ISSN: 2456-7744

Advanced Scientific Research 2018 3(2) 15–19

Advanced Scientific Research
journal homepage: www.advancedscientificresearch.in

Biogas : Renewable source of energy as well as manure for crop production & Government initiatives to produce energy in sustainable way for rural areas

Smriti Dwivedi*

Department of Chemistry, Galgotia College of Engineering & Technology, Greater Noida, U.P., India

ARTICLE INFO

Article history:
Received 20 November 2018
Received in revised form 24 December 2018
Accepted 25 December 2018
Available online 26 December 2018

Keywords:
Biogas
Sustainable
Status
Slurry
Kyoto Protocol

ABSTRACT

The aim of biogas as renewable source of energy is to replace fossil fuels with sustainable energy production systems and to fulfill the requirements of the Kyoto Protocol. On big farms the liquid manure and different energy crops can be used for biogas production. That can improve the economical efficiency of the farm and reduce the CO_2 emissions. The National Project on Biogas Development (NPBD) of the Ministry of Non-Conventional Energy Sources (MNES) was started in 1981-82 for promotion of family type biogas plants, the current potential of which is estimated at 12 million, to provide clean alternate fuel to the rural masses and enriched organic manure for agriculture. The implicit objective of the programme is to reduce the use of nonrenewable fuels and fuel wood. This manuscript discusses about the present status of biogas development in India, economics of biogas plant, selection of proper size of biogas plant along with the Government policy for providing incentive to the user for the construction of biogas plants. For improving the rural economy and enabling the best use of cattle dung to provide smoke free cooking fuel, the cattle dung is put into a specially designed structure called a ''Biogas Plant'', where, after anaerobic digestion of the same, biogas is produced. The remaining material, called slurry, containing about 2.10% nitrogen, 0.046% phosphorous and 2.20% potassium is used as manure for crop production.

1. Introduction

Renewable energy sources draw attention all over the world because they are sustainable, improve the environmental quality and provide new job opportunities in rural areas[1]. Increase in energy demand and the issues about current non-renewable energy sources led researchers to investigate alternative energy sources during the last two decades[2].

Renewable energy potential is high on the subcontinent. Energy from solar, wind, hydro and ocean all have a significant future potential to play in a mixed energy production scenario[3]. However, of particular interest here, in the context of providing a devolved, sustainable energy supply for the burgeoning rural sector in India, is the potential of biogas; the gas created as a product of anaerobic digestion of organic materials. In the rural economy, domestic household sector is the most prominent energy consumer, followed by the agricultural sector. The industrial sector (including commercial establishments) is not very significant in the rural areas as far as energy consumption is concerned, though rural industries like brick kilns are energy-intensive and use fuelwood extensively. Biogas plants in India were experimentally introduced in the 1930's, and research was principally focused around the Sewage Purification Station at Dadar in Bombay, undertaken by S.V. Desai and N.V. Joshi of the Soil Chemistry Division, Indian Agriculture Research Institute, New Delhi. The early plants developed were very expensive and were not cost effective in terms of the gas output, indeed the early models were not producing enough gas to supply a small family[4]. Some of the early models were also prone to burst, so overall, the technology was not viable for dissemination. The most abundant countries in producing biogas are United states of America, United Kingdom, Germany, Indian Subcontinent and China.

Biogas is rich in methane and can be used for various purposes such as cooking, power generation and lighting. In case of anaerobic decomposition of the organic matter in the open, the gas (methane) produced directly goes into the atmosphere and increases the concentration of green house gases in. Use of biogas obtained through anaerobic decomposition in biogas plants converts methane into carbon dioxide and reduces the load of green house gases[5]. Economic efficiency of anaerobic digestion depends on the investment costs, on the costs for operating the biogas plant and on the optimum methane production[6-7].

2. Methodology

When any organic matter, such as cowdung, crop residue, and kitchen waste is fermented in the absence of oxygen, biogas is generated. Biogas contains combustible methane (around 60%) along with carbon dioxide, and traces of other gases. Biogas production is a chemical process occurring in stages during which different bacteria act upon the organic matter resulting in the formation of methane and acids. A typical biogas plant has the following components; (i). A digester in which the organic matter mixed with water is fermented. (ii). a inlet tank used to

* Corresponding author. e-mail: s.dwivedi@galgotiacollege.edu, smriti96@rediffmail.com

mix the feed and let it into the digester. (iii). a gas holder in which the generated gas is collected. (iv). an outlet tank to remove the spent slurry; and (iv). distribution pipeline(s) to take the gas into the kitchen.

Factors influencing biogas production

pH level of feedstock

Works optimally at a pH level of 7 or just above (neutral solution).

Ambient temperature

Functions at an optimal level at a temperature of around 35ºC.

At low temperatures, bacterial activity slows down resulting in substantial decrease in gas generation.

The bacterial activity completely stops at temperatures below 10ºC.

Carbon-nitrogen ratio of the feed material

The carbon-nitrogen ratio should be in the range of 20:1 to 30:1.

Cowdung has a C-N ratio of 25:1 and is therefore considered ideal for maximum gas production.

Solid concentration in the feed material

8-10% of total solids in the feed material is the normal value required.

Cowdung has a solid concentration of about 20%, and therefore, it is recommended that dung and water are mixed in a 1:1 ratio.

Quantities of feeding material

One kilogram of dung produces about 40 liters of biogas.

To produce two cubic meters (2000 litres) of gas per day, which is required to meet the cooking needs.

For an average family of four to five members, a mix of 50 kg of dung and 50 litres of water should be fed into the plant everyday.

Hydraulic retention time (HRT) Hydraulic Retention Time (HRT) is the number of days the feed material is required to remain in the digester to begin gas production. This is the most important factor in determining the volume of the digester which in turn determines the cost of the plant. The larger the retention period, higher the construction cost.

In India, different HRTs are recommended for three different temperature zones. For all the approved models under NPBD, the plant dimensions, requirement of materials for different digester capacities etc. are available for different HRTs **(Table 1)**.

Design

Biogas plant designs

There are two basic designs[8] of biogas plant that are popular in India are:

Floating metal drum type (Table 2), popularly called the KVIC (Khadi and Village Industries Commission) model (KVIC Bombay1,2). This design was developed and popularized by the Khadi & Village Industry Commission (KVIC) of India and, hence, is known as the KVIC model. These were standardized in 1962 and are used widely even now

Fixed masonry dome type (Table 2), commonly known as Deenbhandhu model[9]

The Deenbandhu model was developed by Action for Food Production (AFPRO), New Delhi, India, in 1984. The word deenbandhu means friend of the poor. Until now, this model is the cheapest among all the available models of biogas plant.This model is designed on the basis of the principal of minimization of the surface area of a biogas plant to reduce its installation cost without sacrificing the functional efficiency

Table 1. HRTs for different temperature zones

Zone	Average ambient temperature	HRT (days)	Approximate regions
I	>20ºC	30	Andhra Pradesh, Goa, Karnataka, Kerala, Maharashtra, Tamil Nadu, Pondicherry and Andaman & Nicobar Islands
II	15-20ºC	40	Bihar, Gujarat, Haryana, Jammu region of J&K, Madhya Pradesh, Orissa, Punjab, Rajasthan, Uttar Pradesh and West Bengal
III	<15ºC	55	Himachal Pradesh, North-eastern states, Sikkim, Kashmir region of J&K and Hill districts of UP

Table 2. Features of fixed-and floating-drum biogas

Fixed dome	Floating drum
Digester and gas holder, masonry or concrete structure	Digester and gas holder, masonry or mild steel or fibre glass structure
Requires high masonry skills	Low masonry or fabricating skills
Low reliability due to high construction failure	High reliability, gas holder prefabricated
Variable gas pressure	Constant gas pressure
Digester could be inside the ground	Requires space above ground for three tanks; inlet, digester, outlet
Low cost ($2m^3$ = Rs 500)	High cost of plant due to gas holder (cost for $2m^3$=Rs 8000)

In addition to above types of biogas plant other types of plants are:

Variants of KVIC model, such as digester made of ferro-cement and gas holder made of fibre glass reinforced plastic, are also being promoted.

A bag type portable digester made of rubberised nylon fabric, developed by a private firm namely, M/s Swastik Rubber Products Ltd., Pune is also being promoted. This is also popularly called "Swastik model".

Table 3. Material requirements for Deenbandhu biogas plant

Plant	$2m^3$	$3m^3$	$4m^3$
Bricks (class I) (nos)	1000	1300	1600
Cement (bags)	14	16	22
Stone chips (cu ft)	40	50	60
Sand (cu ft)	40	50	60
Coarse sand (cu ft)	40	50	60
GI pipe ½" diameter with sockets (inch)	7	7	7
AC pipe 6" diameter (ft)	6	6	6
Iron bars (6 mm diameter) for outlet tank	7	10	12
Paint (litre)	1	1.5	2

Cost

The cost of a biogas plants depends on its size and the design.

It also varies for different regions of the country.

Table 4. Average cost of a Deenbandhu plant (Rs)

Plant capacity	40 days HRT	55 days HRT
$1m^3$	5800	8100
$2m^3$	6800	9400
$3m^3$	8200	11500
$4m^3$	10500	14800

Applications

The versatility of biogas is its greatest advantage as a source of energy for the rural areas.

Fuel: Can serve as a convenient fuel that can be used for a variety of applications, such as cooking, lighting, and motive power.

Organic manure: The slurry that comes out of a biogas plant after the gas is produced, can be used as an organic manure in the fields to augment soil fertility.

Lighting: It can be used, through a specially designed mantle, for lighting too.

Further, biogas can partially replace diesel to run IC (internal combustion) engines for water pumping. Biogas can be similarly used to produce electricity, though this has not been attempted on a large scale in the country so far.

Benefits

Cost effective: In terms of cost, biogas is cheaper, on a life cycle basis, than conventional biomass fuels (dung, fuel wood, crop wastes, etc.) as well as LPG, and is only fractionally more expensive than kerosene; ased on the effective heat produced, a 2 cubic meter biogas plants could replace, in a month, fuel equivalent of 26 kg of LPG (nearly two standard cylinders), or 37 litres of kerosene, or 88 kg of charcoal, or 210 kg of fuel wood, or 740 kg of animal dun

Time saving: To the housewife, biogas is easy to use and saves time in the kitchen;

Non-polluting: Cooking on biogas is free from smoke and soot, and can substantially reduce the kitchen related health problems. Since dung is collected systematically when used in biogas, the village environment can be kept clean and hygienic.

Reduction in drudgery: Use of biogas also reduces the drudgery of women in gathering fuel wood.

Reduces exploitation of natural resources: A shift to biogas from traditional biomass fuels results in less dependence on natural resources such as forests, checking their indiscriminate and unsustainable exploitation.

Decentralised: Biogas plants are decentralized systems which can be installed even in remote areas with very low investments.

National Project on Biogas Development (NPBD)

Biogas programme is the oldest and largest renewable energy programme in India. The first major technical achievement was the development of the floating-drum biogas plant by the Khadi and Village Industries Commission (KVIC) in 1952. By 1980, over 80,000 family size biogas plants had been constructed.

The biogas progamme received a major boost with the launching of the National Project on Biogas Development (NPBD) in 1981-82. NPBD began as a part of the Sixth Five Year Plan. To provide impetus to the progamme, it was included in the Prime Minister's Twenty Point Programme and was brought under the Department (now Ministry) of Non-conventional Energy Sources in 1982.

Objectives of NPBD

To provide clean and cheap source of energy in rural areas.

To produce enriched organic manure for supplementing the use of chemical fertilizers.

To improve the quality of life of rural women.

To improve sanitation and hygiene.

Financial arrangement under NPBD

The task of target setting and disbursement of funds is done by MNES

50 per cent of the estimated outlay is given in advance to the implementing agencies at the state level,

50 per cent is released after completion of 25 percent of the total physical targets allotted.

The disbursement of funds at district and block levels varies with different program implementing agencies. The ministry and state nodal agencies provide several incentives to encourage the adoption of the technology under NPBD have been summarized under Box I.

For end user	For field level	For state nodal agencies
Central subsidy (Rs 1800-1500)	Turnkey fees of Rs 500 per plant	Service charges
Bank loans	Rs 50 per plant for initiating village level acceptance	Staff orientation and training courses; Awareness campaigns; Gold and silver honorary shields

Note. A turnkey worker is responsible for the entire process of biogas plant installation including motivating the beneficiary, arranging subsidy and loan, constructing the plant, commissioning, and ensuring a trouble free functioning of the plant for a stipulated period of three years.

The subsidy pattern is designed for different categories of people taking into account physical disparities existing in different parts of the country[10].

Table 5. Subsidy pattern, 1995-96

Capacity of plant (m^3)	NE states (excluding plains of Assam), Sikkim, J&K, HP and 7 hilly districts of UP (excluding terai regions of two hilly districts), Andaman & Nicobar islands, Lakshwadeep	SC/ST, desert districts, small and marginal farmers, landless laborers, plain areas of Assam, terai region of two hilly districts of UP, Western Ghats and other notified hilly areas	All others
1	2800	2000	1500
2	3200	2400	1800
3 & 4	3500	2600	2000

Note. Biogas plants of 6 to 10 cubic meters capacity are eligible to receive the same subsidy amount as applicable for 3 and 4 cubic meters capacity w.e.f. 1st April 1996.

Monitoring and feedback

The monitoring and feedback on the programme is done by the Ministry to ensure the successful implementation.

Table 5. Monitoring of NPBD

Nature of feedback/ monitoring	Frequency	Involved implementing agency/ official
Physical verification of all/5-10%/1-5% of the installed plants	Every month	Block Development Officer/District Level Officer/State Level Officer
Identification and rectification of dysfunctional plants	Every three months	State governments and implementing agencies
100% survey of plants in one block, randomly selected	Every year	Regional offices of MNES
Regular inspections	-	RBDTCs, with assistance from nodal departments, KVIC etc.
Information collection, feedback, performance monitoring	-	Turnkey workers, field functionaries and officers of nodal agencies at block, district and state level
Random sample inspections on operational performance	Every year	MNES and Regional offices

Problems and barriers

The evaluation of NPBD has resulted in identification of technical and social problems faced by various implementing agencies.

Structural defects	Technical problems	Non-technical problems
• damages in foundation	• corrosion/leakage in pipeline	• shortage of dung, and
• cracks in dome, and	• water accumulation in pipeline, and	• lack of interest on part of the owner
• cracks in digester wall	• defects in burner	

Social problems

The most common social problem identified was the shifting of residence and of cattle sheds. The survey also carried out opinion studies on whether the owners would be willing to get the defects rectified. The response obtained was largely negative with an overwhelming 76% of the respondents not agreeing to the prospect of rectifying the defects. The major reasons identified were:

(i) a majority felt that their plants cannot be rectified,

(ii) many were apprehensive as a result of the past failures, and

(iii) they did not know whom to contact for repair.

Barriers to implementation

The following barriers are considered for implementation of biogas plants either at the individual household or at community level.

At the household level the following barriers are considered for those households that have adequate dung for a biogas plant:

Family biogas plant	Community biogas plants
High cost of biogas plants is the primary problem	Absence of community participation owning to factionalism or lack of interest on the part of the managing agency (panchayat, etc.)
Availability of fuelwood at almost zero cost to rural households	Improper planning in terms of dung estimation, site selection, gas distribution system, etc.
In the government programme, there is neither any guarantee on the successful functioning of the biogas plant nor any efficient, reliable repair and maintenancance service	Inadequate maintenance resulting in irregular dung collection, underfeeding, slow disposal of slurry, etc; and
Severe shortage of trained manpower for constructing and servicing the biogas plant; and for educating households on the operation and maintenance of plants	Inability of the poor households to pay even nominal monthly charges of Rs. 30-50.
Inadequate funding at the national level to promote the programme	

Potential and achievements

Overall potential of the technology in the country is about 12 million plants. Which covers only 18.2% of the total population; Only 2.5 million plants have been installed up to March, 1995. The current rate of funding and mode of dissemination, about 0.15 million biogas plants can be built every year implying another 60 years to build 10 million biogas plants.

Feasibility

Family biogas plants come in different sizes depending on the availability of dung and the quantity of biogas required for cooking. The average size of the family is 5-6 persons, and thus a biogas plant of capacity 2-4 m^3 is adequate. The biogas requirement for cooking two meals is estimated to be 150 l/capita/day (about 1200 litres for a family). If the making of tea and snacks is included, about 200 litres of biogas is required/capita/day.

Size selection of rural household biogas plants

Size of the rural household plant to be installed, should be selected on the basis of gas requirement and the livestock manure availability with the beneficiaries. Since, cattle dung is the main substrate for the biogas plant in rural India, the table given below shows the relationship among plant capacity, daily cattle dung requirement and gas use.

Plant capacity	Daily dung requirement	Approx. no. of cells	No. of family members
1 (35)	25	2-3	3-4
2 (70)	50	4-6	5-8
3 (105)	75	7-9	9-12
4 (140)	100	10-12	13-17
6 (210)	150	12-20	18-25

3. Conclusion

Despite the achievements made and all the effort that has gone into the programme, the overall impact of biogas has been very small. One of the main reasons for this is that biogas has been dependent on cattle dung alone as a feedstock thus limiting its reach. Less than 20% of the rural households in the country own 4 to 5 cattle necessary to set up a biogas plant. Use of human waste, the main source of biogas in China which has the world's largest programme, is not possible on large scale due to religious and cultural inhibitions. The efforts to develop alternative feedstocks such as kitchen waste, water hyacinth, etc. have not progressed due to less emphasis on R & D in the programme.

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