SUSTAINABLE OFFSHORE WIND POTENTIAL IN CONTINENTAL PORTUGAL

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Abstract
This study intends to depict the availability of the sustainable offshore wind energy for Continental Portugal and identify the preliminary areas for developing offshore wind parks. Two scenarios were performed to distinct the different offshore wind turbine prototypes assembled by the manufactory energy sector – bottom fixed and floating models. The results achieved until now indicate that Portugal has a very large potential for offshore wind deployments ready to be exploited, especially for deep offshore solutions.

Keywords: sustainable offshore, wind parks, GIS

1.0 Introduction

In the recent years, Portugal has witnessed a remarkable deployment of the wind power sector that brought this country to the international top list of countries with both high growing rate and accumulated operational wind capacity. Moreover, Portugal had in 2009 the second's higher penetration of wind generated electricity in the annual energy consumption, reaching 15% and only overcame by Denmark. This development started in the beginning of the 21st century with the governmental commitment to fulfill the European Directive for Renewable Energies (2001/77/CE) and the definition of the national objective to install 3750 MW of wind capacity by 2010 (RCM 63/2003). This objective was later reinforced by the need to reduce the CO2 emissions under the ratification of Kyoto protocol (2001/81/EC) and the consequent increase of the national wind goal to 5100 MW by 2013 (RCM 169/2005). More recently, the National Strategy for Energy (ENE), presented by the Portuguese Government in March 2010, defined the ambitious goal of the installation of 8500 MW of wind capacity by 2020. LNEG/INETI is a Governmental Laboratory with the mission to aid and contribute to the implementation of public policies, so this Institute initiated the development of methodologies capable of identifying areas and sites with high wind potential, in an initial phase [1,2], and more recently, the development of a planning method to identify and locate the sustainable wind potential [3]. This wind atlas dependent, GIS based methodology was recently applied to the identification and location of the sustainable offshore wind resource [4], both for near-shore and deep offshore waters, what enabled to define the Portuguese offshore wind goals, based on the resource identification. This paper presents the application of the methodology developed for the identification of the Portuguese offshore wind resource, as well as the constraints and priorities used in areas with multi-economic value, having as outcome the mapping of the Portuguese coastal areas with sustainable offshore wind resource, both near-shore and deep-offshore.

2.0 Methodology

The methodology proposed to identify the preliminary offshore areas as well as the respective wind power available resource in each of them was based on a previous work [4] but excluding the specific onshore criteria items such as the grid connection network, operational wind parks and soil occupation factors. The rest of the items were preserved being two of them improved namely the wind resource assessment – that covers the ocean around the coast - and a newer type of restrictions concerning sea purposes near shoreline. Another item was substituted; the slope terrain item was replaced by a bathymetry slope condition and a last added, that being the sea bed type [5], especially relevant for the fixation of near-shore wind turbine foundations

2.1 Offshore Wind Resource Assessment

The offshore wind resource assessment used in this study was done by performing a high resolution (3X3km) long term simulation with a mesoscale atmospherical model, the MM5 [6]. This model is suitable to simulate atmospheric coastal effects caused by local thermal or shearing phenomena circulations (e.g. sea-breeze circulations) among others on a staggered sigma [7] coordinate grid. The MM5 model was coupled with a complete one year of Reanalysis [8] data from NCAR/NCEP's mass storage systems with 6h intervals. Only one offshore wind turbine model was simulated in order to obtain results for wind power production. The simulated offshore wind turbine model was VESTAS V80 with 2000kW of rated power and a hub height of 80m. The wind power results were converted to the well know wind power parameter of NEPs – yearly number of hours at full power (h/year) processed for the same height as the turbine's hub. The tuning parameters for set the MM5 model were chosen according to reference [4] that also presents the validation study for this long term simulation. The intra annual variability factor was also computed and it was considered into the model results. The intra annual variability factor is also presented in [4]. In Figure 1 the offshore wind potential resource assessment obtained with the turbine test model for the hub height at 80m is presented. The map field was clipped between the shoreline and the bathymetric contour depth of 200m and the resource is plotted for NEPs values greater or equal than 2900h/year.

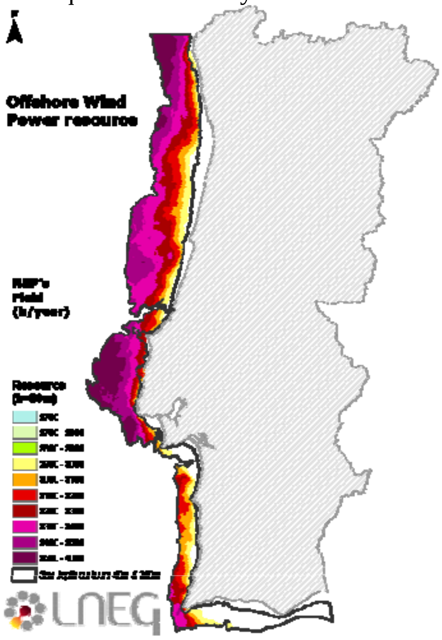

Figure 1 – offshore wind power resource for Continental Portugal (units of h/year) computed for 80m a.g.l. with intra annual variability correction.

The resource from the wind power in Portugal is favorable for the development of offshore wind parks. Values above 2700h/year indicate economical feasibility, if the Portuguese Government adopt a tariff plan similar to the ones being used in other European countries.

2.2 – Sea Constraints in Portugal

There are several sea constraints around the shoreline of Continental Portugal. They can be categorized by the Wave Energy Pilot Zone, seismic faults, seabed types, navigation channels, maritime buoys, military zones, anchorage locations, economic and environmental protection zones and submarine electrical cables. Information for each constraint was transformed into a *shapefile* and imported into the geographical Information System (GIS) software. Figure 2 depicts all the constraints used in this study.

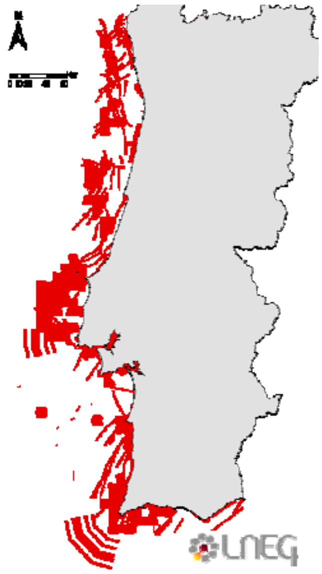

Figure 2 – Illustration of the several sea constraints around the shoreline of Continental Portugal used into the evaluation of the sustainable offshore wind power.

2.3 – Slope of Continental Platform

Unlike the previous common public opinion, the Portuguese Continental Platform is quite smooth at least up to 300m depth for a spatial resolution of 500x500m as showed in figure 3. The bathymetry slope up to 200m derived from Fig. 3 is, in almost all sites, less that 8% (see figure 4). This constitutes another favorable condition for the development of the offshore wind park market in Portugal once the recommendation of the wind turbine manufactors indicate values for the offshore slope below 15%, for structural safety precautions.

3.0 Scenario Results

The methodology implies that all the information needs to be uploaded into a GIS platform once it enables the production of spatial queries among all sources of information from the raster to the vector ones. In this study two scenarios were considered. The first deals with the power production produced by an actual state-of-the-art bottom-fixed offshore wind turbine VESTAS V80 with 2 MW rated power while the second is associated with the wind power capacity to be used by the future generation of fluctuating offshore wind turbines. This niche of technology is currently on the initial phase of prototype sea tests under real ocean conditions, with the first MW-sized floating wind turbine just installed on the coast of Norway in the summer of 2009 [9].

3.1 The near-shore technology

The bottom-fixed offshore wind technology is now available from most of the main turbine fabricants. The actual structural state-of-the-art for those types of wind converters already enables their installation on shallow bathymetry with depths up to 40m and slopes below 15%.

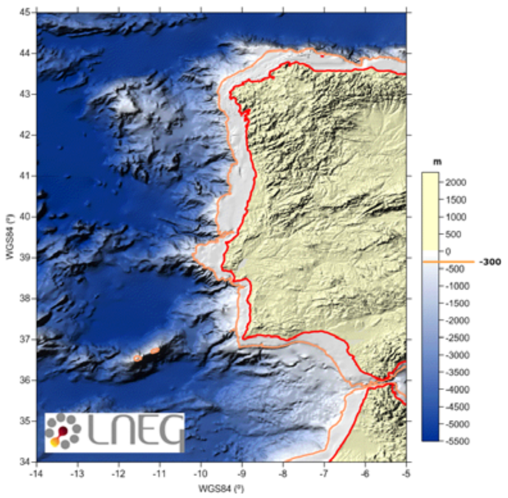

Figure 3 – Bathymetry depths for Continental Portugal processed with spatial resolution of 500x500m (source: http://www.gebco.net/).

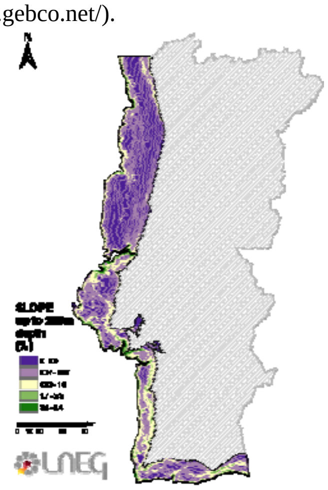

Figure 4 – Bathymetry slope up to 200m depth. Spatial resolution of 500x500m

Inputting this information on queries into the GIS software it was thus possible to produce the availability wind power resource confined to 40m depth as depicted in figure 5. Once the bathymetric line of 40m is very near to the shoreline, the offshore wind resource query was realized with values greater of equal than 2700h/year. This limit was selected since, if Portugal implements offshore tariffs similar to the ones practiced in other European countries with offshore wind capacity or programmes (e.g. UK, Spain or Italy) this constitutes a minimum value above which, the economical feasibility of the project is ensured for bottom-fixed conventional offshore foundations. From figure 5 it is clear that the main energetic wind power spots are almost at the forefront of the main cities and consumption centers, therefore covered by excellent meshed network connections into the Portuguese transmission grid. Table 1 reports the offshore wind power capacity obtained with the application of the described methodology to each spot area (and its surroundings) according the "macro-regions" pre-identified in figure 5.

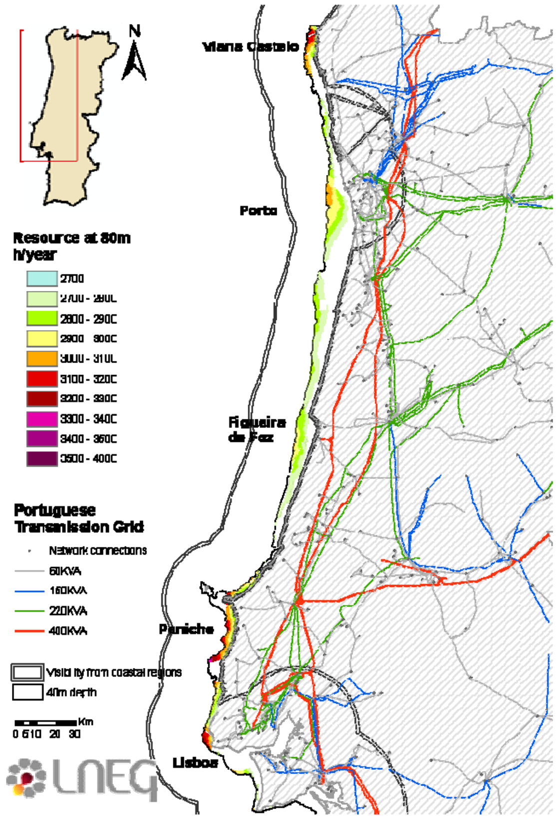

Figure 5 – Existing near-shore wind potential in Continental Portugal for equivalent number of full power above 2700h/year (b<40 m, test turbine V80 – 2MW).

Table 1 – Near-shore wind power sustainable potential for Continental Portugal (2MW test turbine.

Locals	Availability of the offshore wind power capacity in Portugal	
	NEP's >= 2700h/year	**NEP's >= 2900h/year**
Viana Castelo & Porto	1200 MW	550 MW
Figueira da Foz & neighborough	1300 MW	100 MW
Peniche & Lisboa	950 MW	650 MW
South regions (out of the map)	50 MW	10 MW
Total	**3500 MW**	**1400 MW**

Table I shows the offshore wind power capacity for Continental Portugal for two minimum thresholds:
An offshore sustainable wind potential of 3500MW, if one considers the offshore feasibility ensured with 2700h/year (guaranteed with current European offshore tariffs). In another, more restrictive scenario, the economical viability requires 2900 h/year, as minimum number of full capacity, this enabling the identification of a near-shore sustainable capacity of 1400MW.

3.2 Deep-offshore floating applications

The floating offshore wind turbines are yet in a phase of research and definition of the best configuration to tackle the interference between wind and wave effects while maintaining (or even reducing) the installation costs, when compared with the already existing solutions. Hywind [9] was the first manufacturer to launch a MW sized floating prototype in the real North Sea conditions for testing. There are several other technological configurations under design and in pre-prototyping phase, among them, the Nordic concept Sway and the Principle Power US design (to be tested in Portugal) WindFloat. Among these concepts, it is expected that – with some optimism - by 2020, a floating offshore wind turbine is already available for the offshore wind market. With this new technologic offshore wind niche available in the near future, GIS queries were performed for depths between the 40 m of bathymetry (upper limit for bottom-fixed solutions) and a bathymetric upper limit of 200 m, selected by guaranteeing the technical installation of all floating concepts, but still with manageable mooring costs. The outcome obtained for the wind power resource, at deep open sea, offshore Continental Portugal is illustrated in figure 6.

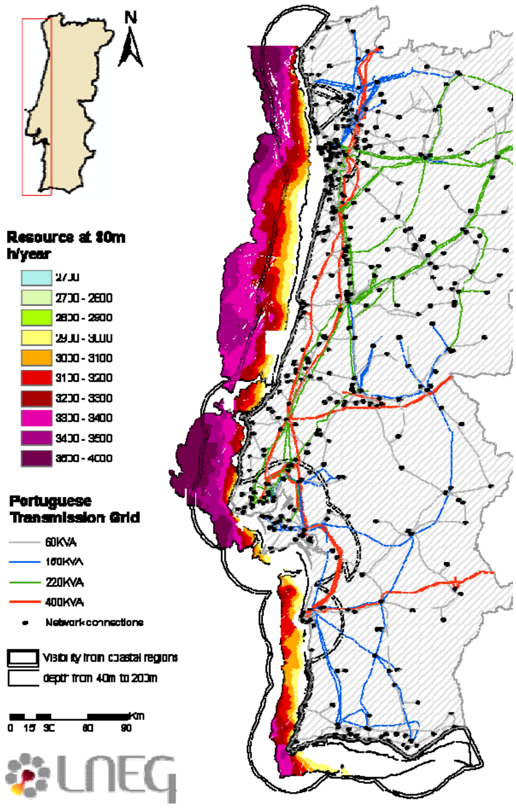

Figure 6 – Offshore wind power resource assessment availability in Continental Portugal for open sea areas from 40m < depth < 200m (offshore test turbine 2MW).

For this deep offshore open sea case, the wind power resource estimated is almost *"unlimited"*. The GIS analysis gives a total capacity value over 40GW of wind power available for all the open sea confined between bathymetric depths of 40m and 200m.

4.0 Conclusions

The study described enabled to conclude that the Continental Portugal coast offers favorable conditions for the offshore wind power exploitation in terms of available resource both for near-shore applications and, especially for the future use of floating technologies. The wind resource was assessed with the most state-of-the-art model available and the methodology is in the up-front line for this sector. The results presented constitute a very powerful tool in the initial phase of development of the offshore wind sector, e.g. for planning purposes and for the motivation of private investment. Nevertheless - although the simulated results were only validated with observational anemometric data from onshore stations corrected with the inter-annual variability factors - as with all outcomes from numerical models, they should be analyzed with care, once experimental wind data from offshore meteorological stations is still not available for the Portuguese Continental coast.

In the near future, more sophisticated studies would be desirable, namely a refinement of the spatial resolution mesh (here 3x3km was used - perfectly adequate to the preliminary goal scope of this study) in order to detect possible special wind condition circulations, such as the barrier jets, gap flows or even Langmuir rolls. A refinement of the seabed classification type would also contribute to the accuracy of the outcomes for the near-shore applications. Another critical constraint for the deployment of offshore wind in Portugal - still not addressed in the present study - are the strong Atlantic Ocean storms, that may not only reduce considerably the windows of opportunity for the installation and maintenance of these power plans, but also have an excessive wave energy content for the safe operation of wind turbines.

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