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Research article

Renewable Energy Usage for Operation of Agriculture Tubewells: Financial Analysis of Biogas and Diesel Tubewells

Muhammad Ghaffar Doggar [1], Farah Alvi[2]

[1]Energy Research center, COMSATS Institute of Information Technology, Lahore 54000, Pakistan
[2]Department of Physics, COMSATS Institute of Information Technology, Lahore 54000, Pakistan

Corresponding author: farahalvi@ciitlahore.edu.pk

ABSTRACT

Pakistan is facing huge energy crisis since 2007. Power shortage up to 7000 MW has been observed (2011) which led to introduction of load shedding program. This has a negative impact on the productivity of all economic sectors and social life style of the people. The economic loss to the GDP (agriculture, industry and service sectors) has been estimated around Rs. 242 billion per annum (2013). The indigenous fossil fuel reserves cannot meet the demand for energy and country is heavily dependent on import of oil and POL products at the cost of about 15 billion US$ per annum.

The potential of renewable energy resources is excellent i.e. biogas, biomass, municipal waste to energy production, solar PV and thermal, wind, micro hydral at canal falls, bio-diesel, geothermal, ocean energies etc. Bio energy resources such as bio gas can provide sustainable solution to the energy problem in rural sector, at farm level. Biogas can be used for heating, cooking, electricity generation and as fuel for Internal Combustion Engines for operating irrigation tube wells. The biogas potential from animals and poultry waste (24.5 million m^3 per day) has been estimated. This can generate 40 million KWh of electricity i.e. 14% of the electricity consumption in Pakistan. The Government of Pakistan is taking keen interest in promoting the use of bio gas energy for domestic energy as well as for tube wells operation, and has fixed the target of generating 9700 MW from renewables by 2030.

The bio gas initiatives taken during early 70's proved un-successful due to poor planning, design and lack of trainings to end users and back up support services. However, after research and development work and with

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improved bio gas plant design, technology has been found more feasible for operation of diesel tube wells. Agriculture Department, Government of the Punjab introduced a pilot project to install 50 biogas diesel tube wells during 2012 which proved a partial success story. However, lessons learned are valuable to implement future projects. It has been concluded that with diesel oil costs as on 2012-13, bio gas tube wells are economically viable and their payback period is less than 5 years.

Keywords: Renewable Energy, Biogas, technology, Diesel Tubewells

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INTRODUCTION

Energy is the life line of an economy and a vital input to sustainable industry, commercial and domestic activities. The energy shortage not only results into loss of economic growth but also employment and adversely affects social cohesion in the society. Pakistan energy crisis has been brewing since 2007 but deepened in 2011-12. Power shortage peaked at 7000 MW in 2011 (Pakistan Energy Year Book, 2012) and is continuing to date.

Absence of effective planning and financial viability strategy and in-capacitated regulator resulted in supply and demand gap. The situation has further compounded due to high transmission and distribution losses (17%), theft of electricity and declining revenue collection, corruption etc. (Economic Survey of Pakistan, 2013). The installed electricity generation capacity of Pakistan is 22,668 MW which is not fully exploited as plants operate at less efficiency or remain shut down due to non-payment of circular debt. On the other hand the demand for electricity is growing at 8% per annum.

The conventional energy resources are insufficient to meet the domestic energy demand. Pakistan has exhausted more than half (68%) of the original recoverable oil reserves and remaining balance will deplete within four years, without oil import and at present consumption rate i.e. 240,000 barrels per day (Economic Survey of Pakistan, 2013). The cost of imported oil/ POL products has reached 14.9 billion US$ (2013) and with growing demand for oil it is likely the import bill shall increase manifold. Similar is the case for gas the balance recoverable reserves (24.7 trillion cubic feet) shall deplete completely by 2025 unless alternative more gas fields are explored and developed (Economic Survey of Pakistan, 2013).

The rural population is heavily dependent upon use of non-commercial fuels i.e. wood, crops residue, animal dung cake etc for domestic energy purpose. Grid connected electricity is available to 62% of the population, and 38% are yet without electricity with majority of them living in rural areas. However, due to prolonged power interruptions (up to 20 hours per day) people are suffering badly and cannot enjoy modern facilities of AC equipment.

Agriculture sector consumes about 1.5% of the commercial energy. Diesel oil and electricity are used for mechanized farming operations which are performed through tractor and tube-wells. The cost of diesel oil and lubricants has increased almost by 350% during the past decade (2005 to 2014). According to a study conducted by Field Wing of Agriculture Department (2013), the energy cost of a farmer having diesel tube well is 35%-40% of total input costs for paddy crop in Pakistan (2013).

Table (1.1). Price of High Speed Diesel Oil (2005-2013)

Year	*Rate of HSD (Rs. per liter)
June 2005	29.15
June 2006	38.82
June 2007	37.80
June 2008	50.22
June 2009	55.80
June 2010	75.95
June 2011	94.44
Sept. 2012	118.00
June 2013	105.00
December. 2013	116.75

Source: Punjab Development Statistics 2008, 2013 & 2014

Punjab is the largest province of Pakistan, has 56% of the population and 33 million acre fertile land which produces all types of crops. The province contributes 65% to the national GDP and has a major share (76%) in the food grains production. It has 60% of the total industrial units (48,000 Nos.) of Pakistan and 68% of the electricity and gas is consumed only by Punjab. The demand for electricity is more than 10,000 MW which is growing @ 6% per annum. Due to prevailing energy crisis Punjab is facing shortfall in electricity supply @3300-3500 MW, and this has led to introduction of load shedding program @ 6-18 hour per day (Over view of Energy, Punjab Energy Department, & Iftikhar Randhawa 2015). The cost of load shedding is high and the province is finding difficulties in maintaining 4% growth rate in economy.

Every year 56 MAF water is diverted from rivers to Punjab canals network. The net available water at farm gate becomes 35 MAF per annum, excluding conveyance losses in canals and water channels. The canal water is sufficient to maintain 50% cropping intensity. To maintain cropping intensity @150% Punjab needs about 70 million acre feet (MAF) of water for agriculture crops. The shortfall is met through tube wells water which play significant role in achieving high production of crops.

There are about one million operational tube wells in Punjab (2012), including 0.863 million diesel and remaining electric. Majority of these tube wells (85%) have prime mover / engine up to 20 HP and 15% have more than 20 HP engine (Punjab Development Statistics, 2013 & 2014).

Table 1.2. Number of Tube wells by Size of Pumps

Tube well	Size of Pump (h.p)					
	< 10	10 to 15	16 to 20	21 to 24	25 & Above	Total
Electric	23766	48720	32085	1188	13071	118831
(%)	20	41	27	1	11	100
Diesel	8626	120772	603855	34506	94890	862650
(%)	1	14	70	4	11	100

Source: Punjab Development Statistics (2013 & 2014).

The annual operational cost (HSD) of the 0.863 million diesel tube wells has been estimated to be Rs. 280 billion i.e. HSD consumption @ 2 liter per hour x 1600 operational hour per annum x Rs 105 per HSD liter (2013). This is a heavy burden on the national economy as well as an expensive option for the farmers operating diesel tube wells. By converting diesel tube wells on to biogas 70%-80% of the HSD cost (Rs. 200 billion) can be saved every year. However, there are issues of resources availability such as animals, financial capacity and technical manpower in the market. Therefore, the government needs to formulate a policy with incentives for promoting the technology.

Pakistan is an agriculture country and produces crops residue @ 81 million ton per annum (Economic Survey of Pakistan 2014). It has 72 million cattle and buffaloes, and 785 million poultry birds, the waste of these can be used to produce bio gas for generating electricity and running diesel tube wells. According to Iqbal, 2014, 24 million m^3 biogas can be produced daily using 50% of the resource potential. Therefore, bio gas energy can play significant role in supplying energy to domestic sector, running diesel tube wells and to generate electricity.

This paper reviews the potential and utilization of biogas energy in Pakistan, especially by Punjab province with particular focus on using bio gas for operation of tube wells. It also discusses the impact of pilot project of Biogas Tube wells" on the income of farmers and compares its financial feasibility with diesel tube wells.

2. ENERGY SUPPLY SITUATION IN PAKISTAN

The primary energy supplies in Pakistan (2013) was at 65.64 million ton of oil equivalent (MTOE) with 48% share of gas, oil (33%), hydro (11%), coal (6%) and remaining nuclear and LPG etc. The indigenous energy resources are in-sufficient to meet the energy demand and country is heavily dependent on import of energy. As on June 2013 out of 1103 million barrels of total oil reserves, 732 million barrels (68%) have been consumed while 32% are the balance recoverable.

The annual requirement of crude oil in Pakistan is about 90 million barrels or 247,000 barrels per day (Economic Survey of Pakistan, 2013 & 2014). With this consumption level the available oil reserves (371 million barrels) shall deplete within 4 years without oil import. Similarly for gas the balance recoverable reserves (24.7 trillion cubic feet) shall deplete by 2025 unless alternative reserves are developed or gas is imported from abroad.

Pakistan imports about 60 million barrels of crude oil every year i.e. 66% of the demand, while the share of indigenous oil is 30 million barrels (33%). The cost of imported crude oil and POL products is 14.90 billion US$ per annum (Economic Survey of Pakistan, 2013). The demand for oil has been projected to reach 67 million ton of oil equivalent in 2030, a 4-fold increase compared with 2012, hence country will become heavily dependent on import of oil at the cost of valuable foreign currency (GoP Vision 2030). Total energy requirement has been projected 361 MTOE by 2030 i.e. six times of that of energy supplied in 2013.

Pakistan's Gross Domestic Product (GDP) is fore-casted to grow by 3.7 percent and the total population is 188.2 million people which represents 2.56 percent of the world´s total population (Pakistan Bureau of Statistics: Population of Pakistan, 2014). The demand for electricity is growing @8% per annum with increased population, urbanization, industrialization and expansion of transport and other economic activities in the country. In order to resolve the growing energy crisis, the Government implemented a new policy in 1994 which was designed to attract foreign investment in power sector. Consequently construction of oil based power plants was undertaken (Beg et al., 2007). The increased prices of HSD /fuels to generate electricity are un-economical for Pakistan.

Pakistan power sector is a mixed industry of thermal, hydro, nuclear. Total installed power generation capacity in Pakistan is 22,865 MW. The ratio of the hydro to thermal installed generation capacity was 67:33 in 1985 but later on due to government policy to install power plants on furnace oil and other political decisions, the share of thermal power increased. Thermal power accounts for about 66% of the electricity generation while hydro power constitutes 30% share and nuclear 4%. Considering thermal power generation only, the share of furnace oil based electricity which was 33% in early 1990s when the country faced a power shortage of about 2000 MW during peak load period (EPF, 1994), increased to 56% in 2012-13 while the share of gas based power generation reached 40% (NEPRA State of Electricity Report 2014).

The low operational efficiency of thermal power plants due to technical problems and for nonpayment of circular debt to independent power producers (IPPs), has resulted into power shortages @5000 MW which deepened to 7000 MW in 2011-12 (Economic Survey of Pakistan, 2013 & Khawar, 2014), especially in summer months because of the high demand for electricity in the sizzling heat and when hydro electric generation is also decreased due to drop in water flow in the rivers. The cost of load shedding has been estimated (Shahbaz, 2013) to be Rs. 242 billion per annum.

Figure 2.1 presents data on electricity generation by source (Pakistan Energy Year Book, 2012) while the figure 2.2. shows escalation in prices of fuel and electricity.

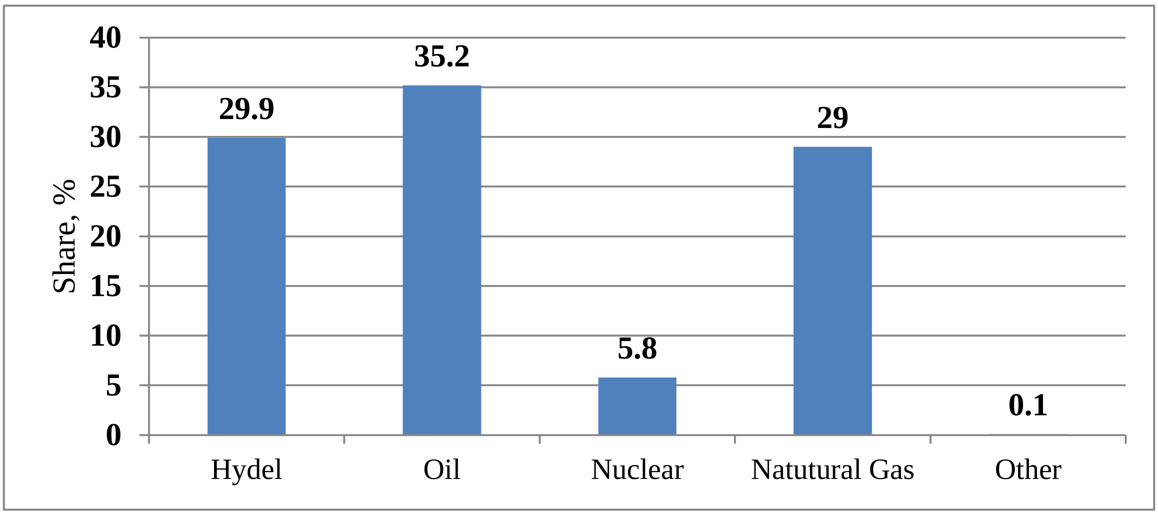

Figure 2.1: Electricity generation in Pakistan

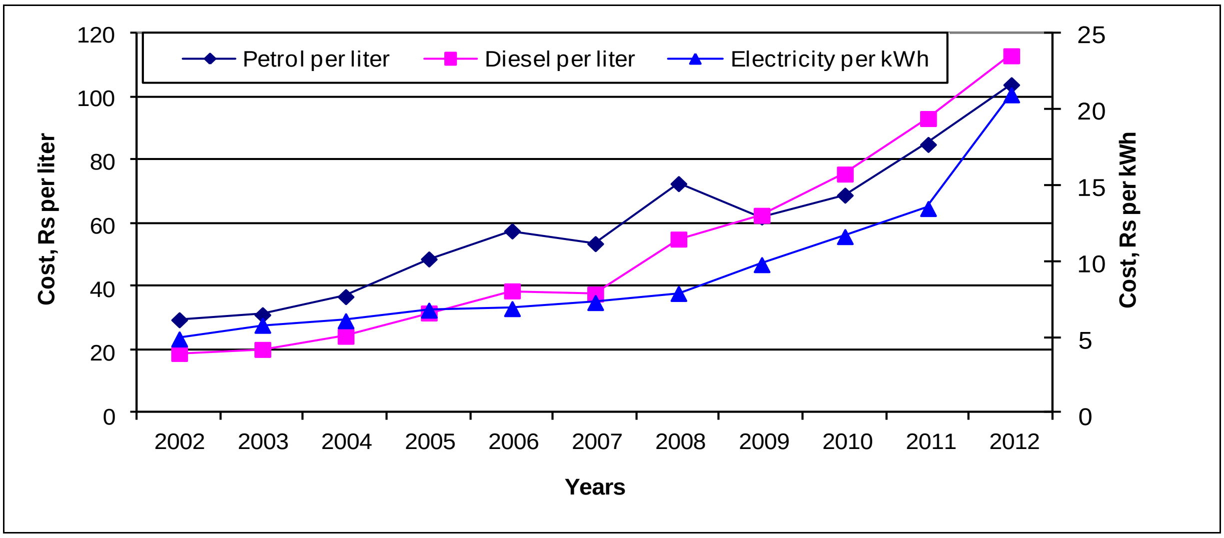

Figure 2.2: Increasing fuel and electricity prices in Pakistan

According to the U.S. Energy Information Administration, Pakistan has proven natural gas reserves of 24 trillion cubic feet (TCF) in 2012. These reserves will last for a period of 17 years based on the country's annual consumption of 1.382 TCF as on 2012 (USEIA, 2012). At the same time, the gas consumption rates are estimated to increase fourfold to nearly 8 TCF per year by the year 2020, further reducing the size of the domestic reserves (Tirmizi and Farooqi, 2011).

The energy production share from different sources in the country for the year 2013-14 as shown in Figure 2.3. It does not indicate any share of renewable energy. The electricity consumption by different sectors is shown in Figure 2.4. Domestic sector got the highest share (about 46%), industry (28%) and Agriculture (13%).

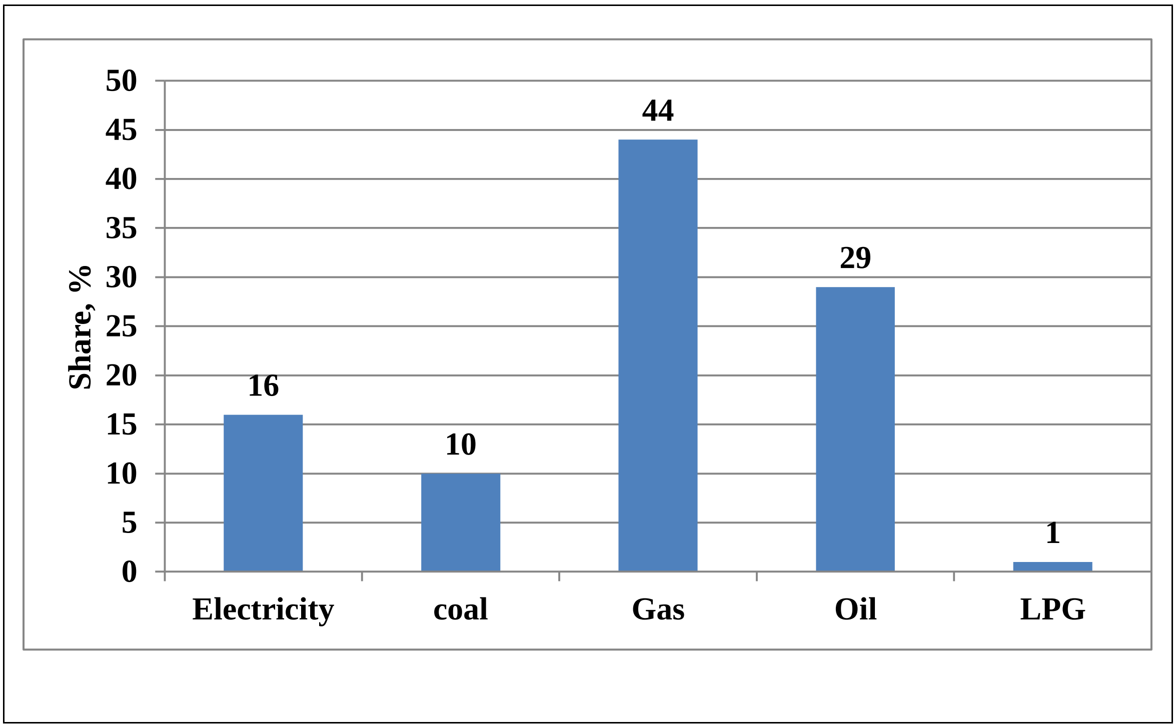

Figure 2.3. Energy mix of Pakistan for the year 2013-14

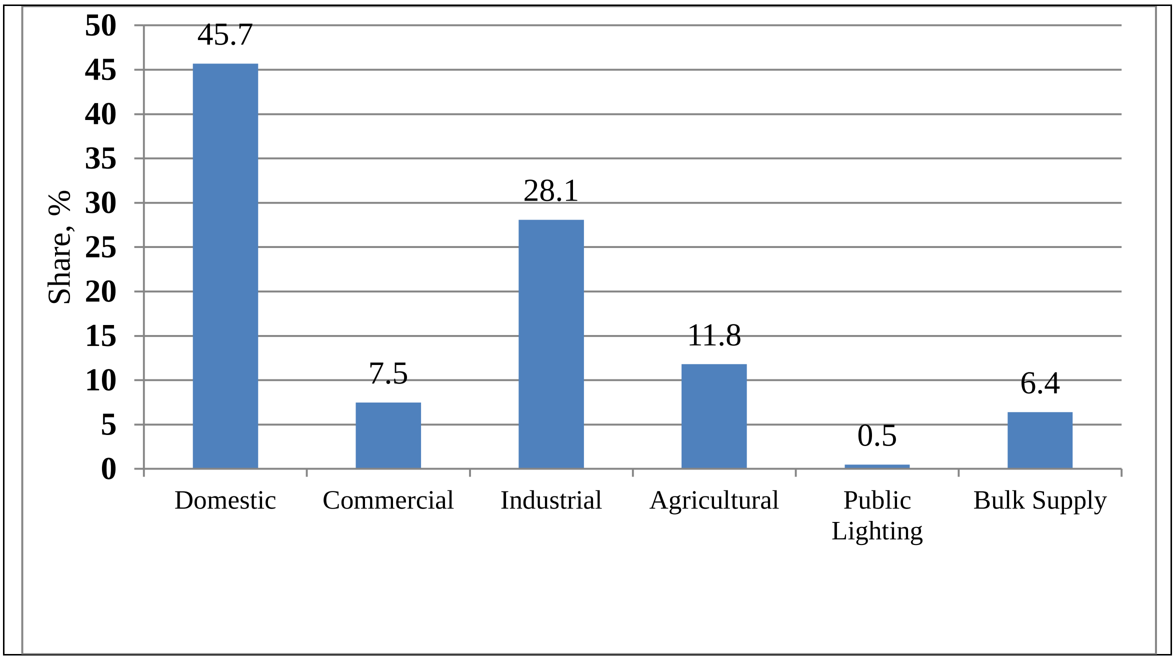

Figure 2.4. Electricity consumption by different sectors

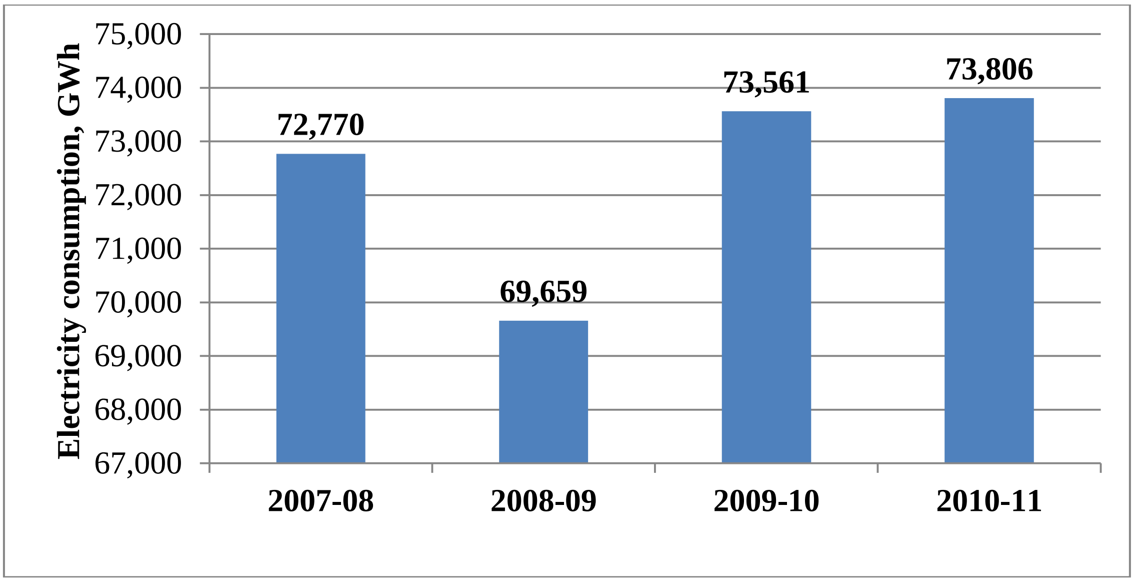

Figure 2.5. Extent of power generated in Pakistan

The problem being faced by the utilities in Pakistan is not only the shortage of generation capacity but also the under utilization and generating 12,000-14,000 MW of electricity mainly due to non-availability of furnace oil to generate power at expensive rates. The solution to this problem are to develop cheap hydro resources and alternate energy resources so that power is supplied at low costs, and reduced dependence on imported fuels for power generation. This means that Pakistan has to make a shift from conventional energy power plants to cheap energy resources and increase their share to 70% to benefit from cheap electricity in true sense.

The use of bio energy resources has largely been ignored in the past and is available in sufficient quantities to generate electricity and eliminate the power crisis in the country. Pakistan has tremendous potential to increase electricity generation by exploring bio-energy resources. At nearly 30%, hydroelectricity is already a major source of electricity generation, but according to the Pakistan Government, this reflects only 13 percent of the total hydroelectric potential of the country (HRP, 2011).

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3. BIO GAS ENERGY UTILIZATION IN PAKISTAN

3.1. BIO GAS TECHNOLOGY

Bio gas is produced by the biological breakdown of organic material in the absence of oxygen. The gases methane, hydrogen and carbon monoxide can be combusted or oxidized with oxygen. The raw materials for biogas include agriculture waste, animal dung, municipal waste, plant materials, sewage, green waste etc. The composition of bio gas is as follows (Gofran, 2012):

- Methane (CH_4): 60%-70%
- Carbon dioxide (CO_2): 30%-40%
- Hydrogen (H_2): 2%
- Nitrogen (N_2): 1%-1.5%
- Oxygen (O_2): 0.3%-0.8%
- Hydrogen sulfide (H_2S): 0.1%-0.2%

The characteristic properties of biogas depend on the pressure and the temperature that prevail during its generation. These are also affected by the moisture content of the substrate to be digested. Biogas is a substitute for oil, gas and coal for cooking, heating, electricity generation and lighting and can also be used to supplement diesel tube wells.

Bio gas characteristics **(Gofran, 2012):**

- Density: 1.22 kg per Nm^3
- Specific gravity: 0.94
- Calorific value: 4500 Kcal/ m^3, 17 MJ / m^3

Bio gas requirement for different applications:

- Cooking: 0.4 m^3 per person per day
- Water heating: 0.28 m^3per person
- Lighting: 0.17 m^3 for two mantels lamp
- Diesel tube-wells (80:20): 0.35-0.45 m^3 per hp per hour
- Generating electricity: 0.6 m^3 per KWh

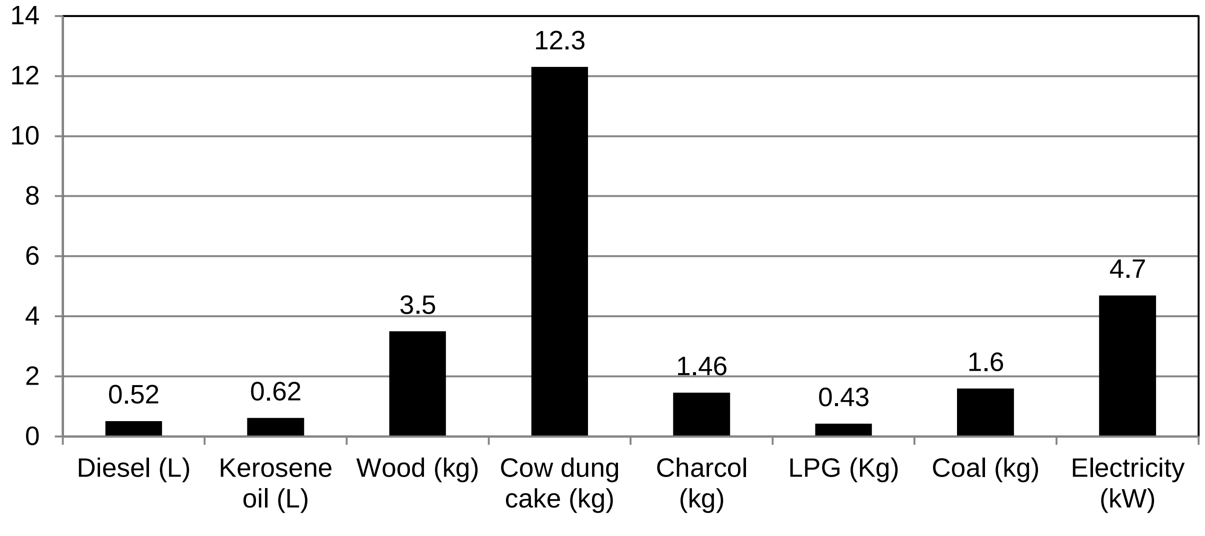

Figure (3.1). Equivalence of 1 m^3 biogas with other fuels (Iqbal, 2014).

3.2. BIO GAS PLANT MODELS

There are mainly two types of biogas plants which have been installed in India, China, Pakistan, Nepal and Bangladesh i.e. floating drum (Figure 3.2 a) and fixed dome (Figure 3.2 b). The floating drum type plant is known as constant pressure biogas plant since the drum (gas storage) moves upward and downward with the gas pressure

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inside the fermentation chamber thus keeping gas pressure constant. These plants have been constructed at large scale in India and Pakistan.

The fixed dome plants have been constructed at large scale in China, Nepal, and Vietnam etc. Main purpose of these plants is to supply gas for domestic energy needs or power generation at small scale. The fixed dome plants are further divided by materials used for construction of its dome part i.e. membrane (Figure 3.2 c) or concrete type.

A combination of floating and fixed dome plants has also been developed and is known as hybrid biogas plant (Figure 3.2. d) has also been constructed and is being promoted in China. The hybrid systems has been found more efficient. However, the cost is a major barrier in adoption of these plants in Pakistan **(BEB presentation on biogas, 2014).** Bag type plants are used in Thailand & China and are not popular in Pakistan.

Different materials are used for the construction of biogas plants. The fixed dome plants are made of bricks, concrete, membrane and fiber glass. The membrane cover (Figure 3.2 c) constitute dome part of the plant. It ensures easy maintenance and is more durable than concrete dome which is susceptible to gas leakage and cracks during operations. In floating type, the gas holder is made of fiberglass or steel and is movable. The fiber glass is durable but susceptible to injuries by iron or sharp tools in field. The steel drum has short life and needs anti corrosion painting. The fermentation chamber and other components are made of bricks and concrete.

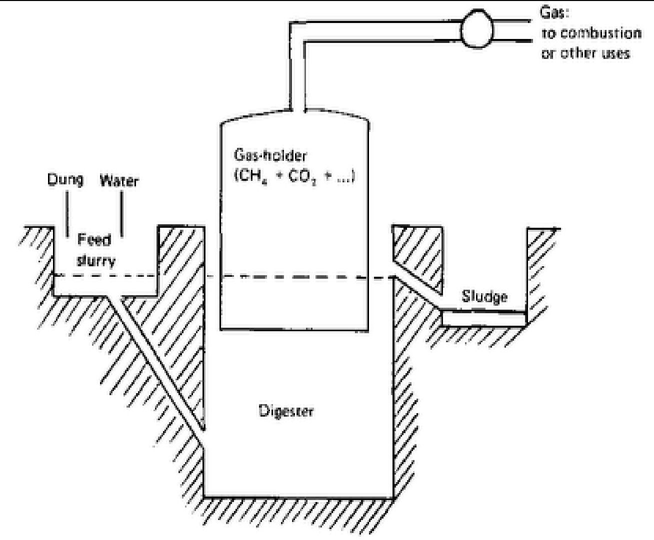

Figure (3.2 a): Floating drum bio gas plant

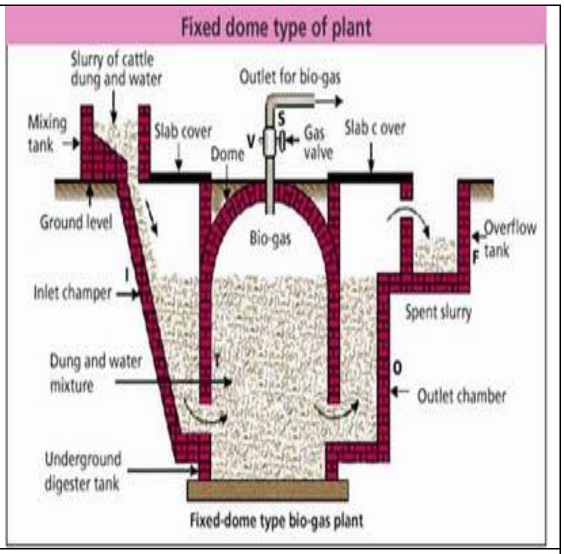

Figure (3.2b): Fixed dome with concrete cover

Figure (3.2 C): Fixed dome with membrane cover

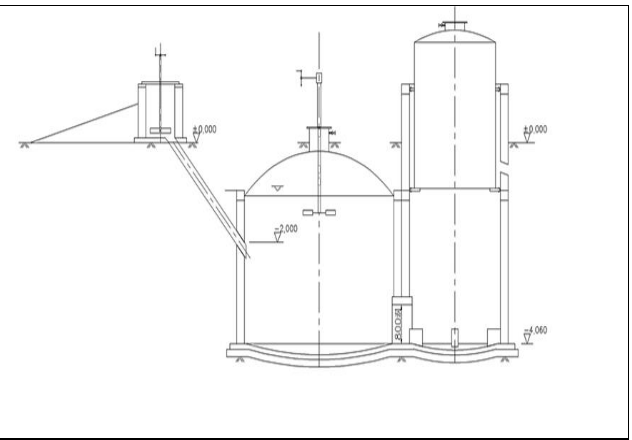

Figure (3.2 d): Hybrid bio gas plant

The technical performance parameters of the four models prepared by M/s Bio Energy Berlin (BEB) Germany, consultant firm working on biogas technology, are shown below:

Table. 3.1: Technical merits and demerits of bio gas plants

Floating drum	Fixed dome	Hybrid
• Bio gas plant consists of digester which is round shape well, made of bricks. • The gasholder is mobile, it floats on top layers of the slurry inside the digester. It is provided with an outlet for gas supply and is made of fiber plastic or steel drum. • Feeding and overflow tanks are made of bricks, cement • As gas production increases inside the fermentation chamber, gas holder rises upward. Its movement is controlled by piping structure with maximum top limit fixed. • The gas pressure also pushes out the fermented slurry into overflow tank thorough outlet pipe which is used as manure. • Gas collected in gas holder is taken out through gas supply line and a control valve. • Raw gas is purified by passing through two scrubbers; to remove Sulphur & moisture. • Gas yield is high and gas pressure remains constant • Easy to construct & maintain • Visible gas storage • Fiber drum is durable and long life • High temperature in summer • Complete hydraulic routing • Easy stirring with vertical movement of drum • Excellent working with large size digesters • Controlled temperature, stirring of digester and gas storage system has proven higher gas production system • No sedimentation occurs due to complete fermentation & stirring • High gas extraction efficiency (96%) due complete stirring. • Life: 10 years	• The biogas plant consists of digester which is well like structure made of bricks. • The roof of digester is fixed and dome-shaped that acts as a storage tank (gasholder) for biogas. • The dome is provided with an outlet for the supply of biogas. • The digester is partially filled with slurry and dome at the top is left free for collection of gas. • As gas gets collected in the dome, its pressure increases that force fermented slurry to go into over flow tank through outlet chamber to be used as bio-manure • On one side of digester tank is a mixing tank made above the ground level and an inlet tank below ground level. On the other side of digester are the outlet tank and overflow tank. • Mixing tank is connected with inlet chamber while overflow tank is connected with outlet tank. • The biogas collected in the gas holder is taken out through the gas control valve. • Bio gas is purified by passing through scrubber to remove Sulphur and dehumidifier to remove moisture • Lower gas yield; and complicated construction and hair line cracks • Scum at the top layer is formed • Invisible gas storage; • Relatively low cost • Relatively low temp in summer • Short hydraulic routing • Larger than 25 m^3 will create dome failure problems. • Low gas production • Sedimentation occurs • Gas extraction efficiency decreases with time due to scum development at the top layer • Life 10 years	• The plant is a combination of floating gas holder and fixed dome type digester. • Fixed dome biogas plant with its external gas holder fully combines the advantage of floating gas holder and provide constant pressure of biogas and is more efficient. • The fermentation takes place in two chambers, first in dome plant digester and then in out chamber /well with gas holder. No un-fermented material is left out in the slurry. Gas extraction from fed material is therefore, is more than other models. • The digester is made of brick-concrete structure as explained in fixed dome plant with gas holder covering the right hand round shape well. • The inlet, outlet, feeding tanks and other accessories are similar to fixed and dome and floating gas holder plants. • The gas is collected from dome part and shifted to gas holder which moves upward and downward with the gas pressure. • Technical demerits of fixed dome avoided in hybrid design and more efficient compared with both designs. • Life: 10 years

3.3. SELECTION OF BIO GAS PLANT

- Based upon the technical performance parameters and costs of biogas plants, the selection of most appropriate design can be made. The cost of biogas plants depend on construction materials, accessories, equipment used with the plants, mode of construction and availability of skilled manpower.

- The costs can be reduced using local made components, labor and avoiding contractor firms for the construction of plants. BEB Germany - consultant (2014) of bio gas project having worked with Punjab Government, ranked the bio gas plants based upon their technical performance, construction time, maintenance and costs as shown below:

Table (3.2.): Costs of bio gas plant models (BEB, 2014).

Type	Fixed dome membrane cover			Floating gas holder			Hybrid			Fixed dome concrete cover		
Digester size (m^3)	30	50	70	30	50	70	30	50	70	30	50	70
Cost (000 Rs.) (without tax)	415	516	577	468	632	767	578	749	891	359	496	609

Table (3.3.): Overall ranking of bio gas plants (BEB, 2014)

	Fixed dome membrane cover	Floating gasholder	Hybrid	Fixed dome concrete cover
Technology	● ● ● ●	● ● ●	● ● ● ●	● ●
Operation	● ● ● ●	● ● ● ●	● ● ● ●	● ●
Price	● ● ● ●	● ● ●	● ● ●	● ● ●
Cons. Time	● ● ● ●	● ● ●	● ● ●	● ●
Score Points	16	13	14	9

3.4. OPTIMUM CONDITIONS FOR BIOGAS PRODUCTION

The process of biogas fermentation is affected by several environmental factors. The quality construction and operation of an airtight biogas digester guarantees an optimal anaerobic digestion, hence biogas production. Main factors that should be taken into account for effective gas production include the followings:

3.4.1. ANAEROBIC CONDITION

There are many groups of biogas bacteria involved in the process of biogas fermentation. The methane-producing bacteria are the most important group, also known as anaerobes and are very sensitive to oxygen. They will die or grow very slowly if oxygen appeared in the fermentation environment. Therefore, an airtight digester is required for digestion.

- **TEMPERATURE**

Action of methane producing bacteria is strongly affected by temperature. The ideal temperature of biogas digester is 35 °C (Gofran, 2014). The gas production reduces when temperature drops and fermentation process stops at 10 °C or less. Similarly bacteria get killed at temperature above 50 °C and gas production declines significantly especially after 60 °C. Three temperature ranges in which the methane is produced are as follows:

- THERMOPILE: The digestion temperature for this ranges from 45-60°C. Thermophilic digestion can be operated with a high loading rate to obtain high gas production. A heating system and insulation are needed to maintain this temperature range during the cold weather.

- MESOSPHERIC: In this the temperature range goes from 25-45 °C. The mesospheric digestions run at a medium gas production, lower than that of thermopile.

- PSYCHROPHILIC: Certain special microbes can conduct anaerobic digestion at temperatures below 10 °C but gas production is the lowest.

The bacteria which grow in the mesophilic range are different from those which grow in the thermo-philic range. In either range, the rate of growth of bacteria increases remarkably with temperature and then decreases. A temperature of about 35^{o}C is considered as the optimum value of operation in the meso-philic range. Tips to enhance the biogas digester heat in colder regions are:

- Biogas plant be constructed in open site/sunny place and any object blocking the sun be removed
- Dome portion may be covered with insulated material to maintain temperature in cold season
- Mix dung and water in the morning and let it get sun heat till afternoon before feeding the plant.

3.4.2. QUANTITY OF FEEDING MATERIAL

Once the initial feeding is done, the user has to feed the biogas digester daily with the required quantity. The quantity of dung to be fed is mainly determined by the size of the plant and the hydraulic retention time (HRT). With a safe assumption of 30-35 days HRT in Pakistan, the biogas plant size for 25 buffalos can be determined as following:

- Available dung of 25 animals = 25 animals x 10 kg/animal = 250 kg
- Amount of water to be added (with a ratio of 1:1) = 250 kg
- Total Feeding mass /day = dung + water = 500 kg = 500 L = 0.5 m^3 per day [@ ρ=1000 kg/m^3]
- Let hydraulic retention time, HRT= 30 days
- Initial feeding =HRT x mass of daily feeding charge = 30 day x 0.5 m3/day = 15 m3
- Keeping more 10% volume as safety for sedimentation accumulation at the bottom = 15 + 0.1(15) = 16.5 m^3 [Size of plant]

Following the above procedure, the plant sizes with respect to the number of animals have been calculated and given below (Table 3.4).

Table (3.4): Biogas plant sizes with respect to the number of animals

Animal, No.	Dung /animal, Kg	Total dung, kg	Water, kg	Feeding rate/day, kg	Density (kg/m^3)	Feeding rate/day, m^3	Hydraulic retention time (days)	Initial Feed Rate m^3	Safe vol add 10%, m^3	Total digester vol, m^3
5	10	50	50	100	1000	0.1	30	3	0.3	3.3
10	10	100	100	200	1000	0.2	30	6	0.6	6.6
15	10	150	150	300	1000	0.3	30	9	0.9	9.9
20	10	200	200	400	1000	0.4	30	12	1.2	13.2
25	10	250	250	500	1000	0.5	30	15	1.5	16.5
30	10	300	300	600	1000	0.6	30	18	1.8	19.8
35	10	350	350	700	1000	0.7	30	21	2.1	23.1
40	10	400	400	800	1000	0.8	30	24	2.4	26.4
50	10	500	500	1000	1000	1	30	30	3	33
60	10	600	600	1200	1000	1.2	30	36	3.6	39.6
70	10	700	700	1400	1000	1.4	30	42	4.2	46.2
80	10	800	800	1600	1000	1.6	30	48	4.8	52.8
90	10	900	900	1800	1000	1.8	30	54	5.4	59.4
100	10	1000	1000	2000	1000	2	30	60	6	66

Source: Iqbal, 2014.

3.4.3. QUALITY OF FEEDING MATERIAL

- **TOTAL SOLIDS CONCENTRATION (TS)**

All feeding materials consist of solid matter and water. The total solid matter (TS) includes volatile solids, organic matter (VS) and non-volatile solids (NS or fixed solid - FS). FS are not affected during digestion and come out of the digester as such.

Fresh cattle dung = 80 % water + 20 % TS (VS+FS)

= 80 % water + 20 % TS [(70 % VS=20% x 0.7=14%) + (30 % FS=20% x 0.3= 6%)]

For easy mixing and handling an 8 – 10 % TS in the feeding is recommended. Thus to bring the TS to 8 – 10 % fresh cattle dung is to be diluted with water and/or urine in a ratio of 1:1.

- **CARBON / NITROGEN RATIO (C/N RATIO)**

Organic matter contains various chemical elements with main elements as carbon (C), hydro (H), nitrogen (N), phosphor (P) and sulphur (S). C/N ratio is an important index to evaluate the capacity of materials to decompose. Generally, biogas microbes need the C to be 25-30 times more than N. Therefore the optimum C/N ratio of feedstock is 25/1 to 30/1. Feedstock with a low C/N ratio (< 25/1) will start fermentation more quickly than that with a high C/N ratio (> 30/1) and moreover the C/N > 30/1 is likely to acidify and bring about the failure of fermentation.

- C/N ratio of cattle manure is optimum
- C/N ratio of human and chicken dung is low (< 25/1) for effective digestion.
- C/N ratio of fresh vegetation is high (> 30/1) and gets very high in old vegetation, therefore these materials should be mixed in proper proportions in order to start the fermentation process and raise the yield of biogas.
- Biogas production varies as per the C/N ratio of the feeding material.

- **PERCENTAGE OF HYDROGEN (PH)**

P^H of a solution is a measure of the concentration of hydrogen ions and it indicates whether the solution is acidic, alkaline or neutral. A neutral solution will have PH =7, Alkaline PH > 7 and acidic PH<7. Most bacteria prefer light alkali conditions with a PH range of 6.8-7.5. However, methane-producing bacteria still grow in a PH range of 6.5 - 8.5.

- **HYDRAULIC RETENTION TIME (HRT)**

HRT is the total time required by a given amount of dung to produce approximately 80-85% of the total gas. Thus HRT is also the time spent by the feed inside the digester before it is completely digested. The HRT depends largely on temperature. The HRT is highly determined by the temperature of slurry and the digester volume. The digester volume is generally chosen so as to retain the daily feed in the digester for a period equal to the HRT so that most of the slurry is digested. For Pakistan, bio-digesters are designed with a HRT of 35 days.

3.5. BIO GAS SLURRY

Biogas slurry is one of the end products of the anaerobic digestion in the biogas plants. The mixture of animal/human waste and water put into the biogas plant undergoes a process of anaerobic digestion or fermentation in a bio-digester. During digestion, 25–30 % of the total dry matter of animal/human waste will be converted into a combustible gas and residue of 70%–75 % of total solids content of fresh dung comes out as sludge, biogas slurry.

The slurry consists of 93% water and 7% dry matter of which 4.5% is organic and 2.5% inorganic matter. Percentage of N, P, K content in slurry on wet basis is 0.25, 0.13 and 0.12 while on dry basis it is 3.6, 1.8 and 3.6 respectively. In addition to the major plant nutrients, it also provides micro-nutrients such as zinc, iron, manganese and copper that are also essential for plants, but required in trace amounts. A comparison of biogas slurry with fresh manure is shown below:

Table (3.5): N, P, K Nutrients of Different Materials

Type	N_2(%)	P_2O_2 (%)	K_2O (%)
Fresh cattle dung	0.3-0.4	0.10-0.2	1.0-0.3
Farmyard manure	0.4-1.5	0.3-0.9	0.3-1.9
Poultry manure	1.0-1.8	1.4-1.8	0.8-0.9
Cattle Urine	0.9-1.2	Trace	0.5-1.0
Paddy straw	0.3-0.4	0.8-1.0	0.7-0.9
Wheat straw	0.5-0.6	0.1-0.2	1.1-1.3
Bio Gas Slurry	1.5-2.5	1.2-1.5	0.8-1.2

Experimental results have shown an increase of yields by 10-25% using bio gas slurry (Gofran, 2012). Bio Gas slurry can be used directly by mixing it with irrigation water. Wet application is rather cumbersome; therefore, farmers prefer to use dry slurry in their farms. For dry use, composting of the slurry is highly recommended. It improves physical structure of soil, increased fertility and water-holding capacity of soil, and enhanced activity of the micro-organisms in the soil.

3.6. BENEFITS OF BIO-GAS TECHNOLOGY

- **ECONOMIC BENEFITS**

  - Low cost fuel: Saving of expenditures on fuel sources: Biogas can be used for; cooking, lighting, and running engines. One ordinary biogas stove with a single burner consumes 0.35 to 0.4 m^3 of gas her hour. A biogas lamp consumes slightly less than half the quantity needed for a single-burner stove (0.15 to 0.175 m^3 of gas per hour).
  - Free organic manure for farmers: Biogas technology allows quick production of bio manure which is rich in organic substances. This reduces the need of chemical fertilizers
  - Reduced inorganic fertilizer:, due to the use of bio-slurry
  - Sanitation: With proper management of animal and other agriculture/organic wastes/ village will be clean leading to better health and hygiene in rural areas.
  - Pollution control: Normally aerobic decay of organic waste leads to emission of green house gases like carbon dioxide or carbon monoxide. The process reduces green house gas emission and helps in arresting depletion of the ozone layer.
  - Employment generation: Such plants can be easily set up and operated at village level and can be managed by women self help groups or local entrepreneurs with lower per capita investment.
  - Maximum Ammonia preservation and accumulation: Within continuous process of manure storage (composting) 50% of ammonia is lost. Total ammonia N completely preserved in bio-fertilizer, besides dissolved ammonia NH4-N content increased by 10-15%. Enhances soil productivity because of the use of bio-slurry (added N,P,K values)
  - Absence of weed seed: 1 ton of fresh cattle manure contains up to 10 thousand weed seeds that are capable for germination even after they passed through animal's stomach. After biogas plant weed seeds lost 99% of their germinating ability.
  - Absence of pathogens: Animal manure can contain human and animal health hazard diseases: salmonellosis, ascariasis, intestinal diseases. Due to special treatment in biogas plant bio-fertilizer is almost free of pathogenic micro flora.
  - No need for preliminary storage: Organic manure produced by biogas plant can be effectively applied without any preliminary storage and has affective result after injection into the soil.

- **HEALTH BENEFITS**
  - Reduction in smoke borne diseases (headache, eye-burning and infection, respiratory track-infection, etc.)
  - Decrease in burning accidents

- **ENVIRONMENTAL BENEFITS**
  - Preservation of forest
  - Increase in soil productivity due to added NPK by using slurry and agricultural residues

- Lower Emissions: capturing biogas reduces emissions by preventing methane release into the atmosphere. Methane is 25 times stronger than carbon dioxide as a greenhouse gas.
- Prevention of land-fertility degradation due to the excessive use of chemical fertilizers
- Increased Energy Security, Biogas offsets non-renewable resources, such as coal, oil, and fossil fuel-derived natural gas.
- Better Economics, Biogas reduces the cost of complying with EPA combustion requirements for landfill gas.
- Cleaner Environment, Producing biogas through anaerobic digestion reduces landfill waste and odors and produces nutrient-rich liquid fertilizer.

- **SOCIAL BENEFITS**
  - Less time spent on firewood collection and cooking especially for women and children
  - Lighting system for quality education and household works

3.7. POTENTIAL OF BIO GAS ENERGY IN PAKISTAN

Pakistan stands fourth in milk production at global level; every year 4 billion liters of milk is produced. The animals population is substantial which could be supply waste for generating bio gas and power to rural sector. According to Iqbal 2014, there are about 72 million cows & buffaloes, 785 million birds in poultry estates and 81 million ton of crops residue produced every year. The animals produce 360 million kg animal dung and birds 30 million kg waste (per day) assuming collection efficiency of 50%. All this sufficient to generate about 41 million KWh electricity daily or about 13,530 GWh per annum (Table 3.6).

Biogas source	Pakistan (Million)	Punjab (Million)
Available animals (Buffalo/Cows)	72	39
Available dung (@10 kg/animal)	720 kg/day	390 kg/day
Collectable dung (@ 50% collection)	360 kg/day	195 kg/day
Biogas from dung (@0.05 m^3/kg of animal)	18 m^3/day	9.75 m^3/day
Poultry droppings	30 kg/day	19.5 kg/day
Biogas from Poultry @ 0.10 m^3 per kg.	3 m^3/day	1.95 m^3/day
Crop residue @60% of 81 million ton Pakistan and 27.8 million ton Punjab)	133 kg/day	46 kg/day
Biogas from crop residue @ 0.025-0.030 m^3 per kg (i.e.0.027).	3.55 m^3/day	1.24 m^3/day
Total Biogas Potential	24.55 m^3/day	12.94 m^3/day
Power Potential @0.6 m^3 per KWh	40 KWh /day	21.57 KWh/day
Sources: Economic Survey of Pakistan 2013 &2014; Iqbal M. 2014 and Calculations made by author		

The power generation potential from bio gas using animal manure only has also been calculated for 2006-07 to 2012-13 and results are shown in Table 3.6. About 10900 GWh of electricity can be generated every year using 50% of the animal waste i.e. equivalent to 14% of the demand.

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Table (3.7). Power potential from animals manure (2006-07 to 2012-13).

Year	Population (Cattle+ Buffalo)	Manure Produced Ton/annum @10 kg/animal /day	Collectable Manure @50% (Ton/annum)	Biogas Production Million m3 @ 0.05 m^3 per kg	Biogas Power Potential (GWh) @ 0.60 m^3 /KWh
2006-07	58,820,000	214,693,000	107,346,500	5,367.325	9,000
2007-08	60,830,000	222,029,500	111,014,750	5,550.737	9,250
2008-09	62,912,000	229,628,800	114,814,400	5,740.720	9,700
2009-10	63,698,000	232,497,700	116,248,850	5,812.443	9,700
2010-11	67,294,000	245,623,100	122,811,550	6,140.578	10,200
2011-12	70,000,000	255,500,000	127,750,000	6,387.500	10,500
2012-13	72,000,000	262,800,000	131,400,000	6,570.000	10,900

Source: Iqbal M., 2014 and data compiled by the author.

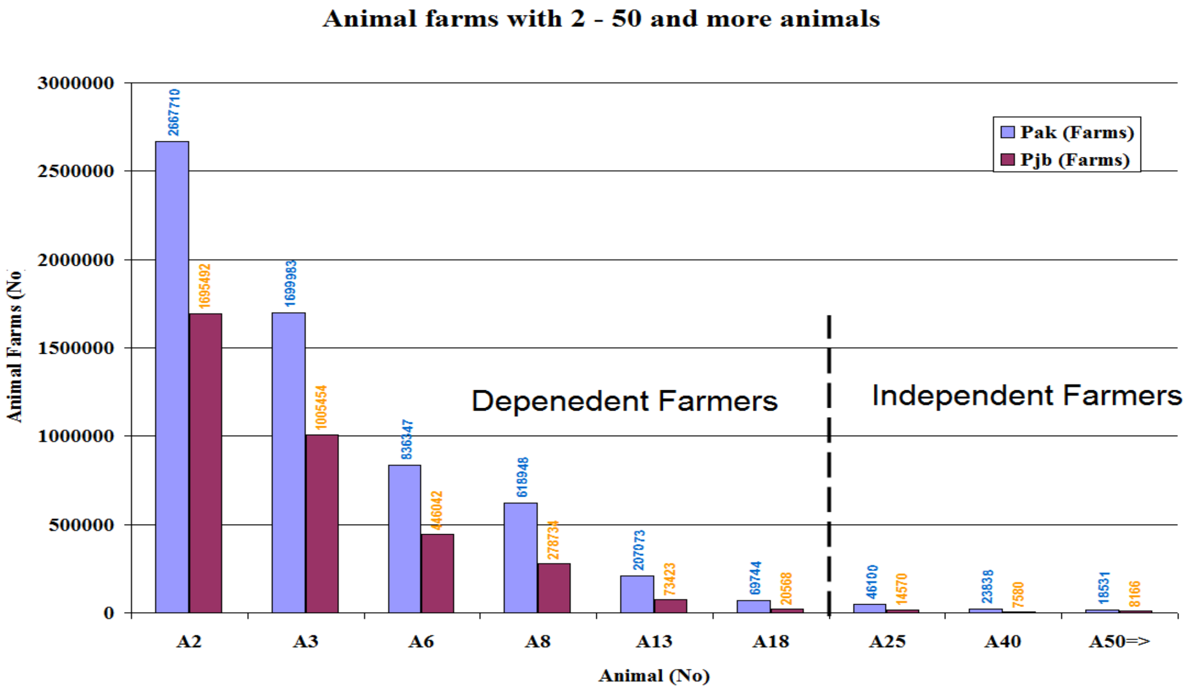

Figure (3.3): Number of animals with farmers (Economic survey of Pakistan 2013).

Punjab has about 33000 households which have more than 30 animals (Punjab Development Statistics 2013; Census of Livestock Population, 2006). These households are the potential customers of bio gas power generation. Assuming 50% collection efficiency, each house hold can generate electricity up to 100 KWh per day easily and use it during load shedding period. The Livestock Farms in public sector have more than 700 animals each and can be potential customers for power generation (>500 KWh) daily.

4. BIO GAS ENERGY UTILIZATION IN PAKISTAN

4.1. BIO GAS INITIATIVES

In Pakistan the work on development and introduction of biogas technology /plant was initiated by individual scientists during 1959 but no serious attempt was made till 1980's. The fact is that Pakistan has vast cultivated lands where all types of crops are grown and crops residue is abundantly available for domestic cooking and heating purposes. The rural population where animals and raw material is available preferred to opt for convenience in burning crops waste and meeting domestic energy needs. Value addition to non conventional energy resources was not considered at that time. Detail of individual efforts made and projects executed on biogas technology development and promotion is given below:

a. Individual attempts were made to develop biogas plants in Pakistan; the first documented bio gas plant running on animal waste was constructed in 1959 in Sind (Panhwar et al., 1959).

b. Domestic Biogas Plants gained attention of Government of Pakistan in 1974 (Heedge and Pandey, 2008). Pakistan Council for Appropriate Technology (PCAT) installed 21 fixed dome plants of Chinese origin which failed to perform due to gas leakage from hair line cracks developed in dome part of the plants and for lack of construction skills and awareness about O&M. Later on an Indian design of bio gas plant (floating gas holder type) was adopted and 10 units were installed in Azad Jammu & Kashmir (AJK). This design performed satisfactorily and was adopted for its promotion.

c. Directorate General, New and Renewable Energy Resources (DGNRER), Ministry of Petroleum and Natural Resources Islamabad, launched a scheme in 1986 to install 4000 biogas plants in the country. Under this project 100 demonstration units sponsored by the Federal Government with 100% subsidy (in 1st phase) were constructed while remaining plants with 50% subsidy were to be installed in 2nd phase, and in phase 3 the subsidy was eliminated but technical support services for construction and operation of plants were provided to the beneficiaries (PCRET, 2010). The cost of plants was born by beneficiaries in phase 3.

d. These initiatives remained un-successful mainly due to with drawl of subsidy, lack of interest shown by beneficiaries in maintenance of plants and awareness campaign, shortage of trained, skilled masons for biogas plants construction, lack of trainings to end users, technicians and public sector technical manpower, non involvement of contractor firms and un-willingness of public sector manpower to work on biogas technology (Mirza et al, 2008).

e. Pakistan Council of Appropriate Technology (PCAT) Initiatives in collaboration with Punjab Agriculture Department (Field Wing) during 1982-85 under which 1000 biogas plants were installed in districts of the Punjab met failure due to the reasons explained above. Another initiative on biogas technology "Biogas Support Program (BSP)" was started in 2000 with the support of Government of Pakistan to install 1200 house-hold biogas units (Ilyas, 2006) but it met to mixed results of success and failure.

f. Pakistan Dairy Development Company (PPDC) undertook biogas units' installation in its Horizon-3 initiative with an aim to provide alternate renewable energy at very low cost to rural groups (PDDC, 2010). Up to May 13, 2009 almost 450 biogas plants were installed. However, due to overwhelming response this number jumped to 556 implementations soon after July, 2009 (PDDC, 2010). The expenses per biogas unit were reported between 35,000 and 40,000 PKR and manure of 4–6 buffaloes and/or cows was enough to run each of these domestic units. PDDC provided 50% subsidy to the client farmers as well (PDDC, 2010).

g. Pakistan Rural Support Programs Network (RSPN) initiated a bio gas program in 2009 and installed 5360 fixed dome bio gas plants till 2014. The use of bio gas was mainly for cooking and heating purposes. 90% plants were of small size (4-15 cubic meters). The applicants were given the choice to select one size of plant according to his capacity and demand. Moreover a subsidy of Rs. 7500 per plant was also given to the beneficiary (RSPN, 2011 & 2014). The technology had been promoted in Pakistan by leaflets, broachers, TV and Radio programs, farmer meetings and manuals (Ilyas, 2006). Trainings to skilled manpower and beneficiaries was given under this program. It was claimed by RSPN that 70%-80% plants are operational however, other sources disagreed to this claim and indicated technical problems and inefficiency in gas production in fixed dome plants.

h. M/s REON Energy Solutions, a subsidiary company of Dawood Chemicals, is offering services for construction of fixed dome biogas plants with improved design. REON has installed 22 large size biogas plants (50 to 400 m^3) for power generation during 2008-13 on payment basis. The clients include large farmers, companies and entrepreneurs.

i. An NGO 'Koshis' helped villagers to build over 200 biogas plants in Sialkot district. In June of 2007, PRSP installed 12 Dome type Biogas plants in Tehsil Pasrur of Sialkot district with help of Foundation for Integrated Development Action (FIDA).

j. Pakistan Council for Renewable Energy Technologies (PCRET) installed almost 1500 house hold size biogas units, 3 community size plants and 1 big thermo phillic unit, but these units failed to work for a longer time and it would be wise to develop big sized biogas plants by following Japanese technique (Tahir and Qureshi, 2008). So far PCRET has installed more than 4500 biogas units with net bio gas generation capacity of 17980 m^3/day, on cost sharing basis.

k. Of these 2513 units were installed during 2007-13 under various subsidy schemes. 50% subsidy was granted to beneficiaries. The Council also installed 1000 biogas units of 5 m^3 each with annual production of 1.941 million m^3 gas, 1.567 million kg of manure and 4.7 million kg of carbon dioxide abatement. In addition, the PCRET has installed 30 commercial size biogas units ranging from 50-250 m^3 by executing technological support for irrigation and for household application.

l. Agriculture Department Punjab has been working on biogas technology since 1980's. Initially research and development work on biogas plant design and its efficient operation was conducted at Faisalabad. With the success of the design, a pilot project was under taken (2009-10) in selected three districts (Sargodha, Jhang, Faisalabad) and 50 floating gas holder biogas plants (15 m^3) were installed and operated successfully. The scheme was extended to all districts of Punjab (2011-13) with total target of 1500 bio gas plants to be installed during 2010-2013. Floating gas holder design was adopted and plants of 15 m^3 for domestic cooking needs were offered with 50% subsidy. Targets were achieved as 1476 plants reportedly were installed with 70% success rate in operation and maintenance of plants. Trainings were imparted to beneficiaries, field engineers and skilled manpower for construction, operation and maintenance of bio gas plants. Post installation period, the department engineers offered technical services for O & M of plants and for trouble shooting that ensured success of biogas technology.

4.2. BIOGAS ENERGY FOR TUBE WELLS OPERATION

- Agriculture Department, Government of the Punjab, initiated a project on utilization of bio gas energy for operation of tube wells on the direction of Chief Minister Punjab (2012). In order to demonstrate the technology, it was decided by University of Agriculture Faisalabad (UAF) and Agriculture Department that two bio gas models (floating gas holder) with digesters sizes: 25 m^3 and 40 $m^{3,}$ shall be installed at the UAF farm and technology be tested and evaluated.

- The Faculty of Agricultural and Engineering & Technology (UAF) was given the task for research and development and demonstration of these models to give feed-back to Agriculture Department so as to implement pilot project titled "Provision of Biogas Supplemented Tube-wells for Irrigation Purposes in Punjab" by Agriculture Department in Punjab.

- Each bio gas model has a fermentation chamber, gas holder made of fiber glass, feeding pit, inlet and outlet etc. The plant was equipped with water and H_2S removing filters, compressor and storage system, water heating and circulation system. The gas produced is passed through filters and is stored in the storage made of steel, at high pressure. Detail of components of bio gas plant /model along with lay out plan for 40 m^3 digester are given in Annexure A, and specifications are given in Annexure B.

- The two models were constructed near the livestock sheds and at agriculture farm of the University where enough animal waste (300 animals) is available and irrigation water can be applied to crops directly. A 22 hp diesel tube well is available on site and connected to bio gas plant. The gas is supplied to diesel engine @70:30, after removing water vapor and H_2S, through air intake manifold directly. A compressor is used to store the gas in gas storage tank at 4-6 bar. This has facilitated to operate the bio gas tube well for long hours, after every 2-3 days.

- The gas produced @0.05 m^3 per kg, from both 40 m^3 and 25 m^3 biogas plants have been calculated as 52 m^3/day (maximum). The actual gas produced @ 80% efficiency, is about 40 m^3 per day. This is sufficient to operate 20-22 hp engine for 5-6 hours per day (Iqbal, 2014).

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Figure 4.1 (a). 25m^3, 40m^3 floating bio gas plants	**Figure 4.1 (b).** Bag type bio gas plant

Table 4.1. Specifications of Bio gas Plants

Description	40 m^3 biogas plant	25 m^3 biogas plant
Fermentation chamber (Dia x Depth)	3.80 m x 4.10 m	3.20 m x 3.80 m
Compressor (hp-rpm-psi)	1.5-1400-150	
Storage tank	Provided.	
H_2S Removal	Scrubber with iron wool (2 kg / 2 weeks)	
Water vapors removal system	Dehumidifier with 5 kg silica gel	
No. of animals (cows and buffalos)	65	40
Animal dung required, kg/day	650	400
Dung-water ratio	1:1	
Max. gas produced (@ 0.05 m^3 per kg), m^3/day	32.5	20
Gas produced @80% efficiency/day, m^3/day	26	16
Total gas produced, m^3/day	40	
Bio-gas consumption @70:30, m^3/hr/hp	0.30-0.35	
Daily operation of 22 hp tube wells	5-6 hours	

Source: Iqbal, 2014

- With the success of these bio gas models the pilot project "Provision of Biogas Supplemented Tube-wells for Irrigation Purposes in Punjab" was implemented under which 50 floating gas holder biogas plants were installed in 11 districts of Punjab during 2013 i.e. Layyah, Bhakkar, Muzaffargarh, Rahim Yar Khan, Bahawalnagar, Jhang, Faisalabad, Gujranwala, Mandi Bahauddin, Narowal and Silakot, and connected these with diesel tube wells.

- Two bio gas digester sizes (25 m^3 and 40 m^3) were offered to farmers and they were given the choice to select one size for their tube well. All farmers having up to 12.5 acre agriculture lands, animals and diesel tube well in good operational condition, were eligible for submitting applications for allotment of a bio gas plant. One member of a family was allowed to apply for the plant.

- The district allotment committees made allotment of bio gas plants to applicants through balloting after verification of eligibility criteria. Uniform level of subsidy Rs. 570,000/- per plant which constitutes about 75% of the cost of 40 m^3 digester and 83% of the cost of 25 m^3 digester, was given to each beneficiary. A contractor firm was hired for construction of plants on turnkey basis including warranty of one year.

- As part of project activity, training programs for the master trainers (engineers) as well as for the farmers for construction, installation, operation and maintenance of biogas plants was also conducted successfully. Training(s) at selected places were arranged by the Agriculture Department where in farmers were imparted practical training on operation of bio gas tube wells.

- A special training program for the master trainers (engineers) as well as the farmers for construction, installation, operation and maintenance of biogas units was also conducted at University of Agriculture Faisalabad (UAF) on April, 13 2013. The bio gas models installed at the University were practically demonstrated to the participants. The queries of farmers were addressed regarding O & M of bio gas tube wells.

- The project ended with success and a saving of 70% to 80% diesel per hour was achieved from operation of bio gas tube wells.

4.3. LESSONS LEARNED FROM BIO GAS INITIATIVES IN PAKISTAN /PUNJAB

a). DOMESTIC BIO GAS PLANTS (RSPN, 2014):

- Farmers / applicants were hesitant to adopt technology due to previous history and failure of plants during 1970’s in the country.
- Applicants wanted high subsidy levels (80%) while the private sector (RSPN) was offering 10%.
- Majority of the farmers /clients do not have cash to pay his share (90%) for biogas plant installation.
- Micro finance institutions showed no interest in providing micro credit loans for domestic biogas plants arguing that it is a non-income generating activity and biogas applicants were not poor.
- Biogas plants are more suitable for installation at farms, not in villages due to slurry management problems. There is need for construction of plants by skilled manpower / contractors for which biogas construction companies may be established. Provision of warranty and after sales services shall attract more customers besides ensuring success of technology.
- Quality Control should be a continuous and top priority otherwise failure is possible
- Awareness campaigns may be launched on benefits of biogas i.e. savings in fuel wood, LPG, kerosene, etc., soil quality improvement and reduced use of chemical fertilizers. Research results of bio-slurry should be channelized through Extension Department
- Large scale and long term domestic biogas programme can only be viable through the public, private partnership mode.

b). AGRICULTURE DEPARTMENT - BIOGAS TUBE WELLS PROJECT

- Small farmers neither have animals, nor resources to operate bio gas tub wells. They need heavy subsidy to operate tube wells on bio gas.
- Farmers must have minimum required number of animals to supply feeding material to bio gas plants for operation of tube wells @4-6 hours per day.
- Absentee land lords/operators of tube well should not be considered for allotment of plants
- Promotion of biogas technology for tube wells operation may be made on cost sharing basis and heavy subsidy may be avoided. The beneficiary must feel sense of ownership of bio gas tube wells owing to his share of investment.
- Awareness campaigns to operate bio gas plants and maintain efficiently, and enhanced use of slurry to minimize the consumption of commercial fertilizer are crucially needed.
- Capacity building of technical manpower and contractor firms for construction services on biogas technology are a must.
- Linkage with research and academia for technology improvements are required.

5. FINANCIAL ANALYSIS OF DIESEL OPERATED AND BIO GAS SUPPLEMENTED TUBE WELLS - A COMPARATIVE STUDY

- In this study financial analysis of biogas and diesel tube wells has been conducted using net present value (NPV) and the results are presented in terms of benefit cost ratio (BCR), NPV and discounted payback period.

- A uniform size of tube wells i.e. one cusec, 28.4 liter per second, has been taken for this study. In case of biogas tube well the biogas energy generated from 40 m^3 bio gas digester will be used to supplement diesel tube well (dual fuel system) and there will be savings in diesel consumption. The diesel tube well shall operate on diesel, HSD only.

- Detail of assumptions and data used for conducting analysis and its results are presented below:

5.1. DIESEL TUBE WELL

- The diesel tube well comprises of 20 hp diesel engine, centrifugal pump and will deliver water @ 28.4 liter per second from 50 feet depth as detailed below **(Annexure C/1):**

Suction/ Delivery	6” x 5”
Water Table	50’
Bore dia / length	10” / 250’
Suction pipe dia/length	6”/100’
Filter dia/length	6”/100’
Filter type	PVC 6 mm thick
Delivery pipe	5” dia M.S. pipe, 70’
Peter Engine	20 hp
Centrifugal pump (high head)	6" x 5"
Life	10 years

- The cost of installation of diesel tube-well shall be Rs. 368,150/- The Operation and Maintenance cost of diesel tube-well (Rs. 330/- per hour) have been calculated using costs of HSD and lubricants as on June 2013 in local market as detailed below **(Annexure C/1)**:-

Annual operation	1600 hour
Consumption of diesel	3 liter per hour
Cost of diesel	Rs. 105 per liter
Change of lubricants	After every 333 hours
Cost of lubricant	Rs. 400 per liter
Repair and maintenance cost.	Rs. 1500 per month

5.2. BIOGAS POWERED DIESEL TUBE WELL

- The 20 hp diesel tube well shall be operated on bio gas on duel fuel system i.e. 80% bio gas & 20% diesel. The bio gas plant is of floating gas holder type with 40 m^3 digester size which is the same model as discussed above i.e. installed and tested at University of Agriculture Faisalabad. Detail of plant components and specifications are given in Annexures A to B.

- The recommended feeding rate to 40 m^3 digester is 650 kg animal dung + 650 kg water = 1300 kg. The bio gas 26 m^3 produced per day can operate 20 hp diesel tube well for 4.5 hour daily. The bio gas shall be purified by scrubbers from water vapors and H_2S and stored in storage tank at 4-6 bar pressure. The farmers could therefore, operate tube wells for long hours after every 3rd day as required for irrigation of crops.

- The cost of bio gas plant is Rs. 800,000/- in local currency. Detailed assumptions and calculations are given in Annexure C /2.

Size of floating gas holder plant	40 m^3
Gas production	26 m^3 per day (with 80% plant efficiency)
Operational hours	4.5 hour per day or 1600 per annum.
Daily feeding rate	650 per day
Cost of biogas plant along with accessories	Rs. 8,00,000/-

- The Operation and Maintenance cost of biogas tube-well (Rs. 183/- per hour) have been calculated using the following information /data (Annexure C/3).

Annual operational hours	1600
Diesel consumption	20% of HSD consumed (0.60 liter/hour)
Rate of diesel	Rs. 105/liter
Change of lubricants	After every 333 operational hours
Rate of lubricant	Rs. 400/liter
R &M cost	Rs. 1500 per month
Labor cost	Rs. 200/day
Animal dung cost	Rs. 320/day

5.3. INCOME OF AGRICULTURE FARM IRRIGATED BY TUBE WELL

- One cusec tube well shall supply water to irrigate 50 acre of agriculture land. It will increase the cropping intensity to 160% after installation of tube well. The agriculture production with bio gas tube well, shall increase @10% to 20% due to application of bio gas slurry.

- For calculation of net benefits the production of crops mix has been taken as per crop yields reported by Agriculture Department. The prices of inputs and crops income have been taken as per prevailing market rates. The net income generated from agriculture farm with bio gas supplemented diesel tube wells is Rs. 1.21 million per annum as shown at Annexure C/4.

5.4. BENEFITS TO COST RATIO (BCR) AND NET PRESENT VALUE (NPV).

- As indicated above the capital cost of diesel tube well is Rs. 0.368 million, and Rs. 1.168 million of bio gas tube well. The O&M cost of diesel tube well is Rs. 330 per hour and Rs.183 per hour for bio gas tube wells**.** A discount factor @15%, has been taken for calculation of NPV / BCR. The Salvage value @15% of the capital cost of tube-well shall be considered for the analysis. The life of both the tube wells is assumed as 10 years. The results are shown in Annexure C/5&6.
- Bio-gas powered diesel tube-wells are highly viable compared with the diesel tube-wells. The beneficiary of biogas tube wells would bear less expenditure and earn more benefits over life of tube well. A farmer having bio gas tube well would earn net income of Rs. 3.62 lac per annum (NPV) compared with Rs one lac per annum for diesel tube well i.e. more than three times. Similarly the discounted payback period for biogas tube well is 4 year only i.e. half of the payback period of diesel tube well.
- Overall 80% savings of HSD i.e. 3840 liter per annum, shall be assured by using biogas energy for each 20 hp tube well.
- Main findings of this study have been summarized below (Annexure C/5&6):

Description	Diesel Tube well	Bio Gas Tube-well
Average discounted cost /annum	Rs. 0.297 million	Rs. 0.249 million
Average discounted income /annum	Rs. 0.41 million	Rs. 0.611 million

NPV	Rs. 1.06 Million	Rs. 3.62 Million
BCR	1 : 1.36	1 : 2.45

6. CONCLUSIONS

- Pakistan has huge resource base for bio gas energy generation but it was never exploited to improve the energy supply situation, especially to meet the energy requirement in rural areas. Individual efforts were made by different government functionaries during 1970's to introduce the technology but no research and development work on design and testing of plants was done as such these initiatives proved un-successful. Major reasons of failure were:

    - Non provision of technical support services for designing, construction, operation and maintenance of bio gas plants
    - Lack of trainings to beneficiaries and skilled manpower
    - Poor operational management of bio gas plants by owners /farmers
    - Poor quality mechanical equipments
    - Non legislative measures for technology development and low awareness campaigns
    - Shortage of contractor firms offering turnkey solutions

- There is dire need for building the capacity of local contractor firms, technical manpower and beneficiaries for construction, operation and maintenance of biogas plants in Pakistan. The operators of plants need trainings and guidance on regular basis to resolve technical problems arising on day to day basis. The provincial governments need to focus on initiating short term courses on biogas technology, generating skilled manpower through trainings, create awareness and offer incentives (subsidy) for the adaptation of technology.

- Overall the use of bio gas energy to supplement diesel tube wells proved to be a success story. Partial failure of some plants are on the part of beneficiaries, not the technology failure, who have less number of animals and dung and handled the plants without following the prescribed guidelines. The bio gas models installed at UAF and in field by Agriculture Department proved successful and are still working. These models can be up scaled and replicated for large scale power generation after proper planning and in view of lessons learned.

- The use of bio gas energy for operation of tube wells has been found highly viable. The beneficiary of biogas tube wells would bear less expenditure (operational cost of energy) but would earn more benefits over the life of tube well (10 years).

- The net income of a farmer operating biogas tube well is Rs. 3.62 lac per annum compared with Rs one lac for diesel tube well owner. This means farmers having bio gas tube well shall earn 52% more income (per annum) than that of the diesel tube well.

- Over the life of tube wells the farmers shall get 242% extra income than that of diesel tube wells. The payback period of biogas tube well is 4 year, and 7 year for diesel tube well.

Description	**Diesel Tube well**	**Bio Gas T/well**	**Remarks**
Average discounted cost per annum	Rs. 0.297 million	Rs. 0.249 million	Average operational cost of bio gas tube well is less by 19% than diesel tube well (per annum)
Average discounted income per annum	Rs. 0.40 million	Rs. 0.611 million	Average income of bio gas tube well is higher @52% than diesel tube well (Per annum)

NPV	Rs. 1.06 Million	Rs. 3.62 Million	Over the life of bio gas tube wells, farmers will earn 242% extra income than diesel tube wells.
BCR	1 : 1.36	1 : 2.45	BCR for bio gas tube well is 80% higher than for diesel tubewells

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ANNEXURE - A

COMPONENTS AND LAYOUT PLAN OF BIO GAS MODELSINSTALLED AT UNIVERSITY OF AGRICULTURE FAISALABAD

FEEDING TANK

The feeding tank is used for the mixing of dung and water in equal ratio. The level of the feeding tank is little bit high than the level of slurry oozing out point because by this the material easily flows to the digester. A mixture pump and a mechanical stirrer can be used for proper mixing of the dung and water to it a homogeneous mixture. A circular PVC pipe in circular shape has been installed at an
angle about 30^0 for easy transfer of material from feeding tank into the digester. A shutter has been employed for opening and closing of the pipe. The feeding tank is to be covered through SS sheet to avoid entry of rain water etc.

Fermentation Chamber

It is round shaped well, made of bricks, cement and concrete. It is constructed underneath the ground surface with wall 2-3 feet above the ground surface.The chamber is connected to feeding tank and outlet pipes.The size of digester taken for financial feasibility study is 40 $m^{3.}$

HEAT EXCHANGER

Heat exchanger has been introduced for keeping the temperature at optimum range about 34℃-39℃. A geyser is used to supply hot water through heat exchanger (S.S Coils dia =25mm) to dissipate heat in the fermentation chamber in order to maintain optimum temperature during winter season. Mechanical stirrer is used to mix the material (manually) in the fermentation chamber.

GAS HOLDER

Each digester has been provided with floating drum of fiber glass. About 60%-65% gas of the daily production can be stored in the gas holder. It works at constant pressure. Gas from the gas holder is extracted to the gas storage tank using compressors.

STIRRING MECHANISM

Stainless Steel horizontal shaft stirring mechanism (having three arms) has been provided to mix the feeding material in the digester. It is operated 2 or 3 times per day manually. Mixing facilitates the microbes to maintain their population. It can prevent the formation of dead pockets in the digester that will increase the plant efficiency.

DEHUMIDIFIER

Biogas contains the moisture content (3-10%) and will cause corrosion if directly used. In order to avoid this problem, a dehumidifier containing silica-jel is used to absorb all the moisture content present in the biogas.

IRON SCRUBBER

Hydrogen sulphide content ranges from 50-5000 ppm in the biogas. Removals of these contents are necessary, because these consents produce pitting in the engine parts at directly combustion. Iron scrubber has the same specification like dehumidifier but the iron wool will be used in it. Iron wool will react with the hydrogen sulphide and it will fetch down it and reduce its amount to a minimum level as the chemical reaction is given below.

$$Fe+H_2S \quad ==========> FeS + H_2$$

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GAS STORAGE TANK

There are storage tanks for the storage of gas. The ordinary compressor can be used to compress the gas at the pressure about 6 bars (88.20 psi).

GAS FLOW METER

A common gas meter will be used to measure the quantity of biogas.

REGULATORS AND PLASTIC PIPES

Gas regulator has been used to regulate the gas flow at every gas consumption point. Without these regulators gas fluctuation will occur and the burner will not give the proper flame. Plastic pipes having diameter meter about 12 mm are employed for the conveying of gas from one point to another point.

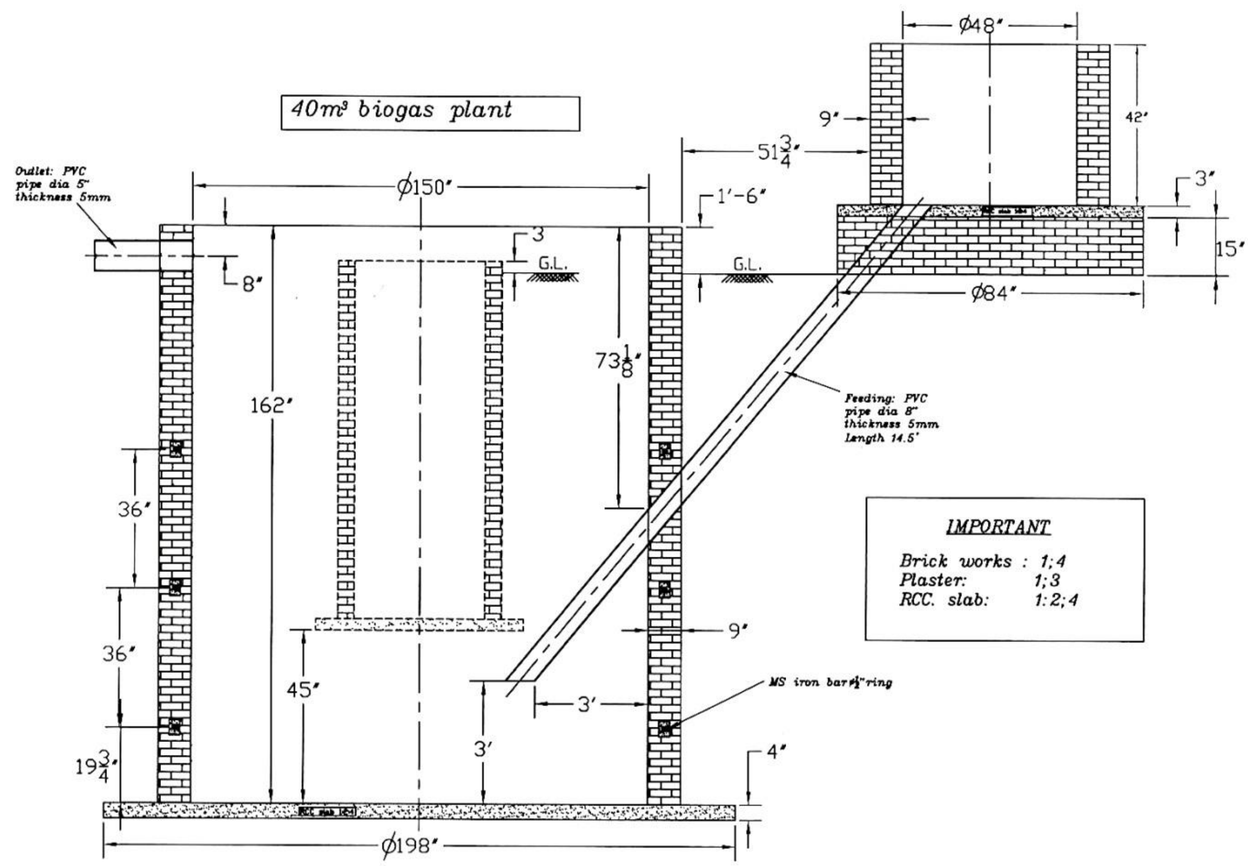
DIESEL ENGINE

An ordinary diesel engine of 22 hp is operated by using the biogas by ratio of 70% biogas and 30% of diesel for pumping of water. Gas is introduced to the engine through air intake manifold directly. Maximum gas produced (@ 0.05 m^3 per kg), from both 40 m^3 and 25 m^3 biogas plants have been calculated as 52.5 m^3/day and the actual gas produced [@ 80% plant efficiency per day, m3/day] calculated as 40 m^3/day. This gas produced in 24 hours has been found enough to operate 0.75 cusec tube well by 20-22 hp engine for 5-6 hr / day.

ANNEXURE A/2

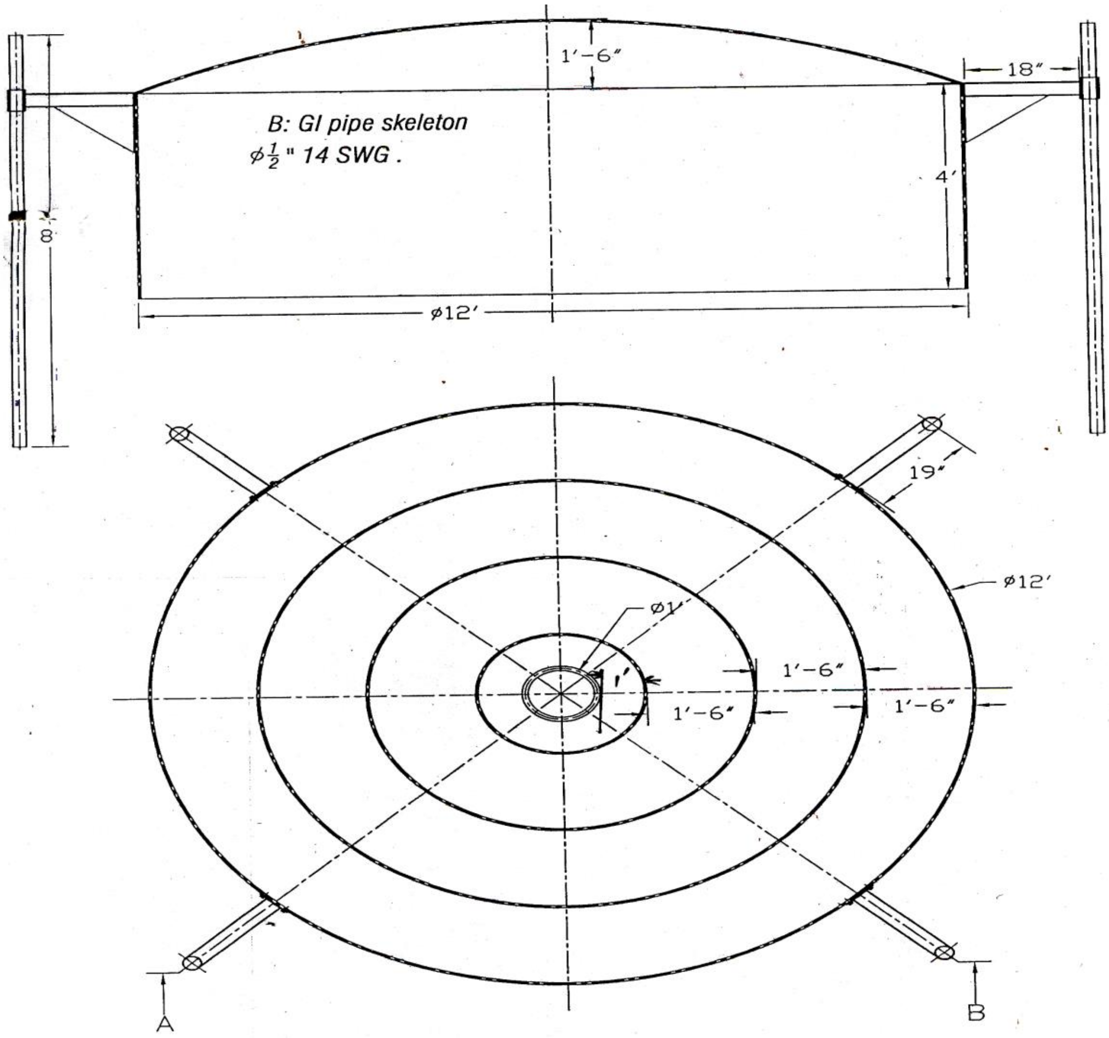
LAYOUT PLANOFBIO GAS PLANT

FERMENTATION CHAMBER, FEEDING TANK, INLET AND OUTLET OF FLOATING DRUM BIOGAS PLANT (40 m^3)



ANNEXURE A/2

LAYOUT PLAN OF GAS HOLDER FOR BIOGAS PLANT (40 m^3)



ANNEXURE - B

SPECIFICATIONS OF FLOATING GAS HOLDER PLANT (40 m^3)

GeneralMake	Local made
Type	Drum type (constant pressure based design)
Application	Production of biogas for tubewell operation
Size	40 m^3

Overall Dimensions

Fermentation chamber	Dia meter (inner) Depth	3810 mm 4115 mm
Gas holder (Fibre Glass drum)	Dia meter Height Wall Thickness (Fibre glass)	3658 mm 1676 mm 6 mm

Fermentation Chamber

Dimension	Inner dia (id) 3810 mm, Outer dia (o.d) 4318 mm,

	depth 4115 mm & wall thickness 229 mm
Material	1st class masonry bricks 228.6 x 114 x 76 mm
Plaster	1:3 (25 mm thick layer inside the well)
Bed	Bricks gravel 102 mm thickness RCC 102 mm thickness (ratio cement, sand & gravel 1:2: 4) Iron bar(M.S. round bar 12 mm dia) grid 230 mm square
Main Hole	914 x 914mm, wall thickness 114 mm, 2516 mm depth, manhole cover Ms/concrete, RCC slab (1:2:4) 76 mm thickness

Drum Supports

Material	M.S. pipe o.d. 64 mm, i.d.60 mm and 2439 mm length (4 Nos) M.S. round 12.7 mm dia (for pins) M.S Lock Plate 178 mm dia., 64 mm inner dia., Lock pin hole dia. 12.7 mm Lock pin 12.5 mm dia.

Feeding Chambers

Dimensions	Outer dia: 1245 mm, inner dia: 762 mm and 229 mm brick wall thickness
Tank depth	915 mm
Feeding pipe	RCC/PVC pipe 203 mm dia (in case of plastic wall thickness 5 mm)
Slurry outlet	RCC/PVC pipe 102 mm dia (in case of plastic wall thickness 5 mm)
Material	1st class masonry bricks 228.6 x 114 x 76 mm
Plaster	1:3
Feeding material Mixer	M.S hallow shaft 25 mm inner dia., M.S Plate 14 SWG, M.S (GI) Handle

Gas Holder (Fibre Glass)

Pipe Skelton	M.S. Pipe 13 mm dia,(14 SWG) impregnated with fibre glass of 6 mm thickness
M.S. plate	4 Nos. M.S. plate (356 x 152 x 8 mm) welded with pipe skeleton and studs 8Nos welded on this plate, impregnated with fibre glass and 04Nos. plates (356 x 152 x 6.35 mm) with 8 holes 12.7 mm dia, M.S plate (406 x 356 x 5 mm) 08 Nos.
Drum coupling (side supports)	04 Nos. Arms of M.S box and M.S plates of length 483 mm 04 Nos. M.S pipe o.d. 80 mm,i.d. 74 mm& length 127 mm welded with arm
Nature	Interior & exterior chemical resistant
Top cover	Semi spherical or conical
Gas outlet pipe / nozzle	G.I pipe with handle cock Dia 19 mm

Pipes & Accessories

Gas supply line	G.I. pipe 19 mm dia, black rubber pipe 19 mm dia, handle valves 19 mm dia, elbow, socket, nipples and clamps etc.

Water trap and Hydrogen Sulfide remover

Water trap	Dia.305 mm, Height. 457 mm Material M.S with bolted air tight cover at top and handle valve 13 mm for water drain out and gas inlet and out let 19 mm dia threaded sockets. Granular silica gel packing
Hydrogen Sulfide remover	Dia.305 mm, Height. 457 mm Material M.S with bolted air tight cover at top and gas inlet and out let 19 mm dia threaded sockets. Iron wool packing

Stirring System

Type	Winged type (Horizontal type, Manual operated)
Material	S.S 304
Power pulley	B-Type ,CI
Bearing	6207 ZZ with bearing lock, bearing coupling, bearing coupling shell, joint bush (S.S 304) and Teflon bush
Oil seal	Rubber 70 x 40 x 12 mm
Main shaft (Hollow)	Outer dia: 60 mm, inner dia: 48 mm length 3960 mm, S.S 304
Stirrer blade	710 x 200 x 5 mm,(4Nos) 560 x 200 x 4 mm, (4Nos) with twist 45^{O} (4 Nos blade) S.S 304

Housing shell	Outer dia: 72 mm, inner dia: 60 mm length 200 mm (S.S 304)
Stirrer operating frame	M.S Angle iron 38 mm x 38 x 5 mm
Pulley	CI, 152 mm dia double grove B Type
Handle	M.S

Heat Exchanger

Type	Hot water circulation based
Material	S.S 304 dia. 25 mm, seamless, Dia of Coil 3200 mm, No of turns 3, Height of coil 1525 mm, connection pipes for heat exchanger, pump and geyser.
Heat exchanger supports	Stainless steel L shaped 14 SWG (grouted in F-chamber wall)
Heating source	Geyser (20 gallon) with thermostat
Water pump	Impeller/piston type (discharge rate 2 gallon/min) electric motor operated or coupled with diesel engine as per requirement

Compressor and Gas Storage

Type	Double Piston type (V shaped) (Built-in NRV and adjustable pressure release valve)
Electric motor/prime mover	1.5 hp (1400rpm) or coupled with peter engine
Piston dia.	60-65 mm
Pressure range	150 psi
Gas storage	MS 1067 mm dia. 1676 mm height, 5 mm wall thickness
Pressure release valve	2-6 Bar, imported
Pressure gauge	0- 150 psi, imported
Limit switch	01 Nos. at the bottom of drum support to stop the compressor
Feeding pipe	RCC/PVC pipe 203 mm dia (in case of plastic wall thickness 5 mm)
Slurry outlet	RCC/PVC pipe 102 mm dia (in case of plastic wall thickness 5 mm)
Material	1st class masonry bricks 228.6 x 114 x 76 mm
Plaster	1:3
Feeding material Mixer	M.S hallow shaft 25 mm inner dia., M.S Plate 14 SWG, M.S (GI) Handle

Miscellaneous

Nuts and bolts	To be tightened with springs/rubber washers
Modifications	To be carried out free of cost, if required
Warranty	Free: 1 year for parts and service

ANNEXURE -C /1 to 6

FINACIAL ANALYSIS CALCLULATIONS

CAPITAL COST AND OPERATIONAL COSTOF DIESEL TUBEWELL (ONE CUSEC OR 28.4 LITER PER SECOND)

A. CAPITAL COST

INPUT DATA

1	Suction / Delivery	6” x 5”
2	Water Table	50'
3	Bore dia / length	10”/250'
4	Suction pipe dia / length	6” / 100'
5	Filter dia / length	6” / 100'
6	Filter type	PVC 6 mm thick
7	Delivery pipe	5” dia M.S. Pipe

CALCULATION (Rs.)

1	Boring Fee @ Rs. 130 per foot	32500.00
2	Transportation charges (including loading & unloading) plus transportation of POL	7000.00
3	Lining/suction pipe PVC 6" dia @ 300/- per ft.	30000.00
4	PVC Filter 6" dia @ 300/- per ft.	30000.00
5	Delivery pipe M.S pipe 5" dia @ 355/- per ft.	24850.00
6	Peter Engine (20 h.p.)	60000.00
7	Centrifugal pump (high head) 6" x 5"	23000.00
8	Accessories (solution for joints, bailplug, screws etc.)	9000.00
9	Gravel for shrouding in annular spaces (100 cft @ Rs. 80/ cft)	8000.00
10	Construction of well (10' dia / 60' depth)	138000.00
11	Misc. Expenses (fitting charges, etc)	5800.00
	Total	**368150.00**
	CAPITAL COST - Million Rs.	**0.368**

B. O&M COST OF DIESEL TUBEWELL(Rs.)

1	Annual operation (hours)	1600.00
2	Fuel charges @ Rs.105/- per liter & 3 liter per hours)	504000.00
3	Lubricant charges	5760.00
4	Repair and maintenance charges @ Rs. 1500 per month	18000.00
	Total O&M (Rs.)	**527760.00**
	Rs. Per Hours	**330**

ANNEXURE- C/2 to 6

ROUGH COST ESTIMATES OF40 m^3 BIOGAS PLANT

Sr. No.	Material / Description	Cost of 40 m^3 (Rs.)
A - Civil Works		
1	Bricks @ 8500 for 40 m^3 @Rs 7000 per 1000 bricks	60000.00
2	Cement @ 60 bags for 40 m^3 @ Rs 500 per bag	30000.00
3	Sand	6000.00
4	Gravel @ 170 for 40 m^3 @Rs 50 per cft	8500.00
5	Steel ½ inches @ 200 kg for 40 m^3 @ Rs 70 per kg	13000.00
6	PVC Pipe	8000.00
7	Excavation	8000.00
8	Labour Charges	25000.00
	Sub Total (A)	158500.00
B. Gas Holder and Supporting Structure /Accessories		
9	Fiber Glass Drum	200000.00
10	Stirrer System	50000.00
11	Heat Exchanger	80000.00
12	Gyser (20 Gallon)	20000.00
13	Gas Storage Tank	70000.00
14	Compressor	40000.00
15	Water Vapor Trap	7300.00
16	H_2S Remover	7500.00

17	Pipe fittings, gas pressure gauge, pressure release valve etc.	9000.00
18	Commissioning charges	40000.00
19	Freight of gas holder / material	30000.00
20	Overhead and atfter sale warrantee	40000.00
21	Profit	40000.00
	Sub Total-B	633800.00

	Grand Total (A + B)	792300.00
	Say	Rs. 800000.00

ANNEXURE- C/3 to 6

OPERATIONAL COST OF BIOGAS TUBEWELL

ASSUMPTIONS

1	Suction / Delivery	6” x 5”
2	Water Table	50'
3	Bore dia/length	10”/250'
4	Suction pipe dia / length	6” / 100'
5	Filter dia / length	6” / 100'
6	Filter type	PVC 6 mm thick
7	Delivery pipe	5” dia M.S. Pipe

CALCULATIONS

1	Boring Fee @ Rs. 130 per foot	32500.00
2	Transportation charges (including loading & unloading) plus transportation of POL	7000.00
3	Lining/suction pipe PVC 6” dia @ 300/- per ft.	30000.00
4	PVC Filter 6” dia @ 320/- per ft.	32000.00
5	Delivery pipe M.S pipe 5" dia @ 400/- per ft.	28000.00
6	Peter Engine (20 h.p.)	60000.00
7	Centrifugal pump (high head) 6" x 5"	23000.00
8	Accessories (solution for joints, bailplug, screws etc.)	10000.00
9	Gravel for shrouding in annular spaces (100 cft @ Rs. 80/ cft)	8000.00
10	Construction of well (10' dia / 60' depth)	138000.00
11	Misc. Expenses (fitting charges, etc)	7000.00
	Total	**375500.00**
	Million Rs.	**0.376**

O&M COST

1	Annual operation of tubewell in hours	1600.00
2	Fuel charges @ 20% of the cost of diesel operated tubewell	100800.00
3	Lubricant charges	5760.00
4	Labour cost + gobar cost @ 200/day and 320/day for 325 days	169000.00
5	Repair and maintenance charges @ Rs. 1500 per month	18000.00
	Total O&M	**293560.00**
	Per hour	**183**

ANNEXURE- C/4 to 6

BENEFITS IN THE FORM OF AGRICULTURE PRODUCTION FROM DIESEL AND BIOGAS POWERED TUBEWELLS

A. DIESEL TUBEWELL

Pre-Development: The annual benefits from 50 acre-farm at 125% cropping intensity before installation of tube well are as under:

Crops	Cropped area in acres	Production (40 Kg)		Value of Production		Cost of Productions	
		Per acre maund	Total maund	Price/ 40 Kg	Total	Per acre	Total
Wheat	27	28	756	950	718200	14000	378000
Cotton	20	21	420	2000	840000	16000	320000
Sugarcane	11	700	7700	100	770000	40000	440000
Maize	2	20	40	320	12800	9000	18000
Fodder Berseem	2.5				150000	8000	20000
Total	**62.5**				**2491000**		**1176000**

- **Note : One maund = 37 kg** Net Income: Rs. 13,15,000/- (Rs. 1.315 million)/annum

Post-Development: The annual benefits from 50 acre-farm at 160% cropping intensity after installation of tube well are as under:

Crops	Cropped area (acre)	Production(40 Kg)		Value of Production		Cost of Productions	
		Per acre monds	Total monds	Price/40 Kg	Total	Per acre	Total
Wheat	34	32	1088	1200	1305600	17000	578000
Cotton	25	25	625	2000	1250000	21000	525000
Sugarcane	14	800	11200	170	1904000	50000	700000
Maize	3	25	75	320	24000	15000	45000
Fodder Berseem	4				240000	9400	37600
Total	**80**				**4723600**		**1885600**
Note : Note : One maund = 37 kg							

- Net Income (post development): Rs. 28,38000/- i.e. Rs. 2.838 million/annum

✓ **Net Income of diesel tubewell after installation= (2.838 -1.315) = Rs.0.80 million/annum.**

B. BIOGAS TUBEWELL

The income of farm shall be increased after installation of bio gas tube wells due to bio gas slurry as yield of crops shall increase @ 10% to 20%. The detail of income calculations is given below:

Crops	Cropped area in acres	Production(40 Kg)		Value of Production		Cost of Productions	
		Per acre monds	Total monds	Price/40 Kg	Total	Per acre	Total
Wheat	34	35	1190	1200	1428000	17000	578000
Cotton	25	27	675	2000	1350000	21000	525000
Sugarcane	14	880	12320	170	2094400	50000	700000
Maize	3	27	81	320	25920	15000	45000
Fodder Berseem	4				240000	9400	37600
Total	**80**				**5138320**		**1885600**

- Net benefit due to slurry: Rs. 0.41 million/ annum, and Net Income of Biogas Tubewell due to post development and slurry = 0.41+0.80=1.21 million.

ANNEXURE C/5 to 6

FINANCIAL ANALYSIS OF DIESEL OPERATED TUBEWELL

(Million Rs.)

Year	Annual Operational Hours	Costs (Tubewell)			Benefits			Discount Factor @ 15%	Discounted at 15%	
		Capital cost	O&M Cost @Rs. 330/ hr	Total	Benefits /50 acre @ 0.80 mill/ annum	Salvage value	Total benefits		Cost	Benefit
1	1600	0.368	0.528	0.896	0.800	0	0.800	0.870	0.779	0.696
2	1600	0	0.528	0.528	0.800	0	0.800	0.756	0.399	0.605
3	1600	0	0.528	0.528	0.800	0	0.800	0.658	0.347	0.526
4	1600	0	0.528	0.528	0.800	0	0.800	0.572	0.302	0.457
5	1600	0	0.528	0.528	0.800	0	0.800	0.497	0.263	0.398
6	1600	0	0.528	0.528	0.800	0	0.800	0.432	0.228	0.346
7	1600	0	0.528	0.528	0.800	0	0.800	0.376	0.198	0.301
8	1600	0	0.528	0.528	0.800	0	0.800	0.327	0.173	0.262
9	1600	0	0.528	0.528	0.800	0	0.800	0.284	0.150	0.227
10	1600	0	0.528	0.528	0.800	0	0.800	0.247	0.131	0.198
11						0.06	0.055	0.21	0.000	0.012
								Total	**2.97**	**4.03**

BCR: 1 : 1.36

NPV: Rs. 1.06 Million

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ANNEXURE C/6 to 6

FINANCIAL ANALYSIS OF BIOGAS OPERATED TUBEWELL

(Million Rs.)

Year	Annual Operation hours	Costs (Million Rs.)				Benefits			Discount Factor @ 15%	Discounted at 15%	
		Capital Cost of pumps	Cost of biogas plant 40 m^3	O&M cost @ Rs. 183/ hr	Total	50 acre@1.21Million per/ annum	Salvage value	Total		Cost	Benefits
1	1600	0.376	0.8	0.29	1.47	1.21	0	1.21	0.87	1.28	1.05
2	1600	0	0	0.29	0.29	1.21	0	1.21	0.76	0.22	0.91
3	1600	0	0	0.29	0.29	1.21	0	1.21	0.66	0.19	0.80
4	1600	0	0	0.29	0.29	1.21	0	1.21	0.57	0.17	0.69
5	1600	0	0	0.29	0.29	1.21	0	1.21	0.50	0.15	0.60
6	1600	0	0	0.29	0.29	1.21	0	1.21	0.43	0.13	0.52
7	1600	0	0	0.29	0.29	1.21	0	1.21	0.38	0.11	0.45
8	1600	0	0	0.29	0.29	1.21	0	1.21	0.33	0.10	0.40
9	1600	0	0	0.29	0.29	1.21	0	1.21	0.28	0.08	0.34
10	1600	0	0	0.29	0.29	1.21	0	1.21	0.25	0.07	0.30
11						0	0.18	0.18	0.21	0.00	0.04
Total										**2.49**	**6.11**

BCR 1 : 2.45

NPV: Rs. 3.62 Million Rs.