Research Article

Transforming the Livelihood of Rural Households: A Case of Successful Adoption of Biogas Technology in Khyber Pakhtunkhwa, Pakistan

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Abstract | Extensive use of conventional energy sources with negative impacts and existing poor farming systems in Pakistan have driven implementation of biogas technology by governmental and non-governmental organizations. This study focuses on the rate of successful adoption of bio gas technology and its multiple impacts on 113 farming households in two purposively selected districts of Khyber Pakhtunkhwa province (*i.e.* district Mardan and Dera Ismail Khan). Based on the descriptive nature of the study, quantitative approach was used with the help of a predesigned questionnaire. Frequency distributions, percentages, and paired T-tests were used to analyze and present the data. Results indicate that time spent on cooking and fuel collection significantly reduced after biogas adoption; and it also generates opportunity of alternative activities in saved time, and enhances fuel energy consumption pattern. Biogas technology brings improvement in the economic condition in terms of reduced expenditure (on buying other fuel energy materials and on buying chemical fertilizers), and in terms of higher earnings from selling trees. In light of the findings from this research, biogas technology has been proved to have great potential to improve the quality of life of farming households which in turn would positively affect the agriculture sector.

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Introduction

Socioeconomic progress of a country is highly dependent on energy which is a major determinant of quality of life and living standard. Therefore, it is important to find energy consumption pattern of a country while determining its economic development (Mirza *et al*., 2008). It is therefore, important to increase scale of energy production keeping in view that greater proportion of the power production comes from the renewable resources in order to reduce CO_2 emissions (OECD/IEA, 2018). The socioeconomic progress of a country also depends on reducing CO_2 emissions in order to fulfil the goals of the Paris Agreement and the Sustainable Development Goals (Hohne *et al.*, 2020).

In Pakistan, the demand for energy has increased dramatically over a period, and the current production level is quite insufficient to meet the demand (Asif, 2009). On the other hand, there is greater rural-urban disparity regarding energy supply in Pakistan where 54% of the rural poor in the country has no access to electricity (IEA, 2009). The rural sector is also characterized with a poor energy consumption pattern by using wood, crop residues, tree residues, fongas and cows' dung (Nawaz and Alwi, 2018). Burning of these fuel materials emits smoke and dangerous gases which pollutes the indoor environment. It brings various diseases such as respiratory diseases and eye-related infections (WHO, 2016), which increases average health costs (Pakistani Rupee 62 billion) annually (WWF, 2010a).

Biogas is made of any organic material *i.e.* animal dung and agricultural wastes *etc.* through anaerobic digestion producing a methane-rich gas (Amigun and Blottnitz, 2007). It not only reduces greenhouse gas emissions but also brings energy security because of its higher energetic potential (Angelidaki *et al.*, 2009). Biogas is produced in biogas digester which is an airtight container for biogas generation, made up of iron or bricks depending on its design. It has an inlet tank where the substrate is put along with water on daily basis and an outlet tank through which a certain amount of decomposed substrate *i.e.* bio-slurry flows out on daily basis. At the upper tip of the airtight container, there is a connection pipe for the provision of gas to the kitchen. Literature study on bio energy production in Pakistan indicates that there are no existing biogas digesters running on input materials other than animals' dung (particularly cows and buffaloes), showing the importance of livestock for biogas production (Akhtar *et al.*, 2017). According to Economic Survey of Pakistan 2016-17, the population of cows and buffaloes is 44.4 and 37.7 million, respectively (GoP, 2016-17). These animals are reared in rural and peri-urban vicinities, where disposal of animals' waste is a problem, causing emission of Green House Gases (GHG) into the atmosphere leading to global warming (WWF, 2010a), and serving as a breeding place for mosquitoes and flies (Flavin and Aeck, 2005). Therefore, animals' dung, not only is a potential source of biogas production, but also a waste to be manage wisely (Khurshid, 2009).

A major portion of Pakistan's population live in rural areas (62%) where a big majority (66%) is associated with agriculture for its livelihoods (FAO, 2009). Generally, farming community live an impoverished life having lack of access to sufficient and affordable energy, and having lack of access to modern farming technologies. Consequently, they are characterized of having lower productivity, lower income and lower savings which pushes them in vicious circle of poverty (Ghafoor *et al.*, 2010). The agricultural sector has been severely affected by the rising energy scarcity in the country. Therefore, a strong linkage between energy and agricultural sector is important for sustainable economic growth in the country (Jan and Akram, 2018).

There is enough research evidence regarding the generation of energy from renewable sources for the purpose to meet the energy demand (Awan and Khan, 2014). Due to aforementioned problems in Pakistan concerning energy scarcity, poor rural energy consumption pattern, higher rate of deforestation, and poor agricultural productivity; the governmental and non governmental organizations in Pakistan started dissemination of Renewable Energy Technologies (RETs) including installation of biogas plants across the country (Zaidi, 2014). Besides these efforts, there is a common perception in the country about failure of biogas technology. In a research conducted by Amir *et al.* (2016), it is noticed from their survey that major portion of households did not intend adopting biogas technology due to general risk of its failure. Therefore, majority of the rural households have been deprived of the usefulness of biogas up to a great extent. Summing up, there is lack of research on determining the rate of *successful adoption of biogas,* and quantification of impacts of biogas technology comprehensively in order to put some light on its contribution in achieving Sustainable Development Goals (SDGs). Successful adoption of biogas technology in this study means the adoption of biogas technology with standard biogas production and with better working condition. Therefore, this study particularly addressed these gaps by focusing on rate of successful adoption of biogas technology and its multiple impacts on the livelihoods of the rural households.

Materials and Methods

The current research was carried out in rural areas of KPK Province in Pakistan (previously known as the NWFP until 2010) which are well known for farming and livestock keeping (Figure 1 and 2). The authors have drawn the maps using GIS (Geographic Information System). Here, the main cash crops include maize, wheat, rice, sugar beets, tobacco, and fruits. In addition, the region has scarce electricity causing the poor energy consumption pattern. The climate of Khyber Pakhtunkhwa varies immensely for different regions, encompassing most of the many climate types found in Pakistan (Shah *et al*., 2010). KPK is relatively less developed ranking at third position out of the four provinces with 13 per cent share in the national economy (Pasha, 2014-15).

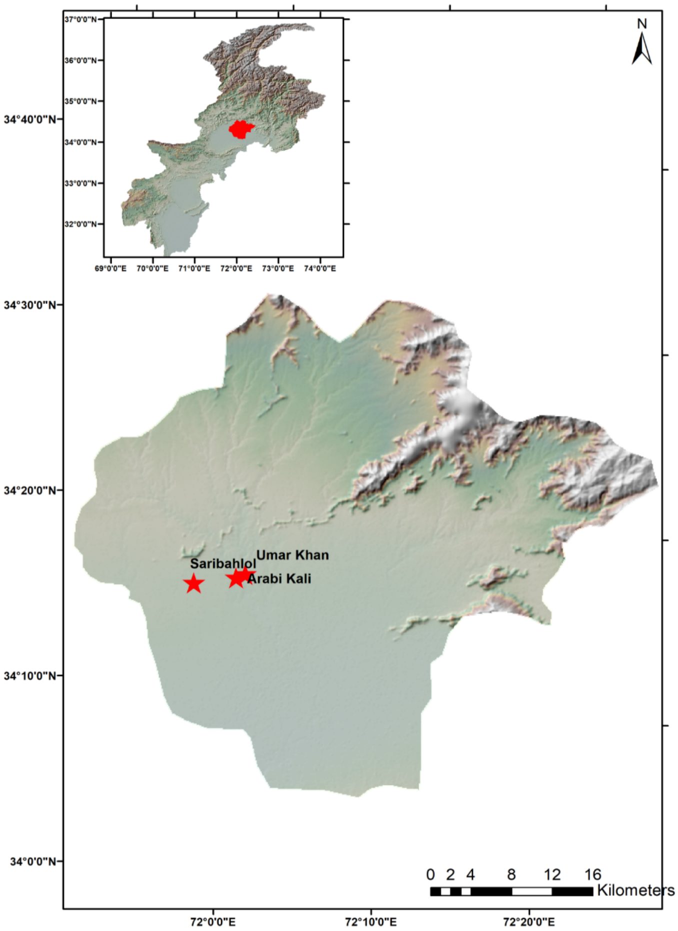

Figure 1: *Location map of selected villages in district Mardan.*

We used purposive sampling method to select study sites (due to relatively higher number of existing biogas plants) and respondents (only those biogas adopters whose plants were in working condition). As such, we selected 2 districts (Dera Ismail Khan and Mardan), then 2 tehsils, followed by 2 union councils and finally 7 villages. A Tehsil is an elected local government body headed by a Naib Nazim (which is equivalent to a Deputy Mayor) and a union council is an elected local government body headed by a Nazim (which is equivalent to a mayor). Data were collected from 113 households' heads having biogas digesters in working condition.

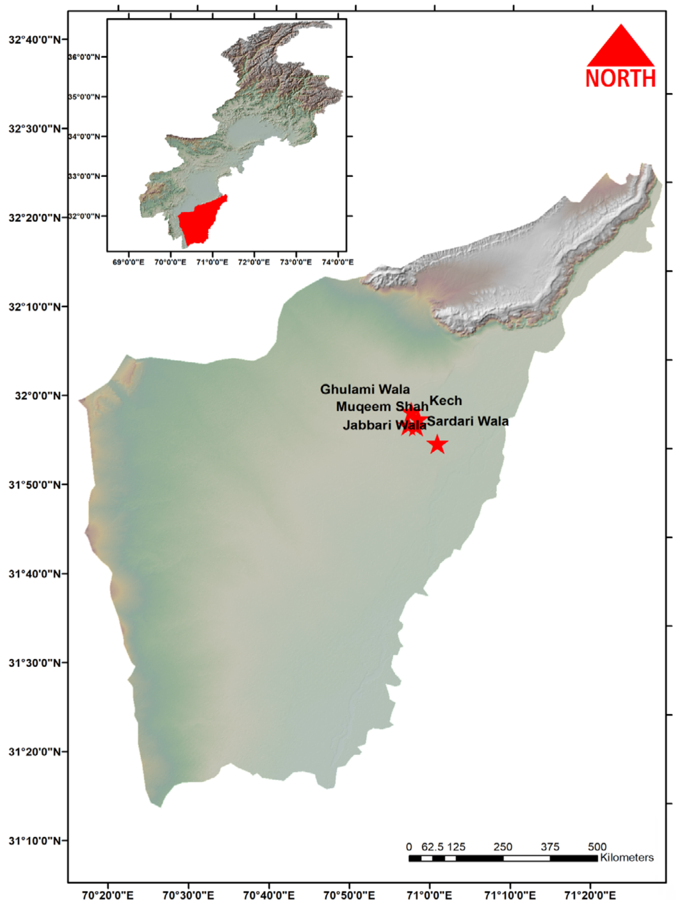

Figure 2: *Location map of selected villages in district Dera Ismail Khan.*

The nature of the study was descriptive and therefore, quantitative approach was employed by using a pre-designed questionnaire. A pilot study was undertaken in order to adjust the contents of the questionnaire, measure the time demand and to review any other issue of concern. For instance, some variables were replaced with others, which were more likely reflecting the subject under study. The data were collected during June-September 2020. Some interviews took place on the farms while some at houses based on the availability of respondents. For the respondents' ease, the interviews were stopped in case of signs of their tiredness; and were restarted later after a break. Variables related to this study were selected based on literature studies (Dirwayi, 2010; Zakaria, 2009). The collected quantitative data was compiled, computed and analyzed statistically. The following hypotheses (*null & alternative i.e.* H_0 *and* H_1 *respectively*) were designed based on the nature of variables under study (Box 1).

Box 1: *Description of null and alternative hypotheses for paired T tests.*

Hypothesis no.1

H_0: *Adoption of biogas plant saves labour's time for collecting fuel materials.*
H_1: *Adoption of biogas plant does not save labour's time for collecting fuel materials.*

Hypothesis no. 2:

H_0: Bio gas adoption saves women' time on cooking activities.
H_1: *Bio gas adoption does not save women' time on cooking activities.*

Hypothesis no.3:

H_0: *Household expenditure on fuel energy sources per year is significantly different before and after biogas adoption*
H_1: *Household expenditure on fuel energy sources per year is not significantly different before and after biogas adoption*

Hypothesis no.4:

H_0: *Household expenditure on buying chemical fertilizers per year significantly varies before and after biogas adoption*
H_1: *Household expenditure on buying chemical fertilizers per year significantly does not vary before and after biogas adoption*

Hypothesis no.5:

H_0: *Household income earned by selling trees per year significantly differs before and after biogas adoption.*
H_1: *Household income earned by selling trees per year does not significantly differ before and after biogas adoption.*

Hypothesis no.6:

H_0: *Household income per year is significantly different before and after biogas adoption*
H_1: *Household income per year is not significantly different before and after biogas adoption*

Source: *Authors' own analysis.*

The data was analyzed by using frequency distributions, percentages, and paired T-tests with the aid of SPSS. The formula of the paired T-test is given below:

$$\frac{\sum d}{\sqrt{n}(\sum d^2} \ldots\ldots (1)$$

Results and Discussion

General characteristics of the households

Table 1 summarizes the socio-economic characteristics of sampled population in the study area including age, cultivated land area, household size, livestock number and education of respondents. The results indicate that most respondents (63.7%) were relatively in the economically active age (up to 50 years), followed by less than half (34.5% respondents) with age group of (51-66 years) and only 1.8 percent with above 66 years.

Table 1: *General characteristics of the respondents.*

Respondents' age	Frequency	Percentage
Up to 50	72	63.7
between 51-66	39	34.5
above 66	2	1.8
Cultivated Land Area (acres)		
up to 5	80	70.8
Above 5	33	29.2
Family size		
up to 7	68	60.2
7+	45	39.8
Heads of cattle		
up to 8	76	67.3
Above 8	37	32.7
Education		
Illiterate	37	32.7
Primary	34	30.1
above primary	42	37.2

Source: *field research, 2020 (This field research was conducted in district mardan and dera ismail khan to achieve objectives of this research).*

Results further reveal that majority of the respondents (70.8%) were having up to 5 acres of land area unlike 29.2 percent of the rest of them having above 5 acres.

The household size has an implication on household labour force for biogas related activities. The results indicate that a majority of households (60.2 %) in the study area have up to 7 family members, while less than half (39.8 %) had a family size of more than 7. It indicates the availability of enough labour for carrying out biogas digester operations.

In fact, sufficient availability of livestock is mandatory for installing a biogas digester. According to Gautam *et al.* (2009), the livestock number is an indicator of availability of raw materials for the biogas adoption. In this context, the majority of the respondents (67.3%) had up to 8 heads of cattle while the rest of 32.7 percent of them had more than 8 animals.

Table 1 further indicates that a majority of household heads (37.2 %) have above primary level education, while (32.7 %) were illiterate, followed by 30.1 percent who had up to primary level education. This implies that a large part of the sample population can at least read and write, meaning that the individuals are trainable as far as knowledge of biogas digester is concerned. Household heads having more education are supposed to be more knowledgeable, informed, and aware of the adverse effects of fossil fuels on the environment (Walekhwa, 2010). They consider clean energy sources as environment-friendly compared to less educated and illiterate households.

Rate of successful adoption of biogas technology

The data presented in Table 2 show union council wise comparison regarding the total number of installed biogas digesters and rate of its successful adoption. The total number of installed biogas digesters in the area was 165 and the rate of successful adoption of biogas technology was found 68.5 percent for the study sites.

Table 2: *Rate of successful adoption of biogas in the study site.*

Union councils	Total biogas digesters	Successful	Rate of Successful adoption
Saribahlol	15	10	66.7%
Kech	150	103	68.7%
All	165	113	68.5%

Source: *Field Survey, 2020.*

However, the highest rate of successful adoption was found for Kech (68.7%), while in Saribahlol it was (66.7%).

Impacts on time spent on cooking and fuel collection

Generally, time is very essential in structuring daily life so that they can live more planned and productive life. In this study, impacts on time spent on fuel collection and cooking were also determined with the main purpose to see if there is quantitative reduction in workload after biogas adoption. A paired sample T-test was conducted to compare time spent on the collection of firewood in hours per month before and after biogas adoption. Table 3 shows that after biogas adoption, the households take significantly less time on collection of fuel materials (mean 13.84 & standard deviation 10.588) than before biogas adoption (mean 49.94 & standard deviation 4.507); [t(112)= 34.662, p = 0.000].

Thus, the null hypothesis was accepted which states that adoption of biogas digester saves labour's time for collecting fuel materials. The average time spent on fuel collection after biogas adoption reduced very significantly (from 49.94 to 13.84) with availability of sufficient amount of biogas. However, amount of biogas was insufficient for those households who had a greater number of family members than the ideal number of family members for a given size of biogas plant. These households had to rely on other alternatives along with biogas such as wood, dung cakes, and crop and tree residues. It is worth considering explaining the balance between time spent on the collection of fuel materials before & after biogas adoption. Before biogas adoption, children were mostly associated with fuel collection such as crop residues or tree residues, and men were involved in cutting trees and bringing it home, while women were making dung cakes (Dung cakes are locally hand-made product from cows' manure processed by rural women for fuel purpose in Pakistan (author's observation during field visit, 2020) inside home. After biogas adoption, the households only spent a little time on feeding biogas digester through mixing animals' dung and water on daily basis.

In this research, changes in time spent on cooking have also been studied with the introduction of biogas intervention. The time spent on cooking (hours per month) before and after biogas adoption, was compared by using paired sample T-test. The results presented in Table 3 shows that after adoption of biogas digester, the households take statistically significantly less time on cooking in hours per month (mean 66.52, standard deviation 2.380) than they took before biogas adoption (mean 97.37, standard deviation 2.151); t (112)= 103.040, p = 0.000. Hence, the null hypothesis is accepted which states that biogas adoption saves women' time on cooking activities. In addition, respondents reported that expenditure

Table 3: *Group statistics of time savings (hours per month).*

Variables		Mean	Standard deviation	Standard error	T value
Time spent on collection of fuel materials	*Before adoption*	49.94	4.507	0.424	34.662 (p=0.000)
	After adoption	13.84	10.588	0.996	
Time spent on cooking	*Before adoption*	97.37	2.151	0.202	103.040 (p=0.000)
	After adoption	66.52	2.380	0.224	

Source: *field research, 2020.*

Table 4: *Activities done by men and women in saved time.*

Statements	Recreation	Agricultural Work	Study	Household works	Sewing and embroidery
Activities done in saved time on collection of fuel sources	1 (1%)	70 (61.9%)	39(34.5%)	3 (2.6%)	–
Activities done in saved time on cooking	6 (5.3%)	2 (1.7%)	9 (7.9%)	56 (49.6%)	40 (35.4%)

Source: *field research, 2020 {Figures without brackets indicates frequencies & with brackets shows Percentages %}.*

Table 5: *Variables related to changes in economic condition of households (in PKR per year).*

Variables		Mean	Standard deviation	Standard error	T value
Expenditure on fuel energy materials	Before adoption	8557.52	1141.256	107.360	65.213 ($p<0.05$)
	After adoption	1230.09	255.610	24.046	
Expenditure on buying chemical fertilizers	Before adoption	6.73 E^4	19786.710	1861.377	106.641 ($p<0.05$)
	After adoption	3.26 E^4	19742.735	1857.240	
earning from selling trees	Before adoption	3504.42	2139.108	201.230	-16.804 ($p<0.05$)
	After adoption	7677.88	4694.426	441.614	
Annual income	Before adoption	3.65 E^5	73582.260	6922.037	-105.671 ($p<0.05$)
	After adoption	4.11 E^4	73430.477	6907.758	

Source: *field research, 2020.*

on health and detergents for washing cooking utensils also drops down with the use of clean and environment-friendly biogas. It implies that biogas is a substitute for fuel. Before biogas adoption, they were cooking through using fuel wood, cow dung, crop residues and tree residues which required more time as compared to biogas.

Because of time saving on collection of fuel materials and on cooking as mentioned earlier, the households spent that time in other activities mentioned in Table 4. According to results, 61.9 per cent of the respondents perceived that they spend the saved time from fuel collection in doing agricultural work. On the other hand, 34.5 per cent reported that their children use the saved time from fuel collection in doing study; followed by 2.6 per cent who allocated it in household activities while 1per cent spent it in recreational activities.

In the same way, 49.6 per cent of the respondents reported that saved time on cooking by female members of their family was spent in household activities; followed by 35.4%, 7.9%, 5.3% and 1.7% who spent it in sewing and embroidery; in study; in recreation and in agricultural work, respectively.

Impacts on economic condition

Economic benefits in terms of financial capital, directly affects households to achieve their livelihood objectives (DFID, 2000). This section presents a comprehensive overview of expenditures and earnings related to biogas. In developing countries, including Pakistan, the expenditure on traditional fuel energy is considerable which has been confirmed in this study. A paired sample T-test was applied to compare annual expenditure on fuel energy sources in PKR per year before and after biogas adoption as shown in Table 5. After biogas adoption, the households spend statistically significantly less expenditure on fuel energy sources (mean 1230.09, standard deviation 255.610) than they spent before biogas adoption (mean 8557.52, standard deviation 1141.256); $t (112) = 65.213$, $p = 0.000$. The null hypothesis is accepted which states that household expenditure on fuel energy sources per year was significantly different before and after biogas adoption.

The reduced expenditure created savings thereby benefiting households. However, before biogas adoption, such expenditure was more for tenants (having no trees) than owners-cum-tenants. Ultimately, they usually had to collect crop residues as well as buying fongas and fuel wood. They reported that using crop or tree residues and dung cakes were not perfectly productive fuel materials. That way, the cooking was difficult and time-consuming, created too much smoke, produced bad smell in the cooked food, and could not create too much heat compared to fuel wood and fongas. Therefore, after biogas adoption, this group of respondents got relatively much benefit. On the other hand, before biogas adoption, such expenditure was lower for owners-cum-tenants than tenants because they had their own trees at the farm. However, after biogas adoption, such expenditure further reduced. In addition, the maintenance cost of biogas digesters was found very low and was dependent on farmers whether they replaced the cooking stove or done other things such as pipe-repairing etc. Therefore, in this regard, some farmers could not biogas digesters and finally failed.

With the higher prices of chemical fertilizers in the country's market, farmers usually face financial scarcity and they look for alternatives. Bio-slurry, (Bio-slurry is the digested form of animals' dung coming out of the biogas plant on daily basis(observed during data collection)) a residual from biogas digester, is an effective fertilizer (Lovrenčec, 2011). Therefore, in order to see changes in farmers' expenditure on buying chemical fertilizers, their annual expenditure was compared based on before & after biogas adoption. As we can see in Table 5 that after biogas adoption, such expenditure is significantly less (t [112] =106.641, p = 0.000) with the mean value of 3.26 $E^4$and standard deviation of 19742.735. In contrast, before biogas adoption, the calculated mean value was far greater (6.73 E^4) with a standard deviation of 19786.710. Here, the null hypothesis is accepted which states that household expenditure on buying chemical fertilizers per year significantly varies before and after biogas adoption.

Similarly, we found remarkable increase in respondents' annual income earned by selling trees. The results presented in Table 5 shows that after biogas adoption, the households earn statistically significantly more income annually by selling trees (mean 7677.88, standard deviation 4694.426) than they earned before biogas adoption (mean 3504.42, standard deviation 2139.108); t (112) = -16.804, p = 0.000. So, the null hypothesis is accepted which states that income earned by selling trees per year significantly differs before and after biogas adoption. This implies that the use of biogas resulted in selling trees as an alternative source of income and thus helped in improving the household economic condition. The increase in earning along with reduced expenditure as mentioned in above section, indicates a better progress to alleviate poverty and income inequalityin country as according to Jamal (2016), the proportion of rural poor in Pakistan is 39.37 per cent.

Interventions for improving rural households' income are considered important for rural development. Considering biogas as an important intervention, annual income of households was determined before and after its adoption. The results in Table 5 shows that after biogas adoption, the households have statistically significantly more income per year (mean 4.11 E^4, standard deviation 73430.477) than they had before biogas adoption (mean 3.65 E^5, standard deviation 73582.260); t (112) = -105.671, p = 0.000. Hence the null hypothesis is accepted which states that income per year was significantly different before and after biogas adoption. Such increase in annual income is a result of rise in savings and additional earning with the use of biogas and, therefore, such rural energy innovations can be used as a poverty reduction strategy.

Conclusions and Recommendations

The main purpose of this study is to find out the impacts of successful adoption of biogas on farmers in two purposively selected districts in KPK province of Pakistan. Frequency distributions, percentages, and paired T-tests were used to analyze and present the data. Results indicate that using biogas not only saves time both on doing cooking and fuel collection, but also generates opportunity of alternative activities in saved time, and also enhances fuel energy consumption pattern. It also improves the economic condition in terms of reduced expenditure (on buying other fuel energy materials and on buying chemical fertilizers), and in terms of higher earnings from selling trees.

In the current study, improvements in farmers' livelihood indicate that adoption of biogas can be one of the effective strategies to contribute in achieving SDGs. Results from this study indicate, a decrease in expenditure and increase in income, indicate a good progress towards achieving SDG number one (No Poverty: End poverty in all its forms everywhere); reduced workload of women in making dung cakes and cooking, play a key role in achieving SDG number five (Gender Equality: Achieve gender equality and empower all women and girls). In this regard the following policy recommendations are suggested:

1. This intervention has proved to have great potential for bringing societal change in rural areas. Therefore, it should be implemented on large

scale by government in order to further broaden its scope.
2. There is need of further research focusing on potential of other organic wastes such as agricultural wastes and municipal wastes which may turn a farm enterprise into a net energy producer and which could eventually make possible to use underground water for irrigating rainfed and fallow lands. All these efforts can make farming system very efficient and sustainable in the long run.
3. There is urgent need from concerned organizations providing biogas technology to do a follow up of the existing biogas plants which are not operational for the purpose to make this technology successful.

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Novelty Statement

Biogas technology is a unique kind of renewable energy used by farming households in Pakistan. There are several studies conducted on determinant factors of this technology, but there lack of a quantitative study focusing on the impacts of bio gas technology on farmers' livelihood in Pakistan. It is relatively newer and therefore not too famous in KP which made our motivation towards this research. These were the major research gaps found during study design phase.

Author Contributions

Syed Muhammad Amir: Designed the study, collected data and wrote the article.
Shehzad Khan: Performed quantitative data analysis.
Asif Ali Abro, Ehsan Inamullah and Tahir Mehmood: Reviewed the literature and final editing of the manuscript.

Conflicting Interests
There is no potential conflict of interest among the authors with respect to the research, authorship, and/or publication of this article.

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