Pak. j. sci. ind. res. Ser. A: phys. sci. 2019 **62A**(2) 113-123

Determinants of Biogas Technology Adoption in Pakistan

Saleem Ashraf[a]*, Muhammad Luqman[b], Zakaria Yousaf Hassan[c] and Asif Yaqoob[d]
[a]In-Service Agricultural Training Institute, Rahim Yar Khan, Pakistan
[b]University College of Agriculture, University of Sargodha, Pakistan
[c]Department of Agriculture Extension and Adaptive Research, Muzafargarh, Pakistan
[d]Institute of Agricultural Extension and Rural Development, University of Agriculture Faisalabad, Pakistan

(received January 1, 2018; revised November 23, 2018; accepted December 31, 2018)

Abstract. This survey research based study sought determinants of biogas technology adoption in rural areas of Pakistan. Stratified random sampling technique was employed to select respondents because the population was unknown and heterogeneous in nature. Total 240 respondents (150 biogas users and 120 potential users) were selected and face to face interviewed using a structured, validated and pre-tested questionnaire. Along with descriptive analysis of data logistics regression model was applied to investigate the determinants of biogas adoption. Findings affirmed significant role of socio-economic characteristics of respondents in the adoption of biogas technology. Empirical findings reported a significant impact of education, the income of households and the number of animals on the adoption of biogas technology. This implies that unit increase in education, income and number of animals will escalate the adoption of biogas technology. Tackling energy crisis, economic benefits, and production of slurry for soil fertility, health gains and environment-friendly nature of biogas were perceived reasons of biogas adoption among the biogas users. Non-government organizations and neighbours were leading motivational factors behind adoption as revealed by users. However, role of electronic media, print media and government institutions in promoting biogas was reported dismal. This study urge that biogas is valuable alternative source of energy to combat energy crisis. In this way, provision of subsidies, interest free loans and technical backstopping could invoke potential users to adopt biogas technology.

Keywords: adoption, biogas, slurry, energy crisis, environmental safety, economic benefits

Introduction

Agriculture has a delectable role in sustaining the economic growth worldwide. In many of the developing and developed countries attention is being paid on agricultural policy development and recommendations for sustainable agricultural growth. Shrinking agricultural land, mounting population and climate change are some indispensable issues hampering agriculture production among developing nations in particular (Karim, 2013; Pimentel *et al*., 1995). In addition to these obstacles shortage of energy/power is another factor limiting agricultural and economic growth. Energy is the pre-requisite to accelerate economic growth and influences livelihoods (Amigun *et al*., 2008; Toman and Jemelkova, 2003). Major farm operations remain solemnly depended upon energy indeed. Conversely, continuous or partial failure of energy may interrupt farm operations (Khan and Ahmad, 2008; Bhutto and Karim, 2007).

Pakistan is an agrarian country blessed with natural reserves. Though, power shortage is the persistent problem affecting industrial growth and efficiency. The power sector in country is a mixed industry of thermal, hydro and nuclear power plants. Energy generation in Pakistan is mainly from Oil and Gas (28.12%) which is comparatively expensive as compared to USA which is producing 50% energy from coal, 25% from gas and 25% from other mixed sources (Younos *et al*., 2009).

To meet the future needs Pakistan would have to generate energy alternate renewable energy sources like Biogas (Amer and Daim, 2011; Jamil and Ahmad, 2010). Pakistan is enriched with a huge population of animals comprising of 46.1 million cattle and 38.8 buffaloes (GOP, 2018). This indicates an immense potential through the dung produced from these animals. The potential further can be authenticated from the findings of Shah and Sahito (2017) where they calculated 129 ton/day animal dung from cattle, buffalo, goat and sheep. A single buffalo and cow can produce 19-28 kg/day and 10 kg/day animal dung, respectively (NERC, 2016; Vija, 2006). From each kg of fresh animals dung about 0.03 m^3 biogas can be produced (Akinbami *et al*., 2001). Shah and Sahito (2017) augmented that average potential of biogas in villages of Pakistan is 12-804 m^3/day while average required biogas to meet domestic affairs is 8-520 m^3/day. About 6kWh of electricity can be produced

*Author for correspondence; E-mail: saleem1828@gmail.com

from 1 m^3 of biogas in Pakistan (Ahmad, 2010). In Pakistan, average electricity consumption is 439 kWh/person/year (Nations Master, 2016) which is equivalent to 1.2 kWh/person/day. These findings certitudes the significance of biogas in Pakistan.

Currently, 5357 biogas plants are installed across the Punjab province with collaboration of Pakistan Council of Renewable Energy Technologies (PCRET), Pakistan Council for Appropriate Technologies (PCAT) and Pakistan Renewable Energy Society (PRES). First biogas plant was established in 1959 in Sindh, Pakistan (Amjid *et al*., 2011). In 1974, further 21 plants were added nationwide with efforts of PCAT. Directorate General of New and Renewable Energy Resources launched a project during 1974 aiming installation of 4000 biogas units till 1986. In 2000, Biogas Support Program (BSP) emerged to build 1200 biogas plants initially and extending to 10,000 units till 2006. About 556 biogas plants were established by Pakistan Dairy Development Company (PDDC) till 2009 (Mat *et al*., 2012). An NGO, Rural Support Program Network (RSPN) invested 256 million in 2009 to construct 14000 biogas units (Ministry of Finance, 2009-2010). PCRET has estab-lished about 4016 biogas plants across the country to bridge energy crisis. The biogas plant installed by the PCRET produced almost 20,454 m^3 biogas per day (Ghimire, 2007).

Biogas offers multifold benefits like gas generation and providing bio-fertilizer for soil health. In addition, socio-economic and environmental advantages are also associated with biogas technology (Han *et al*., 2008). Biogas mitigates greenhouse gases emission, reduces air pollution and improves the uptake of nutrients by crops (Vindis *et al*., 2009). Apart from stated benefits, biogas technology is reliable, affordable and its generation at rural households' level is easier. The locally available raw material is the source for the controllable, usable and containable quantity of biogas. The manifold advantages of biogas urged governmental as well as non-governmental organizations to invest and promote this technology among public. Although the adoption of biogas technology among rural people is meager pertinent to inadequate awareness (Wachera, 2014; Njoroge, 2002). However, the entailed benefits offer a wide scope of adoption if rural people are aware and motivated through technical assistance. In Pakistan, little work has been done to probe the obstacles of biogas technology adoption among rural people and unveil the determinants of adoption.

It is rather difficult to specify the factors affecting adoption of innovative technologies across the world because of socio-demographic and ecological differences. Though, the principal economic rationality assumption (the utility maximization objective of individual household) might stand for households everywhere. The specific attributes affecting the households preferences and attitude (towards adoption) are belike to be similar and consistent on different places. Therefore, considering the assumption, this study was planned to underpin the determinants of biogas technology adoption among rural people.

Materials and Methods

The present study was conducted in rural areas of Sargodha, Toba Tek Singh, Muzaffargarh and Jhang districts of the Punjab province, Pakistan. Study districts were selected because adoption of biogas was generally higher in these areas due to non-governmental organizations efforts. Stratified Random Sampling technique was for the sample selection because the population of study was heterogeneous in nature. Study districts were further divided into sub districts (locally known as "Tehsil") i.e. Kot Momin, Shahpur, Sahiwal and Sargodha for district "Sargodha", Gojra, Kamalia, Pir Mahal and Toba Tek Singh for District "Toba Tek Singh" Ali Pur, Jatoi, Kot Adu and "Muzaffargarh" Ahmed Pur Sial, Shorkot, Chiniot and Jhang for District "Jhang". Rural union councils (sub section of sub-district) in the study districts were identified according to the disposal of biogas unit as well as a number of potential biogas households. On next stage, purpose random sampling was applied to select samples of biogas users (households using biogas plants) and biogas potential users (households not adopted biogas plants, either willing to do so or not). The total sample size was 240 households which were further divided into two groups; 120 households categorized as "Biogas users and producers" and remaining 120 respondents categorized as "potential users of biogas or non-users of biogas". The head of the household was respondent whom from primary data were collected regarding socio-demography, economic attributes and inspiration for the use of biogas.

A structured questionnaire was employed to collect primary data during a household survey. The questionnaire was designed according to the objectives of study and data required as depicted in literature relevant of technology adoption and biogas adoption in particular. The prior final data collection, a questionnaire was pre-tested during an exploratory survey conducted in the study area. Key informant interviews and focus group discussions were held with local peoples to get a deep insight into the driving forces determining adoption of biogas among rural inhabitants. On the basis of results of pre-testing contents of the questionnaire were updated and validity was checked using face validity technique. Later on, final data collection was carried out from the biogas users as well as non-users residing in rural areas across the district under study. The questionnaire was administered using face to face interview technique.

Secondary data were collected from different sources including Government offices, Non-governmental organizations reports and private organizations who were actually involved in installing biogas units in these areas.

Data were analyzed through Statistical Package for Social Sciences (SPSS). Descriptive as well inferential statistics were applied on data. Cross-tabulation, frequencies, percentages, mean, standard deviation, t-test and logistic regression analysis was used for effective interpretation of results.

Calculation of mean. Motivational factors behind the adoption of biogas was analyzed using 5 points Likert scale of strongly disagree = 1, Disagree = 2, somewhat agree = 3, Agree on = 4, Strongly Agree = 5. Mean score used as presented by the formula below:

$$X = \frac{\Sigma Fi(Ai)}{N}$$

where:

X = mean score; Fi = frequency; Ai = value assigned to each response; N = sample size; Σ = summation

Empirical model. In this study, adoption of Biogas technology is the dependent variable explained as production and consumption of biogas from small-scale bio-digester by households. A logistic regression model was applied for in-depth investigation of biogas technology adoption. According to the Burton *et al*. (1999) both logit and probit model are established efforts for the adoption studies. However, the choice of whether to use a probit or logit model is a concern of computational convenience (Greene, 2003). Logistic regression is applied when the dependent variable of the study stays dichotomy and independent variables are of any type. Logit applies Maximum Likelihood Estimation (MLE) after converting a dependent variable into logit variable (Garson, 2012). It estimates the odds of a certain event occurring. The dependent variable is a logit, which is the natural log of the odds, that is:

$$\text{Ln}\,\frac{P}{1 - P} = a + bX$$

Extracting P from this equation, it comes out that

$$P = \frac{e^{a+bX}}{1 + e^{a+bX}}$$

where:

P is the probability of the event occurring; X are independent variables; e is the base of the natural logarithm and a and b are the parameters to be estimated by the model.

The empirical form of the model used in the study is as follows:

$$PrY = \frac{1}{1 + e^{-(a+bX)}}$$

where:

Y is the logit for the dependent variable. The logistic prediction equation for the present study was:

Y = Ln(odds(event))=ln(prob(event)/prob(nonevent))
= ln(prob(event)/[1-prob(nonevent)]
=bo+b1X1+b2X2+……………+bn+Xn

where:

b_0 is a constant term, X1, X2,…,.Xn are independent variables likely to affect the probability of adopting the biogas technology, and b1, b2,…, bn are the coefficients to be estimated. The dependent variable was modelled as Y¼ adoption of biogas technology ¼P(Y)¼{1 if the household chooses to produce and use biogas technology, and α/otherwise}.

Selection of variable likely to explain the adoption of biogas technology. Implementation of disseminated knowledge on technology-based innovation is termed as adoption (Rogers, 2003). Adoption is mainly dependent upon farmers' perception and benefits that would come from practical realities of the innovation likely to be adopted (Forbes *et al*., 2013). In-depth investigation of literature confirms that adoption of innovation depends upon personal, social, economic and cultural factors (Pannell *et al*., 2006). In the present study, selection of prospective variables likely to affect the adoption of biogas technology was grounded in previous literature and field experiments. A significant chunk of literature reported that social, physical, personal and institutional factors affect the adoption process. List of variables assumed as determinants of adoption are given in Table 1.

In most of the studies focused on adoption, it is hypothesized in a first stage that socio-demographic characteristics of households would play a pivotal role in biogas technology adoption. Then on the second stage, specific assumption regarding each variable listed in Table 2 with potential effect was set as follows:

Age. Age of the households' head is anticipated to effect the adoption of biogas in positive or negative means.

Table 1. Explanatory variables

Variable	Type	Description
Age	Contin*	Age of households head in years
Education	Contin	Educational level of households head in years
Farm size	Contin	Total area cultivated by the households in hectares
Family size	Contin	Total number of people in the households
Gender	Binary	Sex of households head (1=male, 2=female)
Cattle	Contin	Total number of animals (cattle) owned by households
Income (000PKR)	Contin	Total annual income (PKR)

* = continuous

Table 2. Potential effect and supporting a literature of relevant confounders used

Description	Potential effect	Supported literature
Age of households head in years	-/+	Wikman *et al*.,2013
Educational level of households head in years	+	Kabir *et al*., 2013
Total area cultivated by the households in hecatres	-/+	Kabir *et al*., 2013
Total number of people in the households	-/+	Suyanto *et al*., 2001
Sex of households head (1=male, 2=female)	-/+	Kabir *et al*., 2013
Total number of animals (cattle) owned by households	-/+	Kabir *et al*., 2013
Total annual income (PKR)	+	Mat *et al*., 2012

Older households could possess higher economic position and enhanced capability to afford biogas technology. On contrary, old aged men are less likely to adopt an innovation. These older men tempt to make adoption decision on risk-averse or risk neutral basis. Potential effect sign of age is an empirical question as the old aged farmers are fertile with experiences and better assessment of modern technology characters as compared to young farmers however, older farmers may be more risk-averse than young farmers and have a lesser likelihood of innovation adoption (Bekele and Drake, 2003). It might be difficult to conclude on the association between age and adoption of innovation because it is tender to variations in parameters. Thus, the net effect of age on adoption cannot be determined a prior.

Education. Years of schooling of household head is expected to have a positive potential effect on adoption. Ashraf *et al*. (2015); Salehin *et al*. (2009); Siddiqui *et al*. (2006), Hassan *et al*. (2002), and had indicated a significant and positive association of education with adoption. Which implies that with the increasing education, chances of adoption of biogas technology will escalate. Educated individuals likely assume biogas as a clean energy source and more environment-friendly as compared to less educated peers.

Gender. Gender was restricted to the discontinuous variable sex for modelling purposes. Thus, either a positive or negative influence of gender is expected on the adoption of biogas technology among households. However, women could tend more to adopt biogas technology particularly in female-headed households because these women dominate rural energy use on a domestic level (Venkatesh and Morris, 2000). Women are direct beneficiaries of biogas rather than men. Men dominate in most of the households and have control over resources and decision making and could directly influence the investment decision regarding biogas technology installation in Pakistan.

Farm size. Farm size possessed by the households might have a positive influence on biogas adoption. It is more likely that with the increasing number of hecatres in possession of households may lead to increased adoption of biogas plants. For the smooth running and management of biogas plants it is essential to install all three components (Bio-digester, fodder component and animal unit) close to each other. This type of installation will make monitoring, maintenance and operational activities easy and effective. For the purpose, it is essential for a household to hold enough land in possession. Thus, it can be expected that households with large hectares could be innovators in the adoption of biogas. Both theoretical and practical studies of adoptions had revealed a positive association between farm size and probability and extend of adoption (Brush *et al*., 1992).

Family size. The size of household is expected to have mixed (positive or negative) influence on the adoption of biogas. Family with a large number of members often has a large number of workers to perform routine biogas operational and management activities. Therefore, larger families could have more probability of biogas adoption. On contrary, insufficient resource and overburden in multiple chores may steep adoption process. In this context, influence may document negative attitude towards adoption of biogas.

Livestock herd size (Cattle). Number of animals kept by the households is a significant factor in the adoption of biogas technology. Because raw material i.e., cowdung comes from animals kept. Therefore, numbers of animals kept by households were used as an indicator of the availability of feed stock for the digesters in Pakistan. Availability of biomass inputs required in biogas plants and the availability of biogas technology and material to build plants made them an attractive option (Gautam *et al*., 2009). It was, therefore, expected that a higher number of animals in possession will result in large number of possibilities of adoption of biogas plants depicting positive association.

Income. Technology uptake and adoption is supported and driven by household income. Households with sound financial background and economic position are more likely to adopt biogas technology as compared to their counterparts with the poor economic condition. Household income is, therefore, expected to be positively associated with the decision of biogas technology adoption therein.

Underpinning the previous assumptions, Table 2 summarizes the prospective explanatory variables with their expected potential effect on biogas adoption model.

Results and Discussion

Profile of biogas users and non-users. The mean values of the variables predicted to influence households' decision to adopt biogas technology were computed and are tabulated in Table 3. Of the total 240 biogas users and non-user households, 228 were male headed while 04 from biogas users and 08 from non-user households were female headed. Education, farm size, cattle and income were significantly different ($P<0.05$) between biogas users and non-users of biogas technology. Biogas users were having statistically ($P<0.05$) higher educational level, farm size, family type and no. of animals relevant to biogas non-users. On contrary, biogas non-users had more age and income as compared to their counterparts' biogas users. During the informal discussion, it was revealed that non-users were more involved in off-farm income sources as well.

Reasons behind the adoption of biogas technology. Data depicted in Table 4 reflect that energy crisis and saving was the leading motivational factor perceived by the adopters of biogas ($\bar{x}$=4.87). Biogas users revealed that they were successfully confronting issue of load shedding through biogas generation. Level of load shedding in country is unprecedented and erratic in

Table 3. Descriptive analysis of respondents

Variables	Users	Non- users	Total sample
Age	37.4	39.8	38.6
Education	11.04	6.09	8.56[a]
Farm size	8.24	7.60	7.44[a]
Family size	6.94	5.28	5.87
Gender			
Male	116	112	228
Female	04	08	12
Cattle (No. of animals)	8.02	6.00	6.92[a]
Income (000PKR)	197.6	209.5	201.55[a]

[a] = indicates the difference between users and non-users of biogas is statistically significant at $p<0.05$ (T-Test applied for the mean differences).

Table 4. Reasons behind the adoption of biogas technology

Reasons for adoption	Mean	Stand. Dev.
Energy crisis and saving	4.87	0.158
Economic benefits	4.61	0.728
No. of animals in possession	4.34	0.999
Soil fertility through the slurry	4.27	0.632
Health benefit	4.18	0.831
Environment-friendly	4.00	0.948
Subsidies	3.71	0.158
Neighbor adopters	3.24	1.382

rural areas in particular. Thus, on households' level, nothing was best except adopting biogas technology which also appeared economically viable as well ($\bar{x}$=4.61). Rural people usually remain concerned with costs and benefits. With this regard, biogas users behaved properly where receiving multiple economic benefits (Kabir *et al*., 2013). Number of animals ($\bar{x}$=4.34) in possession of households paved the way to adoption collateral to energy crisis ($\bar{x}$=4.87) and economic benefits ($\bar{x}$=4.61). Bio-fertilizer (also called slurry) produced from biogas is directly applied in soil to enhance soil fertility (Islam, 2006). Increase in soil fertility through use of slurry ($\bar{x}$=4.27) was perceived another factor of adopting biogas.

Biogas is a clean, smooth and smoke-free gas equally favorable for healthy environment for womens while cooking. Women were perceived benefiting more biogas relevant to their men. Health benefit ($\bar{x}$=4.18) was perceived ahead of increase in soil fertility among users as motivation to adopt biogas. Traditional cooking system mainly reliant on fossil fuel exerts health problems including respiratory diseases due to extensive smoke among womens in particular (Srinivasan, 2008). Subsidy ($\bar{x}$=3.71) on installation of biogas unit offered by government agencies persuaded farmers to adopt biogas technology, but the level of persuasion was of less than high level. Government of the Punjab, allowed subsidy on biogas plants installation for small (with land up to 5 hectares) and medium farmers (with land 6-10 hectares). Subsidy was limited to of 100,000 PKR to the farmers with maximum land of 5 hectares followed by 75000 PKR to farmers having 6-10 hectares of land. For medium farmers amount of subsidy allowed was 50,000 PKR on installation of biogas. Subsidies and awareness motivated households to adopt biogas technology. According to the users of biogas, neighboring adopters motivated them to adopt biogas technology as well ($\bar{x}$=3.24).

The inspiration for biogas technology adoption. The decision to adopt biogas technology at household level was the responsibility of household heads. Though, the decision was made alone by males and sometimes in consultation with their counterparts. This decision was further inspired from different sources including Non-Governmental Organizations (NGOs), skilled farmers, electronic media, public and private sector agencies and livestock extension department. Figure 1 is the illustration of relative inspirational sources perceived by the biogas users. Majority (65.83%) of biogas users perceived NGOs a prominent source of inspiration behind adoption of biogas technology. An NGO, Rural Support Network Program (RSPN) was reported very active in promoting biogas units among rural households. This NGO persuaded households to adopt biogas plants on the small-scale level for their domestic use. Many other inspirational sources were found active as well, but their impact was perceived minimal. About 23.3% respondents were inspired from neighbour farmers who were regular users of biogas. The skills of biogas users facilitated decision-making towards biogas adoption.

Almost one in ten respondents (9.16%) perceived inspiration through electronic media tools. TV and radio had been one of the best companions of rural dwellers and advertisement made on these tools motivated respondents to opt biogas technology. Print media, government agencies, livestock extension department and private organizations were perceived inspirational as well to foster adoption of biogas technology, though relative shares of these sources appeared very low.

Factors affecting the adoption of biogas technology. Four iterations were used to reach the maximum log-likelihood and iterations were stopped on likelihood of -187.291 without any difference in iteration 3 and 4. The assumption behind Likelihood Ratio Chi-Square test was that at least one of the coefficients of regression predictors was not equal to zero. Estimated Chi-Square value certify that coefficients are contrary to zero. The model was significant though Pseudo R^2 was lower (20%). Low coefficient of variation doesn't have any impact on the quality of model which is binary in nature.

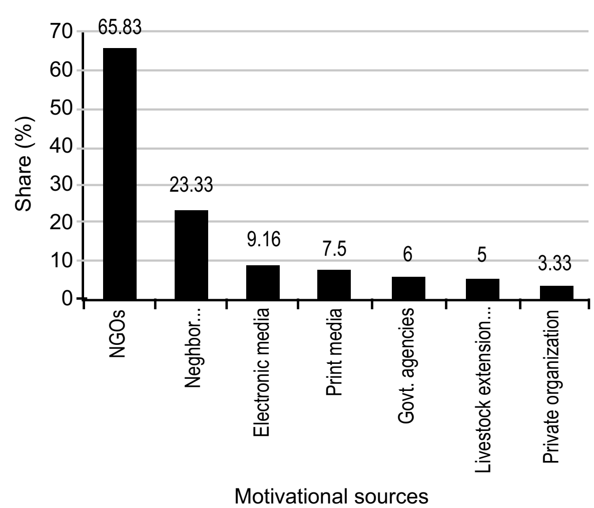

Fig. 1. Motivational sources of respondents.

Bruin (2006) had agreed that low coefficients of variation don't imply any effect on the model in cities Mcfaddens' pseudo R^2 which have no equivalent meanings to the Ordinary Least Squares (OLS) R^2 value pertinent to binary variables.

Total seven variables were included in the model. Outcomes indicated that three variables had a significant relationship with households decision of adoption of biogas technology. Education, income and number of animals had a significant effect at 1% ($P<0.01$) and 5% ($P<0.05$) significance level. Other variables were statistically non-significant. Age and gender were negatively correlated with households decision of adoption of biogas technology. Family size and farm size showed a positive correlation with the adoption decision. Income and number of animals were statistically significant, but the correlation was collateral to family size and farm size owned by the households.

Results infer that socio-economic attributes of the households could be realistic information source to report how families decide whether to adopt biogas technology or not. Socio-economic attributes of the respondents are vital for promotion of innovative technology like biogas.

Age is supposed to be one of the vital aspects of the demographic characteristics of households and decision making. Age of the households head showed non-significant and negatively related to the adoption of the biogas technology. No mean difference of age between biogas users and non-users was found (Table 3). Negative relationship of age of household head with the adoption of biogas technology infers that with the increasing age, decision making powers decreases and the likelihood of adoption of innovation decreases. On contrary, young aged households heads had the maximum probability of adoption of technology. Young aged heads usually take risks of adoption of innovations. The finding of this study is similar to those of Somda *et al*. (2002) and Walekhwa *et al*. (2009) in Burkina Faso and Uganda, respectively, where age appeared negatively correlated with the adoption of biogas technology. However, results are contrary to those of Kabir *et al*. (2013) where they reported a positive correlation of age with the possibility of biogas adoption in Bangladesh.

Based on the gender, households' heads are categorized as male headed and female-headed in Pakistan. More often males dominate the households and make decisions in a befitting manner of family. However, sometimes decisions are made with mutual discussions with their female counterparts. The informal discussion with respondents confirmed that they made decision by taking their females and family members in confidence. This indicates that importance of gender relationships are critical in management, use and control over households assets and decisions in favour of households. Gender showed non-significant negative association with decision of biogas adoption.

Logistics regression model results indicated statistically significant and positive association of education with the adoption of biogas technology at 1% ($P<0.01$) significance level. Results imply that with the increasing level of education, more will be the possibility of adoption of biogas technology. Gujarati (2009) was of the view that in general, if antilog of the jth slope coefficient is taken (in case there is more than one regressor in the model), subtract 1 from it, and multiply the results by 100, you will get the percentage change in the off for a unit increase in the jth regressor. The same mode was applied to this study. Accordingly, there will be possibilities of a 24.6% increase in adoption of biogas with one year increase in education. There was a significant mean difference in education between users and non-users groups. For the biogas users group level of education was 11.4 followed by 6.09 for non-users of biogas. Mean difference and lower educational level of non-users is quite evident that with the increasing educational level there are more possibilities of increased adoption. Results are similar to those of Kebede *et al*. (1990) and Kabir *et al*. (2013) where they endorsed that with the increasing educational level adoption of biogas will be on rising across the nations. The conclusion made indicated that educated users were more capable of understanding the direct and indirect benefits related to health, energy conservation and time saving pertinent to biogas.

According to the report of Pakistan Bureau of Statistics, average households size in Pakistan is 6.8. There was no mean difference found between biogas users and non-users regarding family size. For the biogas users, average family size was 6.94 slightly higher as compared to national level followed by 5.28 average family size for non-users of biogas which is slightly lower than the national average. Logistics regression model results indicated a non-significant but positive association between family size and adoption of biogas technology. Results infer that with the unit increase in the family may boost the possibility of adoption of biogas technology.

For the management and operation of biogas production process, sound number of labour is required. Increased number of workers can encourage households head to adopt biogas technology. Findings are similar to those of Walekhwa *et al*. (2009) where they reported a positive relationship between family size and adoption of biogas technology. However, results are in contrast of Kabir *et al*. (2013) where they found a negative rela-tionship between family size and adoption of biogas technology in Bangladesh.

Average farm size for the biogas users was 8.24 followed by 7.60 for the non-users of biogas. Generally, in both categories the majority of the farmers is small farmers (having less than 5 hecatres of land). Logistics model results revealed a positive association between farm size of households and the adoption of biogas technology. In rural settings of Pakistan, owning a piece of land is assumed big prestige and a person having large farm area has a significant position among the community. Considering the suggestion of Gujarati (2009) there was the likelihood of 8.3% increase in the adoption of biogas technology with per unit increase in farm size (Table 5). Being realistic, it seems impossible not only in Pakistan but also across the world, because arable land is decreasing due to ever-increasing urbanization. Particularly in Pakistan, arable land is shrinking at pace subjected to urbanization and generation to generation distribution of land. Biogas unit consists of biogas plant, an animal unit for provision of substrate and fodder unit to keep animal unit sustainable. All this aggregate setup requires considerable space for the operation and management in an effective manner.

Livestock is the significant contributor of agriculture and had been a source of income particularly for the rural dwellers through commercialization of milk, meat and live animals. The waste produced by these animals is basic raw material for the biogas process. For the production of enough amount of biogas, enough amount of dung is required which is depends upon a number of animals kept. An average number of animals for biogas users was 8.02 followed by an average of 6 animals for biogas non-users. It implies that with effective encou-ragement and motivation these non-users can go for an adoption of biogas technology. According to Table 5, a number of animals had a significantly positive relation-ship with the adoption of biogas technology at 1% ($P<0.01$) significance level. There is likelihood of 21.7% more adoption of biogas technology with a unit increase in a number of animals. Installation of biogas plant depends upon a number of persons to be served or avail-able quantity of cow dung which is prime raw material. Selection of inappropriate size of digestor tends to be uneconomical. According to the Adeoti *et al*. (2000) two heads of cattle's per households/day were sufficient for biogas production from family size digestor. Non-users of biogas were having average cattle's of 6.0 which could be a great encouragement to adopt biogas technology. Lam and Heegde (2012) clarified that 20 kg of animal dung per day is adequate for the smooth running of small-scale biogas plant. In Pakistan, one cattle is capable of producing 15 kg dung/day, which means, with minimum 2-3 cattles small scale biogas plant can be started. This statement is of great worth for the motivation of biogas non-users who already were having average 6 cattles. In the present study, on estimation, non-users of biogas were producing 90 kg of cow dung. On contrary, biogas users were producing 120 kg/day of cow dung.

Just like cattles/no. of animals, households' income appeared another key factor determining the adoption of biogas technology. Logistics regression model indi-cated a significantly positive association with the decision of adoption of biogas technology at 5% ($P>0.05$) signi-ficance level. There is prominent possibility of 53%

Table 5. Factors affecting adoption of biogas technology

Variables [1]	Coefficient [II]	Standard error [III]	Odds ratio [IV]	Coefficient from odd ratio [V=IV-1]
(Constant)	-1.339	1.03	0.91	-0.092
Age	-0.014	0.018	0.53	-0.474
Education	0.084	0.046	0.54	0.246**
Family size	1.072	0.159	1.14	0.142
Farm size	0.015	0.042	1.08	0.083
Gender	-0.677	0.554	0.67	-0.334
Income	0.063	0.034	1.53	0.532*
No of animals	0.277	0.040	1.21	0.217**

Model summary: Log likelihood= -187.291; $LRchi^2$ = 145.20; Pseudo R^2 = 0.214.

increase in the adoption of biogas with the unit increase in income of households. The increased level of income influences the overall financial ability of families, which is a key factor for determining the adoption of biogas technology. During an informal discussion with the respondent, it was revealed that an initial investment in biogas installation is one of the major constraint distressing adoptions. Though, NGOs and Government institutions had offered subsidies and load facilities for small farmers on biogas plants installations.

Non-users perceptions of biogas technology. Non-users of the biogas technology were considered as potential users of biogas. Potential users of biogas were chosen from the neighbouring areas of the biogas users. The intention behind selection was that these potential users had an exposure and awareness of biogas technology. These potential users were having average 6 animals followed by six years of schooling. Overwhelming numbers were male with relatively higher income level as compared to biogas users. Majority of the potential users (74.5%) was aware of biogas technology and half of the potential users (50%) believed in biogas technology and economic gains pertinent to biogas technology. Neighbour farmers/users of biogas and NGOs were the major information sources as perceived by the potential users. During the discussion, potential users disclosed that biogas could be used for cooking, fertilizers, energy and lightening purpose indicating their esteemed interest in biogas. Financial instability, a huge amount of initial investment and inadequate technical knowledge of biogas management were the major factors perceived by 91.4, 86.6 and 69.7% potential users, respectively distressing biogas adoption. The average initial cost of biogas plant of varied size in Pakistan is not more than 95000 PKR with the tendency of producing 10-20 cubic meter of natural biogas in a day (BETAPK, 2016). Potential users showed their willingness of adopting biogas technology conditioned to provision of subsidies on plants by the government and NGOs. Potential users were not in favour of loans provisions which are based on interest; instead, they were in agreement of subsidies on biogas plants. For further effectiveness and likelihood of improvement potential users also recorded their sug-gestions (Fig. 2).

Conclusion

This study investigated the determinants of biogas adoption in Pakistan and cincluded that biogas is a vital renewable energy source bearing multiple beneficial

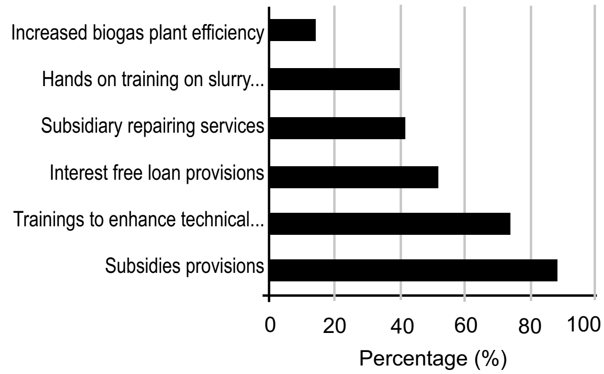

Fig. 2. Suggestions recorded by potential users.

including energy generation and bio-fertilizer. The study further summarized that socio-economic conditions of the rural people are key for adoption of biogas technology. Family size, size of farm, income and number of animals/cattles were positively associated with adoption of biogas technology while age and gender had negative association. Education, income and number of animals were found key factors of adoption of biogas technology. With the unit increase in education, adoption of technology increases. Likewise, households sound in income adopt more biogas technology as compared to households having poor income.

Potential users of biogas had reservations over initial investment on biogas unit and urged subsidies, interest-free loans and hands-on training for installation and operations of biogas unit.

Renowned international organizations like Food and Agriculture Organization of the United Nations (FAO), Economic and Social Commission for Asia and the Pacific (ESCAP), World Health Organization (WHO), United Nations Industrial Development Organization (UNIDO) and United Nations Environment Program (UNEP) had supported biogas technology worldwide. There is need of multi-lateral governmental relations in this regard to invite investors.

Other important sectors like press (print and electronic media) would have to play positive role in familiarizing biogas technology among rural people to persuade adoption.

The scope of biogas in Pakistan is high because the country is blessed with a huge population of animals. The need of the hour is to raise awareness level among rural people to showcase the benefits of this technology.

There is need to conduct research on social acceptability and feasibility of biogas in local settings of Pakistan. Research institutions should conduct research to develop efficient digesters.

Agricultural extension field staff (including livestock extension staff) is frontline workers for farmers and their services in mobilizing farmers to adopt biogas technology could harness better outcomes. For the biogas uptake, facilities extension is required to field staff in terms of moral and economical support of the government of Pakistan.

Conflict of Interest. The authors declare no conflict of interest.

References

Adeoti, O., Ilori, M.O., Oyebisi, T.O., Adekoya, L.O. 2000. Engineering design and economic evaluation of a family-sized biogas project in Nigeria. *Technovation*, **20:** 103-108.

Ahmad, S. 2010. Energy and Bio-Fertilizers for Rural Pakistan, Opportunities, Integrated Technology, Applications, Vision and Future Strategy Managing Natural Resources for Sustaining Future Agriculture, *Natural Research Briefings*, vol. **2,** 31 pp., Natural Resources Division, PARC, Islamabad, Pakistan.

Akinbami, J.F.K., Ilori, M.O., Oyebisi, T.O., Akinwumi, I.O., Adeoti, O. 2001. Biogas energy use in Nigeria. *Renewable and Sustainable Energy Review*, **5:** 97-112.

Amer, M., Daim, T.U. 2011. Selection of renewable energy technologies for a developing county: a case of Pakistan. *Energy for Sustainable Development*, **15:** 420-435.

Amigun, B., Sigamoney, R., von Blottnitz, H. 2008. Commercialisation of biofuel industry in Africa: a review. *Renewable and Sustainable Energy Reviews*, **12:** 690-711.

Amjid, S.S., Bilal, M.Q., Nazir, M.S., Hussain, A. 2011. Biogas, renewable energy resource for Pakistan. *Revewable and Sustainable Energy Reviews*, **15:** 2833-2837.

Ashraf, S., Khan, G.A., Ali, S., Iftikhar, M. 2015. Socio-economic determinants of the awareness and adoption of citrus production practices in Pakistan. *Ciência Rural*, **45:** 1701-1706.

Bekele, W., Drake, L. 2003. Soil and water conservation decision behavior of subsistence farmers in the Eastern Highlands of Ethiopia: a case study of the Hunde-Lafto area. *Ecological Economics*, **46:** 437-451.

Bhutto, A.W., Karim, S. 2007. Energy-poverty alleviation in Pakistan through use of indigenous energy resources1. *Energy for Sustainable Development*, **11:** 58-67.

Brush, S.B., Taylor, J.E., Bellon, M.R. 1992. Technology adoption and biological diversity in Andean potato agriculture. *Journal of Development Economics*, **39:** 365-387.

Burton, M., Rigby, D., Young, T. 1999. Analysis of the determinants of adoption of organic horticultural techniques in the UK. *Journal of Agricultural Economics*, **50:** 47-63.

Forbes, S.L., Cullen, R., Grout, R. 2013. Adoption of environmental innovations: Analysis from the Waipara wine industry. *Wine Economics and Policy*, **2:** 11-18.

Garson, G. 2012. *Logistic Regression: Binary and Multinomial*, 25 pp., Statistical Associate Publishing Blue Book Series, North Carolina State University, USA.

Ghimire, P.C. 2007. *Final Report on Technical Study of Biogas Plants Installed in Pakistan*. Prepared by: Asia/Africa Biogas Programme, Netherlands Development Organisation (SNV), The Netherlands.

GOP, 2018. *Economic Survey of Pakistan*. Federal Bureau of Statistics Islamabad, Pakistan.

Greene, W.H. 2003. *Econometric Analysis*. Pearson Education, India.

Gujarati, D.N. 2009. *Basic Econometrics*, 5th edition, Tata McGraw-Hill Education, New Delhi, India.

Han, J., Mol, A.P., Lu, Y., Zhang, L. 2008. Small-scale bioenergy projects in rural China: Lessons to be learnt. *Energy Policy*, **36:** 2154-2162.

Hassan, M.Z.Y., Siddiqui, B.N., Irshad, M.N. 2002. Effect of socio-economic aspects of mango growers on the adoption of recommended horticultural practices. *Pakistan Journal of Agricultural Sciences*, **39:** 20-21.

Islam, M.S. 2006. Use of bioslurry as organic fertilizer in Bangladesh agriculture. In: *Prepared for the presentation at the International Workshop on the Use of Bioslurry Domestic Biogas Programme*. Bangkok, pp. 3-17, Thailand.

Jamil, F., Ahmad, E. 2010. The relationship between electricity consumption, electricity prices and GDP in Pakistan. *Energy Policy*, **38:** 6016-6025.

Kabir, H., Yegbemey, R.N., Bauer, S. 2013. Factors determinant of biogas adoption in Bangladesh. *Renewable and Sustainable Energy Reviews*, **28:** 881-889.

Karim, A.Z. 2013. Impact of a growing population in agricultural resource management: exploring the global situation with a micro-level example. *Asian Social Science*, **9:** 14-22.

Kebede, Y., Gunjal, K., Coffin, G. 1990. Adoption of new technologies in Ethiopian agriculture: The case of Tegulet-Bulga district Shoa province. *Agricultural Economics*, **4:** 27-43.

Khan, M.A., Ahmad, U. 2008. Energy demand in Pakistan: a disaggregate analysis. *The Pakistan Development Review*, **47:** 437-455.

Lam, J., ter-Heegde, F. 2012. Introduction relevance of domestic biogas for development. *Conference on Biogas*, Compact Course during April, 2012. pp. 10-13.

Mat, S.H.C., Jalil, A.Z.A., Harun, M. 2012. Does Non-farm income improve the poverty and income inequality among agricultural household in rural Kedah. *Procedia Economics and Finance*, **1:** 269-275.

Nation Master. 2016. http://www.nationmaster.com/graph/ene_ele_con_percap-energy electricity-consumption-per-capita. (Accessed 4th October, 2016).

NERC. 2016. Manure Generation Calculator, https://nerc.org/documents/manure.../manure_generation_calculator.xl. (Retrieved 8th January, 2016).

Njoroge, D.K. 2002. Evolution of biogas technology in South Sudan; current and future challenges. In: *Proceedings from Biodigester Workshop*, March, 2002. Available of http://www.mekarn.org/procbiod/kuria.htrml

Pannell, D.J., Marshall, G.R., Barr, N., Curtis, A., Vanclay, F., Wilkinson, R. 2006. Understanding and promoting adoption of conservation practices by rural landholders. *Australian Journal of Experimental Agriculture*, **46:** 1407-1424.

Pimentel, D., Harvey, C., Resosudarmo, P., Sinclair, K., Kurz, D., McNair, M., Crist, S., Shpritz, L., Fitton, L., Saffouri, R., Blair, R. 1995. Environmental and economic costs of soil erosion and conservation benefits. *Science*, **267:** 1117-1123.

Rogers, E.M. 2003. *Diffusion of Innovations*. 5th edition, Free Press, New York, USA.

Salehin, M.M., Kabir, M.S., Morshed, K.M., Farid, K.S. 2009. Socioeconomic changes of farmers due to adoption of rice production technologies in selected areas of Sherpur district. *Journal of the Bangladesh Agricultural University*, **7:** 335-341.

Shah, A.A., Sahito, A.R. 2017. Appraisal of Biogas Potential of Biogas from Animal Dung in Saeedabad, Pakistan. *Mehran University Research Journal of Engineering and Technology*, **36:** 707-718.

Siddiqui, B.N., Muhammad, S., Malik, N.H. 2006. Effect of socio-economic aspects on the awareness and adoption of recommended horticultural practices by apple growers in Baluchistan, Pakistan. *Pakistan Journal Agricultural Sciences*, **43:** 73-76.

Somda, J., Nianogo, A.J., Nassa, S., Sanou, S. 2002. Soil fertility management and socio-economic factors in crop-livestock systems in Burkina Faso: a case study of composting technology. *Ecological Economics*, **43:** 175-183.

Suyanto, S., Tomich, T.P., Otsuka, K. 2001. Land tenure and farm management efficiency: The case of smallholder rubber production in customary land areas of Sumatra. *Agroforestry Systems*, **52:** 145-160.

Toman, M.A., Jemelkova, B. 2003. Energy and economic development: An assessment of the state of knowledge. *The Energy Journal*, pp.93-112.

Venkatesh, V., Morris, M.G. 2000. Why don't men ever stop to ask for directions? Gender, social influence, and their role in technology acceptance and usage behavior. *MIS quarterly*, **24:** 115-139.

Vija, V.K. 2006. Integrated Cycle of Cow-Project for Rural Self Sustainable Economic Development, Centre for Rural Development and Technology, Indian Institute of Technology Hauz Khas, New Delhi, India.

Vindis, P., Mursec, B., Rozman, C., Janzekovic, M., Cus, F. 2009. Mini digester and biogas production from plant biomass. *Journal of Achievements in Materials and Manufacturing Engineering*, **35:** 191-196.

Wachera, R.W. 2014. Assessing the challenges of adopting biogas technology in energy provision among dairy farmers in Nyeri County, Kenya, pp. 1-108.

Walekhwa, P.N., Mugisha, J., Drake, L. 2009. Biogas energy from family-sized digesters in Uganda: Critical factors and policy implications. *Energy Policy*, **37:** 2754-2762.

Wikman, I., Hokkanen, A.H., Pastell, M., Kauppinen, T., Valros, A., Hänninen, L. 2013. Dairy producer attitudes to pain in cattle in relation to disbudding calves. *Journal of Dairy Science*, **96:** 6894-6903.

Younos, T., Hill, R., Poole, H. 2009. Water dependency of energy production and power generation systems. *Water Resources IMPACT*, **14:** 1-12.