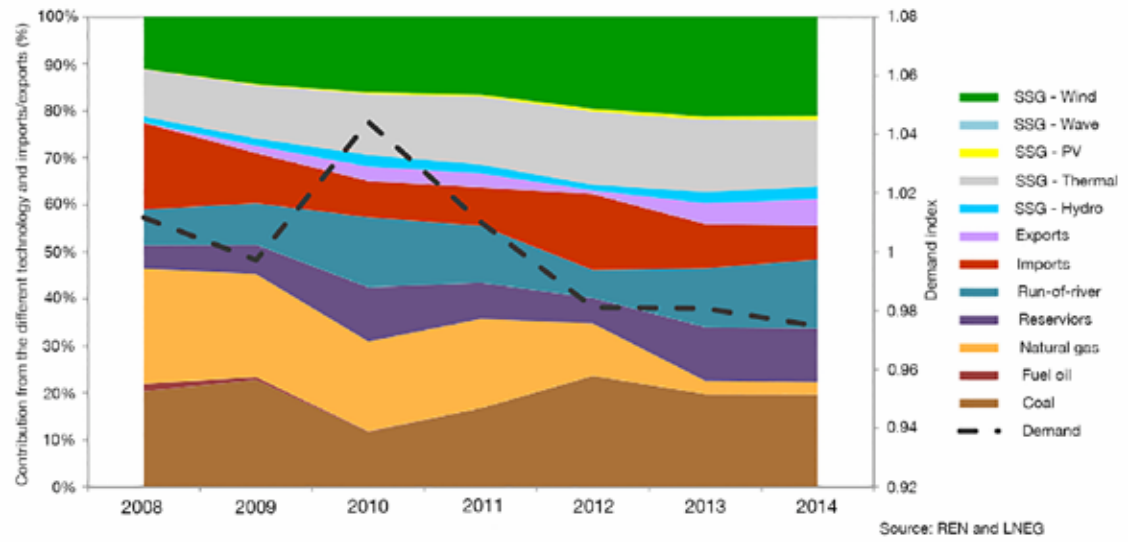

Figure 1. Yearly contribution from each technology to the energy consumption, imports/exports, and demand index considering the period between 2008 and 2014 (continent only) [2]

capacity of the previous year. For the first time in recent years, no new wind power capacity was installed in the Azores and Madeira archipelagos [1].

As shown in Figure 2, the added capacity is in line with that of 2013 demonstrating a slowing of newly installed wind capacity. Compared with the previous ten years, this value was the third lowest since 2004, when the strongest wind deployment began. Cumulative installed capacity until 2014 is distributed over 245 wind farms with 2,496 wind turbines operating across the country (mainland and islands), one of them being a floating offshore wind turbine (the number of operating wind turbines were recently corrected by the competent authority, which revised the values presented in 2013 report to 2476) [4].

The Portuguese wind power fleet in 2014 generated 12.1 TWh corresponding to 24% of the electricity demand. The wind share of total renewable production was 37.4%, a small decrease of 2% compared to 2013. The contribution from wind power was only surpassed by hydropower production that represented 50.8% of the total renewable production in 2014. The remaining mix of renewable sources maintained their share with the biomass sector representing 9.9% followed by PV (2.0 %) and geothermal (0.6%) [2]. In 2014, the average production at full capacity stood at 2,440 hours, which corresponds to a 4% decrease with respect to the same period of 2013 (2,540 hours). This result is mainly explained by the decreased wind energy index.

2.3 National incentive programs

In 2013, a review of the NREAP was issued, providing the structural context, strategy, and objectives for renewable

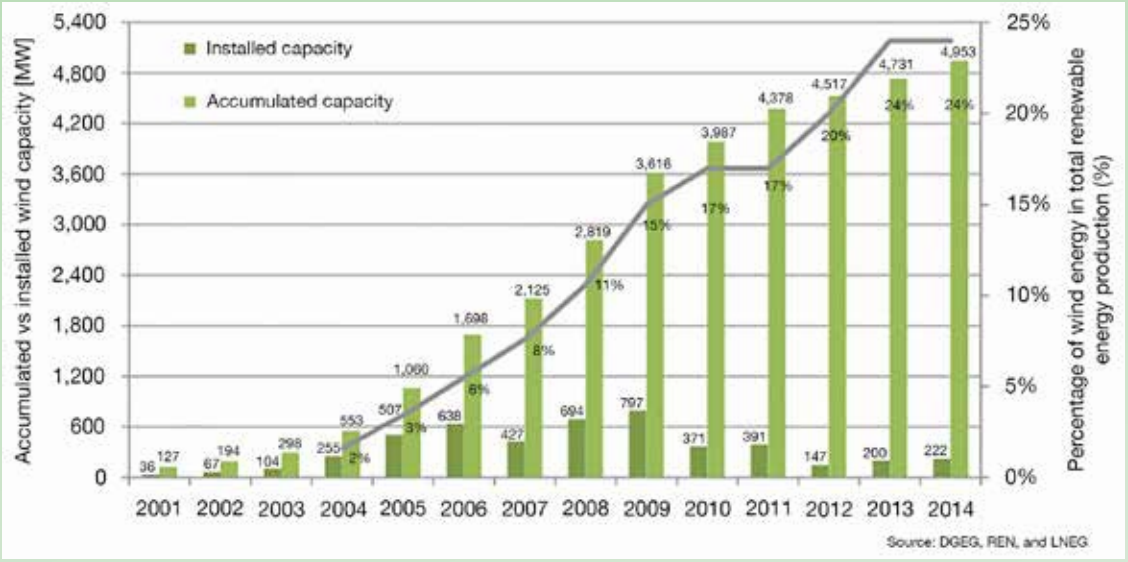

Figure 2. Installed versus accumulated wind capacity (bar graph) and percentage of wind energy production (line graph)

energy investments in Portugal. The targets defined in this plan are set to 2020 and took into consideration the current abundancy of electricity supply due to the reduction in demand in recent years, and the actual low growth economic context [3]. This new plan to support the promotion of renewable energies is based on the indicators from 2010 where the contributions from renewables were 5.5% in transportation, 34.5% in heating and cooling, and 41.1% in electricity. The targets for 2020 aim to raise those contributions to 10.0% in the transportation sector, 35.9 % in heating and cooling, and to 59.6% in electricity [3].

In order to reinforce the capacity of existing wind power plants, as foreseen in the NREAP 2013–2020, the Decree-Law 94/2014 [5] was published, on 24 June. This law amends the legal framework applicable to the overcapacity established in the Decree-Law 51/2010 [6]. Moreover, this law establishes the definition of additional power and energy with a guaranteed remuneration scheme of 60 EUR/MWh (73 USD/MWh). The additional energy is defined as the active energy provided from the use of the additional power. This corresponds to the maximum additional power value taking into consideration the difference between installed power and connection power. It is important to note that the energy generated under this decree-law, can be only delivered to the electrical grid when all the technical and safety conditions are met from the system operator point-of-view.

In Portugal, the renewable energy installations for micro-generation (up to 11 kW) and mini-generation (up to 250 kW) are mainly promoted through incentive programs based on a feed-in tariff (FIT). The micro-generation law was established by the Decree-law 118-A/2011 [7] that regulates the micro-production of electricity from renewable energy sources and provides a simplified framework and licensing regime for connecting renewable energy producers to the distribution grid. For 2014, the tariffs were set by the energy

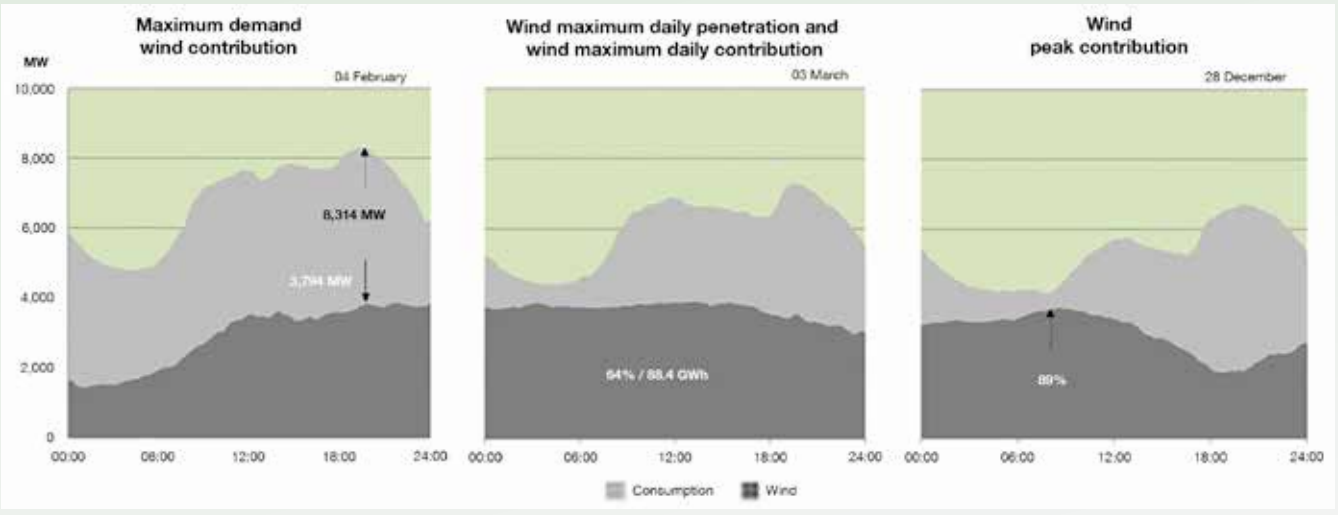

Figure 3. Record wind power penetration and energy generation during 2014 [2]

sector regulator—Direcção Geral de Energia e Geologia (DGEG)—to a value of 218 EUR/MWh (264 USD/MWh) for the first eight years of operation and 115 EUR/MWh (139 USD/MWh) for the second period of seven years with a limit of 11.45 MW for annual grid-connected power approved by ordinance number 431/2012 [8]. The mini-generation program established in Decree-law 34/2011 [9] enables small companies to install renewable-based production centers of up to 250 kW. During 2014, DGEG reduced the reference tariff by 14%, reducing the values from 185 EUR/MWh (224 USD/MWh) to 159 EUR/MWh (193 USD/MWh) with an annual maximum power injection of 30.35 MW.

During 2014, those national incentives for micro- and mini-generation were rectified and merged into a single category designated small production units (UPP) regulated by the Decree Law 153/2014 [10]. UPP enables the installation of renewable-based technology with a capacity of up to 250 kW, with an annual cap limit of 20 MW for grid-connected capacity. This new legal framework replaces the remuneration regime previously applicable to micro- and mini-generation units, contemplating the possibility of self-consumption and also to sell the energy to the public electricity grid. The new remuneration scheme is based on a bidding model where each producer bids discounts to a reference tariff, which is set annually by the government depending on the technology used. However, the previous FITs will remain valid for the existing installations during the statutory period.

2.4 Issues affecting growth

In 2012, the Portuguese government suspended the attribution of new capacity for grid connection to re-evaluate the legal framework for electricity generation [11]. Therefore, the deployment of land-based wind projects during 2014 (and in the next years) corresponds to the installation of the power previously licensed, but still not installed.

For the second consecutive year, Portugal reached a wind contribution of 24% of the annual consumed energy during 2014. This is a very high wind penetration value and the second highest in the world, only surpassed by Denmark. This high wind penetration, although without negative impacts in the Portuguese power system's operation, raises economic and technical challenges that lead to a more conservative approach for the deployment of variable renewables in the near future.

Portugal has installed and is operating a very high share of power production with a stochastic and non-dispatchable behavior as wind power, run-of-river hydropower plants, and also some photovoltaics (PV) plants. In light of the current power system's operation principles, this requires a certain amount of dispatchable sources in order to guarantee the balance between the electric generation and the demand. In power systems such as the Portuguese, the design parameter limit is the extreme penetration of renewable, non-dispatchable sources. The maximum demand instantaneous value was reached on the 4 February 2014 at 19:15 with a wind generation of 3,794 MW representing 77% of the wind power capacity. On 28 December 2014 at 8:00 AM, an instantaneous penetration of 89% from wind generation was recorded. The highest daily consumption supplied by wind energy generation occurred on the 3 March 2014 with 88.4 GWh, which accounted for 64% of the daily demand [2]. Despite the high wind penetration values recorded, it should be noted that no technical problems were reported during these occurrences by the Portuguese transmission system operator, Redes Energéticas Nacionais, S.A. (REN). Figure 3 depicts the wind generation profiles on: (i) the maximum demand day and the respective wind power contribution; (ii) maximum daily and also the maximum daily contribution from wind; and (iii) peak wind penetration.

3.0 Implementation

3.1 Economic impact

The wind industry in Portugal, together with the wind deployment activity (222 MW) supported an estimated 3,200 jobs. In 2014, the wind generated electricity produced an estimated income of 1,170 million EUR (1,417 million USD) and allowed the saving of 4.3 million tons of CO_2 emissions.

3.2 Industry status

During 2014, Enercon reinforced its leading position in Portugal as the most important supplier of turbines. In fact, from the wind turbines installed in 2014, the great majority corresponded to Enercon wind turbine models (Enercon E82 and E92 models) and the remaining wind turbines were manufactured by Senvion. As a consequence, Enercon increased its share of the overall Portuguese market to 56.6% of the installed capacity. In second place is Vestas with a 13.6% share, followed by Gamesa (8.9%), Nordex (8.3%), Senvion (former REpower) (4.0%), GEWE (2.2%), Ecotècnia (2.2%), Suzlon (2.1%), Bonus (1.5%), NEG-MICON (0.2%), and other manufacturers (0.7%), Figure 4 [4]. From the new wind turbines installed in 2014, 2% corresponded to wind parks capacity reinforcement (usually referred as "overcapacity"), a wind plant design principle that allows installation of more wind capacity than the maximum electric power allowed to be inject in the grid.

The offshore floating wind turbine installed in northern Portugal, the WindFloat prototype keeps its successful demonstration phase operating at Aguçadoura. This offshore wind system composed of

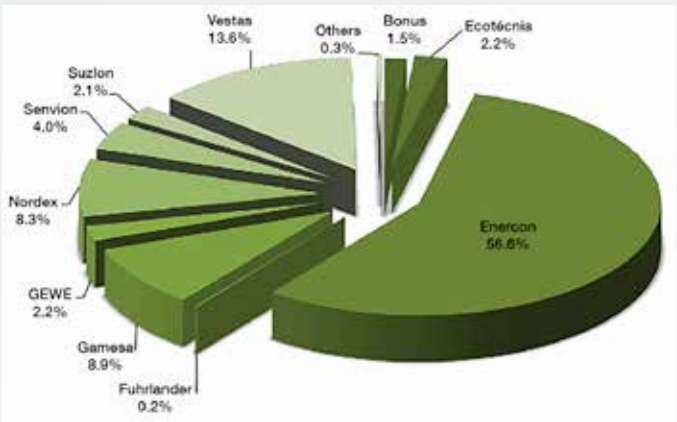

Figure 4. Distribution of installed wind capacity by manufacturer [4]

a semi-submersible structure and a Vestas V80 wind turbine with 2 MW capacity has proved to be an entirely technically viable solution for future floating deep offshore wind plants despite the adverse storm conditions observed in the open sea environment and already experienced in the Portuguese Coast, where the system already survived to 16 m waves with only minor requirements for maintenance. During 2014, the WindFloat reached another milestone; it passed the 10 GWh mark and at end of 2014 was already delivered 12.02 GWh of renewable electricity to the grid [12]. This project is being developed by WindPlus as a joint venture from EDP Inovação, Repsol, PPI, PPI Portugal, and A. Silva Matos. The performance achieved with this floating system has allowed this consortium to exploit the results of the ongoing R&D projects (e.g., FP7 DemoWFloat) and initiate the design of the first wind park with floating technology to be installed in the Portuguese Coast (foreseen for 2015 with a 25 MW capacity planned to be installed on the coast of Viana Do Castelo with EC NER300 co-funding) as well as in the United States coastal waters [12].

3.3 Operational details

In mainland Portugal seven new wind parks were connected to the grid in 2014.The overall installed capacity of the 245 wind parks in Portugal by the end of 2014 can be grouped into three categories; <10 MW, with 52% share; 10–50 MW, with 41% share and >50 MW with 7% share [4]. Figure 5 shows the wind and production indices since 1999. These values were achieved for two typical regions where wind turbines are operating in Portugal: coastal and mountainous. The wind and production indexes were computed based on reference wind data from anemometric stations installed in these two regions. After an atypical year in the mountainous regions in 2013, the Laboratório Nacional de Energia e Geologia (LNEG) indexes for wind and power production show a slight decrease with a wind availability of 1% above the average (1.01) and 4% above average on production (1.04). For the coastal region, the scenario reversed last year's tendency with the production growing 6% (index 1.04) reaching a wind index close to the average (0.98). In the coastal region, the scenario reversed the last year's tendency, with wind growing 7% (index 0.95) and production 12% (index 0.96).

Data from the Portuguese operation of power systems [2] is in the line with the results presented from LNEG, indicating a decrease of 7% in the annual wind generation index from to 1.11, when compared to the previous year. This result reveals the expected similarity to the typical mountains behavior, since the vast majority of the operating capacity in Portugal is installed in those regions.

3.4 Wind energy costs

The average cost per MW installed in 2014 was ***1.35 million EUR (1.64 million USD/MW)***. This amount includes associated costs of project installation and grid connection, among others. Turbine costs were around 80% of the total installation costs and corresponded to approximately 1.08 million EUR/MW (1.31 million USD/MW).

The mean tariff paid to the wind power plants in 2014 was 93.90 EUR/MWh (113.71 USD/MWh). It deserves to be noted that the Portuguese legislation assumes since the 1990s a period of approximately 12 years during which a green FIT (feed in tariff) applies to the retribution of wind generation. Since a representative number of wind plants is reaching the contractual maximum limit for access to green tariffs, the tendency in the near future is to verify an accentuated tendency of reduction on the wind energy mean tariff, as already observed from 2013 to 2014.

4.0 R, D&D Activities

4.1 National R, D&D efforts

The national R&D efforts during 2014 were mainly focused on offshore wind energy and development of tools and methodologies to maximize the penetration of renewable energy not only from a grid security operation point of view, but also from a market perspective. These activities are taking place at the main Portuguese institutes and universities, being financed through national or European programs. Some relevant R&D activities underway in Portugal include the following.

Project IRPWind: European-wide Measures and Structures for a Large-scale Wind Energy Integration: an FP7 European-funded project with the participation of LNEG. This project combines wind energy research projects and activities with the objective of fostering innovation, collaboration, and knowledge transfer between European researchers and leading R&D entities, with the participation of European energy Research Alliance (EERA) Joint Programme on Wind Energy partners.

Project TWENTIES: a project to deal with transmission system operation with large penetration of wind and other renewable electricity sources in networks by means of innovative tools and integrated energy solutions. It is funded by EC FP7 and has the participation of the Portuguese Institute INESC-Porto.

Project DREAM-GO: an international project that aims to contribute to a more sustainable and efficient energy system, based on intensive use of renewable energy and active management of consumers. This H2020 project is led by the GECAD group that belongs to Institute of Engineering - Polytechnic of Porto (ISEP/IPP).

Project MARINA: a project that brings together companies, technology centers, and universities from 12 EU countries. It is led by Acciona Energy and funded by EC FP7 with the Portuguese participation of University of Algarve. The objective is to develop deep-water structures that can exploit the energy from wind, waves, tidal, and ocean current energy sources.

Project FP7 DemoWFloat: a project to demonstrate the sustainability of the Wind Float technology deployed in Portuguese Atlantic waters. A consortium of European and North American partners will address the challenge of wind resource assessment in oceanic deep waters. It is funded by EC FP7 and has the participation of LNEG and several Portuguese and international partners involved in a consortium led by EDP.

Project ESFRI WindScanner: the project will establish a European network of innovative R&D for the acquisition of three-dimensional components of the atmospheric flow and characterization of wind turbulence. It is funded by EC FP7 and has the participation of the Portuguese entities LNEG and Porto University.

Project TROPOS: the project aims to develop a floating modular multi-use platform system for use in deep waters, with an initial geographic focus on the Mediterranean,

tropical, and sub-tropical regions. It will be flexible enough so as to not be limited in geographic scope. It is funded by EC FP7 and has the Portuguese participation of WavEC.

Project Atlantic PC: the project seeks to develop cooperation and joint approaches to facilitate the identification of new market niches and redefine educational and training programs as per the needs of the offshore and marine energy sector in the Atlantic Area. It is funded through the European Regional Development Fund (ERDF) and has the Portuguese participation from WavEC.

Project OTEO: a Portugal-based project funded by the System Support for Collective Actions (SIAC) and has the participation of Instituto de Engenharia Mecânica e Gestão Industrial (INEGI), EnergyIN, Oceano XXI and WavEC. The project established a strategy to apply the Portuguese and international knowledge of offshore energy and to support technologies that increase competitiveness and entrepreneurship in this sector.

Project EERA-DTOC: the project combines expertise to design a tool for the optimized design of offshore wind farms and wind farm clusters. It is funded by EC FP7 and has the Portuguese participation from Porto University.

Project KIC-OTS: a technology project focused on the needs of the market, which was created under KIC-InnoEnergy, a company funded by the European Institute of Technology European Commission. The aim of the project OTS is developing a range of projects and services targeted to current and future needs for offshore renewable parks. This project has the Portuguese participation of WavEC.

Project WindMETER: the project was developed to fill a gap and meet a growing opportunity in the wind energy market, as fiber optic sensors play an increasing role in the structural health monitoring of wind turbines. The project is co-funded by the Portuguese National Strategic Reference Framework (QREN) and is led by the consortium INEGI (technological consultant) and Fibersensing (industrial partner).

Project OceanNET: an international project concerning floating offshore wind and wave energy funded from the PEOPLE Programme (Marie Curie Actions) of the EC FP7. The main goal of this project is to educate a new generation of engineers and scientists in the area of floating offshore wind and wave renewable energies to support the emerging offshore renewable energy sector. This project has the Portuguese participation of WavEC and Instituto Superior Técnico.

Project LEANWIND: an international project concerning the effectiveness and efficiency of the offshore wind farm lifecycle and supply funded by EC FP7. The main goal of this project is to develop innovate technical solutions and processes to optimize offshore wind park deployment, operation and maintenance as well as decommissioning procedures. This project has the Portuguese participation of EDP Inovação.

4.2 Collaborative research

In Portugal, LNEG and other Portuguese R&D entities are active partners in international research efforts. The country participates in IEA Wind Task 25 Design and Operation of Power Systems with Large Amounts of Wind Power. Portugal also collaborates in the IEA Wind Task 30 Offshore Code Comparison Collaboration Continuation with Correlation (OC5) through Wavec, Instituto Superior Técnico/Centec with a participation co-sponsored by EDP-Inovação. In addition to the IEA Wind activities, LNEG is the Portuguese representative in the European Energy Research Alliance Wind Program (EERA-Wind) that is a European initiative that integrates the leading European research institutes in the energy sector that aims to strengthen, expand, and optimize EU energy research capabilities.

5.0 The Next Term

Due to the fact that Portugal is reaching the main goals for land-based wind capacity installation with few pending licensing procedures, and the wind penetration is already at the highest values in the world, 2015 is expected to be a stagnant year. Regarding offshore wind energy and with the NER300 program support, the implementation phase of the first floating offshore wind park on the Portuguese coast (and the world!) with an estimated capacity of 25 MW is expected to start [12]. In January 2015, the registration system for micro- and mini-generation units will open, and the reference tariff value for UPP units will be established by the energy sector regulator.

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Opening photo: Windfarm in Portugal (Credit: Vitor Andrade)

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