Wind energy: studies and reflections on the viability of the potential of this energy in Brazil

MARTINHO, Felipe Miguel [1]

MARTINHO, Felipe Miguel - **Wind energy: studies and reflections on the viability of the potential of this energy in Brazil**. Multidisciplinary Core Scientific knowledge magazine, 1 Year. Vol. 10 pp. 25-38. ISSN. 2448-0959

Summary

Environmental issues and the constant concern with climate change led to a race for the development and integration of renewable energy technologies in electric matrix in several countries. In this context, wind power is considered one of the most promising natural sources of energy, mainly because it is renewable, does not end with, clean, globally distributed and if used to replace fossil fuel sources, assists in reducing the greenhouse effect. In addition to these benefits, can bring global and national advantages, as for example, the benefits of reducing carbon gas emissions and the security of energy supply. The great potential of generation in Brazil is the wind, which makes up only a small part of the brazilian energy matrix, but that is gaining prominence in the auctions, on account of his competitiveness. This study set out to demonstrate the viability of the potential of this matrix and the use of renewable energy sources is important to the pursuit of sustainable development. For this, a systematic literature review was conducted, structured, through a bibliographical revision on articles in the area. From the data presented in the result of this study, discussed the importance of this theme that will serve as a foundation and guide for future studies to demonstrate the country's effort in the search for a social and economic development, to take into account the environment and its sustainability.

Keywords: Sustainable Development, wind energy, renewable energy

1. Introduction

Sustainable development is one of the subjects of greater relevance today, since it is connected not only with the economy, but also with the environment and society (UNITED NATIONS, 1987, p. 64).

The quality of life of a society, in turn, is closely linked to their energy consumption. The improvement in

living standards, particularly in developing countries, generate increased energy demand and thus require a better energy planning to address energy supply security and environmental costs to meet this increase in consumption (GOLDEMBERG, 2008).

Some experts (Welch; Venkateswaran, 2009; Terciote, 2002) consider that wind energy is an energy source able to meet the demands of a society, without prejudice to future generations, and so the use of this type of renewable energy is growing worldwide.

In early 2000, the contracted projects arising from incentive policies, and especially at the end of the decade with the entry of wind power in the regulated market of energy, put Brazil among the countries with the highest growth in deployment of new wind farms and generated optimism among public and private actors in the electricity sector (SIMAS, 2013).

As a result of these factors, the objective of the present study was to conduct a review of the literature on wind energy and the viability of the potential of this energy in Brazil, taking into account the environment and its sustainability. The study is organized into topics, where the first presents the theoretical foundations necessary for clear understanding of the research and then, the methodology used for the compilation of the literature review. Are later presented the results along with the discussion of the facts, ending with the conclusion of the study.

2. Theoretical Foundations

The first evidence of the use of wind power to the mechanical works date back to about 2000 years ago, to being used on the Heron in Alexandria (PINTO, 2012).

According to Duarte (2004), the emergence of wind technology was a consequence of the energy crisis of 1973. On the increase in the price of oil and the need to produce electricity at lower prices and cleanly and renewable were developed today's wind turbines. According to the authors Terciote (2002),
Welch and Venkateswaran (2009), in recent years wind energy has become a key player in the generation of energy, primarily electricity, due to the large expansion in research and development techniques to transform the motion of wind into energy. Currently, this energy source has been described as one of the most important and promising technologies in additional generation of energy, for being easily accessible and abundant in nature (TERCIOTE, 2002; WELCH; VENKATESWARAN, 2009).

With the improvement and increase of the power of the wind machines, the cost of generating electricity from the winds come down, which also reflected in the proliferation of numerous wind farms around the world (WELCH; VENKATESWARAN, 2009).

Wind energy is the kinetic energy contained in the mass of moving air (wind). Thus, it is important to know the behavior and characteristics of the winds so that you can understand the aspects required for an adequate wind modeling in a particular region. The conversion of the Translational kinetic energy of the wind into kinetic energy of rotation occurs from the use of wind turbines, also called wind turbines, which are fundamental for the generation of electricity. The capture of the kinetic energy of the wind can be made basically using two types of turbines: vertical-axis turbines and the horizontal axis. In the first case, gear and generator are placed at ground level and the turbine is driven by forces of drag or support these turbines feature low complexity of manufacturing and are quite suitable for wind characteristics

similar to Southern Latin America (FARRET, 2014).

Horizontal axis turbines already have the gear, shaft and aligned with the direction of the wind, being the most used worldwide in wind generation business parks. Can still be found some settings depending on the number of blades, and the three-bladed turbines are the most employed by less stress, less torque oscillation and by causing less noise (BORGES NETO; Oak, 2012).

The authors above complete that in the last ten years, the generators have grown higher, rising from 50 metres to the 100 to 120 meters, which allows you to capture faster winds. At the same time, the power of the machines has tripled, to 3 megawatts. More efficient generators have reduced the cost of wind energy. Today, the average is 45% smaller than ten years, making wind energy is the second cheapest energy in the country. With that, a "virtuous circle" of attraction of investments.

Investments for implementation of a project of renewable energy training are high, with most investment concentrated in the initial phase of the project, since the cost of equipment match until 75% of the total investment of a wind farm (TOURKOLIAS; MIRASGEDIS, 2011).

Valentine (2010) draws attention to the fact that the place of implementation of a wind farm should be favorable to the formation of winds. However, not always the appropriate locations for the installation of generators are close to the place of consumption, causing costs that can derail the deployment. Furthermore, depending on the distance of the grid, wind power projects may become commercially unviable, creating costs associated with the connection.

However, when it is possible to integrate with other energy sources and therefore use their infrastructure, wind systems can bring economic advantages as an example, the installation of generators close to consumption locations due to no need of transmission networks (TERCIOTE, 2002).

Several major studies conducted in 2010 on the integration of wind energy into the power grid point fresh evidence of low cost provided this type of system (AMERICAN WIND ENERGY ASSOCIATION AWEA, 2005).

In this context, Jannuzzi (2003) comments that the wind electrical systems have differentiated characteristics of the systems used in hydropower plants, because they can be used in the form of distributed generation, which is a large interconnected system of transmission and distribution networks through wind farms with large wind power generators or be used in isolation, through small wind turbines providing a low cost. Terciote (2002) cites other evidence of low cost as being cases of hybrid systems where there are economic gains, citing the wind/diesel systems, where the diesel engine ensures the regularity and stability in energy supply dispensing systems and hybrid deployment of wind turbines (JANNUZZI .2003).

The deployment of renewable energies presents a major impact on the economy, since it favours the development of industries of equipment for domestic consumption and even for export (TOURKOLIAS; MIRASGEDIS, 2011). Malley Silva Gannoum, (2015) of ABEEólica, CITES that last year, the sector created 40000 jobs, and that is provided for the creation of other 50000 new jobs for this year. Comments, installation of generators shall be without prejudice to the farmer or his cultivation, and that the two activities can live together. The authors, Río, Burguillo (2008), add that most of the time, the land on

which are built the wind parks are leased and, this question raises another important aspect, since the wind turbines occupy only a small fraction of the area, and the rest of the leased area can be used for other productive activities on property (RÍO; BURGUILLO, 2008).

Llera Sastresa et al., (2010) adds that within the Northeast where there are winds better than on the coast, the creation of these wind farms often happen in poor regions as in the backcountry. Companies lease the land, build the parks on land used for small rural producers, providing extra income for families before lived only cultivating land. It's not just the landlords who profit from it, but the workers directly involved in the construction and deployment of power plants, since it occurs an increase in demand for goods and services. The competitiveness of firms by the qualification of the workforce, which is an additional asset, favouring new investments and business opportunities (LLERA SASTRESA et al., 2010).

To Mauricio Tolmasquim (2011), President of the energy research company (EPE) which is under the Ministry of mines and energy, said that Brazil's wind production is a reference in the world, being studied by European countries such as Germany, and others from Latin America. Points out that, with the wind farms, the creation of jobs in factories, to meet the installation and maintenance of equipment in the wind park.

2.1 Environmental Impact

Even with a very low environmental impact when compared to most other energy sources, the generation of electricity from wind turbines generates some impacts such as: visual impact, noise, electromagnetic interference and damage to fauna (TERCIOTE, 2002).

The visual impact is related to the area necessary for the installation of the Park. So the wind disturbance caused by a turbine does not interfere significantly in the neighboring turbines operating, it is necessary a minimum spacing between five to ten times the height of the Tower (BORGES NETO; Oak, 2012).

According to Duarte (2004), the related impact for generating noises, while there are low-noise turbine market, it is inevitable that there is a buzz, especially at low wind speeds, the noise of the high wind speeds overlaps the noise of the turbines. Noise can have two origins: mechanical (coming from the gear box that multiplies the rotation of the blades to the generator) and/or aerodynamics (resulting from the movement of the blades due to the wind, which can be more disturbing at night and located in your immediate neighborhood) (TERCIOTE, 2002; CHURRO et al., 2004).

Concern about fauna is with the birds, which may conflict with the structures (high-voltage towers, masts and Windows of buildings) and with wind turbines, due the difficulty of viewing (WELCH; VENKATESWARAN, 2009).

However, the environmental impact that wind power generates, is much lower when compared to energy from fossil fuel (oil), which causes a big environmental impact producing gaseous emissions which, in addition to pollutants, destroying ecosystems. Wind power already, in turn, can serve forever the energy purposes with almost no environmental impact (DUARTE, 2004). This energy, emits no carbon dioxide (CO_2) in the atmosphere and presents an extremely favorable energy balance. At the stage of manufacture and installation of equipment, there are baixissima of CO_2 emissions which, after the period of three to six months of operation of wind turbines, this gas is no longer produced. This impact varies greatly

according to the location of the premises, the arrangement of the towers and the specifications of the turbines (TERCIOTE, 2002).

A point in favour of the use of this energy matrix, is the fact that it is possible to use the area of the wind farm as grassland and other agricultural activity since wind power does not use water as the driving element, or as refrigerant and produces no radioactive waste or gases. Another consideration is that these parks tend to attract tourists, generating income, employment, earnings and promoting regional development (TERCIOTE, 2002).

With the use of this energy in Brazil, noted that renewable energy projects represent 37% of the total projects, being that about 5% of these are from the force of the winds. This represents the generation of about 3,200,000 carbon credits, or about 50 million reais. Evaluating this data, it is observed that Brazil can multiply by 5 issue carbon credits through the wind, which currently only 400 MW from wind energy resulted in carbon credits (Ministry of environment, 2011 MMA).

2.2 Technology

The strong technological advancement of wind energy has been very important to consolidate it as a viable energy, contributing to the increased competitiveness of this process in Brazil. The improvement of technology providing greater efficiency and reduction in price of wind turbines, together with the excessive increase in the prices of oil and natural gas, have made the cost of wind energy to become more competitive, getting close to becoming financially self sustainable, without needing the support of national Governments (WELCH & VENKATESWRAN .2009; TERCIOTE, 2002)

Wind energy is also in a favourable position according to the Return On Investment (ROI), when compared to other energy generation sources because although present high production costs, is not necessarily a technology more expensive in comparison with nuclear energy or other plants. In addition, most research indicates that, if the external economic and environmental costs associated with the various forms of generating electricity are internalized, wind energy would economically superior to production of electricity, even compared to coal-fired power plants (VALENTINE, 2010).

Jannuzzi (2003) complete with opportunities for technological improvements, there should be a reduction in costs, allowing to set targets ambitious enough for generation systems over the next 30 years. Élbia Silva Gannoum, (2015), Executive President of ABEEólica, describes a virtuous growth horizon for wind power. Furthermore, whereas the wind source is still very new in the world, we have a lot of room for technological innovation directed towards the reduction of production costs, in addition to structural factors and a comparative advantage that the country has that are the best in the world for producing winds wind, which causes our capacity factors are very high by lowering production costs.

2.3 production of wind energy in Brazil

The Brazil was the pioneering country in Latin America to install a wind turbine in the early 1990. Historically, Brazil relied on hydropower generation that today supplies 80% of the needs of the country. This system associated with the wind, it becomes an ideal combination to large-scale development of wind power, since it can be used in isolated systems or on systems connected to the grid, and also in hybrid systems, which are systems in which, disconnected from the conventional network, present

multiple generation sources together (VALENTINE, 2010).

The survey conducted by the Ministry of mines and energy (MME), "wind energy in Brazil and World", points out that the country was the fourth in the world rankings of wind power expansion in 2014, with 2,686 megawatts (MW), being surpassed by China (23,149 megawatts), Germany (6,184 megawatts) and United States (4,854 megawatts). The power Expansion Plan (EDP 2022), the Government estimates that wind power installed capacity of Brazil arrives around 24000 MW. Of this total 21000 MW will be generated in the Northeast, which will represent 45% of the total produced in the region (BRAZIL PORTAL, 2016).

The Brazilian wind power potential Atlas released in 2001, estimated at 143 GW technically usable power from Brazil. This mapping, aimed to identify areas suitable for wind-electric utilization. Through this study, it was estimated that the Northeast, Southeast and South regions correspond to approximately 90% (CRESESB, 2016). Only the northeastern region, has a capacity of 75,000 MW. The first sensors and computerized anemógrafos installed in Ceará and in Fernando de Noronha (PE), in the early 1990, enabled the determination of local wind power potential and the installation of the first wind turbines from Brazil (BRAZIL SOLAIR, 2015).

2.4 wind Regime

The first step for an analysis and determine the use of the wind resource is the evaluation of the potential of a region. The topography influences the speed of the wind at a particular location, as well as their distribution and frequency (SILVA et al. 2006). Due to immense territorial extension, Brazil has several areas with features that promote wind power exploitation, being fundamental knowledge and the conduct of the wind, especially their speed and direction not to waste such a natural and renewable resource. Is in those studies the Northeast region, for presenting exceptional features with a free air flow of natural obstacles, high intensity and continuity of the trade winds, even with the addition of the hydrological regime the regime of winds (National Energy Plan _ PNE, 2030).

According to the geographer Telmo Amand Ribeiro da UnB, not all regions have these characteristics. The plateaus of the sertão do not allow the trade winds on the coast to the interior of the country. Explains that these winds blow from Ecuador to the tropics and only reach the northeastern coast, of Maranhão to Rio Grande do Norte, mainly in Ceará (BRAZILIAN PORTAL, 2015).

The Brazilian wind power potential Atlas was created from a system named MesoMap where presented in resolution of 1 km x 1 km annual average wind conditions throughout the Brazilian territory. The analysis of these estimates shows that in the months in which more venta are the months with lower rainfall, it's worth saying that from June to December we have the greatest potential for wind power in Brazil. It was concluded that the use of wind energy is excellent against the low rainfall and geographical distribution of water resources in the country, possibly to preserve watersheds by minimizing the use of hydroelectric power plants. This fact confirms that the wind is a great source to supplement the power generated by hydroelectric plants, today the largest source of electricity in the country (AMARANTE et alii, 2001).

According to Minister of mines and energy, Eduardo Braga (2015) "Brazilian wind is predominantly located in the northern part of the Northeast, with potential identified of 300 gigawatts. It is characterized as a natural vocation of the region. The effectiveness of this potential, has provided significant investment

in this region. Élbia Silva Gannoum, (2015) President of ABEEólica, explains that in the Northeast region the average productivity of a wind generator reaches peak of 83% in compared with the world average which is around 28 to 30%. He adds that in the northeast wind is unidirectional and stable, no gusts, allowing the energy is produced all the time. Furthermore, the electrical energy generated by wind accounts for 5.1% of the national energy matrix, and for 2020, it is estimated that represent 13% of all comes the national energy production (PORTAL BRASIL, 2015).

3. Methodology

This study this is a literature review based on analyzing the viability of wind power potential in Brazil. In this work, followed the precepts of the exploratory study, through a bibliographical research, which, according to Gil (2008), "is developed from material already prepared, consisting of books and scientific articles" and then proceeded to the analysis of the data collected. In the first step, information-gathering was held in books and scientific articles. In addition were researched in magazines and news papers relevant to the viability of wind power potential in Brazil.

This study begins with the determination of objectives set out in the topic. In the sequel, the reflections about the viability of the potential of this energy in Brazil, analyzing environmental impacts, the technologies involved, and the quotation of the Northeast region for its high potential of wind towers installation depending on the wind regime.

It is inevitable to discussion about the use of wind energy as a source of renewable energy, as well as the concerns that arise with its use. These discussions lead the country to seek economic and social development that takes into account the environment and its sustainability.

4. Results

Throughout this article, described himself on the viability of the potential of the energy matrix in Brazil and as the use of renewable energy sources collaborate to the pursuit of sustainable development.

Positive points were presented on the use of this energy matrix and the points that require attention, mainly related to environmental impacts. We know that there are problems and many challenges ahead. Jorge Antonio Villar (2015), Coordinator of the Centre of wind energy of PUC-RS, warning about the disruption and environmental and ecological dynamics of local sand dunes that are modified with the installation of wind farms. He adds that the activity should have a bigger concern relating to methods and procedures by which the environmental impacts can be minimized.

In turn, Gannoum (2015) of ABEEólica, reinforces that the losses are minimal activity, compared with technological advances and benefits for the Country and that the whole enterprise is only hired under an environmental license.

This type of study is fundamental for the socially and economically develop Brazil, since, although there are government programs to promote wind energy, these are still modest compared to the wind potential that the country has.

5. Conclusions

The analysis of the existing literature exposes us nature uncontrollable blinking of wind energy. She becomes a new source in the planning of expansion of the Brazilian electric system, a potential of exploitation which offers environmentally sustainable and sufficient energy to meet the forecast demand in the coming decades. By does not emit carbon dioxide (CO2) in the atmosphere, presents an extremely favorable energy balance, and its environmental impact, it's a lot less than when compared with energy from fossil fuel (oil), which causes a big environmental impact producing gaseous emissions which, in addition to pollutants, destroying ecosystems. Its use is promising, and the factors that allow a virtuous growth horizon for this natural source of renewable energy, are based on an asset that has parents that are the best in the world for producing winds wind, in addition, whereas the wind source is still very new in the world, there are opportunities for improvements and technological innovations that will contribute to the reduction in production costs by consolidating it as viable energy, contributing with the country in economic and social development, to take into account the environment and its sustainability.

Bibliographical References

AMARANTE, Odilon A. Camargo; BROWER, Michael; ZACK, John; SAMUEL, Antonio Elide. CRESESB/ELETROBRAS/CEPEL/MME. Brasilia: MME, 2010. *Atlas of Brazilian wind power potential. Average annual wind speed in Brazil the 50 meters high*. CRESESB/CEPEL. Available at: http://www.cresesb.cepel.br/publicacoes/download/atlas_eolico/mapas_1a.pdf accessed on 10 June. 2016

ABE Wind-Brazilian Association of wind energy. *Wind power has a daily average record in the South and northeast of the countr*y. Available at: http://www.portalabeeolica.org.br/. Set access. 2016.

ANEEL – National Electric Energy Agency. *Type Wind power plants in operatio*n. Available at: http://www2.aneel.gov.br/aplicacoes/capacidadebrasil/operacaocapacidadebrasil.aspAcesso on 29 August 2016.

AWEA-American Wind Energy Association, "*The Economics of Wind Energy,"* (Washington, DC: AWEA, 2005). Available at< http://www.awea.org/pubsfactsheets/EconomicsOfWind-Feb2005.></ http://www.awea.org/pubsfactsheets/EconomicsOfWind-Feb2005.>PDF >

Brazil. Ministry of mines and energy. *Energy expansion plan-EDP 2021*. Brasilia, 2013c. Available in:<h ttp://www.mme.gov.br/mme/galerias/arquivos/notícias/2012/></http://www.mme.gov.br/mme/galerias/ar quivos/notícias/2012/>
Relatxrio_PDE2021_ConsutaPxblica.pdf/>

Brazil. Ministry of mines and energy. *Energy expansion plan-EDP 2022: repo*rt to the press. Brasília, 2013d. Available in:< http://www.epe.gov.br/imprensa/pressreleases/20131029_1.pdf/="">. Access in: 10 jun. 2016.

Brazil. Ministry of mines and energy**.** *National energy plan 2011-2021*. Brasília, 2013e. Available in:<htt p://www.mme.gov.br/mme/galerias/arquivos/notícias/></http://www.mme.gov.br/mme/galerias/arquivos/ notícias/>
2012Relatxrio_PDE2021_ConsultaPxblica.pdf/>. Access in: 10 10. 2016

BORGES NETO, M. R.; CARVALHO, p. c. m. d. *electric power generation: foundations*. São Paulo:

Erica, 2012

CRESESB-REFERENCE CENTER FOR SOLAR AND WIND POWER SÉRGIO BRITTO SAVED. *Wind energy principles and technologies*. Available:

http://www.cresesb.cepel.br/index.php?section=atlas_eolico&. June 10, 2016 access

CHURRO, d. et al. *Wind farms: impact study on soundscape i: influence in local noise.* Lisbon, 2004. Available in:

< http://hidro.ufcg.edu.br/twikipub/CienciasdoAmbiente/Semestre20101/ Parqueeolicosinfluenciaderuidos-Civil.pdf >. Access in: 06 may 2016.

DUARTE, h. m. *n. wind e*n*ergy utilization in hybrid power generation systems aimed at small communities.* Final project. Pontifícia Universidade Católica do Rio Grande do Sul, Porto Alegre, 2004.

FARRET, *f. a. use of small power sources*. Santa Maria: Ed. from UFSM, 2014.

GIL, a. c. *As elaborate research projects.* 4. Ed. São Paulo: Atlas, 2008. 173 p.

J. Goldemberg, *energy and sustainable development.* São Paulo: Blucher, 2010. 94 p. (Sustainability Series, 4).

GOLDEMBERG, J.; LUCON, e*nergy and environment in Brazil. Advanced studies,* São Paulo, v. 21, n. 59, p. 7-20, 2008.

GWEC. *Global Wind Statistics 2011***.** *Global Wind Energy Council, 2012*. Available in: <http: www.gwec.net/fileadmin/images/news/press/gwec_-_global_wind_statistics_2011.pdf="">.</http:> Access in: 2016 03abril.

JANNUZZI, G.DE M. An *evaluation of the recent activities of P&D in energy which may be renewed in Brazil and reflections for the future.* Campinas, SP: Energy Discussion Paper No. 01/03-2.64, 2003.

GUILLERMO SASTRESA, e. et al. *Local impact of renewables on employment: Assessment methodology and case study. Renewable and Sustainable Energy Reviews,* v. 14, n. 2, p. 679-90, Feb. 2010.

MMA. Ministry of the environment. Available in: www.mma.gov.br.

MME/EPE-Ministry of mines and energy. Energy research firm. Brasilia:. *Energy Expansion Plan 2020, 2011*, **v**. 2: il. 1. Energia_Brasil. 2. Energética_Brasil policy 3. Energéticos_Brasil Resources. Available in:<http: www.epe.gov.br/pdee/forms/epeestudo.aspx=""></http:>

MME. Ministry of mines and energy. The restructuring project of the Brazilian electric sector. 2004.

PNE-2030 national energy Plan. *Electric power generation from other sources.* Available at:

http://www.epe.gov.br/PNE/20080512_9.pdf

Pinto, m. o. *wind energy Fundamentals*. Rio de Janeiro: LTC, 2012.

BRAZIL PORTAL. Available at: http://www.brasil.gov.br/infraestrutura/2016/01/brasil-e-um-dos-principais-geradores-de-energia-eolica-do-mundo.

RÍO, p. del; BURGUILLO, m. *Assessing the impact of renewable energy deployment on local sustainability:* Towards a theoretical framework. *Renewable and Sustainable Energy Eeviews,* v. 12, n. 5, p. 1325-44, jun. 2008.

SILVA, Edson Luiz da. *Supply adequacy in electricity markets based on hydro systems-the Brazilian case. Energy Policy* 34; 2002-2011.2006.

SEAMUS, MOANA, and Pacca, Sergio. *Wind energy, job creation and sustainable developmen*t[doi:10.1590/s0103-40142013000100008]. *Advanced Studies (USP. Printed)*,[online] 2013, vol. 27, p. 99.

TERCIOTE, r. a*nalysis of the efficiency of a wind power System isolatio***n.** Campinas: Faculty of mechanical engineering, State University of Campinas. Master's thesis, 2002.

TOLMASQUIM, m. t., Warrior, a., GORINI, *r. Brazilian energy matr*ix-A prospective. New studies, p. 79. 2011.

TOURKOLIAS, C.; MIRASGEDIS, s. *Quantification and monetization of employment benefits associated with renewable energy technologies in Greece. Renewable and Sustainable Energy Reviews,* v. 15, n. 6, p. 2876-86, Aug. 2011.

UNITED NATIONS. *Report of the World Commission on environment and Developmen*t: *Our Common Future, 1987.* Available in:<http: www.un-documents.net/wced-ocf.htm=""></http:>

VALENTINE, S. V. The STEP toward understanding wind power development policy barriers in advanced economies. *Renewable and Sustainable Energy Reviews.* Volume 14, Issue 9, December 2010, Pages 2807-2796.

WELCH, j. (B) and VENKATESWARAN, a. the dual sustainability of wind energy. *Renewable and Sustainable Energy Reviews* 13, p. 1121-1126.2009.

[1] *Graduate course in production engineering from the University of London-UNIARA/SP, Brazil*