Assessment of the Sustainable Offshore Wind Potential in Portugal

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Abstract:

The sustainable offshore wind potential for the west and south coasts of Portugal is presented. Results were carried out using an atmospheric mesoscale model (MM5) and GIS tools. A long term simulation with 1 year of Reanalysis data were made in order to produce a resource assessment simulated with two types of wind turbines namely the GEWE 1500SL at 60m high and VESTAS V80 2000kW at 80m high. Bathymetric lines of 10m, 20m and 40m were digitized in order to identify, using GIS tools, the best coastal areas with gently slopes. Unlike previous common opinions, the preliminary results of this work enhance some interesting areas for developing offshore wind parks.

Keywords: offshore, wind potential, MM5, GIS.

1 Introduction

In countries like United Kingdom and Denmark, offshore wind parks are growing at an interesting rate. This is mainly due to the continuous investigation made by turbine manufacturers, producing nowadays specific turbine models with hub height's ranging to about 100m for sea depths less than 50m, and by the known local sea-breeze circulations near the coast combined with permanent winds generated by large High and Low transient mid-latitude atmospheric systems in North Atlantic Ocean.

In Portugal, there are currently no offshore wind parks while inshore wind parks are proliferating very fast mainly due to the ratification of Kyoto protocol, the European directive for renewable energies and the existence of a high wind resource, specially in mountainous and/or coastal regions. Strong restrictions to the installation of wind parks, such as environmental, territory planning or even administrative constraints, as well as the reduced grid capacity, prevent promoters to disseminate wind parks in some interesting areas. Also the simple idea that the free areas with an economic sustainable wind resource in the mainland are about to finish, lead INETI to start a new project by using the well known atmospheric mesoscale model – MM5 [1] and GIS – "Geographic Information System" tools to study the wind potential offshore, in the west and south mainland coast of Portugal as a first approach.

In this study, some restriction parameters are considered, namely, the energy produced by specific offshore wind turbine types with hub heights higher than 60m, the distance to shore (for economic purposes), the depth of continental platform (lower than 40m), exclusion of navigation channels, among others. Preliminary results of this work show the existence of some areas near coastline with good energy assessment in the west and south coasts of Portugal. Also the identification of the sustainable wind potential offshore can contribute for future planning of the national electric network for this purpose.

2 Offshore assessment

A reasonable wind potential assessment for offshore purposes in coastal areas of Continental Portugal was made in this work by making a high resolution (3X3km) long term simulation with the popular atmospheric MM5 model [1] for all coastal regions of Continental Portugal. Basically, the MM5 is a regional atmospheric model capable to simulate local thermal or shearing phenomena (e.g. sea-breeze circulations) among others in a *sigma* [2] coordinate grid which follows the terrain. For this study, a whole one year of Reanalysis [3] data from NCAR/NCEP's mass storage systems was ingested to MM5 at intervals of 6h. Model output for wind and energy density fields were corrected by an intra annual variability factor computed with help of four anemometric reference stations monitored by INETI for 12 years. Table 1 shows the name of each station and also its height above ground level. Each sensor height is also presented. In figure 1 one can see the location of each mast in mainland Portugal. These stations will be use in this work for validation purposes by compare wind speed results between observed and simulated values.

STATION	STATION ALTITUDE (A.G.L)	HEIGHT OF SENSORS	
		Velocity	Direction
IN_01 S. João Lampas	152m	10m	10m
IN_04 Vila do Bispo	104m	10m	10m
IN_32 Gardunha	1210m	10m	20m
IN_33 Arruda	398m	10m	20m

Table 1: INETI's wind stations used for the scope of this work.

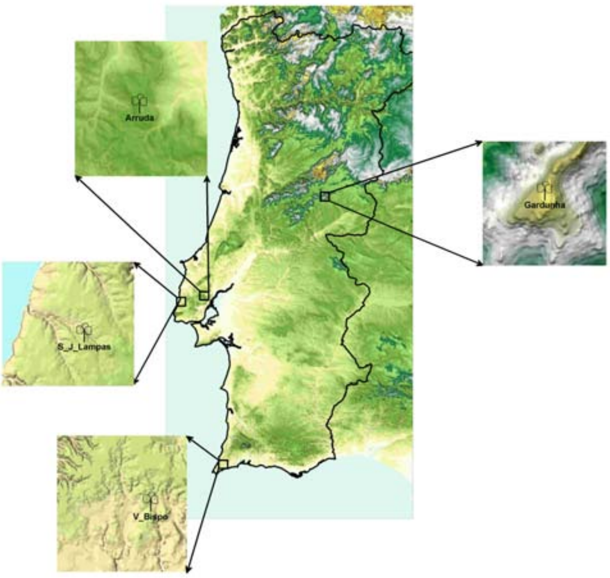


Figure 1: Location of INETI's reference stations for wind comparing results and assessing the intra annual variability.

2.1 Set of numerical simulation

The MM5 model was run with version 3.7.0 updated in what concerns to the formulation of the atmospheric physics, presenting the advantage of being a freeware model constantly improved by it's users in universities and research institutes all over the world. For the study here presented in this work the MM5 model was configured with four one-way nested domains with resolutions of 81km 27km 9km and 3km. Parameterization schemes were previously selected by making a couple of control simulations for 4 selected days in order to minimize the differences between observed and simulated wind speed and direction values. Parameterization schemes like Gayno-Seaman (PBL), RRTM (radiation), GRELL (cumulus) SIMPLE ICE (microphysics) and NOAH soil model were chosen since wind data simulated are better in agreement of observed wind data [4]. Figure 2 shows the high resolution domain (3X3km) used for resource offshore assessment and table 2 shows the grid point dimension as well as spatial resolution and model step time for all four one-way nested domains.

Figure 2: High resolution MM5 domain (3X3km) used for offshore assessment.

Domain	Grid dimensions $nx \times ny \times n\sigma$	Spatial resolution	Model Step (s)
D1	52×63×32	81 km	240
D2	54×72×32	27 km	81
D3	111×96×32	9 km	27
D4	171×276×32	3 km	9

Table 2: Domain dimensions and model step of the simulations.

The meteorological data available from Reanalysis project contains atmospheric data in 17 horizontal levels and also plus 4 levels with special fields for soil model integration.

Two turbine models were also simulated with MM5 at 3X3km resolution in order to produce the annual power production expressed with units of number of hours at full capacity (h/year). The GEWE 1.5SL with 1500 kW with hub height at 60m and the VESTAS V80 turbine model with 2000 kW nominal power and hub height of 80m were selected. Figure 3 shows the power curves for each turbine model. In Figure 4 one can see the simulated output field for the number of hours at full capacity (hereafter NEPs) with MM5 for those turbine models [5]. The intra annual variability is accounted for both of simulations.

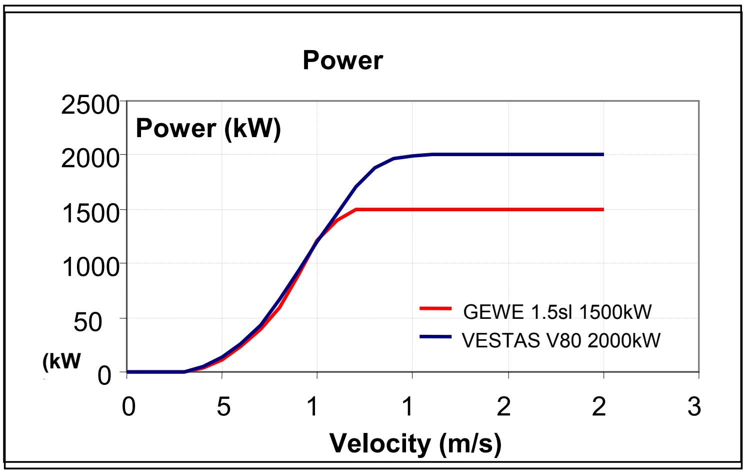
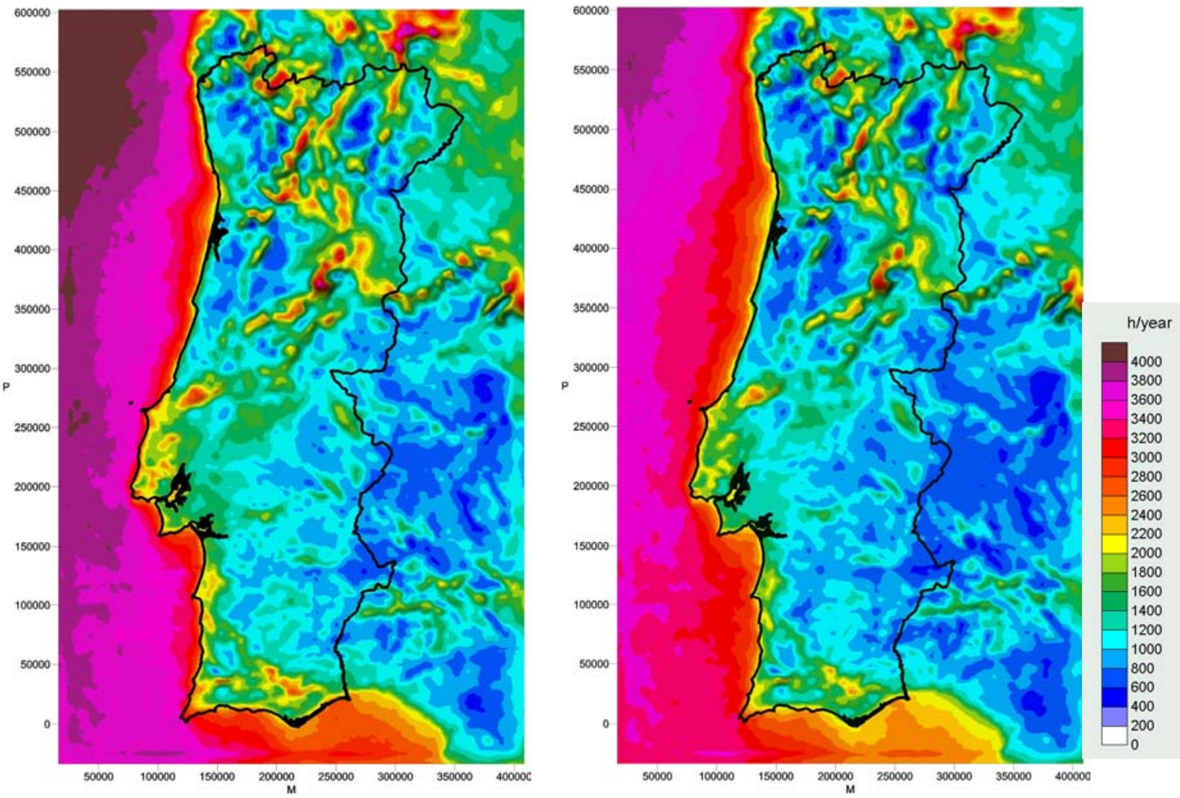


Figure 3: Power curves for two turbine models: GEWE 1.5SL 1500kW (hub height at 60m) and VESTAS V80 2000kW (hub height at 80m).



(a) (b)

Figure 4: Simulated field with MM5 (3X3km) for the equivalent number of hours at full capacity: (a) – GEWE 1.5SL 1500 kW (h=60m); (b) – VESTAS V80 2000 kW (h=80m).

Simulated wind speed data were subjected to a validation procedure. Those results can be reviewed in [6].

2.3 GIS operations

To identify locals with good potential for offshore wind power development, a GIS software with some spatial operations was used to make a simple query taking into account the following factors:

a) Distance to coast below 15km;
b) Sea bathymetry lower than 40m;
c) A gently slope between 20 and 40m depths;

"Acceptable" wind resource (number of hours at full capacity great than 2300 h/year;

d) Proximity to the network with available grid connection capacity.

Preliminary results obtained with GIS operations are presented in figures 7 and 8 for each turbine model.

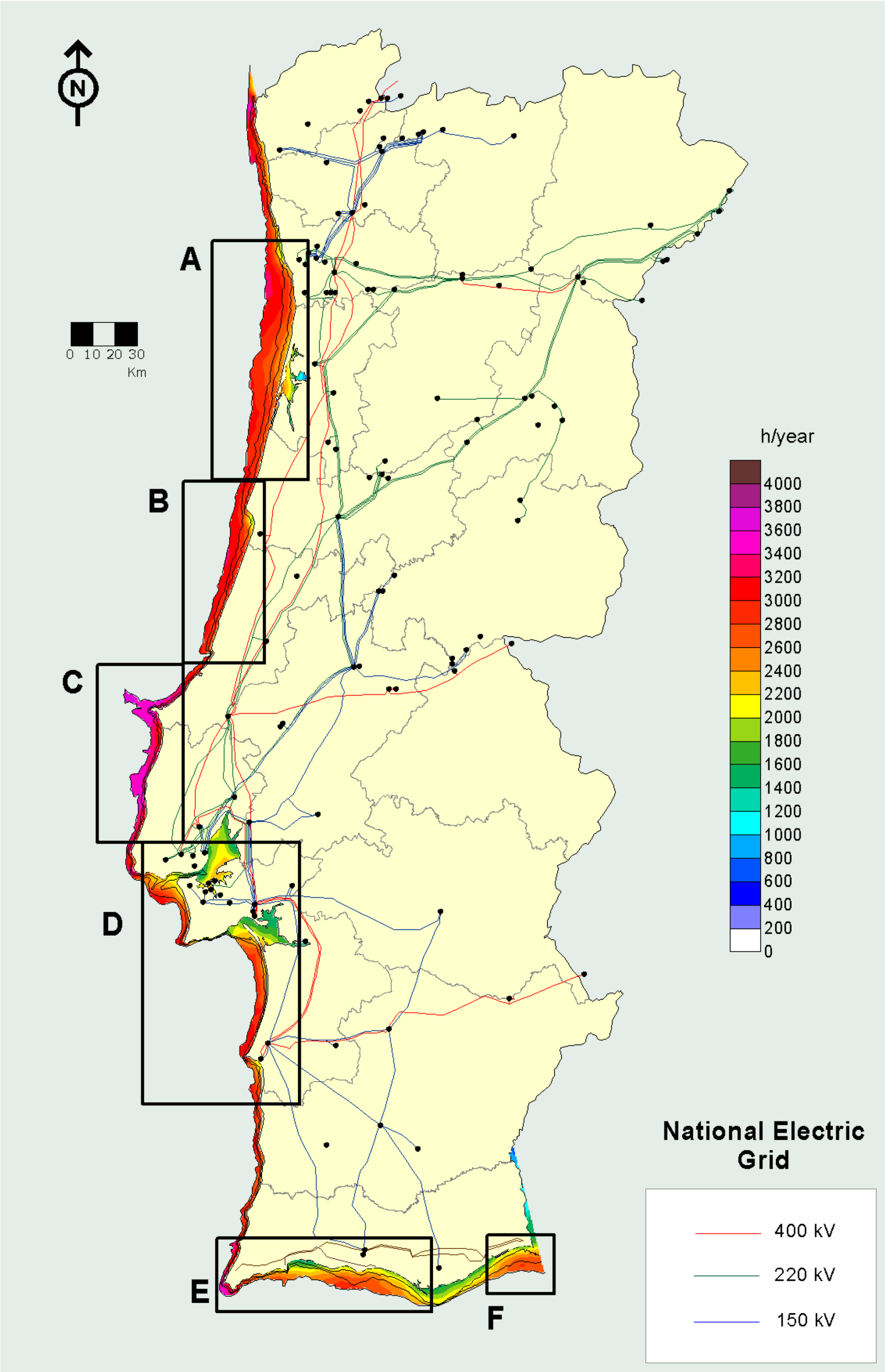


Figure 7: GIS results obtained for turbine GEWE 1.5SL 1500 (h=60m). MM5 simulation with 3X3km

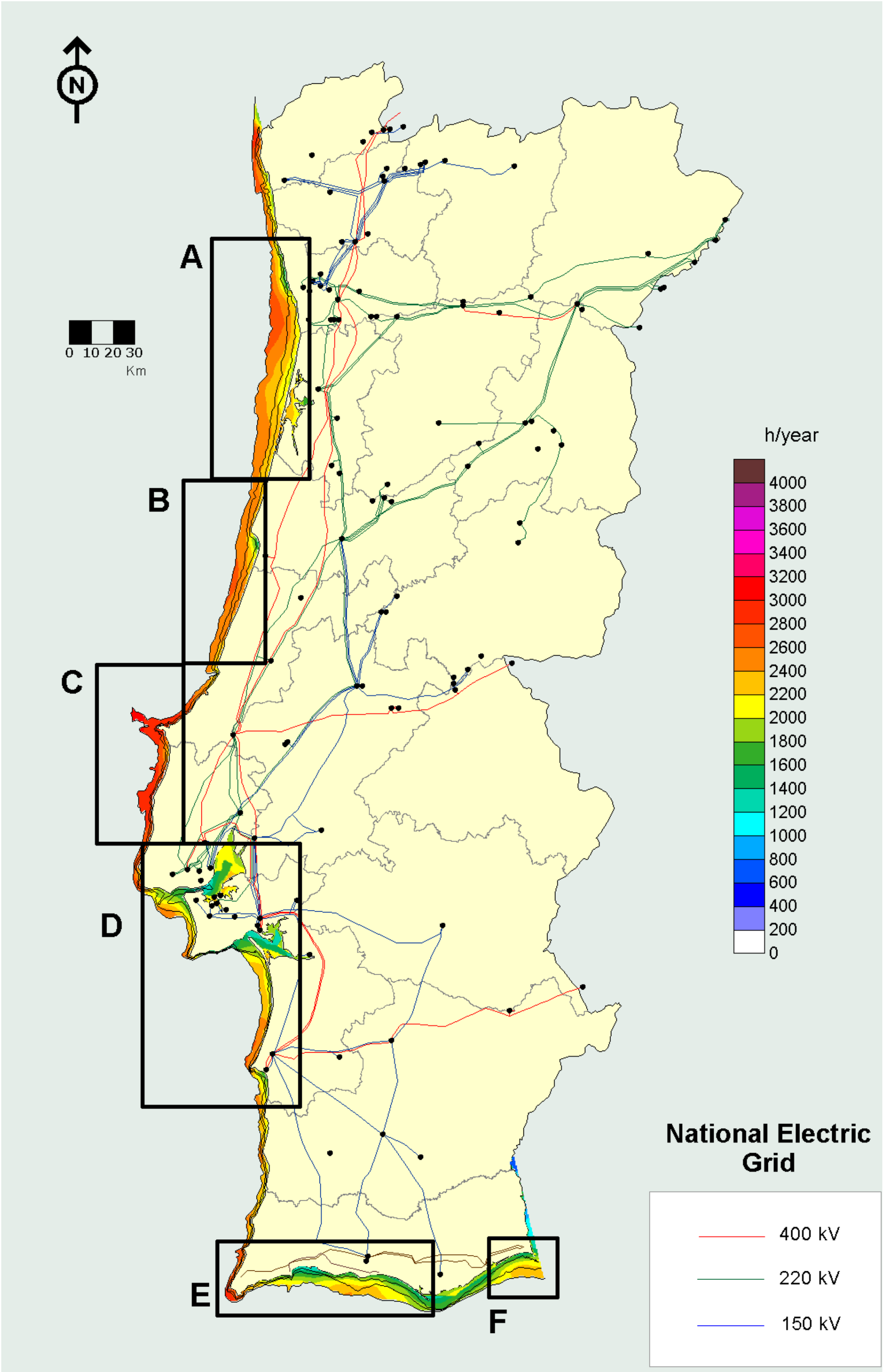


Figure 8: GIS results obtained for turbine VESTAS V80 2000kW (h=80m). MM5 simulation with 3X3km

Five favourable areas denoted by capital letters A,B,C, D, E and F were identified for both turbine models. Although the values obtained with the larger capacity wind turbine (VESTAS V80 2000kW, h=80m) were slightly lower, for both cases one still obtains favourable places for planning offshore wind parks, and namely to carry out feasibility assessment studies. In figure 7 it is possible to observe a "zoom" image for each selected area marked with ellipses. These "new" selected locals are indeed the most relevant places to carry out technical feasibility studies, if the development of offshore wind parks in Continental Portugal is considered economically possible by the developers. Figure 9 shows these selected regions (ellipses) that result from the simulation of the GEWE wind turbine. Selected locals were chosen to each area as follows: Area A - near Oporto and Espinho cities; Area B - Figueira da Foz; Area C – Berlengas and Peniche regions; Area D - Tagus estuary plus Caparica and Troia regions; Area E – Bordeira and Portimão/Albufeira regions; Area F – Vila Real de Santo António.

Those selected regions are located at a reasonable distance to the national electric grid connections except for some locals presented in area C and F where the nearest grid point is marked by a blue square (Rio Maior for area C and Estói for area F). Rio Maior and Estói grid connectors are distanced to about 45km of the interested area for offshore development which, taking into account the usual nominal capacity of offshore wind parks, may prove to be economically feasible.

Table 3 shows the query results expected for both turbine models above mentioned.

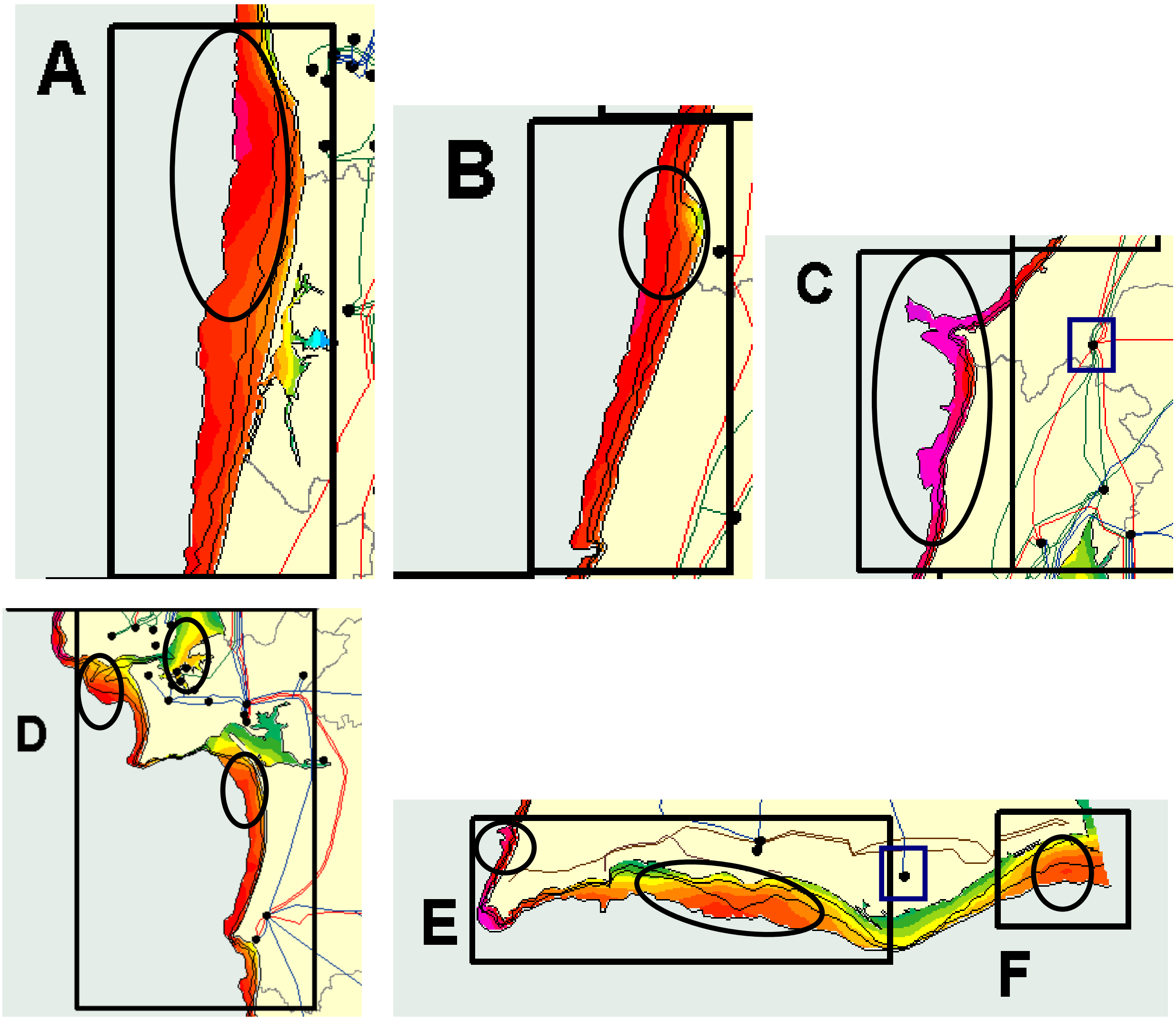


Figure 9: selected "zoom" for each area (A to F) with good offshore resource assessment. MM5 simulation with 3X3km

Area	Region	Production estimates (NEP's) GEWE 1.5SL (h/year)	Production estimates (NEP's) VESTAS V80 (h/year)	Bathymetry depth (m)	Distance to coast (km)
A	Oporto/Espinho	2600 to 3000	2600 to 2800	20 to 30	5
B	Figueira da Foz	2600 to 3000	2600 to 2800	20 to 35	5
C	Berlengas/Peniche	3400 to 3700	2800 to 3200	20 to 40 *random shallow rocks expected*	10 to 15
D	Tagus estuary	2400 to 2600	2000 to 2400	10	0.5 to 7
	Caparica	2600 to 3000	2200 to 2600	10 a 20	5 to 7
	Setúbal/Tróia	2600 to 3000	2000 to 2600	10 a 30	5
E	Bordeira	2600 to 3400	2800 to 3000	20 a 40	2 to 3
	Portimão/Albufeira	2600 to 3000	2200 to 2600	10 a 20	5
F	Vila Real de Santo António	2600 to 3000	2200 to 2600	20 to 35	10 to 15

Table 3: Query results obtained for each selected area taking into account the wind potential (h/year) for both turbine models.

The results presented in table 3 reveal the area C as the area with best resource assessment for both turbine models. Preliminary values show an expected wind potential (h/year) of about 3000 h/year (up to 3700 h/year). Such promising values were encouraging are good indicatives for the potential offshore in Continental Portugal, something that a few years ago was considered to be non-existent. These results obtained by INETI aimed to start a monitoring campaign in Berlengas Island in order to confirm these estimates and validate the methodology used. Although area C represents the best coastal resource region for offshore development in Continental Portugal, one should emphasize that the nearest electrical grid connector is located at 45km, although even bigger problems may be expected since this is a historically known coast by the sailors due to the storms and strong currents that difficult navigation and, in the limit, may prevent wind power development.
Other interesting areas such as the whole south coast of Algarve (areas E and F) present good resource values, ranging from 2600 to 3400 h/year although offshore development for area F (Vila Real de Santo António) also demands a new closest electrical grid connection. This region may be evaluated in Iberian, rather than Portuguese terms, since this area is located in the Portuguese-Spanish frontier, and the grid connection of a wind park may be technically more feasible in the Spanish side. The bureaucratic issues would be without question, a big challenge to the developer, since trans-national wind parks are still an innovative issue in what concerns permits and administrative issues.
The Tagus estuary also revealed good acceptance values for near shore (sometimes also referred as foreshore) development although the presence of these values must be careful interpreted because a couple of more sophisticated studies must be realized taking account for the presence of navigation channels, two suspended bridges and other hydro-dynamical estuarine phenomena.
Finally the Northern coastal areas of Continental Portugal (areas A and B) show the existence of a good compromise between electric grid connections and resource assessment.

3 Concluding remarks

In this work a wind potential offshore resource assessment is shown for Continental Portugal. The atmospheric mesoscale model MM5 was used to produce annual power production fields expressed as “equivalent number of hours at full capacity” (h/year) with a long term simulation for all coastal regions of the country. A complete year of Reanalysis data (1999 year) with a high resolution mesoscale domain with 3X3km was simulated. Simulated wind fields were corrected by the intra annual variability factor with data from four reference anemometric long term stations monitored by INETI. Two turbine models were simulated in order to produce estimates of the annual energy production. The GEWE 1.5SL with 1500kW with hub height at 60m and the well know VESTAS V80 turbine model with 2000kW with hub height of 80m.

Simulated fields were introduced in GIS software to retrieve some acceptable areas for wind potential offshore development.

Unlike previous common public opinions, the preliminary results of this work enhance some interesting areas for developing offshore wind parks, in case this is considered a strategic option and tariffs are defined accordingly. As an example the Berlengas/Peniche region presents the best resource assessment for both turbine models with wind potential values (h/year) ranging from 3000 up to 3700h/year, although that may also be the most challenging location due to rough sea local characteristics.

Although the most nearest electrical grid connector is distanced as far as 45km. Such long distance demands a new electrical grid connector closed to this area.

Other interesting areas are revealed such as the whole south coast of Algarve with good resource values, ranging from 2600 to 3400 h/year in Portimão/ Albufeira and Vila Real de Santo António. This last area also demands a new closest electrical grid connector. Northern areas of Continental Portugal reveal by the same way good resource assessment for offshore purposes offering a good compromise between the electric grid connectors. Other estuarine regions such as the Tagus estuary reveal good acceptance values although a more sophisticated study must be realized in order to deal with the presence of navigation channels bridges and other hydro-dynamical estuarine phenomena.

Results presented in this work lead INETI to start a new monitoring campaign in the Berlengas/Peniche region in order to validate the results here presented. Therefore a high resolution resource assessment campaign in the most relevant coastal areas of Continental Portugal is being prepared with outputs "combined" from long term mesoscale simulations and microscale models to estimate a rigorous and highly accurate assessment for offshore wind power in Portugal.

References

[1].Grell, G. A., J. Dudhia, D. R. Stauffer "A description of the Fifth-Generation Penn State/NCAR Mesoscale Model (MM5)" NCAR Technical Note, NCAR/TN-398+STR, 1995.

[2].Haltiner, G. J. and R. T. Williams, *Numerical Prediction and Dynamic Meteorology*. Second Edition. John Wiley and Sons, New York, USA, 1980.

[3].Kalnay, E. *et al.* "The NCEP/NCAR 40-Year Reanalysis Project". *Bull. Amer. Meteor. Soc.* **77**, pp. 437-471.

[4].Costa, P. *Atlas do Potencial Eólico para Portugal Continental*. Master's Thesis, Faculty of Sciences – University of Lisbon, 2004.

[5].Costa, P. *et. al.*, *Atlas do Potencial Eólico para Portugal Continental*. CD-ROM Publication, INETI, 2004.

[6].Costa, P., P. Miranda., A. Estanqueiro. "Development and Validation of the Portuguese Wind Atlas". To be published in the Proceedings of EWEC 2006, Athens.