BIOGAS AS RENEWABLE ENERGY FROM ORGANIC WASTE

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Contents

Summary

Biomass comprises mainly trees and plant wastes (eg. wood, saw dust, leaves, twigs), agricultural residues, animal and human waste, coal etc. These wastes of plant, animal and human origin are the resources that yield valuable energy and fertilizer. Bio-residues (dung from animal, different types of crop residues such as rice straw, wheat straw, maize stalk, leguminous plant and weeds, aquatic plants) are already widely used in some countries. One of the best options would be to treat the biodegradable wastes into an anaerobic digester in view of producing environmentally sound energy as well as biofertilizer.

Fuelwood resources which represent 78 percent of energy consumption are mainly

consumed in rural Nepal. They are depleting very fast due to over exploitation and lack of proper management. Other biomass sources, agricultural residues and animal waste, provide for about 10 percent of energy requirement. Imported petroleum and coal together make about 11 percent of the total consumption.

The methane bacteria are abundantly found in the marsh or swampy land, rumen of animal, waste water, etc. They develop very slowly and are affected by a sudden change in their environment. Methane, which burns with a clear blue flame without smoke, is non-toxic and produces more heat than kerosene, wood, charcoal, cow-dung chips etc. The gas is used for cooking, lighting and to run electric motors, irrigation pumps, refrigerator and compressors. Common uses of biogas as energy source in the context of developing countries are for cooking and lighting, while other uses are limited.

The technology of production of biogas has become quite popular in the developing countries especially in China, India and Nepal. Although biogas technology was first introduced by a school teacher around 1955 in Nepal, as many as 150,000 family size biogas plants have been established by 28 June 2006 due to concerted efforts of many governmental and non-governmental organizations. It is worth mentioning that among the various actors, the role played by Biogas Support Programme (BSP) created under the framework of the Netherlands Development Organization (SNV) is praise worthy so far as promotion and development of biogas technology is concerned in Nepal. In December 2003, BSP was transformed into an autonomous Non-Government Organization (NGO) called Biogas Sector Partnership-Nepal (BSP-N).

Popularization of biogas technology has relieved the women from drudgery of cooking with firewood which produces hazardous smoke. The biogas potential is generally based upon the cattle population and quantity of dung actually collected from these animals. Based upon cattle population, there is the potential to produce 673 million m^3 of biogas annually (equivalent to 4038 GWh in terms of hydropower) or has the potential to substitute 390 million litres of kerosene. Nepal has a potential of establishing 1.3 million family size (8 to 10 m^3) biogas plants.

Various designs of anaerobic reactors (biogas plants) have been used both in the developed and developing countries of the world. The main designs that are of interest are: Floating Drum Digester, Chinese Model Fixed Dome Digester, GGC Concrete Model Biogas Plant, Deenbandhu Model, Bag Digester, Plug Flow Digester, Anaerobic Filter, Anaerobic Filter, Up-flow Anaerobic Sludge Blanket (USAB).

Biogas technology is best suited to convert the organic waste from agriculture, livestock, industries, municipalities and other human activities into energy and manure. The use of energy and manure can lead to better environment, health, and other socio-economic gain. In this context, it is worth to quote the Denmark's example about the technology of production of energy from refuge. The plant is designed to handle 8 tonnes/hour of waste which enables treatment of up to 22,000 tonnes $year^{-1}$. The municipal waste is collected and brought to Knudmosevaerket. The pre-treated organic waste is transferred, in closed containers, to one of the biogas plants. This fairly solid waste is then mixed with liquid manure to obtain a liquid solution. This liquid is deactivated at 70^0 C for one hour and digested at 55^0 C over a period of 16 days. The total maximum output from the plants supplied with biogas is 2.3 Mw_e and 3.1 Mw_{th}.

The importance of biogas as a cost effective source of clean energy and nutritive organic fertilizer can not be over emphasized [see also – *Bio-Refineries*]. Because of the traditional use of this technology, little effort is made to explore its possible application to meet energy requirements of other establishments such as wildlife resorts, refugee campus, schools and hospitals. In this backdrop, CMS initiated a project to install a pilot biogas plant in one of the wildlife resorts in Chitwan District (Machan Wildlife Resort) utilizing elephant dung. It was envisioned that implementation of this pilot project would provide a base for empirical assessment of the technology for its new use, i.e. for proper disposal of elephant dung and to meet a part of the energy requirement of wildlife resorts.

The eight adult elephants at MWR produce a total of approximately 160 kg dung per day (20 kg/elephant/day) which can be used to feeding a biogas plant. Elephant dung contains high proportion of fibrous materials with a high carbon nitrogen (C/N) ratio of 43. Optimum gas production occurs at around a C/N ratio of 25. The human excreta from the resident employees of MWR and the guests could be used to bring down the C/N ratio of the base feeding material, i.e. elephant dung. Therefore use of human excreta which contains a low C/N ratio (8 to 10) in conjunction with elephant dung was suggested for a smooth functioning of the biogas plant. Although the initial loading of the digester was done with cow dung for quick and easy operation, the digester was operated subsequently with elephant dung and human excreta only. The successful production of methane gas (perhaps the first historical one from elephant dung) was tested on 30th March 1994. The gas was used for cooking the food of the staff and for lighting biogas lamps.

In order to widen the scope of production of fuel (biogas as clean fuel) and organic fertilizer in the country as a whole (see also – *Biotechnology in Rural Arears*), it is imperative to utilize profitably aforesaid sources of biodegradable materials other than animal waste. In Nepal, there exists a tremendous scope for establishing biogas plants in large number of institutions, like security offices (barracks), boarding schools, hostels, canteens, prisons, monasteries etc. where abundant biodegradable wastes such as faecal waste, food waste etc are available as input to produce biogas and bio-manure. In this context, the first pilot bio-digester of $20m^3$ capacity was installed at Shechen Monastery, located at Boudha, Kathmandu, as a pilot institutional plant to represent the hill condition. This is a new design called TED introduced in Nepal, which is based upon Deenbandhu Model in India. The initial feeding of bio-digester was done with cow dung.

After stabilization of gas production, adequate quantity of kitchen waste, soft grasses, and waste paper were be added into the bio-digester to continue the gas production in regular manner. Thereafter, the sewerage system was connected to the bio-digester. As the toilets which are utilized by the majority of the monks (150) are currently connected to a sewer line and are equipped with flush system, the digester was integrated in the existing sewer line. Presently the gas is being used in the kitchen of the monastery to substitute fuel wood. It is believed that the cost of investment for this bio-digester can be recovered within two years due to use of biogas as fuel and the sludge as fertilizer.

1. Introduction

It is estimated that some 60 percent of the world's population live in rural areas of developing countries and rely on agriculture for their livelihood. About one billion people rely on residue as their principal cooking fuel. In many areas, particularly in Asia, the commercialization of bio-residues is a source of modest income but at the same time it is a burden for poor people. Very often the utilization of bio-residue is associated with a very low efficiency and therefore a higher level of smoke emissions and a negative impact on health.

In remote areas of the developing countries, petroleum products are not easily available and even when they are available, they are not affordable to poor people who are the main users of wood-fuels. On the other hand, wood burning in an in-efficient traditional stove built by the households themselves emits harmful gas like carbon monoxide (CO) which is hazardous for health of estate women. It leads to Acute Respiratory Infections (ARI) and Chronic Obstructive Lung Diseases (COLD). Women are the most common victims of these conditions [see also - *Gender aspects of biodiversity and conservation*]. Not only do they suffer physically, but their expenditure on health increases due to illness. The conversion of bio-waste to more dense form such as briquettes increases the efficiency and, if the process is well managed, it can lead to the introduction of technical change and the development of small enterprises in low-income areas.

The urban waste is also a common problem all over the world. Current predictions indicate that in 20-30 years' time, a majority of the world population would reside in urban squatter colonies and the concerned municipalities will find it increasingly difficult to provide them with basic services as much of their resources would be consumed for improving sanitation through waste management [see also - *Principles of Waste Treatment*]. Winbald recognizes the environmental friendly traditions and culture of eastern countries in saying that especially in China and Japan, human waste has always been considered a resource and used as fertilizers. However, for many of the western countries, it is a recent phenomenon to view waste as a part of natural life cycle which can be used as a resource.

Organic residues or broadly speaking “biomass” comprise of materials of plant, animal and human origin. The wastes produced from these organic materials are the resources, which can profitably be used to generate valuable energy and fertilizer [see also - *Recycling of organic wastes using integrated biosystems in rural farming*]. Bio-residues (dung from animal and different types of crop residue) are already widely used in some countries and there is still a great potential to be tapped [see also - *Biotechnoloyg for Domestic Waste*, - *Agricultural and forestry waste as energy source*]. As a result of devastation of vegetation cover, the ecosystem is affected resulting into a diminution of the productivity or a need for more chemical fertilizer to maintain the same level of production. Thus, one of the best options would be to treat the biodegradable wastes into an anaerobic digester in view of producing environmentally sound energy thereby relieving the women from drudgery of cooking with firewood.

The energy resources of Nepal consist of a combination of traditional and commercial sources of energy such as hydropower and renewable forces of energy. Petroleum fuels and coals are imported from other countries. In spite of its large hydropower potential to the tune of 83,000 MW of which about 40,000 MW is established to be technically feasible, so far Nepal has developed only 300 MW of hydropower to date supplying about 1 percent of total energy requirement. Fuelwood represents 78 percent of energy consumption, which is mainly consumed in rural Nepal. The fuelwood resources are depleting very fast due to over exploitation and lack of proper management. Other biomass sources, agricultural residues and animal waste, provide for about 10 percent of energy requirement. Imported petroleum and coal together make about 11 percent of the total consumption. Figure 1 shows the share of different forms of energy in total supply.

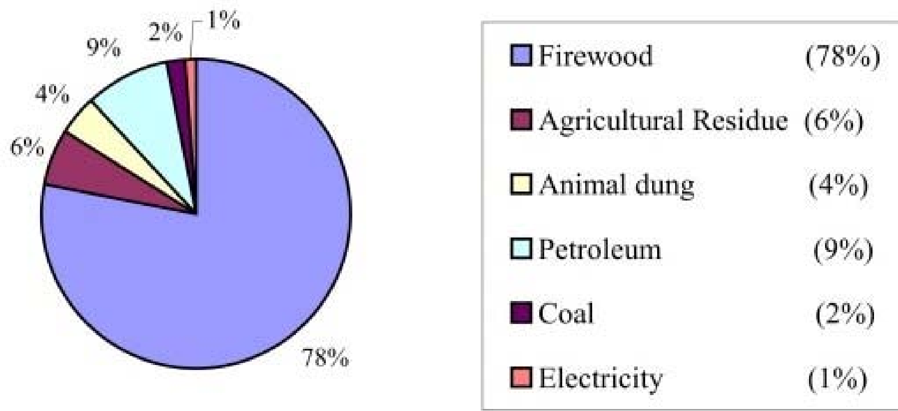

Figure 1: Energy Consumption by Energy Type (1998/99)

2. Biomass Waste

Biomass exists in the thin surface layer of the earth called biosphere [see also - *Origins of Biomass*]. It represents only a tiny fraction of the total mass of the earth but it is an enormous store of energy. This store is being replenished continuously. Sun is the main source for supplying energy. In fact, very small fraction i.e., about 0.5 percent of the solar energy striking the earth is believed to be captured by plants through photosynthesis on world basis. Biomass includes mainly trees and plant wastes (eg. wood, sawdust, leaves, twigs), agricultural residues, animal waste, coal etc.

2.1 Plant Waste

Any biodegradable material whether plant or animal origin can be used for the production of renewable energy [see also - *Agricultural and Forestry waste as energy source*] (biogas or methane) through anaerobic digestion process. Plant materials such as crop residues, weeds, aquatic plants, etc are also the source for methane production. Gas production is better if these materials are mixed with animal or human waste. *Eichhornia_crassipes* commonly known as water hyacinth is considered to be an obnoxious weed. This aquatic weed, which has almost the same C/N ratio as that of cow dung (i.e.24), has proven to be an excellent plant material for methane production. Similarly, *Eupatorium adenophorum* popularly called *Banmara* in Nepal is another weed which has been devastating the forest and pastoral land in Nepal. Experiments were carried out in Nepal to use this weed for biogas production. Various agricultural residues such as rice straw, wheat straw, maize stalk, leguminous plants, etc. have been used to produce methane in conjunction with animal waste.

Cellulolytic plant materials can be easily degraded by the bacteria for methane generation while the ligneous materials are hard to digest by the bacteria and hence, it should be avoided. To facilitate digestion, plant materials have to be chopped into small pieces or crushed before feeding into the digester **[**see also - *Biomethanation***]**.

2.2 Animal Waste

Animal wastes are excellent raw materials for methane generation. In the developing countries, where biogas technology is much advanced, it is customary to use cattle and buffalo dung to feed the digester. A homogenous mixture can be made while mixing the dung with water (slurry) facilitating the digestion process. Chicken or poultry manure is also a good source for biogas production. Raw materials from other animals include goat and sheep manure, horses and elephant dung and so on. It should be noted that while mixing with water, goat and sheep manure has the tendency of floating whereas horses and elephant dung contain fibrous materials.

2.3 Human Waste

Compared to animal waste, human faeces and latrine waste have been used for methane generation in limited scale in most of the developing countries due to social or religious reservation. The only exception is China where latrine waste is traditionally and socially acceptable and is used to produce biogas for cooking and lighting and bio-manure to enhance soil fertility. In recent years, the acceptability of latrine waste is increasing in Nepal as about 40 percent of the installed biogas plants are found attached to the latrines.

Human faeces contain pathogens and has offensive odour. If not treated properly, it can cause diseases and can be detrimental to human health. Therefore, one of the best ways to dispose human waste is to treat it in the anaerobic digester and producing biogas as energy and effluent as fertilizer [see also - *Biotechnology for Domestic Waste*].

3. Energy Production Using Anaerobic Digestion Technology

3.1 Biogas Technology

Anaerobic digestion mitigates a number of other environmental concerns. The process reduces the potential for odour, destroys pathogens, displaces fossil fuels, and reduces methane emissions. The solid and liquid residues from the anaerobic digestion process can be used as a compost or fertilizer, and their use can have positive environmental benefits. Anaerobic digestion products have been used in alternative agricultural practices, being applied to biomass crops and feedstocks for alternative fuels like bio-diesel or ethanol. Recycling nutrients in this way creates a virtuous cycle of sustainability [see also - *Organic waste utilisation for energy, fertiliser, feed and food production using anaerobic digestion*].

Methane is produced by the bacterial decomposition of organic materials in the absence of oxygen. Anaerobic digestion is interesting because it can effectively extract the carbon from human, animal and farm residues for use as fuel while leaving the nitrogen in a sludge which can be used as a farm fertilizer. The gas is used for cooking, lighting and to run electric motors, irrigation pumps, refrigerator and compressors.

As a source of renewable energy, biogas or anaerobic digestion technology has become quite popular in the developing countries such as China, India, Nepal. In the context of Nepal, biogas technology was first introduced by a school teacher in 1955. Now, with the concerted efforts of various national and international organizations, more than 60,000 family size biogas plants have been established.

3.2 Biogas Potential

For the development of biogas, it is necessary to know its potential in the country. In the developing countries, for example in India, China and Nepal, cattle (cows and buffalo) dung is the main source for biogas production. Thus, biogas potential is generally based upon the cattle population and quantity of dung actually collected from these animals. Collection of dung also depends upon whether the animals are left for grazing or stall fed (zero grazing). Among other factors, the production of methane also depends upon the ambient temperature.

As an example, let us calculate the biogas potential in Nepal. The total population of cattle and buffalo in Nepal is estimated to be 10.3 million in 1997/98. These animals produce about 44 million metric tons of dung every year. Assuming that only 75 percent of the dung can be collected, about 33 million metric tons will be available for use in biogas plants. With these figures, Nepal has the potential to produce 673 million m^3 of biogas annually which is equivalent to 4038 GWh in terms of hydropower or has the potential to substitute 390 million litres of kerosene. In terms of average family size plants of 8 to 10 m^3, Nepal has a potential of establishing 1.3 million biogas plants.

3.3 Characteristic and Composition of Biogas

Biogas is a combustible gas produced by anaerobic fermentation of organic materials by the action of methanogenic bacteria [see also - *Biomethanation*]. This gas is principally composed of methane (50 to 70 percent) and carbon dioxide (30 to 40 percent). Average composition of bio-methane is given in Table 1.

Substance	Symbol	Percentage
Methane	CH_4	50- 70
Carbondioxide	CO_2	30 – 40
Hydrogen	H_2	5 -10
Nitrogen	N_2	1 -2
Water Vapour	N_20	0.3
Hydrogen Sulphide	H_2S	Traces

Table 1: Average composition of Bio-methane

Methane is a combustible gas. It is virtually odourless and is invisible in bright daylight.

It burns with a clear blue flame without smoke and is non-toxic. It produces more heat than kerosene, wood, charcoal, cow-dung chips etc. The specific gravity of methane (relative to air) is 0.55, critical temperature = 82.5°C and pressure for liquefaction 5000 psi. Air requirement for combustion (m^3/m^3) is 9.33 and the ignition temperature 650°C.

3.4 Designs of Anaerobic Reactors

The bio-digester is a physical structure, commonly known as the biogas plant. Since various chemical and micro-biological reactions take place in the bio-digester, it is also known as bio-reactor or anaerobic reactor. The main function of this structure is to provide anaerobic conditions within. As a chamber, it should be air and watertight. It can be made of various construction materials and in different shape and sizes. Construction of this structure forms a major part of the investment cost. Some of the commonly used designs are discussed below.

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Biographical Sketch

Professor Dr.Amrit B.Karki obtained his doctorate degree in soil microbiology at the Universite' de Paris-Sud, France in 1972. He has more than 35 years of work experience, particularly in the field of natural science, agriculture, biogas and other renewable energy including solid waste management and the environmental sector. He had worked as a Soil Scientist in the Department of Agriculture (1962-1977) of His Majesty's Government of Nepal, as a Reader in Soil Science in Tribhuwan University (1977-1980) in Kathmandu, Nepal, as an FAO Consultant in more than 20 countries of Asia, Africa and Latin America in the field of biogas and organic recycling (1980-1991). He had been serving as a project coordinator for a number of projects on organic recycling, biogas, solar energy and alternate energy sponsored by FAO, SNV, UNHCR, USAID etc. He has participated in several national and international seminars on organic recycling and biogas technology. He had worked as Chief Technical Adviser of Consolidated Management Services Nepal (P) Ltd, a consultancy firm in Nepal from 1992 to 2000. Presently he has been working as Executive Chairman in the private company named " Yashoda Sustainable Dev. (P) Ltd in Nepal. He is also the Vice-Chairman of Biogas Sector Partnership-Nepal (BSP-Nepal), a leading NGO to promote biogas programme in Nepal.