WIND INDEX FOR PORTUGAL MAINLAND

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Portugal has nowadays a wind power capacity connected to the national grid of about 3.5 GW, enabling it as the 11th country worldwide with the largest installed wind power.

Like other countries with the same high penetration of wind energy, the industry feels the need to have key indicators of the wind resource variability, so called Wind-Indexes (WI). These indicators, should allow owners and grid operators to quantify wind variability and help for a clearer assessment of the operational performance of wind farms and wind farm clusters.

The Portuguese Association for Renewable Energies (APREN), aware of usefulness of such indicator, the development of first WI for mainland Portugal. Megajoule was appointed by APREN to develop a methodology for calculation and subsequently publication of WI related to different areas of mainland Portugal.

The WIs are calculated for 13 windiness Sub-Zones aggregated into 6 larger Zones.

The major wind farm owners contributed to this project by giving operational data from their wind farms, dating back to 2007. The promoters involved represent the majority of installed wind power in mainland Portugal, about 70% of the 3.5 GW, distributed over 109 wind farms.

Production data for each wind farm is reviewed and corrected for low availability and production outliers.

The WI is based on real production data from selected wind farms for each Sub-Zone, which are selected based on the amount of historical data available and in the agreement with the Sub-Zone aggregated production.

The publication APREN's Portuguese WI is being published on APREN's website on a quarterly basis since January 2010 The first revision is underway, during the first quarter of 2011.

1. Introduction

Although the public release of the Wind Index is not generalized in all wind energy producing countries, there are several of them that publish a periodical WI. Among them are Holland, Sweden, Germany, Denmark, United Kingdom and the United States. From all the WI's publish nowadays, the most ancient is the Danish WI, dating back to 1979 [1].

In countries like Holland, Sweden, Germany and Denmark, the WI is published by industry associations similar to APREN, the Portuguese Association for Renewable Energy (Associação Portuguesa de Energias Renováveis). In the other hand, the United Kingdom and the United States have their WI's published by private consultants institutions, like Garrad Hassan for the United Kingdom and Windlogic in the United States, for example.

Nowadays in Portugal, the national transport system operator (REN) already publishes their WI [4]. This WI is calculated since 2006, available in the REN's information centre, and it's based on the total wind energy produced in the country. Thus, although a relevant information, it fails to represent the significant fluctuations in wind resource, or windiness, that occur along the complex Portugal mainland and, as it is based on delivered energy, its dependent of operational set-backs.

In late 2009 MEGAJOULE (MJ) was designated by APREN to develop and publish the first Wind Index for Portugal Mainland. This paper briefly described the concept and methodology and presents the first published results, for 2009 and 2010

2. Production and operation data from Wind Farms

The necessary Wind Farm operational data was provided by a group of Wind Farm owners which supported the project (AUDITERG, EDF Enèrgies Nouvelles, EMPREEENDIMENTOS EÓLICOS do VALE do MINHO, EDP Renováveis, FINERGE, GENERG and IBERWIND). Their Wind Farms represent 70 % of the installed wind power installed, meaning nearly 2.4 GW, scattered by 109 Wind Farms. The geographic coverage was also very adequate and is shown in figure 1.

For each Wind Farm, total monthly energy production and Wind Farm availability was provided for each month of operation. Particular events that may impact energy production (like curtailment, grid limitations, among other).

3. Definition of Windiness Zones and Sub – Zones

The wind variability across continental Portugal can be very accentuated, advising the WI to be calculated for limited areas were monthly windiness can be more consistent [5].

Mainland Portugal is characterized by a particularly complex orography, namely in the Centre and North of the country, were the majority of the wind power is located. Based on wind climate data one could easily define dozens of regions with distinct uncorrelated wind regimes, however, it is also advisable to provide a WI which is simple and easy to read, only possible with a reasonable reduced number of regions.

Together with APREN, it was found wise to limit the number of windiness Zones to 6 large geographic areas. However, as a great amount of simplification exist in order to translate the high wind variations on Portuguese territory into only 6 WI figures, each Zone is still divided into smaller windiness Sub-Zones (13 in total). In fact, it's for this 13 Sub-.Zones that the WI is actually calculated, being the 6 Zones WI simple averages of the WI at the comprised Sub-Zones.

The definition of each Sub-Zone was made by grouping the Wind Farms based on their wind regimes. That is to say, the Wind Farms for which the monthly production figures were correlated. (a clear evidence of correlation in wind regimes). Subsequently, the definition of each Zone was made by grouping the Sub-Zones were total/aggregated monthly production was best correlated. The defined Windiness Zones and Sub-Zones is shown in figure 1.

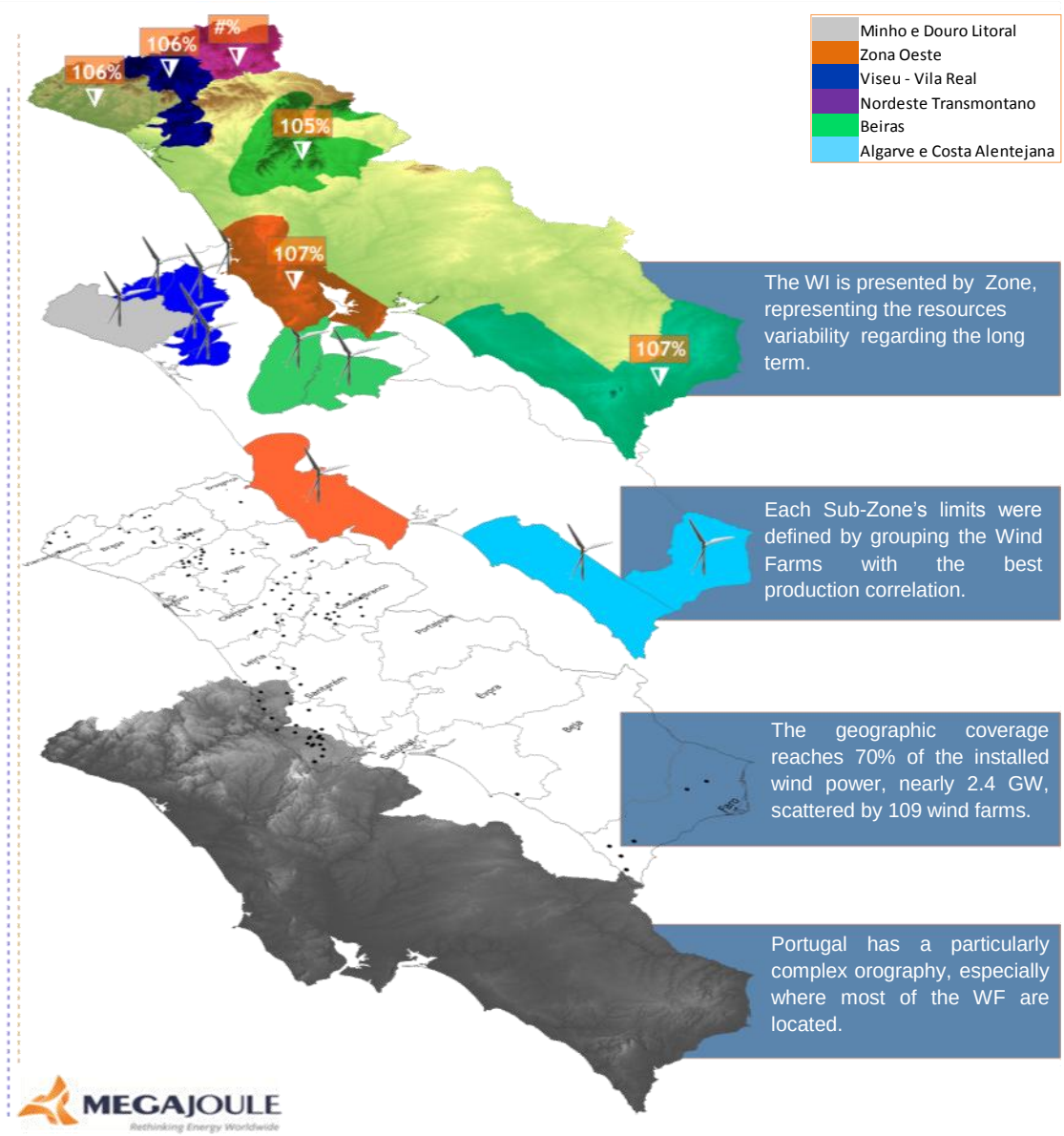


Figure 1 - Location of considered Wind Farms, Sub-Zones and Zones and yearly 2009 WI

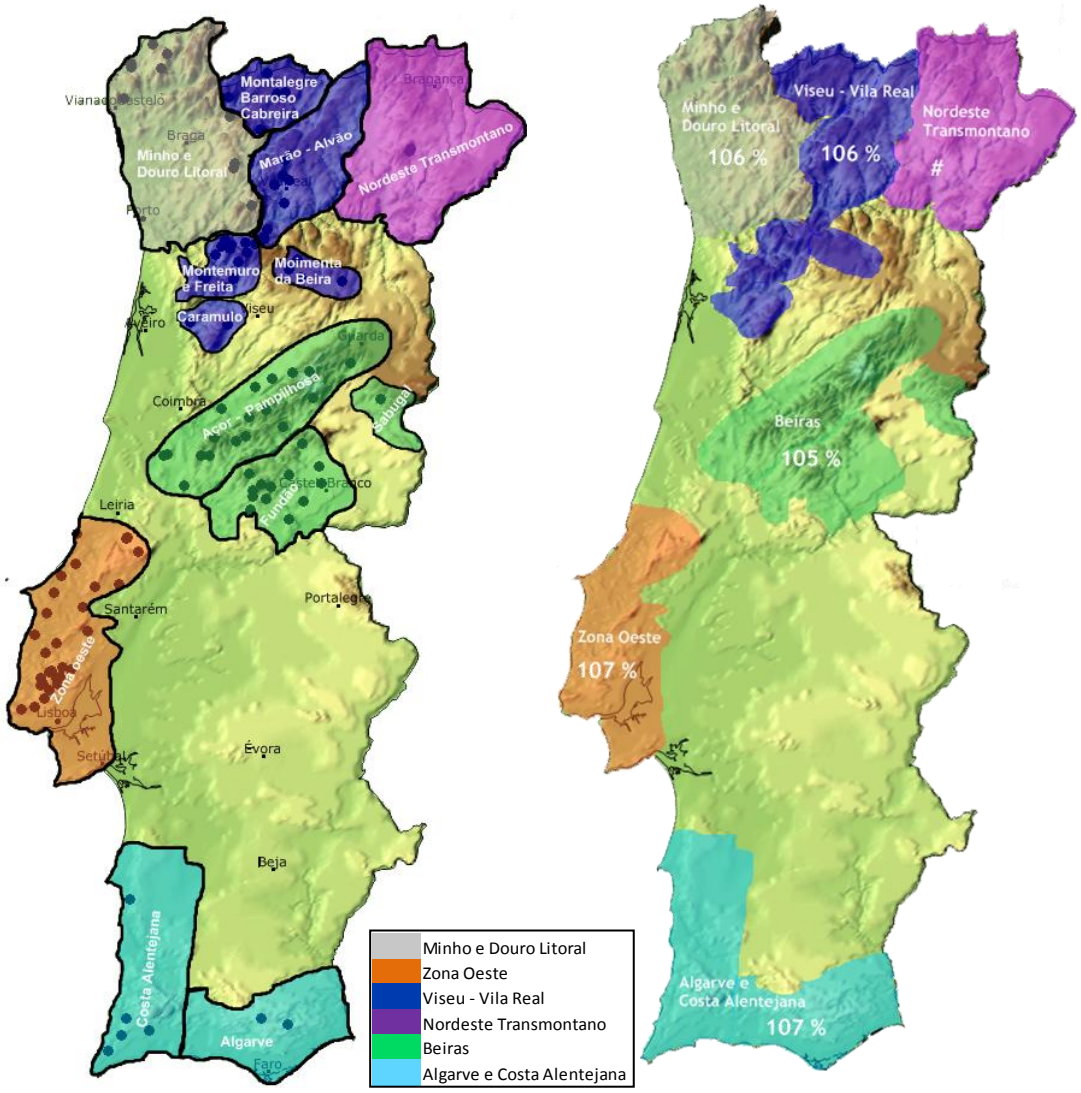


Figure 2 - Representação das Zonas e Sub – Zonas de Eolicidade e os resultados acumulados para o ano de 2010.

4. Definition of Windiness and Wind-Index

Windiness is defined as the amount of wind energy or wind resource available for energy conversion by Wind Farms, in opposite with the actual converted wind power which may, and do, depend on operational performance.

A Wind-Index can be defined as an indicator of a period's windiness, let's say a monthly windiness, when compared to a reference windiness value.

Wind Indexes are generally based on the following, simple, definition:

$$WI = \frac{\text{Windiness}_{\text{Monthly}}}{\text{Windiness}_{\text{Average or LongTerm}}} \quad [1]$$

The above means that, for a given month, an WI above 100 % represents an available wind resource, or windiness, higher than the Long Term annual average windiness for the region.

Needless to say that, depending on the seasonal variations of wind regimes, some months will be typically show WI above 100 % while others usually below 100 %.

As a wind resource indicator, windiness's are obviously best defined with measures of wind energy, or wind intensity. Also known is that, for modern Wind Farms, met masts for Wind Farm monitoring purposes are a very common practice. Thus, apparently, the observations taken at the Wind Farm's monitoring masts should be the best approach to quantify windiness. Unfortunately, this is hardly the case.

First, the access to this information is far from easy. Whilst the industry recognizes the importance of taking local measurements of wind climate to keep track of Wind Farm's operation, it still lacks the culture of keeping good records during time. Secondly, the reliability of this data is very much hindered by the lack of care given to of these mast's condition and operation, as observations are used for mostly empirical analysis.

Other national networks of wind observation exist, the most relevant of which being the Portuguese Meteorological Institute surface masts network. However, as this observations are taken for overall weather analysis and forecasts, wind intensity measures are typically conducted with less care for accuracy than it would be advisable for wind energy purposes. The use of this kind of observations would oblige for a extended effort to inspect the available masts to assess actual reliability of the observations and to keep track of their conditions over time.

Other possibilities were considered, as the use of mesoscale numerical simulations of local wind regimes departing from global weather datasets, as the global reanalysis data from NCEP/NCAR, however the effort needed was outside the promoters scope at this stage.

Given these limitations, the choice was to consider the actual Wind Farms production data as windiness measure. If limitations are considered and operational or performance trends are avoided this can be reliable measures of each region windiness.

5. Calculation of the Wind Index

The Wind-Index for each Sub-Zone is calculated based on the Normalized Corrected Production for a carefully selected small group of Wind Farms, called Reference Wind Farms (R-WF).

The Normalized Corrected Production represents the Wind Farm production divided by the Wind Farm's capacity and corrected for unavailability or other deviations to normal operation, as explained in section 6.

The following simple expression is considered:

$$WI_{Sub-Zone\,j,\,i} = \frac{\sum_{k}^{Nbr\,R\text{-}WF} P_{Observed} *_{k,i,\,j}}{\sum_{k}^{Nbr\,R-WF} P_{LongTerm} *_{k,\,j}} \quad [2]$$

$WI_{Sub\text{-}Zone\,j,i}$ is the WI for month i at Sub-Zone j;

$P_{Observed}{}^{*}{}_{K,i,j}$ is the Normalised Corrected Production at month i for R-WF k at Sub-Zone j;

$P_{LongTerm}{}^{*}{}_{k,j}$ is the Long Term annual average Normalised Corrected Production for R-WF k at Sub-Zone j

The reason the WI is based on a limited number of Wind Farms, rather than the totality of Wind Farm on a given Sub-Zone, is to allow a better control on the reliability of production data delivered.

This R-WF are chosen based on i) extent of reliable production history ii) correlation of Wind Farm production with Sub-Zone aggregate production iii) reliability and consistency of present operation.

A minimum of 2 year of historic production is considered to select a R-WF.

In cases where the choice between longer historic data or better correlation to Sub-Zone aggregated production is not clear, sensitivity tests on Sub-Zone WI are performed.

Figure 3 illustrates the correlation between a R-WF and the aggregated production for Sub-Zone “Marão/Alvão”.

The WI for a given Zone is simply the average of the WI for the comprised Sub-Zones.

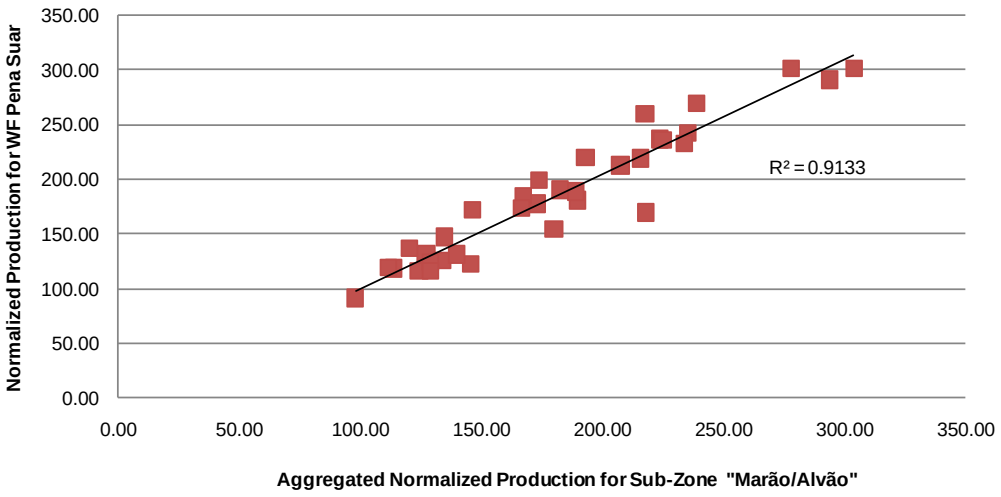


Figure 3 - Correlation between aggregated Normalized Produciton for Sub-Zone “Marão/Alvão” and R-WF “Pena Suar”

6. Wind Farm data quality control and processing

As the WI is based on real production data the production figures must be corrected for deviations or trends from solely Wind Farm non-ordinary operation or performance. Most of these are related to turbines, plant or grid unavailability, but other factors (like curtailment, grid limitation, etc.) may apply.

This so called non-ordinary events will alter Wind Farm production figures, most likely lowering them, with no relation with the period's windiness. If not corrected, these production data will give false windiness trends. untrue

These non-ordinary pevents are identified by the following criteria:

1. Indication from Wind Farm owner or operator of unusual turbine or plant operation or performance
2. Low turbine or plant availability : < 90% and
3. Monthly production outlying "typical" trend for Wind Farm – "outlier"

The identification of an "outlying" production is done by comparing the Wind Farm monthly production with the aggregated production for the Sub-Zone, using a simple linear regression. An "outlier" is identified whenever the data lies outside the 90% confidence limits for the best fit linear regression, as illustrated in figure 4.

For the overall WFs non-ordinary monthly production is excluded from the data-base to prevent any fictional trend on calculations.

For the R-WF, any non-ordinary production figure is corrected, or replaced, by an estimate. This is done by taking the production from the linear regression between the R-WF in question and the other 2 R-WFs for the same Sub-Zone, or for the total production for the Sub-Zone if all R-WF data for that month are rejected.

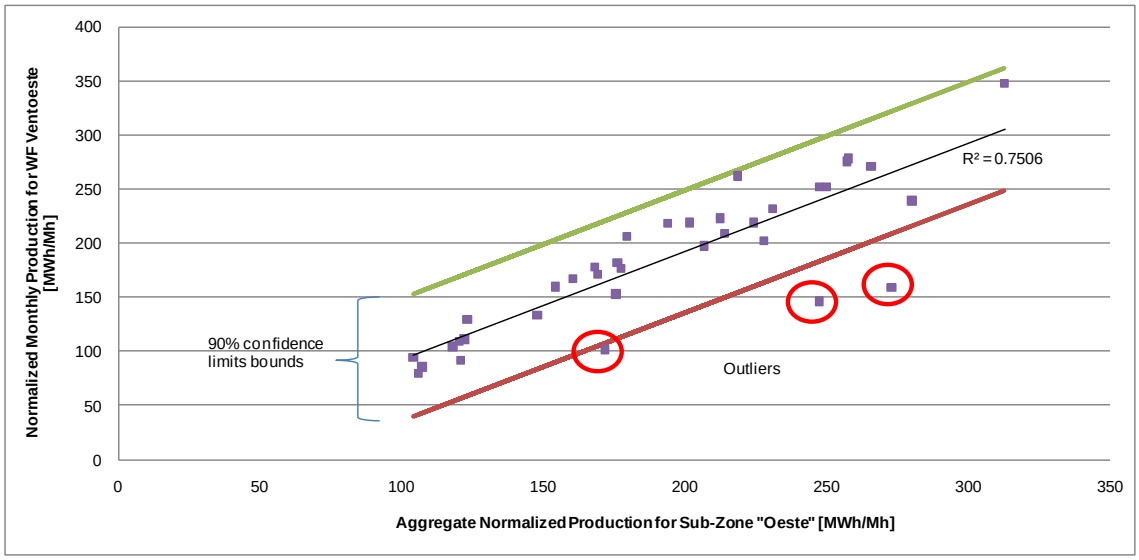
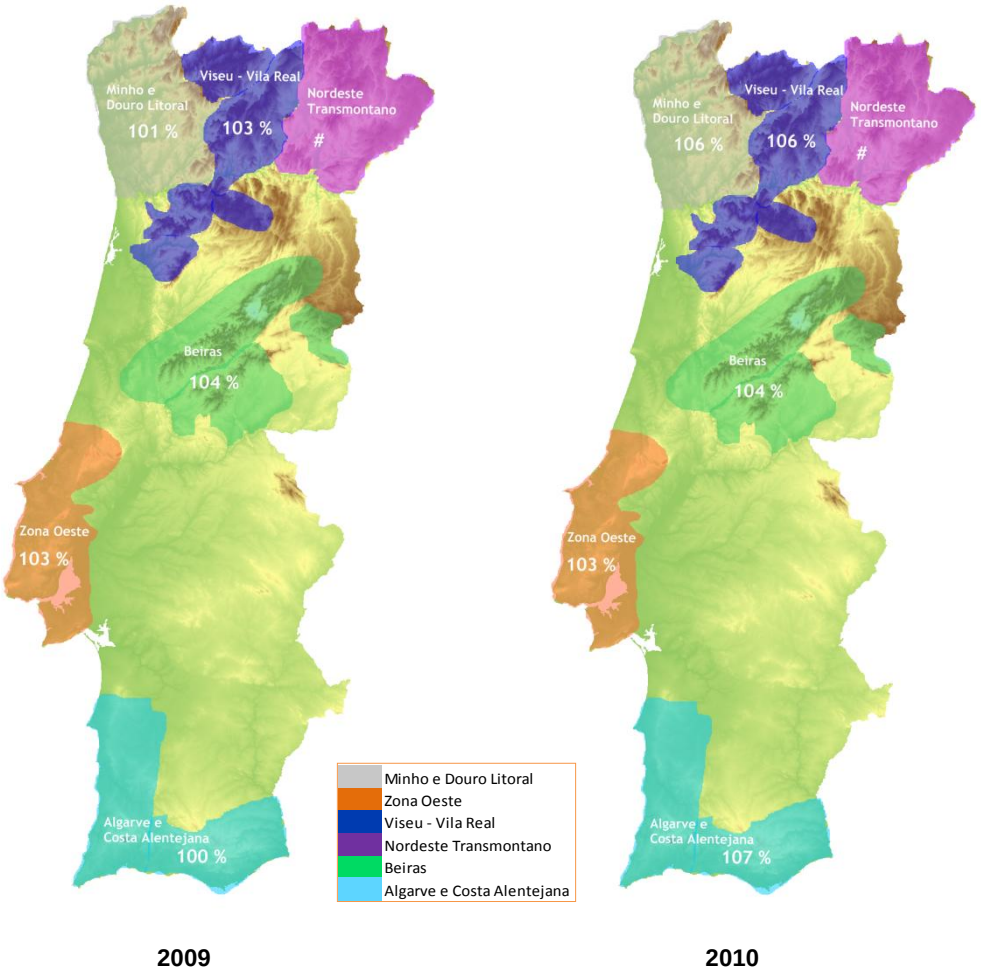


Figure 4 - Identification of production "outliers" for "Alto do Talefe" Wind Farm at "Montemuro/Freita" Sub-Zone

7. Results – WI for 2009 and 2010

The yearly WI for 2009 and 2010 were already published by APREN. These are shown on the following figure.

For one of the windiness Zones (“Nordeste Transmontano”) there wasn’t enough data to allow the calculation of reliable WI.



2009 **2010**

Figure 5 - Yearly Wind-Index for 2009 and 2010

8. Updates and Revision of the Portuguese Wind Index

It is advisable to update the WI definition with a given frequency. Major reasons are i) update of historic production data with most recent years, ii) changes in Wind Farm distribution throughout the country, iii) changes in Wind Farm distribution in a given Sub-Zone and iv) appearance of new, best performing, R-WFs

Any revision of the WI should also consider the revision, or re-calculation, of previous published WI. This will ensure a consistent and coherent time series of WI for each windiness Zone.

Ideally, an annual revision of the WI will be made in the beginning of each civil year and previous monthly WI will be updated accordingly.

The first revision of the Portuguese WI is underway and first results should be available end of first quarter of 2011.

9. Final Remarks

During 2010 the first Wind Index for mainland Portugal was published by APREN, based on actual production data from a large number of Wind Farms. Results have been welcomed by the Portuguese wind sector

Results were released for year 2009 and 2010, and WI will continue to be published in a quarterly basis.

Revision of the Wind Index calculation is already underway and should be finished during the first trimester of 2011.

10. References

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