# An evaluation of wind energy potential in Topoja area, Albania.

Elena Bebi[1,*], Majlinda Alcani[2], Lorenc Malka[2], Artan Leskoviku[3]
Department of Production and Management, Faculty of Mechanical Engineering.
Polytechnic University of Tirana, Albania[1]
ebebi@fim.edu.al
Department of Energy, Faculty of Mechanical Engineering.
Polytechnic University of Tirana, Albania[2]
Renewable Energy Directorate,
National Agency of Natural Resources, Albania[3]

***Abstract:*** *Climate change and efforts to reduce greenhouse gas emissions, have significantly increased interest globally in implementing technologies utilising renewable energy sources such as wind energy. This rise in interest it also in countries in which there is a lack of data showing longitudinal measures of wind speed. Balkan Wind Atlas was developed from Sander&Partner Institute in October 2014. It offers wind maps that are suitable to identify the windiest areas covering a surface of 325 000 km$^2$ and a database for secured planning of wind energy for Albania, Kosovo, North Macedonia, Montenegro and Serbia. This study investigated the high level of consistency of empirical wind measurements conducted on-site, compared to the ones offered in Balkan Wind Atlas. We also explore the ways of utilising the atlas through the WasP software to study wind potencial even in those areas where there are no on-site measurements, thus lowering costs for investments in wind farm projects. The evaluation of the wind energy potential in Topoja area was taken as a case study.*
***Keywords****: WIND ENERGY DATA, BALKAN WIND ATLAS, WAsP, ALBANIA.*

## *1. Introduction*

Renewable power generation is becoming the default economic choice for new capacity. Solar PV and onshore wind projects are able to produce power for less than the cheapest new fossil fuel-fired cost project. It has become clear that renewables will become the backbone of the electricity system and help decarbonize electricity generation [1]. For the most of world's population, electricity production from new renewables is more cost effective than from new coal-fired power plants [2]. 2020 was the best year in history for the global wind industry with 93 GW of new capacity installed, driven by China and the US [3]. For onshore wind projects, the global cumulative installed capacity between 2010 and 2020 grew from 178 GW to 699 GW [1].

In most of Europe, the increase in utilization of wind power for electricity has resulted in increased economic stability against fluctuating fuel prices. Renewable energy sources are able to reduce the European Union's dependence on foreign energy imports, also meeting sustainable objectives to tackle climate change and to enhance economic opportunities[4].

One of the major economic advantages of harvesting wind energy in Albania is the reduction in the country's economic dependency on hydropower for producing electricity. Based mostly on one source of the energy resources, Albania has been facing severe energetic crisis which express visibly the high scale of the hydrological risk in the stability of electricity generation for the uninterrupted supply of customers of the Electricity System[5]. Albanian government has considered the promotion of renewable energy use as an important tool of energy policies for the increase of the security for energy supply, economic development, energy sector sustainability and environment protection[6].

But the lack of long-term measurements by the standards required by the assessment of wind farm projects, is among other reasons, that has hindered the development of this energy sector in Albania. The history of wind speed measurements in Albania is mainly related to meteorological studies for weather forecasting or for air and naval services. Many researchers have noted that a major barrier to deployment in many regions of the world is a lack of reliable and detailed wind resource data[7]. On the other hand, wind data analysis and accurate wind energy potential assessment is critical for proper and efficient development of wind power application and is highly site dependent. The wind potential assessment of a site requires the knowledge of statistical characteristics, prediction of wind speed, persistence, availability, diurnal, and monthly variation, etc.[7].

The most serious effort for wind resource assessments in Albania was the study conducted from CETMA Consortium in cooperation with Department of Physics in University of Genova, based on an agreement between the Albanian government and the Italian Ministry for Environment, Land and Sea (IMELS), on 30 July 2008 in Tirana[8]. Figure 1 shows the map of average wind distribution over the territory of Albania assessed at a height 50m above the ground level.

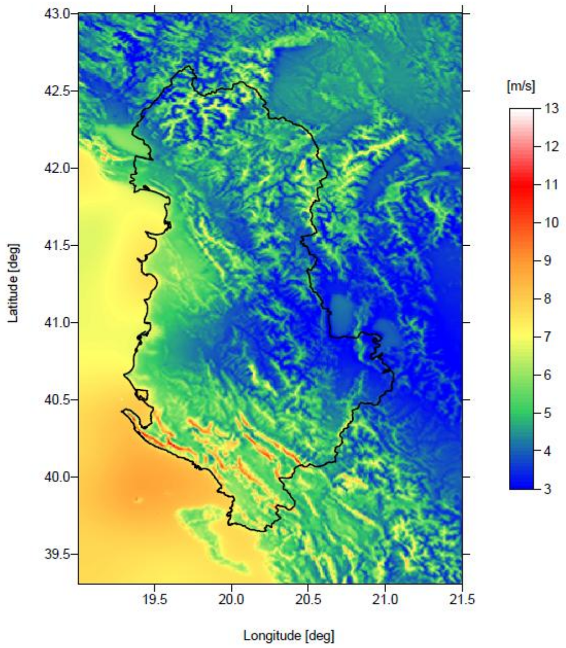


***Fig. 1*** *The map of the distribution of average wind speed at 50m above ground level, over Albanian territory.*

And undoubtedly an important development was the publication in October 2014, with the support of the Bank KfW which has financed many energy projects in Albania, the Wind Atlas for Balkan Peninsula, by the Sander & Partner Institute(Fig.2). This atlas offers wind maps that are suitable for identifying windy areas. It includes wind data for more than 40,000 locations in the form of 30-year time series data with a 3km resolution, including wind speed and direction, temperature and air pressure, and solar irradiation. The Wind Atlas for the Balkans offers wind maps and data for it covering the territories of Albania, Kosovo, North Macedonia, Montenegro, and Serbia. The weather model calculates the wind under the influence of the regional topography and other regional features like vegetation or the water exchange from the soil to the atmosphere(Wind-Atlas-Balkan, Workshop, October 23, 2014, Tirana).

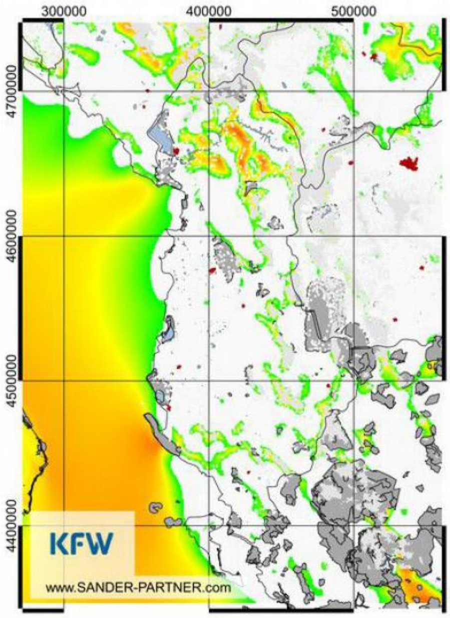


***Fig. 2*** *Map of areas with wind energy potential, good wind conditions, no conflicts with inhabited areas and respecting natural parks.*

In this study, data collected over a 15-month period (March 19, 2013, to June 14, 2014) in Mamaj, Tepelena, were compared with those obtained from Wind Balkan Atlas for the closest point to this area in 2013 which make up the last year of the atlas data. By this comparison was investigated the high level of consistency of empirical wind measurements conducted on-site, compared to the ones offered in Balkan Wind Atlas. Furthermore, using the longitudinal data from Balkan Wind Atlas is very useful for investors. By using the WAsP (Wind Atlas Analysis and Application Program) software, investors can develop wind potential distribution maps (resource grids) at 50m above ground level for the site of interest. The initial evaluations of the wind conditions are typically based on numerical products, such as wind atlases, which generally provide convenient, fast, and easy access to estimations of the characteristics wind conditions at a site[9].

Wind Atlases are produced for many countries including Egypt, South Africa, Finland, Germany, Greece, Russia, Iceland[9], Oaxaca(Mexico)[10], Armenia[11], etc. They are used for assessment of wind energy potential in several topographic regions all over the world, for determining the location of areas with high wind potential and for setting up wind farms, such as: Eritrea[12], Thailand[13], Spain[14], Qatar[15], etc.

The goal of this study is to raise awareness to both Albanian and foreign investors on the usefulness of Balkan Wind Atlas's data for assessing wind potential in areas of interest. This data would help investors find the appropriate location of anemometric towers to run on-site measurements of wind speed. Furthermore, considering that areas of interest for Albanian investors are relatively small, as well as that the Energy Regulatory Authority(ERE), approved Feed-in-Premium tariffs of 76€/MWh for wind farms up to 3MW installed power on July 27$^{th}$, 2017, there is a high incentive for wind farm engineers to utilize data from the Balkan Wind Atlas as well as the WAsP software. Making use of these tools would allow them to correctly choose the exact location and type of wind turbines to produce the highest capacity factor, as well as cut down on significant costs.

## *2. Materials and Methods*

In the area of interest in setting up a wind farm, in Mamaj, north of Tepelenë, Albania (Fig.3), measurement campaign started on March 19, 2013, and lasted until June 14, 2014. Wind speed data were acquired through anemometers with 3 cone shaped cups installed on 40m, 50m and 60m height and averaged every 10min. Wind direction was acquired through wind vanes mounted at 45m and 55m height. Air temperature was measured on height 13m.

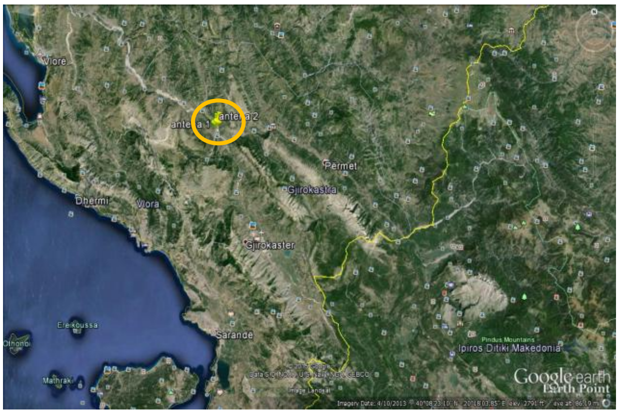


***Fig. 3*** *The site of Mamaj, Tepelenë, Albania*

The meteorological measurement data were obtained from 2 measurement stations installed in two separate towers(Valley and Hill tower) with a height of 60m each and in a distance of about 800m from each other(Fig. 4). The geographical details of the data measurement stations are given in Table 1. State-of-the-art wind data analysis tool Windographer(2011) was used for obtaining the statistical summaries of all the data: diurnal and seasonal variation of the wind speed, seasonal Weibull shape and scale parameters, wind power density, vertical wind shear, etc.


***Fig. 4*** *The location of the measurement towers in the site of Mamaj, Tepelenë, Albania*

***Table 1:*** *Geographical Details of Data Collection Station.*

| Station | Latitude ($^0$) | Longitude ($^0$) | Altitude (m) |
|---|---|---|---|
| Valley | 20.0166E | 40.3233N | 158.3 |
| Hill | 20.0090E | 40.3090N | 311 |

The data collected for the period March 2013-December 2013 from the anemometric tower installed in the valley, were compared to those extracted from the hypothetical anemometric tower of Balkan Wind Atlas for this area in 2013.

Geographical coordinates of the location of these two towers are shown in the Table 2. The distance between them is 580m.

***Table 2:*** *Geographical Details of Data Collection "Atlas" and Valley tower.*

| Station | Latitude ($^0$) | Longitude ($^0$) | Altitude (m) |
|---|---|---|---|
| Valley | 20.0166E | 40.3233N | 158.3 |
| "Atlas" | 20.0120E | 40.3160N | 147 |

Figure 5 shows the reciprocal position of Valley tower and the hypothetical anemometric "Atlas" tower which is closest point to this area obtained from Balkan Wind Atlas.

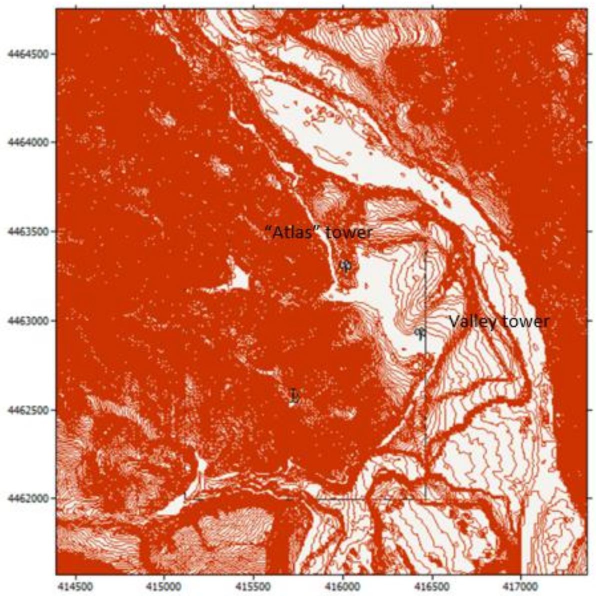


***Fig. 5*** *The location of the measurement towers in the site of Mamaj, Tepelenë, Albania*

In Table 3 are shown the monthly mean wind speed values for the period 19 March 2013-December 2013, based on measurements carried out by the anemometric tower in the valley as well as that hypothetical “Atlas”.

***Table 3:*** *Mean monthly wind speed respectively by the “Atlas” and Valley tower for the period March 2013-December 2013.*

| | Mean wind speed (m/s) by “Atlas” tower | Mean wind speed(m/s) by Valley tower |
|---|---|---|
| March 2013 | 7.52 | 8.3 |
| April 2013 | 4.84 | 5.04 |
| May 2013 | 5.31 | 5.43 |
| June 2013 | 4.98 | 3.77 |
| July 2013 | 4.63 | 3.84 |
| August 2013 | 4.48 | 3.92 |
| September 2013 | 4.38 | 4.2 |
| October 2013 | 5 | 4.7 |
| November 2013 | 7.31 | 6.8 |
| December 2013 | 4.86 | 4.602 |
| Overall Mean Wind Speed | 5.331 | 5.0602 |

The graph (Fig. 6) reveals a noticeable trend where the data from Balkan Wind Atlas matches the measured data.

The greatest data discrepancy pertains to months June, July, and August.

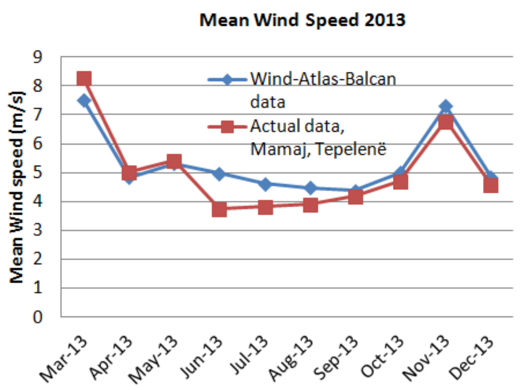


***Fig. 6*** *Mean monthly wind speeds in 2013, by Balkan-Wind-Atlas and actual data measurement in Mamaj, Tepelenë, Albania*

Many records (about 4%) from on-site measurements conducted during these months were considered erroneous and were deleted. We stress that the cone-shaped anemometers lacked a calibration date. But in terms of overall average wind speed for this period, the mismatch was about ±5%.

WAsP (Wind Atlas Analysis and Application Program) was used to determinate Observed Wind Climate(OWC), by using the wind speed and direction information. The WAsP is a PC software that extrapolates vertical and horizontal statistics regarding wind climate[16]. WAsP simulation program is a program that can conduct an analysis by using the wind speed data obtained from meteorological stations and analyzes the data by modeling regarding the direction of wind on the land to establish wind farms[17].

According to the data coming from Observed Wind Climate (OWC) from each anemometric tower, the average wind speed at 50m above ground level, for Valley tower was U=5.32m/s from March 2013 to June 2014, while the average wind speed for “Atlas” tower was U=5.52m/s from January 2013- December 2013. In this case the mismatch rate was ±3.7%.

Therefore, the long-term data coming from Balkan Wind Atlas can be used with high confidence especially in non-complex terrains of the Western Lowland of the country. According to National Agency of Natural Resources of Albania, 4 investment company are licensed to develop wind farms with 3 MW installed power each of them in the Topoja area which lies in the Western Lowland, near the Adriatic Sea (Fig. 7).

***Fig. 7*** *The Topoja area, Fier, Albania.*

The best wind potential area is shown in Figure 8.

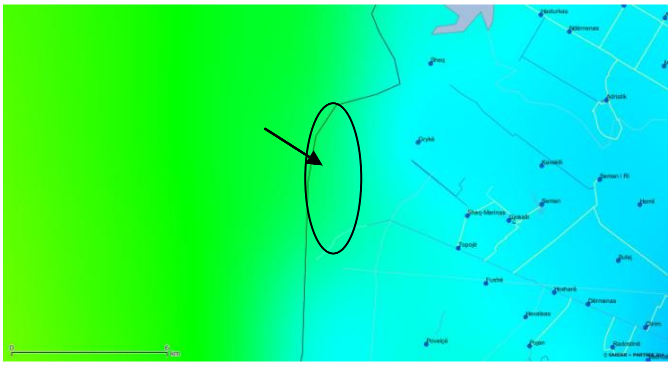

***Fig. 8*** *The windiest site in Topoja area, Fier, Albania.*

This is an area of 5.6km$^2$ and 2-2.5m above sea level. Data obtained from Balkan-Wind-Atlas for the period 2000-2013, were used to study wind climate in the area of interest in Topoja, Fier, Albania for the hypothetical anemometric tower with the coordinates 40$^0$47’57.5’’N, 19$^0$22’08.7’’E whose position on the topographical map is shown in Figure 9.

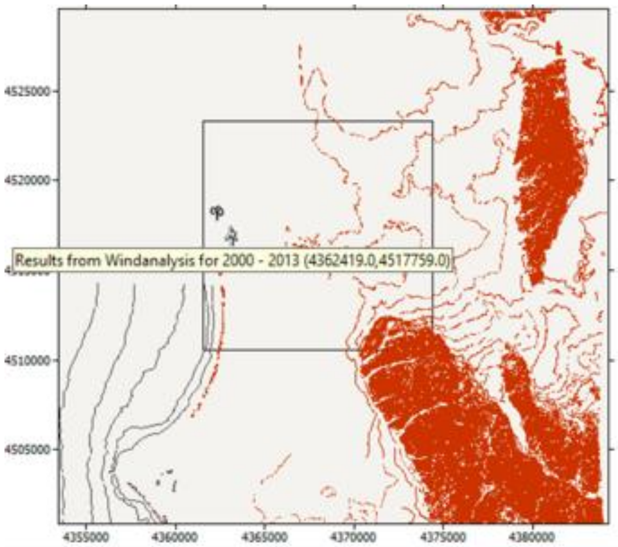


***Fig. 9** The hypothetical anemometric tower in Topoja area, Fier, Albania.*

According to the Observed Wind Climate(OWC) of the hypothetical anemometric atlas tower, mean wind speed and the power density in 50m a.g.l. were found to be 5.08m/s and 150.27W/m$^2$ respectively. Turbine with 50m height hub was placed in the area and by using WAsP software wind rose and Weibull distribution were studied (Fig. 10), (Fig. 11). It is noted that the probability of having wind speeds above 5.5m/s in 50m a.g.l is 36.6%.

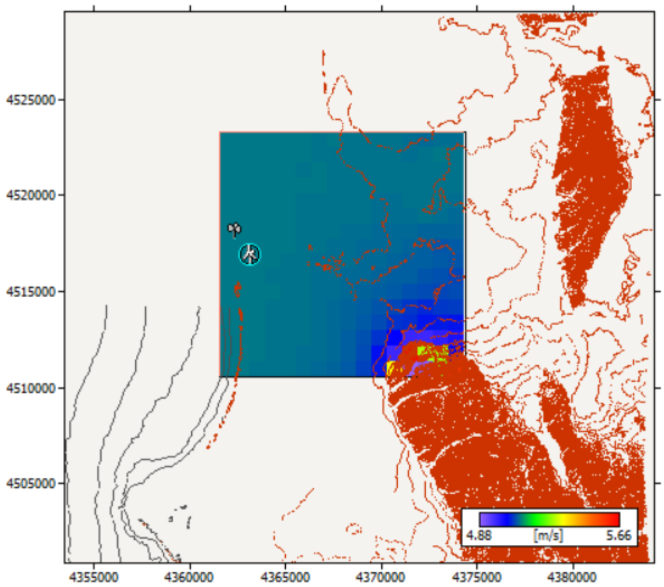


***Fig. 10** Resource grid of Topoja area for 50m a.g.l..*

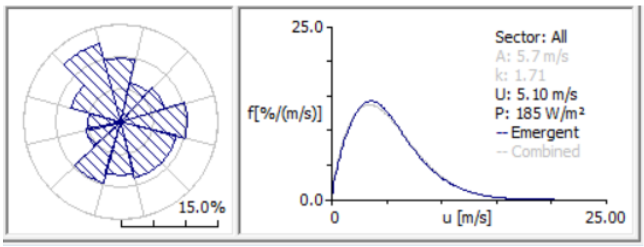


***Fig. 11** Frequency wind distribution and Weibull distribution in the windiest potential area of Topoja.*

According to the wind turbine, the average wind speed, and the wind power density at 50m a.s.l are 5.10m/s and 185 W/m$^2$. This identifies the Topoja area as class 1 wind power[7].

However, of interest will be comparing these results with those of real measurements that are being carried out on the site. Furthermore sensitivity economic analysis would help the decision-makers to estimate the sensitivity of important financial indicators in relation to key technical and financial parameters in order that the investments in Topoja area to consider acceptable [19].

## *3. Conclusions*

This study supports the idea that the use of Balkan Wind Atlas data is an important tool for identifying areas with wind energy potential especially for countries where long-term measurement data is lacking. To increase reliability in Balkan Wind Atlas, data collected over a 15 month period (March 19, 2013 to June 14, 2014) in Mamaj, Tepelena, were compared with those obtained from Wind Balkan Atlas for the closest point to this area in 2013. This reveals a noticeable trend where the data from Balkan Wind Atlas matches the measured data. In this case the mismatch rate was ±3.7%.

The long-term data coming from Balkan Wind Atlas were used to evaluate the wind energy potential in one of the non complex terrains of the Western Lowland of the country, in Topoja area. The wind turbine, was located by WAsP in the windiest area given by Balkan Wind Atlas. The average wind speed and the wind power density at 50m a.s.l are 5.10m/s and 185 W/m$^2$ respectively. This identifies the Topoja area as class 1 wind power.

Provided with this context, there is high interest in comparing these data to those of real measurements being carried out on the ground. The comparison will further increase the reability of Balkan Wind Atlas data which will eventually serve as a tool for conducting initial assessments of wind potential in areas of interest to investors in the field.

Conducting a thorough analysis on wind potential in areas of interest is particularly important in a country like Albania where no wind farms have been established yet. Assessing wind energy potential as well as conducting an economic sensitivity analysis will be crucial for guaranteeing success for future investors.

References:

1. IRENA (2021), *Renewable Power Generation Costs in 2020*, International Renewable Energy Agency, Abu Dhabi. Avaible from: https://www.irena.org//media/Files/IRENA/Agency/Publication/2021/Jun/IRENA_Power_Generation_Costs_2020.pdf
2. REN21. 2021. *Renewables 2021 Global Status Report* (Paris: REN21 Secretariat) Avaible from: https://www.ren21.net/wp-content/uploads/2019/05/GSR2021_Full_Report.pdf
3. GWEC (2021), *Global Wind Report 2021*, Global Wind Energy Council. Avaible from: https://gwec.net/global-wind-report-2021/
4. F. Cucchiella, I. D'Adamo, M. Gastaldi, "*Future Trajectories of Renewable Energy Consumption in the Europian Union*" Resources **7**(1) (2018) Avaible from: https://www.researchgate.net/publication/323545283_Future_Trajectories_of_Renewable_Energy_Consumption_in_the_European_Union
5. AKBN. (2019), *Bilanci Kombëtar i Energjisë 2018.* Avaible from: http://www.akbn.gov.al/wp-content/uploads/2014/06/Bilanci-Kombëtar-i-Energjisë-20181.pdf
6. ERE. (2018), *Republika e Shqipërisë, Gjendja e Sektorit të Energjisë në Shqipëri dheVeprimtaria e ERE-s Gjatë Vitit 2018.* Avaible from: https://www.ere.gov.al/doc/raporti_vjetor_ere_2018.pdf
7. Manwell JF, McGowan JG, and Rogers Al *"Wind Energy Explained"* pg 65-66 (2002)
8. E. Bebi, J. Kaçani, E. Ismaili "*The assessment of wind potential in Mamaj, Tepelenë, Albania"* IJEES Volume **5/2** (2015) pg 277-286. https://www.ijees.net/journal-31-International--Journal-of-Ecosystems-and-Ecology-Science--(IJEES)--Volume-5-2,-2015.html

9. M.Dörenkämper, B.T.Olsen, B.Witha, A.N.Hahmann, N.N.Davis, J.Barcons, Y. Ezber, E. García-Bustamante, J.Fidel González-Rouco, J.Navarro, M.Sastre-Marugán, T. Sile, W. Trei, M.Žagar, J. Badger, J. Gottschall, J. Sanz Rodrigo, J. Mann *"The Making of the New Europian Wind Atlas – Part 2: Production and evaluation"* Geoscientific Model Development, **13** (2020) pg 5079-5102 Available from: https://doi.org/10.5194/gmd-13-5079-2020

10. D.Elliott, M. Schwartz, G.Scott, S. Haymes, D. Heimiller, R. George *"Wind Energy Resource Atlas of Oaxaca"* National Renewable Energy Laboratory (2003) Available from: https://www.nrel.gov/docs/fy03osti/34519.pdf

11. D. Elliott, M. Schwartz, G.Scott, S. Haymes, D. Heimiller, R. George *"Wind Energy Resource Atlas of Armenia"* National Renewable Energy Laboratory (2003) Available from: https://www.nrel.gov/docs/fy03osti/33544.pdf

12. T. Negash, E. Möllerström, F. Ottermo *"An assessment of Wind Energy Potential for the Three Topographic Regions of Eritrea"* Energies **13** (2020) pg. 1846-1858 Avaible from: https://www.diva-portal.org/smash/get/diva2:1422979/FULLTEXT01.pdf

13. L. Niyontham, J. Waewsak, C. *Chuncham "Assessment of Wind Energy using Global Wind Atlas Metodology: A Case Study of Central Region of Thailand"* Thaksin University Journal Vol. **23** (2020) pg 39-48 Avaible from: https://ph02.tci-thaijo.org/index.php/tsujournal/article/view/225376

14. A.Sánchez-del Rey, I. Cristina Gil-García, M. Socorro García-Cascales, A. Molina-García *"Online Wind-Atlas Databases and GIS Tool Integration for Wind Resource Assessment: A Spanish Case Study"* Energies **15/3** (2022) pg 852-878 Avaible from: https://doi.org/10.3390/en15030852

15. C. Méndez, Y. Bicer "Assessment of wind energy potential and characteridtics in Qatar for clean electricity generation" Sage Journals Wind Engineering (2021) Avaible from: https://doi.org/10.1177/0309524X211043855

16. Mortensen, N.Gylling *"Planning and Development of Wind Farms: Wind Resource Assessment and Siting"* DTU Wind Energy (2013) I No. 0045(EN) Available from: https://backend.orbit.dtu.dk/ws/portalfiles/portal/51569749/Planning_and_Development_of_Wind_Farms.pdf

17. U. Yilmaz, F. Balo, L. S. Sua *"Simulation Framework for Wind Energy Attributes with WasP"* ScienceDirect (2019) Procedia Computer Science 158, pg. 458-465 Available from: https://doi.org/10.1016/j.procs.2019.09.076.

18. E. Bebi, J. Kaçani, E. Ismaili *"An evaluation of the wind energy potential in areas of interest in Albania using Wind-Atlas-Balkan data"* IJEES **5**(4) (2015) pg. 507-518 Available from: https://www.ijees.net/images/pdf/InternationalJournalofEcosystemsandEcologyScience(IJEES)Volume542015-1fe1f68397.pdf

19. E.Bebi, L.Malka, I. Ikonomi, M. Alcani *"An Analysis towards a Sustainable Energy System in Albania Highly Supported by Large Scale Integration of Wind Resources: A Case Study of Mamaj Wind Farm"* IJEEP Vol. **11**(1) (2021) pg. 355-372