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Review

State-of-the-art, challenges, and issues of biogas production technology in India: A review

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ABSTRACT

This paper presents the state-of-the-art, challenges, and issues related to biogas production technology on small and large scale in India. The biogas development in India occurred in several stages mainly from year 1950-2020. First Stage focused on research and development for practical digester in India as the design and construction of biodigester for production of biogas is one of crucial factor. During this period 15 types of Indian digesters were designed and found virtually feasible, efficient and further development was perpetuated. In the second stage launched and initiated several National Biogas Programmes with immense incentives across the rural India. In third stage installation of household size biogas for cooking fuel and lighting in rural from 1984-2004 largely subsidized and further scaled up to urban and peri urban areas till 2019. Fourth stage development and installation of large scale and industrial biogas plant from 2005-2016 were done. The fifth stage commenced with setting up of Compressed Biogas Plant. To utilize municipal solid waste as substrate efficiently, there is requisite of huge incentives and congruous guidelines cognate several issues of biogas production and plant from ministries. To enable biogas more economically viable and sustainable technology, its production should be merged with other strategies such as improvement of fertilizer quality and sanitation issues. Additionally, the hindrance factors of biogas development in India must be eliminated. Biogas-fertilizer-Waste Treatment plant should be set up with three output such as biogas, fertilizer and waste treatment.

Keywords: Biogas, biodigestor, fertilizer, biomass, biofertilizer, industrial biogas plant, waste treatment.

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INTRODUCTION

India is second most populated country having 1.37 billion population in 2020 which contributes to 17.7% of global population. Presently 35% of total population in India live in urban area having density 464/ km^2. In rural India biomass is considered as a most important fuel which include firewood i.e. 81% and agro-waste i.e.15% and in total 96% of energy consumption is covered by biomass. About 57% requirement of national energy demand is alone fulfilled by biomass as source (Tata, 1998). Because of increase in demand of energy there is huge gap between availability and consumption of energy in India. Hence, globally energy demand requirement is estimated to grow at an annual rate of 4.6% (EIA, 1998). Considering increasing biomass dependable rural population with reduction in forests area, it is essential for rural India to make a joint effort to supply itself locally available, dependable and sustainable source of energy.

Biogas is the main product obtained by degradation of various biowaste by anaerobic microbes, these microbes digest waste and release various gases and acids in slurry. Biogas comprises of 55 to 70% methane, 24 to 40% carbon dioxide, 0 to 2% nitrogen, 0 to 3% hydrogen sulphide, 0 to 2% hydrogen, and 0 to 3% oxygen. History of biogas technology is well document in literature from the 19th century. At present India has 2nd largest number of biogas plant in world. India's total biogas production currently is about 2.07 billion m^3/year which is estimated to be in the range of 29 to 48 billion m^3/year. It is quite low in comparison to estimated. Biomass are increasing per day in huge amount due to increase in population, industrialization and change in living life style in India. Huge source of 141 M. Ha of agricultural residues or energy crops of arable land which can produce over 700 Metric Ton Per Annum (MTA) biomass is available with estimated surplus quantity is 150MTA.

There is potential of short cycle cellulosic biomass production from 50 M.ha arable land which in under mono cropping. 300 million cows and buffaloes can produce 1000MTA of cattle dung whereas 500 million poultry birds can produce 8MTA droppings. Co-digestion of agricultural residues with urban and industrial wastes also increases potential of biogas. In India about 207,000 cubic meters of biogas produced from various sources which is equivalent to 5% of total LPG consumption and equivalent to 6.6 crore domestic LPG cylinders in the year 2014-15. Biogas will be the best decentralized energy source concluded in the draft of Ninth Plant: GOI 2000. Presently India generates about 62 million tons of solid waste annually of this 60 to 65% of waste is organic waste and has potential to generate 100 MTA production of biogas, biofertilizers and organic manure. Hence, there is dire need to focus on all three objectives biogas, biomanure/biofertilizer and waste treatment which give solution to human needs, country economy, health and environmental issues. Government of India is giving subsidy/incentives for setting up biogas plants and started from 2016 for compost generated from Municipal solid waste, however the systems and technologies for biogas production needs more enhancement and progression. A program should be initiated for Biogas-Fertiliser-Waste treatment Plant and development of matured integrated technology.

It has been found that fund is given for biogas production plant and but support for other two objectives biomanure/biofertilizer production plant and wastes treatment plant has been minimal especially for the rural India. Thus, this sector become unstable, unsustainable and fails and hence it required to provide support to three types of plants and has to be funded by related Ministry. The Ministry of New and Renewable Energy, Ministry of Agriculture, Ministry of Food Processing Industry, Ministry of Environment Forests and Climate Change, Ministry of Rural Development, Ministry of Urban Affairs and Housing and Local Bodies have to launch programme for three objectives and to join hands under a co-ordination body, umbrella organizations, Cabinet Secretariat of government of India.

The government sees potential in biogas technology as an alternate energy source, path to diminish rural poverty, and as an instrument in part of wider drive for rural development. Therefore, government gives incentives and launched biogas and related programme. Indian Renewable Energy Development Agency (IREDA), which functions under the Ministry of Non-Conventional Energy Sources (MNES) has encouraged alternative energy options. Government of India has initiated the National Project on Biogas Development nation-wide in order to promote and disseminate information about biogas technology wherein several NGO's are part of it and actively implementing the program at the grass root level. The Khadi and Village Industries Commission (KVIC) undertook active dissemination of information about the biogas technology in the context of rural development from small scale income generation activities

Applications

Biogas has extensive application in the form of heat, electricity and fuel and used as cooking, vehicle fuel, electricity generation, turbine and fuel cell (Khanal, 2008). Biogas is also been used to heat swimming pools, industrial plants, products treatment, disinfecting milking equipment's etc. Biogas is also been used in buses, taxis, transporters, private vehicles and trains (Deublein and Steinhauser, 2008). It is a clean, cheap, environment friendly form of energy source. Biogas has the potential to fulfill the needs for cooking, basic fuel, electricity and the upgraded biomethane which then used as transportation fuel, in industry as well as utilization of biogas as a fuel for thermal and engine applications (Kamath et al., 2002).

Benefits

Biogas has benefits to several sectors such as energy, health, transport and other sector. Biogas has direct and indirect benefits which imprints large impacts on rural and urban life always in positive way. Direct benefits of biogas are used as cooking fuel, heat and electricity generation. Indirect benefits are several like reduces pollution, avoid use of firewood, reliance of fossil fuels, global warming etc (Bond and Templeton, 2011). Biogas technology helps improves life in urban and rural areas with hygienic conditions. Biogas technology is effective and convenient way for scientific disposal of organic wastes. Good quality enriched manure produced also help improve the soil fertility. It also lowers fuel import bill. All consequences of biogas formed from anaerobic digestion of wastes are positive and benefit to human beings, society and environment which is given in Table 1. There is no negative impact of biogas in any ways.

Objectives

The objectives of this review paper are to recognize the major and important stages of biogas progress and

Table 1. Consequence of biogas formed from anaerobic digestion of wastes.

S. No	Consequence of biogas	Theory	Reference
1.	Improve health	Solid biomass combustion during cooking release particulate particle which accumulate into lung to cause respiratory disease, heart disease etc. Use of biogas help avoid these problems.	(WHO,1979; Mihelcic et al., 2009; Smith, 1993)
2.	Biogas as energy	Biogas generated by bio degradation of waste can be used as fuel for various purposes; It release less pollution as natural gas.	(Sivertsen et al., 2004)
3.	Deforestation	Use of wood for cooking lead to deforestation but use of biogas for cooking purpose lead forest conservation.	(Douglas and Simula, 2010; Katuwal and Bohara, 2009; Niles et al., 2002)
4.	Use all human and animal waste	Excreta lead to environmental problem due to nutrient run off but use of excreta for biogas generation provide benefits	(Antweiler et al., 1995; Tchobanoglous et al., 2003)
5.	Slurry as fertilizer	Nitrogen, phosphorus essential for soil fertility, digested material of biogas plant is rich in nitrogen and phosphorus.	(Jonsson et al., 2004; Smil, 1999; Tchobanoglous et al., 2003)
6.	Quenching of methane and carbon black	Carbon, methane both lead to global warming and methane has 21 time more potent for global warming, biogas generation lead to decrease in use of both gases	(WHO, 2011; Cakir and Stenstrom, 2005; Kandlikar, et al., n.d.; Edwards, et al.,2004)

development in India, present the state-of-the art of biogas production biotechnology on small and large scale in India, distinguish the factors responsible for hinderance in dissemination of biogas technology through the detailed study of literature and brief overview of further steps required so as to make biogas more economically viable technology option for rural and urban India.

METHODOLOGY

A qualitative and comprehensive approach was followed to find out the historical and present status of biogas technology development and its utilization on the ground. The given below are steps used to extract and review the relevant literature and information.

- Systematic search was conducted of research and review articles published after 1800 to 2020 in the Scopus database.
- Technological development, operational and maintenance related information studies done through manual screening and work experience.
- Government interventions and futuristic scenario studies on biogas done through Google and government portals.

EVOLUTION OF BIOGAS TECHNOLOGY IN INDIA

In India, Biogas was first time used for lighting at Matunga asylum in Mumbai in 1897. Biogas technology is well known technology in India from long time extending from mid of 20th century to today. In the 1930's biogas plants were experimentally introduced and research was mainly 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. After 1990 commercially feasible biogas digestors were available in India. Under dissemination programme a large number of biogas units of different capacities were constructed and installed within last 30 years. Government had launched several dissemination programme for biogas and given subsidy to farmers, social organization and private company.

Biogas technology in India has evolved from use of biogas lamp to research and development of biogas technology, installation of family type biogas plant, industrial biogas plant and compressed biogas plant with the help of incentives and subsidy from Government of India. Biogas technology in India exists from past 20th century to today and has a long history. The bulk of biogas plants were constructed within last 15 years and the process for scale up initiated only when different models, design, practical and scientific information is available for dissemination. In this period there was also a political foundation for promulgating a large-scale diffusion programme administered on a national level.

MECHANISM OF BIOGAS

Biogas production by anaerobic digestion of different category of organic waste is blending activity of diverse microbial population (Heeg et al., 2014); Sequential Steps for Mechanism for Production of Biogas:

- High molecular weight compound like carbohydrate, lipid etc are hydrolyzed by hydrolytic bacteria.
- Produced mono and oligomer are degraded by acidogens
- Acetogens act after acidogens to digest produced acetate, ethanol, lactate, H_2.
- In final step methanogenesis process in which all produced matter are digest by methanogenic bacteria (acetoclastic and hydrogenotrophic Archaea) to convert biogas (methane).

Diagrammatic steps are given below

Hydrolysis, fermentation, anaerobic oxidation and methanogenesis these are four different microbial main steps in biogas formation. In the process of hydrolysis, enzymes are exuded to degrade large organic molecules like proteins and polysaccharides to smaller molecules, that is, amino acids and simple sugars. During the fermentation process these molecules are converted to alcohols, fatty acids and other intermediate products by diverse microbial population (Jarvis and Schnürer, 2009).

Hydrogen gas and acetic acid are produced by acetogens during the anaerobic oxidations, (McMahon et al., 2001). Since the hydrogen gas concentration needs to be kept at low level in order for the anaerobic oxidations to function properly these microorganisms cooperate with the methanogens that consume hydrogen gas. From the acetic acid and hydrogen gas methane is produced by two different types of methanogens, that is, hydrogenotrophic methanogenesis and acetotrophic methanogenesis (Jarvis and Schnürer, 2009). Anaerobic digestion is a multi-layered process which is affected by the type of feedstock, physical conditions of the digester, climate and the way the plant is operated. Figure 1 exemplifies the schematic representation of microbial stages involved in biogas formation.

STAGES FOR DEVELOPMENT OF BIOGAS TECHNOLOGY IN INDIA (1950-2020)

Development of biogas technology in India has been divided into five stages based on innovation for development of anaerobic digestor, biogas development programme launched by government and utilization of various types of wastes and biogas application spectrum. Figure 2 gives a glance picture of biogas development in India.

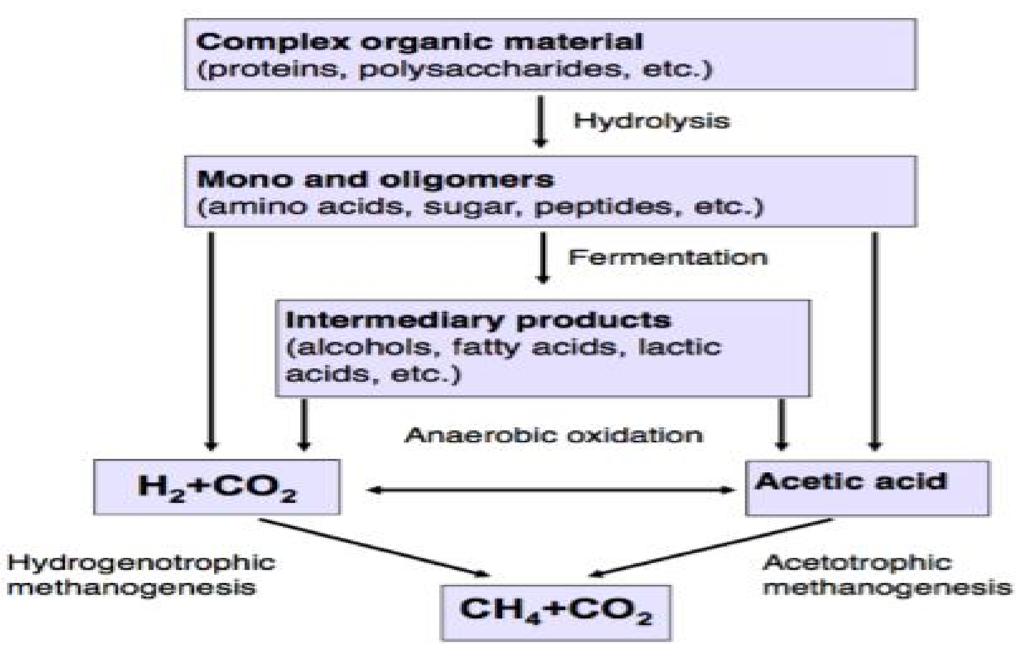

Figure 1. Schematic picture of the different microbiological steps of the biogas process (Jarvis and Schnurer, 2009).

Figure 2. At a glance picture of biogas development in India.

Stage I: Research and development for practical biogas design in India (1950-1980)

Biogas research and development had started in the 1920's through carrying out sewage treatment. From early 1950's to 1980, biogas technology initially received less and later received more attention from researchers and scientists from agriculture. During this period mainly agriculture scientists from Indian Agricultural Research Institute (IARI), Prof. N. V. Joshi from Academia (Chawla 1986) and Mr. Jashbhi Patel from KVIC conducted research to understand the process, designing practical digester, and to develop practically feasible biogas technology. During this period two types Indian indigenous plant KVIC and Garma lakshmi (Singh, 1974) was designed and installed at Osmania university, Hyderabad in 1950 (United Nations, 1984). But designed digester was not affordable to rural farmer. In 1952 Jashbai Patel developed floating dome model, Grama Laxmi III. M.A. Idani (1964) reported that a project was implemented by IARI in the mid 1950's. In twelve different villages twelve biogas plants were installed free of cost for the farmers. The first period of time after installation plant was working well and later started to malfunction. It was due to traditional living which could be overcome by education.

During this period designed practical biogas plant were installed in Maharashtra and near to Delhi city and started operation and collection of data. Mr. Patel continued to work during the fifties and institutions like the Rama Krishna Mission in Calcutta and Khadi Pratishthan Sodepur in West Bengal developed new biogas designs (Chawla, 1986). Khadi and Village industries Commission started dissemination programme for biogas technology in 1962 therefore earlier field trials could be started. Technology dissemination in KVIC's work plans was included to spread it across the nation (KVIC, 1976; WHO, 1979). While 1961 Gobar Gas Research station was established in Ajitmal in 1961 by the Planning Research and Action Division (PRAD) of Uttar Pradesh. Janata biogas plant, meaning public designed which was similar to Chinese fixed dome design was developed in 1977. The main advantage observed in the Janata and the KVIC design, was that the it reduced the cost for construction. The electrification in rural India started by the creating the Rural Electrification programme in 1950/51 (Sinha and Kandpal, 1991).

During 1972-75 there was huge crisis of natural oil and fuel wood. Therefore, Government, scientist and farmers have realized the potential of biogas due to high price of natural oil and started research on alternate renewable energy. Biogas could be a solution for high expenditure on oil import and fuel-wood crisis. This was very important step for the dissemination and dispersal of biogas technology and started getting especial attention. But there were severe scarcity of infrastructure and skilled people for expansion of biogas technology programme on large scale and huge investment. Due to these reasons dissemination of biogas was getting hindered. Moulik and Srivastava (1975) recommended strongly to provide subsidies to the farmers for installations of biogas plants. All India Coordinated Biogas Programme (AICBP) came to existence in 1975 to improve biogas technology. Till 1980 about 90,000 units were installed and of this a small number were from the Janata type (Sarkar, 1982; Ellegard et al., 1983) under biogas development programme.

Stage II: Nation-wide programme for development of biogas technology (1981-1985)

By 1980, well tested and an infrastructure for carrying out national wide dissemination for biogas was in exist. With the aim install 1.5 million biogas units by 2001, AICPB was created (Moulik 1988). It was the main initiator but other such as the IARI, PRAD, and the Indian Institute of Management (IIM) were also involved. The implementation of the programme held by KVIC. In the meantime, during the period between 1973-78, there had been almost 7 million biogas units constructed in China (Qui et al., 1990). The main emphasis of the Chinese programme was to provide a good fertilizer from the main feedstock pig manure rather than the Indian emphasis which was more and more turned towards the energy aspects of biogas technology. In India first national program for biogas development was launched in

1981.Capital subsidy was given for installation of the small biogas plants. One of the criteria applied to avail the subsidy under the programme was to have ownership of 2-3 cattle.

Government of India in 1981/82 launched an extension and development programme called National Programme for Biogas development (NPBD) implemented by the Ministry of Agriculture to make it more effective. NPBD is still exists today with the goal to provide clean and cheap source energy in rural area, provide enriched organic manure for supplementing the use of chemical fertilizers and improve sanitation, and hygiene and remove drudgery of women (MNES, 1996).The program encourage to construct and dissemination of biogas mainly through direct support in the form of subsidy to the beneficiary if installing an approved biogas design. The project is given to on turnkey fee basis to organizations, corporate bodies and approved entrepreneurs who construct biogas plants with a 3-year warranty. In direct support for training courses for users, turnkey worriers/ masons, representatives of organizations in addition to throughout support of communication and publicity activities. Low cost Deenbandhu design was developed by Action for Food in 1984. Started large scale National Programme based on subsidies, multiorganization and multi design approach in 1985.

Stage III: Household biogas plants for cooking fuel and lighting in rural area (1986-2019)

Household biogas plant is designed and installed in rural area for animal manure to produce biogas in the range of 1 to 10 m^3/day. Table 2 shows replacement values for different fuels by 1 m^3 of biogas.

First biogas plant was designed by an Indian scientist in 1946. Later, several research work to design anaerobic digestor set up and operation of the biogas plant were carried out with data analysis for further improvement. The MNRE is supporting household size biogas by giving funds as a part of the National Biogas Manure Management Programme (NBMMP). Household size biogas units are defined with size ranging 1-10 m^3 capacity however biogas subsidy from MNRE under National Biogas Manure Management Programme have been given to size 1 to 6 m^3 capacity biogas (https://mnre.gov.in/img/documents/uploads/0ce0bba7b9f24b32aed4d89265d6b067.pdf).

Under the program, around 13 lakhs household size biogas units were set up during the period 1989-1990 whereas in 1995 around 22 lakhs. Compare to 1995, 34 lakhs household size biogas units were set up in 2002. And in 2006 and 2007, installed 38.4 and 39.4 lakhs household size biogas units respectively to get economical source of energy for the rural users. Maximum biogas designs are using animal waste as substrate which have been systematized to large extent and started distribution of the information extensively across the India.

In rural parts of India domestic digesters are in operation in many rural places across India. During the period 1986 to 2004 household size biogas units were installed across rural India with incentives and subsidy from government of India which was utilized for culinary fuel and illumination in rural area. During period 1986 to 1992 there was installation of large number of household size biogas units. Table 3 depicts the state wise biogas units set up from 1978 to 2012 and subsequently till 2019 and Table 4 provides information about the total number of plants installed across India.

During 1991-92 due to economic crisis and economic liberalization (Kurien, 1996), Indian Government was required to take decision of drastically reduced the financial expenses. In this period, the Department of Non-Energy Sources was converted to a separate ministry called Ministry of Nonconventional Energy Sources (MNES) and this was other reason for decease in subsidy, incentives of Biogas technology. During the period of 1991-2002 there was huge decrease in subsidies and funding organization related to biogas technology was restructured. In July 1992 the DNES was formally converted to the MNES. But the MNES followed the same strategy for sourcing the funds for biogas plants until 1993. But in July 1993, the MNES followed more out based approached and improve the execution policy (Sinha, 1994).

Table 2. Replacement values for different fuels by 1m^3 of biogas.

S. No.	Fuel	Replacement value	Estimated Equivalent with 15083 mm^3 of biogas/annum (in millions)
1	LPG	0.45 kg	6787.35 kg
2	Firewood	3.47 kg	52338.01 kg
3	Cattle dung cake	12.30 kg	185520.9 kg
4	Charcoal	1.4 kg	21116.2 kg
5	Diesel	0.52 liter	7843.16 liter
6	Electricity	6.5 KWh	98039.5 KWh
7	Kerosene	0.62 liter	9351.46 liter
8	Gasoline	0.8 liter	12066.4 liter

Ref: http://vikaspedia.in/energy/energy-production/bio-energy/biogas.

Table 3. State wise number of biogas plant installed from 1974-2012.

State	1974-81	1990	1995	2002	2007	2010	2012
Andhra Pradesh	2854	89327	173388	334054	419884	457938	474213
Arunachal Pradesh	0	24	185	1514	2345	2957	3282
Assam	75	8557	13936	51269	59942	81592	94905
Bihar	9826	58553	81090	121913	125306	125888	129523
Chandigarh	0	77	92	97	97	97	97
Chhatisgarh	0	0	0	3047	23399	32050	40661
Delhi	51	578	654	676	677	679	681
Gujrat	9185	92908	258327	351745	387251	411950	420686
Goa	0	1448	2367	3355	3807	3893	3976
Gujrat	9185	92908	258327	351745	387251	411950	418055
Harayana	10277	18129	28383	44160	50266	54083	57281
Himachal pradesh	0	20822	35647	43933	45046	45716	46587
J&K	0	708	1105	1965	2212	2489	2739
Jharkhand	0	0	0	400	2543	4933	6596
Kerala	1587	23471	42100	42100	114183	126463	133887
Karnataka	7799	65968	160562	340270	396681	418759	445586
M.P.	152	37332	89620	204100	258747	295580	324737
Maharashtar	1923	370662	556693	675177	735196	780527	824203
Manipur	0	339	877	1956	2128	2128	2128
Meghalaya	0	167	379	2309	4586	6661	9326
Mizoram	0	591	1109	2818	3570	3770	3920
Nagaland	0	124	294	294	2892	4153	6649
Orissa	622	48407	106774	185690	228295	239818	253054
Punjab	5612	14802	27992	68745	83771	105289	143162
Rajasthan	409	34864	5096	66552	66990	67348	68121
Sikkim	0	364	1382	3475	5959	7333	8326
Tamilnadu	6565	127096	176271	201295	211242	216516	219540
Tripura	0	114	476	1719	2549	2793	2999
UK	0	0	0	1547	7354	10508	14704
UP	27883	180806	253551	370219	413052	422269	431631
West bangal	2413	40474	81151	203679	273287	318510	355496
Total	89213	1237390	2188885	3369857	3934136	4253561	4545026

Ref: https://shodhganga.inflibnet.ac.in/bitstream/10603/25598/14/14_chapter4.pdf and https://mnre.gov.in/img/documents/uploads/0ce0bba7b9f24b32aed4d89265d6b067.pdf.

MNES had variety of projects including conducting research and innovations for biogas, upgradation of chulla and development over mini hydro and solar photovoltaic (PV) power, establishing institutions like the Indian Renewable Energy Development Agency (IREDA) (MNES, 1996). During these period NPBD was yet one of prime projects and allocated significant amount of budget. The ministry is split up into six functional areas in order to support and promote diverse features of Renewable Energy Technology and proper administration.

National programme was launched in 1995 in order to recover energy from urban solid waste, industrial waste and agro residues. In rural India, mostly household size mini biogas plants have been set up which has capacity between 1 and 10 m^3 biogas generation per day. Household size biogas units are managed by individual households required financial support so as to cover the initial cost but yielding only non-monetary benefits such as biogas as cooking fuel as an alternative to firewood. Whereas in the case of large-scale commercial biogas plants managed by entirely private or public private partnership aim to yield monetary gains, that is, electricity, Bio-CNG, fuel or heat. There are different factors which impacts on these two different biogas systems in India including macro environment, scale of production, utilization area, and feedstock type etc.

Trendline of Cumulative No of Household size biogas units installation across India

Factor responsible for setting up of Household size

Table 4. Total number of biogas plants installed in India from 1974 to 2019.

1974-81	1990	1995	2002	2007	2010	2012	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19
89213	1237390	2188885	3369857	3934136	4253561	4545026	4628566	4713448	4760938	49,66,628	50,01,358	50,51,436

biogas units across the Indian states including financial support, research, trained manpower for installation, space availability, substrate availability, willingness of people and administrative support from Government side. The details about the periodical progress made from 1974 to 2016-17 has been summarised as below. Trendline of Cumulative number of biogas installed across the states from period 1974 to 2019 has been depicted in Figure 3.

Stage IV: Large and industrial biogas plant for electricity generation and industrial application in India (2005-2015)

High cost of fossil fuel and electricity are major problems in India. At present scenario the best method is to fulfill electrification requirement through developing new power plant based on renewable biogas energy. The purpose of all these digesters is to generate combustible biogas that is utilized to provide energy for a whole range of industrial uses. Large scale industrial digesters are also installed and operated in urban area. Large and industrial scale plants having above 5000 m^3 per day biogas production capacity mostly based on urban or industrial organic waste to produce biogas. The biogas produced further utilized for electricity generation, heat and transport fuel. Besides household size biogas units 400 biogas off-grid power plants have been set up with a power generation capacity of about 5.5 MW. Due to high capital and operation cost with very less monetary benefits, utilization of household organic waste to produce biogas has been very limited in urban areas as well as rural areas in comparison with other waste processing technologies like composting.

A few biogas-based electricity generation plants exist in India which are 56 in numbers and majority of them are present in three Indian States such as Maharashtra, Kerala and Karnataka. The projected total potential of biogas production in India was about 40734 Mm^3/year from different organic wastes. And about 120 lakhs household's biogas plants can be installed across India. Till year 2014 about 47.5 lakhs which is about 40 per cent of the estimated number of biogas. As estimated, India has potential to produce power of about 17000 MW using biogas and which contributes to 10% of India's energy need. Presently most of the plants are based on the animal waste however advance technology can successfully cater to the new feedstock such as municipal solid waste, agriculture residues, industrial waste etc. Numerous programs for biogas to power generation has been launched by the Central and State Government in India. UP State government has approved for biogas plant based on dairy wastes which is designed and installed to produce 3 to 250 KV.

Stage V: Compressed biogas plant for electricity generation and vehicular fuel through private partner/player (2016-2020)

During the decade, biogas technology has been encouraged largely as a culinary fuel in the villages and industrial applications in urban area. During the period of 2016-2020 biogas has been emphasized as vehicular fuel. Compressed biogas Plant is a recent concept in India. The new policy for such type plant has launched in 2018. Thus, effects can be seen after few years. India consumed about 146 million standard cubic meters per day of natural gas of which 56% is imported from other countries. It is estimated that there is potential to produce 62 million tonnes of Compressed Bio Gas (CBG) from wastes. It will be 6 to 7% of natural gas imported. By application of anaerobic decomposition process biomass sources such as agro-residue, cow-dung, press mud from sugar industry, urban solid waste, sewage treatment plant waste etc can be disintegrated to formation of biogas.

The biogas purification process is carried out through removal of hydrogen sulfide (H_2S), carbon dioxide (CO_2), and water vapor (Angelidakia et al., 2018). It is compressed as CBG, which contains methane (CH_4) more than 95%. Both CBG and CNG have similar calorific value and other properties. Hence it can be utilized as green renewable automotive fuel. Thus, CBG can be used in automotive, industrial and commercial areas. It is possible due to abundance biomass availability within the country. Ministry of Environment and Forests notified Municipal Solid Waste (Management and Handling) Rules 2000 and amended in 2016 and extended its area of jurisdiction. Government has made new policy and made it mandatory for the electricity distribution companies (DIACOMS) to purchase 100percent of electricity generated from waste to

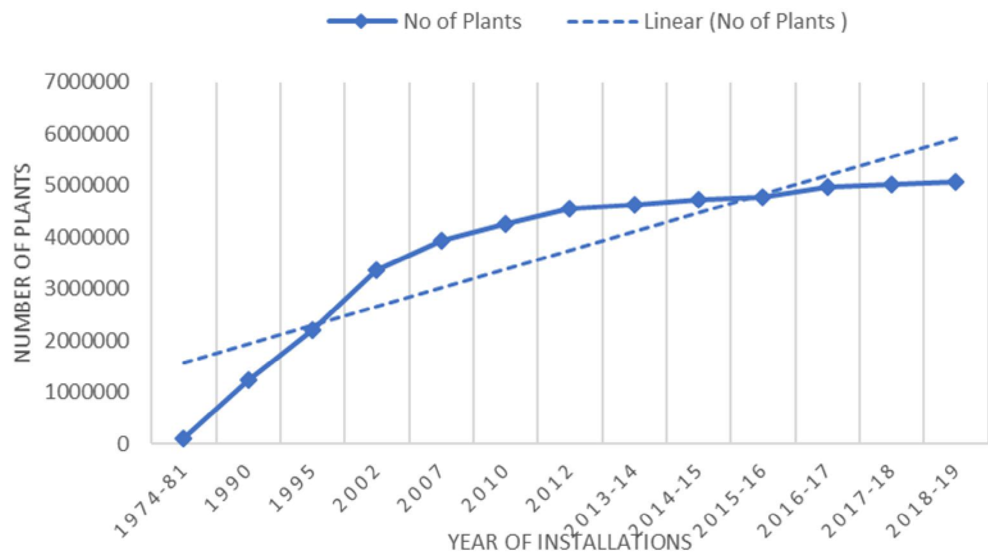

Figure 3. Trendline of cumulative no. of family size biogas plants installation across India.

energy plants. Electricity generated from the waste to energy plant shall be procured by the DIACOMs based on the collective tariff announced by the Ministry of Power. Prime Minister Narendra Modi has made very attractive announcement for promotion of biogas technology with strategies to fulfill climate change goal, apart from creation a buffer against crude oil price fluctuations and increase the income of farmer in 2018. Government has also plan to integrate compressed biogas networks with CNG gas distribution network to increase the domestic supply as well as its market. Under the policy 5000 compressed biogas plant across India will be set up by 2022 which will require capital of Rs.1.75 lakh crore as per Ministry of Petroleum and Natural Gas. According to an estimate a biogas plant with 100 Ton Per Day (TPD) of agricultural residue feedstock can produce 10 TPD compressed biogas and 30TPD of dry manure. This type of plant costs about Rs3500 lakhs and would need 6-15-acre land for setting up of plant. The CGD networks in 86 new cities will be expanded hence the number of CNG stations will increase from 1,500 to 10,000 in five years. Its consumption will be high in near future.

About 100 to 125 tons per of press mud can be generated by processing of 3500 tonnes of sugar care/day by one sugar industry in India. Average biogas production from one tonne of press mud is equal to 85 to 100 m³ raw biogas. The biogas plant having 100TPD per day capacity can product 850-950 kWh of power which is equal to 4,000 kg of purified methane gas (CH_4 >95 per cent). The excess press mud produced during crushing season can be stockpiled and utilized during offseason.

Reserve stock of press mud will allow the biogas plant to keep operational for the entire year. The central government is providing subsidy up to Rs 40 million in order to encourage Bio-CNG sector. The government has given guarantee for selling price Rs 46 per kg of bio-CNG. Compressed biogas has several benefits which can be produced through anaerobic digestion of various wastes, followed by purification and compression on a commercial scale. These are given below:

- Provide unique solution of waste management which will results in decrease in carbon emissions and air pollution.
- Create extra earning source for farmers.
- Significant increase in entrepreneurship, rural economy and employment.
- Help in fulfilling the country commitments and attaining climate transition goals.
- Limited import of natural gas and crude oil due to use of compressed biogas on commercial scale.
- Prove a good buffer against crude oil/gas price fluctuations.

Difference in characteristics of biogas and compressed biogas

Significant difference in characteristics of Biogas and Bio -CBG like in biogas methane constitute to 55-65% whereas in Bio-CBG it is 92 to 98%. However, CO2 percentage is less in Bio-CBG i.e.2 to 8% and higher in biogas i.e.35 to 45%. Bio-CBG has higher calorific value i.e. ~ 52000 and ~19500 kJ/kg in Biogas. Table 5 shows the difference in characteristics of biogas and compress biogas.

CHALLENGES AND ISSUES FOR BIOGAS TECHNOLOGY

Dissemination of biogas technology to reach across rural

Table 5. Difference in characteristics of biogas and compressed biogas.

Parameters	Biogas	Bio-CBG
Methane (v/v)	55-65%	92-98%
CO_2 (v/v)	35-45%	2-8%
H_2S (ppm)	500 – 30,000	<20 ppm
Moisture	Saturated	< -40 deg
Other Impurities	Present	Not present
Calorific Value (LCV)	~ 19500 kJ/kg	~ 52000 kJ/kg

Ref. https://www.globalmethane.org/documents/16.Ag2.1.Dhussa.pdf.

and urban India is very important. Several issues (Mittal et al., 2018) which hinder the technology especially household size biogas become popular which are given below.

Financial issues

High cost of biogas technology is one of a crucial issue in rural area of India for its application in the villages (Rao and Ravindranath, 2002). Because of low income level the cost of biogas construction, labour and equipment cost, installation of biogas is not affordable by the villagers. The installation of one household size biogas plant having capacity 1 m^3 of biogas production every day cost about Rs 2000 (Samar et al., 2016; Mittal et al., 2018).

A subsidy given to install one household biogas plant of different size 1 to 6 m^3 is around Rs 8000 to 14000. It is 20-40% of total installation cost of biogas plant. In rural area low income household's average monthly expenses is less than Rs10000 (MOSPI, 2015). It reveals that it is difficult to bear cost of biogas Plant even after receiving subsidy. Thus, they do not agree to accept biogas technology.

Usually there is postponement in the release of capital subsidies due to procedure, guideline followed which increases the administrative cost and create additional financial burden on the project receivers (Chandra et al., 2006b; Rao and Ravindranath, 2002). Low income households are unable to use to biogas for cooking purpose because of limited availability of initial funds required installation of biogas which is besides the high initial cost (Ravindranath and Balachandra, 2009).

Marketability issue

Other renewable energy gives tough competition to biogas. The selection of fuel depends on several factors such as household income, fuel cost, ease of procurement and assurance of fuel supply (Bansal et al., 2013). In rural area people prefer cheaper fuel alternative such as conventional solid fuel, wood, dung cakes which are local resource and ease in operation. However, high income households prefer liquid petroleum gas because of assurance of continued supply and procurement is easy, no construction required.

In Sirsi area there is limited access to get LPG and has been important reason for wide range of biogas publicity and utilization by the local community (Bhat et al., 2001). Still biogas faces race with LPG in areas where there is well LPG delivery network.

Societal issues

In rural India there are numerous civic problems such as humankind and biogas owners are not willing to use faecal matter in bio-digestor and the gas produced for cooking purpose because of attached communal disgrace (personal communication). This is also creating difficulty in the process of adopting biogas as technology for cooking, electricity generation in Indian villages. Other reason for limitation in adopting biogas in rural India is women do household work such as cooking, cleaning etc. and inhales polluted air caused due to burning of biomass. And in rural society women has limited decision making power and low status. Therefore, providing clean fuels for cooking become less important.

Administrative and government institutional issues

In the NBMMP program central government has adapted a top-down approach for its implementation. One of the criteria to get the subsidy as a capital cost is given to the rural households who possess 2-3 cattle. This is making program insufficiently targeted towards the rural population. Because of not having the ownership of 2-3 cattle, the rural households are not eligible to get the subsidy which hampers the adaptation of biotechnology by the countryside population (Raha et al., 2014).

Hence, most of the low-income households in the villages are depends upon the firewood, dung cakes etc. for preparing meals and other. The National Biogas Development Program is being implemented by involvement of several agencies. Between these organizations there is deficiency in coordination and race for the incentives has been identified for poor performance and limited spread of technology among the village population (Bansal et al., 2013; Kaniyamparambil, 2011). Apart from capital subsidy there is cost involved in identification of appropriate beneficiaries, providing technical guidance, constant monitoring of the program and extensive outreach, but due to limitations in funds and delay in dispersal makes it difficult for the NGOs or organizations involved for grass root implementation.

Technical and operational issues

In order to keep biogas, run it with its full capacity there are two key parameters needs to keep in mind. Either supply less quantity or no feed will make the biogas plant fail. Reliable and continuous supply of substrate to biogas plant cannot be ensured through the ownership of 2-3 cattle. Water and feedstock mixing ratio shall be maintained as per the standards otherwise improper ratio effect on the plant working. During cow grazing in winter season there is problem of collection of scattered dropping of cattle and becomes difficult to collect in these months (Rupf et al., 2015). In rural areas there is deficiency of technical expertise or services required to be provided for biogas and less number skilled manpower is available for construction and repairs also.

Biogas production rate is influenced by temperatures i.e. very important factor to be considered while operating biogas plant. Biogas production decreases during winter season in cold areas where temperature goes down drastically this resulted in inhibiting the growth of methanogenesis bacteria. The hydraulic retaining time also rises to about 120-150 days at lower temperature below 15°C (Zeeman, 1991; Daxiong et al., 1990, Kalia and Kanwar, 1998). Biogas is not produced in enough quantity during winter season specially and hence users are required to shift other fuel sources. Apart from this, problems like unavailability of skilled human resource for fixing technical problems when technical fault observed while operating the biogas plant. This turned to be another obstacle preventing the diffusion of biotechnology Indian Villages (Kaniyamparambil, 2011).

Knowledge and guidance issues

In rural areas people don't have knowledge about biogas technology, its benefits and not aware about the incentives given by the central and state government towards the implementation of technology. Knowledge and guidance have observed as a one of reasons for people in rural areas not using biogas for preparing meals (Blenkinsopp et al., 2013; Rao and Ravindranath, 2002). Households do not possess required number cattle which can provide sufficient quantity of manure as an input/raw material for formation of biogas which leads low adaptation of biogas by the rural India. Households are not aware and they are not been told about the alternative source can be useful as feedstock in the digester (Raha et al., 2014). Even though government has been running the information dissemination program from several decades still low acceptance of biogas technology by the village population is considered as a fundamental problem. Various problems related to technical knowledge and infrastructure such as feedstock crushing, unavailability of cattle dung, insufficient guidance to user create problems in biogas operations. Running of plant below with its capacity, variation in biogas generation dampens the use technology by rural households which ultimately results in low acceptance by the rural population. When there is insufficient supply of biogas then rural households have to shift to other available resources in order to attain the daily demand of cooking fuel or seasonal electricity requirements. In rural area people design and install biogas plant of higher capacity even though non-availability of feedstock for higher capacity. This happens due to lack of awareness and knowledge among rural people.

This shows that reasonableness and consistency of biogas supply are the most important factors to the acceptance and use of biogas technology by the rural households.

To recapitulate this, techno-financial issues such as lack of technical and operational knowledge, high capital and installation cost, along with societal issues don't allow the acceptance of biogas technologies in the rural areas.

ISSUES THAT AFFECT LARGE AND INDUSTRIAL SCALE BIOGAS PLANT

Financial problems

- Large and industrial scale biogas plant required high capital cost for electricity, heat and fuel in installation process.
- Higher interest rate on funding and financial problems are major challenges.
- Financial institution takes high interest rate (12 to 14%) and does not approve long term financing that affects the financial feasibility of the biogas projects.
- Small developers are not willing invest in biogas sector because of low revenue and high capital cost requirement that is one of obstacles for
- Developer shall calculate the economic viability of large-scale biogas based on three outputs i.e. biogas, fertilizer and waste water treatment.

Market issues

- Power generated from biogas-based plants are costlier than the power generated from the coal and natural gas fired power plants.
- Operational and maintenance cost of the biogas plant is

more than thermal power plants.
- Solar, hydro and wind power is economical than biogas-based power generation technology due to government incentives like fixed feed-in tariffs and renewable power requirements.
- Cost of handling and long-distance transportation makes biogas-based power generation costly which affects negatively.
- Consumers pay less electricity cost, generated by technology other than biogas-based power generation.

Administrative and government Institutional Issues

- In 2016, state electricity regulatory commissions (SERCs) announced basic rates for the power generated from biogas and waste to energy projects however it has still not fixed basic rates for electricity generated from biogas-based power plants.
- It is possible to use compressed and bottled bio-methane in CNG vehicle without any modification. However, biogas cannot be used as transport fuel or injecting in the natural gas grid, government needs to issue legal standards for the same (Vijay et al., 2015).
- Thus, developer/inventor get grant approvals from different government departments. However, these regulatory requirements are time consuming processes and hence contribute in hamper the growth of biogas segment in India.

Procedural and infrastructural issues

- Improper collection, segregation, transport thereby failure in supply of required quantity of waste to plant by the operator is one of reason for slow growth of biogas technology.
- Lack of supply of high-quality segregated waste leads to damage of blades of crusher and shredder.
- Lack of skilled manpower for operating and maintains of the biogas plant.
- Other issues like marketing of product i.e. biogas and strong competition from other fuels and waste treatment technologies and government and regulatory issues also impacts on scale up of biogas.
- Biogas yield is directly depending upon quality and sustained supply of required substrate and lack of provision of the same face challenge of lowering down electricity generation.

INDIAN BIOGAS TECHNOLOGY

Appropriate Rural Technology Institute (ARTI) biogas

ARTI researched and evolved a compress designed biogas plant for treatment of urban solid waste including food waste rather dung or animal fodder and gas generated utilized for cooking purpose. In urban and rural households of Maharashtra state ARTI biogas are being used for kitchen waste processing and about two thousand units are currently working. The ARTI has also set up some plants in other states of India and foreign countries.

A few have been installed in other parts of India and even elsewhere in the world. ARTI has won the Ashden Award for Sustainable Energy 2006 in the Food Security category. The technology can be used in developed cities because substrate use for biogas generation is food waste, Starchy Agro waste(like banana, nutgrass), Non-edible seeds(tamarind, mango kernels, spoilt grain) and Oilcake of Non edible Oilseeds (Pongamia, castor) or leftover food are use as feed with filling capacity of 1 m^3. It is observed that 250 g gas is generated from 1 kg waste, we can feed up to 2 kg per day but after that increase in substrate concentration hamper the biogas generation process due to change in pH, This Biogas generation technology is fast and aims to improve biogas efficiency and decrease cost, it require less labor, replace fossil fuel, reduce waste, generate energy, reduce BOD and COD. These digesters are made up of high-density polythene water tank, this consists of 2 tanks one is 1 m^3 digester and other is use as gas holder.

Nisargruna biogas technology

Nisargruna biogas technique was developed by Dr. Sharad P Kale, the technique is based on degradation of various waste like kitchen waste, grass, dry leaves, paper and agriculture waste etc. Nisargruna include 2 steps process i.e. aerobic and anaerobic digestion. In first step slurry mixed is feed into digester, this step increase temperature due to exothermic process and in second step after exothermic reaction all feed slurry in transfer into anaerobic digester for Methanogenesis process to generate CH_4, CO_2, H_2S. Nisargruna plant generates more methane (70-80%) than traditional biogas plant (55 to 65%) and also slurry has good C/N ratio 12:1 to 16:1. Generated methane can be used to generate power which would supply to Urjwa Market and operating machines at the plant.

Compressed biogas technology

Prof. Vijay has given emphasis on Biogas-Fertilizer-Waste Treatment plant coined term for biogas plant. He developed technology for compressed biogas known vehicular fuel (Chandra et al., 2011). His concepts on linking higher educational institutes for village development and biogas purification and bottling technology were well adopted by Government of India and launched as programs by concerned ministry in the Government. He got patent on biogas small scale biogas upgradation technology which has been licensed to

7 industries and many gaushalas in field areas. He has been operating India's first biogas car for last 6 years which has crossed more than 50000 km run on biogas. Typical capacity of a commercially viable Biogas Purification and Bottling Plant is 1000 NM3/Day. The above-mentioned capacity plants required waste quantity is about 20 Tons/Day of Cattle Dung or 10 Tons/Day of Pig, Poultry or Food Waste to achieve desire output. Such plant produces approximately 400 kg/Day CNG and 6 Tons/Day of Semi Dried Manure. This includes an Anaerobic Digester, Biogas Purification Plant, High Pressure Compressor and CNG Cylinder Storage Cascade (Kapdi et al., 2005). The initial investment of about Rs 25 million is required for setting up of entire plant which includes construction, machinery and hardware, digestors, etc but excludes land cost. Compressed biogas can be used to substitute commercial LPG or Vehicular fuel with the normal marketing price at the rate of Rs.70/kg. Organic manure generally sold at the rate of Rs 3-4/kg. Plant has a very good economics with a payback period of 4-5 years.

Biogas potential in India

India generates larges of quantity of organic kitchen waste, agriculture waste and other biomass which have been potentially used as substrate for biogas generation, Table 6 describe the biogas yield (Horvath et al., 2016). Biogas had been potentially used for cooking in kitchen, BIO-CNG to run vehicle, generate heat and electricity, it is estimated that in India about 17000 MW power have been generating from biogas and the biogas cover 5% consumption of total LPG requirement. Cattle and buffalo substrate of 718.24 MT/annum has capacity of 15083 Mm^3/annum, Municipal Solid Waste substrate quantity 127,486 tons/ day produce 9.29 Mm^3/day of biogas and crop residue quantity 686 MT/ annum has biogas production capacity of 45.8 Mm^3/day (Rupnar et al., 2018). It is estimated that there is potential to generate about 40,734 Metric m^3/year of gas from different types of waste. India has largest number of cattle populations in the world which is about 512.1 million. In India the total animal populace is about 299.9 million followed by goat and sheep about 2003 lakhs populace. It is stated that the available cow dung can be sufficient to build 12-30 million plants however we have requirement of about 100 million biogas plants to fulfill energy demand. Power generation from Biogas produced from different types of waste is shown in Table 7.

Table 6. Biogas generation from various sources.

Source	Substrate	Cow dung	Slurry ratio (Substrate and water)	Methane content (%)	Biogas yield	References
Animal	Waste from different animal separately	50 kg	1:1		Horse	Mandal and Mandal (1995)
Food waste	Food + straw	300 kg	1:1	1.06 m^3	0.396 m^3	Liu et al. (2018)
Dairy industry	Whey	100 kg	1:1	78%	5.5 m^3	Wesołowska-Trojanowska and Targonski (2014)
Meat waste	Waste meat stuff	200 kg	1:1	194 m^3	0.275 m^3	Zakrzewski et al. (2009)
Agricultural waste	Cotton waste	250 kg	1:1	6.5-8.0 m^3	0.10 m^3	Isci and Demirerb (2007)
Sludge waste	Sludge	200 kg	1:1	64%	0.640 m^3	Laskri and Nedjah (2015)
Microbe	Algae (300kg)	700 kg	1:1	64%	0.003 m^3	Mussgnug et al. (2010)
Crop	Sugar beet	332 kg	1:1	53%	0.004 m^3	Abdien (2003)

Table 7. Power generation from Biogas produced from different types of waste.

Waste	Power
Distillery effluent	1 MW/30 kL
Dairies (milk processing)	100kW/3 lakh litres
Paper mills (Black liq+)	1 MW/60 TPD paper
Slaughter waste	100kW/10-12 TPD
Poultry droppings	1MW/ 1 Million birds
Cattle manure	100 kW/25 TPD
Spent wash from distillery	1MW/30kL
Cattle manure	1MW/250 tonnes/day

Ref: www.globalmethane.org › 16.Ag2.1.Dhussa.pd.

Therefore, there is need to identify and research biogas production from other sources of waste. A large number of 70-88 million biogas plant can be operated with fresh/dry biogas residue. 1150 billion tons of biomass a fifth portion of available would be adequate to fulfill the requirement. Table 6 provides information like quantity of cow dung required in order to get 1:1 percent of slurry in the different feedstock.

BIODIGESTER FOR BIOGAS PRODUCTION

Biogas digester is a digestion tank in which all type of biowaste are potentially use for digestion and biogas generation. Commonly used Bio digester consist of a dome shaped top connected with underground cylinder of variable length and diameter, can be made up of fiber or concrete, surely makes it confirm that digester should be strong and can handle gas pressure. There are two holes in digester, one connected with inlet and other from outlet pipe. Outlet pipe should be at least 10" above to the bottom of tank so that after removal of slurry some slurry should remain in digester as inoculum for further use. There is a nozzle connected at the center of top for easy removal of gas whenever it uses (Bhol et al., 2011).

Four types of biogas digester are available in market including fixed dome, floating dome, bag type and containerized /prefabricated digester. Fixed and floating dome digester required construction whereas plastic and containerized are prefabricated and required less time for installation. Table 8 shows comparison between four types of biogas digesters explaining their advantages and disadvantages and also provides comparative information of four types of biogas digesters.

Ministry of Non-Conventional and Renewable Energy has approved Chinese fixed dome plant, Janta Model, Deenbandhu, CAMARTEC, Pragati Model, Ganesh Model, KVIC model for installation biogas plants across India. The details about these models are explained by comparison of theory, substrate suitability, construction material, size and advantage and disadvantage etc. MNRE suggested different models of biogas to be suited for different feedstock and availability of space. Table 9 provides comparative information about the commercial biogas digesters.

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BIO-CNG CONSUMPTION IN INDIA

Apart from substituting CNG, LPG, Bio-CNG can be used in the place of biogas and in India Bio-CNG has good market potential which is predictable to 1281 MW e.g. Biogas fulfils about 75% energy demand of distilleries, sugar and starch industries and hence can be potential customers for Bio-CNG.

Similarly, paper industry, milk processing industry and slaughter houses can use Bio-CNG to fulfil their energy requirement and possible customers. In India there is six key operational Bio-CNG Plant given in Table 10.

As reported in Renewable Watch Research the quantity of bio-CNG 46,178 kg is produced per day from 17 bio-CNG plants. These 17 Bio-CNG plants are situated in north and west part of the country. National Agricultural Cooperative Marketing Federation of India has planned to develop a Bio-CNG facility near Azad Mandi, New Delhi. Bio-CNG produced at this plant will be procured by Indraprastha Gas Limited (IGL). To set up biogas and Bio-CNG plants an MOU has been signed in January 2018 between the Punjab Bureau of Industrial Promotion, Punjab Energy Development Agency and Indian Oil Corporation Limited (IOCL). IOCL is planning to make the total investment of Rs 50 billion. Over the next few years the state government plan to increase and expand these up-to 400 units. The Ministry of Petroleum and Natural Gas in partnership with IOCL, Bharat Petroleum

Table 8. Comparison between four type of biogas digester.

Type	Brief	Material	Size	Advantage	Disadvantage	Cost	Example
Fixed Dome Digester	Fixed gas holder, construct under ground	Masonry and cement	Mini plant 5 m^3. Large plant 200m^3	Corrosion free, long life, creates local employment	Labour intensive, construction Require skills, Gas pressure fluctuation	Low cost,	1. Chinese fixed-dome plant, 2. Janata model 3. Deenbandhu 4. CAMARTEC
Floating Dome Digester	Floating gas holder, rises & down acc. To gas pressure, cylindrical shaped	Brick and concrete, 2-2.5 mm steel sheets	Mini plant 5-15 m^3. Large plant 20-100 m^3	Constant & visible gas pressure, easy to construct	Require polishing, Rusting, short life	Expensive	KVIC model Pragati model Ganesh model
Bag Type Digester	Gas store in upper part of balloon,	Heat sealed plastic or rubber bag	2 m^3	Low cost, easy transportation of gas, easy Maintenance	Short life, low gas pressure, susceptible to mechanical damage.	2- 5 year	1. Under ground 2. Semi burred 3. Ground digester
Flexi type Digester	flexible above-ground system, made inside green-house tunnel	plastic bag made of PVC tarpaulin	2 m^3	Low cost, save time, pure gas, rid from smoke, improves agricultural productivity	Training requirement, its repair and maintenance of puncture, labor of daily basis	Low cost	
Containerized /Prefabricated type Digester	Flexible about ground, crusher, digester all inclusive	Metal, movable	60-300 m^3	High cost, save time, non-corrosive	Automated and less manpower required	Expensive	Above ground Underground

Table 9. Comparison between commercial biogas digester.

Name	Theory	Substrate	Construction material	Size	Disadvantage	Advantage
Chinese fixed-dome plant	Cylindrical digester with dome shaped gas storage	Rice barn, Wheat straw, Fruits and Vegetables.	Brick and concrete	20 m^3	Low cost and no risk of rust	Cracks and irregular gas pressure.
Janata model	Fix dome digester, made in reference of china	Cattle dung and municipal waste. Plant residue	Concrete	15 m^3	Easy to construct and low cost	Cracks and leakage of gas

Table 9. Continues.

Deenbandhu	successor of janta model, with crack proof	Cattle dung and kitchen waste, plant residue.	Brick, masonry and concrete	6 m^3	Crack proof, can work in cold weather	Training and Maintenance
CAMARTEC	Hemisphere dome, consist of 2 layer wall	Undiluted cattle dung, chopped plants, leaves and solid waste.	1. Brick and concrete. 2.Cement plaster	8 m^3 – 16 m^3	Leakage proof, Long life	Construction cost and lobar intensive
Pragati Model	Hemisphere digester with cylindrical floating dome.	Cattle dung, kitchen waste, liquid waste.	Brick and concrete digester with steel holder	12 m^3 20%< KVIC	Leakage proof, long life, constant gas pressure.	Training, rust, maintenance, cost
Ganesh model	plastic water containers digester and low cost floating drum	Agrowaste, cattle waste, municipal waste.	Angular steel and plastic foil	15 m^3	Low cost	Training, rust, maintenance
KVIC Model	Cylindrical shaped and widely use floating type digester	Cattle dung, kitchen waste	Bricks and cement digester with steel gas holder	10 m^3	No leakage, constant gas pressure	High cost, rust, and maintenance

Table 10. Key Operational BIO-CNG Plants.

Developer	Capacity (kg/day)	Location
Spectrum Renewable Energy Limited	8000	Kodoll, Maharashtra
Green Elephant Private Limited	7290	Kissanveer Sahkari Sugar Mill, Satara, Maharashtra
Bharat Biogas Energy Limited	6538	Ahmedabad, Gujarat
Amul	6000	Vadodara, Gujarat
Brajdham Power Private Limited	3000	Delawas, Rajasthan
Mahindra Research Valley and Mahindra World City Developers Limited	400	Chennai, Tamil Nadu

Ref: MNRE; Renewable Watch Research.

Corporation Limited, Hindustan Petroleum Corporation Limited and GAIL (India) Limited, plans to set up bio-CNG plants across the India with the cost of Rs 70 billons. Some of the important key challenges of Bio-CNG are as below:

- The cost of installation required for bio-CNG plants are very high.
- Requirement of high-quality segregated waste and processing become costlier and this could reduce the acceptance of Bio-CNG technology.
- One of major constraints is availability of skill professionals this might get bigger unless skill development programs are conducted along with

technology advancements.

- For municipal solid waste processing highly effective waste to energy technology is not available so far which is also affecting the scale up of bio- CNG across India.

The MNRE has been providing financial support for research and development related to waste to energy and bio-CNG project in India. The MNRE has provided capital subsidy of Rs 10 million per MW of power or 12000 cubic meters of biogas in a day and with the maximum cap Rs 50 million per project. The government launched Organic Bio-Agro Resources Dhan (GOBAR-DHAN) scheme in the Union budget 2018-19 for conversion of cattle dung and solid waste to compost, biogas and Bio-CNG. In India Bio-CNG certainly has bright future and will emerge as an alternative to CNG considering the high amount of solid waste generation.

CONCLUSIONS AND POLICY RECOMMENDATIONS

First Biogas lamp was used in year 1878 in Mumbai however biogas technology development began very late i.e from mid-1950. Biogas development in India took place in five stages are research and development for practical biogas, National biogas programme and incentives launched and continued in present time also, Installation of household biogas plant, Development of large scale and Industrial biogas plant and Compressed biogas plant. Different model of biogas digestors and plants in India have been developed since 1960s. Out of 15 models, 7 models have identified by government of India for incentives. Different kinds of waste including municipal solid, food, dairy, industrial, sewage, agricultural and human waste etc. can be treated or reused by using biogas technology. In the 70's biogas technology was used for the rural development and it was perfectly suited for the rural development through integrated manner. At the end of 80's and 90's biogas technology was apprehended as resource to implement sustainable development.

The important conclusions of the paper are: 1) There is enormous potential in utilization of biogas technology and if it will be achieved will bring the real difference for rural, urban people as well as industrial sector. However, India still has not explored the biogas technology maximum, its expansion and dissemination on both urban and rural level required. 2) There is still need for an efficient technology for digestion municipal solid wastes to biogas is not available. 3) Dire need to review of dry digestion or digestion to enable it to solve the problem of waste water problems so as to make biogas technology viable for urban as well rural for different fraction of organic waste. 4) It is required to bring in practice of dry anaerobic digestion process or use less water for the process. Since huge amount of water is required in biogas plant which is usually not available in rural area. This problem makes biogas technology unpopular in rural area. 5) Setting up biogas-fertilizer-waste treatment plant with three outputs biogas, fertilizer and waste treatment will give unique solution of energy, society, health, agriculture, employment and economy related issues of country. Biogas plants are provided financial support whereas fertilizer and waste treatment plant does not get approval for funds. 6) Biogas technology will be a channel to diminish countryside poverty and it will instrument as a part of large-scale drive of rural development and employment.

Based on our conclusions, numerous policy recommendations are drawn to enhance the biogas technology utilization. Now in India mature biogas technology is available based on usage of different substrates. Also, commercial biogas plants for different substrates and usage such as domestic, industrial and CNG biogas plants are available in Indian market. Experience suggests considerable government involvement will be good option for the support networks/agencies/NGO to be continued over time. Biogas gives unique benefits to human with respect to health improvement, sustainable alternate energy source and clean environment. Domestic/household biogas plant in rural area usually uses cow dung, organic waste, human excreta, weeds and crop residues but there are financial, technical and operational problems, social issues, market, working way of government programme and incentive which hinders diffusion of biogas technology in Indian villages.

Simultaneously, household biogas digesters face numerous problems which need to overcome in order to continued propagation and scale up of biogas technology in the 21st century across rural and urban India. Biogas designs with lower cost, robust, enhanced functionality, ease in construction and operation, with low maintenance, this would help marketing of biogas technology.

Moreover, to enable India to go beyond a dependence on livestock manure to other organic manure there is definite need for small scale bioreactors which would effectively digest locally available feedstock in both rural and urban scenarios.

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