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Sustainable utilization of biogas technology: A promising solution to combat the energy crisis in India

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ABSTRACT

India is facing a significant energy crisis due to its rapidly growing population, which is not being met by an equivalent increase in energy supply. According to the US Energy Information Administration, India's electricity consumption is projected to grow by 3.3% annually until 2035. Biogas technology, which converts waste into clean energy, offers a promising solution to this problem and accounts for 9% of global energy consumption. Despite being introduced in 1981, biogas technology's potential in India remains largely untapped, with only 7.34 MWe of off-grid projects generated by 2020. However, Tamil Nadu and Karnataka have significant potential for biogas generation. The National Biogas and Manure Management Program (NBMMP) have installed 5,056,139 biogas plants between 1981-82 and 2020-21, with Maharashtra being the top performer. India's agrarian economy provides ample raw materials for biogas generation, making it a crucial renewable resource for the country's energy crisis. Given the pressing need to address global warming, greenhouse effects, depleting fossil fuels, and pollution, biogas technology is essential for a cleaner, more sustainable future. Focusing on biogas technology can help India meet its increasing energy demands and contribute to a cleaner and more sustainable future. From 2018-19 to 2020-21, the NBMMP received a total allocation of INR 1,439,249,000.

Introduction

Energy plays a crucial role in the development of any nation, and per capita energy consumption is a key indicator of socioeconomic progress (Omer, 2017). Efficient utilization of energy services is essential for poverty alleviation, as no government can significantly address poverty without such services (Rao *et al.,* 2009). In India, energy demand is rising, and the country's massive population exacerbates this situation. This escalating demand has created an energy crisis, calling for the exploration of renewable energy sources with multiple environmental benefits, such as maximizing locally available resources, efficiency, job creation, and reducing greenhouse gas emissions (Rajendran, *et al*., 2012). Biogas is a clean fuel with several advantages compared to fossil fuels and untreated biomass (Pathak, *et al.,* 2009). India, an agrarian country with more than 70% of its population living in villages, has abundant raw materials accessible for biogas generation. However, despite its potential, the adoption rate of biogas technology in India remains low. Currently, India has a biogas production capacity of 2.07 billion m^3/year (Mittal, *et al*., 2018).

In the early 1970s, India launched several programs to distribute biogas technology. By 2017, India achieved an overall energy sufficiency of 63%, but electricity shortages are still common, although India is the 4th largest producer of electricity worldwide (Minde *et al.,* 2013). Biogas is one of the most effective substitutes for reducing greenhouse gas emissions, indoor air pollution, and global climate change (Pathak *et al.,* 2009). According to the researchers Sharma and Neema (2013) biogas has greenhouse reduction potential upto 262.5 kg CO_2/day and 6.25 kg CH_4/day and can save approximately 6 LPG cylinders and 2850 kg wood/year by installing 2m^3 capacity of biogas plant for 4 person. Additionally, biogas digestate can be utilized, as shown in Table 1.

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The total number of biogas plants established in India under the National Biogas and Management Program (NBMMP) from 1981-1982 to 2020-2021 as of June 30, 2020, is shown by the following state:

States/UTs	No. of Biogas Plants
West Bengal	1105
Uttarakhand	364582
Uttar Pradesh	440930
Tripura	3710
Telangana	19702
Tamil Nadu	223894
Sikkim	9044
Rajasthan	72446
Punjab	185998
Puducherry	17541
Odisha	271809
Nagaland	7953
Mizoram	5856
Meghalaya	10659
Manipur	2128
Maharashtra	**924111**
Madhya Pradesh	376558
Kerala	153203
Karnataka	510916
Jharkhand	7823
Jammu and Kashmir	3200
Himachal Pradesh	47706
Haryana	63433
Gujarat	435272
Goa	4226
Delhi	578
Dadra and Nagar Haveli	681
Chhattisgarh	59850
Chandigarh	169
Bihar	129925
Assam	138483
Arunachal Pradesh	3609
Andhra Pradesh	558962
Andaman and Nicobar Islands	97
India	**5056159**

*Source: Rajya Sabha Unstarred Question No. 1095, dated 20.09.2020 Downloaded from:http://www.indiastat.com/table/power-data/26/biomass/452705/1383399/data.aspx

organic fertilizers and amendments to increase soil fertility while avoiding the harmful impacts of artificial fertilizers. In 1981, the Indian government established the National Programme on Biogas Development to offer rural communities environmentally sustainable options for improving their quality of life.

Despite the government's efforts, the rate of biogas distribution in rural households remains low, and there is a need to explore the progress made toward biogas development and the cash raised for state biogas development. The National Biogas and Management Management Programme is a Central Government Scheme that provides subsidies to rural and semiurban households to establish family biogas units. As per Table (1), 5056159 biogas plants were found under the NBMMP in India, with Maharashtra having the most, followed by Andhra Pradesh, Karnataka, Uttar Pradesh, and Gujarat. From 2018-19 to 2020-21, India's National Biogas and Manure Management Programme (NBMMP) received total funding from Rs. 14 39, 24,900/- (table 2).

Given the urgent need to address global warming, greenhouse effects, fossil fuel depletion, and pollution, biogas technology is a crucial renewable resource and a key solution for India's energy crisis. Focusing on biogas technology can help India meet its increasing energy demands while contributing to a cleaner, more sustainable future. The National Biogas and Manure Management Programme (NBMMP) was founded in India in 1981 to improve the quality of life in rural areas through environmentally friendly choices and to reduce the energy crisis in rural areas (Milieu en Natuur Planbureau and Shukla, 2007).One of the program's key goals is to reduce the usage of LPG and other conventional fuels by producing clean biogas that may be used for cooking. This is accomplished by establishing family biogas units in rural and semiurban homes using central government subsidies supplied through the NBMMP scheme. In addition to offering an alternate fuel source, the programme intends to meet the Integrated Energy Policy's lifetime energy demands for cooking.

Another important goal is to supply organic biogas manure to reduce the need for chemical fertilizers, which are harmful to the environment. This organic manure can be used to boost crop output and soil fertility, resulting in more sustainable agricultural practices (Khoiyangbam, 2011). The programme also aims to reduce the strain on forests and the hard work of rural women.

Table 2: Funds allotted to selected states under India's National Biogas and Manure Management Programme (NBMMP) (2018-2019 to 2020-2021-up to 31.08.2020)

Amount in Rs			
State/City	**2018-2019**	**2019-2020**	**2020-2021-upto 31.08.2020**
Andhra Pradesh	36019890	37350338	27901400
Chhattisgarh	24473397	24917666	0
Gujarat (NDDB)	0	24000000	12000000
Haryana	6600000	0	0
Karnataka	106269050	36684000	42000000
Kerala	2393812	14631994	0
KVIC, Mumbai	60626136	30736748	0
Madhya Pradesh	46128729	39907500	39952500
Maharashtra	42000000	54000000	0
Meghalaya	1250000	0	0
Odisha	8267000	4800000	972000
Punjab	38159298	33487208	21099000
Rajasthan	14700000	0	0
Tripura	2203150	3365000	0
Uttar Pradesh	4740100	0	0
Uttarakhand	3600000	18260000	0
India	**397430562**	**322140454**	**143924900**

Source: Rajya Sabha Unstarred Questions No. 1095, dated 20.09.2020. Downloaded from: http://www.indiastat.com/table/power-data/26/biomass-biogas/452705/1383402/data.aspx

who are frequently required to collect firewood for cooking. The programme helps to maintain trees and alleviate the strain on rural women by reducing their reliance on firewood (Gautam *et al*., 2009 and Liu *et al.,* 2008). The NBMMP also aims to enhance rural sanitary conditions by linking hygienic toilets to biogas plants, which can assist in addressing the issue of open defecation in rural regions. This link also allows for the creation of biogas from human waste, which helps to reduce carbon and methane emissions, both of which contribute significantly to climate change.

As stated in Table 3, the government has made concerted efforts to promote biogas growth in both rural and urban regions by providing subsidies and executing various programmes. Under the NBMMP scheme, these efforts have resulted in the building of a substantial number of biogas plants in India, with Maharashtra leading the way. Despite the tremendous potential for biogas generation in India, the adoption of this technology is still limited, particularly among rural households. As a result, ongoing efforts are required to promote and scale up biogas technology in India to meet rising energy demands while reducing the environmental impact of traditional fuel sources. As of 2020, 5056159 biogas units with capacities ranging from 1 to 25 M3/day were erected under the New National Biogas and Organic Manure Management Programme. The details are presented in Table no. 3. The funds granted by the Central Financial Assistance for developing renewable energy schemes in India are shown in Table no. 5. The NBMMP provides a category-specific subsidy for the installation of household biogas plants with capacities ranging from 1-6 m3/day:

- For the general category-Rs 9000/plant
- For SC and ST-Rs, 11,000/plant
- Latrine-attached R chromosome 12,000/plant

Economics of family-sized biogas plants in India

According to the findings of Pathak *et al.* (2009), a small family-sized biogas plant has the potential to mitigate global warming by 907/t CO_2 equivalent/year at a cost of US $10/t CO_2 equivalent, earning a carbon credit of US $97/year under the Clean Development Mechanism (CDM). Four calves in a home biogas plant may generate 4,400 kilograms of manure (dry weight) and 2,200 cubic meters of biogas per year, eliminating the need for 316 liters of kerosene, 5,535 kilograms of firewood and 10,571 kilograms of CO_2 equivalent. Approximately 1,275 kilograms of carbon may be replaced by biogas slurry created from the waste of four calves in place of 62 kg of nitrogen, 28 kg of phosphorus, and 85 kg of potassium. Additionally, methane is 21 times more aggressive than CO_2; thus, animal dung management can prevent the emission of methane gas (Yua *et al.,* 2008). Biogas can be a good substitute for fossil fuels and greatly contributes to the available energy needed for heating and cooking (Nasery, 2011; Gautam *et al*., 2009). There are 335 million tons of manure produced annually in India, 225 million of which are usable for biogas. India can earn $4,818.7 million annually in carbon credits by recycling this material, which is enough to power 51.2 million family-sized biogas plants and reduce annual global warming by 496 million tons of CO_2 equivalent.

Table 3: Biogas development in India

Year	Policies Implemented
1981	• The first biogas development program, known as NPBD, was launched. • A capital subsidy was provided under this program for the installation of small-scale biogas facilities. • One of the criteria for receiving the capital subsidy under this NPBD was owning 2-3 cattle.
1995	• Energy recovery from municipal, agricultural, and industrial wastes is the focus of NPBD, a nationwide initiative.
2006	• National Biogas and Manure Management Programme (NBMMP) is a government initiative with the same goals as NPBD, thus it was renamed after the Ministry of New and Renewable Energy (MNRE). • To promote decentralized electricity as an option in rural regions (3kw to 250kw), the MNRE has this year established an off-grid biogas power-generating scheme. • The development of a biogas power plant and the production of bio-CNG using biomethanation technology have both received funding support.
2016	• In 2000, the Ministry of Environment and Forest (MoEF) increased its authority and subsequently in 2016, revised its guidelines for solid waste management and disposal. • A new tariff policy mandated by the federal government mandates that all electricity supplied by electrical distribution companies be produced entirely from garbage. • The general tariff for electricity produced by waste-to-energy plants has been announced by the Ministry of Power.

Table 4: **Number of Biogas Plants (1-25M3 Per Day) Installed in India Under the New National Biogas and Organic Manure Programme (As of June 2020)**

States/UTs	Small Biogas Plants Established (up to June 2020)
West Bengal	1105
Uttarakhand	364582
Uttar Pradesh	440930
Tripura	3710
Telangana	19702
Tamil Nadu	223894
Sikkim	9044
Rajasthan	72446
Punjab	185998
Puducherry	17541
Odisha	271809
Nagaland	7953
Mizoram	5856
Meghalaya	10659
Manipur	2128
Maharashtra	**924111**
Madhya Pradesh	376558
Kerala	153203
Karnataka	510916
Jharkhand	7823
Jammu and Kashmir	3200
Himachal Pradesh	47706
Haryana	63433
Gujarat	435272
Goa	4226
Delhi	578
Dadra and Nagar Haveli	681
Chhattisgarh	59850
Chandigarh	169
Bihar	129925
Assam	138483
Arunachal Pradesh	3609
Andhra Pradesh	558962
Andaman and Nicobar Islands	97
India	**5056159**

Sources: Lok Sabha Unstarred Question No. 1979, dated 22.09.2020 Downloaded from: http://www.indiastat.com/table/power-data/26/biomass-biogas/452705/1378511/data.aspx

Table 5: Central finance assistance funds for the renewable energy scheme

SN	Year	funds sanctioned
1.	2016 -17	4307 crore
2.	2017-18	4080 crore
3.	2018 -19	5146.63 crore
4.	2019-20	3891.74 crore

There are annual savings of 5,535 kg of firewood, 4,400 kg of cattle dung cake and 316 L of kerosene when a family-sized biogas system is used instead. Compared to burning firewood, heating with calf dung cake reduces yearly emissions by 3.5-12.2 kg of NOx, 3.9-6.2 kg of SO_2, 436.9-549.6 kg of CO, and 30.8-38.7 kg of volatile organic compounds. The yearly emission savings for a biogas system that serves a single household are 16.4 kg of nitrogen oxides, 11.3 kg of sulfur dioxide, 987.0 kg of carbon monoxide, and 69.7 kg of volatile organic compounds. The State of Assam in India has approximately 85,000 family-type biogas plants, according to the National Biogas and Manure Management Programme (NBMMP). Farmers who own biogas plants are more likely to use organic agricultural methods, which is a major contribution to long-term sustainability. With 2,828 out of 85,346 hectares under organic cultivation in the North East (Hazarika *et al.,* 2015), organic farming has become a major focus in Assam's agricultural sector. A survey of rural communities in Sirsi, Karnataka, South India, revealed that 43% had access to dung supplies for operating biogas plants, while 65% had constructed such plants. All the biogas plants are running, and 85% of families with biogas use it to

satisfy their cooking energy needs, improving women's lives everywhere.

Conclusion

India launched its biogas development plan in 1981 to address the country's energy shortage in rural areas, fuelled by concerns about global warming and improper garbage disposal. For the sustainable use of energy resources, policymakers should promote the installation of biogas facilities by making them economically viable through carbon market mechanisms. Biogas technology can alleviate the need for firewood, help with indoor air pollution control, and provide low-cost lighting. Biogas also slows deforestation, soil degradation, flooding, and desertification because less of the world's forest cover is used for electricity at home. The byproduct of valuable manure benefits soil health and crop yield and generates cash for the rural population. The biogas project is expected to provide numerous local jobs, including the experts needed to construct methane digesters that can
benefit regional businesses. It also frees women's time and effort in tasks such as gathering fuelwood and preparing meals, improving soil quality, increasing agricultural output, and reducing costs compared with chemical fertilizers. The carbon market offers India the global potential to address the energy crisis and generate new revenue. Carbon revenues generated by industry can encourage farmers to develop biogas as a profitable activity while combating climate change. Repurposing biomass into cleaner and greener technologies in rural areas could lead to an improved standard of living, a healthier local environment, and a decreased global warming potential.

Conflict of interest

The authors declare that they have no conflicts of interest.

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