Italian Ministry for the Environment, Land and Sea

WIND ENERGY RESOURCES ASSESSMENT
REPUBLIC OF ALBANIA
FINAL REPORT

EXECUTIVE SUMMARY

Introduction

The Wind Energy Resources Assessment (WERA) of the Republic of Albania is developed as a part of the activities carried out by the Italian Ministry for the Environment, Land and Sea (IMELS) within the framework of the following Memorandum of Understandings:

- "Cooperation on Environmental Protection", signed on May 30th, 2005 between IMELS and the Ministry of Environment, Forestry and Water Administration of the Republic of Albania;
- "Cooperation on Sustainable Development and Greenhouse Gases Emissions Reduction" signed on December 19th, 2007 between IMELS and the Ministry of Economy, Trade and Energy of the Republic of Albania.

The above Ministries at the Joint Committee held in Tirana on July 30th, 2008 agreed on the implementation of the WERA over the territory of the Republic of Albania. The CETMA Consortium (CETMA) was then entrusted to develop the WERA, in close cooperation with the Albanian counterpart and with the support of the Department of Physics (DIFI) of the University of Genoa.

Methodology

The study is developed in three main parts:

- Part 1 applies the simulation code WINDS for calculating the theoretical wind speed and wind potential maps, obtained combining a statistical analysis of the wind at high altitudes with computer simulations to build three-dimensional wind fields over the whole Albanian territory;
- Part 2 estimates the actual wind speed and wind potential maps through the introduction of a correction factor which takes into account the available ground measured data and other reliable wind measured data sources.
- Part 3 evaluates the main existing constraints (altitude, site accessibility, infrastructures, natural protected areas, power grid), in order to provide an estimation of the exploitable wind potential. Moreover, an exercise on the economic feasibility of wind farms installation in Albania is outlined. This analysis only represents a preliminary estimation to be refined and revised with the support of the Albanian competent authorities.

Theoretical Wind Speed and Wind Potential

The theoretical wind speed and wind potential were estimated based on a methodology which combines the statistical analysis of data relative to the wind speed aloft with numerical modeling of wind flows over complex terrain to realize a first-guess calculated wind potential map of Albania.

The territory of Albania has been subdivided into a number of computational domains about 100x150 km^2, with a grid step lower than 1 km. These domains are partially overlapping. Almost 500 three-dimensional wind flow simulations have been performed over each domain by means of the diagnostic mass-consistent code WINDS (Wind–field Interpolation by Non–Divergent Schemes), initialized by means of high altitude wind velocity values. These wind aloft data belong to a dataset of wind speed and direction obtained, at the top of the atmospheric boundary layer (i.e. around 3,000-5,000 m above sea level), from the re-analyses of the European Centre for Medium-range Weather Forecast (ECMWF). The statistical analysis of these data provided the weights (the frequency occurrence) for the numerical simulations performed, in order to calculate the mean wind field and the maximum calculated wind potential over Albania.

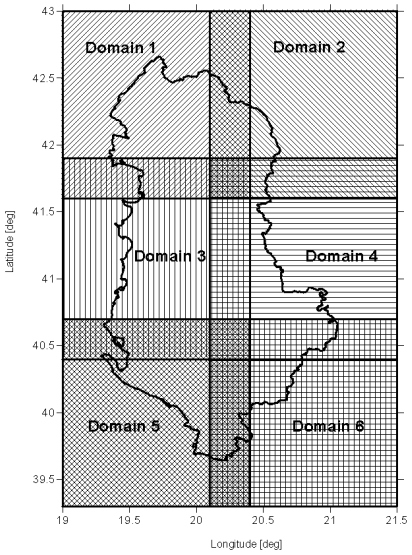

Figure 1: Selected Computational Domains

This methodology was applied in 2002 to develop the Italian Wind Atlas. The same methodology was then applied in 2006 by CETMA and DIFI to realize the Wind Energy Resources Assessment of the Republic of Montenegro, approved by the Government of Montenegro on February 2007.

The input to the WINDS code consists of:

- wind initialization data for the domain and stability conditions of the lower atmospheric layers;
- topography data of the domain and land cover data, parameterized through the roughness length and the displacement level.

A statistical analysis was performed on the wind aloft data, based on the calculation of the joint frequency distribution of wind speed and direction. A total number of 549, 538, 519, 512, 545, 538 three-dimensional simulations for the computational domains 1 – 6 were performed.

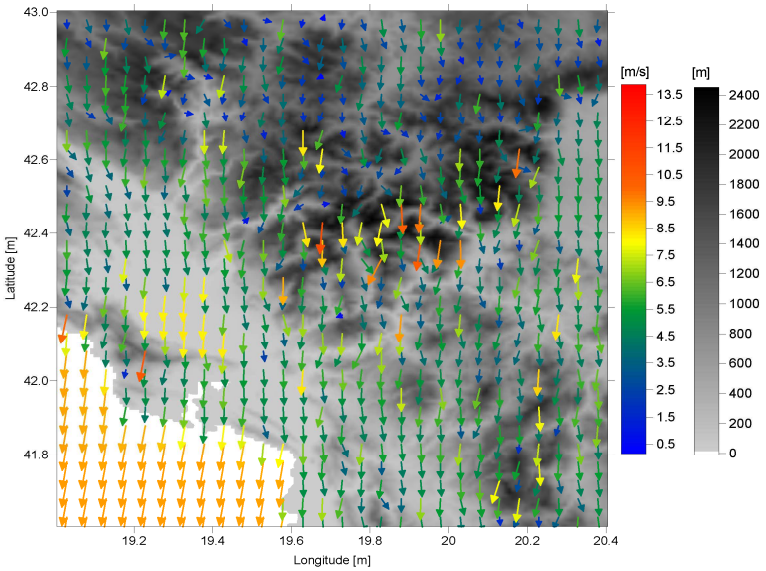

Figure 2: Example of Simulated Wind Fields over Domain 1

A frequency of occurrence, f, obtained in the statistical analysis of the wind aloft can be assigned to each simulation in order to calculate the climatological mean wind velocity through the following relation:

$$\overline{V} = \sum_i f_i v_i$$

where, for example for Domain 1, f_i (i=1,…,N=549) are the frequencies of the 549 wind velocities aloft, while v_i are the three-dimensional simulated wind fields. Figure 3 shows the map of the simulated average wind speed at 50 m a.g.l. over the Albanian territory.

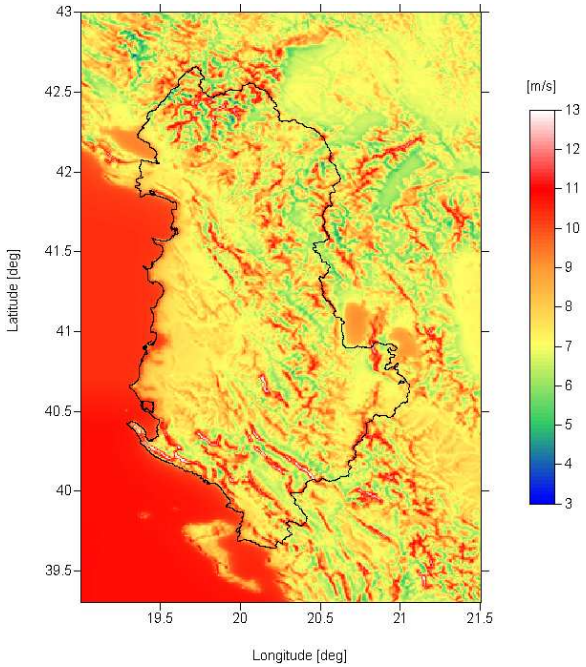

Figure 3: Theoretical Average Wind Speed at 50 m a.g.l. over the Albanian Territory

Actual Wind Speed and Wind Potential

In order to build a more realistic wind map, the simulated wind potential calculated by means of the numerical simulations was compared with available measurements from a set of anemometric stations throughout the Albanian territory, shown in Figure 4. These data can be divided into 3 groups: statistical values relative to 15 onshore meteorological stations of the Hydro-Meteorological Institute (hereinafter HM) of the republic of Albania; raw speed and direction measurements in other 7 onshore stations, 6 of them belonging to the METAR network; and Quikscat satellite data relative to 15 points offshore.

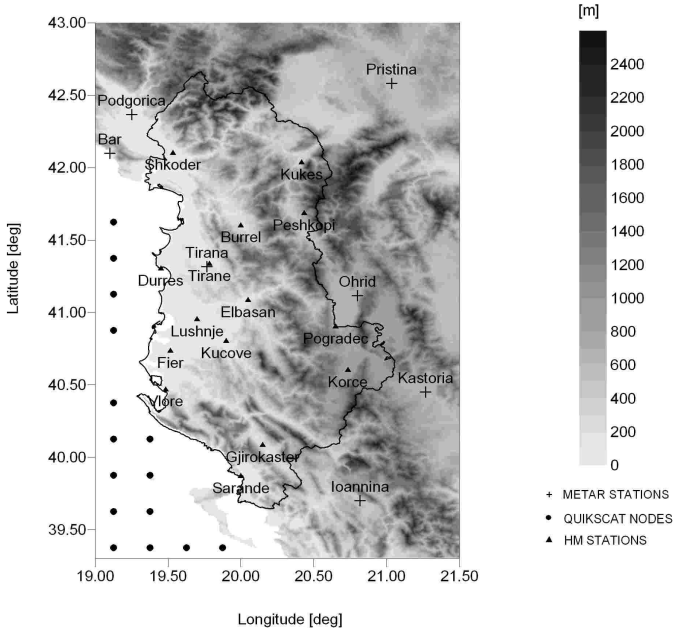

Figure 4: Anemometric Stations over the Simulation Domain

The simulations have been corrected adjusted the definition of a "correction factor", Φ, as performed for the realization of the Italian Wind Atlas, intended to more realistically estimate the wind potential of Albania. The primary source of information to build up the correction factor is the local ratios measurements/simulated average wind speeds in correspondence of the anemometric stations (or satellite points). It is noted that the simulated wind fields are expected to be generally overestimated with respect to measured data, because simulations have been performed under neutral stability conditions only. This behaviour was also noted during the realization of the Italian Wind Atlas, where the correction factor calculated over Italy ranges between 1, over high relieves like the Apennines in southern Italy, and 0.6 over broad plains in the north, like Pianura Padana, whereas it is around 0.7 in the southern Adriatic sea.

A careful analysis of the spatial dependence of the estimated correction factors for Albania reveals in the inland a variability which could be defective because of the low spatial representativeness of V_m values. Furthermore, these values are systematically too low with respect to the corresponding factors obtained for the Italian Wind Atlas. Experience gained during the realization of the Italian Wind Atlas and other similar studies in neighbouring areas (i.e. Montenegro) suggests that usually the average wind speed measured by anemometric stations, with characteristics analogous to the 22 stations considered in this study, are under evaluated of about 40% with respect to the corresponding values measured in an environment completely homogeneous and free of obstacles. Indeed, the wind speeds and directions in these stations could be due to an inappropriate location of the anemometric mast with respect to the recommendations of the World Meteorological Organisation. It was therefore decided to correct all the onshore Φ correction factors by multiplying their values by a factor 1.4. The figure below shows the results of the interpolation process, obtained trough the radial basis function algorithm. The Φ values outside the borders of Albania have no influence on the following results, which have to be considered for Albania only.

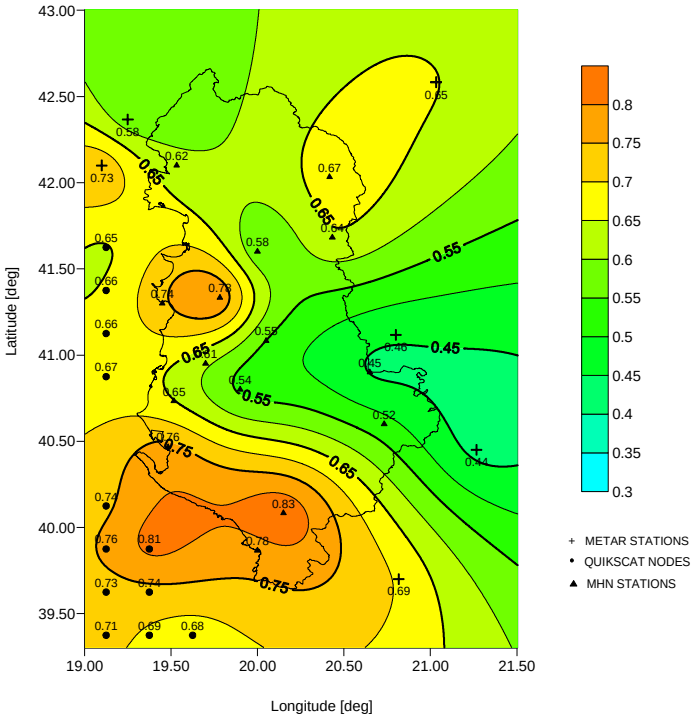

Figure 5: Correction Factor over Albania and Surrounding Areas

The actual wind velocity, v', for each simulation can be calculated multiplying the corresponding wind field, v, by the correction factor, so that $v' = \Phi v$. The figure below shows the map of actual average wind speed at 50 m a.g.l. all over Albania.

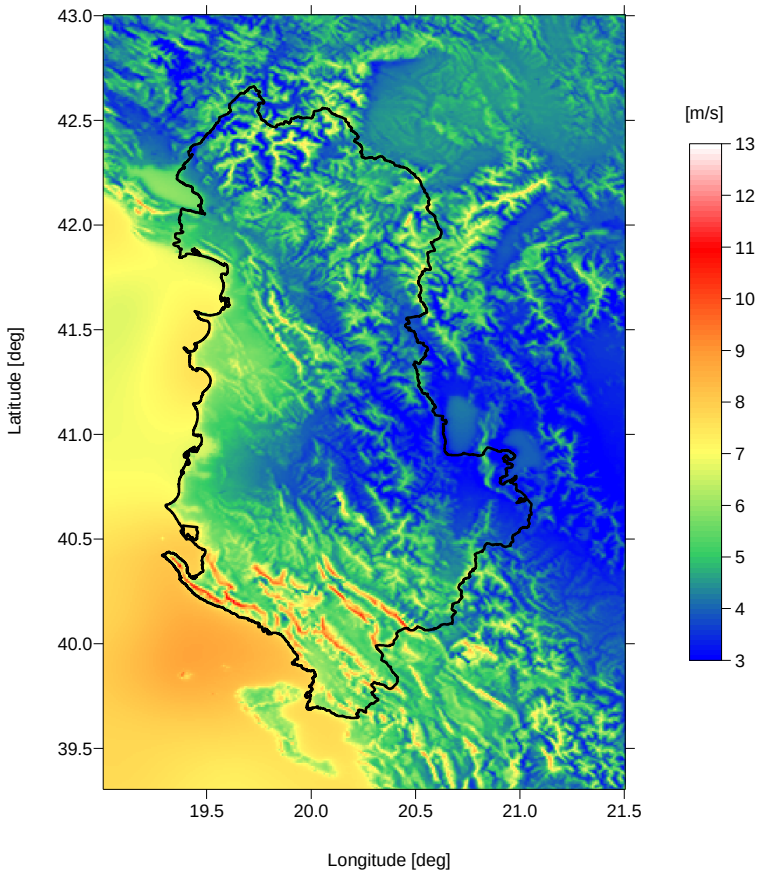

Figure 6: Actual Average Wind Speed (m/s) at 50 m a.g.l

Estimation of the Exploitable Wind Potential

A tentative identification of the most suitable areas for the development of power plants based on the exploitation of the wind energy was performed, representing a preliminary estimation to be refined with the support of the Albanian competent authorities.

The main existing constraints (altitude, site accessibility, infrastructures, natural protected areas, power grid) were applied to the actual wind speed and wind potential maps, in order to provide an estimation of the exploitable wind potential. The maps obtained applying the simulation code, subsequently corrected with ground measured data, clearly show the windiest areas, unfortunately not entirely suitable to wind power exploitation due to natural, economic or financial constraints. In order to estimate the actually exploitable areas of Albania, the following (positive and negative) constraints were taken into account:

- height above sea level (areas lower than 1,800 m);
- natural or protected areas;
- road network (distance from national or well-kept gravel roads less than 5 km);
- electric power supply system (distance from the electric power supply system less than 10 km).

Due to financial constraints, the suitable areas for wind power production are limited to those areas located not too far from the main roads and the power supply system, and having capacity factors (i.e. the ratio between the actual energy produced in a given period and the hypothetical maximum) above given thresholds. In order to identify these areas, the constraints outlined above were superimposed to the wind maps, considering only areas characterized by a yearly average wind speed at 50 m a.g.l. between 5.5 and 7.0 m/s, or greater than 7.0 m/s. This evaluation is merely indicative, to provide an idea of the order of magnitude of potentially installable wind power in Albania.

The constraints on the yearly average wind speed are expressed through two different productivity scenarios: high productivity potential (HPP) and medium productivity potential (MPP). As shown in Figure 7, the obtained suitable areas are divided into a) ridges (red lines), for mountain areas where wind power plants are usually put linearly along the highest ridges, b) flat, or nearly flat areas (green areas), where it is likely to install windmills not only in a single row, and c) offshore areas (blue areas), although the feasibility of offshore power plant goes beyond the scope of this study. In general, the windiest suitable areas are located on the ridges of the mountains or along the seashore.

The most interesting areas for wind energy exploitation in Albania, namely the ridges and the areas showed in the aforementioned figures, correspond to the following total values:

- **HPP scenario** – 261.5 km of ridges, 66.3 km^2 of mostly flat areas;
- **MPP scenario** – 1,329 km of ridges, 1,689 km^2 of mostly flat areas.

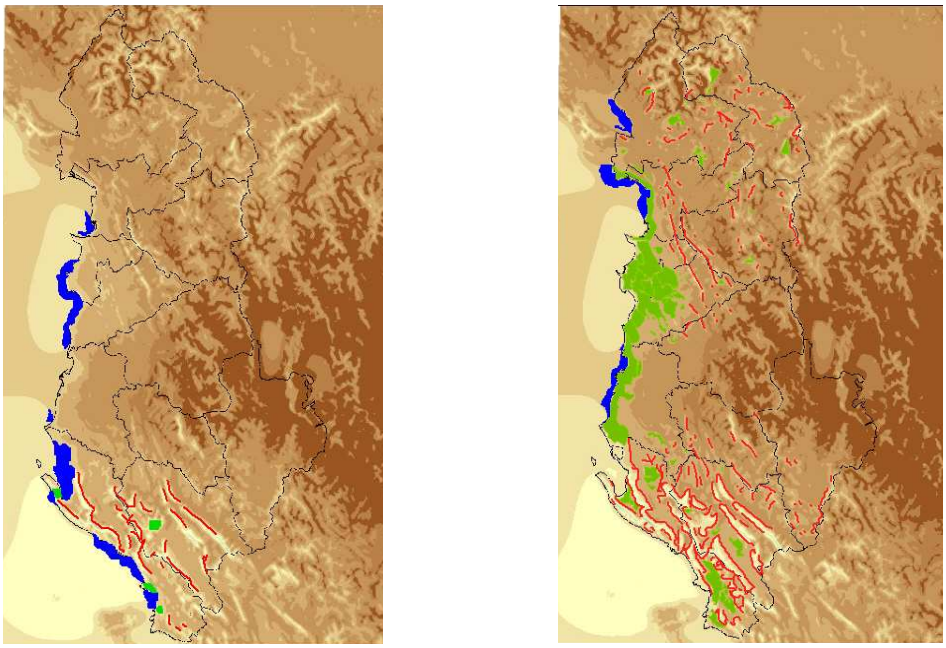

Figure 7: High Productivity Potential (left) and Medium Productivity Potential (right)

Conclusions

According to this WERA estimates, Albania shows an excellent wind potential, with wind speed values exceeding 8-9 m/s in many areas. A number of interesting areas, especially along the coast and on the ridges of the mountains, with particularly strong winds in the southern part of the Country, have been identified. Their overall exploitable wind potential has been estimated taking into account the main constraints preventing the development of wind power plants (i.e. distance from roads, power lines, protected areas, etc.).

A tentative identification of the most suitable areas for the development of power plants based on the exploitation of the wind energy was performed, representing a preliminary estimation to be refined with the support of the Albanian competent authorities. Two scenarios of productivity potential were considered: i) high productivity scenario (HPP) and ii) medium productivity scenario. The selected areas would allow a total installed wind power ranging between 980 and 11,700 MW, which correspond to an overall annual energy production between 3,000 and 25,800 GWh/year.

The exercise on the economic feasibility of wind farms installation in Albania showed that, at the current tariffs, the financial feasibility is acceptable only for high productivity areas (i.e. capacity factor 35%). A possible future option, based on adequate forms of incentives (as the Italian Green Certificates), was included in the analysis, resulting in attractive financial parameters for the realization of wind farms.