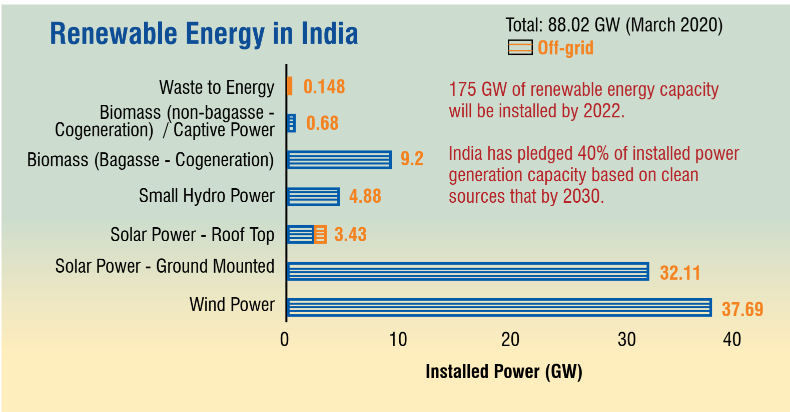
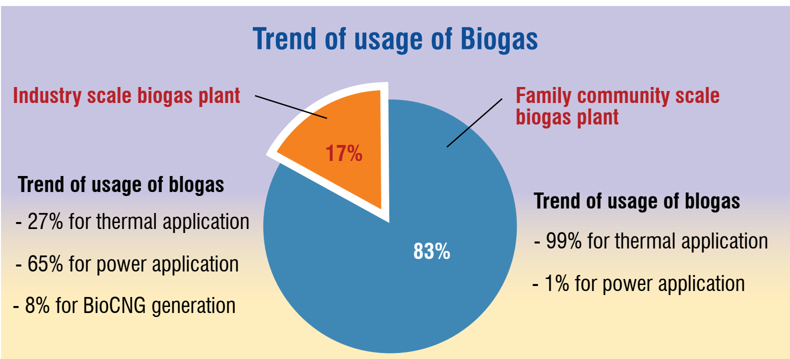
Biogas In India

By Deepika Lal

Biogas is an often overlooked and neglected aspect of renewable energy in India. While solar, wind and hydropower dominate the discussion in the country, they are not the only options available. Biogas is a lesser-known but highly important option to foster sustainable development in agriculture-based economies, such as India.

Of the total 88.02 GW installed renewable power capacity in March 2020, most was solar or wind. Waste to Energy (WTE) constituted a miniscule amount or just 0.1% of the above capacity. Within WTE, India's production of biogas is quite small; it only produces about 2.07 billion cubic metres per annum of biogas, while the total potential is much higher at 48 billion cubic metres per annum being an agricultural economy. India plans to reach a target of 175 GW of installed renewable energy capacity by 2022 and has pledged that 40% of all power will come from clean sources by 2030. That opens a lot of scope for biogas to reach its potential.



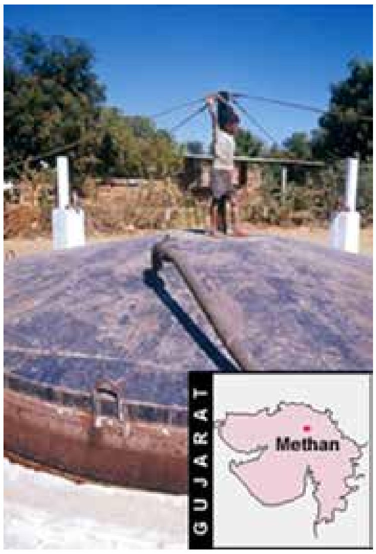


Biogas & its Benefits

In simple terms, biogas is the production of gaseous fuel, usually methane, by fermentation of organic material. It is an anaerobic process or one that takes place in the absence of oxygen. Biogas contains high methane content (55-65%). Biogas, in its raw form, that is without any purification, can be used as clean cooking fuel like LPG, lighting, motive power and generation of electricity. It can be used in diesel engines to substitute diesel up to 80% and up to 100% replacement of diesel by using 100% biogas engines. The nitrogen content in the slurry after anaerobic digestion enhances compared to untreated animal manure, thus can be used as organic fertilizer. Besides, biogas offers several social and environmental benefits. Biogas development can be integrated with strategies to improve sanitation as well as reduce indoor air pollution and greenhouse gases. Biogas can be purified to clean biogas with +95% of methane content by removing carbon dioxide and traces of other gases, such as Hydrogen Sulphide to make it suitable to be used as a green and clean fuel for transportation or filling in cylinders at high pressure of 250 bar or so and called as Compressed Biogas (CBG).

Types of Biogas Plants

The classification of the biogas plants is done on the basis of their size. Family-type small biogas systems with capacities ranging from 1 to 25 m3 biogas per day predominantly exist in rural areas. Animal manure and agricultural wastes are primarily used as feedstocks in household biogas digesters, producing biogas and bio-slurry that can be used as organic fertilizers. Mostly small-scale plants are managed by individual households to generate energy for self-consumption. These require financial investment but yield non-monetary benefits i.e biogas used as cooking fuel substituting gathered fuelwood. Community-based plants with capacities ranging from 20 to 1000 m3 per day are set up for use by a community largely for thermal application. Large and industrial-scale biogas plants with a capacity above 2500 m^3 biogas per day largely utilize municipal or industrial organic wastes to generate biogas which can yield financial benefits by selling end-products i.e electricity, transport fuel, or heat.



Methan Village Biogas Plant

Policies Supporting Biogas in India

The Ministry of New and Renewable Energy (MNRE) promotes the installation of biogas plants by implementing various schemes in India. We will take up five of these schemes here: **1. NNBOMP 2. BPGTP 3. WTE 4. SATAT and 5. Gobar-Dhan.**

Biogas Success Stories

Biogas has many success stories across India which would make you go for it sooner than later. Here are a few of them…

1. **Choithram fruit and vegetable market, Indore:** Approximately 20-25 Metric Tonnes Per Day fruit and vegetable waste is generated on daily basis in the Mandi. Mahindra & Mahindra set up a bio-CNG plant of 20 MTPD capacity to generate bioCNG with all this waste. Approximately 800 kg of purified and compressed Bio CNG having 95% pure Methane gas is generated on daily basis being used as a fuel in city buses.
2. **Khamtara village in Katni district, Madhya Pradesh:** This village has 150 biogas units. After the installation of biogas plants, people stopped cutting trees for firewood. There has been an estimated 80% reduction in the quantity of smoke in Khamtara's kitchens because of firewood.
3. **Methan village in Patan district, Gujarat:** Methan is home to one of India's largest biogas plant, run by Silver Jubilee Biogas Producers and Distributors Cooperative Society Limited. The biogas plant has been running since 1987 and supplies gas to the villagers. The biogas plant has eight digesters with a total capacity of 630 cubic metres and biogas is transported to individual households through underground pipelines. The community manages the system; the plant uses local supply of cowdung; villagers use waste from the plant in their fields; the village saves huge quantities of fuelwood; and kitchens have cleaner, smoke-free fuel.
4. **Satara district, Maharashtra:** One of the largest biogas plants in India, this plant generates 25,000 cubic meters of biogas every day from 600 tonnes of sugarcane waste obtained from sugar mills in the vicinity. Gas obtained is converted to CBG and used as fuel.
5. **The Karunalaya Leprosy Care Centre in Puri, Odisha:** This centre looks after 1,000 people living with leprosy. The centre also runs a high school, a home for children of leprosy patients, a small hospital and an orthopaedic workshop. A three cubic metre-biogas unit run on animal waste is the latest addition. While earlier the centre used to buy four LPG cylinders a month for the kitchen, the number has reduced by half since the installation of the biogas unit.
6. **The Xavier School of Management (XLRI), Jamshedpur, Jharkhand:** XLRI converts about 400 kilos of food waste to energy as part of its programme to reduce carbon emissions. Food waste from the college's five cafeterias go into a giant biogas digester that generates gas equivalent to two LPG cylinders per day, or about a fifth of the kitchen fuel needed to feed 1,100 students on campus.

Biogas Plant-XLRI

NNBOMP and BPGTP are central sector schemes under off-grid/distributed and decentralized renewable power and are targeted at rural areas and aim at providing clean cooking fuel for kitchens, lighting, and other thermal and small power needs of agriculture/ dairy farmers and household users. A back-ended capital subsidy is provided for the setting up of biogas plants in both schemes. The two schemes are:

1. New National Biogas and Organic Manure Programme (NNBOMP): This scheme is for biogas plant sizes ranging from 1 cubic metre to 25 cubic metre per day. Under NNBOMP, around five million family biogas plants (40%) have been installed under the biogas development program against the total potential of 12 million domestic biogas gas plants estimated by the MNRE.

2. Biogas Power Generation (Off-grid) and Thermal energy application Programme (BPGTP): This scheme is for setting up biogas plants in the size range of 30 m3 to 2500 m3 per day, for a corresponding power generation capacity range of 3 KW to 250 KW from biogas or raw biogas for thermal energy/cooling applications. Under BPGTP, 8.753 MW of power generation capacity and 86,595 cubic metres per day of biogas generation capacity have been achieved. These plants set up under BPGTP are especially beneficial for meeting off-grid power requirements for individual dairy and poultry plants, dairy co-operatives for the operation of dairy equipment, and other electrical, thermal, and cooling energy requirements for plant operation. The installations of such biogas systems replace diesel in DG sets. The nutrient-enriched organic bio-manure is another stream of income generation from biogas projects and at the same time-saving in the expenditure of chemical fertilizers by reduction of the use of chemical fertilizers and other profitable ventures like organic farming.

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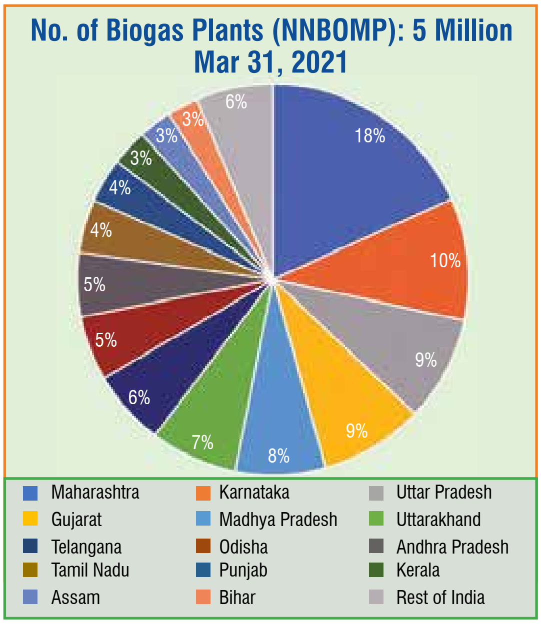


3. Waste to Energy Programme: This programme targets plants with a capacity range of >250 kW using industrial, agriculture and urban waste. Most of these projects are set up in industrial sectors such as distilleries, paper and pulp, solvent extraction, rice mills, textiles, and pharmaceutical industries, etc. A back-ended capital subsidy is also being provided for setting up plants in this scheme. As of 31.12.2020, the total installed capacity of WTE projects was 373.54 MWeq. This included 168.64 MW capacity of grid-interactive Waste to Power projects and 204.90 MW capacity off-grid Waste-to-Energy projects.

4. Sustainable Alternative Towards Affordable Transportation (SATAT): The government launched the SATAT programme in October 2018 to promote the use of CBG. CBG is similar to commercially available natural gas in its composition and energy potential. With calorific value (~52,000 KJ/kg) and other properties similar to CNG, CBG can be used as an alternative, renewable automotive fuel. The solid by-products of CBG can be used as bio-manure.

Conversion of waste/ bio-mass into CBG has multiple benefits like reduction of natural gas import, reduction of GHG emission, reduction in the burning of agriculture residues, remunerative income to farmers, employment generation & entrepreneurship, and effective waste management.

The potential for CBG production from various sources in India is estimated at about

62 million tonnes per annum. The government aims at setting up 5000 CBG Plants to produce 15 MMT of CBG per annum and 50 MMT of bio manure by 2023. This needs an investment of Rs 1.75 lakh crore and will help generate 75,000 jobs. The amount of CBG generated by these plants translates into about 40% of the current CNG consumption of 44 million tonnes per annum in India.

The CBG plants are set up by entrepreneurs and the offtake will be by the oil and gas companies or OMCs (IOC, BPCL, HPCL, GAIL and IGL). CBG is to be sold through cascades initially at OMC's fuel stations and later it can be integrated with the gas grid. The government has offered a procurement price of Rs 46 till the year 2024 with a take-off assurance of 10 years plus GST.

The government has allowed CBG to be shipped via natural gas pipelines to industrial consumers. The fuel will also substitute CNG and auto LPG at retail outlets. The Ministry of Road Transport and Highways (MoRTH) has amended the Central Motor Vehicles Rules, 1989 and included the provisions for usage of upgraded biogas, in the form of bio-CNG, in motor vehicles, provided its meeting the fuel specification as per the prescribed specification of biomethane from BIS. In April 2021, the government has also come out with the guidelines to co-mingle CBG produced with the natural gas in CGD network. According to it, GAIL will finalize operational modalities for supply of CBG co-mingled with domestic gas at uniform base price across all CGD entities. The scheme will be reviewed after a period of three years or as and when the percentage of CBG in the overall mix of CNG/PNG in the CGD sector reaches 10% whichever is earlier. Also, the bio manures produced from CBG plants have been included as Fermented Organic Manure (FOM) under Fertilizer Control Order 1985.

The government via IOC has signed initial

Composition of Biogas & CBG

Constituents	Biogas	CBG/BioCNG
Methane	60%	95%
CO2	37%	4%
Other gases	3% (H2S, N2, O2)	1% (N2, O2)
Calorific value	~19500 kJ/kg	~52000 kJ/kg

Pricing and Supply Chain of CBG

Item	Price
Basic Price of CBG meeting IS 16087 : 2006 standard compressed at 250 bar and delivered at OMC Retail Outlet in cascades	$0.29/lb (Rs 46.00/kg)
GST at 5%	Rs 2.30/kg
Total supply price (Incl. GST) to be paid to party	**$0.31/lb (Rs 48.30/kg))**

Support to Biogas Schemes in India

Financial	Inter-ministerial	Institutional
• Concessional rates of 5 % GST for WTE projects (>250 kW): ○ Biogas production ○ Equipment procurement for biogas projects • BCD of 5% for imported equipment for biogas projects • 40 % Accelerated depreciation on WDV method • Feed in Tariff (~10 cents/ Kwhr) by CERC for biogas-based Waste To Energy projects • Tax holiday on Net Income up to 10 years (for end use as power > 1 MMel) • Central Financial Assistance (CFA) for projects of different categories: ○ NNBOMP: 1-25 m3 ○ BPGTP: 3- 250 kW ○ WTE: 250 kW+	• SATAT ○ Secured offtake of compressed biogas for 10 years. ○ Upward price revision every three years • Electricity Policy- Distribution Licensee/ Discoms to compulsorily procure 100% power (RPO) produced from all the Waste-to-Energy plants • Motor vehicles rule: Provisions made by Ministry of Road Transport and Highways for usage of biogas (Bio-CNG) in motor vehicles • Biogas standards by BIS- Composition of biogas for applications in engines, automotive and piped network	• Implementation bodies State Nodal Departments/ State Nodal Agencies, KVIC • Introduction of Eight BDTCs as knowledge hubs for Biogas programmes

CBG Plants Commissioned So Far under SATAT (August 2021)				
Sl. No.	Name of the Plant/Company	Location	CBG Production Capacity (Tonnes per day)	Feedstock
1	Bleach Energy	Umreth, Gujarat	2	Cow dung, pressmud, potato waste
2	Clarus Bioenergy	Sangli, Maharashtra	4	Pressmud
3	Glow Green Biotech	Surat, Gujarat	2.1	Cow dung, spent wash, press mud
4	Green Earth Biogas	Surendranagar, Gujarat	5	Press mud, cow dung, potato waste, MSW, agricultural waste
5	IOT Biogas	Namakkal, Tamil Nadu	15	Chicken litter and press mud
6	Noble Exchange Environment Solutions	Talegaon, Pune	14	Municipal Solid Waste
7	Solika Energy	Shadnagar, Hyderabad	2	Poultry litter
8	Spectrum Renewable Energy	Rohtak, Haryana	6	Press mud and cattle dung
9	Spectrum Renewable Energy	Kohlapur, Maharashtra	6	Press mud
10	Sri Lakshmi Venkateshwara Green Projects	Kadapa, Andhra Pradesh	3	Press mud
11	T R Mega Foods and Beverages	Ludhiana, Punjab	5	Dairy waste
12	Indian Potash	Muzaffarnagar, Uttar Pradesh	9	

agreements with companies including JBM, Adani Gas, Torrent Gas and Petronet LNG for 1,550 CBG plants for over 3.5 MMTPA capacity as of May 2021. So far, CBG sales from 12 CBG plants (with a total CBG production capacity of 73.1 TPD) have been initiated and a total of 1369 tonnes of CBG (till May 2021) has been sold from the retail stations.

5. Galvanizing Organic Bio-Agro Resources Dhan (GOBAR-DHAN): The GOBAR-DHAN scheme was launched by the government in 2018 to convert cattle dung and solid waste in villages/rural India to Bio-CNG/ CBG and compost. The biogas plants are to be set up by self-help groups, gram panchayats, bulk waste generators and entrepreneurs. The state will choose to develop at least one project per district to achieve effective bio-waste management in the villages. The state, districts and gram panchayat are the key stakeholders. The financial support (back-ended) is provided on the basis of the total number of households in each gram panchayat. A total of 288 biogas/ CBG plants to date with a biogas capacity of 10,691 m3 of capacity have been established covering 139 districts under the GOBAR-DHAN scheme.

The government has allowed CBG to be shipped via natural gas pipelines to industrial consumers.

Satara Biogas Plant

Biogas/CBG Economics

Biogas is a powerful driver for economic growth, particularly in rural areas in need of economic opportunities. Biogas lowers greenhouse gas emissions, contributes to clean air and water, and improves soil health. It turns waste, which would be a problem if not used, into valuable resources. Biogas checks all the right boxes and protects the climate. It's a closed-loop system, which provides energy, recycling, and fertilizer services. As per the broad estimates, biogas faces good price competition in its consuming segments for cooking and power generation in rural and urban areas. But if you compare the cost of CBG vis-à-vis the other competing fuels across the consuming segments, you will come to the conclusion that it is the cheapest. As can be seen in the table, in the industrial segment, it can easily compete with piped natural gas with of course a better environmental impact while in the domestic use category for cooking purposes CBG has a huge

Biogas/CBG Economics (Rs/MMBTU)	
Biogas for Industrial Use	
Cost of CBG/BioCNG	985*
Cost of PNG (industrial)	1224
Biogas for cooking (domestic)	
Cost of Biogas	775**
Cost of CBG	985*
Cost of LPG	1363 - 1932
Kerosene	1250
Cost of PNG (Domestic)	806
Coal	1538
Biogas for Transport	
Cost of CBG/BioCNG	985*
Cost of CNG	1343
Cost of Petrol	3238
Cost of Diesel	2521

*CBG buying price under SATAT scheme including GST, after compression & cascading of Rs 48.3/kg. Reimbursement for transportation to the OMC Retail outlet is extra. If the gas is injected into CGD network the producer has to arrange to deliver at the delivery point and will be given Rs 38 per Kg.

**@Rs 38/kg price of clean biogas.

cost benefit over LPG and domestic PNG. Similarly, in the transport sector, it is the cheapest if you compare it with CNG, petrol or diesel.

Issues & Constraints

Barriers to setting up biogas plants differ in different regions depending on the degree of market maturity and availability of natural resources like biomass, land, and water. Barriers such as low ambient temperature and water unavailability in arid regions are area-specific whereas others are specific to technological scale-like lack of distribution infrastructure hindering the biogas expansion in a centralized system. Socio-cultural barriers like objections towards using animal and human waste as raw material are very specific to the local values and culture. Technical and informational barriers such as lack of technical capacity for construction and maintenance, competition from freely available firewood and lack of awareness mainly exist in rural areas. Some barriers are specific to its utilization i.e transport fuel or heat production. High variation in the seasonal demand for heat acts as a barrier for utilization of biogas for heat production whereas a limited number of filling stations acts as a barrier for utilizing biogas as vehicle fuel.

High capital cost is one of the key barriers to biogas technologies for both rural and urban applications. The upfront costs such as construction, labour & equipment cost of installing a biogas plant are quite high for rural households. The government provides a subsidy for family biogas plants depending upon plant capacity. But still, the upfront installation cost of biogas plant is significantly higher than the monthly household expenditure of low-income households in rural areas. E.g. to produce 400 kg/day of Bio-CNG requires a capital investment of Rs. 1.65 crore while 5000 kg/day requires Rs 16 crores.

High transaction costs, price competition from other fuels and lack of coordination among different government and institutional agencies are some of the barriers that are faced both in rural and urban areas. Involvement of many ministries but, the non-harmonised nature of the frameworks from individual ministries leads to the inadequacy of required support to the industry. One crucial aspect for slow adaptation rate is also the absence of a level playing field, in form of standards, for participants in the biogas ecosystem. Availability of specific standards for installation, operation, and maintenance of these plants is also missing. The other challenges include aggregation of feedstock, inadequate and poor supply of feedstock, low-cost finance to entrepreneurs, availability of equipment, proven technology, and skilled technicians, and lack of awareness.

Incentives like guaranteed feed-in tariffs and regulatory power purchase obligations (RPPOs) are necessary for the diffusion of the technology in the relatively immature market. This is evident in the case of solar and wind technologies in India where strong political

CBG Plant at Namakkal, Tamil Nadu

Waste Management in Indore

> Most global biogas production today comes from crops and animal manure and most of the biogas produced goes to the power sector.

will and investment-friendly policies provided by the government have driven the growth of renewables in the last decade. In absence of these government policies, biogas projects are not economically viable at a large scale that discourages private investment in this sector.

A Look at the Global Scenario…

Global biogas production was about 35 Mtoe in 2018 vs only 6.7 Mtoe in 2000. However, biogas consumption represented only 0.3% of the global energy mix in 2018. The development of biogas has been uneven across the world. Europe, China and the US account for 90% of the global biogas production. The rise of biogas globally has been shaped by two main factors: Policy support and feedstock availability.

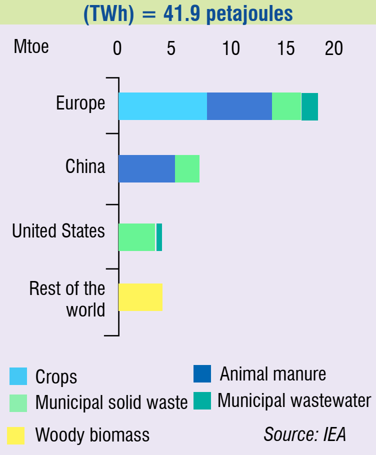
Most global biogas production today comes from crops and animal manure and most of the biogas produced goes to the power sector. Also, most of the countries lack a harmonized agenda between government agencies and sector representatives. Because biogas can be produced at different scales, and for varied uses, regulatory processes are often complex and conflicting.

Let's see what has helped Europe, China and the US to stay ahead of others…

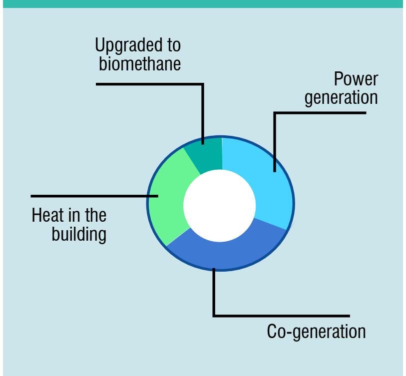
Policy Support and feedstock drive availability production in Europe: 60% of global biogas production capacity lies in Europe and North America. Europe is the largest producer of biogas today with around 20,000 biogas plants (2018). Germany is its largest market and home to two-thirds of biogas production capacity. Energy crops were the primary choice of feedstock that underpinned the growth of Germany's biogas industry, but the policy has recently shifted more towards the use of crop residues, sequential crops, livestock waste and the capture of methane from landfill sites. Other countries such as Denmark, France, Italy and the Netherlands have actively promoted biogas production.

Global Biogas Production by Region Feedstock Type, 2018 (Mtoe)

1 Mtoe = 11.63 terawatt-hours (TWh) = 41.9 petajoules



Global Biogas Consumption by End Use, 2018



In China, policies have supported the installation of household-scale digesters in rural areas with the aim of increasing access to modern energy and clean cooking fuels; these digesters account for around 70% of installed biogas capacity today. Different programmes have been announced to support the installation of larger-scale co-generation plants (i.e. plants producing both heat and power). Moreover, the Chinese National Development and Reform Commission issued a guidance document in late 2019 specifically on biogas industrialisation and upgrading to biomethane, supporting also the use of biomethane or Renewable Natural Gas in the transport sector.

In the US, the primary pathway for biogas has been through landfill gas collection, which today accounts for nearly 90% of its biogas production. There is also a growing interest in biogas production from agricultural waste since domestic livestock markets are responsible for almost one-third of methane emissions in the US. The US is also leading the way globally in the use of biomethane in the transport sector, as a result of both state and federal support.

Around half of the remaining production comes from developing countries in Asia, notably Thailand and India.

Most of the global biogas produced goes to the power sector: Almost two-thirds of biogas production in 2018 was used to generate electricity and heat (with an approximately equal split between electricity-only facilities and co-generation facilities). Around 30% was consumed in buildings, mainly in the residential sector for cooking and heating, with the remainder upgraded to biomethane and blended into the gas networks or used as a transport fuel.

In 2018, there was around 18 GW of installed power generation capacity running on biogas around the world, most of which is in Germany, the US and the UK. Capacity increased on average by 4% per year between 2010 and 2018. In recent years, deployment in the US and some European countries has slowed, mainly because of changes in policy support, although growth has started to pick up in other markets such as China and Turkey.

The levelised cost of generating electricity from biogas varies according to the feedstocks used and the sophistication of the plant, and ranges from USD 50 per megawatt-hour (MWh) to USD 190/MWh. A substantial part of this range lies above the cost of generation from wind and utility-scale solar photovoltaic (PV), which have come down sharply in recent years.

Globally too, the relatively high costs of biogas power generation mean that the transition from feed-in tariffs to technology-neutral renewable electricity auction frameworks (such as power purchase agreements) in many countries could limit the future prospects for electricity-only biogas plants. However, unlike wind and solar PV, biogas plants can operate in a flexible manner and so provide balancing and other ancillary services to the electricity network.

For the moment, a relatively small but growing share of the biogas produced worldwide is upgraded to biomethane. In 2018 around 3.5 Mtoe of biomethane was being produced worldwide with the majority of production in European and North American markets, with some countries such as Denmark and Sweden boasting more than 10% share of biogas/biomethane in total gas sales. Sweden and Germany may serve as examples of effective implementation of biomethane in the transport sector; however, it is done in different ways (Sweden (non-grid transport use) and Germany (mainly via injection to gas grid)). Their experience can be useful for countries starting development of biomethane production and use, e.g. Poland.

Countries outside Europe and North America such as Brazil, China and India are also catching up quickly. Biomethane represents about 0.1% of natural gas demand today; however, an increasing number of government policies are supporting its injection into natural gas grids and for decarbonising transport. For example, Germany, Italy, the Netherlands and the UK have all introduced support for biomethane in transport. Around 60% of plants currently online and in development inject biomethane into the gas distribution network, with a further 20% providing vehicle fuel. The remainder provides methane for a variety of local end uses.

The Way Forward: Potential Barrier Breakers

- Socio-economic characteristics like household size & income, agro-climatic conditions should be considered while developing policies for biogas dissemination in rural areas.
- Provision of microfinance options for cattle purchase could be an option as this can enhance income as well as access to dung by rural households. The biogas system installation cost barrier can also be reduced by providing low-cost credits like interest-free loans or subsidized loans or cheap technology like low-cost polythene biogas plants that are used in Nepal and Uganda.
- Greater penetration of information and communication technologies in rural India now provides an opportunity to streamline the process of approval and transfer of subsidies to the beneficiaries via digital technologies and integration with other government programs to reduce the transaction costs of operating the NBMMP.
- A steady supply of substrate is essential for the smooth functioning of biogas plants. Therefore, subsidy for cattle insurance also helps to reduce the risk of supply disruptions.

Unlike wind and solar PV, biogas plants can operate in a flexible manner and so provide balancing and other ancillary services to the electricity network.

Biomethane has quickly found a place in Sweden because Sweden's natural gas prices have always been higher than in Europe and Sweden does not have an extensive gas network. Sweden has well developed non-grid-based transportation of biomethane. The biomethane is transported mainly not only in compressed form in mobile storage units but also in liquefied form or by local gas grids. Biomethane has been used in Sweden since the 1990s and in 2018, almost 60% of the produced biogas was upgraded and used as transport fuel. Swedish experience shows that municipalities could create local markets with a lot of benefits for their communities.

Biogas/biomethane has scope in transport sector

In 2019, there were over 27 million NGVs in the world, with over 32,000 refilling stations. China, Iran, India, Pakistan, Argentina, Brazil and Italy all had more than 1,000,000 NGVs each. Several large auto manufacturers, such as Audi, Fiat, Ford, Iveco, Opel, Seat, Skoda, Suzuki and Volkswagen, have at least one car model that can use CBG. The models are a mix for different purposes, like small city cars, executive coupe cars, SUVs, light commercial vans and trucks. However, compressed methane is a gas fuel and requires large volumes to transport and CNG/CBG is thus more appropriate for smaller sized vehicles than heavy duty vehicles.

- Co-digestion and dry anaerobic digestion could also be potential options in areas of cattle dung and water scarcity. Therefore, technology type and scale should be adapted based on the local conditions for the smooth functioning of biogas plants. Techniques such as pre-digestion using microbial additives and mechanical pretreatment for biogas production enhancement exist in the literature, but the awareness and use of these production enhancement techniques are as yet absent.
- Another barrier to accessing organic biomass feedstock in villages is the absence of local markets for these feedstocks. The government should create an enabling environment for greater involvement of private players in the biogas sector in rural areas.
- Closing the information and implementation gap through demonstration programs and participation of rural organizations can deliver sizable benefits of affordable and clean energy access to rural households.
- Furthermore, the sustained benefits of biogas deployment require targeted policies and financial support to strengthen training programs for rural technicians and setting up post installment maintenance and repair centres.
- The biogas market is immature in the urban areas and strict policy measures are required to increase the biogas production from municipal and industrial wastes. Municipal corporations are primarily responsible for waste management in urban areas but they have limited financial capacities, therefore public-private partnerships should be encouraged to increase private investment in the waste to the energy sector in India.
- Financial support from central and state governments is required to bridge the viability gap and make biogas projects economically viable.
- Policy lessons should be learnt from developed countries like Germany & Sweden to promote the dissemination of biogas technologies in urban areas. Taking a cue, the government should enforce strict waste management rules to stop the disposal of organic wastes to landfills to avoid water and air pollution.
- Participation of biogas project developers in waste collection, segregation, and transportation within the cities would help in achieving better control over the substrate quality. Awareness campaigns through television and newspapers regarding the need for waste segregation should be conducted in the shortterm to bring the change in people's behaviour.

With petrol and diesel prices soaring high and our country largely an oil and gas importing country, harnessing the huge potential of biogas to convert it into electricity or for heating purposes or using it as a transport fuel could help the country in being self-reliant to some extent.

Epilogue: Towards a Holistic and Sustainable Energy Supply

Integrating biogas in energy supply could be the way forward towards a holistic and sustainable energy supply. Biogas can have benefits for the whole economy. It not only uses and recycles the waste produced but also presents a solution to the growing energy problem of our country. With petrol and diesel prices soaring high and our country largely an oil and gas importing country, harnessing the huge potential of biogas to convert it into electricity or for heating purposes or using it as a transport fuel could help the country in being self-reliant to some extent. Also, it has the potential to become one of the major renewable sources of energy in a country like India if we take care of the challenges faced today in its implementation and learn from countries like Germany and Sweden going forward. We need to spread awareness that garbage is not waste, but a valuable resource to produce biogas. To act at the right time is important and we must do that as soon as possible.

Sources: MNRE, IEA, IOC, Indian Biogas Association, UNIDO, NGS Research