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Potential Assessment of Biogas and its Social Values in Khyber Pakhtunkhwa

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***Abstract*—** Khyber Pakhtunkhwa is considered to be one of the greenest province of Pakistan. But the province is in a great threat of deforestation as majority of the population are cutting trees rapidly in order to meet their need of cooking fuel. Majority of the rural population are using firewood as their cooking fuel as they have no access to national gas transmission line and cannot afford the LPG cylinders. Installation of domestic biogas plant is one of the alternative green solutions to this problem. This research is conducted to evaluate the overall potential of biogas from cattle manure in KPK and to carry out the multi prospect assessment of current biogas plants in KPK. Potential of biogas from cattle manure was calculated from statistical data of KPK and literature review. Questionnaires were designed to conduct survey of 15 installed biogas plants in different districts of KPK. The total potential of biogas from cattle manure in KPK was found to be 532.9 million cubic meter per year. The equivalent potential of electricity generation from biogas is 1,344200 GWh per year. FATA regions have the highest potential of biogas which is 22 percent of the total whereas district D.I. Khan has a potential of 8 percent of the total. From the results of multi prospect assessment of current biogas plants it was found that 26.67 percent of the total plants were dismantled. 60 percent of the plants were fixed dome type while 40 percent were floating type. 40 percent of the plants were funded by the government, 33.33 percent by the NGOs and 26.67 percent were constructed by user on their own finance. 100% of the user agreed that biogas helps in firewood reduction. 92.86 percent of the users complaint about the maintenance of plant as a major challenge. 64.29 percent of the users wanted storage of biogas facility in the plant. On average, Rs. 2130 per month per household were saved in energy expenditure of cooking fuel with the help of biogas. 40 percent of plants users were satisfied, 33.33 percent were highly satisfied and only 26.67 percent responded as not satisfied.

***Keywords*—** Biogas, Sustainable Energy, Social Values, SPSS

I. INTRODUCTION

Energy is thought to be the backbone of any economy and most important measure of socioeconomic development of a country. In Pakistan the current situation of energy and human development process is at susceptible and the power outage and energy crisis is affecting each and every sector of the economy and ultimately the human development. Although Pakistan has abundant natural resources and there is huge potential of investment in the renewable and green energy resources [1]. Pakistan has always been facing severe crisis of energy since decades and currently facing an electricity outage of almost 8-12 hours in urban areas while 18 hours in rural areas. These energy crisis has directly or indirectly affected all sectors of the economy of the country [2]. The installed capacity of electricity generation in year 2017-2018 was 33,433 MW which has now recorded as 34,242 MW in July 2019. Similarly the generation in 2017-2018 was recorded as 82,011 GWh which has now increased to 84,680 GWh. The percentage increase in capacity counts 2.5% and in generation 2.1% [2] Due to increasing population, the demand of energy in Pakistan is increasing day by day. Like many other developing nations of Asia, Pakistan is dependent on import oil and LNG.

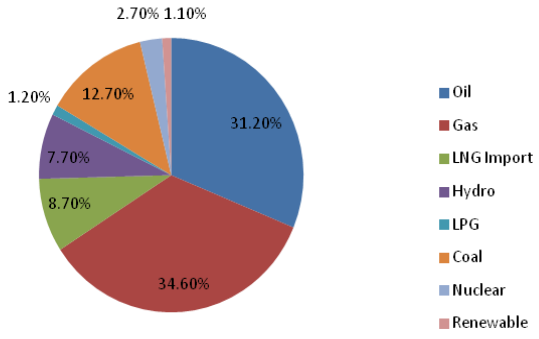

Figure I Energy Supply Mix of Pakistan [3]

Since the renewable sources of energy are gained of natural process, they are more reliable, always available and cost effective in some cases. They have widespread benefits to meet the energy crisis. Renewable energy resources are clean, green and free of carbon dioxide. The contribution of renewable energy in Pakistan energy supply was 0.3% in 2015. This contribution has steadily increased to 1.1% in the year 2018.

The total install capacity of renewable energy in Pakistan is 1,637 MW, while the generation is 3857 GWh [3].

TABLE 1: ELECTRICITY FROM RENEWABLE ENERGY SOURCES [3]

Technology	Capacity(MW)	Genration (GWh)
Solar Energy	430	768
Wind Energy	1006	2101
Bagass	201	988
Total	1637	3857

Per capita consumption of energy of a country is directly proportional to its economic growth. In Pakistan period of a high GDP growth rates were found because of high per capita consumption of energy and vice versa. However, the growth rate of energy consumption per capita as a whole is very discouraging. Pakistan is ranked as 164th in world based energy per capita consumption that is 449kWh. Comparison of Pakistan with other developed nations is given in the figure below [4].

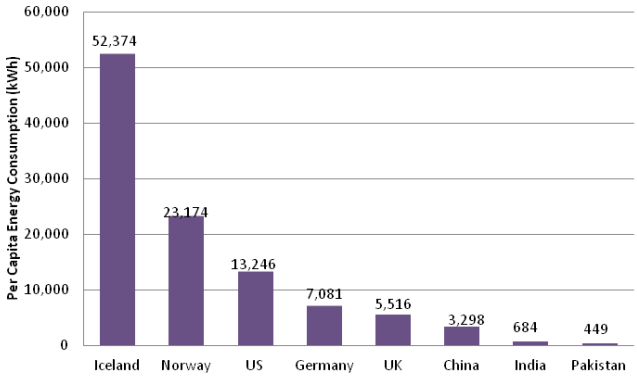

Figure I-1: Per Capita Energy Consumptions in 2013 (kWh) [4]

A. *Domestic Fuel used in Pakistan*

As per Household Survey of Pakistan (2015-16) the table below shows the average monthly expenditure on energy (cooking fuel and lightning) of Pakistan rural and urban areas at the household level. The total expenditures on energy, at the domestic level is about Rs. 2622.92 in Pakistan.

TABLE 2: HOUSEHOLD AVERAGE EXPENDITURE ON ENERGY IN PAKISTAN[5]

Energy Type	Pakistan	Rural Area	Urban Areas
Average Exp. in Rs. Per month	2622.92	2520.52	2800.36
PercentExpenditure	100.00	100.00	100.00
Fire Wood	20.70	30.80	4.94
Kerosene Oil	0.61	0.95	0.08
Charcoal	0.44	0.66	0.10
Coal	0.08	0.12	0.01
Dung Cakes	5.00	7.78	0.65
Gas(Piped/LPG)	13.07	8.78	19.76
Electricity	50.64	38.61	69.40
Generator	2.59	1.48	4.34
Cotton Sticks	3.44	5.40	0.40
Other	3.43	5.42	0.32

The highest single expenditure on energy in rural and urban areas of Pakistan is electricity. Similarly the second highest expenditure is natural gas in the urban area and firewood in the rural area of Pakistan. It is clear from the table that the rural areas consume more of their expenditure on the fuels for cooking puposes. 50.18% of their energy expenditure, is on biomass fuels (wood, agricultural wastes, coal, and dung) [5].

B. *Rural Area Dependency on Biomass*

Rural households in Pakistan are mostly dependent on biomass (Firewood, shrubs, Dung Cakes, Agri. Wastes) for their cooking needs. About 29% of biomass consumers residing in rural areas have reported that they buy wood for the cooking needs. In this about 84% of biomass consumers buying firewood in urban areas and the remaining are collecting it. Another major source of fuel for cooking needs in rural areas is dried animal dung cakes. About 70% of the Pakistani population lives in rural areas. Collecting of firewood and shrubs and manual formation of dung cakes is mainly done by women and children in rural areas of Pakistan [6].

C. *Biogas as an Alternative*

The energy crises can be very efficiently solved with the help of biofuels with advanced energy technologies. Like other renewable sources of energy, biogas (methane rich) that is obtained through the process of anaerobic digestion (AD) is thought to be an important source of energy. The development of this technology is very high in Europe due to their supportive renewable energy policies. For example the highest rate of biogas technology adoption is in Germany where 8700 large scale biogas plants are operating for the generation of heat and electricity. In Germany 137 biogas plants supply gas to the transport sector [4–6] Similarly this technology is also advanced in China. They are using densified biofuels at small as well as large scale. These densified fuels are very popular due to high energy density [7,8]. In developing nations however this technology is used only as a fuel for cooking and lighting at the domestic level. In order to overcome the current energy crses of Pakistan, initiatives are required to harness other sources like hydel, biogas energy, nuclear energy, micro hydel and biodiesel energy [12].

D. *Potential of Biogas in Pakistan*

Mostly people in the rural area of Pakistan, are self employed and have adopted livestock animal for their source of income. Almost 30 million to 35 million of people, get their 30 percent to 40 percent of income, from livestock animals [13]. By 2017-18 economic survey of Pakistan the total population of livestock is about 196.5 million that produce total manure of 744 million of Kg per day, that can be use for the generation of biogas with the help of anaerobic digestion. As 1 m^3 of biogas can be produced from 6 kg of animal manure. So the total potential of biogas from animal manure in Pakistan is 124 million m^3 [14].

E. Benefits of Biogas

The aim of a biogas plants technology is to utilize the organic wastes like animal manure and produce two worthy products, which are biogas and the digested slurry which is also called the digestate. The first one is a source of renewable energy, that could be further use for the purpose of green electricity generation, cooking, heat, and as a transport fuel etc. The digestate can be utilized as an organic fertilizer or can be processed to a refine fertilizer product [15]. According to a research, a family sized biogas plant replaces 316 L of kerosene, 5,535 Kg of firewood, and 4,400 Kg of cattle dung cake per year. Which means that a family sized biogas plant can reduce NOx of 16.4 KG, SO_2 of 11.3 KG and CO of 987 Kg where as volatile organic compounds of 69.7 KG per year [16]. In most of the developing countries diseases of respiratory infections, pneumonia of younger childrens, pulmonary diseases, asthma, cataracts, tuberculosis, hypertention and lung cancer have been reported, which are associated with the indoor smoke of biomass fuel burning [17]. Use of biogas technology for the rural household can help to relief from the abdominal pains associated to the reduced workload on the women and children which are collecting and carrying the fuelwood over a long distance and making of the dung cakes from the animal manure [18]. The use of the digestate from biogas plant as biofertilizer is an efficient way, to maintain nutrients in society. By adopting it, it will be possible to regain the broken cycle of nutrient between the consuming people of the cities nowadays and the productive soils of the countryside , which could help to reduce the use of synthetic fertilizers [19].

II. METHODOLOGY

The research methodology for this study consists of Literature Review, Data Collection, Questionnaire Survey and Data Analysis. First of all in order to evaluate the total potential of biogas plants in KPK, data of livestock in KPK was collected through different organization. Using literature review and that data of livestock the total potential of biogas plants in KPK was calculated. In the second phase a questionnaire was designed for a survey based on different questions to investigate different biogas plants that are installed in KPK. The socio-economics of those plants were investigated along with sustainability and challenges related to biogas plants. SPSS software was used to analyze this survey data. In the third phase a survey was conducted of the households who are not using biogas. Data was collected through questionnaire about their cooking expenditure, biogas potential, livestock existence, health concerns etc.

In order to evaluate the social and economic values, sustainability, impacts on society, health and environment of biogas plants, 15 biogas plants that are installed in KPK were visited. These plants were selected from different districts of KPK Dir, Swat, Mardan, Malakand, Nowshehra, Pesawar and Kohat. Both self installed, government installed and NGO installed plants were assessed. 100 households randomly were interviewed from different rural areas of KPK.

Since the objectives of this research is completely based on the qualitative analysis. So, the methodology approach for the qualitative analysis of current biogas plants installed in KPK was the use of SPSS software. Different parameters about the biogas plants were entered into this software and complete analysis were performed with the help of it.

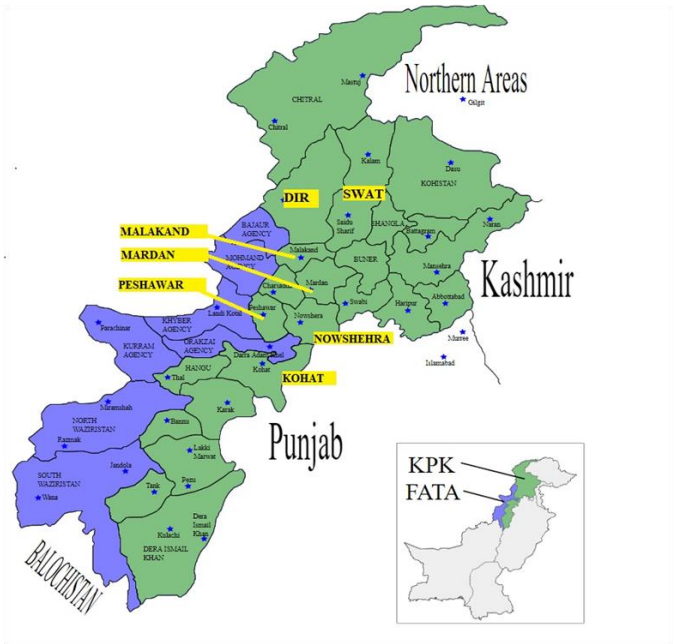

Figure II-1: Location of Biogas Plants Survey

A. Calculations for Total Biogas Potential

For the assessment of total potential of biogas in KPK, statistical data of livestock has been used from the KPK Bureau of Statistics. The data which is used for the determination of biogas potential in KPK is only for the dairy cattle and buffaloes. Because the attainability of manure from the cattle is maximum. The following formulae will be used to calculate the overall potential of biogas in KPK from manure of cattle. These formulas will be applied over the manure obtained from cattle each district wise.

The fresh manure obtained in tons per day is given by the following formula.

$$M_F = \frac{N_A \cdot M_{PPA}}{1000}$$

Where M_F is fresh manure obtained in tons per day (t/d), N_A is total number of animals, M_{PPA} is Manure production per animal in Kg. In Pakistan, the average manure production per animal(cattle/buffalo) per day is 15Kg [13].

Now, the total solid manure obtained in tons per day is calculated as follow:

$$M_S = M_F \cdot M_{SR}$$

Where M_F is Fresh Manure in tons per day and M_{SR} is Solid manure ratio and is equal to 12.5% for fresh manure [20].

The main factor required for the total potential of biogas annually is called annual total usable soild manure and is calculated in tons per year by the following relation.

$$M_{TUS} = M_S \cdot M_A \cdot 365$$

Where M_{TUS} annual total usable solid manure in tons per year, M_S is solid manure in tons per day and M_A is attainability of

manure in percentage. We will take the attainability of animal manure as 50%.

After calculating the total annual usable solid manure the relation for total biogas amount in cubic meter per year is as follow:

$$BG_T = M_{TUS} \cdot BG_{Conv}$$

Where BG_T is the total biogas amount in cubic meter per year and BG_{Conv} is the amount of biogas obtained in cubic meter from 1 ton of solid manure. This value is 200m^3/t and is assumed to be constant [21].

B. Calculations for Total Electricity Generation from Biogas

Once, the total biogas production from the animal manure is obtained in cubic meter per year. The next important stage is to determine the total potential of electricity from biogas. For that the heating value of biogas will be important to calculate. If a gas engine is used for the electric generation from biogas, we must first find out the total heating value of biogas from the following equation:

$$H_{VT} = BG_T \cdot H_V$$

Where H_{VT} is the total heating value in MJ of the total biogas BG_T. Whereas, H_V is the heating value of unit cubic meter of biogas. It is important to note that the H_V of one cubic meter of biogas is known to be 22.7MJ/m^3 [21].

Now the final equation for the potential of electricity generation from biogas of animal manure will become as follows:

$$E_{BG} = \frac{H_{VT} \cdot \eta_{BG}}{3 \cdot 6}$$

Where, E_{BG} is the total electricity potential from biogas in MWh per year. If a gas engine is used for the electricity generation. Then using biogas as fuel its efficiency is η_{BG} which is 40% [j].

C. Population of Livestock in KPK

Since the last census of livestock has been carried out in 2006 and there is no latest data available in Pakistan Bureau of Statistics. So, our results will be based on data of census 2006. In this research our target is to calculate the potential of biogas from manure of cattle and buffaloes. The total population of cattle and buffaloes in KPK according to the census 2006 is given in table below [22].

TABLE 3: POPULATION OF LIVESTOCK IN KPK [22]

District	Cattle	Buffaloes	Total Heads
Peshawar	223,150	143,481	366,631
Nowsheha	190,669	106,892	297,561
Charsadda	239,899	110,697	350,596
Mardan	247,445	115,841	363,286
Swabi	203,076	103,566	306,642
Kohat	174,299	27,277	201,576
Hangu	70,451	9,521	79,972
Karak	212,496	2,054	214,550
D.I. Khan	411,432	205,634	617,066
Tank	67,104	17,975	85,079
Bannu	168,927	56,181	225,108
Laki Marwat	98,550	3,827	102,377
Abbottabad	111,415	104,582	215,997
Haripur	130,215	106,911	237,126
Mansehra	181,973	191,064	373,037
Battagram	119,699	78,233	197,932
Kohistan	250,910	51,163	302,073
Swat	253,790	117,101	370,891
Shangla	204,946	129,041	333,987
Buner	131,985	79,644	211,629
Chitral	174,842	296	175,138
Upper Dir	232,013	4,964	236,977
Lower Dir	249,007	16,258	265,265
FATA Regions	1,619,593	145,292	1,764,885
Total in KPK	5,967,886	1,927,495	7,895,381

III. RESULTS AND IMPACTS

A. Total Potential of Biogas in KPK

According to the calculation as discussed in the methodology chapter, the results of total biogas potential were generated using excel sheet. The attainability of manure M_A was assumed as 50%. The formulae were putted in excel sheet and after putting value of different constants against every district of KPK the potential was calculated. According to these calculations, the overall potential of biogas in KPK is 532.9 million cubic meter per year. Similarly the total potential of equivalent electricity from biogas is calculated as 1,344200 GWh per year. The results of biogas potential and electricity potential from animal manures district wise in KPK are shown in the excel sheet below:

TABLE 4: BIOGAS POTENTIAL RESULTS

District	N_A	$M_P = N_A.M_{PPA}/1000$ (t/d)	$M_S = M_P.M_{SR}$ (t/d)	$M_{TUS} = M_S.M_A.360$ (t/y) (1000)	$BG_T = M_{TUS}.BG_{Conv}$ (m^3 y) (million)	$H_{VT} = BG_T.H_V$ (GJ/y) (1000)	$E_{BG} = H_{VT}.\eta_{BG}/3.6$ (GWh/y) (1000)	Percentage%
Peshawar	366,631	5,499.5	687.4	123.7	24.7	561.8	62.4	4.6%
Nowsheha	297,561	4,463.4	557.9	100.4	20.1	455.9	50.7	3.8%
Charsadda	350,596	5,258.9	657.4	118.3	23.7	537.2	59.7	4.4%
Mardan	363,286	5,449.3	681.2	122.6	24.5	556.6	61.8	4.6%
Swabi	306,642	4,599.6	575.0	103.5	20.7	469.9	52.2	3.9%
Kohat	201,576	3,023.6	378.0	68.0	13.6	308.9	34.3	2.6%
Hangu	79,972	1,199.6	149.9	27.0	5.4	122.5	13.6	1.0%
Karak	214,550	3,218.3	402.3	72.4	14.5	328.7	36.5	2.7%
D.I. Khan	617,066	9,256.0	1,157.0	208.3	41.7	945.5	105.1	7.8%
Tank	85,079	1,276.2	159.5	28.7	5.7	130.4	14.5	1.1%
Bannu	225,108	3,376.6	422.1	76.0	15.2	344.9	38.3	2.9%
Laki Marwat	102,377	1,535.7	192.0	34.6	6.9	156.9	17.4	1.3%
Abbottabad	215,997	3,240.0	405.0	72.9	14.6	331.0	36.8	2.7%
Haripur	237,126	3,556.9	444.6	80.0	16.0	363.3	40.4	3.0%
Mansehra	373,037	5,595.6	699.4	125.9	25.2	571.6	63.5	4.7%
Battagram	197,932	2,969.0	371.1	66.8	13.4	303.3	33.7	2.5%
Kohistan	302,073	4,531.1	566.4	101.9	20.4	462.9	51.4	3.8%
Swat	370,891	5,563.4	695.4	125.2	25.0	568.3	63.1	4.7%
Shangla	333,987	5,009.8	626.2	112.7	22.5	511.8	56.9	4.2%
Buner	211,629	3,174.4	396.8	71.4	14.3	324.3	36.0	2.7%
Chitral	175,138	2,627.1	328.4	59.1	11.8	268.4	29.8	2.2%
Upper Dir	236,977	3,554.7	444.3	80.0	16.0	363.1	40.3	3.0%
Lower Dir	265,265	3,979.0	497.4	89.5	17.9	406.5	45.2	3.4%
FATA Regions	1,764,885	26,473.3	3,309.2	595.6	119.1	2,704.2	300.5	22.4%
Total in KPK	7,895,381	118,430.7	14,803.8	2,664.7	532.9	12,097.7	1,344.2	100.0%

The district wise potential of biogas is shown in the figure below. According to this figure the highest potential area is FATA, which is almost 120 million cubic meter per year. District D.I.Khan has the second highest potential of biogas which is about 41.7 million cubic meter. Similarly, Peshawar, Charsadda, Mardan, Nowshehra, Mansehra, Swat, Shangla and

Kohistan are the high potential areas having potential more than 20 million cubic meter per year each. The low potential Districts are, Hangu, Kohat, Bannu, Laki Marwat, Tank, Lower Dir, Upper Dir, Chitral, Battagram, Buner, Haripur, Abbotabad, and Karak which have potential of less than 20 million cubic meter per year each.

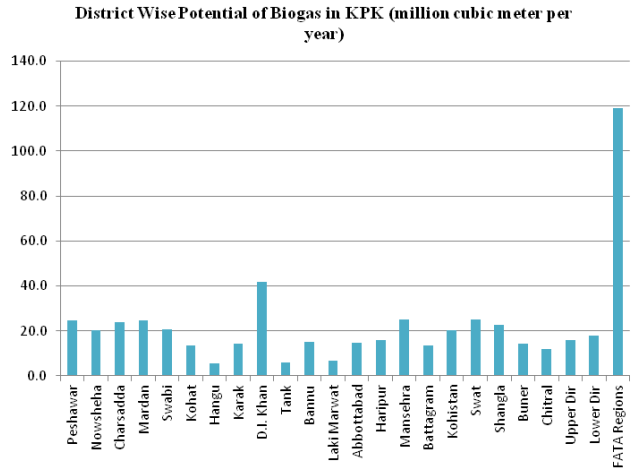

Figure III-1: District Wise Potential of Biogas in KPK

B. Analysis of Biogas Plantsin KPK

In order to understand the current situation of biogas plants in KPK, 15 biogas plants were visited in different districts of KPK. Different aspects of the plants were observed on the household. Like its social impact, social value, environmental benefits, impact on energy expenditures, and challenges related to the plants.

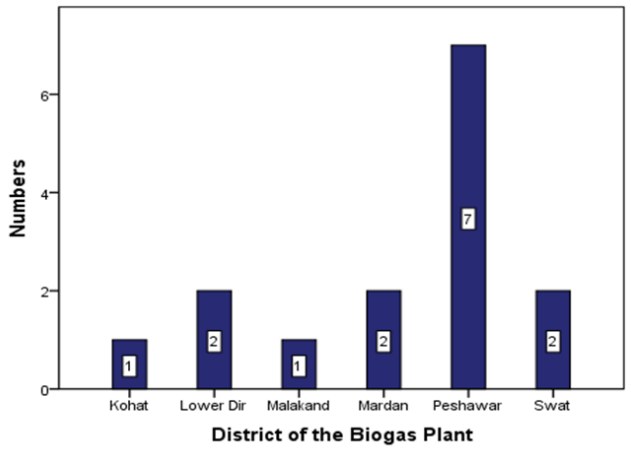

Figure III-2: Plants Visited Each District

Out of the total 15 plants, 4 plants were found non operation and were dismantled. Only 11 plants, which become 73.3% of the total were in operational conditions.

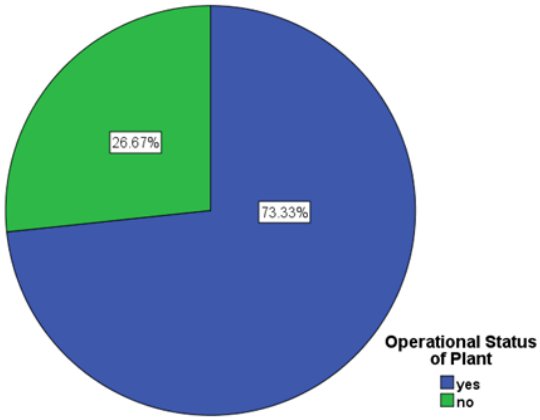

Figure III-3: Operational Status of Plants

The main reason of the dismantled plants was maintenance. The plants constructed with government subsidy were dismantled. It was observed during the visit that there were only two types of the plants installed in KPK. In which 60% of the plants were fixed dome plants. While 40% of the plants were floating type. It is worth noting that the plants installed by PCRET with the government subsidies were floating type.

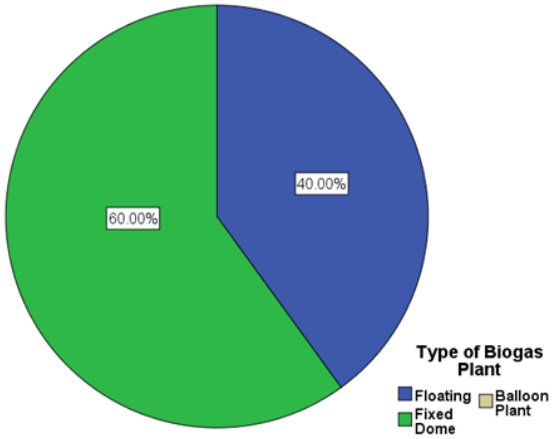

Figure III-4: Types of the Plants

40% of the plants were funded by government, 33.3% were sponsored by NGOs while only 26.6% of the plants were constructed by owners on self financed basis. This means, that adoptability of the plants with self finance is very less in KPK and people cannot afford to construct the plants on their own

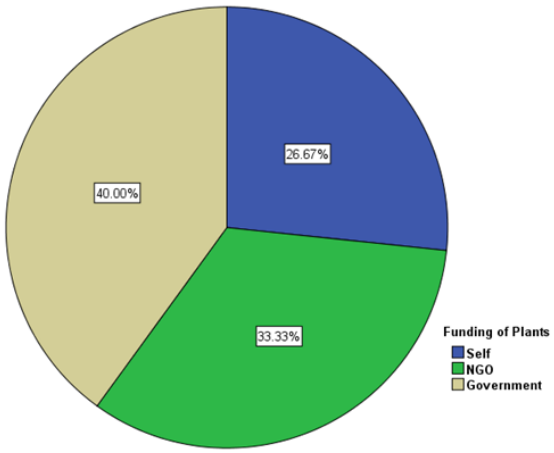

Figure III-5: Funding of the Plants

The biogas plant owners were asked about the benefits of it through structured questionnaire. Out of the 11 operational plants, 100% agreed that using biogas helps to reduce the use of firewood. 36.3% agreed upon reduction in electricity bills. 72.3% of the owners said that biogas is always available. 45.5% agreed with health benefits of using biogas.

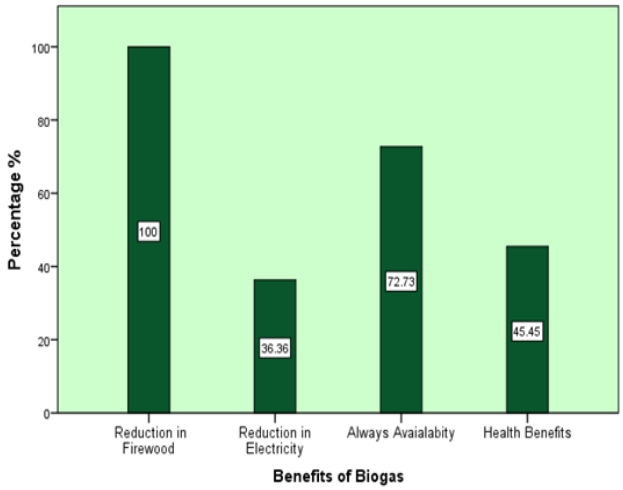

Figure III-6: Benefits of Biogas Plants

92.86% users complaint about the maintenance of the digester. The next important challenge to the biogas owner was the storage of biogas. 64.29% of the respondents said that they want to store the gas in cylinders. 42.86% of the users said that they face difficulties in operation of the plants. 28.57% of the users said that they face difficulties in providing animal manure to the plant, since they have less quantity of cattle.

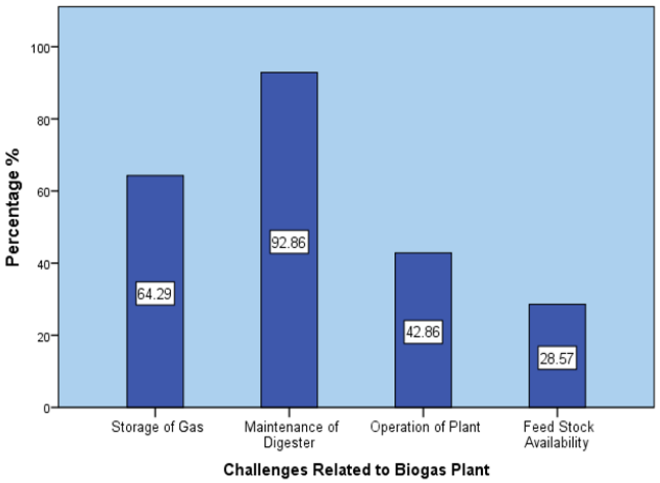

Figure III-7: Challenges Related to Biogas Plants

Considerable amount of reduction have been reported by the biogas plants owners in their household cooking fuel's expenditures. 1 of the 11 plants was installed by a restaurant owner and according to that owner the total saving of cooking fuel bill was recorded as Rs. 2000-3000 per day. 4 of the households have reported reduction in cooking fuel expenditure by Rs. 2000-3000 per month. Similarly, 3 households recorded reduction by Rs. 1000-15000 per month, while the other 3 households said that their energy expenditure on cooking fuel has been reduced by Rs. 1500-2000 per month. On average Rs. 2130 per month can be saved by each household with the help of biogas.

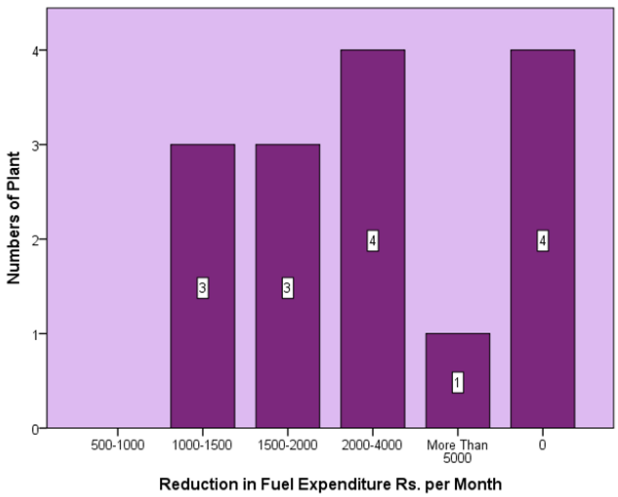

Figure III-8: Reduction in Fuel Expenditure (Rs. Per Month)

The satisfaction level of the biogas plants user was quite satisfactory as 5 numbers of the users responded to the question as highly satisfied. While, 6 numbers of users responded as satisfied. 4 numbers of the users were those whose plants were dismantled so they responded as not satisfied to the question.

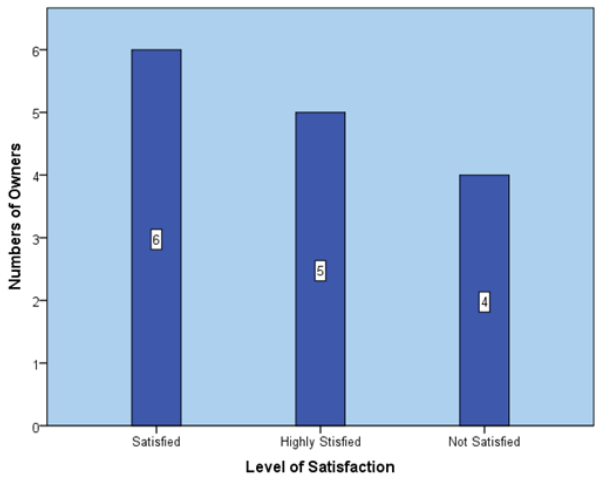

Figure III-9: Leverl of Satisfaction of Households Using Biogas

In Khyber Pakhtunkhwa the average energy expenditure on cooking and lighting fuel was recorded as Rs. 3364.28 per month per household. In which the major share was recorded of firewood which was 35.81% of the total expenditure.

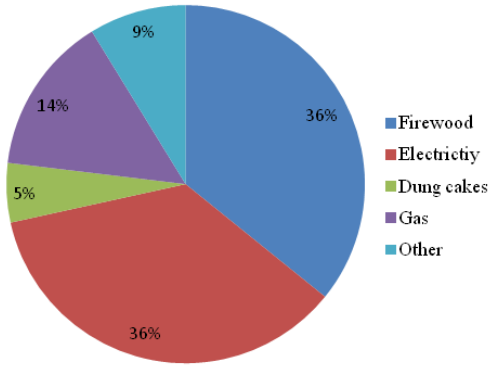

Figure III-10: Expenditures on fuels for cooking and lighting in KPK

The next major share was of electricity which was 35.78% of the total expenditure. Other than that, SNGPL gas expenditures were 14.33%, and dung cakes were as much as 5.34% of the total expenditure.

CONCLUSION

From the literature review it is concluded that biogas has plenty of benefits towards the sustainable development of communities. With increasing population, the need of cooking fuel is increasing as well. The need of the time is to go towards the alternative energy solutions that should be sustainable, affordable as well as eco friendly. Biogas is one of the energy alternative options that cover these three important aspects. Majority of the population in KPK is depending on agriculture and livestock as their source of economy. Having a huge population of 7.89 millions of cattle, KPK has potential of 532 million cubic meter of biogas production per year in KPK and has a potential of equivalent electricity generation of 1,344200 GWh per year. The highest potential district of KPK is D.I.Khan, which has 8 percent of total potential. FATA regions have collectively 22 percent of the total potential. It is concluded from the structured questionnaires designed for the analysis of current biogas plants at KPK, that 26.67 percent of the plants in KPK has been dismantled while 73.33 percent of the plants are in perational conditions. 40 percent of the users were satisfied with the biogas technology, 33.3 percent of the respondents were highly satisfied, while only 26.67 percent of the respondents were not satisfied. The average expenditure on cooking fuel in KPK is Rs. 3364.28 per month per household Whereas, the average reduction by biogas in cooking fuel expenditure per household per month was found to be Rs. 2130. 100 percent of the plants installed in KPK are for cooking purpose, while 26.67 percent of the plants were also running generators through biogas. 100 percent of the respondents were facing challenges in the maintenance of the plants. It was also found through the study that most of the plants user wanted gas storage facility so that they can have gas for any emergency use. It is worth noting that, 100 percent of the plant owners said that the biogas plant helps in firewood reduction and during survey it was noted that those household who has biogas plants installed have no use of firewood for the cooking purpose, which means that deforestation issue can be solved by developing the biogas technology in the rural communities of KPK. The bio slurry of the plant was used as a bio fertilizer for the agricultural activities by 73.3 percent of the users and they were very satisfied with the yield of crops and other agricultural products.

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