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Identifying an economic power production system based on agricultural straw on regional basis in India

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ABSTRACT

The utilization of biomass resources for power generation can reduce environmental emissions while fulfilling energy requirements in developing countries. But, the biomass conversion to electric power seems to be financially viable under optimized conditions (for some economic objectives). This paper presents a step-by-step methodology to determine the possibility of installation of straw based power plants in a region. Further, various issues regarding installation of power plants are discussed and reviewed. The study takes into consideration the average fuel distribution, the straw collection mechanism, the plant characteristics and the economic objectives. The methodology has been used for optimal sizing of the straw based plants in Punjab (a north Indian state) for minimum power cost and investment. The optimization models that can handle all possible restrictions for installation of the plants are applied and the results are analyzed under the influence of input parameters. The study indicates that the optimum capacity of plant is of the order of 20 MW, which can produce electricity at a cost of 5 Rs/kW h. Each plant requires a collection radius of 14 km for providing a continuous and sustainable fuel to the plant. The capital cost required for installation of the plant has been estimated to be 45,144 Rs/kW. In order to achieve these objectives, it is essential to integrate the power generation system with the biomass management system. The literature review shows that an efficient biomass recovery system is required to be developed for collection of agricultural straw (within the stipulated time) for implementation of power generation programme in the state. In overall, the study reveals that the efficient utilization of straw for electric power requires careful identification of different techno-economic parameters like biomass management cost, scale factor, fuel supply and thermal efficiency.

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1. Introduction

1.1. Biomass resources and their sustainability

Biomass is a product of natural resources such as land, water, air and sun's energy, which possess excellent potential as an alternative, reliable and renewable source of energy. It represents the organic matter produced by the plants (both terrestrial and aquatic and their derivatives). The plant material uses sun's energy to convert the atmospheric carbon dioxide to sugars during the photosynthesis process. On combustion of the biomass, energy is released as sugars are converted back to carbon dioxide. This energy is harnessed and released in a short time frame making the biomass as a potential source of renewable energy. The amount of energy produced during this process will depend on a number of parameters such as chemical composition, environmental conditions, thermal efficiency etc. Therefore, the combustion process will lead to production of energy along with other products depending upon the chemical composition of the biomass [1,2].

Although, fossil fuels are also derived from atmospheric carbon dioxide, but the time frame is very long (of the order of millions of years) as compared to biomass. Moreover, their use is also related to emission of green house gases that leads to environmental degradation. Therefore, the use of biomass for energy production especially in rural areas can contribute significantly in reducing energy poverty and attaining economic development in the developing country [3]. Further, it can also help to reduce local and global emissions by eliminating the use of fossil fuel resources for energy purpose [4]. But, the utilization of biomass for energy production requires innovative policies for promotion of bioenergy technologies and programmes in different parts of a country [5,6].

The agricultural biomass can be classified into two categories i.e. the primary residues that are produced during the harvesting of crops and the secondary residues that are generated during the processing of crops [7–9]. The secondary residues are readily available as a source of energy at the processing sites and these requires no collection mechanism. But, the primary residues are distributed over the fields and are required to be collected for energy production [10]. Moreover, these are left unused without any significant use. The straw produced by crops like rice, sugarcane, wheat, corn, cotton, mustard, maize, groundnut etc. is the major source of primary residues in India.

Although, the crop straw has many competing uses, but a major part of straw produced in India has been found to be surplus for energy production [5,8,9]. But, the availability of the crop straw varies across various regions of the country. This may be attributed