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GIS based planning of a biomethanation power plant in Assam, India

Antara Brahma, Kangkana Saikia, Moonmoon Hiloidhari, D.C. Baruah *

Energy Conservation Laboratory, Department of Energy, Tezpur University, Napaam 784028, Assam, India

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ABSTRACT

Electricity generation for rural applications through biomethanation process is very promising in countries like India where availability of biomass feedstock is very high. However, sustainability of biomass power plants requires meticulous planning starting from assessment of feedstock availability to collection, storage, transport and conversion in power plant. All these parameters are spatially interlinked and therefore use of spatial tools such as GIS is helpful in such planning. This paper investigates electrical power generation potential of a newly constructed biomethanation plant in Sonitpur district of Assam, India. Spatial availability of locally available biomass feedstocks for methane generation is assessed using GIS. The GIS is also used for optimal biomass collection and transportation network design. Altogether, 7 different types of biomass feedstock (kitchen waste, vegetable waste, cow dung, pig droppings, goat droppings, poultry droppings and rice straw) are identified in the surrounding villages of the plant within optimum biomass supply radius. Biomass feedstock of the area can produce 37,000 m^3 methane; sufficient for continuous generation of 5.3 MW electricity. Power supply from the proposed plant would improve rural living standard and key areas such as education and health will be particularly benefited. However, biomass assessment and supply logistics would require managerial attention to minimize cost of power generation.

Contents

* Corresponding author. Tel.: +91 9435508563.
E-mail address: baruahd@tezu.ernet.in (D.C. Baruah).

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1. Introduction

Energy plays a vital role in socio-economic development of mankind. The current energy scenario depicts a lack of access to the most basic services for billions of people across the globe. About 18% of global population (1.6 billion) lack access to electricity and 38% of global population (2.6 billion) lack clean cooking facilities [1]. Wide variations exist between energy consumption of developed and developing countries, and between rich and poor, leading to significant variations in life style. The major share of energy at present is derived from fossil fuels. The common problems associated with the use of fossil energy are that they are exhaustible in nature and take millions of years to be restored. This leads to the problem of energy crisis, which is escalating all over the world at an alarming rate. Moreover, fossil fuel based energy sources are responsible for global warming and climate change [2–4]. These crucial issues have restricted the increase in energy generation using conventional sources bringing renewable energy sources into the focus with increased importance. Another important aspect is the difficulty of extending conventional grid to remotely located rural areas. Thus, renewable energy sources with proven technology could fulfill the demand of energy for such situations ensuring required development.

Among the common renewable energy sources (wind, solar, hydro, and biomass), biomass is a potential candidate. Bioenergy is derived from plant or animal origin biomass materials such as agro-forestry residues, animal manure, municipal organic waste, vegetable oils or animal fats. Bioenergy is the most versatile form of renewable energy. It is the only resource that comes in solid, gaseous or liquid form and can provide heat and electricity as well as transportation fuels. Bioenergy, unlike most other renewable energy sources, can be stored relatively easily and can, therefore, provide energy to dispatch as needed [5]. Some distinct socio-economic-environmental benefits of bioenergy are (i) reduce the dependency on fossil fuels, (ii) uses of bioenergy results in less carbon di-oxide emission than its fossil counterparts, thus helping in protecting the environment through climate change mitigation, (iii) apart from providing energy, numbers of valuable byproducts could also be produced during bioenergy generation process, (iv) scope for development of bioenergy based entrepreneurial activities in rural areas, (v) feasibility of generating decentralized mode of energy for remote areas. Today, bioenergy is the largest renewable energy source in the world and provides 10% of global primary energy demand [6]. In fact, biomass resources are the major source of heating and cooking fuels for most of the population of developing countries.

Biomass is one of the promising renewable energy resources in India also. The bioenergy potential in the country is 25 GW, largely contributed by agro-forestry residues. India produces 687 million tonnes of agro-residue biomass annually, of which 234 million tonne is available as surplus for bioenergy generation [7]. Today, bioenergy is the 2nd largest renewable energy provider in India (after wind energy) with installed capacity of 4.3 GW (as of December 2014) [8]. India also has the world's largest number of livestock population and hence biogas production potential through livestock manure is also very high. India's biogas program is world's 2nd largest only after China. There is a potential of more than 1.2 million numbers of family type biogas plants and 0.47 million numbers have been installed in country as of March 2014 [8]. Similarly, India is world's 2nd largest sugarcane producer (after Brazil) and sugarcane bagasse based heat and power generation as well as bioethanol production potential is also significant. The bioenergy potential of India is mostly lies in the rural sector. But this sector is facing limited access to conventional sources of energy compared to the urban consumers [9]. Thus, biomass resources available in rural India can be utilized for off grid renewable energy to alleviate rural energy crisis.

Biomass can be converted to bioenergy through different routes including biomethanation process. Organic fraction of biomass is converted into biogas through biomethanation in an eco-friendly manner. In general, biogas contains around 65% methane and 34% carbon dioxide [10]. The yield of biogas and methane depends on many parameters like feedstock type, digestion system, and retention time. Optimization of operating parameters (pH, temperature, carbon to nitrogen ratio, hydraulic retention time and inoculums) helps to maximize specific biogas yield [11]. The methane fraction of biogas can be utilized for electricity generation through biomethanation power plant consisting of digester, heat engine and generator. Such power plant can produce electrical power by utilizing organic wastes, including industrial, agricultural and municipal wastes. It is reported that biomethanation is a highly efficient and low cost technology [12]. Further, from the feasibility studies carried out in different countries, biomethanation has also been proved as an effective technology from both environmental and economic point of views [13–15]. While assessing biomethanation potential of wastes generated from medium-sized agri-food industries in Spain, it is reported that profitable energy generation with less than 4 years of payback period could be achieved, resulting in significant amount of carbon emission reduction [13]. The prospect of huge amount of human generated wastes (about 0.6 billion kg day^{-1}) has been indicated in India for biomethanation potential, targeting waste management as well as energy security [14]. Encouraging results were also obtained while investigating the prospect of biomethanation of human generated waste in a specific Indian tourist city. Further, generation of electricity from the waste is also demonstrated as a measure of carbon emission reduction [15]. There are many other examples of successful demonstration of biomethanation technology. However, some important issues are still to be addressed for a long term sustainability and hassle free management of such power generation program. This is particularly important for new locations where uncertainties concerning availability of resources (biomass), technology and social behavior of the population exist.

Utilization of biomass resources for power generation needs their quantitative and qualitative assessment of availability on a sustainable basis. Inadequate and inaccurate information regarding availability of biomass resources act as a barrier for planning as well as implementation. The biomass feedstocks are distributed resource in terms of space and time. Therefore, one important aspect of planning is the identification of optimal transport network to avoid excessive cost and energy consumption. This is practically relevant, because transportation bears a major part of the total cost of power production. Remote sensing and Geographical Information System (GIS) can be used to identify the geographical locations of biomass and for the quantification of biomass resources. Remote sensing is the science of acquiring information about an object of interest using remotely placed device such as satellite, aircraft or balloon. Satellite remote sensors