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Economic and Environmental Benefits of Biogas Plant and its Impact on Women Health in Punjab Pakistan

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Abstract:
Solid fuel consumption leads to increase indoor air pollution and health burden. The study aims to quantify the impact of biogas fuel on women's health and to conduct the economic feasibility of the biogas plant by considering environmental benefits. The study was based on primary data, collected through a well-structured questionnaire from 282 respondents by employing a multistage sampling technique. We employed the Poisson regression model cost-benefit analysis and internal rate of return (IRR). The results indicated that total time spends in the kitchen and polluted cooking sources has a positive and number of windows in the kitchen, education has a significantly negative impact on the frequency of diseases among women working in the kitchen. Biogas contributes to improving the environmental and economic wellbeing that subsequently flourishes the living standard of rural people. The benefit-cost ratio indicated that Rs. 1.2 can be generated in return by spending Rs.1 on small size biogas plants. The internal rate of return from a single small size biogas plant is 30 percent. All sizes of biogas plants can recover its cost in 4th year after the plant installation. So, we can suggest that biogas can be the finest and profitable substitute for solid fuel.

INTRODUCTION

Globally a large number of populations (3 billion) are dependent on solid fuels (coal, wood, and agriculture residues) (Bonjour *et al.*, 2013; Edelstein *et al.*, 2008; Guta, 2014). In Pakistan wood and animal dung are the major sources of cooking among solid fuels. Solid fuel is the main component of indoor air pollution. According to an estimate, two million people die every year due to indoor air pollution (Lambe *et al.*, 2015; Organization, 2017). Due to the burning of solid fuel different types of gases like carbon dioxide, methane, carbon monoxide and sulfur dioxide emit (Majdan *et al.*, 2015) that leads to damage the air quality, human health, deforestation, climate change, global warming, soil erosion and loss of biodiversity (Bruce *et al.*, 2000; Chafe *et al.*, 2014; Dincer, 2000; Lacey *et al.*, 2017; Makai and Molinas, 2013; Mohapatra *et al.*, 2018; Pieprzyk *et al.*, 2009; Rosenthal *et al.*, 2018). However, in this modern era use of solid fuel is not being recognized as an environmental hazard in Pakistan and there are no policy measures to control air pollution at the household level (Fatmi *et al.*, 2010).

Among the overall application of biogas, at the household level, use as a substitute for solid fuel is considered to be more economical and eco-friendlier that lessens the poverty and health cost (Amigun and von Blottnitz, 2007; Lam *et al.*, 2011; Makai and Molinas, 2013; Rajendran *et al.*, 2012). Sixty percent efficiency increases by converting animal dung to biogas through anaerobic digestion (Mirza *et al.*, 2008). Globally biogas production has reached 58.7 billion Nm^3 with an average growth of 11.2 %. 50 percent contributor to the production of biogas is European countries (Bharadwaj, 2017). We can observe large variation between countries in the development of the biogas sector. China and Germany showed rapid growth in the biogas sector during the last decade.

Pakistan is an agriculture-based country where 60 percent population is living in rural areas. So, Pakistan holds great potential for biogas that leads to minimize the gap between supply and demand of energy (Ali *et al.*, 2013; Amjid *et al.*, 2011; Shaukat *et al.*, 2016). Livestock provides healthy food and economic benefits along with negative environmental externalities (Lin and Tanaka, 2006). Pakistan's total livestock population is 159 million that can produce almost 16.3 million m^3 of biogas daily and over 27 million tones bio-fertilizer per annum (Ali *et al.*, 2013; Asif, 2011). The literature reveals that 1kg manure emits 24 kg methane per annum (Dalibard, 1995). This implies that Pakistan can reduce 19% methane emission by using animal dung for biogas production. The main purpose of biogas plant installation is to provide reliable and cleaner sources of energy to women working in the kitchen which will not only be expected to increase their productivity but also leads to improve health (Katuwal and Bohara, 2009).

Under sustainable development goals (SDGs), the rural population of developing countries needs to shift towards a cleaner source of energy for cooking and heating and Pakistan is implementing SDGs with its full capacity (Scoones *et al.*, 2018). Since 1974 almost 4137 plants have been installed by the government of Pakistan under the umbrella of the National Rural Support Program (NRSP) and rural support program network (RSPN). But the rate of adoption of biogas technology is relatively slow in Pakistan compared to our neighboring country like China. One of the possible reasons is that investors have no idea about the return on investment in this sector. Therefore, one of the objectives of this study is to estimate the Internal Rate of Return (IRR) from the investment in biogas plants which will help to motivate the investors to invest in this sector.

Many studies revealed that solid fuel has negative impacts on children's health (Bates *et al.*, 2013; Bruce *et al.*, 2000; Devakumar *et al.*, 2014; Lim *et al.*, 2012; Rinne *et al.*, 2006). One possible reason could be that literature did generate enough empirical evidence that switching from solid fuel to biogas energy is economically viable. The current study is attempting to fill this gap by providing empirical evidence that biogas technology is economically viable. In this paper, we highlight the cooking fuel impact on women's health symptoms and investigate the economic feasibility and environmental benefits of biogas at the household and community level in the districts (Jhang, Sargodha, and Rahim Yar Khan) of Punjab, Pakistan.

MATERIALS AND METHODS

Punjab is the largest province of Pakistan. In this study, three districts of Punjab (Sargodha, Jhang, and Rahim Yar Khan) were purposely selected based on the highest number of installed biogas plants. This study covers 10 percent population of Punjab who has a strong rural-based economy. Primary data is collected during September and October 2019. Data is collected from 282 households, containing 96 wood and dung cake users, 36 LPG, and 150 biogas users to investigate the impact of biogas and solid fuels on health. There were three different sizes of biogas plants installed in the study area. The small size biogas plant is 6 m^3, medium size 8 m^3 while slightly large size biogas plant is of 10 m^3. The small, medium, and large biogas plants are sufficient to fill the need of a family with 6, 8, and 10 persons, respectively. 150 biogas users purposely and randomly 132 non-biogas users were selected to make a comparison between clean and polluted cooking sources. According to statistical formula sample size with a 6 percent margin of error, 95 percent confidence level, and 50 percent likely proportion should be 267 but data was collected from 282 respondents, slightly higher than the minimum level.

Detailed information about different costs like plant construction cost, the input used and operational costs are collected from biogas users. The average life of the biogas plant including size and labor cost is also collected. Further, the health benefits of biogas use are investigated through face-to-face interviews. To estimate the environmental benefits, detail about the consumption of solid fuel is collected from respondents and the amount of solid fuel carbon emission is estimated by employing a standard conversion factor.

The common diseases that appear due to the use of solid fuels are eye infection, respiratory irritation (asthma), and headache. These symptoms are added up for all the female family members (involved in cooking) in each family to make a count variable. To investigate the health impacts of biogas use, the Poisson or negative binomial regression model will be employed depending on the test statistic. The hypothesis is given below.

H_0 = The dependent variable (count) is over-dispersed

H_1 = The dependent variable (count) is not over dispersed

The Poisson distribution is defined by (Cameron *et al.*, 1988) which can be summarized as below (Eq.1).

$$Prob\left(Y_i = {}^{y_i}/_{x_i}\right) = \frac{e^{-\lambda_i}\lambda_i^{y_i}}{y_i!} \qquad (1)$$

Where Yi is the dependent variable (frequency of health symptoms) and x_i is a vector of independent variables. λ_i is conditional mean and variance of dependent variable Yi. In more detail, complete empirical model is written in equation 2.

$$\mathrm{D_i} = \beta_o + \beta_1\mathrm{HHS_i} + \beta_2\mathrm{AAge_i} + \beta_3\mathrm{CL_i} + \beta_4\mathrm{TK_i} + \beta_5\mathrm{KS_i} + \beta_6\mathrm{KW_i} + \beta_7\mathrm{TEdu_i} + \beta_8\mathrm{Poll_{di}} + \beta_9\mathrm{Edu_{ci}} + \beta_{10}\mathrm{Edu_{pi}} + \beta_{11}\mathrm{Pol_{dpi}} + \beta_{12}\mathrm{Pol_{doi}} + \beta_{13}\mathrm{DJ_d} + \beta_{14}\mathrm{DRYK_d} + \epsilon_i \qquad (2)$$

Where,

β_o **:** Intercept

D_i : Frequency of diseases (Headache, respiratory irritation and eye infection) to women working in kitchen of i-th family in last six month (number)

HHS_i : Total number of working women in house of i-th family (number)

$AAge_i$: Average age of women working in kitchen of i-th family (years)

CL_i : Cooking location of i-th family (outdoor = 1, indoor = 0)

TK_i : Total time spends in kitchen by women working in kitchen of i-th family (hours per day)

KS_i : Kitchen size of i-th family (square meter)

KW_i : Number of windows in i-th family kitchen (number)

$TEdu_i$: Total years of education of i-th family women working in kitchen (Years)

$\mathrm{Pol_{di}}$: Dummy for polluted cooking source used by i-th family (polluted = 1, otherwise = 0)

Edu_{ci} : Education with clean cooking source used by i-th family (years)

Edu_{pi} : Education with polluted cooking source by i-th family (Years)

$\mathrm{Pol_{dpi}}$: Dummy for polluted cooking source used inside (close) the kitchen (polluted source used in indoor kitchen = 1, otherwise = 0)

$\mathrm{Pol_{doi}}$: Dummy for polluted cooking source used outside (open) the kitchen (polluted source used in outdoor = 1, otherwise = 0)

$\beta_{13}\mathrm{DJ_d}$: Dummy for district Jhang (resident of district Jhang = 1, otherwise = 0)

$\mathrm{DRYK_d}$: Dummy for district Rahim yar Khan. (Resident of district Rahim Yar Khan = 1, otherwise = 0)

To achieve one of the purposes of the study is to calculate the net benefits (economic and environmental) of the biogas plant. The standardized techniques of the project evaluation (benefit-cost ratio (BCR) and internal rate of return (IRR)) are employed to study the feasibility of the biogas plant. The formulas of the above-mentioned project feasibility indicators are given in the following equations.

$$A\Pi_i = \sum_{j=1}^{2} AP_{gj}AY_{gj} + ABenefit_{bsi} + P_{cj}\,AC_{gj} + ABenefit_{hi} - WC_i - AOPC_i - AOPCAD_i - AFC_i. \quad (3)$$

Where,

$A\Pi_i$: is the average profit from i-th size of biogas plant per annum (rupee)

AP_{gj}, AY_{gj} : is the average price and quantity of j-th type of fuel used by g-th family per annum (rupee)

$ABenefit_{bsi}$: is the average benefit getting from bio-slurry by i-th size of biogas plant per annum (rupee)

$P_{cj}AC_{gj}$: is the price of carbon emission and average quantity of carbon emissions from j-th fuel used by g-th family per annum (rupee)

$ABenefit_{hi}$: is the health benefit of i-th size biogas plant per annum (rupee)

WC_i : is water cost consumed in i-th size of biogas plant per annum (rupee)

$AOPC_i$: is operational cost to i-th size of biogas plant per annum (rupee)

$AOPCAD_i$: is opportunity cost of animal dung used by g-th family per annum (rupee)

AFC_i : is the average fix cost of i-th size of biogas plant (rupee)

The formula of net present value, IRR, and BCR are given in equations 4 and 5.

$$NPV_s = \sum_{t=0}^{15} \frac{A\Pi_{st}}{(1+r)^t} \quad (4)$$

BCR= Present value of benefit/ present value of cost (5)

RESULTS AND DISCUSSION

Descriptive Statistic

The average value of different variables was compared between two groups using polluted (solid fuels include, fuel wood and dung cake) and clean sources (LPG and biogas) of energy. The mean value of the two groups was compared by employing t-test. It is observed that the total number of diseases faced by women using the polluted source of energy (3.8) (working in the polluted environment) is significantly higher than those using cleaner sources of energy (0.48) (working in cleaner environment). This implies that polluted sources of energy create significantly higher health risks than their counterparts and this supports the findings of earlier studies (Bruce *et al.*, 2000; Siddiqui *et al.*, 2005). Working women spend more time in the kitchen with polluted fuels (4.6 hours) as compare to clean cooking source of energy (3.7 hours). It is mainly because family size of families depending on polluted cooking sources (6.8) is higher than clean energy users (6.5). Kitchen size of families using polluted source of energy has significantly small size of kitchen (0.94 square meter) than their counter parts (6.7 square meter), implying that family using polluted fuels are economically poor which is restricting them to small size of kitchen.

The numbers of windows are also higher (0.95) in the families using cleaner source of energy than their counterparts (0.08). Besides low income, this also reflects poor awareness about the benefit of an airy kitchen among families depending on polluted sources of energy. The average education of women of cleaner sources of energy (9.97 schooling years) is significantly higher compared to the families depending on polluted fuels (6.4 schooling years). Again, most probably it is because of insufficient resources to invest in education, and education is one of the key drivers for the adoption of cleaner sources of energy (Bahadur et al. 2019). Measures to avoid health risks are important to reduce the health effect of cooking sources. Only 30 percent of polluted cooking sources are adopting any measure to avoid health risks remaining are not adopting any measure. Mostly clean cooking fuel users are using public transport and polluted source users are using public transport because clean energy users are economically well so they prefer to public transport (Table 1).

Table 1. Comparison of the clean and polluted cooking sources (t test).

Variables	Clean source of cooking (1)	Polluted source of cooking (0)
Women total disease (numbers)	0.48***	3.8
Number of working women (numbers)	1.66*	2.1
Ave age of working women (years)	38.8ns	37.6
Time spend in the kitchen (hours)	3.7***	4.6
Family size (numbers)	6.5ns	6.8
Kitchen size (meter sq.)	6.7***	0.94
Kitchen window (numbers)	0.95***	0.08
Average education of women (years of schooling)	9.97***	6.4
Measure to avoid health risk %	0	30
Private transport %	90	14
Public transport %	10	84
Dummy for district Jhang %	69	31
Dummy for district RYK %	57	43

- ***, **, and * indicate the level of significance at 1%, 5%, and 10% respectively.
- ns is not significant

Although it is apparent from the survey that the majority of the population in the study area is aware about biogas but not aware about the subsidy given by RSPN, NRSP in past years. It is observed, 94 percent of wood users and 97 percent of LPG users are aware about the existence of biogas technology. About 25 percent wood users and 2 percent LPG users are aware about the subsidy given on the adoption of biogas technology (Table 2). Hence, under the situation of well-informed or widely announced subsidy on biogas plant could significantly enhance the demand for biogas technology.

Table 2. Awareness about biogas.

Awareness/ Cooking fuel	Wood and dry manure (%)	LPG (%)
Awareness about biogas	94	97
Not aware about biogas	6	3
Aware about subsidy	25	2
Not aware about biogas subsidy	75	98

Econometric Analysis

Cooking fuel impact on women health

The study attempted to investigate the factors (Socioeconomic, physical and preventive measures) affecting the health symptoms (respiratory irritation, eye infection, headache) faced by women due to the source of energy used in the kitchen. A large body of literature indicates that respiratory irritation (Amigun and von Blottnitz, 2007; Das *et al.*, 2017; Dohoo *et al.*, 2013; Siddiqui *et al.*, 2005),

eye infection (Das *et al.*, 2017; Pant, 2012; Siddiqui *et al.*, 2005)) and headache (Bedi *et al.*, 2017; Das *et al.*, 2017; Diaz *et al.*, 2007) is caused by solid fuels.

Results revealed that the dependent variable was not over dispersed so the null hypothesis was rejected and the Poisson regression model was employed. By using the model expressed in Equation 2. Our empirical result of the Poisson regression model demonstrates that 1-hour increase in time spend in the kitchen leads to the difference in the log of expected count is expected to increase by 0.16 units with 1 percent significance level. It is consistent with the economic theory that women spending more time in the kitchen are inhaling more poison particulates through breath that lead to increase the chances of getting sick (Ezzati *et al.*, 2000). However, the coefficient of the polluted cooking source is comparing polluted and clean cooking sources. The difference in the log of expected count is expected to be 1.77 units higher for polluted as compared to a clean cooking source. It is in line with the general perception that polluted cooking fuel emanates different hazardous gases that affect the health of women working in the kitchen (Bruce *et al.*, 2000; Das *et al.*, 2017; Dohoo *et al.*, 2013; Edelstein *et al.*, 2008; Mohapatra *et al.*, 2018).

The results of the Poisson regression model are little difficult to explain but their marginal effects are more straight forward to explain. Therefore, in the literature marginal effects have been presented more commonly than direct coefficients of regression (Pant, 2012) because marginal give the per unit change in the dependent variable arises due to per unit change in the independent variable.

The results of marginal effect demonstrate that number of women working in kitchen have positive impact on frequency of disease that leads to one additional working women adds 0.16 unit of symptoms to the women working in the kitchen. As the number of women increase then there is equal chance of adding the same number of males in the family. One additional window leads to decrease health symptoms by 0.64 unit faced by women working in the kitchen. It is consistent with medical science that working in clean environment help to reduce health symptoms (Patel *et al.*, 2019). The education of women have negative impact on health symptoms because educated women's are more cautious about their health and know how to minimize the impact of air pollution (Alim *et al.*, 2014). Empirical finding indicates that one additional year of education leads to decrease health symptoms by 0.02 units per family. One additional unit of polluted cooking source increase the health symptoms by 2.52 units as compare to his counterpart clean cooking. One additional respondent from each of the district Jhang and Rahim Yar Khan face 0.1 unit symptoms more than the Sargodha district respondents. Because the people of Sargodha district are more economically well than the other two districts.

It is fact that explanatory variables have different units of measurement (e.g. frequency of disease is taken in numbers while average age is taken in number of years), therefore, coefficient of different variables are not comparable. Hence, we employed standardized regression model for better understanding and coefficients are comparable. The coefficient of standardized regression model can be explained as per standard deviation. The results of standardized regression model are reported in column IV of Table 3. Our empirical results indicate women working in open kitchen are facing 1.08 less symptoms than those working in close kitchen and coefficient is significant at 10 percent level. This implies that open kitchen helps to reduce symptoms of indoor air pollution. The time spend in kitchen is found to have positive and statistically significant impact on women health. Our results reveal that increase in one hour in kitchen lead to increases the symptoms by 0.37 standard deviations (SD). Results indicates that increases in number of windows by 1 standard deviation leads to decrease health symptoms by 1.32 SD, implying that awareness about the importance of window in the kitchen need to impart in the study area. Type of energy has serious consequences on health symptoms. Women working in polluted environment are facing significantly higher health symptoms by 3.03 SD compared to those working in clean environment.

The problem was further investigated in more depth by analyzing and comparing the situation. The results of Poisson regression model II revealed that their marginal effect and standardized regression model are explained in column V, VI and VII of Table 3. The results standardized regression model was explained for simplicity. The educated women using clean energy has significant and negative impact on health symptoms compared to their counterparts (uneducated) and similarly, educated women using polluted sources of energy are not facing any adverse health impact of indoor air pollution.

Table 3. Factors affecting the working women health.

Variables/Type of regression	**Poisson regression model I**			**Poisson regression model II**		
	Poisson regression coefficient	**Marginal effect**	**Standardize regression coefficient**	**Poisson regression coefficient**	**Marginal effect**	**Standardize regression coefficient**
Total number of working women in kitchen	0.17* (0.10)	0.16* (0.09)	0.28 ns (0.18)	0.15 ns (0.1)	0.14 ns (0.09)	0.28 ns (0.18)
Ave Age of women working in kitchen (years)	- 0.004 ns (0.005)	-0.004 ns (0.01)	-0.0 ns (0.01)	-0.004 ns (0.005)	-0.0 ns (0.01)	0.0 ns (0.01)
Dummy for open kitchen (i.e. If kitchen open=1, otherwise zero)	-0.45ns (0.32)	-0.39 ns (0.26)	-1.08* (0.64)			
Total time spend in kitchen (hours)	0.16*** (0.67)	0.15*** (0.06)	0.37*** (0.13)	0.16*** (0.07)	0.15*** (0.06)	0.37*** (0.13)
Kitchen size (square meter)	-0.013 ns (0.042)	-0.01 ns (0.04)	-0.03 ns (0.06)	-0.01 ns (0.04)	-0.01 ns (0.04)	-0.03 ns (0.06)
Number of windows in kitchen	-0.69*** (0.17)	-0.64*** (0.16)	-1.33*** (0.31)	-0.69*** (0.17)	-0.64*** (0.16)	-1.32*** (0.31)
Total Education of women working in kitchen (years)	-0.02** (0.001)	-0.02** (0.01)	-0.03** (0.01)			
Dummy for polluted energy	1.77*** (0.19)	2.52*** (0.39)	3.03*** (0.45)			
Dummy for district Jhang	0.1** (0.06)	0.1** (0.05)	0.09** (0.04)			
Dummy for district RYK	0.1*** (0.04)	0.1*** (0.04)	0.09** (0.05)			
Education (clean source user)				-0.041*** (0.02)	-0.04*** (0.01)	-0.04*** (0.02)
Education (polluted source user)				-0.01 ns (0.01)	-0.01 ns (0.01)	0.003 ns (0.024)
Dummy for polluted cooking source use in close kitchen				1.51*** (0.24)	3.06*** (0.88)	3.03*** (0.46)
Dummy for polluted cooking source use in open kitchen				1.07*** (0.36)	1.29*** (0.56)	1.95*** (0.51)

Note:

***, **, and * indicate the level of significance at 1%, 5% and 10% respectively.

The value in parenthesis shows standard errors of the respective coefficients.

ns is not significant.

Simply, because they are aware based on knowledge that how to keep themselves safe from indoor air pollution by adopting preventive measures. Moreover education is one of the key deriver for the adoption of cleaner sources of energy (Rahut *et al.*, 2019). Interestingly, our results reveal that when polluted energy sources are used in close kitchen it is creating health symptoms 3.03 SD compared the situation when same polluted sources are used in open kitchen it creates health symptoms by 1.95 per SD. These results demonstrate that awareness about the use of polluted sources of energy in open kitchen could significantly help to reduce the indoor pollution health burden in the study areas.

Cost Benefit Analysis of Biogas Plant

Construction cost, operation cost and input cost all depends on the size of biogas plant, implying that economic evaluation of biogas plant varies from size to size. Hence, we made economic evaluation of each size of plant separately. Cost and benefit analysis for of biogas plant has been discussed in detailed below.

Small size biogas plant (6 m^3)

We evaluated and discussed the cost and benefits of 6 m^3 biogas plant. Average total cost for construction of 6 m^3 biogas plant is Rs.66062. According to sample data the operational cost (labor and maintenance) is Rs.33840 per annum. Water is an essential for the generation of biogas. The water cost in terms of electricity bill is Rs.600 per month or Rs.7200 per annum (Table 4). The animal dung used for the generation of biogas can be used for other purpose so the opportunity cost of animal dung is also part of the variable cost which is Rs.26717 per annum. Hence, the total cost (water, labor and maintenance etc.) was 67757 per annum per family.

There are different economic, environmental and social benefits of biogas plant. Farmer save money by not spending on wood and dung cake and also get bio slurry from biogas plant which can be used as bio fertilizer and can also be sold in the market. Based on our sample data, a family of 6 members consumes almost 80 kg of wood with 484 units of dung cake per month. Average market price of wood and animal dung is Rs.10.6 per kg and Rs.4.6 per unit respectively. A 6 m^3 biogas plant is anticipated to save almost Rs.36893 per annum on the account of conventional fuels spent otherwise. The public get benefit in the form of clean environment because wood and animal dung emit hazardous gases.

According to sample data a small size family of six members is consuming 1 ton of wood with 5808 units of dung cake per annum. According to (Kazulis *et al.*, 2017) the complete combustion of one kg wood emits 0.5 kg carbon. This implies that by shifting from polluted to cleaner sources of energy (biogas) 0.53 ton of carbon emission can be reduced each year. Average weight of dung cake is 0.68 kg per unit and carbon emission from burning of 1 kg of dry animal dung is 22.9 g or 0.023 kg (Venkataraman *et al.*, 2005). Almost 484 units of dung cake are used per month by a family of 6 members. Summarizing the discussion, it is concluded that 0.62 tons of carbon emission per year can be reduced by each family after installing 6 m^3 biogas plants by not consuming wood and dung cake.

One ton price of carbon emission in international market is Rs.9700 (50 Euro). Hence, each plant of 6 m^3 can generate environmental benefits in terms of emission reduction is Rs.6014 per annum. A family of 6 members using solid fuels (wood and dung cake) spend Rs.6902 per annum on health (eye infection, respiratory irritation and headache) faced due to indoor pollution while clean energy users are spending only Rs.900/family/annum. This implies that shifting from polluted to clean energy can generate health benefit of Rs.6002 per annum per family. Bio fertilizer has an additional benefit from biogas plant. According to our sample data, a 6 m^3 biogas plant owner can earn additional Rs.38088 per annum by selling bio slurry in the market. Total benefit from a 6 m^3 biogas plant is Rs.86995 per annum (Table 5). If we simply subtract the cost from benefit then each year biogas with plant of 6 m^3 will generate a net benefit of Rs. -46823 per annum per family.

The study further evaluated the investment by employing cost benefit analysis and internal rate of return (IRR) tools of project evaluation. The values of economic analysis of 6 m^3 biogas plant are reported in Table 5. The present value of costs and benefits are estimated by using current market interest rate (7 percent) as reported in Table 5. Due to space constraint we take only 5 years in Table 5 while in Appendices 1, the cost and benefit of biogas plant is reported for 15 years (plant life).

Cost and benefits analysis of medium (8 m^3) and large (10 m^3) biogas plant are given in Appendices 2 and 3. By subtracting present value of costs with adding each year from present value of benefits adding each year net return are calculated. Our results reveal that all size of biogas plants recover its cost in the 5th year after installing the biogas plant which is consistent with the earlier findings (Mel *et al.*, 2015). The average life of the biogas plant is 15 years (Cahyani *et al.*, 2019).

Table 4. Per annum cost and benefits of biogas plant of small size of biogas plant.

	Quantity /annum	**Price per unit**	**Total cost/ benefits/annum**
The installation cost of each 6 m3 biogas plant in pkr	1	66062	66062
Cost of wood consumption per annum for average family of 6 members@80 kg per month (tons/annum)	1.058	9616	10176
Average benefits from dung cake per annum benefit@Rs.4.6/unit (Numbers/annum)	5808	4.6	26717
Labor cost per annum (Rs.) cost@Rs.2000 per month	12	2000	24000
Maintenance cost @Rs.820 per month (Rs. /annum)	12	820	9840
Monetary value of carbon emission from wood @50euro€/ton (tons/annum)	0.53	9700	5141
Total carbon emission from dung cake @0.02 kg per kg (tons/annum)	0.09	9700	873
Monetary benefits from emission (wood and animal dung) @50euro €/ton (tons/annum)	0.62	9700	6014
Net health cost per annum (Rs. /family)	1	6002	6002
Average income from bio fertilizer@Rs.3174/month	12	3174	38088
Water cost in terms of electricity cost@Rs.600 per month	12	600	7200

After 3rd year biogas plant will purely generate profit. In the last 12 years plant will generate net profit (benefit-all costs) i.e. after deducting all operational costs. The present value of net benefit of last 10 years (after recovering the construction cost) is Rs.214664. Benefit cost ratio indicate that if we spend Rs.1 on biogas plant then it generates Rs. 1.2 in return while the return from medium and large size biogas plant is Rs 1.1 and 1.2 respectively. Internal rate of return (IRR) from a small size biogas plant is 30 percent while from medium and large size biogas plant IRR is 26 and 33 percent respectively Appendices 1. The values of IRR indicate that investment on biogas plant generates higher profit than the ongoing market interest rate, reflecting viability of the investment in biogas sector.

Table 5. Economics of a small size biogas plant (6 m^3).

Cost/Benefits	Years				
	0	**1**	**2**	**3**	**4**
Cost of construction (Rs.)	66061				
Operational cost per year (labor cost and maintenance) (Rs. /annum)	33840	33840	33840	33840	33840
Cost of animal dung (opportunity cost in case owns animal) (Rs. /annum)	26717	26717	26717	26717	26717
Water cost (Rs. /annum)	7200	7200	7200	7200	7200
Total cost (Rs. /annum)	133818	67757	67757	67757	67757
Present value of total cost (Rs. /annum)	133818	63324	59181	55310	51691
Present value of total cost with each adding year (Rs.)	133818	197142	256323	311633	363324
Economic benefit (cost of wood and dry manure) (Rs. /annum)	36893	36893	36893	36893	36893
Environmental benefits (price of carbon emission from wood and dry manure) (Rs. /annum)	6014	6014	6014	6014	6014
Net health benefits (reduction in health cost) (Rs. /annum)	6002	6002	6002	6002	6002
Benefits from bio slurry (Rs. /annum)	38086	38086	38086	38086	38086
Total benefits (Rs. /annum)	86995	86995	86995	86995	86995
Present value of total benefits (Rs. /annum)	86995	81304	75985	71014	66368
Present value of total benefits with adding each year (Rs.)	86995	168299	244284	315297	381665
Net return	-46823	-28843	-12040	3664	18341
Benefit cost ratio	1.2				
IRR	30 %				

CONCLUSION AND POLICY RECOMMENDATION

People residing in rural area heavily dependent on solid fuels (Dung cake, wood) to meet their cooking fuel needs. Solid fuel is the major cause of indoor air pollution. This study quantifies the effect of cooking fuel on women health and cost benefit analysis of biogas plant in three districts of Punjab. Result of the study demonstrates that polluted cooking source is the major cause of respiratory irritation, eye infection and headache. In more depth the women more spend time in kitchen more likely to health symptoms. Education is most important indicator that reduces the health symptoms among women. Shifting from biomass to biogas significantly reduces the disease symptoms among women. From the biogas cost benefit analysis of biogas plant investing by households stand to economic benefits mainly through bio slurry, save expenses on traditional cooking fuel and net health benefits. A 6 m^3 biogas plant recovers its cost in 5^{th} years after plant installation.

Results are highly sensitive to both actual, market-based price and cost of replaced energy source. The government should make policy for the awareness of rural communities about the benefits of biogas plant. Government can assist to promote biogas technology by changing the mode of investment to alleviate poverty. Rather than giving subsidy in cash under BISP, which is neither generating any environmental benefit nor economic activity is viable to sustain for a longer period. However, investing the same resources alternatively on clean energy will be self-sustained and also generate economic activity. Government can train the local masons that ensure the quality of biogas plant in term to increase in the plant life that will raise the confidence of people on biogas and help to improve its profitability.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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