Renewable and Sustainable Energy Reviews 74 (2017) 221–229

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

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

Economic review of different designs of biogas plants at household level in Pakistan

Abdullah Yasar*, Saba Nazir, Rizwan Rasheed, Amtul Bari Tabinda, Masooma Nazar

Sustainable Development Study Center, GC University, Lahore, Pakistan

ARTICLE INFO

Keywords:
Biogas
Bioenergy
Biogas plant
Animal dung, Alternate energy

ABSTRACT

Energy shortage in developing countries is one of the major challenges for sustainable development. Such challenges can be met and managed via indigenous, clean and reliable alternate energy sources like biogas and bioenergy especially at household levels. The household biogas technologies are now flourishing and conveniently accessible through certain Government and NGO funded schemes. In the current study household scale floating drums and fixed dome type biogas plants and their economic aspects were reviewed along-with technological and operational assessments. The results shown that 1 kW of energy can be generated from 0.65 m^3 of biogas by such household biogas units, furthermore it was evident that fixed dome type biogas plants were more economical with shortest payback period of about four months. Additionally effluent slurry being generated by such biogas plant can be a profitable provision in-terms of bio-fertilizer for agricultural. Overall the study results deliberated an optimistic picture for a developing country like Pakistan on the basis of installation of such small household biogas plants and utilizing indigenous technologies and feedstock. The net annual savings calculated were as US$ 837.67, US$ 829.03 and US$ 845.25 for steel floating drum type, fiberglass composite (FRP) floating drum type and fixed dome type household biogas plants, respectively.

1. Introduction

Energy demand is continuously rising because of increase in population and industrial development. Currently there is huge difference in consumption and availability of energy resources [1]. Pakistan is among some developing countries suffering more severely with issues of poverty, population pressures and severe energy shortage. On average now the people of Pakistan are facing power cuts of up-to 10–14 h per day [2]. Energy availabilities and per capita energy consumption are the key reflections of affluence and prosperity in any community. Traditional energy resources like coal, oil and natural gas are fulfilling the major demand of energy worldwide however they pose two main problems like, their diminishing reserves and deterioration of natural environment due to their exploitation and use [3]. The solution to such problems is the investments and progression in alternate-renewable and sustainable energy technologies like biogas and bioenergy [4]. Biogas is a methane rich gas that is being generated by anaerobic fermentation of organic material [5] and a biogas plant can effectively utilize various feedstock sources including animal-manure, vegetable-fruit waste, sugar, poultry waste and molasses etc. [6].

An average sized household in Pakistan consumes about 2325 kg of firewood biomass or 1480 kg of dung or 1160 kg of crop residues per year to cope up with its energy demands. Whereas the expenditures and efforts on these resources can be efficiently replaced with better and effective renewable energy source of biogas [7]. According to a study there are about 159 million cattle-animals are available in Pakistan which produce almost 652 million kg of manure from cow and buffalo only. That is sufficient to generate 16.3 million m^3 biogas per day and 21 million tons of bio fertilizer per year [4].

On the other hand Pakistan being an agro-livestock based economy; is also having huge biomass resources in the form of crop residues, poultry litter, sugarcane bagasse and wood wastes etc. [8]. Research studies shown that 1 m^3 of biogas could be generated from about 20 kg wet mass of manure, so there is a capacity of generation of about million m^3 of biogas daily in Pakistan. That can meet the energy needs of almost 112 million people in Pakistan who are residing in rural-sub urban setups. [9,10].

Domestic-household scale biogas installations were started in Pakistan in 1959 in Sindh province and at present there is fair number of such working units. Biogas Support Program (BSP) was started in year 2000 by Government of Pakistan for household biogas units and so far 1200 Nos. biogas units, have been installed and functional under the program. Whereas there is a target to steep another 10,000 units in

* Corresponding author.
E-mail address: yasar.abdullah@gmail.com (A. Yasar).

http://dx.doi.org/10.1016/j.rser.2017.01.128
Received 17 December 2015; Received in revised form 2 January 2017; Accepted 19 January 2017

the coming 05 years, that will harvest almost 27% of country's biogas potential. An average household scale biogas unit of 10 m^3 can lead to save about 92,062 PKR per year on account of conventional fuels spent otherwise [8,11,12,13].

There are several biogas digesters models available now days which are adopted throughout the world. Two main type of biogas plants which are widely used at household scale are; fixed dome type and floating drum type [14]. The structure and construction of such household-scale digesters is relatively simple and practical [15]. Fixed dome biogas plants considers more effective in Asian environments like India and Pakistan most and also have many design variations like Indian Deebandhu, Chinese fixed dome, etc. However each designs share a common feature of the same semi-circular dome casing [16–18]. On the other hand floating drum design comprises of an underground digester and a movable gas holder or drum either cylindrical or dome shaped above ground. Furthermore a guiding frame is also provided so to prevent tilting of gas digester [17,19,20].

Biogas and bioenergy technologies have been proven the environmentally safer with fewer or lowest health impacts, economically effective and helpful in energy conservation [7]. It has been evident that alteration of traditional biomass fuels with bioenergy enabled household scale user can reduce GHG emissions on average by about 1.9 t of CO_2 equivalent per digester per year. Biogas technologies have further helped in reducing depletion of woody biomass through enhancing efficiency of energy use and energy substitutions. It have also assisted in improving the fertility of soil via reducing biomass removals as fuel and the direct use of nutrient enriched bio-slurry in-terms of bio-fertilizer. Furthermore, the reduction of biomass removals contributed to carbon sequestration [9,21].

There are many socio-economic factors that lead to adaptation of biogas digesters at the rural households so to meet their needs of cooking, lightening, heating and feedstock [22,23]. Also the outputs of biogas digester i.e. gas and slurry. Gas is valuable as source of energy and slurry has importance as fertilizer. It is considered as clean, gender friendly, cost effective source of energy and has many environmental, economic and health benefits [24,25]. In addition Installation of biogas digesters also created new employment opportunities because it requires several skilled personnel for designing, micro financing and fabrication-construction along with other unskilled labour required for daily operations and maintenance [26].

A study [27] indicated that biogas unit of 10 m^3 size had saved nearly 150$US per year on account of conventional fuels spent otherwise. Health maintenance cost accounts 10 US$ per month. Bio-slurry i.e. digestate could replace chemical fertilizer to an amount of 10$US per month. The installation cost of each biogas unit was reported between 565$US and 650$US, whereas these domestic scale plants were successfully operable with 4–6 cow's-buffalo's manure. Government had been providing 50% subsidy to the farmer communities for the construction and installation of such plants so to assure their sustainability [12].

A socio-economic study [28] in Bangladesh regarding various scales biogas plants shown that household scale plants of about 6 m^3 and above and commercial scale biogas plants had been successful in meeting the community's demands of cooking and heating etc. and hence avoided 564 kg/month and 1691 kg/month of fuel wood on average respectively. The economic aspects of the study highlighted a very high income and large internal rate of return that was even without the utilization of digestate-slurry. While the Government was also giving subsidy, however despite of that the net present value of such projects was quite viable and user communities had also been greatly satisfied by the functionality and income status against these plants.

A study [29] in sub-Saharan Africa deliberated that fixed dome biogas plant type has been greatly utilized for small and household scale applications there. The most common reasons for the deployment of this design is its effectiveness for sole wet feedstock digestion. The study further revealed that capital installation cost for such plant had been dependent upon the size of dome i.e. for gas storage capacity (dome), built design, labour expertize and major building material in-terms of cement. Whereas the generalized energy cost form these fixed dome type digester had been calculated as < 1 € cents/MJ.

Another study compared the floating type biogas digester and fixed dome type digesters of varying capacities used to run the small-medium sale agricultural tube-wells in Punjab, Pakistan and found that fixed dome type biogas plants were economically more efficient. That was due the reason; floating drum type plants cause more gas losses from the reactor, hence the fixed dome biogas plants had not only saved costs but more environmental friendly. The study further had shown that fixed dome biogas plant revealed 14% more tube-well water pumping performance as compared to floating drum type biogas plant [30].

Other research studies indicated that various types of biogas reactors do have variable durability and life-time. The performance and lifespan of biogas digesters are significantly subject to the quality and type of built-design and building materials deployed like quality of brick-work or concrete and cement that is used for conduction of fixed dome type plants. Similarly the materials like bricks, metal, plastic or fiberglass-composite (FRP); those were deployed for fabrication of floating dome plants. All these material and deign variable determine the life-time of such plants which may approximately range from 15 to 20 and 12–15 years for fixed dome and floating drum type plants respectively. However some more cheaper type biogas reactors could also be built using polyethylene materials but they do also sustain for a much lesser time i.e. up-to 2–5 years only [16,31]. It was a general conclusion that durability and sustainability of a biogas plant has been significantly dependent on cost and or financial value of the biogas reactor i.e. simply can be culminated that the greater the price of a typical the biogas plant the grater shall be its lifespan and durability [32]. On the other hand it had also been highlighted and vitally so that poor low income families can better sustain by the provision of low priced, smaller and simpler biogas plants, although with lesser life-time and permanence [33].

This main objective of current study is evaluating the household biogas user's perception and preference about the appropriate biogas plant type in-terms of costs, performance efficiency and to assess the benefits and challenges of these plants. The study is also reviewing the economic impacts of such household scale biogas plants on the users.

2. Methodology

2.1. Description of the study sites

The sites that were surveyed for the present study include suburbs of Lahore like; Jallo park, Bedian road, Mehmood booti, Mandiawala, Jia Bagga, Ghanikey, Mouza Korian Barki, Mouza Opal Barki, Guru Manget, Mouza Pathankey, Raiwind road and suburbs of Faisalabad like Ganga Singh, Ram Diwali, and Mamunkanjan.

2.2. Sampling unit

Random sampling method was done for the household survey i.e. based on questionnaires via various users of biogas. As the objectives of the study is to compare two working designs of biogas reactors based on user's perceptions so a sample of thirty household was drawn. Fifteen house hold were using floating drum type biogas plants and fifteen had been deployed fixed dome type plants. However different capacities of said plant types were selected for a comparative study and design analysis. The biogas household respondents were carefully monitored for their responses and knowledge regarding the relevant biogas systems they were having during data collection via semi-structured questionnaires.