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Cogeneration through bagasse: A renewable strategy to meet the future energy needs

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ABSTRACT

Electricity generation through sugarcane bagasse is a extraordinary worth in Pakistan as its exploration through the sugarcane crop can provide food, feed, fuel, fiber, fodder, and fertilizer for future generations. Normally about 0.450 MWh of electricity is generated from 1000 kg of bagasse through cogeneration technology. Electricity potential of bagasse is estimated about 1598 GWh to 2894 GWh in Pakistan. The national policy regarding the subject is weighed up from J-tariff in 1990 to present biomass cogeneration policy 2013. Surplus electricity generated through cogeneration technology can be consumed to meet the household-level demands and creation of employment in rural areas. A substantial amount will be available to the factories. It will also help in reduction of green-house effect created by oil based generation.

Contents

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1. Introduction

The prosperity's cost of a civilization lies in the annual per capita energy consumption [1]. Pakistan is among the countries which are scarce in energy supply [2]. Owing to limited local fuel resources, the energy demand is mainly fulfilled by external contribution. The state assets of oil and gas are estimated to be sufficient only for thirteen and twenty-one years, respectively [3].

Worldwide, electricity constitutes the most widely used form of energy [4]. Per capita availability is only 520 kWh [5] much lower than developed countries. The rural population representing almost 2/3rd of the total population of Pakistan have almost no access to electricity [6].

Most of the factories has nonstop working and cannot afford any risk of power breakdown, although it is very common in Pakistan. These power cuts can damage the power breakdown sensitive instruments and ultimately induce the loss of production. Power generated from bagasse is capable to solve this problem.

Electricity is primarily generated through hydro-power or thermal energy plants in Pakistan [7]. Presently hydro-power plants are producing about 30% of total electricity while the rest is generated by thermal power projects. Enormous foreign exchange is used to import fossil fuels for operating thermal power plants. The international price of liquid fuels is gradually rising, so the cost of electricity generation is also increasing. Therefore the exploration of secondary and renewable fuel sources to attain optimal energy mix becomes indispensable.

Sugarcaneis an excellent converter of solar energy into biomass [8,9] and sugar. Attributable to its high energy-to-volume ratio, it is considered to be the most economically significant energy crop [10]. The climatic and physiological factors limiting its cultivation to tropical and sub-tropical regions have resulted in its concentration in developing countries. In turn it is imparting a remarkable role of such countries in the world's transition to sustainable use of natural resources [11].

Concurrent production of electrical energy with valuable heat energy from a single source such as natural gas, oil, coal, or bagasse is referred to as co-generation [12]. The thermal energy of the affluent stream is commonly used for heating purpose; as the distillery columns [13]. If heat energy not utilized, may radiate to the atmosphere. The system works at operational efficacies, much higher than achieved when thermal energy and power are generated separately [14].

Pakistan is suffering from severe electricity shortage [15] due to amplifying requirement of expanding industrialization, high population growth rate [9] and inappropriate availability of new energy-based projects. Pakistan needs more assured supplies of power to attain self-adequacy in food and to earn foreign exchange through exports.

This review addresses the issues of power co-generation from bagasse and associated policies in Pakistan. Furthermore the potential socioeconomic role is also been elaborated.

2. Sugar and co-products from sugarcane

Sugar mills manufacture "Sugar" as the major product whereas bagasse exhibits the key co-product [16] with significant economic potential for electricity generation [17]. The operation of a typical Pakistani sugar factory for the production of sugar, molasses and bagasse through processing of 100 t of sugar cane has been illustrated in the Fig. 1 with the potential of surplus electricity generation by cogeneration technology. For valuable and credible application of sugar industry by-products, the sugar mills are being converted to "cogeneration complexes" in sugarcane producing countries, especially in Brazil, India and South Africa [18]. Following this trend, Pakistani sugar units are also in struggle to transform themselves into bagasse-based cogeneration complexes. The annual production of bagasse is about 15 million t in Pakistan [6].

3. Global bagasse cogeneration scenario

Above 1.7 billion tons of sugarcane [19] is produced globally, in more than hundred countries [20]. Energy production through bagasse cogeneration is very utmost and efficacious energy ventures; presently established in many sugarcane producing countries such as Brazil, Mauritius and India. The technology can generate one fourth of the current power demand of world's main sugarcane cultivating nations [21]. Mostly back-pressure turbines are employed for bagasse cogeneration in Brazil [22]; the installed capacity corresponded to 787 MW in Minas Gerais state only. Currently bagasse-cogeneration based electricity share in Mauritius is 14% and expected to be 28% in future [23]. In India estimated cogeneration potential of sugar industry is more than 3500 MW [24]. If bagasse cogeneration system is applied in Zimbabwe, it can generate up to 210 MW [25]. The potential is still unexploited as ample prospects for the extensive application of sugarcane bagasse cogeneration in countries like Pakistan, Thailand, Mexico, Cuba, Colombia, Philippines and Vietnam are present.

4. Electricity generation potential of Pakistani sugar mills using bagasse

Bagasse is the left over fibrous material [26] having a moisture content of about 50%, obtained after the crushing of sugarcane [17]. Sugar mills commonly utilize it as a captive fuel for steam generation due to high combustible capacity. Gross calorific value of bagasse is 9731.984 kJ kg^{-1} [26. Electricity can be produced from bagasse by installing the high pressure boilers and special steam turbines. Normally about 0.450 MWh of electricity is generated from 1000 kg of bagasse [27].

3 kg of bagasse is required for generating 1 kWh of electricity through conventional technology [28]. The same magnitude of electricity can be produced from 1.6 kg of bagasse [29]. 1 kWh electricity generation requires about 2 kg of bagasse [30]. Estimated electricity potential of bagasse is about 1598–2894 GWh in Pakistan [31].

Conventional boilers produce 2.2 t of steam having pressure of 23 bars with temperature 350 °C from one ton of baggase [32], 11 kg steam is consumed to generate 1 kWh of electricity [6]. Potential of electricity generation of the bagasse produced in last five seasons has been estimated in Table 1. Surplus electricity is also calculated, which is very low in this case.

High pressure boilers can generate 2.40 t of 65 bar steam with temperature of above 500 °C [6]. In case of cogeneration technology only 5 kg steam is consumed for the production of 1 kWh