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Assessment of wind energy potential in Niamey, Niger

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Abstract— *Renewable technologies are considered as clean sources of energy and optimal use of these resources minimize environmental impacts, produce minimum secondary wastes and are sustainable based on current and future economic and societal needs. Renewable energy technologies provide an excellent opportunity for mitigation of greenhouse gas emission and reducing global warming through substituting conventional energy sources. In the Sahel of West Africa, dramatically affected by desertification processes and rainfall shortages, wind energy is often viewed as a technology to mitigate deforestation although its development is extremely limited. The purpose of this study is to assess wind power potential in Niamey, Niger, a country where forest areas have declined by 34.5% over the 1990-2005 period. From 3-hourly meteorological data collected at the Niamey-Airport synoptic station over ten years (1998-2007), we evaluate the wind speed characteristics and the wind power potential at a height of 10 meters above ground level at diurnal, monthly, and yearly scales. We find very large differences in wind speed at the diurnal (2.40 – 5.11 m/s), monthly (2.61 – 4.11 m/s) and yearly (3.21 – 3.73 m/s) scales, with a global average wind speed of 3.42 m/s. We conclude that the wind powered energy is not economically feasible in Niamey due to its low wind potential.*

Keywords: Wind speed characteristics, Wind power potential, Meteorological method, Niger, Sahel

I. INTRODUCTION

Desertification is defined as land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities. It is taking place due to population pressure, socioeconomic and policy factors which lead to overgrazing, deforestation and poor agricultural practices. In addition, rainfall shortages enhance degradation in the fragile dryland ecosystems [1].

Over the last decades, Niger, a country located in the Sahel of West Africa, has suffered two dramatic contiguous droughts [2-6]. On the other hand, the population of Niger has tripled since 1950, from 5.9 to 15.9 million inhabitants in 2010, and is forecasted to be multiplied by ten (58.2 million people) by the second half of the 21st century. The population is one of the poorest of the world with 86% of the people living with less than 2 US$ per day and 28% facing food shortages [6]. Increasing urban population levels are even much more impressive and cause profound environmental degradation. Such increasing human pressure leads to uncontrolled deforestation in order to satisfy the needs in fuel and construction wood and to make place for shifting cultivation [7]. In addition, larger and larger herds occupying contracting pasture areas leads to overgrazing and trampling. All these processes provoke the degradation of the vegetation cover, a constant diminution of crop yields, and a strong reduction of the biodiversity.

Deforestation is of the highest importance in arid, semi-arid and dry sub-humid areas since it contributes to the advancing desertification [8]. The United Nations Food and Agriculture Organisation (FAO) has calculated a forest decline of 34.5% over the 1990-2005 period in Niger, one of the highest rate of deforestation in the world [9]. Yet, from the analysis of 44 forest areas in the Sahel, it appeared that over 34% of those forests disappeared since 1950 while all the others declined by over 50% of their initial surface [7]. This deforestation clearly enhances biodiversity decline [10-11], increases erosion [8,12], impacts economy and human well-being [13-15], and negatively influences the carbon dioxide budget [16].

In Niger, fuel wood represents over 90% of the energy needs [6]. This is why wind energy is often viewed as a technology to mitigate deforestation although its development is extremely limited [17-18]. In recent years, many conferences took place in Niamey in order to evaluate the wind energy opportunity for reducing deforestation as well as greenhouse gas emissions [19] but these conferences were more dealing with political and economical aspects of the potential projects, such as how to get money from the Clean Development Mechanisms (CDM) defined in the Kyoto Protocol as a flexibility mechanism contributing to prevent dangerous climate change by reducing greenhouse gas emissions.

Yet, for what regards the technological aspect of the feasibility, only one study provides data for Niger [20]. But this study, which quantifies the world's wind power potential shows that most Africa, and especially the continental Sahel which includes Niger, is not appropriate for adequate wind power production [Fig. 1].

Since that study used wind speeds that are calculated at 80 meters, and that it used undefined available data collected between 1998 and 2002 (at best, used data –more than 20 valid readings– were collected on an hourly basis but were usually not available with this precision in Africa) out of which daily average wind speeds were calculated (usually averaging 0000 and 1200 UTC data), the results obtained by

[20] are seen by Niger's authorities as probably erroneous and so there is a need for further analysis of the wind power potential in Niger, and particularly Niamey. This is the scope of the present study.

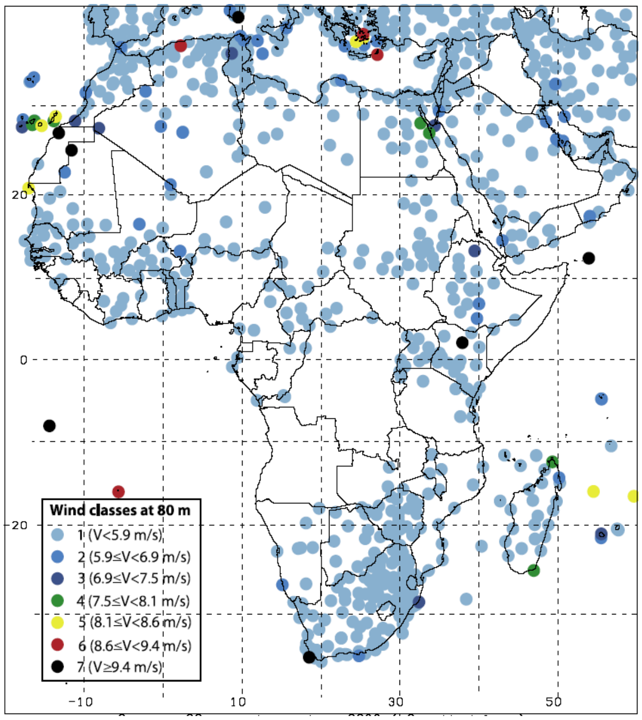

Figure 1. Map of wind speed extrapolated to 80 meters and averaged over all days of the year 2000 at surface and sounding stations with 20 or more valid readings in Africa [20].

II. Data and Methods

The synoptic station of Niamey Airport is located in south-western Niger at latitude 13°29'N and longitude 2°10'E; the altitude of the station is 222 meters above the sea-level (Fig. 2).

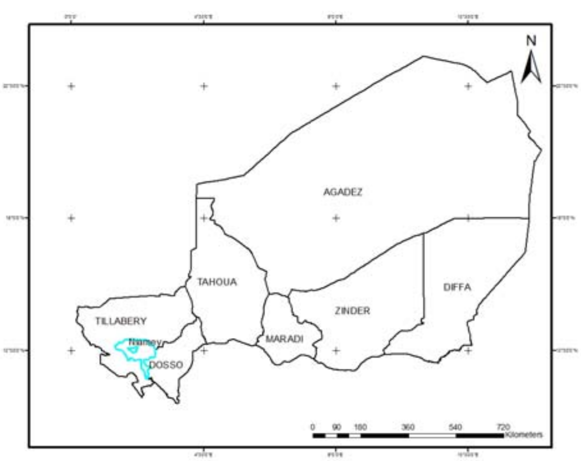

Figure 2. Map of Niger and location of Niamey.

Wind speed data measured at 10 meters above the ground level have been collected at the "Direction de la Météorologie Nationale (DMN)" of Niger. The dataset extends from 1998 to 2007 with 3-hourly measurements (0:00, 3:00, 6:00, 9:00, 12:00, 15:00, 18:00, and 21:00 UTC).

Since the wind speed measurements are collected in the site at 10 meters above the ground level. For wind projects, it is necessary to estimate the wind speed at the turbine hub height. According to the literature, the most commonly used method to adjust the wind velocity at one level to another is the power law method [21] expressed by:

$$V=V_{mes}\ (h/h_{mes})^{\beta}$$

where V_{mes} is the wind speed recorded at anemometer height h_{mes}, V is the wind speed to be determined for the desired height h and β is the power law exponent estimated using the wind speed measurement at the considered altitude.

The major wind turbine manufactures give actually the power curve of their product in the technical note. So, it is simple to estimate the power output of any wind turbine when a series of measurement is conducted in the studied site. For this study, we have selected the AAER A-1500-70 wind turbine. Its hub height is 65 meters above the ground level. The cut-in wind speed is 4 m/s and the cut-out wind speed is 25 m/s. The power curve is presented in Fig. 3. As shown, the power output of wind turbines quickly increases and takes its maximum value at the nominal wind speed of 12 m/s.

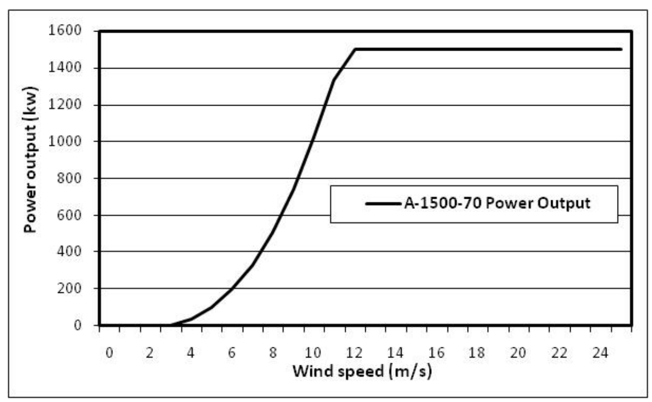

Figure 3. Power output of the AAER A-1500-70 wind turbine [22].

III. Results

The meteorological analysis is performed using wind speed data measured at 10 meters above the ground level. We successively describe the wind speed at the diurnal, monthly and yearly scales. Afterwards, the wind speeds will be estimated the wind speed at the turbine hub height, which is 65 meters above the ground level in order to retrieve potential wind energy output.

A. Diurnal wind speed characteristics

Fig. 4 presents the 3-hourly mean wind speed calculated over the 1998-2007 period. It shows large differences between day time and night time. Yet, mean wind speed is below 3 m/s from 18:00 to 6:00, and is above 4 m/s from

9:00 to 15:00. The highest value of mean wind speed is observed at 9:00 with 5.11 m/s, and the lowest value is recorded at 21:00 with 2.40 m/s.

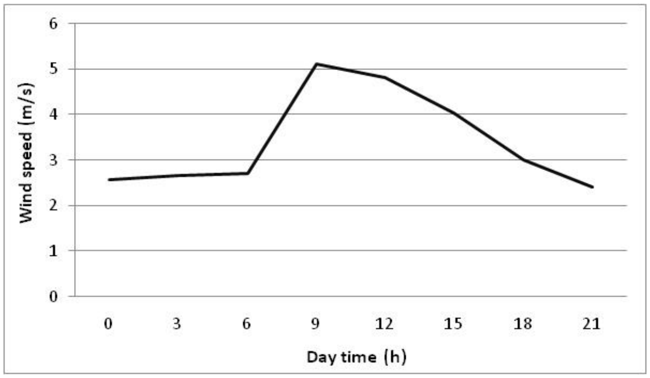

Figure 4. Mean 3-hourly wind speed at 10 meters.

B. *Monthly wind speed characteristics*

Monthly mean wind speed calculated over the 1998-2007 period is presented at Fig. 5. It shows two different periods. One characterized by mean wind speed above 3.3 m/s that extends from January to July, and another one with mean wind speed below 3.2 m/s from August to December. The highest value of mean monthly wind speed is observed in June with 4.11 m/s, and the lowest value is recorded in October with 2.61 m/s.

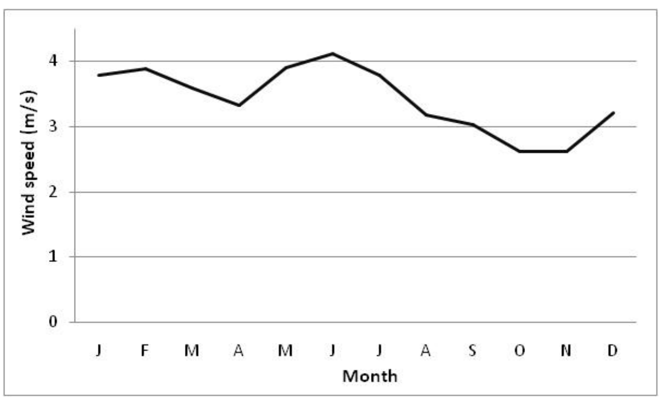

Figure 5. Mean monthly wind speed at 10 meters.

C. *Yearly wind speed characteristics*

Yearly mean wind speed over the 1998-2007 period is presented at Fig. 6. It shows a relative stability during the 10-year period with an average value of 3.42 m/s. The highest value of mean yearly wind speed is observed in 2000 with 3.73 m/s, and the lowest value is recorded in 2006 with 3.21 m/s.

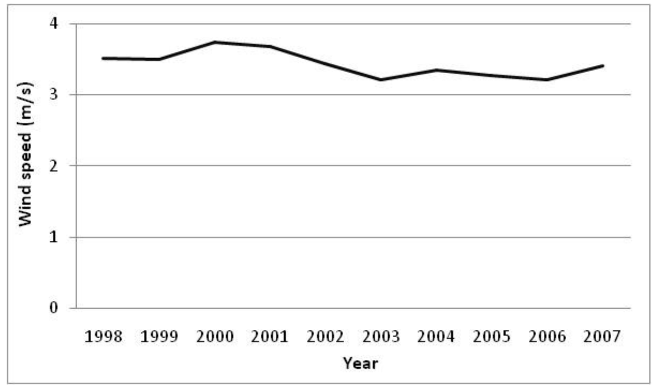

Figure 6. Mean yearly wind speed at 10 meters.

D. *Wind speed distribution*

Wind speed distribution may vary from year to year. This was shown in previous studies in the Sahel and particularly in Niger [8,23]. Wind speed distribution changes may be due to natural factors, technical (anemometer) change, or displacement of the place of measurements. Fig. 7 presents wind speed distribution for two distinct periods, 1998-2001 and 2002-2007, and shows a typical example of technical change. Yet, although it was not possible to retrieve historical data of the station equipment, it is very likely the anemometer has been changed or cleaned up between 2001 and 2002. This can be seen from the frequency of wind speeds ranging from 0 to 2 m/s which are extremely different from one period to another. Yet, the frequency of no wind cases was 16.3% during 1998-2001 and decreased to 5.0% in the next six years. The same is true for the 2 m/s wind speed with frequencies of 16.3% and 28.1%, respectively. However, such changes essentially affect low wind speeds (≤ 3 m/s) which represent 55.6% and 61.9% in 1998-2001 and 2002-2007, respectively, with an average frequency of 59.4% over the 10-year period of analysis. These wind speeds do not impact on the power output of the turbine since the cut-in wind speed is 4 m/s (at 65 meters above the ground level) (Fig. 3). Cumulated wind speed frequency is shown at Fig. 8.

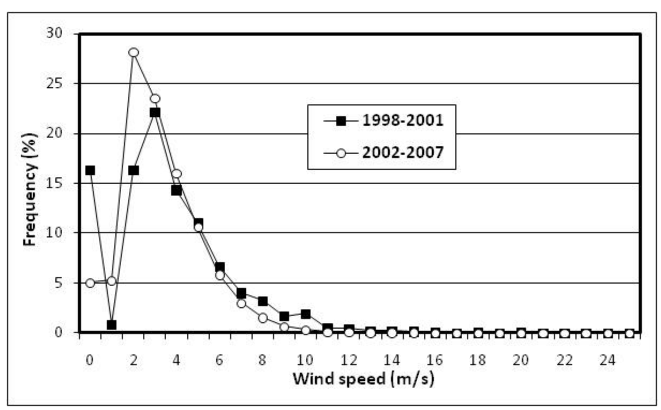

Figure 7. Wind speed frequency at 10 meters.

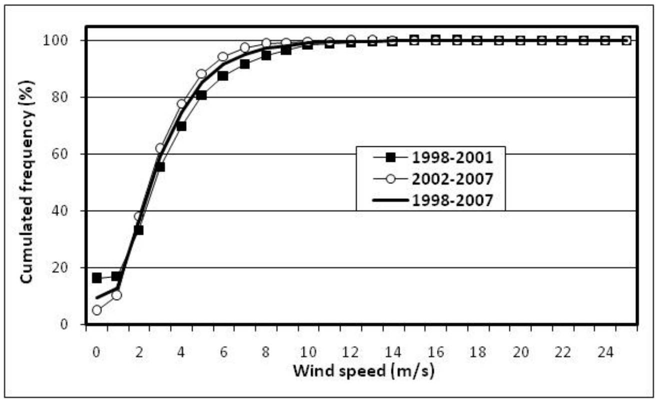

Figure 8. Cumulated wind speed frequency at 10 meters.

E. *Wind energy output*

All wind speeds were converted at the turbine hub height, which is 65 meters above the ground level, so that the energy output for the AAER A-1500-70 wind turbine can be estimated.

Average yearly energy output production is estimated at a value of 487 944 kW h, with very large inter annual differences as shown in Fig. 9. Yet, the maximum energy output production is estimated at a value of 770 593 kW h in 2000 while the minimum value is of 349 214 kW h in 2006.

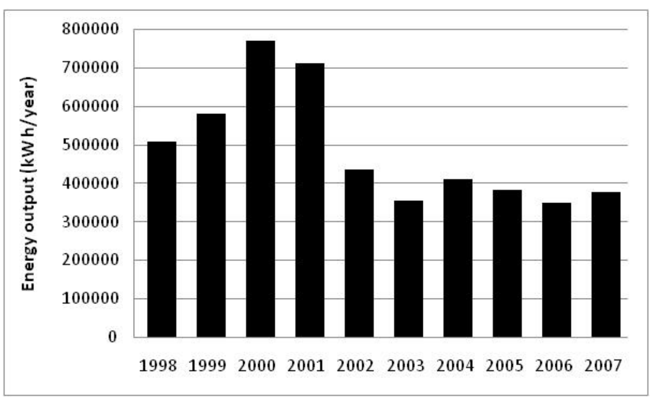

Figure 9. Yearly energy output estimated for the AAER A-1500-70 wind turbine.

Fig. 10 presents the 3-hourly mean energy output production estimated over the 1998-2007 period. It shows very large differences between day time and night time. Yet, mean energy output production is below 250 000 kW h/year from 18:00 to 6:00 with the lowest value at 21:00 (143 700 kW h/year), and is above 600 000 kW h/year from 9:00 to 15:00 with the highest value of 1 214 422 kW h/year observed at 9:00. In average, the cut-in wind speed is not reached in 59.4% of the time with again considerable disparity between day time (32.6%) and night time (75.5%). Yet, there is no energy production in 83.2% of the time at 21:00 while there is energy production in 73.4% of the time at 9:00. The frequency of the nominal wind speed of 12 m/s is at the maximum at 9:00 with 5%.

The monthly mean energy output production estimated over the 1998-2007 period is presented in Fig. 11. It shows two different periods. One characterized by mean energy output production below 350 000 kW h/year from August to November with the lowest value in October (217 243 kW h/year), and another 8-month period above 450 000 kW h/year from December to July with the highest value of 675 302 kW h/year observed in January. The cut-in wind speed is not reached in 42.4% of the time in June and 74.8% in October.

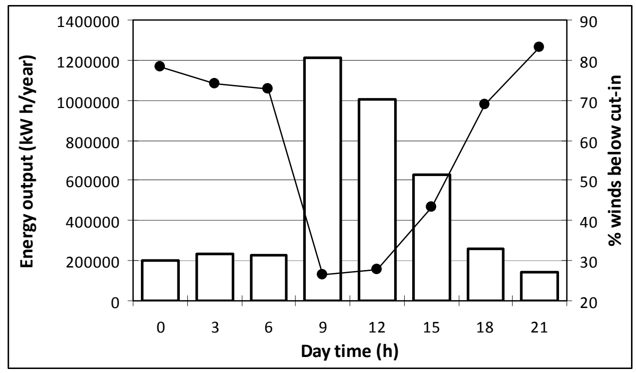

Figure 10. 3-hourly energy output estimated for the AAER A-1500-70 wind turbine and percentage of winds below the cut-in wind speed (4 m/s).

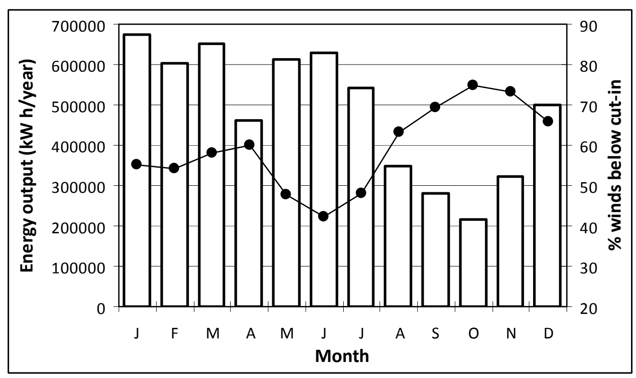

Figure 11. Monthly energy output estimated for the AAER A-1500-70 wind turbine and percentage of winds below the cut-in wind speed (4 m/s).

IV. Discussion and Conclusion

Based on 10 years of 3-hourly wind speed data, the electrical capacity generation of the site of Niamey-Airport in Niger is discussed. The mean wind speed, the wind probability distribution and the estimation of wind energy output production are presented at diurnal, monthly and yearly scales.

In order to be economically profitable, wind turbines of 1.5 MW have to produce 3,300 MW h per year. To do so, they should run 2,200 h per year at the nominal wind speed of 12 m/s, that is 25 % of the time [24]. In Niamey, our results show that the maximum energy output production is estimated at a value of 771 MW h with a 10-year average of 488 MW h. In addition to that figure, in average, the nominal wind speed is reached only 1.7% of the time (150 h per year), far below the acceptable frequency required for the investment to be profitable.

So, the present study concludes that the site of Niamey-Airport does not present a promising wind potential, that it is not worth creating a wind park project in Niamey, and that policies should focus on the importance of choosing other types of alternative energy sources in order to diminish current human pressure on forest resources due to firewood overuse.

References

[1] United Nations, Elaboration of an international convention to combat desertification in countries experiencing serious drought and/or desertification, particularly in Africa, 1994. http://www.unccd.int/

[2] A. Ozer and P. Ozer, "Désertification au Sahel : Crise climatique ou anthropique ?," Bulletin des Séances de l'Académie royale des Sciences d'Outre-Mer, vol. 51, pp. 395-423, 2005.

[3] T. Lebel and A. Ali, "Recent trends in the Central and Western Sahel rainfall regime (1990–2007)," Journal of Hydrology, vol. 375, pp. 52-64, 2009.

[4] P. Ozer, C. Bodart, and B. Tychon, "Analyse climatique de la région de Gouré, Niger oriental : récentes modifications et impacts environnementaux," Cybergeo: Revue Européenne de Géographie. No.308, 02/05/2005, 24 p., http://www.cybergeo.presse.fr.

[5] P. Ozer, Y. C. Hountondji, and O. Laminou Manzo, "Evolution des caractéristiques pluviométriques dans l'est du Niger de 1940 à 2007, " GEO-ECO-TROP, vol. 33, pp. 11-30, 2009.

[6] P. Ozer, Y. C. Hountondji, A. J. Niang, S. Karimoune, O. Laminou Manzo, et al., "Désertification au Sahel: Historique et perspectives," Bulletin de la Société Géographique de Liège, vol. 54, 2010, pp. 69-84.

[7] S. Ariori and P. Ozer, "Evolution des ressources forestières en Afrique de l'Ouest soudano-sahélienne au cours des 50 dernières années," GEO-ECO-TROP, vol. 29, pp. 61-68, 2005.

[8] P. Ozer, "Les lithométéores en région sahélienne: un indicateur climatique de la désertification," GEO-ECO-TROP, vol. 24, pp. 1-317, 2000.

[9] FAO, Global Forest Resources Assessment 2005. FAO Forestry Paper No. 147, Rome, Italy, 2006.

[10] P. Gonzalez, H. Sy, and C. J. Tucker, "Local knowledge and remote sensing of forest biodiversity and forest carbon across the Sahel," in: A. M. Lykke, M. K. Due, M. Kristensen, and I. Nielsen, Eds. *The Sahel*, SEREIN Occasional Paper No. 17, Institute of Geography, Copenhagen, Denmark, pp. 23-37, 2004.

[11] A. Wezel, "Local knowledge of vegetation changes in Sahelian Africa – implications for local resource management," in: A. M. Lykke, M. K. Due, M. Kristensen, and I. Nielsen, Eds. *The Sahel*, SEREIN Occasional Paper No. 17, Institute of Geography, Copenhagen, Denmark, pp. 37-52, 2004.

[12] A. J. Niang, A. Ozer, and P. Ozer, "Fifty years of landscape evolution in Southwestern Mauritania by means of aerial photos," Journal of Arid Environments, vol. 72, pp. 97-107, 2008.

[13] P. Ozer, "Estimation de la pollution particulaire naturelle de l'air en 2003 à Niamey (Niger) à partir de données de visibilité horizontale," Environnement, Risques, Santé, vol. 4, pp. 43-49, 2005.

[14] F. De Longueville, S. Henry, and P. Ozer, "Saharan Dust Pollution: Implications for the Sahel?," Epidemiology, vol. 20, p. 780, 2009.

[15] F. De Longueville, Y. C. Hountondji, S. Henry, and P. Ozer, "What do we know about effects of desert dust on air quality and human health in West Africa compared to other regions?," Science of the Total Environment, vol. 409, pp. 1-8, 2010.

[16] P. Friedlingstein, R. A. Houghton, G. Marland, J. Hackler, T. A. Boden, et al., "Update on CO_2 emissions," Nature Geoscience, vol. 3, pp. 811-812, 2010.

[17] I. M. Bugage, "Renewable energy for sustainable development in Africa: a review," Renewable and Sustainable Energy Reviews, vol. 10, pp. 603-612, 2006.

[18] J. A. Wisse and K. Stigter, "Wind engineering in Africa," Journal of Wind Engineering and Industrial Aerodynamics, vol. 95, pp. 908-927, 2007.

[19] M. Garba Abdou, Faisabilité de l'énergie éolienne dans la ville de Niamey au Niger: une perspective pour la lutte contre le déboisement? TFE en Master complémentaire en Gestion des Risques Naturels, Université de Liège, Belgium, 2008.

[20] C. L. Archer and M. Z. Jacobson, "Evaluation of global wind power,". Journal of Geophysical Research, vol. 110, D12110, 2005.

[21] A. W. Dahmouni, M. Ben Salah, F. Askri, C. Kerkeni, and S. Ben Nasrallah, "Assessment of wind energy potential and optimal electricity generation in Borj-Cedria, Tunisia," Renewable and Sustainable Energy Reviews, vol. 15, pp. 815-820, 2011.

[22] http://www.inl.gov/wind/software/powercurves/pc_**aaer**.xls

[23] P. Ozer, "Lithometeors and wind velocity in relation with desertification during the dry season from 1951 to 1994 in Niger," in: G. Demarée, J. Alexandre, and M. De Dapper, Eds. *Tropical climatology, meteorology and hydrology : in memoriam Franz Bultot (1924-1995)*, Royal Meteorological Institute of Belgium / Royal Academy of Overseas Sciences, Brussels, Belgium, pp. 212-227, 1998.

[24] Duquesne M., "Eolien: quelle est la répartition des coûts entre les différents postes d'un projet?," 2010. http://www.uvcw.be/articles/3,492,486,486,3446.htm#_ftn8