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# POTENTIAL TO STORAGE THE EXCESSIVE ENERGY TROM WIND ENERGY THROUGH AMMONIA IN THE NORTHEAST OF BRAZIL

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## ABSTRACT

The northeast region of Brazil is experimenting an increasingly large percentage of power is being generated from wind energy. This increase in the use of wind energy, this being an intermittent energy, together with the reduction of reservoirs of energy accumulation in this region, increases the need to find different sources of energy storage. Ammonia is one of the best candidates wanting to reduce the carbon emissions for energy storage, making it with hydrogen by water electrolysis. The objective of this paper is to analyze the potential of wind energy in the state of Ceará, calculating the energy potential of 6 types of wind turbines with the aim of comparing it with energy consumption in the same region to obtain the energy that is being wasted and be able to calculate how much energy can be stored with ammonia.



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# INTRODUCTION

The world energy matrix is based on the use of fossil fuels, which release gases associated with the greenhouse effect and global warming. According to this scenario, there is a continuous reduction of petroleum reserves and an increase in environmental control policies, and an alternative and competitive way of producing energy that could replace these fuels has been sought. Renewable sources of energy, such as solar and wind, have great potential, but their use is difficult because of their fluctuating and intermittent nature. In large electricity grids, renewable energy sources with low output can be balanced by conventional power generation, but a larger percentage would require a better energy storage system [1]. Large-scale energy storage methods can be used to meet fluctuations in energy demand and integrate the generation of electricity from wind farms and intermittent renewable solar energy into power grids. Currently, there are a variety of mechanical, chemical, thermal and electrical technologies available to store adaptive electrical power from small to large applications. Of all these technologies, only compressed air energy storage, Pump Hydro and chemical energy storage systems have sufficient commercial maturity and the ability to store energy for large scale applications over long periods of time. The first two suffer the limitation of site placement due to their geographic and/or geological needs. Thus, chemical storage via hydrogen and/or byproducts (such as ammonia) and hydrocarbons present a viable option for practical energy storage. Bearing in mind the desire to reduce carbon emissions, only hydrogen and ammonia remain as candidates to boost the storage of large amounts of energy [2]. Hydrogen transport and storage proved to be more complex than for ammonia, for which a fully developed infrastructure has existed for more than a century, positioning ammonia as a strong candidate to support the concept of flexible energy storage on a larger scale [3]. Brazil has some of the best wind resources in the world, surpassing the current electricity needs of the country three times. Wind energy was the most competitive technology in the country, with an average price of R$ 98.62/MW h (around US $30/MWh) well below the prices of large hydroelectric plants according to the 2017 report of the global Wind energy council [4]. According to the Atlas of Brazilian Wind Potential [5], Brazil's wind potential reaches 143 GW, of which about half in the Northeast. According to new estimates made by the National Institute of Space Research (INPE), considering the current technologies for wind energy production and, especially, the use of wind turbines positioned at 100 meters high, the Brazilian wind potential can reach 880.5 GW, of which 522 GW are considered technically feasible. In the Northeast, wind power supplied more than 60% of the electricity demand in 2017, surpassing all previous generation records during a period when hydroelectric reservoirs in the region were very low. Considering that the remaining economically feasible hydroelectric potential in the Northeast is close to its exhaustion, the expansion of this electric generation source in the Region is compromised. Thus, wind energy will gradually increase in the electric power generation matrix of the Northeastern Region, since it is currently the most competitive alternative [6].

In the Brazilian northeast, electric power generation has come until recently from the water source, but this scenario has changed in the last years because of the occurrence of years of low rainfall and the increase of installed capacity of wind power in the region, being, in the year 2010 the presence of the wind source was 1.96% and in 2017 it became 45.37% [6]. The large-scale penetration of intermittent renewable energies, such as wind and solar energy, represents a challenge to maintain the reliability and stability of electricity grids. In the Brazilian electrical system energy storage has always been carried out using reservoirs to ensure the continuous supply of electricity. The progressive reduction of the construction of hydroelectric plants with accumulation reservoirs together with the increase in the use of intermittent renewable energy sources that replace the use of fossil fuels, there is a need to find other forms of energy storage to make compatible the production and the electricity demand [7]. The main use of ammonia in the world is in the agriculture sector, which corresponds to 80%. Ammonia has many applications in the industrial area, is used in the manufacture of household cleaning products, nitric acid used in the manufacture of dyes, fibers and plastics, explosives, ammonium nitrate, trinitrotoluene (TNT) and nitroglycerin. It is also used in the manufacture of synthetic polymers, such as nylon and acrylics [8], for industrial refrigeration purposes, scientists and refrigeration technicians are seriously analyzing natural refrigerants such as air, water, ammonia, carbon dioxide and others as a long-term alternative to industrial refrigeration [9]. Ammonia also has potential to be a energy vector, the viability of ammonia as an energy carrier depends on the overall process conversion efficiency, including the ability to convert it to the required power levels at the point of consumption with minimal environmental impact [2].

The calorific value of ammonia is 22.5 MJ/kg (9690 BTU/lb), which is about half of the diesel. In a normal engine, in which the water vapor is not condensed, the caloric value of the ammonia will be about 21% less than this value. It can not be easily used on existing Otto cycle engines without a high $NO_x$ production penalty due to its very narrow flammability range and low flame temperature. As ammonia does not contain carbon, its combustion can not produce carbon monoxide, hydrocarbons or soot [10]. In addition, fuel cells are recommended because of their high efficiency, low environmental impact and attractive technology for the direct conversion of fuel into electricity. Fuel cells are categorized according to their operating temperature, efficiency, applications, costs and electrolytic materials. Among these different types of fuel cells, SOFCs have a great advantage in combining environmentally friendly power generation with fuel flexibility. Since SOFCs are feasible at high temperatures between 1073 K and 1273 K, various alternative fuels, such as hydrogen or by-products (ammonia), biogas and bio ethanol, can be used directly in a SOFC [11].

**Case study and wind data:** In this study, the characteristics of wind for hydrogen production in Ceará is investigated. Fortaleza is a Brazilian municipality, capital of the state of Ceará, located in the northeastern region of the country. It is located on the Atlantic coast, at an average height of sixteen meters, with 34 km of beaches. Fortaleza has 313,140 $km^2$ of area and 2.643.247 inhabitants estimated in 2018, in addition to the greater population density among the capitals of the country, with 8.390.76 inhabitants per $km^2$. It is the largest city of Ceará in population and the fifth in Brazil. The Metropolitan Region of Fortaleza is the sixth most populous in Brazil and the first in the North and Northeast, with 4.051.744 inhabitants in 2017. It is the northeastern city with the largest area of regional influence and has the third largest urban network in Brazil in population. Wind speed data from the city of Fortaleza were provided by the MASTER group of the University of São Paulo (USP). Wind speed and direction data are from the January 2008 to October 2018 period. The METAR data platform used for the study is located at Pinto Martins Airport at latitude 3.78 ° S, longitude 38.53 ° W and the wind speed was measured at 10m. The energy consumption data of Northeast Brazil were obtained by NOS. The energy consumption data refer to the period from January 2008 to December 2018. ONS is the body responsible for coordinating and controlling the operation of the electric power generation and transmission facilities in the National Interconnected System and for planning the operation of the isolated systems of the country, under the supervision and regulation of ANEEL.

# ANALYSIS METHODOLOGY

**Weibull distribution:** One of the parameters adopted for the analysis of wind speed data directed to the Fortaleza region will be the application of these data in the Weibull distribution density function. According to the studies of [12–14] wind speed data serve as the basis for the Weibull distribution which is described as a probability density function (PDF) represented in Equation (1) by $f(v)$ and a cumulative distribution function (CDF) represented in Equation (2) by $F(v)$:

$$f(v)dv = \frac{k}{c}(\frac{v}{c}v/c)^{k-1}\exp\left[\left(-\frac{v}{c}\right)^{k}\right] \quad \text{………………(1)}$$

$$F(v) = {}_0^v f f(v')dv' = 1 - \exp\left[\left(-\frac{v}{c}\right)^{k}\right] \quad \text{………………(2)}$$

To determine the Weibull distribution, it is necessary to know the form parameter $k$ (without dimension) and the scale parameter $c$ (m/s). For the calculation of these parameters in this work will be calculated with the following equations [15–17]:

$$k = (\sigma/v_m)^{-1.086} \quad \text{……………..(3)}$$

$$c = \frac{v_m}{\Gamma(1+\frac{3}{k})} \quad \text{……………..(4)}$$

where $v_m$ is the average wind speed, $\sigma$ is called the gamma function, can be calculated with the equations 5, 6 and 7.

$$v_m = \frac{1}{n}\sum_{i=1}^{n} v_i(m/s) \quad \text{…………….(5)}$$

$$\sigma = [(\frac{1}{n-1}\sum_{i=1}^{n}(v_i - v_m)^2]^{0.5} \quad \text{…………….(6)}$$

$$\Gamma(x) = \int_0^{\infty}\exp(-u)\,u^{x-1} \quad \text{……………..(7)}$$

**Wind Power Density:** The wind power density is proportional to the wind speed cube, for a theoretical probability distribution f (v), which can be calculated by Equation (8) and can also be calculated from Equation (9) based on the function of probability of the Weibull [17]:

$$P = \frac{1}{2}\rho v^3 \quad \text{…..………….(8)}$$

$$P = \frac{1}{2}\rho c^3\Gamma(1+\frac{3}{k}) \quad \text{…………….(9)}$$

where $\rho$ is the density of air. The density of the dams depends on the place where the study is being done. According to [18] the density can be calculated as:

$$\rho = \rho_b[\frac{T_b}{T_b+L_b(h-h_b}]^{(1+\frac{g_0 M}{RL_b})} \quad \text{…………...(10)}$$

where $\rho_b$ is the density of air at sea level with a mean temperature of 15 °C and atmospheric pressure of 1 atm, which is equal to 1,225 kg/m$^3$, $T_b$ is 288.15 K, $L_b$ is 0.0065, $H_b$ is 10 m, $g_o$ is 9.81 m/s$^2$, R is 8.3144598 Nm/mol.K and M is 0.0289644 kg/mol.

**Extrapolation of wind speed:** The power law is widely applied in studies of large wind turbines as seen in the study [19]. It is a method of extrapolating wind speed characteristics based on height. As the data were obtained from a METAR data platform that is 10m high, it can be used Equation (11) as described in the study [19].

$$v_2 = v_1 \frac{\ln(\frac{h_2}{h_0})}{\ln(\frac{h_1}{h_0})} \quad \text{......................... (11)}$$

where $h_0$ is the roughness element of the soil surface, $v_1$ is the wind speed at height $h_1$; $v_2$ is the wind speed at height $h_2$.

However the data as described in the time series shown show certain wind speed variations, and can be described as in the equation below:

$$v_2 = v_1 (\frac{h_2}{h_1})^m \quad \text{.......................(12)}$$

According to the study [19] the value $m$=1/7 is considered the most frequently used value. It is important to emphasize that according to the characteristics of the spatial distribution of wind speed data there is the presence of outliers in a power curve of a wind turbine and according to the study of [20] these outliers can be in the form of stacked in the wind bottom curve, outliers stacked mid-curve, stacked outliers in the upper curve and outliers scattered around the curve.

Thus, four types of outliers are described in this study. Weibull parameters can be estimated at a given height $h_2$ by knowing the Weibull parameters ($c_1$, $k_1$) at a height $h_1$ The best method for extrapolating the Weibull parameters is the one proposed by Justus and Mikhail [18] as can be observed in the following equations:

$$c_2 = c_1 (\frac{h_2}{h_1})^n \quad \text{...................(13)}$$

$$k_2 = k_1 \frac{1 - \frac{\alpha_0 \ln(\frac{h_1}{h_r})}{\ln(v_h)}}{1 - \frac{\alpha_0 \ln(\frac{h_2}{h_r})}{\ln(v_h)}} \quad \text{..................(14)}$$

$$n = \alpha_0 \frac{1 - \frac{\ln(\frac{c_1}{h_r})}{\ln(v_h)}}{1 - \frac{\alpha_0 \ln(\frac{h_1}{h_r})}{\ln(v_h)}} \quad \text{...................(15)}$$

$$\alpha_0 = (\frac{z_0}{h_r}) \quad \text{...................(16)}$$

Where $n$ is the exponent of the power law, $v_h$67 m/s, $h_r$is 10 m/s and $\alpha_0$is the roughness coefficient that can be calculated with Equation (13), where$z_0$is the surface roughness length.

***Estimation of capacity factor:*** The capacity factor is defined as the ratio between the average power and the nominal output power of the generator [21]

$$CF = \frac{\exp\left[-\left(\frac{v_{cin}}{c}\right)^k\right] - \exp\left[-\left(\frac{v_r}{c}\right)^k\right]}{\left(\frac{v_r}{c}\right)^k - \left(\frac{v_{cin}}{c}\right)^k} - \exp\left[-\left(\frac{v_{cout}}{c}\right)^k\right. \quad \text{.................(17)}$$

Where, $v_{cin}$is the cut in speed, $v_{cout}$is the cut off speed and $v_r$is the rate output wind speed.

The power generated by a wind turbine can be determined by Equation (18), where $P_r$ is the nominal wind turbine power and h is the number of hours to be determined in the case of a year 8760 hours.

$$W = CF \cdot P_r \cdot h \quad \text{.................................(18)}$$

**Wind turbines chosen for the study and its characteristics:** Table 1 shows the mechanical characteristics of the 6 selected wind turbines, the most installed in the northeast region of Brazil in 2018 [22].

**Hydrogen production from wind energy:** The potential of mass production of hydrogen (HMP) will be calculated by Equation (19) [23], related to the wind turbine used. The advantages of using PEM are: 1- High efficiency, 2- Low GHG emissions and 3- Capacity to work with wind energy [23].

$$HMP = \frac{\eta_1 \eta_2 W}{LHV} \quad \text{................(19)}$$

where $\eta_1$ is the efficiency of electrolysis (0.75), $\eta_2$ is the coefficient of loss of the system (0.90) and LHV is the lowest heating value (0.0333 MWh / kg).

***Production of ammonia via Haber-Bosch process:*** The use of the Haber-Bosch process for the production of ammonia, which uses nitrogen and hydrogen, is considered for this project. It is assumed that nitrogen will be extracted from the air by means of an air separation unit (ASU) and hydrogen will be produced by means of electrolysis from the wind source. The water required for the electrolyzers should be distilled with almost no solid dissolution, so the water desalination system must supply high purity distilled water [24]. It is assumed for this work that the wind farm will be operating close to the sea, so that the reverse osmosis process can be used, since it is a known technology and high efficiency, this desalination method is the most appropriate, getting the water of the mineral salts, considerably removing part of the organic compounds, even removing 99% of the dissolved salts [25].

# RESULTS

**Wind charasteristics in Ceará:** Wind characteristics for each year, including half speed, standard deviation, k-shape parameter and c-scale parameter, followed by wind power density are shown in Table 2. The average of the wind speed per year, and consequently the wind power density, as it is directly related, in the years 2008 to 2011 is relatively lower compared to the rest of years, where it can be observed that from 2001 to 2017 remains more or less constant, less for the last year. As can be seen in table 2, the shape parameters remain constant for all years, thus representing a constant wind distribution for all years, thus having a higher reliability when it comes to knowing how much power to expect from the wind. Figure 1 plots the probability density for half of the 10 years of shape and scale parameter data.

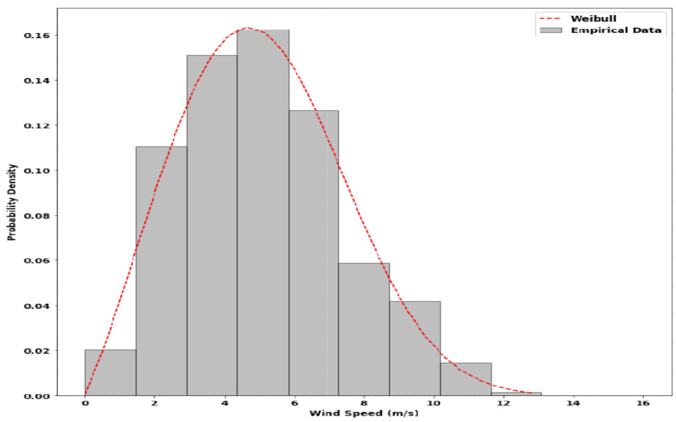


**Figure 1. Probability density for half of the 10 years of shape and scale parameter data**

Knowing that for each year the two parameters remain constant, it can be known that the wind frequency and consequently power will be maintained for the next years in the same way, thus having a reliability of the intermittent energy generated by the wind source in the city from Fortaleza.

An important analysis that has to be done for wind resource analysis is the wind direction. It is not possible to install a wind farm in one place without having a precise knowledge of wind direction variations. Wind direction data is measured at a height of 10 m and has a range from 0 to 360. A suitable way to show wind direction is the wind rose, which represents the percentage of wind directions based on the compass sector. All Fortaleza wind direction data for the 10 years were analyzed and are represented in Figure 2, showing that the dominant wind from Fortaleza is in the east direction, with a frequency of 42.58%.

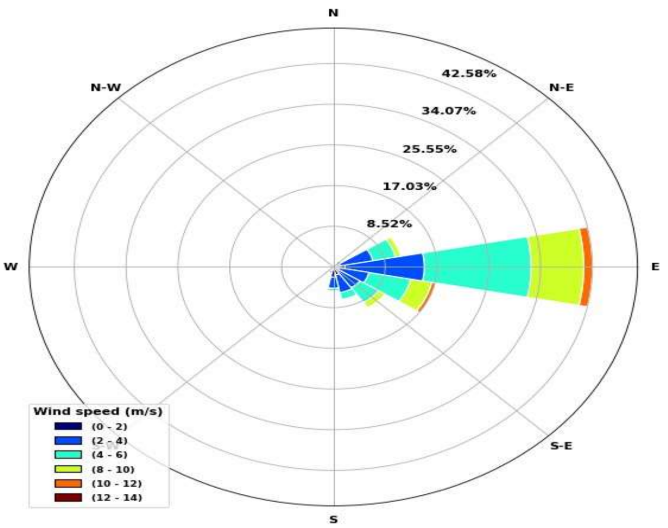


**Figure 2. Dominant wind from Fortaleza is in the east direction**

***Electric consumption in the Brazilian Northeast:*** Energy consumption data from the Brazilian Northeast were obtained from ONS. The energy consumption data refer to the period from January 2008 to December 2018.

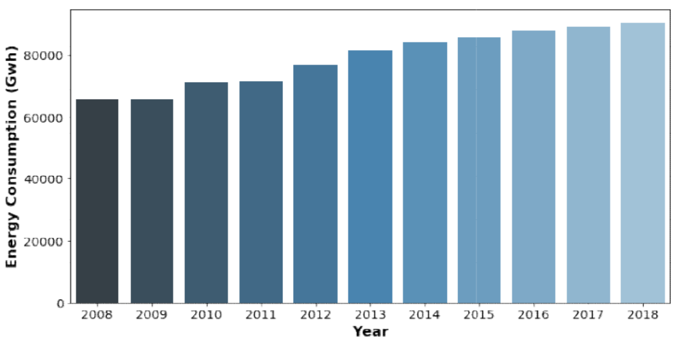


**Figure 3. Evolution of energy demand in northeastern Brazil per year**

Figure 3 shows the evolution of energy demand in northeastern Brazil per year. It can be clearly seen how energy expenditure is increasing per year, this fact is due to the constant increase of the population, in 1900 was one billion, in the year 2000 of 6 billion and is expected to be 9 billion in 2050 [25], thus the energy expenditure will increase directly proportional with the increase of the population, since not only the consumption per person will be higher, if not all the companies will have to increase their productivity in order to reach this population increase. This increase in population and energy expenditure will require higher energy production and as commented in the chapter in the literature review, the prices for producing a kWh of energy from solar and wind energy will be cheaper and cheaper. The need to find a way to store this energy should become a priority.

***Power generated by Wind turbines:*** The wind turbines chosen for this work are shown in Table 1. The half speed at a height of 10 meters collected at Fortaleza airport for 2008 and 2018 will be used as a meter to calculate how much energy could generate the wind turbines mentioned, the roughness length will be 0.2 since the place of study is an airport [18]. Table 3 shows the energy data that would produce the wind turbines in half. The wind turbine that performs better in the city of Fortaleza is the model V136/3450 from the multinational Vestas. It can be observed that even having a lower capacity factor than others shown in the table can generate more energy, this is because this wind turbine has a higher rated power than those with the highest capacity factor, is one of the highest heights and how The last attribute is that this wind turbine starts generating power at a speed of 2.5 m/s, adjusting the Fortaleza wind speed more than as shown in Figure 3 of the speed histogram there is a higher percentage at lower speeds.

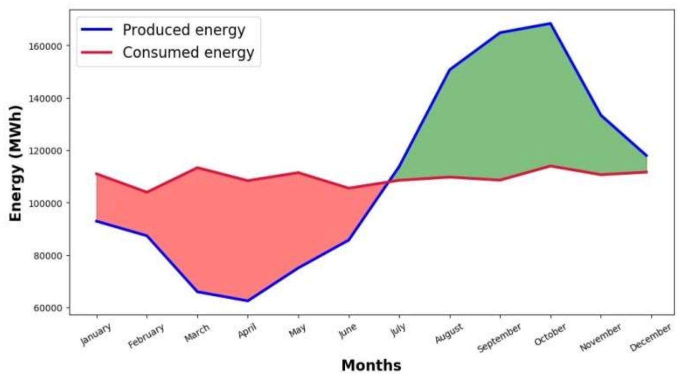


**Figure 4. Energy produced in half for each month in a year and the energy consumed in half**

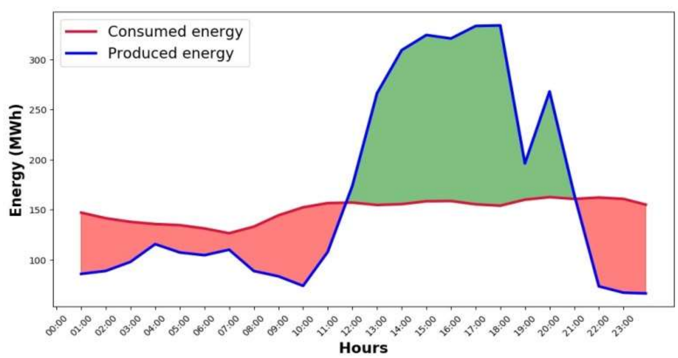


**Figure 5. Energy consumed versus that produced in half for each hour of a day**

***Production V.S consumption:*** In order to demonstrate the objective of this project it will be assumed that it wants to set up a wind farm in the city of Fortaleza that could produce 1% of the energy consumption of northeastern Brazil. This amount of energy corresponds to 1313 Gwh, so the number of wind turbines needed to reach this amount of energy will be 127. Figure 4 shows the energy produced in half for each month in a year and the energy consumed in half, can be observed as from January until June the wind turbines can not reach the required energy and from June until December There is an excess of energy. Wind energy is an intermittent wind dependent energy, the result shown in Figure 4 was already expected, but this does not mean that in January there is always a loss of energy, this means that in half there is a loss or a surplus, but depending on the time of day there may be a surplus of energy in the months when there is a loss of energy and in contrast to the months with surplus. This is shown in Figure 5, which shows the energy consumed versus that produced in half for each hour of a day. It can be observed how there is an amount of energy generated by the wind turbines and consequently a higher wind speed from 11:00 to 21:00 hours,

**Table 1. Technical data of selected wind turbines with hub height of 89 m and 120 m**

| Wind Turbine | Rated Power | Height (m) | Speed Undercut (m/s) | Speed of great wind (m/s) | Speed cutting highter (m/s) | Diameter of the rotor(m) |
|---|---|---|---|---|---|---|
| AW-125/3000 | 3000 | 120 | 3,5 | 12 | 25 | 125 |
| E92/2350 | 2350 | 110 | 2 | 13 | 25 | 92 |
| G114-2.0 | 2000 | 120 | 2.5 | 10 | 25 | 114 |
| GE 2.0-116 | 2000 | 94 | 3 | 10 | 25 | 116 |
| ECO 122 | 2700 | 89 | 3 | 10 | 34 | 122 |
| V136/3450 | 3450 | 112 | 2.5 | 11 | 22 | 136 |

**Table 2. Wind Characteristics in Fortaleza City by Year**

| Year | Average | SD | K(-) | (m/s) | WPD ($m/s^2$) |
|---|---|---|---|---|---|
| 2008 | 4.26 | 2.10 | 2.16 | 4.81 | 84.03 |
| 2009 | 4.00 | 2.02 | 2.10 | 4.52 | 71.47 |
| 2010 | 4.23 | 1.93 | 2.34 | 4.77 | 76.63 |
| 2011 | 4.75 | 2.17 | 2.35 | 5.36 | 108.63 |
| 2012 | 5.69 | 2.26 | 2.73 | 6.40 | 167.57 |
| 2013 | 5.68 | 2.34 | 2.62 | 6.39 | 170.85 |
| 2014 | 5.59 | 2.40 | 2.50 | 6.30 | 168.55 |
| 2015 | 5.59 | 2.39 | 2.52 | 6.29 | 167.32 |
| 2016 | 5.56 | 2.31 | 2.60 | 6.26 | 161.63 |
| 2017 | 5.27 | 2.26 | 2.31 | 5.52 | 119.73 |
| 2018 | 4.89 | 2.26 | 2.31 | 5.52 | 119.73 |
| Total Average | 5.05 | 2.22 | 2.43 | 5.69 | 130.67 |

**Table 3. Energy produced by wind turbines**

| Wind Turbine model | $c_2$ | $k_2$ | Capacity Factor | Annual energy production (MWh) |
|---|---|---|---|---|
| AW-125/30000 | 8.83 | 2.85 | 0.36 | 9475.45 |
| E92/2350 | 8.70 | 2.83 | 0.30 | 6230.87 |
| G114-2.0 | 8.83 | 2.85 | 0.52 | 9170.57 |
| GE 2.0-116 | 8.47 | 2.80 | 0.48 | 8469.40 |
| ECO 122 | 8.39 | 2.78 | 0.48 | 11255.79 |
| V136/3450 | 8.72 | 2.84 | 0.43 | 13133.36 |

**Table 4. Total production, total consumption, energy surplus and lack of energy**

| Month | Days | Total Production (MWh) | Total consumption (MWh) | Energy surplus (MWh) | Lack of Energy (MWh) |
|---|---|---|---|---|---|
| January | 31 | 92869.24 | 110953.38 | 18316.30 | -36400.50 |
| February | 28 | 87287.22 | 103925.59 | 16137.30 | -32775.70 |
| March | 31 | 65898.74 | 113300.34 | 4854.27 | -52255.90 |
| April | 30 | 62425.53 | 108345.59 | 5163.78 | -51083.80 |
| May | 31 | 75000.66 | 111413.96 | 9599.28 | -46012.60 |
| June | 30 | 85638.70 | 105478.34 | 16348.00 | -36187.70 |
| July | 31 | 113745.52 | 108489.77 | 30894.00 | -25638.20 |
| August | 31 | 150687.99 | 109697.71 | 56836.100 | -15845.80 |
| September | 30 | 164876.32 | 108543.23 | 67276.00 | -10942.90 |
| October | 31 | 168394.04 | 113943.81 | 64495.40 | -10045.20 |
| November | 30 | 133341.20 | 110623.99 | 47937.30 | -25220.10 |
| December | 31 | 116263.77 | 111713.21 | 35868.10 | -31317.60 |

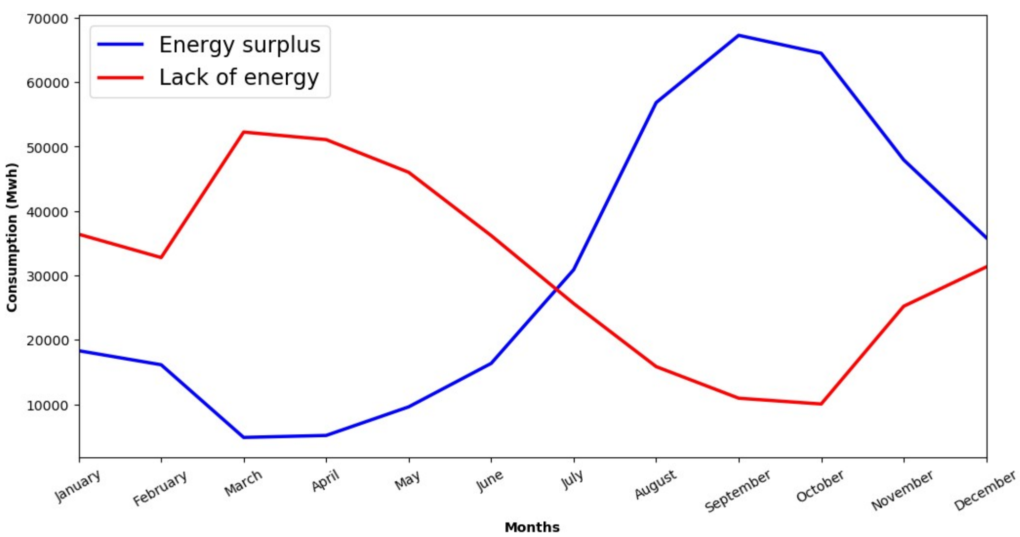


**Figure 6. Total production, total consumption, energy surplus and lack of energy**

meaning that to have an idea of how much energy is being used or not the energy generated should be calculated. for every hour of the year.

***Calculation of the lack of energy or thereal surplus energy:*** Given the wind speed for each hour of each day of the ten-year year, it was calculated at half for each hour in the ten-year period and how much energy the wind turbine chosen could produce. Consumption for each hour of the 10-year old is also known so a comparison can be made so you can know how much energy is being exceeded or how much energy is failing to achieve the required. This is shown in table four which summarizes the total output of all these times of the year and grouped into messes to be easier to understand visually. Table 4 shows the months of the year, the number of days each month, the total production of these wind turbines, the total electricity expenditure in northeastern Brazil, the energy surplus and the total energy shortage that existed in those months. Figure 6 is the graphical representation of table 4 to have a clearer idea of this loss and lack of energy, shown graphically. It can be observed that the excess energy and the lack of energy are complementary, this is due to the fact that by the end of the year the wind turbine will be able to reach this total amount of energy, but not when necessary due to the intermittent wind. As seen in Figure 4, there is a greater loss from January to June and a surplus of energy from June to December, because of having less to more wind in those months, but as mentioned there is a lack of energy and excess in every month.

**Calculation of the energy return through Ammonia:** Having data on how much surplus energy exists throughout the year can now be calculated how much energy we can recover through the entire process. This process is fully electric where electricity is generated from wind turbines, hydrogen is manufactured by PEM electrolysis and ammonia is manufactured by the Haber-Bosch process and once ammonia can be stored for long periods of time, transported and stored. finally transformed back into electricity through a SOFT fuel cell, which can produce electricity directly with ammonia. One kilogram of ammonia needs 1.67 kg of water for electrolysis, where the energy expenditure for reverse osmosis is 0.01 kWh/kg [24]. To make 1 kg of ammonia requires 0.176 kg of hydrogen, so according to the previous section for 1 kg of ammonia will require energy 8.68 kWh / kg, which has to be added to the water desalination of 0.016 kWh/kg. Also, to this sum should be added the expense of the synthesis cycle of Haber-Bosch and the process of the air separation unit which has a total expense of 0.72 kWh/kg [24]. The energy requirements for the production of fully electric ammonia are about 9,416 kWh / kg, with an energy density of 22,5 MJ/kg and assuming a soft fuel cell with an efficiency of 50% for this work. [2], the total process will have an efficiency of 33.18%. In the previous section, a total surplus energy of 373.72 GWH has been calculated, so that it could be recovered through this process 124 GWh, which represents exactly 33.18% of the energy that wind turbines could not produce due to lack of wind.

## CONCLUSION

Continued growth of renewable energy is necessary to reduce carbon emissions in the atmosphere, but this growth has to be well studied, taking into account, as mentioned in this paper, that if these renewable energies are intermittent, a study of the source of this Energy must be realized in order to know if this energy can provide the necessary energy when needed. Brazil has enormous potential to generate wind energy, so wind energy is one of the cheapest energies to generate in this country, so its use is needed to make the Brazilian energy matrix fully renewable, but as shown. In this work there is the problem of the surplus energy that is generated. With the current energy storage system through accumulation reservoirs, an effective method but with a very large geological limitation, the chemical storage system using ammonia presented here is a totally viable system to be installed in Brazil. the effectiveness shown in the results of 33.16% will increase over a relatively short period of time as the technology for making hydrogen by electrolysis will be less expensive and there are and there are many studies that study ammonia-fueled fuel cells directly. Therefore, its efficiency has increased and manufacturing costs have decreased, making this technology economically viable, thus converting ammonia as an economically viable energy vector for long-term storage, transport and energy production. Ammonia should not be seen as a competitor of hydrogen, if not as a driver of its economy, thus enabling the use of hydrogen for power generation and fuel, and ultimately replacing oil effectively.

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