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A Case Study to Bottle the Biogas in Cylinders as Source of Power for Rural Industries Development in Pakistan

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Abstract: Pakistan is one of the developing countries with very low energy consumption, correspondingly low standard of living and high population growth. The country is trying to improve its living standards by increasing its energy consumption and establishing appropriate industries. It has immense hydropower potential, which is almost untapped at the present time. Employment generation and poverty alleviation are the two main issues related with rural development. These issues can be tackled by rural industrialization using local resources and appropriate technologies. However, sufficient number of industries can not be set up in rural areas so far due to scarcity of energy supply i.e. electricity, diesel etc. Biogas, a renewable fuel may be able to fill the gap in energy availability in the rural areas. Biogas can supply energy near to biogas plant which makes it hindrance in its wide spread application and therefore mobility of biogas is must, which is achieved by bottling of biogas. Here a model is conceptualized to bottle the biogas in cylinders and then use it to power the rural industries. It is found that use of bottled biogas can save diesel of the worth US $ 147 in 12 hours and also generate employment for 12 persons.

Key words: Employment · rural industries · biogas · bottling

INTRODUCTION

Pakistan is situated in the south Asian region covering a total land area of 888,0000 square kilometers. It has a population of 140 million. Pakistan is agricultural country, more than 70% of the population is involved in agriculture and per capita income is about US$ 480 [1, 2]. The poverty rate of Urban population 87.7% living on less than $2 a day [1-2]. About 70% population in Pakistan live in rural areas and majority of them are engaged in agriculture. Energy is one of the prerequisites for the growth of agriculture and industry.

The energy requirements are met mainly through commercial energy sources like oil, electricity, etc. which are non renewable and non-local. In recent years, the prices of these commercial energy sources have increased sharply and their availability is limited. There is always short supply of these sources. Villages are severally affected by this and most of the time electricity is available only for few hours in a day.

Biogas is a potential renewable energy source in this context. An estimate indicates that Pakistan has a potential of generating 8.58×10^{10} cubic meter of biogas from 1287 million tones of cattle dung annually produced. The heat value of this gas amounts to 1.8×10^{12} MJ. In addition, 350 million tones of manure would also produce along with biogas [3].

More than 0.024 million domestic biogas plants have been installed in Pakistan. These plants are of small size (1-10 m^3) capacity and mainly used for cooking and other domestic applications. Biogas provides a clean fuel for both petrol and diesel engines.

Whereas biogas in diesel engines is used in combination with diesel, petrol engines can be run on hundred per cent biogas. Use of biogas as an engine fuel offers several advantages. Biogas being a clean fuel causes clean combustion and reduced contamination of engine oil.

However, these applications of biogas are restricted to the place where it is produced. To make it a convenient fuel for rural industries, large quantity of biogas generation has to be ensured for running diesel engines. The large quantity of biogas can significantly replace conventional fuel mainly diesel in the rural areas. This can be facilitated by bottling of biogas in cylinders. Bottled biogas can be taken at any place for

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production of motive power to run rural industry. Therefore, a decentralized energy source which is independent of the utility system and based on biogas offers a better option in order to meet the rural energy requirements in the country. The only criteria are to have large size biogas plants and assurance of cow dung supply in large quantity for such plants.

Purification and bottling of biogas: Biogas consists of methane (55-60%), carbon dioxide (35-40%), hydrogen sulfide (<1%) and traces of water vapour. To have more energy per unit volume of biogas, the carbon dioxide content in the biogas should be removed. Hydrogen sulfide (H_2S) content may deteriorate compression system due to corrosive property.

There are many methods for carbon dioxide (CO_2) removal i.e. absorption in water, absorption using chemicals, pressure swing adsorption and membrane separation.

However, absorption of CO_2 in water is simple, cost effective, eco-friendly and practical method for CO_2 removal from biogas in rural areas. It is a continuous process and simultaneously removes H_2S also. This method is most popular in sewage sludge based biogas plants in Czech Republic, France, Sweden, New Zealand and USA. High purity biogas (> 95% methane content) can be obtained using this technology [4]. When biogas is produced from cattle dung, hydrogen sulfide content is usually less than one per cent. The concentration of hydrogen sulfide more than this level should be removed before use in engines [5].

A scrubber is designed and developed at University of Balochistan, Quetta, Pakistan for removal of CO_2 from biogas. The scrubber is 150 mm in diameter and 4500 mm height with 3500 mm packed bed length. It has been designed to purify the biogas from 60 to 95% methane content. Pressurized water from top and pressurized raw biogas from bottom is sent in the scrubber in counter-current direction through packing material (Resching rings), so that maximum absorption of carbon dioxide in water takes place. Purified gas is stored in pressure vessels for bottling in cylinders.

Feasibility study on biogas bottling: A model has been developed for biogas bottling system in a village having a 60 m^3 day^{-1} capacity biogas plant [6]. The system has two components

- Removal of CO_2 by water scrubbing
- Compression of purified biogas in cylinders.

The composition of biogas is assumed to have 60% methane and 40% carbon dioxide. Considering 75% plant efficiency (account of seasonal and other factors) the average gas availability will be 48 m^3 day^{-1}. The energy balance of the whole process is shown in Fig. 1. For purification, the raw biogas is compressed at 1000 kPa pressure and fed at bottom into a scrubber having a packed bed absorption column in which pressurized water (1200 kPa pressure) is sprayed from top in counter-current action. The scrubber is designed to absorb the CO_2 available 40% in raw biogas to 5% in purified biogas,

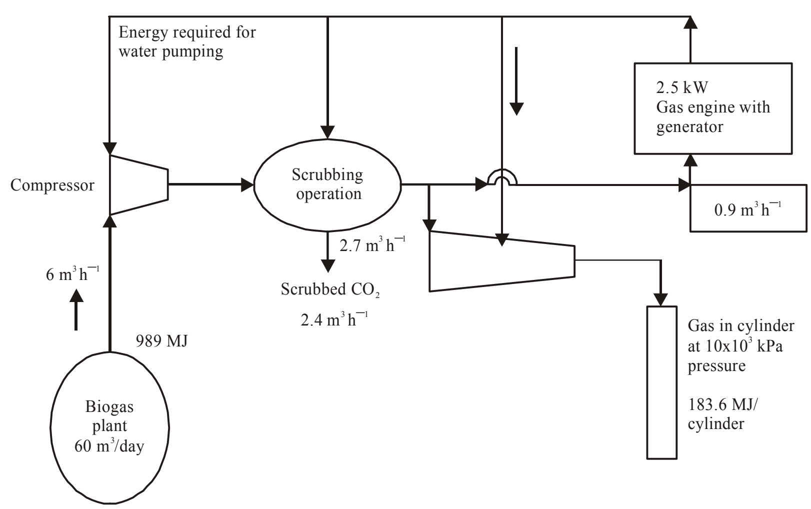

Fig. 1: Energy balance for purification and compression of badgas

Table 1: Feasibility analysis on purification and compression of biogas

A. Assumptions	
Capacity of plant	60 m^3 day^{-1}
Plant efficiency	75%
Generated gas	48 m^3 day^{-1}
Purified gas consumption in running dual fuel engine	0.18 m^3/kW
Calorific value of purified biogas	17 MJ m^{-3}
Gas capacity for 0.0215 m3 water capacity cylinder	2.7 m^3
Gas flow rate for 8 hours of working in a day	6 m^3 h^{-1}r
Heat rate of raw gas	125 MJ h^{-1}r
Total energy available in one day from biogas plant	979 MJ
B. Energy required for purification	
1For pumping and pressurizing water at 1200 kPa	0.7 kW
2For pressurizing the gas at 1000 kPa. Energy required	0.5 kW
Energy required @ 80% efficiency	0.7 kW
C. Energy required for compression	
Energy required	0.9 kW
Energy required at 80% efficiency	1.1 kW
D. Total energy required per day (B+C)	2.5 kW
E. Process plant energy (B+C) met by purified gas driven engine	
Rated power of gas engine	2.5 kW
Purified gas consumption	0.9 m^3 h^{-1}
Gas energy consumed day^{-1}	245 MJ
F. Net purified gas available for compression and storing in cylinders	5.4 m^3 h^{-1}
Net heat rate available for storing in cylinder	183.6 MJ h^{-1}
Total purified gas per day	21.6 m^3 day^{-1}
Net energy available in cylinders	735 MJ
G. Estimation of cylinders filled with compressed gas	
Total purified gas available at NTP	21.6 m^3 day^{-1}
Number of cylinders filled in one day	4 cylinders
Weight of gas in one filled cylinder	3.5 kg
Energy value per cylinder	183.6 MJ

thus methane level goes up from 60 to 97%. The purified gas is compressed up to 20×10^3 kPa pressure using a three-stage compressor and stored in 0.0215 m^3 water capacities CNG cylinders. About 4 such cylinders will be filled per day with purified biogas (Table 1). The energy required for water pumping and compression are met through a dual fuel engine-cum-generator operated by using part of purified biogas. From theoretical estimation about 245 MJ day^{-1} energy is required for purification and compression operation which is about 25% of the total energy generated per day through biogas. The net energy available in terms of compressed biogas is about 735 MJ day^{-1}. It is bottled at 10×10^3 kPa pressure in 4 cylinders in a day.

Considering US $ 6250 as capital expenditure and US $ 634 annual operational expenditure for 60 m^3 day^{-1} capacity biogas plant and bottling system, the cost of bottling biogas in cylinders is calculated as US $ 0.25 per m^3 of purified gas. Thus, cost of filling 21.6 m^3 purified biogas in 4 cylinders in a day comes to US $ 10. Installation of Biogas bottling plant in the village will generate employment for 2 people.

Application of bottled biogas in rural industries: As agriculture is main occupation in rural areas, industries related with agricultural produce such as food processing unit (Fruits, Chilies, tomato sauce, jam, vegetable drying etc.), flour and spice mill, mini oil expeller etc. are more successful in these areas. They are not only based on local produce, but also provide employment to people when they need it most. These industries can run easily on power develop by diesel engine using bottled energy of biogas than diesel/electricity. Here rural industries which can power through 60 m^3 day^{-1} capacity biogas-

Table 2: Matching of energy requirement of industries with bottled biogas and its economics

S. No.	Rural industry	Power requirement kW	Purified gas required $m^3 h^{-1}r$	Diesel litre	Cost US $	Electricity kWh	Cost US $	Employment Persons
1	Flour and spice mill	2.5	0.9	80	49	20	3	4
2	Food processing unit	2.5	0.9	80	49	20	3	6
3	Mini oil expeller	2.5	0.9	80	49	20	3	3
	Total	7.5	2.7	240	147	60	9	13

cum-bottling plant is considered and savings of conventional fuel i.e. diesel/electricity are discussed. The details are given in Table 2.

It is evident from Table 2 that 240 l diesel worth cost US $147 per day can be saved using bottled biogas. Net savings after deducting cost of filling compressed biogas in cylinders is US $ 140. Savings in terms of electricity is less as it is subsidized in Pakistan. Thus, application of bottled biogas to energize rural industries is not only economical, but also ensures uninterrupted energy supply. It would be advantageous in terms of local resource utilization, decentralization energy generation, diversified rural activities, environmental friendliness and employment generation etc. Large capacity biogas plant will also produce enriched organic manure high in nitrogen, phosphorus and potash content in good quantity. The spirit of the whole process is to develop self sustained rural enterprises and decentralized energy system based on compressed biogas to make rural areas economically developed and competitive in all respects.

In the proposed set up raw materials for most of the units are locally available. This will be advantageous in many respects and will increase the efficiency of resource utilization of the total industrial development as proposed. The initial financial support required for these facilities may be made available through bank or government bodies on soft loan basis.

CONCLUSIONS

Biogas is a potential renewable energy source for rural Pakistan. Biogas generation and subsequent bottling will cater the energy needs of rural industries in villages, supply enriched manure and maintain village sanitation. The bottling system will work as a decentralize source of power with uninterrupted supply using local resources, generate ample opportunities for employment in rural areas and income of the people through setting of rural industries. The model bottling plant could save 240 liters diesel per day. It should be replicated at mass scale for the development of villages.

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