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Energy crop storage: An alternative to resolve the problem of unpredictable hydropower generation in Brazil

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ABSTRACT

Due to the lack of energy storage in the new hydropower plants in the Amazon region, Brazil will require thermoelectric power plants to generate electricity during the dry period (May–October). Biomass based electricity generation, especially eucalyptus trees, can be used to replace the expensive liquefied natural gas infrastructure required to generate electricity during the dry seasons and emergency generation during dry years in Brazil. This article presents a new electricity generation scheme called "Energy Crop Storage". In this scheme, biomass is grown and stored in eucalyptus plantations in order to match the supply of energy to its demand. For example, during wet years in Brazil, when biomass plants operate at 50% capacity, the eucalyptus trees are allowed to continue growing. During dry years, the biomass stored is used more intensively as biomass generation raises to 90% of its capacity. It was concluded that natural gas is a high risk investment in Brazil because, if there are several consecutive wet years, the expensive infrastructure dedicated to natural gas based electricity generation will remain on standby. Biomass plantations, on the other hand, are a more reliable investment as the biomass is stored when the biomass demand is lower.

1. Introduction

The Brazilian Southeast is currently going through one of its worst droughts [1]. This is starting to bring into question the capability the country has to rely on its hydropower generation and energy storage capacity. The published decennial electricity plan 2013–2023 [2] expects that the Brazilian hydropower storage potential will generate electricity until the end of the dry period and that, with additional support from natural gas backup generation, the annual demand for energy would be met. In addition, hydropower storage would serve as a buffer to the wind and solar intermittent electricity generation. The Brazilian climate seems to be changing over recent years, either due to global climatic changes or due to changes in regional climate resulting from deforestation, the reliability of hydropower generation in Brazil is becoming questionable [3].

Over the next 10 years, the hydroelectric energy storage capacity will not increase as the new hydropower generation, which will increase 33% in the next 10 years. This increase will be in the Amazon water basin with no storage and most of its electricity will be generated during the wet period without storage [2]. Other alternatives such as wind and solar will partially complement the electricity generation. The Brazilian wind potential has started to be explored and is foreseen to reach 24 GW of wind power by 2024. This is convenient because it generates more electricity during the dry period, when hydropower generation is reduced. Solar power has less seasonal variations and is set to increase by 7 GW capacity by 2024.

Natural gas based electricity generation in Brazil has an estimated capital cost of US$ 1.07 million/MW and an operation cost of US$ 66/MWh[2] [4] to cover the infrastructure to explore, extract, process and transport the gas to the power plant and to generate electricity with the gas. This investment should cover the worst

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[2] Brazilian Reals to Dollar to conversion of 3.5.

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scenario in order to guarantee that there will be enough electricity generation in case of a dry year in Brazil.

Considering the supply over the last few years, this infrastructure was used at only around 28% of its capacity, see Fig. 1. This is not an appropriate investment as the capacity is under-utilized. In addition, it increases the cost of natural gas in the market for the industrial, residential and commercial sectors to guarantee the supply of natural gas for electricity generation. The priority program for thermal power plants schemes was created especially to subsidise natural gas for electricity generation and has been extensively criticized [5].

Fig. 1 shows a trend of increased natural gas generation. This is a result of lower than the average rainfall in 2012, 2013 and 2014, which resulted in an increase in electricity prices up to 70% in 2015. The consumption of natural gas is set to increase even further during the dry period due to the lack of increase in Brazilian storage capacity.

Biomass electricity generation based on eucalyptus plantations has an estimated capital cost of US$ 1 million/MW and flexible operation cost of US$ 44/MWh to cover the costs of land use, seeding, harvesting, cutting, biomass transportation, gasifying or burning the biomass to generate electricity [7]. This article argues that an important aspect of biomass is its flexible operation cost, which makes it possible to generate energy when it is required. For example, if there are 4 wet years in a row, the investment in the eucalyptus plantations will be reduced after the second year and the eucalyptus trees will continue growing, reducing the future investment costs.

This article compares both natural gas and biomass sources of energy and proposes a solution to the unreliable Brazilian hydroelectric storage potential through the planting of large-scale eucalyptus plantations. This assures the generation of electricity when there is lower than average hydropower generation.

This paper is divided into sections. Section 1.1 describes the issues Brazil will have to face to generate electricity in the next decades and presents alternative solutions. Section 1.2 presents the environmental and social issues involved in the plantation of eucalyptus. Section 1.3 indicates that the reduction in paper consumption will facilitate the increase of eucalyptus based electricity generation. Section 2.1 presents the new scheme called “ECS” (Energy Crop Storage). Section 2.2 shows that the ECS scheme is suitable to the Brazilian energy sector and climate. Section 2.3 describes how ECS could be implemented in Brazil. Section 3 presents the results of the implementation of ECS in Brazil. Section 4 discusses the other aspects that influence this research, and presents the advantages and disadvantages of biomass electricity. Section 6 presents the conclusion of this paper.

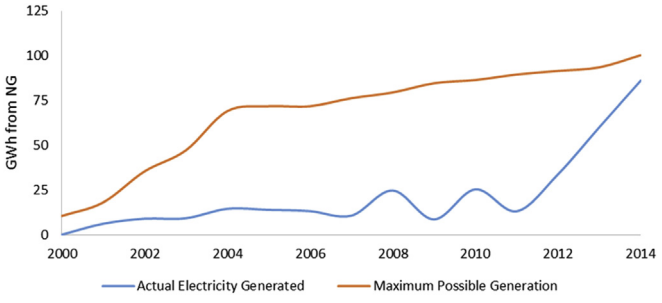

Fig. 1. Maximum and actual electricity generation capacity from natural gas in Brazil. Data taken from Refs. [2,6].

1.1. Brazilian electricity generation for the next decades

Brazil generates around 70% of its electricity from hydropower and still has an enormous hydroelectricity potential to be developed in the Amazon Watershed. However, due to its flat geology, large storage reservoirs are not practical in the Amazon region [3]. Thus, they will generate most of it electricity during 6 months in the wet season (November–April).

Current studies propose the further development of the Amazon hydro potential with the inclusion of Seasonal Pumped-Storage Schemes, named “Enhanced-Pumped-Storage”, in the Southeast region, to store energy during the six wet months and generate electricity during the six dry months [8]. The South, Southeast and Northeast regions of Brazil have the appropriate geology for the construction of storage reservoirs and can be used to store the energy generated in the Amazon. Fig. 2 shows how this Enhanced-Pumped-Storage could be used to allow Brazil to develop all the hydropower potential in the Amazon region, by increasing the storage capacity in the other regions.

The current Governmental solution is to generate thermoelectricity during the six dry months, especially with LNG (liquefied natural gas) based Gas fired power plants. In addition, in case of an exceptionally dry year, as in 2013, 2014 and 2015, the power plants would operate as base load throughout the year to replace the lack of hydropower.

The proposed solution in this article is similar to the current Governmental solution. However, instead of LNG based electricity generation, the thermoelectricity would be generated with eucalyptus using the ECS scheme.

1.2. Myths and truths about eucalyptus in Brazil

Eucalyptus plantations in Brazil are increasing and the market for its products are promising. In 2013, Brazil already had 7.2 million hectares of planted eucalyptus trees, out of 360 million hectares of arable land, as shown in Fig. 3. With current policies and government incentives, the country is set to double its planted forest to 16 million hectares in 10 years [9].

Although some sectors of society believe that eucalyptus may cause negative effects on biodiversity, it can be seen as an alternative for nature conservation because it reduces the impact on native forests. Moreover, eucalyptus plantations show environmental benefits such as reduced erosion, increased infiltration of rainwater, local climate conservation, biomass production, capture and storage of CO_2, among others. Currently, there is no more space in the market for productive segments that do not reconcile economic activity with environmental preservation. In this context, the growing eucalyptus is presented as a sustainable forest plantation, able to meet these new environmental assumptions [9]. Table 1 presents the main products and services resulted from eucalyptus plantations. Another benefit from biomass energy crops is the high number of jobs created [10].

Fig. 4 shows the average productivity of eucalyptus plantations in Brazil. It varies considerably with the climate, especially the average precipitation of the region. The average production of planted eucalyptus forests is 41 m^3/ha/year, with a maximum potential of 70 m^3/ha/year [11]. It is, therefore, essential to the search for increased productivity of these forests, both in nurseries and in the field [12].

1.3. Decrease of paper production

Around 33% of forestry plantations in Brazil are used to produce cellulose [14]. The production of cellulose in Brazil increased from 9 billion tons in 2003 to 15 billion tons in 2013 [15].