Renewable and Sustainable Energy Reviews 43 (2015) 126–132

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

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

Waste to energy analysis of shakarganj sugar mills; biogas production from the spent wash for electricity generation

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ARTICLE INFO

Article history:
Received 7 January 2014
Received in revised form
2 September 2014
Accepted 1 November 2014

Keywords:
Spent wash
Biogas
Electricity
CDM
Renewable energy

ABSTRACT

Waste to energy analysis of a large scale sugar industry was performed. Biogas Power plant of Shakarganj Sugar mills is generating its own electricity from biogas produced by the waste (spent wash). The analysis of the spent wash indicates that it contains high Chemical Oxygen Demand (95000 mg/l) which reduces to 18000 mg/l during biogas production. Biogas is produced by using the anaerobic digestion of the spent wash. The biogas is passed through desulphurization and dehumidification units to remove the sulfur contents from 30000 ppm to 250 ppm. The results indicate that the total biogas production from 0.5 million M^3 of spent wash was 20.34 million M^3 during October to September. The total electricity production was 37.7 million kWh and the total steam (28260 t) generated was used by the mill. The electricity production efficiency by using new biogas boilers was 92%. The estimated CO_2 emission reduction during the year was 28032 (tCO_2e). Due to CDM the emission factor was zero. The total revenue generated from the utilization of sugar industrial waste during the study period was USD 3.56 million.

Contents

1. Introduction

Renewable energy is gaining attention for energy production. In Pakistan its demand is increasing to fulfill the present and future energy demands of the country [1]. The factors that cause country switching on renewable and alternative energy sources are energy prices, population increase and climate change issues

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http://dx.doi.org/10.1016/j.rser.2014.11.038
1364-0321/

[2]. The sugar industry is an important part of the Gross National Product (GNP) of the country. It is the second largest sector after textiles. The average contribution of sugar sector in Pakistan's total GDP from 1995 to 2000 was 1.9%. Sugar Industry contribution in GDP was maximum (2.4%) during 1997–1998 [3] which was increased to 4.2% of the GDP in 2010 [4]. Because of the involvement of sugar industry in the national economic growth, industrialization can be a good option. However, due to increased demand for energy it exerts significant pressure on the natural resources. As energy safety is a matter of global interest, energy sources are needed to be available in a continuous supply and at low cost. At the same time alternate approaches of electricity production are required to avoid damaging health and environmental effects of the conventional methods of electricity generation [5]. The disposal of sugar industry effluent without proper treatment has long term adverse effects upon the local plants, animals and aquatic life. The waste produced by the industries is a main environmental issue and so it is essential for the industries to take up an appropriate waste treatment process for the disposal of highly polluting wastewater.

Electric Energy requirements and treatment of the industrial wastes are the main problems of the sugar industries. The treatment of the effluent for the removal of COD and color with previous methods is less effective and energy intensive [6]. Anaerobic digestion could be the best solution, which is gaining huge acceptance due to the production of biogas and minimal energy requirements [7,8]. Biogas is a renewable energy source derived from anaerobic digestion of biological wastes. The pretreatment of waste slurries by producing biogas has become an eco-friendly and a sustainable environmental measure. Due to production of biogas from the industrial wastes problems of energy crises and financial systems can be solved. The main benefit of biogas is its immediate storage and can be used easily in place of the natural gas [9]. It can be used for the production of electricity, heat and power. Typical biogas contains 50 to 65% methane 30 to 45% carbon dioxide moisture and small amount of hydrogen sulphide. To meet the future energy strain renewable energy deriving from biomass sources has huge probability for growth as it is an important resource of methane. It is produced in the absence of oxygen and in the presence of anaerobic microorganisms for the biodegradation of the biological waste [10]. Uses of biogas as a vehicle fuel is growing in Sweden as well as in Switzerland, and there is rising demand in other countries, including Austria, France Spain, Germany, USA, China and India [11]. Ethanol which is a distillery product of cane molasses can be used as a fuel. After India and china, Thailand is considered a rising industry of fuel ethanol [12]. Bioethanol production from corn and sugar cane, in the USA and Brazil contributes more than 70% to world production of bioethanol [11]. The use of bagasse, is significant as the major energy source which reduces to zero fossil energy inputs downstream sugar processing [13].

The potential of sugar industries for electricity generation has been increased during the last few years. Different variables are considered to be important which mostly influence the performance of the biogas plant [14]. Bio-energy should be produced with minimum fossil energy inputs; the lower the contribution of fossil energy, the less CO_2 is emitted. Sugarcane stands positively in view of its relatively high biomass acquiesce level under low fossil energy inputs between a varieties of energy crops. Surplus electricity and molasses is produced together with the sugar [13]. Under the Clean Development Mechanism (CDM) power generation from industrial waste, the main factors are the financial requirements and continuity of the process [15]. Biogas is at second position, In terms of the number of CDM projects involving technology transfer followed closely by Wind and Landfill Gas. The total Biogas projects are 57 out of which 35 are with technology transfer. Estimated annual emission reduction (ktCO_2e/yr) from the all projects is 2093. Although estimated annual emission reduction from projects with technology transfer is 755 ktCO_2 e/yr [16].

Present case study focuses its interest on the reduction in pollution of spent wash and production of biogas by anaerobic treatment. This work starts by describing the efficiency and efficacy of the process of biogas, electricity and steam production, and then estimates the carbon dioxide reductions through CDM. Cost benefit analysis and possible technological risks and uncertainties are also reviewed.

2. Methodology

2.1. Study area

Shakarganj Mills Ltd. (SML) is the largest sugar mill located in the district Jhang Punjab Pakistan (Fig. 1). SML's biogas plant was built in 2003 by engineering services from Ecoboard Industries, Ltd. Shakarganj Mills has fired up the country's first sugarcane waste biogas plant which is now operating at the site of Shakarganj Mills.

2.2. Sample analysis

The samples were collected from a Shakarganj Sugar mills. Samples of spent wash and the final outlet were analyzed. The parameters determined were temperature, pH, COD, BOD volatile acids, alkalinity, total dissolved solids and suspended solids. In addition, the feed before and after the heat exchanger as well as digester was recorded. COD was determined for the inlet and the outlet of the plant to determine the plant performance in terms of the percentage reduction in COD. The analysis was performed in accordance with Standard Methods for the Examination of Water and Waste water [17].

2.3. Process description

Different processes and steps involved are shown in Fig. 2. Hot spent wash has to be cooled to about 37 °C by passing through a plate type heat exchanger, since the digester is large; it has a certain amount of stability to absorb temperature fluctuations for a few days without affecting the digester temperature. The Biogas cleaner is a biological filter where the Bacteria of Tiobasillis family converts H_2S to sulphur, mainly sulphates and free sulphur. During the scrubbing and the H_2S removal biogas becomes 100% humidified so, it has to be dried before entrance to engine. For this purpose the gas is cooled from 38 °C to 12 °C in a tabular heat exchanger by using chilled water. Moister condenses and gets separated. Clean biogas is then used to operate GE Jenbacher engines of 8 MW installed capacity. Exhaust gases with a temperature of about 500–550 °C are used to produce steam in the specially designed boilers with a total steam generation capacity of 5.6 t/hr.

2.4. Net electricity generation

Net electricity generation was calculated by using the equation "$EG_{NET, PJ, y} = EG_{TOT, PJ, y} - EC_{AUX, PJ, y} - EC_{Grid, PJ, y}$". Where $EG_{NET, PJ, y}$ is electricity generated by the cogeneration plant in year of the crediting period [MWh/yr]. $EC_{AUX, PJ, y}$ is auxiliary electricity consumption of the cogeneration plant (which also includes electricity consumption by the desulphurization and dehumidification unit) in year of the crediting period [MWh/yr]. $EC_{Grid, PJ, y}$ is