Adoption of Biogas: A Story from Rural Pakistan

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Energy plays a vital role in the economic development and has repercussion effects on society, environment, and eco-system services. (Amigun 2008). With the growing needs of energy and un-promising supply, the sustainable growth and development in the development countries is in question. Moreover, energy crisis can exacerbate the condition of economy and subsequently stalled the economic growth. Almost 2.5 billion (34%) people of the world depend upon traditional or conventional energy sources for cooking, heating, and lighting purposes (IEA, 2004). Due to the incombustible nature, these resources are the source of black carbon, indoor air pollution and greenhouse gases. So, it is imperative to provide eco-friendly energy services to the rural population (Bhat et al. 2001).

For example, a country like Pakistan, who is facing severe energy crises, and spends solely 20 percent of the foreign exchange on fossil fuels. At household's level, 41 percent of their energy expenditures are incurred on electricity followed by 27 percent on fuel wood and 8 percent on dung cake which is considerably very high (GoP 2013-14). In the quantitative terms, households consume nearly 2325 kg of firewood or 1480 kg of animal dung cake or 1160 kg of crop residue per year (Mirza 2010). It is expected that the demand for fossil fuels increase three-fold by 2050, while supply condition is not promising (Asif 2010). This situation is challenging to explore cheap, clean, socially acceptable, and de-centralized renewable energy resources in Pakistan. By exploiting these resources, Pakistan can recognize itself as environment-friendly country among the international community.

Given the dual need of affordable and clean energy, biogas is one alternative which called as Cinderella - the most beautiful resource among the other renewable energy sources (de Alwis 2002). Biogas is produced through anaerobic process (fermentation) by using animal dung and crop residue. It is combustible gas composed of 60-70% of methane (CH_4) 60% (Shin et al., 2005; Batzias, 2004). Biogas-digester is a type of improved cook stoves which is an effective tool to tackle indoor air pollution, deforestation and climate change issues (Srinivasan, 2008).

Being the agro-livestock country, Pakistan has the potential to provide enough substrate in the form of animal-dung to produce biogas. The livestock population; cows and buffaloes are approximately 65.2 million which can produce 652 million kg of animal dung (GoP 2010). According to recent estimates Pakistan has the potential of producing 16.3 million m^3 biogas

(Sheikh 2009). This can easily substitute the wood-fuel and crop-residue need of 112 million rural population.

Realizing the need, benefits, and potential a lot of efforts are made at government and Non-governmental level recently in Pakistan for promotion and diffusion of biogas. But the adoption of this technology is not increasing at encouraging rate. So, it is the need to identify and determine the important drivers which affects the adoption behavior. This implies for further research, technology diffusion, and technology improvement.

Although international organizations and communities are striving hard to provide clean energy to the impoverished households in developing nations, but still the future of these technologies is uncertain. According to Rogers 2002, even after the adoption the technology passes through the complex stage of implementation and confirmation. In particular, the biogas technology, which though has benefits, has been expensive at rural household level. So, it is essential to understand the adoption decision of biogas by not only taken into account the household demographic and socio-economic characteristics but also the supply side factors. A recent extensive literature review of the main drivers of adoption of improved fuels and cook stoves reveals only eight articles and eleven regression analysis (Lewis and Pattanayak, 2012). This review emphasized the importance of contextual variables (credit, supply chain, and social marketing) for future in-depth analysis. In following, Hazara et.al.2014, has studied the adoption of biogas and fuel use, and also considered health perspective in adoption decision in Orissa, India. Similarly, Kabir 2013, in Bangladesh finds out the determinant of biogas adoption. In Africa; two detailed studies have been done on biogas adoption (Mwirigi et.al.,2009;Walekhwa et.al., 2009); and two studies have been done on factors which affects the functionality and non-functionality of biogas digester after the adoption decision (Chand and Murthy 1988; Mwirigi et.al.,2009); and only one study has been done to quantify the fuel wood consumption at post-adoption stage (Xiaohua and Jingfei 2005). As this study is specifically conducted to understand, what are the drivers of adoption and its continuity to use and its impact on fuel wood use, adds to limited literature in quantitative perspective.

We focus on central Punjab, which is mainly agro-based and have large no of livestock. A Pakistan Domestic Biogas Program (PDBP) was started in 2009 with the objective to provide biogas as an alternative for wood fuel, animal dung cake, crops residue, and Light Petroleum gas (LPG). This

program aimed to provide 14,000 biogas digesters using market-based approach, and use partial subsidy as incentive to encourage biogas-digester adoption.

A four-stage sampling technique was used for the present study. In the first stage, Punjab province is selected, where the intervention was introduced by considering the largest province in terms of population and abundance of small farmers. The second stage involves selection of districts; Faisalabad, Jhang, and Sargodha districts are selected due to the availability of adopters. Third, two tehsils/towns from each district are selected to collect the data. Fourth, a sampling frame was made by taking the list of adopters from the Pakistan Domestic Biogas Programe office, Faisalabad. As the adopters were too scattered, we randomly selected three or more adopters' households from each village of the respective tehsil. In total, we covered 80 villages and selected 55 adopters and non-adopters from each tehsil. We collected the detailed information of 630 households from six tehsils. The non-adopters were selected from the nearby household of the adopter considering its socio-economic characteristic. Due to the non-responsive and missing data, we left with a sample of 624, with equal proportion of adopters and non-adopters. On the separate note, PDBP had done the selection of the adopter household on the basis of having at least one-cow/buffalo and one acre of land holdings

Following Hazra et al. (2014), we specify the models, which includes; demographic, socio-economic and biogas-digester specific and subsidy related variables. To conduct a detailed analysis, we consider adopters and non-adopters. The adopters group is who had installed the biogas-digester at their homes or at farm, to use it mainly for cooking, while the non-adopters is a group who had not installed or waiting to get it installed. We also analyzed the factors that were behind the adoption of biogas at household level. Furthermore, Village-level fixed effects are also incorporated in one specification for each model.

Focus group discussion (FGD)

The present study in Pakistan concerns about the drivers which affects the adoption decision of the household to adopt biogas-digester and their functionality. To understand and identify the variation and similarities in characteristics of the proposed area, the field visits were made in 2013. It is followed by focus group discussions (FGDs) to take detailed insight of biogas-digester adopter attitudes, perceptions, and functionality of biogas-digester in three districts- Faisalabad, Sargodha,

and Jhang. Pakistan domestic biogas program started its operation from Faisalabad in 2009 and gradually spread to Sargodha and Jhang. We conducted focus groups in our sample districts in central Punjab to understand the adoption decision process and factors affecting it. We come up with following issues in the study area:

- High upfront cost.
- Insufficient subsidy to encourage adoption.
- Confusion among the potential adopters due to multiple subsidy schemes offerings for two types of digester (floating and fixed). High subsidies from other non-governmental organizations is limited to a few cases.
- Biogas Construction Company, which supposed to provide after sales services, has a positive effect on the functionality of biogas digester. The households who have adopted the biogas-digester continue to use firewood (fuel-stacking)
- Women awareness about technology is a positive factor to adoption, they are trying to persuade male counterpart towards adoption.
- Lack of proper financial products to enhance biogas digester adoption.
- The subsidy varies from 60$USD to 400$USD irrespective of the plant size.

Table 2: Test for difference in mean adopters and non-adopters

Variables	**Observations**		**Mean**		**T-test**	
	Adopter	**Non-Adopters**	**Adopter**	**Non-Adopters**	**T-test**	**p>|t|**
Age of household head (years)	312	312	43.82	36.99	7.26	.00
Education of the household head (years)	312	312	8.59	8.54	.13	.89
Household Area (marls)	312	312	20.64	16.29	4.22	.00
Family Size (No.)	312	312	9.31	8.88	1.11	.27
Family Male (No.)	312	312	3.31	3.17	.80	.42
Family Female (No.)	312	312	2.77	2.80	-.27	.79
Family Children (No.)	312	312	3.26	2.91	1.78	.07
Primary cook education (year)	312	312	4.79	3.02	4.93	.00
Secondary cook education (year)	312	312	2.02	1.28	2.34	.02
Second secondary cook education (year)	312	312	1.26	1.08	.64	.52
Distance from the Bank (KM)	312	312	26.12	23.24	3.07	.00

Total land holding (acres)	312	312	19.17	11.08	5.43	.00
Large animals (No.)	312	312	15.81	10.79	4.03	.00
Total dung (Kg)	307	312	132.50	96.70	3.89	.00
Firewood expenditures before adoption (Rs)	312	312	283.43	341.76	-.98	.33
LPG expenditures before adoption (Rs)	312	312	979.89	659.94	3.78	.00
Log of Monthly income (Rs)	312	312	4.93	4.81	5.16	.00
Log of Monthly Expenditure (Rs)	312	312	4.75	4.68	4.01	.00
Log of Monthly Health expenditures (Rs)	312	312	3.24	3.10	4.97	.00
Log of crop revenue (Rs)	312	312	5.64	5.32	3.30	.00
Fuel collection time (hrs)	312	312	.91	1.09	-7.95	.00

In total sample both the adopters and non-adopters households differ significantly from each other in different characteristics, as can be observed with simple tests for differences in means (Table 2). The households who adopted biogas are significantly different in (a) age of the head of the household, (b) household area, (c) the education level of the women, (d) the land holding, (e) number of large animals, (f) availability of dung, which is the basic criteria for the selection of the household used by Pakistan domestic biogas program. The financial position is peroxided by variables; Income, expenditures and farm revenue are also significantly different between the two groups. Furthermore, expenditure on other clean fuel (LPG) and fuel collection time is significantly different at mean.

Table 4: Adoption reasons of Biogas-digester

Reasons/Factors	**B. Most important factor=1**			**Least Important Factor=5**		
	1	**2**	**3**	**4**	**5**	**Total**
Non-availability of other fuel sources	149 (48.8)	45 (14.4)	23 (7.4)	26 (8.3)	69 (22.1)	312 (100)
Economic benefits	173 (55.4)	127 (40.7)	8 (2.6)	3 (1.0)	1 (0.3)	312 (100)
Motivation from existing plant owners	153 (49)	90 (28.8)	49 (15.7)	16 (5.1)	4 (1.3)	312 (100)
Subsidy provided by the program	95 (30.4)	65 (20.8)	63 (20.2)	58 (18.6)	31 (9.9)	312 (100)
The female of the house urges you	96 (30.8)	63 (20.2)	52 (16.7)	75 (24)	26 (8.3)	312 (100)

Availability of the inputs	219 (70.2)	64 (20.5)	16 (5.1)	4 (1.3)	9 (2.9)	312 (100)

Values in parentheses are percentages

The sample was equally divided between the adopters and non-adopters of biogas digester. The biogas adopter group elicit their reasons for adoption on 5-level, likert-scale. Table 4 highlights the reasons for adoption which were categorized during the focus group discussions (FDGs). Among adopters group, 70 % households hold the availability of the inputs (animal dung and water) the most important reason. The second most important reason was economic benefits attached to technology, reported 49%. The third and fourth most important reasons were motivation from existing plant owners and non-availability of other fuel sources, 49% and 48.8% respectively. Albeit Pakistani rural community is male dominant and mostly the male household head make all the economic and social decisions. But still women have shown their influence for the adoption of technology. The fifth most important reason of the adoption was the desire of female counterpart of the households. Because the women in most of the developing countries are primary cook therefore they were mainly benefited from this technology.

Table 5: Benefits for biogas-digester Adoption

Factors	**B. Most important factor=1**				**Least Important Factor=5**	
	1	**2**	**3**	**4**	**5**	**Total**
Enough gas for cooking	276 (88.5)	23 (7.4)	10 (3.2)	1 (0.3)	2 (0.6)	312 (100)
Enough gas for lighting	2 (0.6)	9 (2.9)	8 (2.6)	7 (2.2)	286 (91.7)	312 (100)
Enough gas for irrigation	2 (0.6)	4 (1.3)	0 (0.0)	3 (1.0)	303 (97.1)	312 (100)
Bio Slurry	77 (24.7)	114 (36.5)	96 (30.8)	7 (2.2)	18 (5.8)	312 (100)
Cleanliness of the household	94 (30.1)	143 (45.8)	60 (19.2)	8 (2.6)	7 (2.2)	312 (100)
Workload reduction	122 (39.1)	133 (42.6)	34 (10.9)	13 (4.2)	10 (3.2)	312 (100)
Health Improved	88 (28.2)	134 (42.9)	67 (21.5)	10 (3.2)	13 (4.2)	312 (100)
Social Prestigious	104 (33.3)	114 (36.5)	69 (22.1)	11 (3.2)	15 (4.8)	312 (100)

Values in parentheses are percentages

The households' strategies the fuel use, known as fuel stacking, relay on both traditional and improved or clean fuels. (Masera et al. 2000) The benefits attached to improved cook stoves more than the realized benefits (Pattanayak and Pfaff 2009). During the survey the adopter households were asked to scale the benefits which they being reaped from this technology. Table 5 shows that the most important benefit realized is enough gas for cooking, 88.5%. The second most important benefit is, 39%, workload reduction at household level. The third most important benefit is social prestige which is reported 33%. Cleanliness of home is at four, 30%, and at five is health improvement, 28%. Bio-slurry most important benefit is about 25 percent. The enough gas for lighting and cooking are with low percentages.

Table 6: Information sources for biogas-digester adoption

Source of Information	**Total Number**	**Frequency**	**Percentage**
Through publicity. (Radio, Wall Chalking, leaflet)	312	35	11.2
Through PDBP	312	7	2.2
Through BCCs	312	43	13.8
Through marketers / sales persons	312	8	2.6
Through community leaders/Activists	312	5	1.6
Through friends/relatives	312	139	44.6
Through other biogas owners	312	75	24.0
Total		**312**	**100**

Finally, information is key part of technology diffusion process. The information disseminated and received through different channels and each has its own importance and effectiveness. Table 6 shows the sources of information by which the adopters received the information about the biogas digester and its subsidy. The information sources are comprised of : Publicity (Radio, Wall Chalking, leaflet) (11%); Pakistan Domestic biogas Program (PDBP) (2%); Biogas construction Companies (BCCs) (14%); Marketers/Sales persons (2.6%); community leaders/Activists; friends/relatives (44.6%); and other biogas owners (24%).Though these proxies are not

incorporated in adoption regression due to the least impact and wrong leading results but these sources of information clearly depict that how many people gather their information from the sources. It is evident from the table 6 that the maximum people 44.6% received the information from friends and relatives instead of Government advertisement 2%. It shows that Government need to advertise properly.

Among all these sources friends and relatives is most effective and reliable source of information. They exchange the information at social gatherings and combined sittings in the villages. And also information from other biogas owners can be effective because the households often visited each other and observe the functioning and use of plant; which demonstration effect on them.

Table 7: Adoption of Biogas digester

Variables	**(1)**	**(2)**	**(3)[1]**
Age (Years)	0.044 (5.53)**	0.046 (0.008)**	0.039 (0.009)**
Family Male (No.)	0.064 (1.02)	0.084 (0.064)	0.026 (0.069)
Family Female (No.)	-0.104 (1.41)	-0.147 (0.075)	-0.178 (0.079)*
House hold Area (in marls)	0.016 (1.93)	0.017 (0.009)	0.022 (0.009)*
House hold location at daira	0.249 (1.12)	0.385 (0.231)	1.049 (0.316)**
Household head's Education (schooling years)	-0.028 (1.24)	-0.047 (0.024)	-0.055 (0.025)*
Total land holding (acres)	0.026 (2.72)**	0.020 (0.010)*	0.018 (0.010)
Large animals (No.)	0.014 (1.46)	0.016 (0.010)	0.014 (0.011)
Fuel collection time (minutes)	-0.043 (6.53)**	-0.039 (0.007)**	-0.043 (0.007)**
Log Monthly Expenditure (Rs)	0.310 (0.57)	-0.046 (0.573)	0.347 (0.614)
Kitchen and living rooms are different	0.499 (2.51)*	0.589 (0.217)**	0.640 (0.250)*
Primary cook's education (schooling years)		0.092 (0.022)**	0.100 (0.024)**
Secondary cook's education (schooling years)		0.084 (0.027)**	0.070 (0.029)*
Log Monthly Expenditure on Health (Rs)		0.671 (0.306)*	0.792 (0.330)*
Most Patient household		-0.208 (0.297)	-0.061 (0.342)
Most risk averter household		-0.423 (0.230)	-0.353 (0.262)
Constant	-1.541 (0.62)	-2.313 (2.522)	
Observations	624	624	624

*Level of Significance:- *** p<0.01, ** p<0.05, * p<0.1*
1=Fixed effect Logit model at village level

After comparing the households who had adopted the biogas digester (50% of the sample) with households that did not adopt the biogas-digester, we applied binary-logit regression to know the factors behind the adoption of biogas digesters. (Table 7). In the first specification eleven socio-economic and demographic variables were included. In first model land holding, age, and separate kitchen from living room were found positively and significantly associated with biogas adoption. Interestingly, fuel collection time was found significantly and negatively associated with biogas adoption, it may be due to free availability of the substitutes. Households who collected the substitutes of the biogas were not much interested in adoption, usually the free availability of crops residuals, animal dung, and firewood stops the household from adoption. Though the variables male family members, household area, household location, large no. of animals, and monthly expenditures were not significant but they were positively associated with adoption.

Another very interesting results was found about the female members of the households, it was found that as the number of the female household members increased the probability of adoption decreased. It was due to the free availability of the labor, in rural area of Punjab, Pakistan mostly female counter part have to collect the fuel for cooking. The free availability of the labor in form of female of the households stop the households from biogas adoption.

For further confirmation of results and to study the impact of other household factors on the adoption, a second model with more variables was run. It was found that primary and secondary cook's education was significantly associated with the adoption of biogas-digester. As the education of the primary cook and secondary cook increased there were more chances to adopt the biogas technology. Furthermore, as the expenditure on health increased the probability to adopt the biogas technology also increased, this variable was also significantly associated with adoption. The hypothetical questions asked from the households to understand their attitude towards risk and patience. We also checked the robustness of the results and found that that the same sign and significance of the coefficients. In the same way outcomes of the analysis were the same in significance and association with the village-level fixed effect except few exceptions.

Conclusion

This research is very useful in understanding the adoption and diffusion of biogas-digesters. Our quantitative analysis adds to the limited literature of adoption process and compatibility of biogas-

digester. The study found that the adoption was positively correlated with socio-economic factors such as age, land holdings, health expenditures of the households, education of the cook, structure of the kitchen, location of the kitchen and large animals. On the other hand as the number of the female at households increased the probability to adopt the biogas technology reduced. This was due to easy availability of the free labor, women usually collet the firewood and dry the animal dung for cooking fuel. Adoption of biogas technology can be increased by providing the educational opportunities to the households' females. From descriptive analysis we found that proper advertisement, BCC reputation, and enhancing the subsidy level the adoption rate could be increase.

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