Effective Use of Technology to Convert Waste into Renewable Energy Source

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Abstract: As energy demand is increasing in the world, renewable energy sources are utilized. Biogas is a renewable energy source which helps us in conserving fossil fuel. There are favourable scenarios for using biogas energy in rural areas through an arrangement of community biogas plants. This technology is not only used in houses for lightening and cooking purposes but it also serves as a good fertilizer. It can also be used in various automotive applications. This study proposes the method to convert animal waste into biogas.
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1. Introduction

Energy is an absolute need of everyday life .It is used in the form of light, heat and electricity. Pakistan is facing serious energy crisis in gas and electricity, because no steps have been taken for a long time to increase the capacity of energy resources. Observation indicates that earth's average temperature is increased by 0.6°C during the last century (Wong, 2011). It has caused serious problems like sea-level rise, threats to food supplies and human health .Human activities like consumption of fossil fuels are the cause of global warming that occurred in last 40-50 years. As a result, levels of carbon dioxide are increasing rapidly. Therefore, government should look for some alternative energy sources. Alternative energy sources are now become important to cater for energy crisis. These alternative resources include sun, wind, water, biomass etc and are known as renewable energy sources.

1.1 Waste to Energy

Waste is any unwanted or undesirable material. Waste to energy conversion technologies have the potential to get renewable energy sources from waste including municipal solid waste, industrial waste or animal waste. It utilises the waste that would have been disposed off in the lands. There is an obvious need to stop generating this waste and to recycle it. Thus by converting waste into energy we can get rid of pollution from landfills and can make use of lands which would result in safe and secure environment. Moreover, the heat produced can be used to generate electricity.

1.2 Renewable Energy Sources and Biogas

Renewable energy is obtained from natural resources like wind, sun etc. It is a form of energy which is replaced by natural resources. As these resources are obtained from natural processes, thus are more reliable and cost effective. It offers excellent benefits to meet energy crisis. Renewable energy is clean and carbon dioxide free source. Globally, 16% of total energy consumption comes from renewable sources, with 10% comes from biomass, and 3.4%from hydroelectricity. The renewable power capacity globally has now reached 200 GW and by 2030, the overall demand is predicted to almost double the current levels (Energy Business Reports August 2008). It plays a vital role to fulfil energy demands. Biogas is a renewable energy source, produced by anaerobic digestion of recyclable materials like municipal solid waste, animal manure, Biomass etc. (NNFC Renewable fuels and energy Facts sheet, 2011). It is mainly composed of carbon monoxide and oxygen with few amounts of Hydrogen sulphide, moisture etc. The gases released after combusting with oxygen are used as a fuel. It may also serve as a source of electricity after proper treatment. After compression it can replace CNG and can be used as fuel in vehicles. It protects the environment from adverse affects of gases emission due to climate changes. Thus farmers can use animal waste as a source of energy and fertilizer as well.

1.3 Biogas Production Aspects in Pakistan

Renewable energy source is very helpful in Pakistan to meet the energy demand of people, special living in rural areas. People in these areas belongs to agriculture thus keep livestock with them. There are 62.9 million of animals (Buffaloes, Cows, Bullocks) in Pakistan (Arif, 2008-09) .If on average 50% waste is obtained from these livestock, then millions of cubic meters biogas can be produced. Thus the land which would be used for digging the waste could be used for agriculture purposes. Cost of producing the biogas is very low. If plants are also included in biogas production process then the residue can be recycled as good quality fertilizer in

the farming. Farmers do not need to buy any fertilizer. When Biogas is produced from the grass, it can help in setting the structure of landscapes.

1.4 Research Question

The main focus of this research is to address the following research question:

How the effective and efficient use of technology can help to meet the energy demand by converting livestock waste into Biogas?

1.5 Objective

With conversion of animal waste to biogas, the manure can not only be used as a source of energy but also to reduce the adverse effects of waste on environment. The objective of this paper is to design a biogas production process from animal wastes and to propose an environment friendly and safe method to treat waste. Thus the harmful effects of waste on environment can be mitigated and this waste can be best utilized to meet energy demand. It is an economical process as no extra labour is required for this purpose. During processing, waste going into the machine is equal to the waste that comes out after decomposition. But the out coming material has fewer odours, becomes a good fertilizer and causes no pollution to the atmosphere. The liquid part is used as a fertilizer and the solid part is recycled. Fresh waste is preferred as it contains more moisture. The source of waste could be human excreta, slaughter house waste, manure, fruit and vegetable waste etc. Cattle dung and manure is the most suitable for biogas production. Usually fresh cattle dung is collected and water is added in it, when carried to the system. Chicken droppings can also be used as a raw material for biogas. When this waste is converted to biogas, the remaining slurry or sludge can be used as excellent fertilizer. It reduces the odour comes out of waste because the gas is burnt in the machine before coming to the environment. The environmental impacts as well as the benefits of biogas will also be studied in this research Biogas. Fruitful results have been observed in Pakistan because 50% of Pakistan's population living in rural areas and have cattle(Tirmizi.A, 2008). Biogas is not only a fuel for green energy but it has many other benefits, not only for producers but for society as a whole. It provides an alternative use for food by-products. Instead of wasting huge amount in land filling these by products, they can be used biogas production.

2. Literature Review

Pakistan is situated in South Asia, having population of 176 Million, living in land of 796,095 square kilometres (estimated population as per PCO population census organization). Mainly, Pakistan has agriculture economy and has per capita income of about $1207(Zeb, 2011). Pakistan is facing severe energy crisis and energy requirements are increasing by an average of 24% annually (Hamza, 2010). The 4% of total land area is covered by forests (land cover assessment and monitoring Pakistan Volume 10). About 98% of the total wood is used as a fuel (FAO report, 1997). The annual deforestation rate of Pakistan is over 2% which is quite high. (Faisal Rahman Channa, 2011). Renewable energy sources are helpful to meet the growing energy demand and to improve the living standard of people. These resources are used for cooking and lighting purposes. Biogas is one of the most valuable energy sources, produced by biological breakdown of organic matter. Pakistan has to depend on external support to meet the energy demand. Pakistan is having huge oil resources but most of them are still unexplored. Due to lack of technical knowledge, awareness and government funding, the efforts made in utilizing renewable energy resources were not successful. The results achieved from the initial experiments were not as anticipated. There are multiple renewable energy resources in Pakistan. Among all those resources, micro-hydel, bio-energy, wind and solar energy are more feasible but still unexploited here. Pakistan must utilise these resources to meet the energy demand. Many attempts have been made in last years to use substitute energy resources but the most successful method in the field of Bio-energy is

2.1 Wastes to Energy Conversion: An Effective Way to Overcome Energy Crisis at Domestic Level:

Quantities of waste is increasing due to increase in population and changes in living standard of people, and it's a serious threat to our environment. But now due to technological development and awareness, wastes to energy plants are designed specially to produce clean environment. These plants are equipped with pollution control equipment to reduce harmful emissions.

2.2 Biomass Energy; What and How?

Biomass energy is a form of renewable energy resource which is derived from the wastes generated due to several human activities as well as animal wastes. Bio energy is stored in materials made with the help of living things e.g. wood. Biogas and Alcohol are one of the major sources of bio energy The energy derived from biogas is renewable energy because its source can be easily available again without taking a lot of time. A question may arise that fossil fuels are made by living organisms too so is it renewable or not. The answer to this question is that no doubt it takes the living organisms to convert the raw material to fossil fuels but it takes a time so long that it would take millions of years to replace it

and hence cannot be tagged as renewable energy source. Peat (a type of coal, soft brown) is another resource that is not easily replaced, taking hundreds of thousands of years to renew it. To be considered renewable, the resources must be replaceable within our lifespan. For example, the wood used in your campfire replaces itself as the forest grows. Coal on the other hand can be taken from the earth only once, and cannot be replaced. (Tiwari, G. N.; Ghosal, M. K). There are various types of waste materials available from different sources, but not all waste materials are biodegradable. Only biodegradable waste materials can produce biogas. Again, the biogas generation capacity is not the same for al1 biodegradable waste materials.

The degree of biogas generation capacity of the various types of dung is found to be in ascending order of:

Cow dung < buffalo dung < mixture of animal dung < camel dung < horse dung

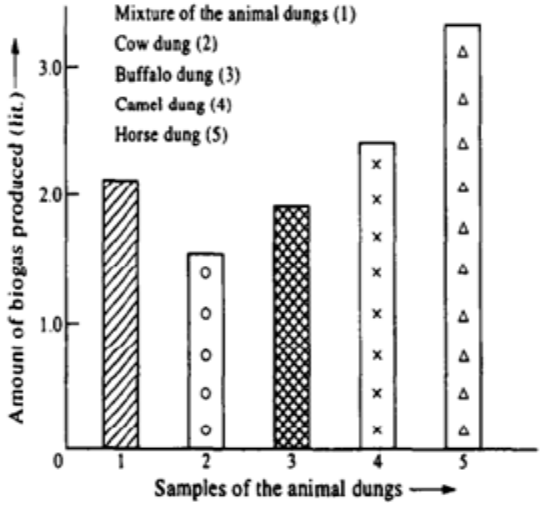


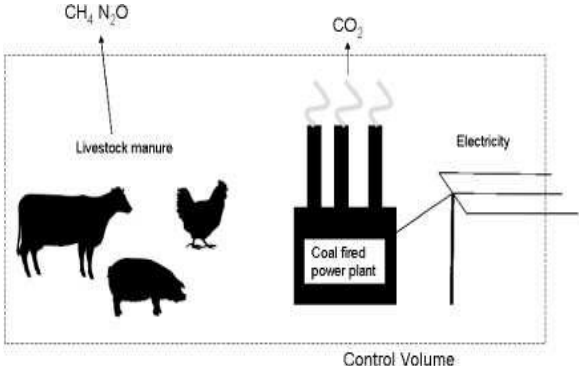
Fig. 1 Biogas Generation Capacity of the mixture of the animal dungs and its individual components

The above results were obtained at a specific temperature of 37°C. The biogas generation capacity of each waste material will be different at other temperatures (Tanusri Mandal and N.K. Mandal, 1997)

2.3 The Energy and Emissions Benefits of Converting Manure to Biogas:

To meet the energy requirements and to reduce green house gas emissions, analysis of converting animal waste into biogas could be supportive. Methane and Nitrous oxide is emitted with these disposal methods. Both of these green house effect gases have 21 and 310 times global warming potential of Carbon dioxide respectively. In 2005, emissions from this sector in US were equivalent to 7% of the total emissions in this country. Out of this, 51 to 118 Metric million tons of carbon dioxide was due to animal manure, and this amount is increasing from 1990 to 2005. Thus minimizing agricultural contributions to climate change can be helpful to mitigate the emissions from these green house gases. Anaerobic digestion can minimize GHG emissions from livestock manure. This process converts manure to methane-rich biogas. Using Biogas as alternative to fuel can replace two Green house gas emission sources i.e. manure and coal combustion, as its source is Biogas combustion, so has less carbon dioxide contribution. In US, Biogas energy potential was calculated using values from energy that can be contributed by each animal in a day and number of animals units present in the country. It was concluded that 1 quad of renewable energy can be produced from 95 million animals units, which is equivalent to 1% of total energy consumption in US. Generating electricity from biogas could contribute 88±20 billion kWh, or 2.4±0.6% of annual electricity consumption in the US. Replacing coal and manure GHG emissions with the emissions from biogas would produce a net potential GHG emissions reduction of 99±59 million metric tons or 3.9±2.3% of the annual GHG emissions from electricity generation in the US. (Amanda D Cu´ellar and Michael Ewebber, 2008).

Here is the comparison of two scenarios regarding the treatment of livestock manure.

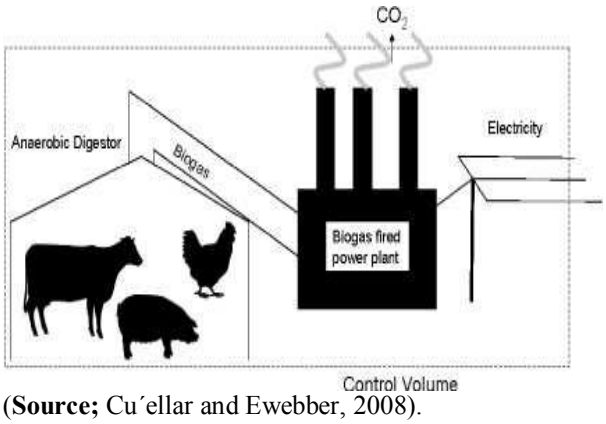


(**Source;** Cu´ellar and Ewebber, 2008).

Fig. 2 Scenario A: business as usual. Livestock manure and coal-fired power emit greenhouse gases

Scenario A shows green house gas emissions from animal waste as well as from coal combustion.

Scenario B shows treatment of waste in anaerobic digesters. The Biogas coming out of digesters is further burnt to produce electricity. In this case, carbon dioxide is only green house gas emission, going to environment.



(**Source;** Cu´ellar and Ewebber, 2008).

Fig. 2. Scenario B: biogas is produced and used for electricity generation, replacing two sources of GHGs untreated manure) with one source of GHGs (biogas combustion)

2.4 Biogas Potential in Pakistan:

In Pakistan total available biogas generation potential is round about 503 MMCFD. A lot of work is in progress all over Pakistan by PCRET (Pakistan Council of Renewable Energy Technologies) regarding biogas plants manipulation and build-up. PCRET has mounted more than 1600 plants (most of them having capacity of almost 71 ft^3/day) so far if we look into last 3 years. This development is not limited to this, almost same number of plants have also been established by various private sectors and NGO's. Before this period, operation uncertainty level for all built-up biogas plants is very high due to deficiency of available sources of maintenance and repair. For the time being, state of the art digesters are producing more appropriate gas which clearly meets the environmental circumstances with upholding internal temperature; because of this more options are available for more plants installations in the country with much better long lasting existence. In Punjab specifically in Bahawalpur region, Biogas plants are drawing high attractiveness of farmers and it's a good sign. Some more workings are also under process like a prolific project at Landhi Cattle Colony, Karachi by AEDB and its initial phase is expected to be sponsored by NZAID (New Zealand Aid). Biogas plants/generators will generate electricity & ultimately high class organic fertilizer by using waste (From around 400,000 cattle in the area). At initial stage, the plant will generate 250kW electricity and after extension it will increase up to 30MW and ultimately throughput of 1500 ton /day organic fertilizer. In Shakarganj Mill, another biogas electricity generating plant is under building phase, again with the collaboration of AEDB. Its estimated power generating capacity is 8.25MW (Munawar 2009).

3. Research Methodology

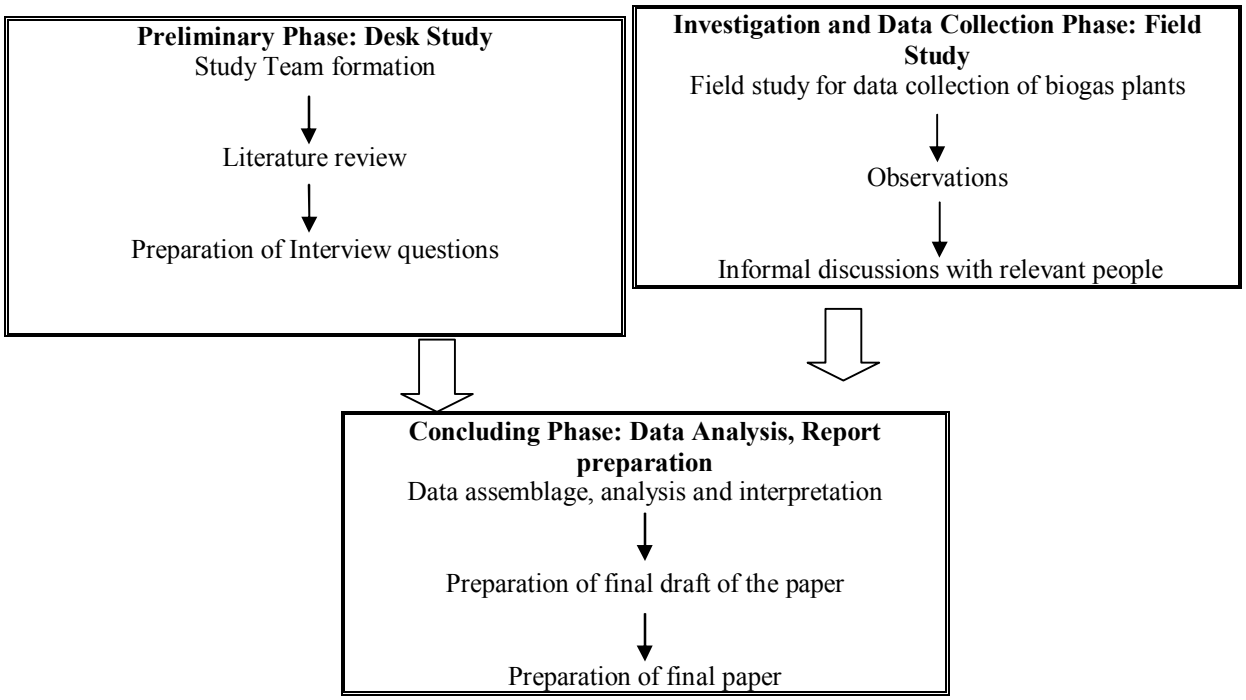


Fig. 3 Research Methodology

- The interview were conducted for one time and laddering technique was used to get deep insight of installed plants. Then the pros and cons of existing methods will be identified.

On the basis of interviews and study of existing plants, solutions will be proposed to meet the limitations.

4. Results

From the interviews conducted the following information was obtained:

4.1 Types of Biogas plants in Pakistan

Pakistan Council of Renewable Energy Technologies has installed three types of biogas plants in Pakistan. These are:

- Plants with moveable gasholder
- Plant with built-in fixed dome gasholder
- Low cost bag / balloon type plant

The installation of these biogas plants was on experimental basis to select the appropriate design based on social and cultural norms of the particular rural areas

4.1.1 Moveable Gasholder:

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Year	No. of Biogas plants installed	Type	Results
1976	21	Chinese	Unsuccessful
1979	10	Indian	Successful
1980	100	Indian	Satisfactory
1983	350	Indian	Satisfactory
1986	4000	Indian	Failed
1993	50	-	Successful
2006	1600	-	Successful

Fig. 4 History of Biogas plants in Pakistan

4.1.2 Fixed Dome Gasholder:

Advantages	Disadvantages	Advantages	Disadvantages
• The pressure of the gas is controlled by the gasholder • Gasholder assists in stirring • Gasholder also helps in breaking down the hard crust, if formed • If the gasholder is painted black, it helps to create a greenhouse effect within the digestor which helps in keeping the temperature high in winter season • Slurry can be easily collected due to gravity flow	• Heat losses may occur due to the gasholder exposure to the atmosphere • Corrosion is the main problem for the gasholder as it dips in slurry and stays in contact with moisture • Periodic painting of the gasholder is required to avoid rusting	• Space is better utilized since it is underground • Steady temperature is easy to maintain inside the digester • Post installation maintenance is rarely needed (e.g. painting, plastering etc)	• Special construction skills are required • Stirring and froth breaking is generally difficult • Controlling the gas pressure is difficult • Leakage of gas might occur from hairline crack in the dome or from sides of manhole cover • A noticeable quantity of gas that is produced inside the slurry chamber is not fully utilized and is wasted • Slurry is to be taken out manually

Fig.5 Fixed Dome Gas holder

4.1.3 Low Cost Bag/ Balloon type plant

Low density polyethylene was used to design a bag type biogas plant. It was low cost plant and was installed for field testing. It was found from the experiments and tests that a high density polyethylene or some other composite material having better elasticity and strength is required for a sustainable bag type biogas plant. Hence this design was not very successful.

4.2 Average Capacity of Biogas plants

The annual biogas generation capacity of the biogas plants installed during last 7 years is more than 2.5 million m^3 along with production of 4 million kg/year of bio-fertilizer.

4.3 Most common Biogas Purification method

4.3.1 Water Scrubbing

Water scrubbing is used to remove H2S and CO2 from biogas. It is a well established technology and removes these gases as both of them are more soluble in water. However H2S cannot be completely removed by this process as its solubility in water is lower than that of carbon dioxide. The H2S that came in contact in water and still remained desorbed can

result in odour problems. Pre-removal of H2S is a more environmentally friendly approach.

4.4 Biogas/diesel dual fuel engine for electricity generation

A study was conducted where biogas was used in a single cylinder, compression ignition engine, which has been modified to operate under dual-fuel condition to generate electricity. The primary fuel was biogas, which is ignited by a pilot diesel liquid injection. This long term operation was carried for 2000 h. Weight of Engines components were compared by measuring it before and after this long term operation. Visual inspection was also done and rating was given for wear tear. Results shows performance between diesel and dual-fuel operations was comparable. Bio gas diesel-fuel engine proved to be successful with biogas rate above 90%. Results indicated that Biogas engine was able to generate 1.45 KW electricity. Thus dual-fuel engine proved to perform well an has potential to be used for on-farm utilization (Tippayawong et al, 2007).

4.5 Benefits of household biogas

Biogas is very beneficial for its users. It has a number of benefits which are as follows:

4.5.1 Health benefits

Biogas provides numerous health benefits. As per Integrated Environmental Impact Analysis carried out for 600 biogas users and 600 non-users, the non biogas users had 4% more respiratory diseases than biogas users. Qualitative information from various household surveys carried out by Biogas Sector Partnership (Nepal) has revealed that problems like respiratory illness, eye infection, asthma and lung problems have much decreased after installing a biogas plant.

Disease	Problems in the past (households)		Present status of households	
	Yes	No	Improved	Remained same
Eye Infection	72	18	69	3
Cases of burning	29	71	28	1
Lung problem	38	62	33	5
Respiratory problems	42	58	34	8
Asthma	11	89	9	2
Dizziness/headache	27	93	16	11
Intestinal/diarrhoea	58	42	14	44

Fig. 6 Health benefits of biogas (Source: Acharya et al, 2010)

Following are the primary organisms killed in biogas plants:

- Typhoid
- Paratyphoid
- Cholera and dysentery bacteria
- Hookworm
- Tapeworm and roundworm

The biogas can also have sound effects on dietary patterns. As this gas is cheaper and easily available, so water can be boiled more easily and regularly, thus reduces various harmful diseases.

4.5.2 Economic benefits

Biogas reduces the expenses on fuel for cooking, and over the long run. Savings of fuel expenses as a result of installing biogas plants makes it possible to recover the total plant investment cost within four to five years typically. Bio-slurry obtained from the plant has proved to be excellent organic manure. This manure is more effective and is of higher quality than traditional manure such as farm-yard manure. The use of bio slurry as manure helps in increasing farm production and the farmer's income. It also reduces the high cost of chemical fertilizers and the adverse effects arising from their use.

4.5.3 Environmental benefits

Being a smokeless fuel, biogas keeps the indoor as well outdoor environmental clean. The manure that was previously wasted or left in open (which emitted green house gases) is now properly managed. Biogas production reduces the demand of firewood and hence saves us from deforestation. It can also be used to manage wastes from poultry as well as dairy farms.

4.5.4 Other benefits

Biogas provides benefits to the rural women in their household activities by reducing their workload in collecting firewood. As it is easier to cook food using biogas and cooking time is much faster as compared to solid biomass fuels, it is very friendly. A study has showed that biogas saves approximately 2 hours per day per family due to reduction in time that was previously wasted in collecting biomass and making dung cakes. As it is a smokeless fuel, the utensils also remain clean from soot after being used for cooking on biogas. (Pandey, Bajgain 2007)

5. Analysis

Biogas technology is working tremendously all over the world, under different climatic conditions. They are very useful for rural as well as urban population. These systems well responds to industries. But still there are many countries in which this technology is not yet fully commercialized. The reason might be high capital investment. This technology is not well accepted universally because it cannot resolve every problem of a village, farm etc. Biogas plant must be able to fit the existing waste disposal and productions systems. It is unfavourable and expensive to make changes in the existing systems to best suit the production plant. This technology has many competitors. There are many others ways of producing energy like solar systems, micro-hydro-power, fuel wood and many others renewable energy sources. High quality fertilizer can be obtained from many other techniques which are closer to traditional methods. The only solution to make it most favourable and attractive method is to provide simultaneous solutions to problems.

5.1 Limitations of Biogas

The reasons why Biogas technology is in limited use are follows:

- It requires many animals for collecting daily waste to be installed in houses.
- Its initial cost is also very high.
- It requires significant economic status of the potential users.
- Its users must have animal and land resources.
- They must have mortgage ability.
- As it requires care for handling slurry and feeding plants, thus it increases workload. Continuous Water supply is required to keep the dung fresh. This production process is dependent on temperature.

6. Conclusions

In today's world there is lack of communication between Biogas stakeholders. People are unaware of each others techniques and technologies. They don't know each others ideas in this sector. Therefore there is need to share knowledge and views to establish a good communication channel between stakeholders. Big and small manufacturers should work together by sharing their ideas and technologies. Biogas is sustainable in long run. Underdeveloped countries should adopt this technology as a renewable energy source to meet their energy demands. It can be continued indefinitely in the future.

7. Recommendations

- The government should take major steps to commercialize the technology. For this purpose, the cost of the biogas plants should be reduced so that people in the lower economic brackets consider it as an economic friendly technology.
- User guides and manuals should be available to the users in the local languages. However, promotion is only effective when it is followed by technical training provided to the users.
- The users should participate in installation and successful operation of their biogas plants. They should be accountable for collecting construction supplies such as sand, stone/bricks, gravel etc., provide labours for back filling, making manure pit and regular feedings, so that the plant is properly maintained.
- Government of Pakistan should encourage the users of this technology by subsidies and loan support programs. Moreover, the government should identify the key stakeholders.
- One of the basic reasons for the failure of this technology in our country is the lack of effective promotion. It should be promoted country wide through calendars, Radio and TV advertisements, leaflets, posters etc in clear form.
- The companies constructing the biogas plants should provide after sales services, maintenance and training if required to keep the biogas functional at its best as every non functioning plant harms the reputation of the technology. (Zafar 2006).

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