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Economic analysis of biogas adoption technology by rural farmers: The case of Faisalabad district in Pakistan

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ABSTRACT

This study attempts to estimate the economics of biogas plants in Faisalabad District and identify the factors affecting the adoption of biogas technology. The key stakeholders of the biogas plant are farmers. Primary data from 160 respondents having biogas plants of 4 m^3, 6 m^3, 8 m^3, 10 m^3, 15 m^3, 20 m^3 and 25 m^3 from villages in Faisalabad was collected through stratified random sampling, using questionnaires. A benefit-cost ratio (BCR) is employed to estimate the financial benefits. A Logit model is used to analyze the factors affecting adoption of biogas plants. Results showed that BCR values are greater than 1 for biogas plants of all sizes. The most feasible size for a plant is 10 m^3 because it fulfills the cooking needs of an average family. However, small farmers with plant size of 4 m^3 benefit more than large farmers. Moreover, biogas adoption is not only financially feasible but environment-friendly as well. We conclude that biogas technology can be popularized by developing effective motivation strategies such as awareness through public service advertizing, through print and electronic media and by adoption of models of biogas plants best suited to the conditions of rural people in Pakistan. This further highlights the demand for the required policy framework to promote such renewable energy adoption technologies by local government and agricultural institutions, researchers, and policy makers.

1. Introduction

Energy, without any doubt, is the backbone of an economy. It is the most vital instrument for socio-economic development and has been recognized as one of the most important strategic commodities [1]. In this modern time of industrialization, increasing demand for energy and dependency of countries on energy indicates that energy will be one of the biggest problems in the world in the next century. That is why alternative and renewable sources of energy have become very important [2].

Pakistan is a net importer of energy. From July 2013 to April 2014, it spent $12.205 billion (over 35% of its total imports) to import petroleum products to meet energy needs. Oil imports are a heavy burden on the country's foreign exchange. Recent high oil prices and their continuous fluctuation have further increased this burden [3]. Most of the imported oil is used for electricity generation. Indigenous natural gas dominates the commercial energy sector of the country, accounting for 43% of energy consumption in the country. This is followed by oil (29%), electricity (16%), and coal (10%). Roughly 30% of the country's total primary energy comes from traditional biomass fuel [4].

Keeping in view the importance of energy and its scarcity, alternative energy resources have become very important. One alternative energy resource is biogas. It can be defined as a "mixture of methane and carbon dioxide produced by feeding animal dung (especially the manure of buffaloes, cattle and sheep) and water into an airtight underground tank, known as a digester, and allowing it to decompose [5]." It is produced by the biological breakdown of organic matter in the absence of oxygen [6]. Biogas is an excellent substitute for firewood, kerosene oil, cattle dung cake, and agricultural residues which are used as fuel in rural areas. One major benefit of biogas is that it does not produce air pollutants such as CO, NOx, SO_2, volatile organic compounds and particulates [7].

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The availability of biomass in Pakistan is widespread. Approximately 50,000 tons of solid waste, 225,000 tons of crop residue and over 1 million tons of animal manure are produced daily. It is estimated that the potential production of biogas from livestock residue is 8.8–17.2 billion cubic meters of gas per year (equivalent to 55 to 106 TWh of energy). Additionally, the annual electricity production from bagasse (the fibrous residue remaining after sugarcane or sorghum processing) is estimated at 5700 GWh; that is about 6.6% of Pakistan's current power generation [8].

The use of Biogas Slurry (BGS) as fertilizer yields a second advantage of biogas. The fibrous material, inorganic solids which cannot be digested or converted into methane either settle down in the plant or come out with the slurry liquid through an outlet. This contains many rich and nutritive elements including nitrogen, phosphorous, potassium, iron and trace amounts of Zn, Fe, Ni, Cu, Cd, Cr, boron, calcium and sodium, among others [9].

Despite the fact that household biogas technology was introduced in the early 60's in Pakistan, the number of biogas plants is still limited to almost six thousand—only a fraction of the potential capacity the country is believed to have [10]. An important factor in the case of Pakistan is that biogas use is currently feasible only in areas where people are not being supplied by, or anticipating, piped natural gas. Natural gas is a convenient source of fuel and at the current price inexpensive as well. At present around 18% of households, mostly in urban centers, have access to natural gas. Although it is not cheap for large numbers of rural households to have access to piped natural gas, the anticipation of pipeline extensions is a major deterrent to investment into alternatives such as biogas, particularly in areas close to urban locations that are served by a gas pipeline [11].

To the best of our knowledge, only a few studies have so far investigated biogas technology adoption by farmers and carried a benefit-cost analysis in Pakistan. This study has endeavoured to answer such questions and fill the knowledge gap. The specific objective of the study was to estimate the costs and benefits of biogas plants and to investigate the factors affecting the adoption of biogas technology by farmers.

The paper is divided into the following sections: Introduction, Review of Literature, Materials and Methods, Results and Discussion, and Conclusion.

2. Review of literature

The potential of biogas energy has been determined for India [12], Thailand [13], Bangladesh [14] and Pakistan [15,16]. Studies have been carried out to assess environmental benefits from the perspective of manure treatment, energy provision and agriculture for the entire biogas system and to analyze whether biogas system implementation is a good choice for achieving sustainability [17,18]. The profitability of biogas plants has been assessed for India [19,20] and Africa [21]. It was found that economic valuation methods need improvement on inadequate assumptions on which monetary valuation methods were based and with respect to their motivational capacity [22–27]. This is because several studies used different assumptions pertaining to local conditions and demand. A benchmark approach, or a widely accepted or adopted approach, was lacking in the preceding studies, especially for low-income countries such as Pakistan. There have been few studies conducted in South Asian countries such as Bangladesh, India, Nepal [28–32] that covered different aspects of biogas adoption assessment and technologies. The United Nations is committed to promote sustainable renewable energy by adopting new arrangements on subsidies, taxes, and other policies. The existing subsidy and flat-credit system can be continued for a standard level where men can have seen visible incentives offered by government, and public advertisement of renewable energy as well as biogas technology could be broadcast to rural people. Thus, electronic and print media could help spread the technology throughout the country [33].

Fewer studies have been conducted in Pakistan that determined the potential and constraints of biogas development in Pakistan [34–36]. All of them have shown that considerable potential for biogas is present in the country, but the adoption rate is not up to the mark. However, even fewer have taken into account economic analysis of biogas technology adoption among rural farmers in Pakistan. Furthermore, few, if any, of the previous studies combined economic and sensitivity analysis for rural biogas adoption technologies in Pakistan. Such gaps in academic knowledge are addressed by the present research study. This would also help establish a baseline for further economic analysis-based studies in similar socio-economic study areas.

3. Materials and methods

3.1. Determinants of adoption of biogas technology

The main objective of this section is to explain various tools and techniques employed for the data collection, analysis and interpretation of the data. Currently the number of biogas plants is small, but adoption is increasing with the growing problem of energy shortage. Due to shortage of time and resources, the study was restricted to Faisalabad District, which is the third largest city in Pakistan. The focal area is rural Faisalabad. The major sources of energy in villages of Faisalabad are electricity, fuel wood, agricultural waste and dung cake. Some villages have also been supplied with natural gas, which is rare.

A Logit model was used to estimate adoption of different technologies. In the adoption decision, where the random variable is discrete or dichotomous, limited dependent variable models and tools such as the ordinary logit model seem most appropriate [37]. The logistic regression is useful for situations in which we want to predict the presence or absence of a characteristic or outcome, based on values of a set of predictor variables. Logistic regression coefficients can be used to estimate odd ratios for each of the dependent variables in the model. Multivariate logistic regression has been applied to data to check the adoptability of biogas plants. The general form of the binary logistic regression model is:

$$P(Y) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 - \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8$$

Logistic regression coefficients can be used to estimate odd ratios for each of the dependent variables in the model.

$$\ln\{P(X)/(1 - (P(X)\} = B_0 + B_1 X_1 + B_2 X_2 + \ldots B_8 X_8 + e$$

where

P = Probability that biogas technology is adopted.
$P = 1$ shows that biogas technology is being adopted.
$P = 0$ shows that biogas technology is not being adopted.
B_0 = Constant Term
X_1 = Age of house hold head in years
X_2 = Number of livestock kept
X_3 = Access to extension services relevant to biogas plants
X_4 = Activities other than agriculture
X_5 = Education of the respondent No. of livestock kept
X_6 = Family Size
X_7 = Family income of the respondent
X_8 = Farm size in acres
X_9 = Access to credit