Renewable and Sustainable Energy Reviews 96 (2018) 58–63

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Sugarcane bagasse cogeneration in Belize: A review

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ARTICLE INFO

Keywords:
Electricity generation
Sugarcane Bagasse, Biomass, Renewable Energy in Belize

ABSTRACT

Sugarcane is the most important crop for the economy of Belize. Sugar is Belize's largest contributor to the agricultural sector with exports approximating US$70,000,000 for the year 2015. The biomass residue from the sugar production process, bagasse, is used to generate electricity through cogeneration. The single cogeneration plant in the country contributes about 15% of electricity to the national grid. Belize currently imports about 42% of its electric energy needs from Mexico, and to date, this is the country's most reliable energy source. With energy needs of the country projected to rise at a rate of 4% per annum, and with the costly import of energy, there exists the need to explore the expansion of co- generation energy technologies to increase local energy generation output to the national grid. The current work reviews the state of bagasse cogeneration in Belize and assess its potential for further expansion.

1. Introduction

The increasing demand for energy is a global conundrum with challenges in areas of economics, the environment, and social development [1]. Population growth throughout the world has brought with it the continuous surge in energy demand. Though small, the Central American nation of Belize is no exception to this issue. With a population of about 350,000, growing at a rate of 2.4%, the country's energy demand is expected to rise at a rate of 4% annually [2]. It has been estimated that within the next 20 years, Belize will need to increase energy generation by about 80% to satisfy this growing demand [3]. The country currently receives majority of its electricity supply from Mexico through a direct line into its national grid. This source constitutes 42% of the demand for electricity, and is to date, the country's most reliable source of energy. For its size, Belize has a relatively high electric energy demand. The country's peak demand is approximately 96 MW [4]. The costly import of electricity from Mexico has prompted the country to explore several renewable energy initiatives. This started with the Chalillo and Mollejon hydro-electric systems. These systems contribute about 37 MW of power to Belize's national grid which is 39% of the grid's total demand in peak hours [5].

Belize's finances are rooted in the agricultural industry. The sugar industry in Belize is over 150 years old and in the mid 1990's substantially upgraded its capacity to 120,000 t of sugar per year. Bagasse, the fibrous residue from the production of sugar, has been widely utilized in various countries as a means of renewable energy generation. Sugarcane bagasse is readily available in Belize, and, has recently been used for electricity generation through means of cogeneration. Section 2 of this paper briefly presents a historical perspective of the Belize sugar industry and its establishment as an imperative proponent in supplying Belize's energy demand.

A second imperative proponent in supplying Belize's energy demand are the policies affecting expansion in local energy generation technologies. The Ministry of Education, Science & Technology, and Public Utilities (MESTPU) launched a 2012–2017 Strategic Plan which discussed strategies and pertinent policies that the ministry intends to implement to foster the development of sustainable and environmentally friendly technologies [6].

Section 3 of this paper will outline the current policies that surround the bagasse cogeneration industry in Belize and their overall contribution to a comprehensive and effective framework addressing both energy demand and generation.

There is a dire and immediate need to create employment opportunities and mitigate poverty as a result of an unemployment rate of 8.0% in 2016 and a reported 2009 poverty rate of 41.3% [2]. With 42% of Belize's energy imported from Mexico, there is ample opportunity for improving the economy of Belize with investment in renewable energy technologies, specifically bagasse co-generation technologies. Section 4 of this paper discusses the economic benefits garnered from investment in co-generation by analyzing the current co- generation power plant, Belize Co-generation Facility (Belcogen), and the possible addition of a new co-generation plant, through an investment by the Santander Group. Additionally, Section 5 of this paper examines the technical aspect of co-generation technologies and makes recommendations for

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https://doi.org/10.1016/j.rser.2018.07.034
Received 15 October 2017; Received in revised form 5 July 2018; Accepted 20 July 2018

both the existing co-generation plant and the possible new plant that would yield economic benefit and adhere to the current policies. In totality, the paper attempts to contribute to the field by exploring recent technical developments in the renewable energy sector, namely bagasse co-generation technologies, and forming correlations to the economy of the country, thus, presenting an assessment for continued development of renewable energy technologies in Belize.

2. Existing cogeneration strategies and renewable energy alternatives

Sugarcane is a crop produced globally on a massive scale. It is estimated that over 1.9 billion tons of sugarcane is produced annually in over 100 countries [23]. Brazil, the world's largest producer of sugarcane, is responsible for 41% of the world's production while India stands at second with 18% of global production [24]. The abundance of land in these geographically expansive countries has allowed them to see substantial production of sugarcane. With such large volumes of sugarcane being produced, energy production from sugarcane is very established in these countries. In Brazil, nearly 20% of the country's energy demand is met by energy obtained from sugarcane products [22]. India has seen its peak production of energy from bagasse cogeneration supply over 3000 MW of power to the country's national grid at times [26]. A typical schematic of the cogeneration process is shown in Fig. 1. Bagasse collected after the milling process is fed into a boiler. Steam from that boiler is fed to a turbine which is connected to a generator that outputs electricity. Part of the electrical energy generated is fed back into the loop to power the boiler and other processes in the factory while the surplus electricity is fed out to an external grid for storage and use in the country's national grid.

It is clear that sugarcane bagasse cogeneration can have a substantially positive effect on a country's ability to meet its energy demand using renewable resources. It is often the case, however, that this potential is not realized in several economies of lesser scale which also produce sugarcane. Belize, Mauritius, Morocco, Mexico, Pakistan, and Portugal find themselves among the countries which produce large amounts of sugarcane for their respective sizes but are unable to fully realize its benefits in the renewable energy sector.

High technological demands, lack of local expertise, and the unavailability of needed capital are all factors which play into these countries' inability to fully capitalize on the renewable energy benefits obtained from sugarcane bagasse. This section will highlight several countries with developing economies and their implemented strategies for dealing with the major setbacks associated with the improvement of cogeneration technologies in their respective countries.

One of the major impediments to development of cogeneration technologies in several countries with developing economies is the high investment cost associated with cogeneration systems. It has been estimated that the investment cost for such systems lies at US $1400 per installed kW, moreover, once installed, operation costs can rise to US $84.00 per kW per year [25]. In Mauritius, investment in cogeneration technology has been sparked by the volatility of worldwide sugar prices [27]. Sugar production companies already present in the country have sought to expand their cogeneration capabilities in the hopes of selling electricity to the national grid and other nearby countries. It is believed that such sales would offer stability in the revenue streams coming from current sugar mills by offsetting the volatility of sugar prices [27].

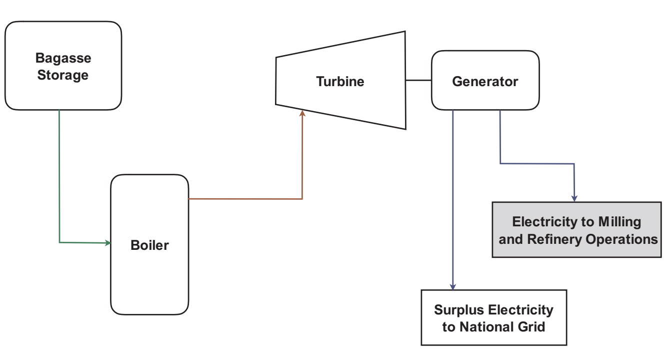

Fig. 1. Schematic of Cogeneration system used to generate electricity.

In Pakistan, the government has produced several fiscal incentives for companies to invest in alternative and renewable energy in the form of rebates, loans, grants and tax incentives [29]. Measures were put in place to finance projects based on their energy capacity. Financial packages are determined based on the amount of energy a project is slated to produce for a particular local. Projects have been grouped into two categories: those having a capacity between 1 and 50 MW and those with capacity of 0.004–1 MW [29]. The government hopes that such strategies will increase the amount of energy Pakistan draws from alternative and renewable energy sources as conventional energy sources (gas, oil, coal, electricity) currently meet 90% of the country's energy demand [29].

In 2010, the World Bank recommended that Mexico increase its efforts in bagasse cogeneration. The World Bank's report, however, cited that initial investment costs could be an issue, and that Mexico should look toward the private industry as a source of investments for the required infrastructure [33]. The country has since had success with securing investments from the private sector. Most recently, Grupo PIASA, a company led by Arca Continental inaugurated their cogeneration electrical plant in Oaxaca, Mexico. The plant, requiring an investment of US $61 million, will be able to generate 50 MW/HR [34].

Along with dealing with the struggles of finding capital to support such projects, developing countries wishing to use bagasse cogeneration also face the added difficulty of having poor access to required technology. Nunes et al. study the efficiency of technologies for cogeneration implemented in Portugal. The country's government had intentions to build cogeneration plants with the most effective technology but was forced to cancel several of the projects citing the high cost of raw material and the necessity to import much of the needed equipment as reasons for the projects' cancellation [28]. It seems that at the time the only solution Portugal has to dealing with its issue surrounding the need for advanced technologies in its cogeneration ventures is to scale back its intended framework for development in the area.

Cogeneration presents an opportunity for greater electricity production in Belize; however, alternative renewable energy alternatives such as hydropower, solar power, and wind power are noteworthy. As aforementioned, the Chalillo and Mollejon hydro-electric systems currently contribute approximately 37 MW of power to Belize's national grid. Previous work has shown that potential sites for the development of hydropower exist, but hydropower faces several barriers such as limited access to potential sites, limited hydrological and meteorological on potential sites, and lack of thorough environmental feasibility studies [35]. Moreover, historically, the implementation of hydropower technologies has faced resistance due to possible ecological damage to terrestrial habitats and the disruption of water availability to downstream communities [36]. It is evident that whilst hydropower is an alternative source of renewable energy for Belize, there is significant resistance due to the possibility of severe environmental damage. The second alternative in consideration is solar power. Reports indicate that Belize's average daily solar radiation is estimated to be approximately 5–5.5 kW h per square meter. The reported range of 5–5.5 kW h per square meter per day is below the necessary threshold for the successful implementation and maintenance of concentrating solar power solar plants [5]. Additionally, solar power plants require vast areas of land for generation to be worthwhile. This requirement is disadvantageous to Belize because of Belize's dependence on land for agriculture. The realization of solar power in Belize depends on technological advancements such as more efficient panels and smaller land area requirements.

The third alternative in consideration is wind power. Reports