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A long-term solution to overcome the problems caused by droughts in the Brazilian Power Systems

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Abstract

Brazil has had issues in efficiently providing the required amount of electricity to its citizens at a low cost. One of the main causes to the decreasing performance of energy is due to reoccurring droughts that decrease the power generated by hydroelectric facilities. To compensate for the decrease, Brazil brought into use thermal power plants. The power plants being on average 23.7% more expensive than hydroelectric. Wind energy is potentially an alternative source of energy to compensate for the energy decrease during droughts. Brazil has invested in wind farms recently, but, due to issues with the delivery method, only 34% of wind farms are operational. This paper reviews the potential benefit Brazil could receive from investing more resources into developing and operating wind farms. It also proposes that utilization of the best value approach in delivering wind farms could produce operational wind farms quicker and more efficiently than previously experienced.

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Keywords: Procurement in Brazil; power system delivery; droughts in Brazil; power shortage; developing country

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1. Introduction

Brazil is one of the world's top four emerging countries and is regarded as one of the greatest promises of economic growth in the world (next to Russia, India, and China). During the past 20 years, Brazil has experienced constant average growth higher than the rest of the world. The confidence of the rest of the world in Brazil's development was seen in the awarding of the right to host the 2014 FIFA World Cup and the 2016 Olympics. Brazil was expected to continue its high growth and eventually come to establish itself as one of the top five global economies; this did not happen. A literature search identifies two causes for Brazil's economic decline:

1) Bad economic policies
2) Lack of preparation of the Brazilian power matrix in facing droughts

This research will look at the issues Brazil is facing trying to provide consistent and reliable energy to the country. Energy is a basic necessity that all industries and people rely on to operate and live. The increasing reliance on technology to communicate and perform services makes reliable energy a requirement to maintain a healthy and growing economy.

Brazil currently uses hydroelectric power plants to deliver the majority of the country's energy [7]. Brazil's hydroelectricity capacity is one the largest in the world [7]. This energy is inexpensive, clean, and for many years was the most efficient electrical generation model in the country. However, to build a highly efficient hydroelectric power plant and generate electricity at a low cost, it requires a large amount of funding and changes to the environment. It requires the construction of a dam, and in many cases, the dam will require the flooding of lots of land regions.

The major risk to the Brazilian production of hydroelectric energy is droughts [7]. Decreasing the water supply greatly reduces the efficiency and productivity of the hydroelectric power plants. The frequency of droughts experienced in Brazil in the recent years has caused the hydroelectric power plants to be unreliable in meeting the country's energy production expectations. This has raised concerns with the country's long term energy plans.

2. Problem

Brazil's energy consumption has increased at an annual average rate of 3.3% from 2000 to 2011 [16], this is still below China and India's (2 largest developing countries) demand, which are 4.3% and 5.4% respectively [15]. It is, however, larger than the average demand across Europe, which decreased by 14% from 2000 to 2008 and the United States' demand has decreased on average by 13.5% [24].

The country has relied on the hydroelectric power plants to produce the majority of its energy needs, which makes up over 75% of the overall electric power supply [7]. Brazil has a potential estimated hydroelectric capacity of about 260 GWh or almost twice the total amount of energy produced in Brazil in 2014, counting all electricity produced from all sources of power generation in Brazil [7]. Despite this large capacity, the increase in the number of droughts as well as their intensity have caused the country to be unable to meet the energy demand of its people.

One of the main problems with the hydroelectric energy sources Brazil depends on is their location. For example, 52% of the hydroelectric power capacity is located in the Amazon Hydrographic Basin [29]. The Amazon Basin is essentially a plain region, which makes it difficult to build dams without flooding a large amount of land. Furthermore, much of this region is protected indigenous land or has high biological value, which invalidates the possibility of any project. It is still possible to build small hydroelectric plants within the available territories, due to their size, however, they would be less efficient and more expensive.

According to the Brazilian Electricity Regulatory Agency (ANEEL, for its wording in Portuguese), in 2011, approximately 71.58% of Brazilian total electrical power capacity came from hydroelectric power plants [7]. The majority of the rest of the power came from thermal power plants. They were responsible for 25.65% of the energy. The rest of the power could be generated through other sources, allowing Brazil to be almost 100% self-sufficient. However, the most recent energy report (2015), the same agency identified that 61.96% of the total electrical power came from hydroelectric plants, while the thermal power plants increased to 26.83% [3]. It also showed that Brazil was required to import energy from other countries to meet the demand of electricity.

In the last five years, electric power generated through hydroelectric power plants in Brazil has been decreasing, causing other sources of energy to grow. However, the growth of some forms of energy might not be sustainable for the country due to their harm to the environment and the cost of the electricity.

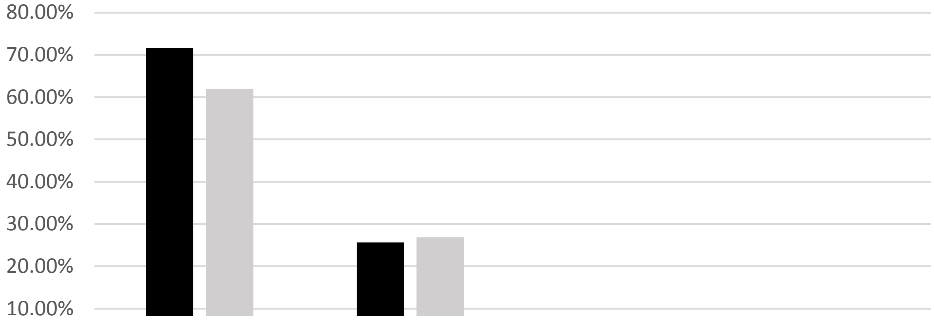

Fig. 1. Difference between the generated power in Brazil in 2010 and 2015 [7, 3]

One of the steps taken to try and meet the energy demand by the government of Brazil was to operate all emergency thermal power plants. Thermal power plants, according to the National Electrical System Operator (ONS), can reach values eight times more expensive in some plants than those generated from hydropower [17]. This move forced ANEEL to authorize an increase in electricity bills, which became 24.2% more expensive on average in 2015 than the previous year [10]. This coupled with large changes made to the country’s economic policy caused a spike in inflation of 9%.

3. Proposal

Hydroelectric power plants are becoming increasingly more unreliable in Brazil. If the country wishes to decrease the quick fall it has had from potentially being a top global economy, it needs to develop the capacity to not only find an alternative form of energy, but one that is sustainable long-term as well.

This paper analyzes different forms of energy that can be utilized in Brazil, which have been developed or not. Then, a more thorough analysis of hydroelectric power compared to the more viable option (if any) will be conducted through a comparison of both.

4. Methodology

1) Identify the different sources of alternative energy and their costs
2) Identify the success of developing the alternative energy sources
3) Identify the alternative with the most potential and how the energy can be efficiently delivered

5. Research

Advances in technology have made it possible to generate energy in multiple ways. The following are the most used and viable energy options: wind, solar, hydroelectric, biomass, nuclear, and imported.

To identify the best energy options for Brazil, these sources were analyzed in terms of: availability, level of technicality, materials needed, energy produced, future risk, size of investment, initial effort, cost (not only to find an alternative form of energy, but one that is sustainable long-term as well).

Table 1 - Brazil’s Energy Sources and Constraints [23, 16, 22]

Possible Electricity	Availability	Technicality	Materials	Energy	Future	Size of	Effort	Cost

Source			Needed	Produced	Risk	Investment		
OPTIMAL	HIGH	LOW	LOW	HIGH	LOW	LOW	LOW	LOW
Wind	High	Low	Low	High	Low	Low	Low	Low
Solar	High	Low	High	High	Low	High	High	High
Hydroelectric	Unstable	Low	Low	High	High	None	Low	Low
Biomass	Unstable	High	Unstable	High	High	High	High	High
Nuclear	Low	High	High	High	High	High	High	High
Import	Unstable	Low	Low	Low	High	High	High	High

Possible electricity sources are ranked according to how they compare with the most optimal electricity source. The availability of the source is the first analyzed, utilizing the other rankings as differentiators among similar availabilities. Although imported energy yields better results than nuclear, it does not aid Brazil in being an energy-sufficient country; putting it at the bottom of the list. When compared to biomass energy, nuclear energy falls short because of its low availability, making it the least viable option compared to all of the others (biomass and hydroelectric sources are not low in availability, they have just not proven to be constant over time mainly due to weather changes). Nuclear and biomass energy also requires the workers to have a high technical knowledge to be able to generate power. Hydroelectric energy is the main source for electricity found throughout Brazil today, making it the only source that does not need any additional investments. The recent increment of drought occurrence and potency, however, has caused the availability of this energy to be rated "unstable," since most power plants depend on high water levels to generate power. Solar energy becomes, then, a more viable option than hydroelectric energy due to high availability and low future risk. On the other hand, solar power is not the most optimal option due to the high level of materials needed for production; the large investments needed at first with high long-term costs and an effort larger than if wind power was utilized. Wind power is at par with the optimal energy source. Although large efforts are needed at first when trying to generate electricity through wind power, Brazil already has programs and capital allocated for the proliferation of it, giving wind power source effort a "low" rating and making it on par with an OPTIMAL power source.

Following one of the worst modern-day droughts in 2002, the Brazilian government set into place the Programa de Incentivo às Fontes Alternativas de Energia Elétrica (PROINFA), a program created to diversify different sources of electric power structured around incentives. The first phase of the program sought to boost the growth of biomass power plants, small hydroelectric plants and wind farms. The country identified wind energy as the most viable and has made it the main focus of the PROINFA program.

In 2001, the Atlas of Brazilian Wind Potential identified that 143.5 GWh could be generated through the utilization of wind, which is slightly less than the amount of the total electrical energy capacity installed in Brazil of 147.7 GWh [8, 3]. Technology has changed since 2001 and it must be actualized, but even if only 50% of this potential could be used, it already demonstrates a huge source of renewable energy that could be made available to the public.

With the technology surrounding wind energy increasing, the Mines and Energy Ministry already foresees the potential of wind generated electricity reaching up to 350 GWh, which is much higher than Brazil's hydropower potential of 260 GWh [12]. Furthermore, the Atlas of Brazilian Wind Potential identified that the winds in Brazil are strong and more constant in the winter [2].

Winter is also the time when there is less rainfall across the country. Due to the lack of rainfall, hydroelectric plants provide less energy, causing power shortages. Wind farms, on the other hand, would be thriving during this time, which means the wind farms and hydroelectric plants would complement each other throughout the year, generating a more stable and reliable power, and making the county much more resistant to droughts. The contrasting peaks of these power sources are demonstrated in a graph generated and presented in 2009:

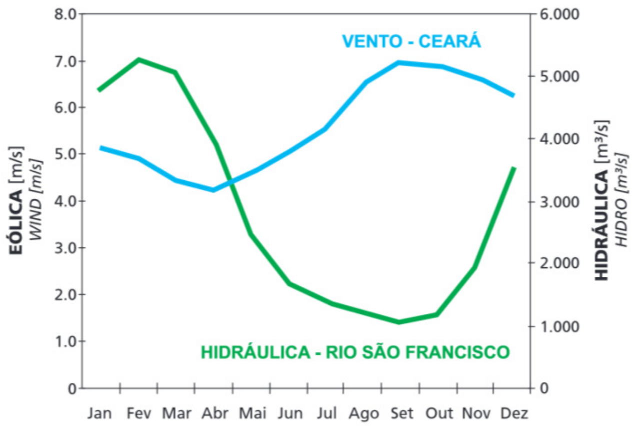

Fig. 2. Complementation of Wind and Hydroelectric Energy through the Year [6]

The Brazilian government has identified the benefits of wind power and continues to increase the amounts of investments towards projects. In Figure 1, wind farms represented 4.36% of the total electricity capacity this year, instead of only 0.82% five years ago. Although wind energy in Brazil is still not as common as it is in other developing countries, wind energy has helped confront the excessive increase in Brazilian electricity bills because it is far cheaper than the energy generated by fossil fuels, and almost as cheap as hydroelectric power. In the last auction conducted by ANEEL, the cost of generation was R$100.00/MWh ($30/MWh), which makes wind power the second cheapest energy source in Brazil, losing only to the hydroelectric power. The cost of wind power, however, continues to decrease as time goes by [19].

According to Efe la Asociación Brasileña de la Energía Eólica (ABEeólica), Brazil's wind power association, the country will continue its investments in 2015, with an additional US$14,782 million through 2018 devoted to the development of wind energy [4].

These large investments are backed up by the worldwide community as of 2011, when a survey identified wind power as having a 93% approval, falling second only to solar (97%) [13]. Because of its low cost of production, maintenance, risk, and high returns on energy produced, especially during the months hydroelectricity outputs are low, wind energy has been identified as the best option for Brazil.

Brazil's efforts in boosting the development of electricity generated using wind has caused an increase in interest by contractors and manufacturers in the country. There are currently 11 manufacturers involved in the delivery of wind farms, each with an average production capacity of 500MW/year of equipment, which should be able to deliver 5,000MW of machines. This, however, does not occur for 3 reasons [5, 26]:

1. Not all 11 manufacturers are established in Brazil and the speed of delivery varies upon the size of the orders they receive.
2. Interest rates are too high without financing from BNDES, Brazil's Development Bank.
3. Manufacturers must comply with FINAME's regulations and standards, an organization of the Brazilian Development Bank, to obtain financing from BNDES.
4. Specific layout designs are needed for each wind farm.

Despite these challenges, there's been an increase of wind power interest since 2009, as certain manufactured parts dropped in price. The drop in price was caused by the drop in quality by the manufacturers, as it has been seen from an increase in parts malfunctioning [11, 28]. The increase in perceived competition also caused the government to resort to a low-bid system of auctioning when selecting companies for wind power projects.

Through the Ministry of Mines and Energy, the Brazilian government only allows plants to be built once they have won bids in energy auctions and are guaranteed long-term contracts. Although it has granted 31 GW of new capacity in Brazil through the contracting of new projects, the auctioning system fails to account for expertise when selecting a vendor.

Characteristics of the auctioning system [5]

- Fully controlled by the government
- Price caps
- Defines product
- Government does the preparation and transmission planning
- Extensive technical pre-requisites
- Need to submit guarantees by the contractors
- Several vendor penalties are applicable

The results have been less than stellar [20, 26, 27]:

- In 2012, a lack of transmission lines caused 600MW of wind electricity to be wasted, forcing the country to increase in its imported power, as previously stated. The government also paid around US$150 million to the contracted companies that could not sell the power.
- It was estimated that by the end of 2013, 1.3GW of generating wind projects will not be connected to the main grid.
- Study by ONS, national grid operator, identified that only around 7GW could be connected, well under Brazil's potential of more than 100GW.
- As of 2015, 48 out of 140 wind farms will not be in operation due to a lack of transmission lines being connected to the main electricity grid. This means only a bit over 1/3 of electrical capacity will be available.

By observation, this has caused a decrease of wind power interest by all parties involved. The delivery system being utilized is not the best for these projects and, coupled with a controlling government, it is causing wind power projects to be delivered over schedule, over budget and with failing parts in the transmission lines [government is directly responsible for transmission lines].

5.1 Best Value System

During an internship at Arizona State University, the researcher was exposed to the Best Value System (BV PIPS), a documented high performing system that has proven performance of improving the delivery of both construction and non-construction services worldwide.

The Best Value System originated in the Performance Based Studies Research Group (PBSRG), at Arizona State University. It has been tested for 22+ years in the deliverance of 1,700+ projects, 96.70% of which were delivered on budget and 93.50% on time with a 98% customer satisfaction rating [21].

Additionally, PBSRG has implemented the BV PIPS in over 6 countries and 31 states yielding the following results [25, 21]:

- In the Netherlands, Best Value was introduced in 2006 and by 2012 it became the system of choice following the largest test ever ran of BV technology. This occurred through the procuring of a $1B through Rijkswaterstaat. Upon completion, procurement time and costs were reduced by 50%, and projects were completed 25% faster. These results gave Rijkswaterstaat the 2012 Dutch Sourcing Award and all governmental procurement firms licensed all of PBSRG's technologies.
- 8 of the top 25 Canadian choose the BV approach to procure services. At the University of Alberta, $200M dollars in over 11 projects have been procured using Best Value. Service performance has increased 14% since the introduction of BV, and the BV approach holds a 9.8/10 customer satisfaction.

- Arizona State University [ASU] continues to be most reoccurring client with over 13 projects procured and ran using Best Value valued at over $1.7B with 100% customer satisfaction. The 2 main projects have been on Dining Services, which had a 79% reduction in client management requirements and IT networking project, which saved ASU $2.75M annually.

What makes the Best Value System successful is its replacement of management, direction and control (MDC) with the utilization of expertise; in other words, allowing expert vendors to add value to projects. The Best Value System can be utilized to procure the expert vendors in the wind power industry, hold the vendors accountable, ensure that the vendors are thinking long term, evaluate performance via simple metrics, and promote transparency ultimately increasing the performance of the wind power projects.

6. Conclusion

Upon a review of the major sources of electricity in Brazil, it has been found that, due to the increase of droughts, hydroelectric energy is no longer a viable option despite its past success. Hydroelectric energy should not be completely disregarded, since it is still the cheapest, but it should be complemented through times of lower production. Aside from drought periods, Brazil also experiences lower rainfall over the winter, which is when overall wind currents increase in speed and become more constant; making wind power a viable option to complement hydroelectric power.

The Best Value System originated in the Performance Based Studies Research Group (PBSRG), at Arizona State. Although the government of Brazil has identified the large potential for energy generated by using wind, it has not yet been successful in delivering all projects it has invested in. The current auctioning systems forces everyone involved to lower their price at the cost of lowering their performance. As more projects mature into their initial completion dates, it has become more and more evident that a different delivery method must be utilized in delivering wind power projects.

The Best Value System is the only delivery method with high documented performance, capable of easing the delivery of wind power projects in order to meet the energy demands of the Brazil’s emerging economy.

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