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Carbon credit potential of biogas plants in Pakistan

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----------ABSTRACT----------
Biogas technology, beside the source of energy and manure, supplies an admirable prospect for alleviation of greenhouse gas (GHG) emission and reduces global warming through replacement of firewood for cooking. A study is carried out to calculate biogas potential from animal dung in Pakistan, global warming potential from animal's dung and GMP by domestic biogas plant and thereby earning carbon credit in Pakistan. Dairy information of Pakistan states that Pakistan has approximately 39.7 and 34.6 million animals in the form of cows and buffaloes respectively produce about 1.12 million kg accumulated dung per day. The international market of CO_2 is USD20 to 40/ton, carbon market initiative increased in 2018 as USD7 to 16/tCO_2e as compared to 2017. It is about 9.7ton CO_2 equivalent global warming per annum can be mitigated by a domestic biogas plant. In the light of clean development mechanism (CDM), it can be earned USD242.5 through carbon credit yearly from the mitigation of GHGs discharge. A domestic range biogas plant can replace usage of fossil fuel approximately 4,400 kg animal dung, 5,535 kg firewood and 316 Litters of kerosene oil. In this way with the replacement of fossil fuels to biogas, yearly about to 16.4, 11.3, 987.0 and 69.7 kg of NO_X, SO_2, CO and volatile organic compounds can be reduced respectively from the atmosphere. Presently, about 6000 domestic biogas plants has been installed throughout country by government of Pakistan, which are capable to mitigate 0.06 Mt CO_2 equivalent and yearly earn USD 1.455 million as carbon credit under Clean Development Mechanism. If total collectable dung is used for biogas production, then in Pakistan about 5 million biogas plants can be installed and annually USD 1206.5 million can be achieved as carbon credit with reduction in GHGs production from household burning of firewood and kerosene oil. The declination in global warming should encourage policy makers to promote biogas technology to war of climate change and integration of carbon revenues will help the farmers to develop biogas as a profitable activity.

KEYWORDS : Biogas Potential, Global warming potential, Global Warming Mitigation, Carbon Credit.

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I. INTODUCTION

Pakistan has been facing the energy crises for last decades. Annually on energy sources, Pakistan is spending millions of USD to fulfill energy demands. Pakistan is populated country with estimated 207 million people, and it is poorly surviving as an energy deficient country in South Asia. Yearly average increment in population is about 2.5%. In Pakistan, about 54% of the energy supplies are encountered by conventional resources, whereas the remaining 46% energy is achieved from biomass sources such as fuel, wood and agricultural residues. Wood is taken from forests. Annually Pakistan is losing forest about 41000 hectors and this quantity of cutting trees is becoming cause of deforestation at the average rate of about 1.63% per year [1]. In Asia continent from total emissions, Pakistan is producing 18% CO_2 and N_2O emission from animal waste and is estimated 86,855 kg per annum [2]. Pakistan is full of renewable energy resources like solar, wind, hydropower and geothermal energy but these resources are expensive. Besides it, biogas is one of the cheapest bio-fuel and renewable substitute as compare to the other renewable energy resources [3, 4].

The biogas is produced by anaerobic digestion (AD) of animal's dung (buffaloes and cows) in the absence of oxygen. Biogas contains 56-70% methane, 21-40% CO_2 and some traces of others. Such as H_2, SO_2, NH_3, N_2 and water vapors [5, 6]. The cake of animal dung emits the Greenhouse Gases (GHGs) about 900 thousand of CO_2, methane gas, Nitrous oxides (N_2O) into the environment so biogas technology is used to overcome these issues. The byproduct of the AD is used as biochemical stimulants for providing the Nitrogen, Phosphorus and Potassium to the agriculture [4, 7]. On the bases of Pakistan Livestock census, annually about 20 Billion m^3 of biogas is produced from the animal manure and is generated by about 0.07 Billion cows and buffaloes, more than 0.09 Billion of goats and sheep [8]. The animal manure generates the biogas which does not meet the energy demand. Biogas is a smokeless and ash-free kitchen which improve health of humans particularly of women and children in developed and developing countries, improve the quality of environment but also reduces the unemployment because the construction, operation and maintenance the biogas plant [9,10].

It is observed from the recent research that global warming poses the foremost ecological tasks and majority of greenhouse gases that generated after the combustion of fossil fuels [11]. There is a requirement to improve greenhouse gases (GHGs), reduction policies to decrease the adversarial impact of environmental changes. Technology of biogas delivers the best chance to the reduction of GHGs and decreasing CO_2 emissions by substituting the wood for food preparation, replacement of the Liquefied Petroleum Gas (LPG) and oil for heating and lighting, replacing biochemical stimulants and valid for saving deforestation [12]. The objectives of the present study were to: estimate the biogas potential from the animal manure in Pakistan; estimate the global warming potential through non-renewable sources; estimate the reduction of global warming and carbon credit by replacing fossil fuels with biogas.

II. SUPPLIES AND TECHNIQUES

Global Mitigation potential (GMP) and credit of carbon with installation of biogas plants in Pakistan is estimated at given heights: a domestic biogas plant (GMP-Domestic), the presented biogas plants (GMP-Presented) and Prospective biogas plants when biogas is produced from entirely contributed dung (GMP-Potential). GMP and credit of carbon by installation of a domestic biogas plant (GMP-domestic) is estimated taking five features in account as displayed in Eq.1.

$$G.M.P\ (Carbon\ dioxide\ equivalent) = A + B + C + D - E \quad (1)$$

Where,

A = Global Warming Potential of CO_2 discharge diminution with the lake usage oil and wood-fuel
B = Diminution in methane discharge from wood-fuel usage
C = Diminution in discharge of Carbon dioxide from chemical stimulant generation
D = Diminution in nitrogen oxide discharge from nitrogen stimulants elicitation
E = Discharge of methane trickle from biogas plants.

List of applied constants are displayed in **Table 1.** Generation of biogas from a domestic biogas plant ($5m^3$ volume), five cattle's dung is used to operate a plant, usually available in every household, it was estimated on the basis that about 0.5 m^3 biogas can be produced from one-kilogram dung (dry wt.) [13].

Table 1 Constants used for calculation of GHGs mitigating potential of biogas plant

Factor	Conversion factor
Discharge of $CO_2$from kerosene-oil combustion (kg/L)	2.4
Discharge of CO_2 from wood-fuel blazing (kg/kg)	1.83
Discharge of $CH_4$from firewood blazing (g/kg)	3.9
Calorific significance of biogas (kcal/L)	4.81
Significance Calorific value of CH_4 (kcal/L)	8.0
Methane Concentration (kg/m^3)	0.71
Significance Calorific value of CH_4 (kcal/L)	8365
Significance Calorific value of firewood (kcal/kg)	3824
Biogas equivalent of Kerosene (l/m)	0.58
Kerosene concentration (kg/L)	0.81
Biogas equivalent of Firewood (kg/m)	1.26
Annual production from dung per cattle (kg in dry-weight)	1100
Generation of Biogas from cattle dung (m^3 /kg) (dry- weight)	0.5
In biogas methane content (%)	60
In slurry content of C (kg/kg) (dry-weight)	0.4
In slurry content of N (kg/kg) (dry-weight)	0.014
In slurry P content of P (kg/kg) dry-weight)	0.011
In slurry content of K (kg/kg) (dry -weight)	0.008
Discharged CO2 for production of N fertilizer (kg/kg)	1.3
Discharged CO_2 for production of P fertilizer (kg/kg)	0.2
Discharged CO2 for production of K fertilizer (kg/kg^{-1})	0.2
Discharged N_2O-N from application of N fertilizer (kg/kg)	0.07

Supposition under taken that 80% wood-fuel and 20% kerosene-oil was replaced by produced biogas. By using these calorific values of Kerosene and firewood, production of biogas equivalents can be calculated **Table 1**. This involved that estimated amount of kerosene oil and firewood can be saved with the installation of a domestic biogas plant, besides it, emissions of GHGs in environment can be controlled on the combustion of kerosene and firewood as fuel. Carbon dioxide (CO_2) emissions took 2.41kilogram/litter and 1.83kilogram/kg from combustion of kerosene and firewood respectively. Firewood flaming also discharges 3gC/kg CH_4. Kerosene-oil and wood-fuel have 80% and 40% burning efficiency correspondingly as generally household stoves are inefficient [14]. Mostly two well-liked biogas digesters floating drum type and fixed dome type are installed in the country. A few amount of biogas is leaked in atmosphere from gas holders, inlet and outlet pipes in both types of biogas plants [15]. As 10% leakage of methane is estimated from digester, IPCC estimated range is 5-15% [11]. From biogas plants, slurry is achieved as by-product and it is used as substitute for bio-chemical stimulant. In biogas generation a little amount of dung is loss, assumption is taken that 1.4% nitrogen, 0.8% Potassium and 0.5% phosphorus is generated from one ton of dung which is used for biogas production [16]. CO_2 emissions, which emit for production of fertilizer, can be reduced with usage of slurry as substitute of chemical fertilizer. CO_2 emission was estimated by Eq.2 [17].

$$CO_2 - emissions = fertilizer - N \times 1.3 + (fertilizer - P + fertiizer - K) \times 0.2 \quad (2)$$

With the usage of biogas slurry instead of N fertilizer, then discharge of NOx can be reduced with applied N at an average of 0.7% [18]. Potential of global warming is defined as how much heat is trapped in atmosphere with the time of interval. Amount of 21 global warming potential for methane (commonly time horizon is taken 100 years), 310 for nitrogen oxide and 1 is taken for carbon dioxide. The GWP of estimated GHGs discharge diminution is calculated by Eq.3.

$$G.W.P = 21 \times CH_4 + 310 \times N_2O + 1 \times C0_2 \quad (3)$$

Price of carbon credit in international market varies USD 5 to 10 M/g CO_2-equivalents. It depends on quantity and time [19]. According to Kyoto Protocol, carbon credit is being sold in range of USD 20 to 40/tCO_2-equiv. [12]. In Pakistan, estimation of the Global Mitigation Potential of presented plants of biogas (Presented plant's-GMP), record of domestic plants of biogas around country were obtained from the PCRET. The GMP and carbon credit of domestic biogas plant are estimated from presented plants of biogas around country.

Table 2 Population of livestock 2018, total dung production and dung available for biogas production in Pakistan

Province	Cattle population Million	Buffalo population Million	Total dung produced Mt/year	Dung to gas production Mt/year
[A] Punjab	14.945	14.122	159.14	103.5
[B] Sindh	11.703	11.1	124.83	81
[C] KPK	9.4	6.9	89.24	58
[D] Baluchistan	3.7	2.46	33.73	21.92
Total	39.748	34.582	406.94	264.42

[A] Source: Census 2018, Livestock Department Govt. of Punjab.
[B] Source: Projected Census 2018, Livestock Department Govt. Sindh.
[C] Source: Census 2006, Livestock Department Govt. of KPK with growth rate 3.343%/year.
[D] Source: Census 2006, Livestock Department Govt. of Baluchistan with growth rate 3.343%/year.

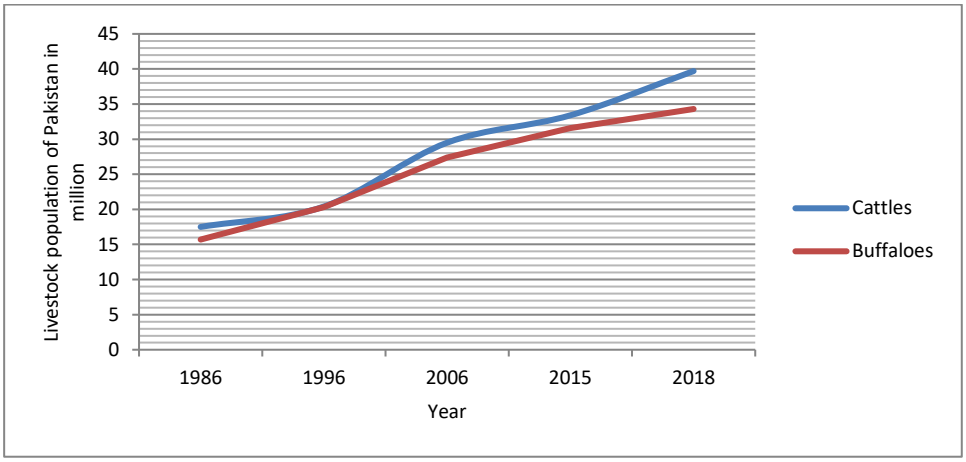

Figure 1 Graphical Representation of Livestock Population

The estimation of collectable dung for biogas generation depends on the livestock (Cattle and Buffalo) population in various provinces of Pakistan, total generated dung, loss of dung during collection and quantity of domestic biogas plants. Generation of total dung (TD) around Pakistan is determined by using Eq.4.

$$Total - dung\ \ (TD) = LC\ (N \times DE) \qquad (4)$$

Where, LC shows livestock quantity in category (cattle, buffaloes), N is quantity of animal in each category, DE shows average dung annually generated/head. As for as, few quantity of dung is lost at some stage of assortment and utilized in building purpose. Thus, authentic dung accessibility for biogas generation is estimated by Eq.5.

$$Accessible\ of\ dung\ for\ generation\ of\ biogas\ (D_A BG) = TD \times \{1 - (DC + DL)\} \qquad (5)$$

So, DC and DL denotes the dung used for building and loss of dung during collection, respectively. Record of livestock census in various Pakistan's provinces **(Table-2)** is achieved by Livestock department. According to livestock census 2006, an average of 2.5m^3 of biogas can be generated by only a cow/buffalo [20]. Fresh dung content 18% of dry matter achieved from literature review [18, 23]. Figures of dung production per head and dung quantity are utilized for building purpose was achieved from published papers [21, 22]. Figures of lose throughout assortment. Number and figures of potential of environment contamination with the combustion of kerosene-oil, wood-fuel and dung-cake were found from papers review [23, 24, 25, 26 and 27] in **Table 3**.

Table 3 Emission of atmospheric pollutants from kerosene-oil, wood-fuel and dung-cake and quantity of contamination diminution due to use of biogas from a domestic biogas plant

Pollutants	Atmospheric emission factor			Pollution reduction due to a biogas plant (kg/year)			Total
	Oil	wood fuel	Dung cake	oil	wood fuel	Dung cake	
NO_x	2.3a	2.2b	0.8b	0.7	12.2	3.5	16.4
SO	24.0a	0.7b	1.4b	1.3	3.9	6.2	11.3
CO	1.8a	99.3e	99.3h	0.6	549.6	436.9	987.1
VO mixes	0.5a	7.0a	7.0h	0.2	38.7	30.8	69.7
Matter10	0.3a	3.0a	3.0h	0.1	16.6	13.2	29.9
Matter <2.5	0.3c	2.1c	6.5c	0.1	11.6	28.6	40.3
Organic matter	1.3c	1.3c	4.0c	0.4	7.2	17.6	25.2
Black carbon	0.3c	0.6g	2.5g	0.1	3.3	11	14.4
Organic carbon	0.2d	3.5f	12.6f	0.1	19.4	55.4	74.9

Pollution declination due to domestic biogas plant is calculated on basis of saving the wood-fuel, kerosene oil and dung-cake. From calculation, it is assumed that up to 30% kerosene-oil and 70% wood-fuel would be saved with installation of domestic biogas plant.

III. OUTCOMES AND DISCUSSION

GMP of biogas plant annually: It is about 9.7-ton CO_2 equivalent global warming per annum can be mitigated by domestic biogas plant and international market of CO_2 is around USD25/ton per year as in **Table 4**. In the light of clean development mechanism (CDM), it can be earned USD through carbon credit from the mitigation of GHGs discharge. A domestic biogas plant can replace usage of fossil fuel approximately 4,400 kg animal manure, 5,535 kg firewood and 316 Litters of kerosene oil. With the replacement of fossil fuels to biogas, yearly about 16.4, 11.3, 987.0 and 69.7 kg of NO_X, SO_2, CO and volatile organic compounds can be reduced from the atmosphere, respectively as in **Table 2** [7].

Global mitigation potential with the potential generation of cattle dung use for biogas : Pakistan is an agriculture country and rich in livestock with population of 74 million (Buffaloes and Cows) **Table 2,** whereas, the highest population of animals is in Punjab which is 29.067 million followed by the Sindh has 22.803 million population and generates 159.14M ton and 124.8M ton dung per year, respectively. Similarly, KPK and Baluchistan have the animal population 16.3 million and 6.16 million and produces 89.24M ton and 33.73M ton dung per year.

Table 4 Global mitigation potential and credit of from a domestic biogas plant in Pakistan

Parameters	**Values**
Cattle's quantity	5
Quantity of dung (kg-dry weight)	5,000
Generation of Biogas (m^3)	2,500
[X] Kerosene-oil equivalent 18-20% to biogas (Litter)	320
Emissions from kerosene-oil (kilogram CO_2-equivalent)	765
[X] Wood-fuel equivalent 75-80% to biogas (kilogram)	5,535
Emissions from wood-fuel (kilogram CO_2-equivalent)	10,571
Generation of slurry (kilogram-C)	1,750
N-equivalent fertilizer (kilogram)	65
P-equivalent fertilizer (kilogram)	25
K-equivalent fertilizer (kilogram)	38
Emissions from fertilizer production (kilogram CO_2-equivalent)	305
Leakage of methane/plant (kilogram)	98
Emissions from leaked-CH_4 (Kg CO_2-equivalent)	1,970
[Y] Emission reduction per domestic plant (Kg CO_2-equivalent)	9,667
Carbon credit's market (USD tCO_2-equivalent)	20-40
Credit of carbon/plant (USD)	242.5

[X] Assumption is under taken as 75-80% and 18-20% of wood-fuel and kerosene-oil were substituted by biogas respectively. Correspondingly, wood-fuel and kerosene-oil are 40% and 80% efficient.

[Y] Global warming potential (kilogram CO_2-equivalent) = 765 + 10,571 + 305 − 1,970 = 9,671

Carbon credit of biogas plant annually : According to calculation and estimation the total 406.96M ton dung can be collected around the country, of 35% could be lost and used for construction. With the utilization of such amount of dung about 5 million domestic biogas plants can be installed around the country. These huge numbers of plants have potential to reduce GMP by 48.36Mton of CO_2-equivalent. In this circumstances government of Pakistan can earn USD1208.8 million annually as carbon credit as in **Table 5.**

Table 5 Global mitigation potential and carbon credit from current operational biogas and potential biogas plants in Pakistan

Existing biogas plants			Potential biogas plants		
No. of biogas plants ('000)	**GMP ('000 tons CO2 equiv.)**	**C-credit Million USD year^{-1}**	**No. of biogas plants ('000)**	**GMP ('000 tons CO2 equiv.)**	**C-credit Million USD year^{-1}**
6	580.26	145.065	5000.5	48355	1208.8

IV. CONCLUSION

In Asia, Pakistan is the biggest agriculture and livestock producer country. According to the reports, Pakistan has approximately 74 million livestock in the form of cattle and buffaloes. It is one of the best region to produce biogas with appropriate availability of livestock and atmospheric conditions. This study brings to conclusion that Pakistan has potential of 5 million domestic biogas plants. Besides it, with the installation of potential biogas plants about 48.5 million tons CO_2-equivalents global warming per annum can be mitigated. The international market of CO_2 is around US$25/ton per year. In the light of clean development mechanism (CDM), it can be earned million USD 1208.5 through carbon credit from the mitigation of GHGs discharge. Potential biogas plant can replace usage of fossil fuel approximately 25000M kg animal dung, 27,675M kg firewood and 1580M Litters of kerosene oil. With the replacement of fossil fuels to biogas about 82, 56, 4935 and 348.5 million kg of NO_x, SO_2, CO and volatile organic compounds can be reduced from the atmosphere, respectively. Biogas technology can be useful to government of Pakistan and householders in the form of carbon credit. On the basis of financial returns, resulting from avoid currently incurred costs for cooking and lighting fuels respectively. The IRR is substantially higher when other benefits of saved labor, improved health, increased agricultural productivity, and reduced greenhouse gases are included.

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