Landscape Analysis of BioCNG in India

OCTOBER 2021

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CONTENTS

List of Figures and Tables

List of **Figures**

List of **Table**

ABBREVIATIONS

2G	Second Generation
AD	Anaerobic Digestion
AD	Accelerated Depreciation
AIF	Agriculture Infrastructure Fund
ASBR	Anaerobic Sequencing Batch Reactor
BPCL	Bharat Petroleum Corporation Limited
BRLLR	Baroda Repo Linked Lending Rate
CAPEX	Capital Expenditure
CFA	Central Financial Assistance
CGD	City Gas Distribution
CH4	Methane
CLU	Change of Land Use
CMC	City Municipal Corporations
CPCB	Centre Pollution Control Board
CPSU	Central Public Sector Undertaking
CRA	Credit Rating Agency
CSTR	Continuously Stirred Tank Reactor
CTE	Consent to Establish
DOF	Department of Fertilizers
EBLR	External Benchmark based Lending Rate
EIA	Environment Impact Assessment
EOT	Electric Overhead Travelling
ETP	Effluent Treatment Plant
FCO	Fertilizer Control Order
FOM	Fermented Organic Manure
FPO	Farmer Producer Organization

GAIL	Gas Authority of India Limited
GOI	Government of India
GOBAR	Galvanizing Organic Bio-Agro Resources
GST	Goods and Service Tax
HPCL	Hindustan Petroleum Corporation Limited
IGL	Indraprastha Gas Limited
IREDA	Indian Renewable Energy Development Agency Ltd
IOCL	Indian Oil Corporation Limited
JLG	Joint Liability Groups
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
LOI	Letter of Intent
MHUD	Ministry of Housing Urban Development
MMTPA	Million Metric Tonnes Per Annum
MNRE	Ministry of New and Renewable Energy
MOA	Ministry of Agriculture
MOC&F	Ministry of Chemicals and Fertilizers
MCA	Ministry of Corporate Affairs
MOEF&CC	Ministry of Environment, Forests and Climate Change
MOP	Ministry of Power
MOPNG	Ministry of Petroleum and Natural Gas
MSW	Municipal Solid Waste
MT	Million Tonnes
NABARD	National Bank for Agriculture and Rural Development
NAFED	National Agricultural Cooperative Marketing Federation of India Ltd.
NBFI	Non-Banking Financial Institution
NCGM	National Cleaning Ganga Mission
NGG	Natural Gas Grid
OEM	Original Equipment Manufacturer

OGMCs	Oil and Gas Marketing Companies
OIDB	Oil Industry Development Board
OPEX	Operating Expense
PACS	Primary Agricultural Credit Societies
PESO	Petroleum and Explosives Safety Organization
PNG	Piped Natural Gas
PPM	Part Per Million
PPP	Public-Private Partnership
PRESPL	Punjab Renewable Energy Systems Private Limited
PSL	Priority Sector Lending
SATAT	Sustainable Alternative Towards Affordable Transportation
SBM	Swachh Bharat Mission
SDF	Sugar Development Fund
SHG	Self Help Groups
SEIAA	State Environment Impact Assessment Authority
SNA	State Nodal Agencies
SPCB	State Pollution Control Board
STP	Sewage Treatment Plants
SWM	Solid Waste Management
TPD	Tons Per Day
TOESL	Thermax Onsite Energy Solutions Limited
UASB	Upflow Anaerobic Sludge Blanket
UTs	Union Territories
VLE	Village Level Entrepreneurs
VOF	Volatile Organic Fraction
WTE	Waste To Energy

Message

तरुण कपूर
सचिव
Tarun Kapoor
Secretary

सत्यमेव जयते

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October 22, 2021

Energy consumption is an indicator of economic growth. With the objective of achieving energy security, the Government of India has set targets to reduce crude oil imports and increase the share of natural gas in the energy mix.

India has huge potential to produce BioCNG from various organic waste materials such as paddy straw, pressmud from sugar industries, and vegetable market waste, among others. The utilization of organic waste to produce BioCNG will not only address the air pollution issue, due to reduced open burning, but also will create wealth, generate local livelihood opportunities, and contribute to the rural economy.

Under this context, MoPNG has launched the *Sustainable Alternative Towards Affordable Transportation (SATAT)* scheme to promote the production and utilization of BioCNG and envisaged the target to deploy 5000 BioCNG. Furthermore, to create an enabling ecosystem, various provisions have been made, such as guaranteed BioCNG offtake at a fixed price, biomanure market facilitation, CGD network, central finance assistance, and interest rate subvention. However, there are certain challenges associated with feedstock availability, technology, financing, implementation, and operational aspects. Establishing partnerships among the national and global actors will be a key to addressing these challenges.

The report by GGGI on *Landscape Analysis of BioCNG in India* has outlined key aspects of the BioCNG ecosystem in India and will be a useful document for stakeholders. I would like to thank GGGI for preparing this report.

I request that the associated government departments, oil and gas marketing companies, and other stakeholders review this report and build upon it further to develop strategies for immediate, mid-term, and long-term actions.

Tarun Kapoor

[Tarun Kapoor]

Message

Dr. Frank Rijsberman
Director-General
Global Green Growth Institute (GGGI)
Seoul, Republic of Korea

Decarbonization of the energy sector is imperative to reduce GHG emissions and mitigate climate change risks. While countries are shifting from fossil fuels to renewable energy, it is important that this transition is both environmentally sustainable and socially inclusive.

We have witnessed the disruption of the electricity sector triggered by solar and wind energy across developed and developing economies. A green gas economy, driven by BioCNG and green hydrogen holds the potential to complement similar disruptions in other sectors. BioCNG and green hydrogen present an opportunity to decarbonize the gas-based economy and hard-to-abate sectors. Lack of robust policy framework, institutional capacity, innovative business models, and access to affordable finance impede the adoption of such solutions.

GGGI, through its BioCNG program, is supporting governments in India, Indonesia, and Thailand to develop a vibrant BioCNG market (robust demand and supply) with an ecosystem of service and technology providers.

In India, GGGI is working with the Ministry of Petroleum and Natural Gas as well as oil and gas marketing companies to conduct pre-feasibility/ feasibility studies, develop bankable business model(s), support bid advisory, and develop investment proposals for mobilizing finance for the BioCNG projects. This will in turn help develop and set up a model implementation template for Bio CNG projects in India with replication potential to meet the targets. GGGI is also working on developing new partnerships and alliances of technology providers, private sector stakeholders and other relevant entities to ensure the efficient deployment and operation of the projects.

In the report titled, 'Landscape Analysis of BioCNG in India,' it outlines the policy, technology, financial and operational aspects of BioCNG in India and features key results achieved for the (BioCNG) program in the country. I hope that this report will stimulate conversation and action on accelerating the deployment of BioCNG projects in India at scale.

I would like to thank the Ministry of Foreign Affairs of Denmark and the Ambassador of Denmark to India for supporting GGGI's BioCNG program in India.

Date: October 20, 2021
Seoul, Republic of Korea

Dr. Frank Rijsberman

Message

Mr. Freddy Svane
Ambassador, Royal Danish Embassy
New Delhi, India

Improving air quality and decarbonizing the energy sector are some of the key priority areas for India. Promoting circular economy through Waste-to-Energy and identifying rapidly growing markets to utilize BioCNG as a clean and green fuel is the way forward.

Under the Indo-Danish initiative, the Green Strategic Partnership offers the opportunity for both Indian and Danish stakeholders to collaborate and enhance their knowledge and capacity on green energy and waste management. The Green Strategic Partnership is a platform that allows technology stakeholders to showcase the expertise in the field of clean energy and green technology and offer solutions to some of the pressing developmental problems of India. We have taken a significant leap under this initiative as experts from Denmark in the fields of water, energy, urbanization and intellectual property rights have already developed connections in India and are collaborating with the Indian government and various other stakeholders in the public and private sector on measures needed to implement the Green Strategic Partnership. BioCNG is one of the potential sectors under the Green Strategic Partnership.

The report entitled *'Landscape Analysis of BioCNG in India'* will be a beneficial knowledge document for all stakeholders, including Danish technology companies who will gain greater understanding into the existing scenario of BioCNG in India.

I would like to congratulate the GGGI for publishing this important report for the development of the BioCNG sector in India.

I would also like to thank the Ministry of Petroleum and Natural Gas of the Government of India for their guidance on GGGI's BioCNG program in India.

Freddy Svane

Date: October 20, 2021
New Delhi, India

Acknowledgments

This report has been prepared by the Global Green Growth Institute (GGGI) as part of the GGGI's Biological Compressed Natural Gas (BioCNG) Program in India, which is aimed to reduce global greenhouse gas (GHG) emissions, support clean energy transition, as well as promote energy security through the use of sustainable raw material/organic waste, improve air quality, support circular economy practices.

GGGI would like to express gratitude to the Ministry of Foreign Affairs, Denmark for providing funding support for GGGI's BioCNG program.

1. Introduction

The Global Green Growth Institute (GGGI) is undertaking a Biological Compressed Natural Gas (BioCNG) program with funding support from Ministry of Foreign Affairs, Denmark, in three target countries–India, Indonesia, and Thailand. The BioCNG program is supporting the governments of target countries to develop a robust demand and supply BioCNG market ecosystem that includes the service and technology providers.

The program is focusing on waste streams including organic municipal solid waste (MSW), sugarcane press mud, wastewater/sewage, industrial waste and agricultural waste. Implemented with the help of technical assistance, a business environment will be enabled for the BioCNG markets, barriers will be reduced for the use of BioCNG, and there will be an increase in support for environmentally sustainable and commercially scalable business models conducive for the local conditions. With rapidly growing markets, the target countries have high potential to utilize BioCNG as fuel. This multi country intervention under the program is expected to witness inclusive development in regard to indigenous clean energy development and push the learning curve upwards.

GGGI has signed a Memorandum of Understanding (MOU) with Ministry of Petroleum and Natural Gas (MOPNG), Government of India to support Sustainable Alternative Towards Affordable Transportation (SATAT) initiative as a knowledge partner. Under this agreement, GGGI will develop a model implementation template including bankable business models for BioCNG projects based on different waste streams. GGGI will also extend support in mobilizing green finance for these projects. This program will support in developing robust BioCNG/Bioenergy ecosystem in India and help MOPNG achieve its target of deploying 5000 BioCNG projects by 2024.

2. India's Energy Context

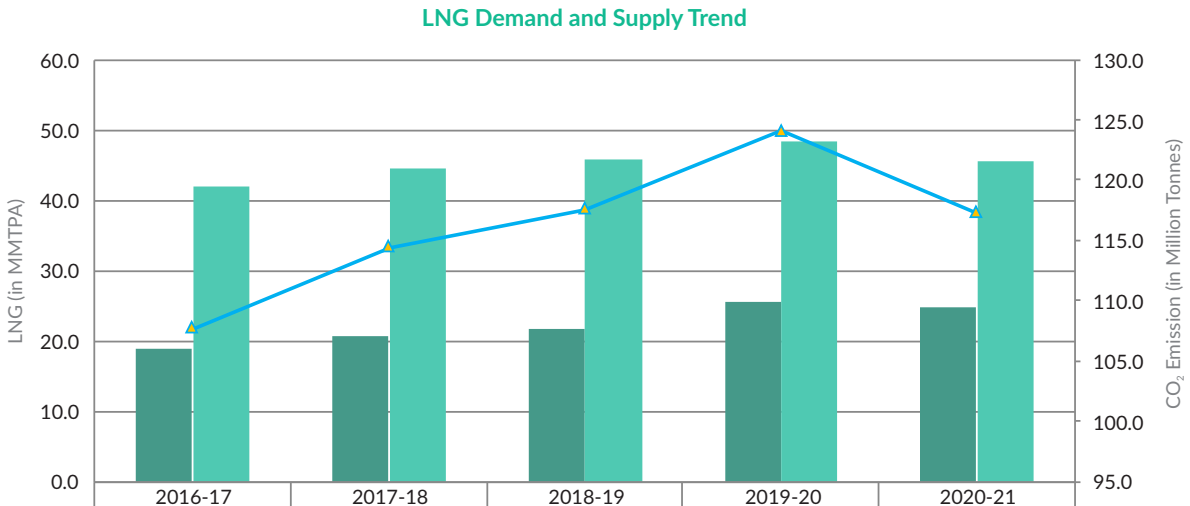
India is among the fastest growing economy in the world and its energy consumption is expected to increase rapidly. It is the third largest primary energy consumer in the world after the US and China, having recorded a Compounded Annual Growth Rate (CAGR) of 4% in its energy consumption over the last decade.

2.1. Oil and Gas Demand and Import Dependence

From April 2020 to March 2021, India's total consumption of petroleum products was 194.6 million metric tonnes per annum (MMTPA) and the total import of petroleum products was 43.5 MMTPA with a total import value of USD 14.2 billion. Due to high consumption demand of Liquefied Petroleum Gas (LPG) in the transport, industrial and domestic sectors of India, it is one of the major petroleum products that is imported. India consumed 27.6 MMTPA of LPG in 2020-21, out of which 16.6 MMTPA was imported.

India also imported ~25 MMTPA of Liquefied Natural Gas (LNG) to meet its 45.8 MMTPA demand, in 2020-21. The demand and supply trend of LNG and the estimated carbondioxide (CO_2) emission from it is presented in Figure 1[1]. In 2019-20, India's LNG import value was USD 8.7 billion which means the cost of imported LNG per kilogram is USD 0.34 (~INR 25).

Figure 1: Demand and supply trend of LNG and estimated CO_2 emission from it

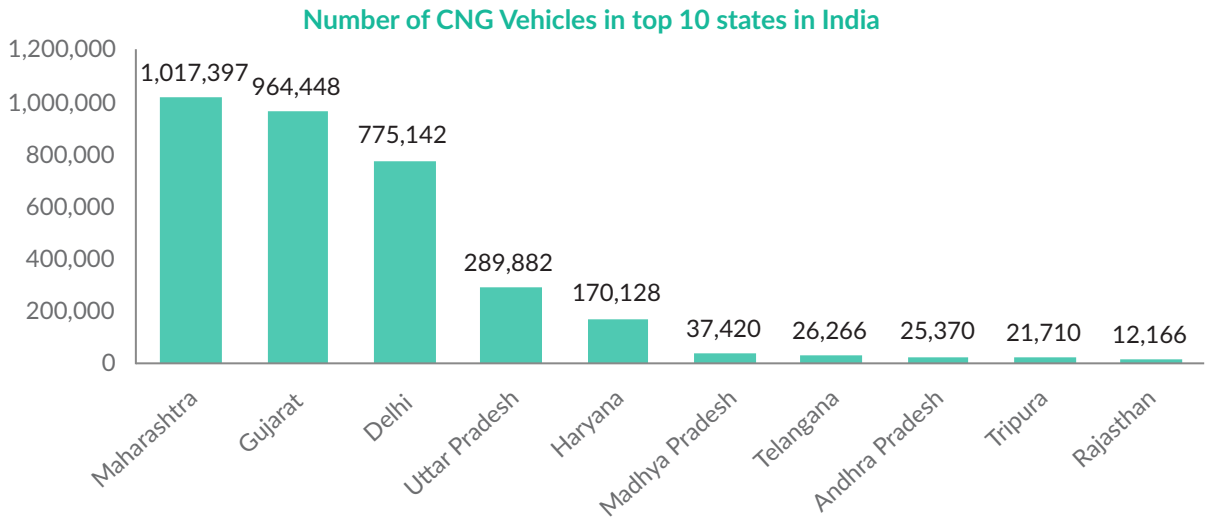


	2016-17	2017-18	2018-19	2019-20	2020-21
Import	18.8	20.7	21.7	25.6	24.8
Total Consumption	42.0	44.7	45.9	48.4	45.8
CO_2 Emission	107.8	114.5	117.6	124.1	117.3

[1]Petroleum Planning & Analysis Cell, Ministry of Petroleum and Natural Gas, India

The CNG vehicles have increased from about 1.47 million in March 2014 to ~3.4 million in March 2020. Thus, with more than 33,75,718 CNG vehicles in India, the automobile sector has a heavy demand for this fuel. This clearly establishes an opportunity for BioCNG to be an alternative or additional fuel for the vehicles. Figure 2 represents the top 10 states with a high number of CNG vehicles[2].

Figure 2: Top 10 states with a high number of CNG vehicles in India



2.2. Import Reduction Target

India's import dependence on crude oil, natural gas and large share of carbon intensive energy sources necessitates action to ensure energy security and environment sustainability. As a result, the Government of India (GOI) has set a target of reducing crude oil import dependence by at least 10% by 2022[3]. Furthermore, the GOI has set a target of increasing the share of natural gas in India's energy mix to 15% by 2030[4].

2.3. International Commitments

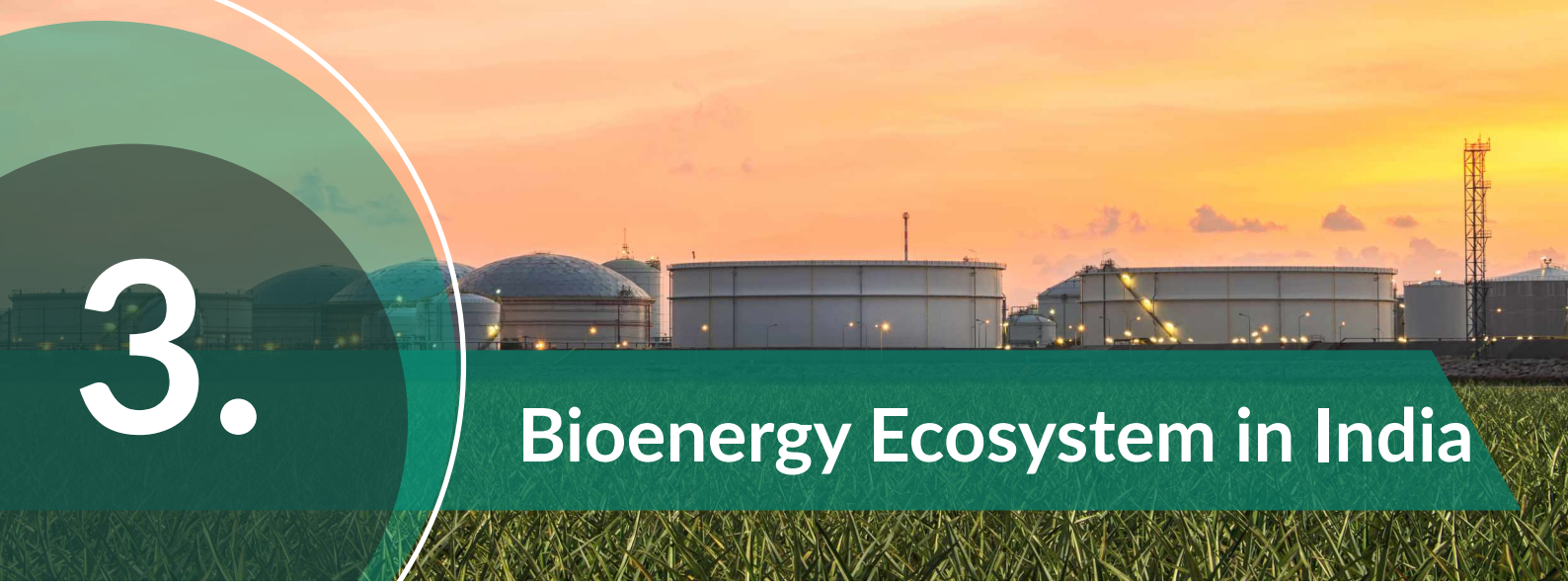
India's energy strategy is to move towards a low carbon economy, thereby contribute in achieving Government's ambitious energy target of 450 GW of renewable capacity, reduce energy emissions by 33-35% and to scale up the share of non-fossil fuel based capacity in the electricity mix above 40%, among others by 2030[5].

2.4. Energy Security

The Government of India is engaged in several initiatives to design and implement energy efficiency and clean energy programs. India has made significant progress in realizing energy saving through adoption of new technologies, policies and programmatic reforms, and consumer sensitization. India is working on national strategic plan for energy efficiency to realize the immense energy saving potential in the various demand sectors such as industry and transport among others.

As India progresses towards a clean energy ecosystem, Compressed Biogas (CBG) or BioCNG is expected to play an instrumental role in promoting energy security and environment sustainability. BioCNG has calorific value and other properties similar to Compressed Natural Gas (CNG) and can be utilized as green renewable automotive fuel. Thus, BioCNG can replace CNG in automotive, industrial, and commercial sectors.

[2]PPAC's Snapshot of India's Oil & Gas data, Abridged Ready Reckoner March, 2020
[3]https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1576407
[4]https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1603308
[5]https://pib.gov.in/newsite/printrelease.aspx?relid=128403



3. Bioenergy Ecosystem in India

The GOI has created an enabling ecosystem to increase the share of BioCNG in the total energy matrix. National level programs/policies/schemes have been prepared to decarbonize the transport sector and meet the emission targets that will further help in promoting the Circular Economy. The brief details of the relevant policy landscape, and programs and schemes for BioCNG in India are outlined in this section.

3.1. Rules and Policy Landscape

Enabling policies such as the National Policy on Biofuels 2018 and the Auto Fuel Vision and Policy 2025 along with the provisions under the Solid Waste Management Rules are some of the key drivers for BioCNG in India. Details of the rules and policy are provided in the Table 1 below.

Table 1: Details of Rules and Policy Related to BioCNG

S.No.	Policy	Details
1	**National Policy on Biofuels**	The National Policy on Biofuels 2018 aims to develop and promote domestic feedstock, and its utilization to produce biofuels including BioCNG. This would increase substitute fossil fuels and contribute to National Energy Security, climate change mitigation, apart from creating employment opportunities. The policy aims to make possible 20% blending of ethanol in petrol and 5% blending of biodiesel in diesel by 2030. However, the target of 20% blending of ethanol in petrol has been advanced by five years to 2025. The strategy to achieve the goal is by- reinforcing ongoing ethanol/biodiesel supplies through increasing domestic production, setting up Second Generation (2G) bio refineries, creation of new feedstock for biofuels, development of new technologies for conversion to biofuels, and build an environment for integration of biofuels with the main fuel. The policy advocates scaling up of advanced biofuels including BioCNG using lignocellulosic feedstocks (i.e. agricultural and forestry residues, e.g. rice & wheat straw/corn cobs & stover/bagasse, woody biomass), industrial waste, animal dung, food/vegetable waste, municipal solid waste (MSW) and sewage waste.
2	**Solid Waste Management Rules (SWM)**	The Ministry of Environment, Forests and Climate Change (MOEF&CC), had issued the Solid Waste Management (SWM) Rules, 2016. These rules replaced the MSWs (Management and Handling) Rules, 2000. The SWM Rules are applicable to all urban local body outgrowths in urban agglomerations, special economic zones, state and central government organizations, and all domestic, institutional,

S.No.	Policy	Details
		commercial or any non-residential solid waste generator, among others. The SWM Rule converges multiple government ministries to manage and derive value out of solid wastes. These ministries involved are Ministry of Environment, Forest and Climate Change, Ministry of Housing Urban Development, Department of Fertilizers, Ministry of Chemicals and Fertilizers, Ministry of Agriculture, Ministry of Power, and Ministry of New and Renewable Energy Sources.
3	**Auto Fuel Vision and Policy 2025**	Auto Fuel Vision and Policy, an initiative by MOPNG, is envisaged to promote the use of alternative fuels and encourage the switch over from liquid fuel to CNG/LNG. The policy proposes to lower road tax and encourages tax incentives/disincentives and subsidies for vehicles using alternative fuels.

3.2. Programs and Schemes

The number of programs and schemes has been formulated to accelerate the deployment of BioCNG projects in India. Sustainable Alternative Towards Affordable Transportation (SATAT), MNRE's Waste-to-Energy program, Swachh Bharat Mission (SBM), and Galvanizing Organic Bio-Agro Resources (GOBAR) – DHAN scheme are some of the programs and schemes having various provisions for BioCNG promotion in India. Detailed provisions under the programs and schemes are provided in Table 2 below.

Table 2: Details of Programs and Schemes for BioCNG Projects

S.No.	Programs/Schemes	Details
1	**Sustainable Alternative Towards Affordable Transportation (SATAT)**	The MOPNG has launched SATAT Scheme to promote the production and utilization of BioCNG as an alternative, green fuel for the transport segment and reduce India's dependence on oil and gas imports by producing BioCNG using agricultural residues, cattle dung, sugarcane press mud, municipal solid waste, and sewage treatment plant waste. MOPNG has envisaged the target production of BioCNG from 5000 plants at 15 MMTPA by 2024 (which is ~32% of the current LNG demand). Under SATAT, the industry players are expected to invest ~ USD 24 billion (INR 175,000 crore) in infrastructure development for BioCNG distribution. It is anticipated that this initiative will generate employment for 75,000 people and produce 50 million tonnes (MT) of Biomanure for crops.
2	**MNRE program on Waste-to-Energy**	The MNRE, GOI, through its waste-to-energy program, is promoting setting up of Biogas/BioCNG/Power projects using Urban, Industrial, Agricultural Waste and MSW. The program offers Central Financial Assistance (CFA) in the form of back-ended subsidy for installation of waste to energy projects, for instance, CFA of ~USD 0.54 million (INR 4 crore) can be provided to setup a 4.8 TPD BioCNG plant and a maximum CFA of ~USD 1.33 million (INR 10 crore) can be granted per project.
3	**Swachh Bharat Mission (SBM) and Galvanizing Organic Bio-Agro Resources (GOBAR) - DHAN scheme**	The focus of GOBAR-DHAN scheme is not only to keep the villages clean, but also to increase the income of rural households, and generate energy from cattle waste. It is one of the key sub-programs under Swachh Bharat Mission (SBM Gramin). The focal point of this scheme is to manage the bio-waste like cattle waste by converting them into biogas and organic manure. This scheme has improved the lives of villagers, particularly farmers, by providing them economic benefits.

S.No.	Programs/Schemes	Details
		Additionally, the expression of interest notified by oil and gas companies to procure biofuel (i.e. Bioethanol and BioCNG) at pre-defined guaranteed prices has given a fillip and increased the participation of investors and project developers. It is now possible to sell BioCNG directly to the users at higher prices depending upon the states.

3.3. Roles of Various Ministries in Promotion of Bioenergy

Bioenergy being the cross-sectoral domain would require the participation of various line ministries/ departments for promotion and the effective implementation of the bioenergy projects. The brief detail regarding the roles of some of the relevant ministries is presented below in Table 3.

Table 3: Relevant Ministries and their Roles in Promotion of Bioenergy in India

S.No.	Ministry/Department	Role in Promotion of Bioenergy
1	**Ministry of Petroleum and Natural Gas**	Formulates and monitors the implementation of policy, program and schemes of Biofuels/BioCNG.
2	**Ministry of Environment, Forest and Climate Change**	Monitors the implementation of SWM Rules.
3	**Ministry of Housing Urban Development**	Formulates national policy and strategy on SWM including policy on waste-to-energy.
4	**Department of Fertilizers, Ministry of Chemicals and Fertilizers**	Provides market development assistance for compost generated in cities and ensures promotion of co-marketing of compost with chemical fertilizers.
5	**Ministry of Agriculture**	Implements Fertilizer Control Order for manufacturing and sale of compost and propagate utilization of compost on farmland. It sets up laboratories to test quality of compost.
6	**Ministry of Power**	Determines tariff of the electricity generated from the waste-to-energy plants; ensures mandatory purchase of power generated from waste-to-energy plants by DISCOMs.
7	**Ministry of New and Renewable Energy**	Facilitates infrastructure development for waste-to-energy plants, and provides appropriate subsidies or incentives for such plants.

4. Technology Landscape

BioCNG is produced from biogas through a process of desulphurization, upgradation and compression. Biogas is first desulphurized to reduce the hydrogen sulphide content below 20 part per million (ppm). The desulphurized gas is then upgraded to increase the methane content to ~92-98% and calorific value to ~47-52 mega joules (MJ) per kilogram (kg). The gas is then compressed to more than 250 bar pressure and stored in cascades/bottles or injected to the gas pipelines. The chemical composition of biogas and BioCNG is presented in Table 4.

Table 4: Chemical Composition of Biogas and BioCNG

S.No.	Composition	Biogas	BioCNG
1	Methane	55% – 65%	>90%
2	Carbondioxide	30% – 40%	<4%
3	Hydrogen sulfide	0.1 – 4%	<16 ppm
4	Ammonia Z	0.1%	~0%
5	Nitrogen	3%	<0.5%
6	Oxygen	0.1 – 2%	<0.5%
7	Moisture	1 – 2%	~0%

BioCNG/Biogas can be generated using various organic waste/biomass like agricultural residue, fruits and vegetable waste, sugarcane press mud among others. However, the biomass-to-BioCNG conversion efficiency varies with input feedstock and technology used. The biomass-to-BioCNG conversion efficiency from agriculture waste-based plants is ~10%, while conversion efficiency from sugar press mud is ~5%, it is 5% from waste sewage treatment plants (STP) sludge and 4% for vegetable waste-based plants. Biomanure is the byproduct of biomass-to-BioCNG conversion process. A 100 TPD fruit and vegetable market waste-based plant can produce around 4 TPD BioCNG, which can provide fuel for ~57 buses (70 kg per fill) or 400 cars (10 kg per fill) or ~600 rickshaws (06 kg per fill) daily[6]. It is estimated that 500 such plants can produce 7.3 lakh tonnes of BioCNG per annum and ~3 million tonnes of Bioslurry per annum.

[6]https://gggi.org/site/assets/uploads/2019/08/Waste-to-Energy-Short-report_Final.pdf

4.1. Typical Steps of BioCNG Project

A typical Biogas/BioCNG production plant has pre-treatment, reactor (anaerobic digestion), upgradation & purification, and storage & distribution sections. Details of each of the Biomass-to-BioCNG conversion process are given in Table 5. Schematics of BioCNG plant is presented in Figure 3.

Table 5: Steps for Biomass-to-BioCNG Conversion Process

Step 1: Feedstock pre-treatment	• **Mechanical pre-treatment** grinds the solid particles of the feedstock and increases the specific surface area. Screw press, shedder, etc. are some of the machineries conventionally used in biogas industries. • **Thermal pre-treatment** thermally degrades the feedstock. Based on quality of feedstock, the temperature range of the pre-treatment unit is decided. • **Chemical pre-treatment** destructs organic compounds by means of strong acids, alkalis or oxidants. Such treatments are used in wastewater sludge, lignocellulosic biomass etc. • **Biological pre-treatment** includes both anaerobic and aerobic methods; specific enzymes may also be used to enhance the degradation rate of feedstock. • **Combination of various pre-treatments** uses thermo-chemical pre-treatment and thermo-mechanical pre-treatment.
Step 2: Anaerobic Digestion	Anaerobic digestion (AD) is a process of degradation of organic matter by micro-organisms in an oxygen-free environment, which produces raw biogas. Biogas is produced using waste/bio-mass sources like agriculture residue, fruits and vegetable waste, cattle dung, sugarcane press mud, municipal solid waste, sewage treatment plant waste, etc. The biogas mainly constitutes of 40–65% methane and 35–55% CO_2 with a calorific value of 19.5 MJ/kg. Micro-organisms, reactor/digester design, and operating conditions are key factors in anaerobic digestion. • **Micro-organisms:** Four groups of microbes are most frequently used in biogas production plants—hydrolytic bacteria, acidogenic bacteria, acetogenic bacteria, and methanogenic groups. • **Reactor Design:** Different kind of reactors are used for the anaerobic digestion process, like batch, continuous one-stage, and continuous two-stage systems, Continuously Stirred Tank Reactor (CSTR), tubular reactor, anaerobic sequencing batch reactor (ASBR), Upflow Anaerobic Sludge Blanket (UASB), among others. The technology of anaerobic digestion in multiple stages is considered a viable option to control variables, optimize operations, assure solid removal and production of methane. The continuous two-stage anaerobic digestion technology is reported to be a suitable technology for conversion of fruits and vegetable waste and agricultural residues to produce biogas/BioCNG. • **Operating Conditions:** Conditions for the operation of AD system favors methanogenic bacteria growth, improves the separation of liquid and solid fractions, helps degradation of the substrate, and provides higher biogas yield. Temperature – 35 °C, pH – 7.0, Feedstock C/N ratio – 20 to 30, and Retention Time – 10 to 30 days are optimum operating conditions for Biogas/BioCNG production.

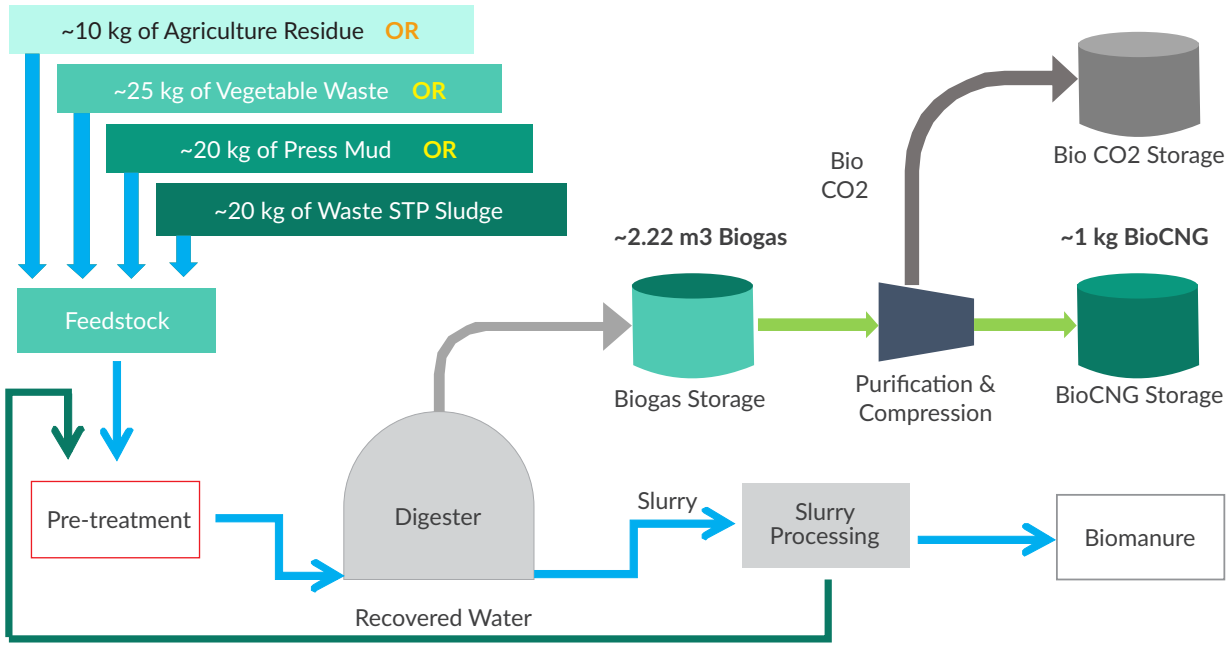
Step 3: Upgradation & Purification

Removal of CO_2 and H_2S from biogas needs to be done to improve the quality (calorific value) of the gas in the fuel. Scrubbing, chemical absorption, pressure swing adsorption, membrane purification, and cryogenic separation are some of the technologies used for absorption, adsorption and membrane separation for upgradation and purification of biogas.

Step 4: Storage and Distribution

Calorific value of BioCNG is in the range of 47 to 52 MJ per kg. BioCNG is stored at gas filling stations using two common systems i.e. buffer and cascade storage systems. In buffer storage system, the pressure of BioCNG is maintained at 250 bar for all the reservoir cylinders, whereas, in cascade storage, the reservoir cylinders are maintained at low, medium and high pressures. It can be distributed through pipelines—at low (~ 40 bar), medium (~160 bar) and high (~250 bar) pressures.

Figure 3: Schematics of BioCNG plant



4.2. List of BioCNG Plant Machinery and Components

The BioCNG plant machinery and components vary with the type of technology adopted at various steps of the production process. An indicative list of plant machinery and components is mentioned in Table 6.

Table 6: List of Plant Machinery and Components for the BioCNG Plant

S.No.	Plant and Equipment Component
1	**Feeding and Pre-treatment** Receiving platform, hopper, conveyor, sorting system, Electric Overhead Traveling (EOT) crane, screw conveyors, grinders, feeding tank, feed pump, agitators etc.
2	**Anaerobic Digester** (double membrane balloon gas holder, CSTR agitators etc.)

S.No.	Plant and Equipment Component
3	**H_2S scrubber**
4	**Co_2 recovery unit**
5	**Biogas balloon**
6	**BioCNG purification and recovery unit**
7	**BioCNG compressor unit**
8	**BioCNG cascade**
9	**BioCNG piping network to inject into gas grid**
10	**BioCNG injection system to tankers/dispensers firefighting systems**
11	**Slurry Processing Unit** Solid liquid separator, compost sewing machine, turners, earth mover etc.
12	**Balance of plant (electrical, instrumentation)**

4.3. Challenges Associated with the BioCNG Plants and its Production

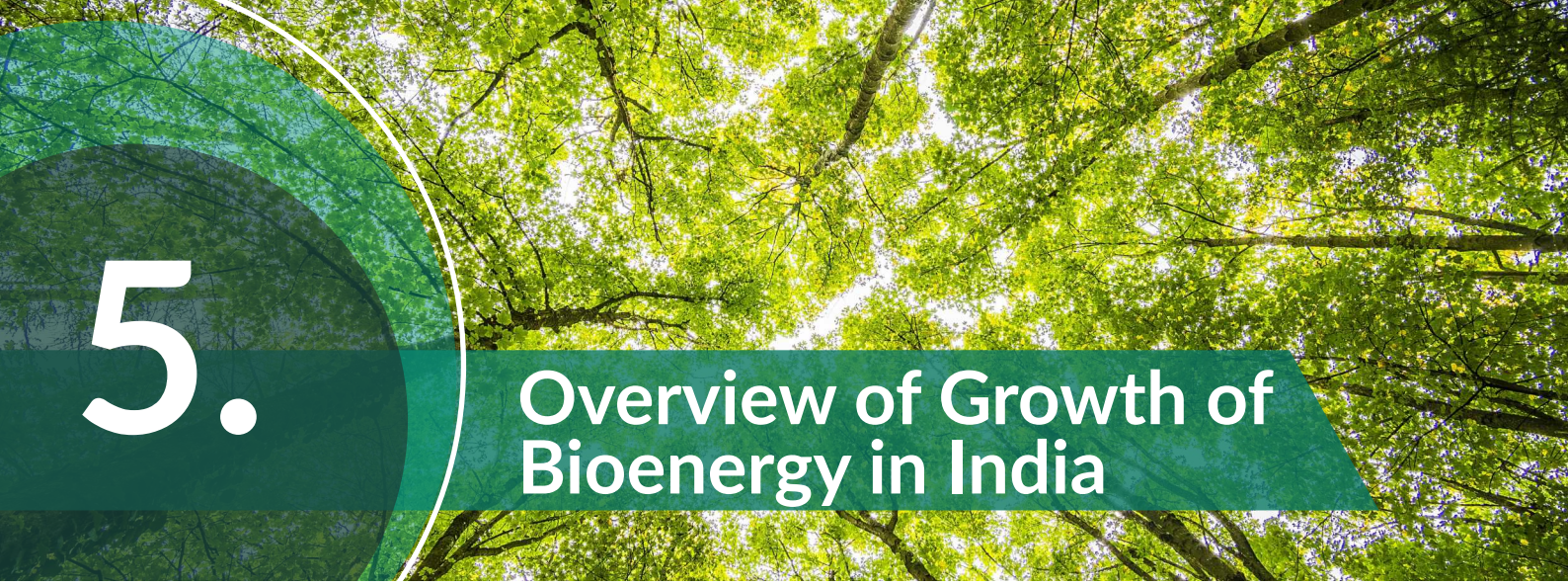
The GOI has formulated various policies and schemes to promote and mitigate challenges associated with the BioCNG sector. There are still some operational and technological challenges such as sensitivity towards biomass quality, biogas upgradation process among others which are impeding the uptake of BioCNG projects. Following is the list of challenges associated with the BioCNG plants.

- Supply of desired quantity and quality of feedstock (mainly vegetable waste) which are segregated at source.
- Requirement of significant storage space for biomass and associated safety risks such as propensity to catch fire in dry state.
- Varied chemical composition of feedstock (carbon/nitrogen ratio) - Unavailability of desired quality of feedstock throughout the year. This impacts the yield of Biogas/BioCNG.
- Selection of Biogas/BioCNG technology (including reactor and pre-treatment process) suitable for available and multi-feedstocks.
- Adoption of biogas upgradation process based on operational efficiency and economic feasibility.
- Maximizing the utilization of plant equipment such as compressor.

4.4. Technology Developers, OEMs and EPCs

Under SATAT Scheme, around 13 BioCNG projects have already begun supply of BioCNG and several other projects are in different stages of development[7]. Some of the projects undertaken are by Leafiniti Bioenergy, Solika Energy Pvt. Ltd., T R Mega Foods and Beverages LLP, CNM Energy Solution Pvt Ltd, Carboneu Pvt Ltd, Cities Innovative Biofuels Private Limited and CEF Budhana Energy Private Ltd among others. Several domestic and international firms are involved in the value chain of BioCNG projects. Annexure A has the list of global and Indian companies which are technology developers, Original Equipment Manufacturer (OEMs), and Engineering, Procurement, and Construction (EPC) for BioCNG/ Bioenergy projects.

[7]https://pib.gov.in/PressReleasePage.aspx?PRID=1742272



5. Overview of Growth of Bioenergy in India

5.1. Implemented Projects

India's journey of bioenergy started in 1982 when GOI launched the Biogas program under which over 5 million cattle dung-based family type biogas plants (2-6 cubic meter biogas generation capacity) were setup for cooking and other applications. In 2002, a program on energy from urban, industrial, agricultural wastes/residues and MSW was initiated and it has resulted in the deployment of around 180 projects since then till now. Around 75% of these are captive projects for power and thermal applications. A brief information about the Biogas/BioCNG projects in India is given in Table 7.

Table 7: Type of Biogas Projects in India

S.No.	Type of Project	Aggregated Capacity	Number of Projects
1	MSW power plants	65.7 MW	6 projects
2	Grid power projects in industries	71.8 MW	18 projects
3	Captive off-grid projects	111.4 MW	70 projects
4	Biogas for captive thermal	About 6 lakh m3/day	74 projects
5	BioCNG projects	46 tonnes/day	12 projects

A large number of these projects were installed mainly in distilleries, starch, paper and solvent extraction plants etc., and it helped to meet ~75 % of their energy demand through biogas. However, a large potential of implementing biogas projects is observed in sugar, milk processing, cattle farming, poultry and food, fruits and vegetable processing industries. Meanwhile, the distribution of biogas projects across industrial sectors is presented in Table 8 and details of bioenergy capacity from various industrial effluents are presented in Table 9.

GOI has also set an ambitious target of 175GW renewable energy capacity by 2022, comprising 100 GW from solar power, 60 GW from wind power, 10 GW from bioenergy and 5 GW from small hydropower. Owing to the enabling policy and regulatory framework , bioenergy projects with more than 10 GW successfully started functioning by the end of 2020.

Table 8: Distribution of Biogas Projects Across Industrial Sectors

S.No.	Industrial Sectors	Number of Projects
1	Solvent Extraction Plant	6
2	Starch Industries	70
3	Slaughter House	2
4	Distillery Industries	40
5	Poultry Industries	12
6	Pharmaceuticals	2
7	Leather Industries	5
8	Yeast Industries	2
9	Food and Fruit Processing	6
10	Paper Industries	10
11	Municipal Solid Waste	4
12	Vegetable Market	2
13	Sewage /Sludge Plant	3
14	Cattle Dung	8
15	Dairy	1
16	Agriculture Waste	1
17	MSW	6
	Total number of Projects	**180**

Table 9: Details of Bioenergy Capacity from Various Industrial Effluents

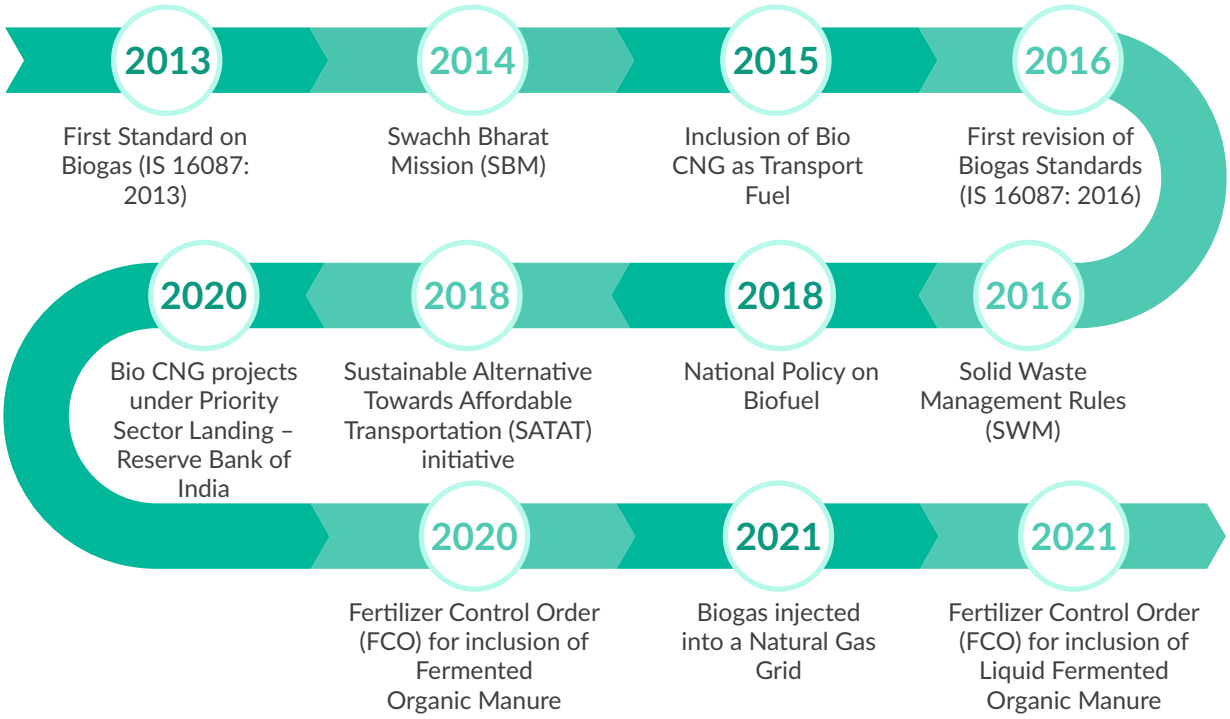
S.No.	Industrial Waste Type	Power Generation Capacity	Biogas Production Capacity	BioCNG Production Capacity
		MW	*m3/day*	*kg/day*
1	Dairy Industry Effluent	0.04	7200	0
2	Distillery Effluent	74.3	0	15920
3	Gelatine Industry Effluent	0	5260	0
4	Leather/Tannery Industry Effluent	0	1588	0
5	Mixed-Poultry, Sago, Press Mud	2.4	0	0

S.No.	Industrial Waste Type	Power Generation Capacity	Biogas Production Capacity	BioCNG Production Capacity
		MW	*m3/day*	*kg/day*
6	Oil Industry Effluent	15.3	36000	0
7	Paper Industry Effluent	0.3	75596	5460
8	Pharma Industry Effluent	0	12096	0
9	Seafood Industry	0	10000	0
10	Starch Industry Effluent	22.4	365478	0
11	Sugar Industry Effluent	10.7	0	0
12	Yeast Industry Effluent	0	34860	0
13	Total WTE capacity from industrial waste	125.5	548,078	21,380
14	Total WTE capacity from all kind of waste	248.9	597,120	46,628
15	% of WTE capacity from industrial waste as compared to all kinds of waste	50.4%	91.8%	45.9%

5.2. Timeline and Key Interventions in India

In past decade, the GOI has undertaken key interventions periodically to promote the uptake of Biogas and BioCNG in India. While the initiatives such as formulation of standards and inclusion of BioCNG as transport fuel has increased the BioCNG demand, whereas, the National Biofuels Policy and SATAT scheme are envisaged to ensure the supply of BioCNG. The timelines and the key interventions undertaken are presented in the following Figure 4.

Figure 4: Key interventions and respective timelines



5.3. Growth of BioCNG in India

BioCNG has the potential to reduce net carbon emissions, replace CNG and LPG in domestic, commercial and industrial applications. This in turn will save foreign exchange due to less dependence on import of petroleum products. BioCNG can be produced from various feedstocks including agricultural residue, MSW, sugarcane press mud, distillery spent wash, cattle dung, and STP waste. It is estimated that approximately 62 million tonnes (MT) of BioCNG can be created in India from various sources that can include bio-manure generation capacity of ~206 MT[8]. In order to realize this potential and meet national targets, global commitments, energy security and environment sustainability, GOI had launched the SATAT Scheme.

5.4. Sustainable Alternative towards Affordable Transportation (SATAT) Scheme

In 2018, MOPNG, had launched SATAT Scheme to tap the huge BioCNG potential in the country and envisaged a target of 15 million metric tonnes per annum (MMTPA) of BioCNG production from 5000 plants by 2024.

India's Oil and Gas Marketing Companies (OGMCs) such as Indian Oil Corporation Limited (IOCL), Bharat Petroleum Corporation Limited (BPCL), Hindustan Petroleum Corporation Limited (HPCL), Gas Authority of India Limited (GAIL), and Indraprastha Gas Limited (IGL) among others are mandated to facilitate the deployment of BioCNG plants and offtake the BioCNG produced. Furthermore, an agreement has been inked by these oil and gas majors for the promotion of the SATAT Scheme. Under this pact, a solid marketing strategy will be drawn up for the entire BioCNG quantity produced in the plants. IOCL is the coordinator of the scheme and is expected to liaison with the government and other agencies on behalf of the industry members, whereas, GAIL is the coordinator for the implementation of the CBG-CGD synchronization scheme.

In order to meet the targets under the scheme, OGMCs have invited Expression of Interest (EOI) from entrepreneurs/sole proprietorships/partnerships/ limited liability partnerships/companies/ cooperative societies/technology providers for supply of BioCNG from plants across the country. EOI highlighted the BioCNG pricing framework wherein long-term procurement price of BioCNG (as per IS 16087: 2016 standards and 250 bar pressure) would be INR 48.3 per kg of BioCNG till 31 March 2024 with a provision of periodic revision in procurement price from 1 April 2024 to 31 March 2029[9]. The procurement price of the BioCNG appears to be cost competitive with comparable fuel in the market. Table 10 presents the calorific value, fuel cost, and cost of energy comparison of various fossil based liquid and gaseous fuels with BioCNG.

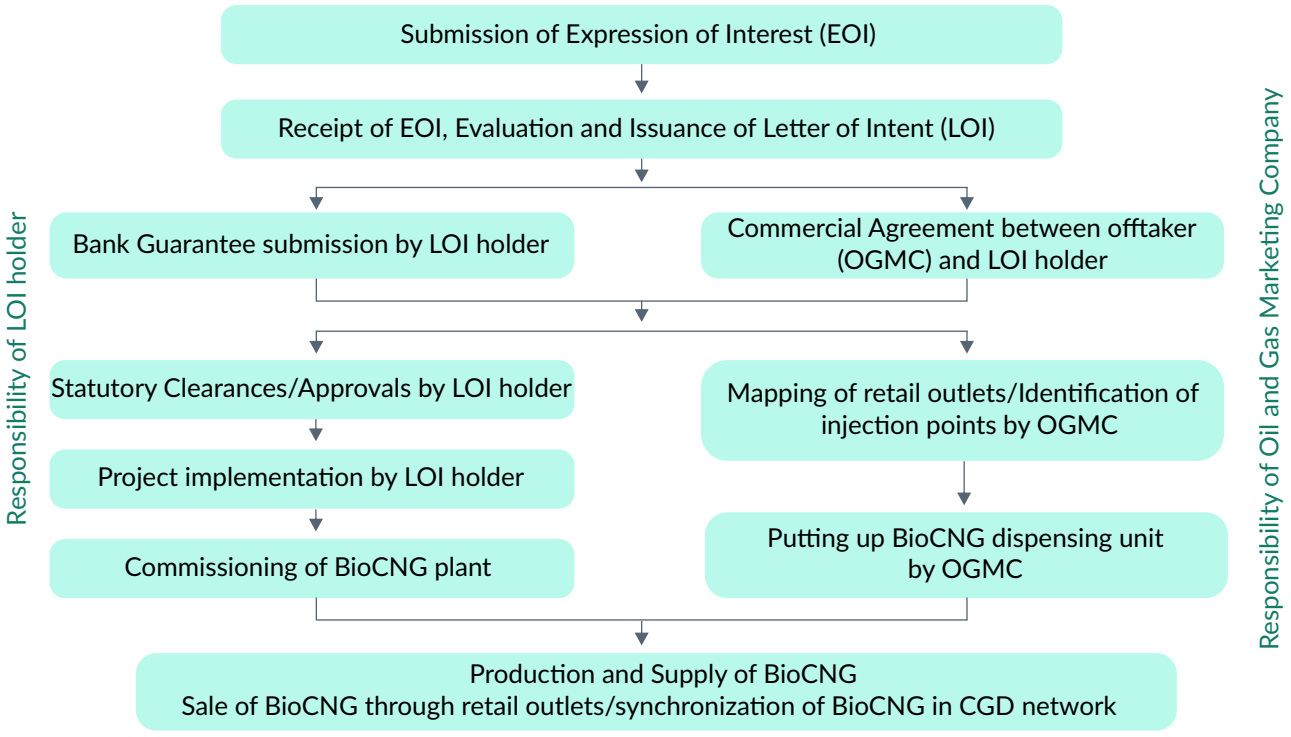
[8]https://pib.gov.in/newsite/PrintRelease.aspx?relid=183787
[9]https://www.gailonline.com/pdf/EOI_23_29.01.2021.pdf

Table 10: Fuel Cost (Selling Price) Comparison in India

S.No.	Fuel	Calorific Value	Fuel Cost[10]	Cost of Energy
1	Compressed NG (CNG)	47.1 MJ/kg	INR 51/kg	INR 1.1/MJ
2	**BioCNG[11]**	**47 MJ/kg**	**INR 48.3/kg[12]**	**INR 1.0/MJ**
3	LPG – Domestic (subsidized by Govt.)	46.6 MJ/kg	INR 59.6/kg[13]	INR 1.2/MJ
4	LPG – Commercial (No subsidy)	46.6 MJ/kg	INR 85/kg	INR 1.8/MJ
5	Gasoline/Petrol	33.7 MJ/litre	INR 102/litre	INR 3.0/MJ
6	Diesel	36.9 MJ/litre	INR 90/litre	INR 2.4/MJ

OGMCs had received an overwhelming response as a large number of applications were received for the EOI. After evaluation basis financial and technical criteria, around 2500 Letter of Intent (LOIs) have been issued to various applicants. Interestingly, more than 1500 LOIs have been issued by IOCL alone. It is noteworthy that around 900 MOUs have been signed by various OGMCs for procurement of BioCNG. OGMCs will also leverage the existing and upcoming City Gas Distribution (CGD) Network across the country to transport the BioCNG produced in the plants. The role and responsibilities of LOI holders and OGMCs has been represented in Figure 5.

Figure 5: Role and responsibilities of LOI holder and OGMCs



[10] Average post-tax price in the National Capital Region (NCR) - India in August 2021
[11] BioCNG fuel specification as per the Bureau of Indian Standard (IS : 16087 : 2016)
[12] As per the Sustainable Alternative Towards Affordable Transportation (SATAT) policy initiative, the Government of India has fixed the price (incl. 5% GST) of BioCNG to be purchased by the oil marketing companies (OMCs) at INR 48.3 per kg (~0.64 USD per kg)
[13] https://www.hindustantimes.com/business/commercial-lpg-cylinders-now-costlier-by-rs-73-5-cooking-gas-rates-unchanged-101627803609257.html

5.5. Standards and Specifications of BioCNG

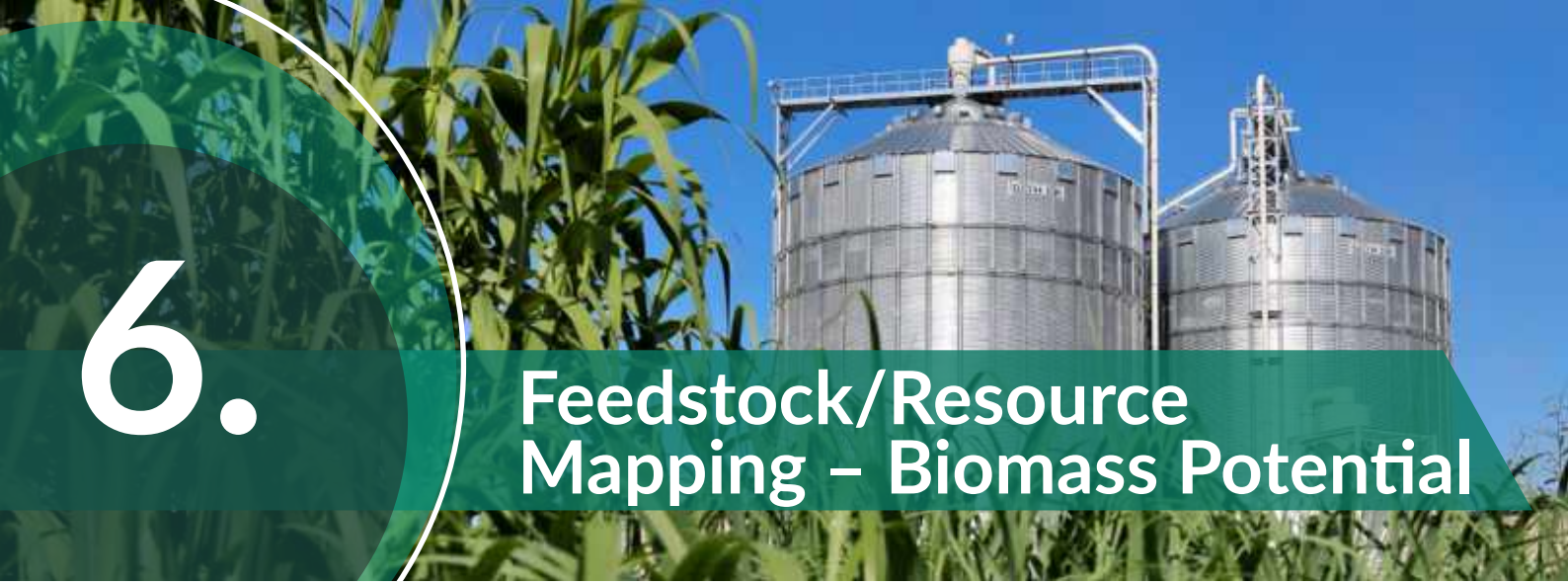
BioCNG supplied from the plants shall meet IS 16087:2016 standards. An outline is presented in Table 11 (any further revisions in the said standard shall be adopted and complied by project developers).

Table 11: IS 16087:2016 Standard for BioCNG

S.No.	Characteristic	Requirement
1	Methane percentage (Ch_4), minimum	90.00%
2	Only carbondixoide percentage (CO_2), maximum	4%
3	Carbondioxide (CO_2) + Nitrogen (N_2) + Oxygen (O_2) percentage, maximum	10%
4	Oxygen (O_2) percentage, maximum	0.50%
5	Total sulphur (including H_2S) mg/m3, maximum	20 mg/m3
6	Moisture mg/m3, maximum	5 mg/m3

In addition to the IS 16087:2016 standards, BioCNG from the plants should also meet the following specifications:

- BioCNG shall be compressed at 250 bar pressure
- BioCNG shall be free from liquids over the entire range of temperature and pressure encountered in storage and dispensing system
- BioCNG shall be free from particulate matter such as dirt, dust, etc.
- BioCNG delivered shall be odorized similar to a level found in local distribution



6. Feedstock/Resource Mapping – Biomass Potential

Organic waste/biomass such as agricultural residue, fruits and vegetable waste, cattle dung, sugarcane press mud, MSW, sewage treatment plant waste, etc. are needed for production of BioCNG and are abundantly available in India. These feedstocks can be broadly classified as urban, agricultural and industrial wastes as given in Figure 6.

Figure 6: Classification of biomass feedstocks

Urban Waste

- Kitchen
- Garden
- Household Garbage
- Cattle Dung
- Fruits and Vegetable
- Poultry Waste
- Commercial and Industrial Garbage

Agriculture Waste

- Paddy Straw
- Agro-processing Industries residues/effluents
- Green Grass

Industrial Waste

- Agro Processing
- Paper and Pulp
- Milk Processing
- Spent Wash from Distilleries
- Pharmaceutical
- Oil Extraction Plants
- Sugar Industry
- Slaughter House/Tanneries

Agriculture Waste: India generates an average 500 million tonnes (MT) of agricultural residue annually. After discounting its usage as fodder and fuel for domestic and industrial applications, ~150 MT is available as surplus. The annual production of horticulture products in India (in 2020-21) is estimated to be ~326 MT, out of which around 65-72 MT (20-22%) goes waste[14]. This horticulture waste can additionally produce around 2.0-2.5 MT of BioCNG annually which can be used in vehicles as fuel or for other energy applications.

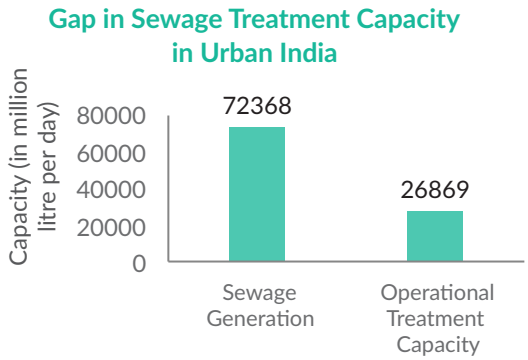
Municipal and Industrial Waste: A large amount of solid and liquid waste is generated in the industries and urban regions. The potential creation of BioCNG from industrial wastes, including liquid and solid waste streams, has been estimated to about 9.317 MT[15]. According to a recent estimate, about 50 million tonnes of solid waste (1.40 lakh tonnes per day) and about 14000 million cubic metre of liquid waste are generated every year by our urban population and this has the potential of generating over 2600 MW of power in the country. This figure can go beyond 5200 MW by the year 2027[16] and an estimated energy recovery of about 1300 MW can be done from industrial wastes. The potential of energy from industrial wastes for the year 2017 is estimated to be over 1600 MW.

[14] https://www.business-standard.com/article/economy-policy/india-s-horticulture-production-set-for-1-8-growth-in-in-2020-21121030801339_1.html
[15] UNIDO Report on Identification of Organic Waste Streams in India (2018)
[16] Report of The Sub-Group for Twelfth Plan Energy from Urban And Industrial Wastes

Cattle Waste: Based on the availability of cattle dung of about 304 million tonnes, about 18,240 million cubic meter of biogas can be generated annually. The increasing number of poultry farms is another source that can contribute in the generation of biogas of 2173 million cubic meters annually. In addition to this, waste from the kitchens of all institutions, universities, restaurants, barat-ghars, industries, parks and gardens in urban and semi-urban areas also offer a huge potential for the creation of biogas. This potential can be translated to an aggregated estimated capacity of 8165 MW per day of power generation or availability 22,06,789 LPG cylinders or making of 21304 lakh kg of urea equivalent or 3974 lakh tonnes of organic/bio-fertilizer per day[17]. Thus, there is immense potential of around about 11,240 MW based on available resources and about 20,000 MW based on energy plantation resources, which can be used for developing biogas by the utilization of waste.

Sewage Waste: The ever-increasing urban population generates large quantity of sewage waste which has to be treated as per environmental standards. Most of the untreated sewage goes into water bodies that poses as a health and environmental hazard. Some of the STP plants are producing a large amount of biogas as a byproduct. There is a large gap between sewage generated and sewage treated in India. Many new upcoming STPs especially under the National Cleaning Ganga Mission would be capable to produce significant quantities of BioCNG if waste sewage is properly treated. Figure 7 highlights the gap in sewage treatment capacity in urban India as per 2020 data[18].

Figure 7: Gap in sewage treatment capacity in urban India



Based on the above scenario, the estimated potential of BioCNG can reach around 70 MT annually. It could be possible to tap around 20-25% of such waste into BioCNG with state-of-the-art technology, investment and suitable regulatory and policy instruments in a time bound manner in the next 5-6 years.

An estimated potential of BioCNG production from various organic waste streams is represented in Table 12. Distribution of various types of organic wastes in some Indian states is presented in Figure 8, Figure 9, Figure 10 and Figure 11[18,19]. Assumption and calculation basis considered to arrive at the data/information is provided in Annexure B.

[17] Report of Sub-Group No. 2.4.2 on Decentralized Energy Systems for Biogas and Organic/Bio-Fertilizer Production and Applications
[18] National Inventory of Sewage Treatment Plants 2021, CPCB
[19] https://aps.dac.gov.in/

Table 12: Estimated Potential of BioCNG Production from Various Organic Waste Streams

S.No.	Categories of Organic Waste	Annual Feedstock Potential	Estimated Potential of BioCNG (MT)	%
1	Surplus Agro-residues	150 MT	20	32
2	Spent wash/Press Mud	20 MT	2	3
3	Municipal Solid Waste (MSW)-Organic Fraction	62 MT	5	8
4	Sewage Treatment Plants	50 MT	10	16
5	Recoverable Cattle dung, Chicken litter etc.	190 MT	25	41

As per the estimation in Table 12, the available agriculture residues can meet the projected bioenergy plans for the next five years with ease. Present consumption and projected demand of agro-residues for energy projects is presented in Table 13.

Table 13: Present Consumption and Projected Demand of Agro-residues for Energy Projects

S.No.	Sectors	Units	Present Installed Capacity	Existing Consumption (MT)	Annual Demand (MT)	Demand after 5 years (MT)
1	Combustion-based Power Plants	MW	1400	6.1	0.8	4.3 (1000 MW new biomass power plants
2	Bagasse Cogen in Sugar mills	MW	7974	43.6		43.6
3	Non-Bagasse Cogen in Industries	MW	772	4.2		4.2
4	Waste-to-Energy for Power	MW	168	0.7		0.7
5	Upcoming BioCNG Plants (250)	MT		--	6 (80 Plants for 2.4 lakh ton/yr)	120 MT (5000 plants for 15 MT/yr BioCNG)
6	Co-firing from Biomass pellets (7%) in Thermal Power Plants	MT	2,00,000 MW	--	2 (10K MW Coal Plants)	20.4 (100K coal-based power plants)
	Total					**193.3 (~200 MT/yr)**

Owning to the National Policy on Biofuels and increasing demand of bioethanol by OGMCs, a large fraction of surplus agriculture residues may be used to produce bioethanol (lingo-cellulosic) as number of projects are expected to be commissioned soon. The current demand of bioethanol is met mainly through ethanol produced in distilleries.

Figure 8: Statewise estimated potential of surplus agriculture residues (Paddy straw and Wheat straw)

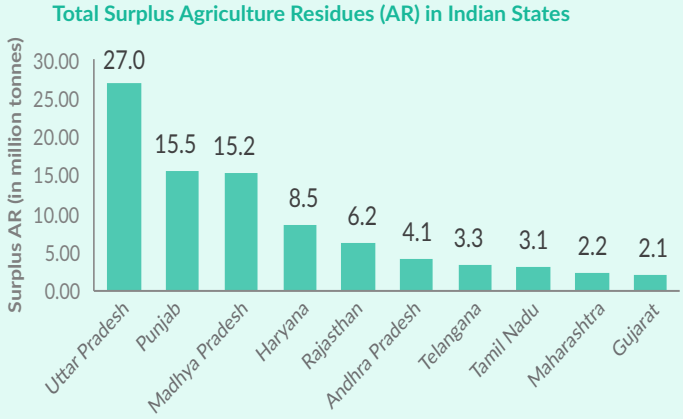


Figure 9: State wise estimated potential of fruits and vegetable waste

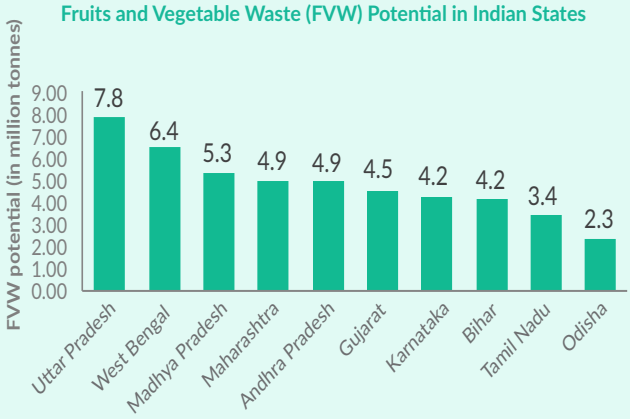
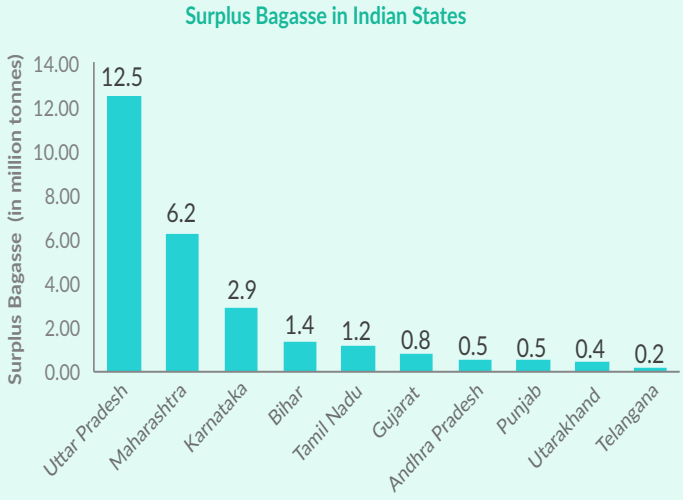


Figure 10: Surplus bagasse and press mud generated from sugar industries



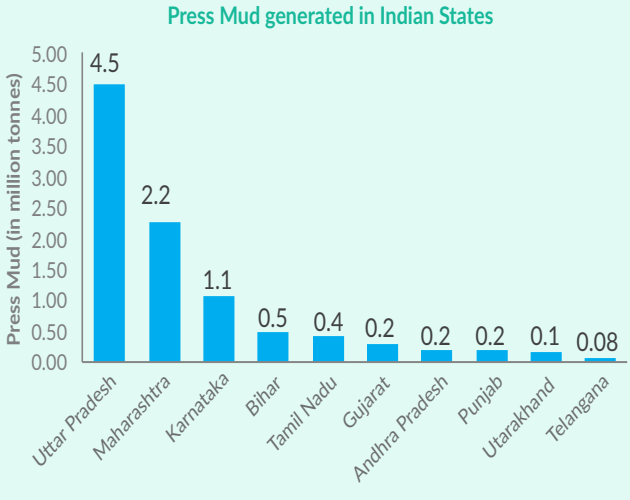
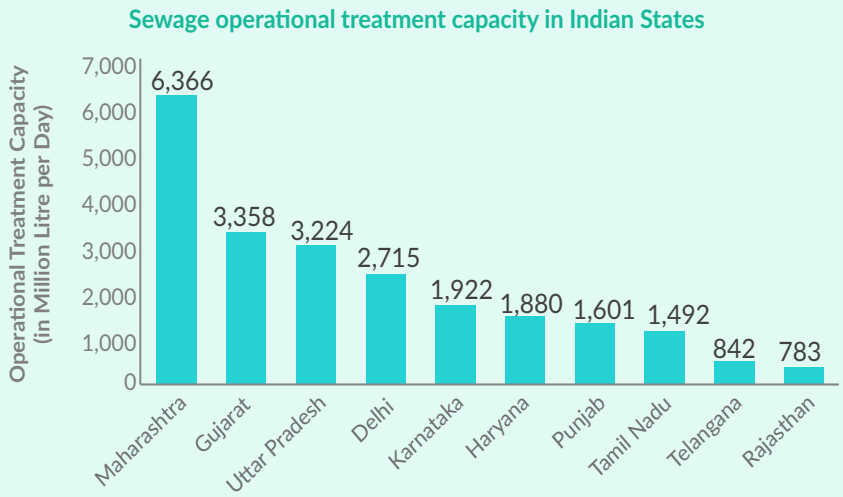


Figure 11: Sewage operational treatment capacity

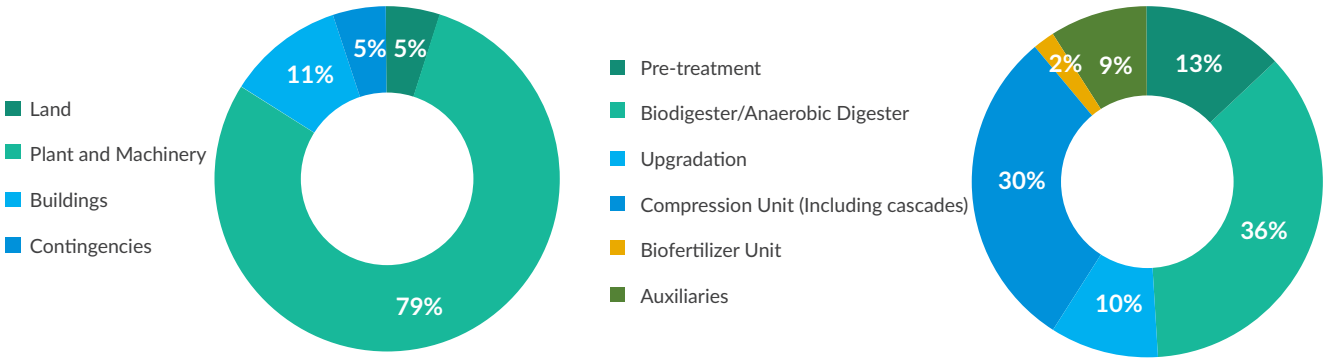


7. BioCNG Project Cost and Financing

7.1. Project Cost – CAPEX and OPEX

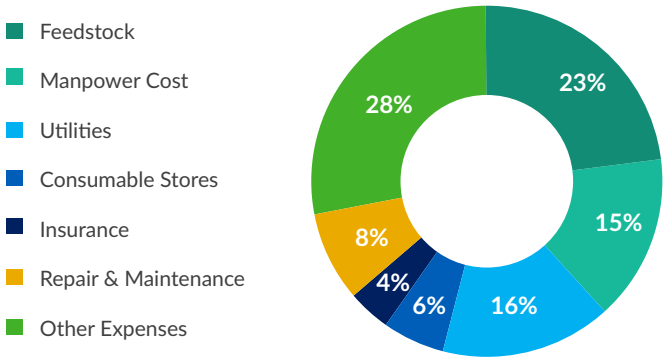
The capital expenditure (CAPEX) for a typical 8-10 TPD BioCNG plant varies from 4.7 – 6 million USD Crore which varies based on the type of biomass feedstock and technology deployed. It has been estimated that the plant and machinery costs contributes ~76% of CAPEX (i.e. 3.3 – 4 million USD) and varies with BioCNG production capacity, pre-treatment requirements, type of technology used for upgradation etc. A broad overview of the CAPEX cost for an 8-10 TPD BioCNG project in India is given in Figure 12.

Figure 12: Overview of the CAPEX cost break-up



The OPEX cost for an 8-10 TPD project is generally 1.3 – 1.6 million USD and may vary based on feedstock prices, transportation expenses etc. OPEX cost basically includes electricity cost, water cost, consumables cost, manpower cost, repairs and maintenance cost, administrative overheads and raw materials/feedstock cost. A broad overview of OPEX cost for 8-10 TPD for BioCNG in India is given in Figure 13.

Figure 13: Overview of the OPEX cost break-up



7.2. Financing Support from Institutions/Stakeholders

To ensure the financing of BioCNG projects, extensive support by the government, financial institutions and players in the oil and gas sector is required. Through financial assistance/subsidies and low cost affordable loans, stakeholders and financial institutions are supporting the development of BioCNG ecosystem. Brief details of the central financial assistance available in India and low-cost finance options from national and international agencies are outlined in Table 14 and Table 15.

Table 14: Central Financial Assistance (CFA) Available in India

S.No.	Source Detail	Details
1	Waste-to-Energy Program - Ministry of New and Renewable Energy (MNRE)	Details about the Waste-to-Energy program of MNRE is given in **Section 2.2 - Programs and Schemes.**
2	Agriculture Infrastructure Fund – Ministry of Agriculture	The Agriculture Infrastructure Fund (AIF) is a medium to-- long term debt financing facility for investment in viable projects for post-harvest management infrastructure and community farming assets through interest subvention and credit guarantee. Eligible beneficiaries include farmers, Farmer Producer Organization (FPOs), Primary Agricultural Credit Societies (PACS), Marketing Cooperative Societies, SHGs, Joint Liability Groups (JLGs), Multipurpose Cooperative Societies, Agri-entrepreneurs, Start-ups, and central/state agency or local body sponsored Public-Private Partnership projects. AIF's debt financing facility can be used for BioCNG projects. The BioCNG projects have been included as one of the eligible projects under community farming assets: bio-fertilizer plants too have been included as eligible projects under organic input production. Loans up to a limit of INR 2 crores for eligible projects will have an interest subvention of 3% per annum, which will be available for a maximum period of 7 years.

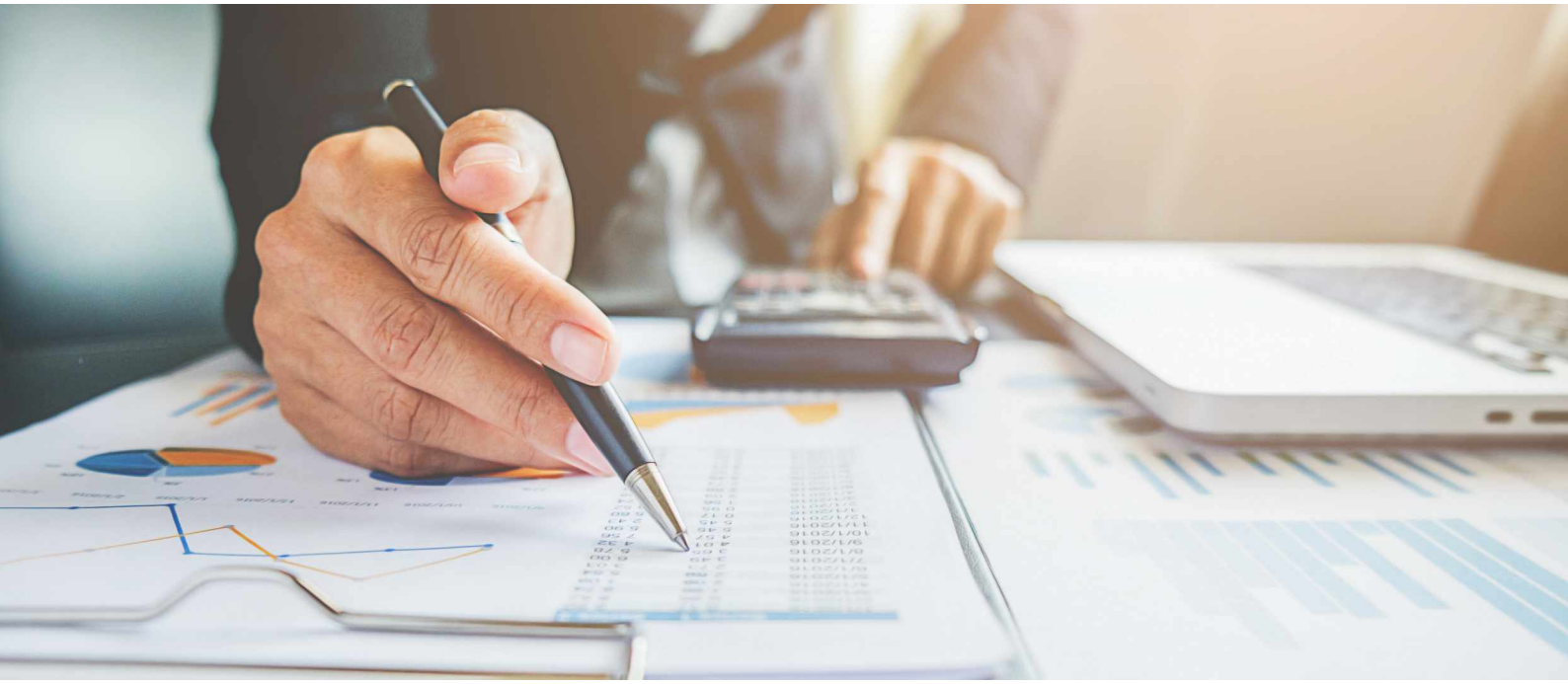
Table 15: Low-cost Finance Option from National and International Agencies

S.No.	Source Detail	Details
1	Bank of Baroda	Bank of Baroda (BOB) has launched a financing scheme to support compressed biogas plants set up across India with a minimum design capacity of BioCNG plant i.e., 2 tons per day. Eligible beneficiaries are entrepreneurs and other constitution of borrowers who have been awarded LOIs by OMCs for production and supply of BioCNG. Following are the key information regarding the financing scheme • **Nature of facility:** Working Capital/Term Loan/Bank Guarantee/LC • **Margin:** Term Loan (30%) and Working Capital (25%) • **Interest rates and charges:** Baroda Repo Linked Lending Rate (BRLLR) + Strategic Premium + 0.50% to BRLLR + Strategic Premium + 5.40% (Present BRLLR: 6.85%). As per BOB guidelines and policies promulgated from time to time.

S.No.	Source Detail	Details
		• **Loan tenure and repayment:** The term loan to be repayable in 10-15 years (including moratorium of a minimum of 6 months and maximum of 2 years period).
2	State Bank of India	State Bank of India has developed a new loan product for financing of BioCNG projects and has included compressed biogas under Priority Sector Lending (PSL) to provide financial assistance to new projects. Eligible beneficiaries would be entrepreneurs who have been awarded LOIs by OMCs for supply of compressed biogas under SATAT Scheme. Following are the key information regarding the financing scheme. • **Nature of facility:** Working Capital/Term Loan • **CRA Rating:** SB-10 & better • **Margin:** Term Loan (minimum 30% of the Project Cost) and working capital (minimum 25%) • **Interest rates and charges:** Pricing will be based on the internal CRA rating of the unit, ranging from 8.50% to 13.00% p.a., as per present EBLR/6 months MCLR. • **Loan tenure and repayment:** The term loan to be repayable in 10-12 years. The overall door-to-door tenor (moratorium + repayment tenor) not to exceed tenor of offtake agreement, which is 15 years and may be extended on mutual consent.
3	Canara Bank	Canara Bank has developed a new loan scheme for financing of BioCNG projects. Eligible beneficiaries would be entrepreneurs who have been awarded LOIs by OMCs for supply of compressed biogas under SATAT Scheme. Following are the key information regarding the financing scheme • **Nature of facility:** Working Capital/Term Loan • **Margin:** Term Loan (15-25% of the Project Cost) and Working Capital (15-25%) • **Interest rates and charges:** Rate of interest is applicable as per agriculture advances • **Loan tenure and repayment:** Term loan repayable in 10-15 years. Repayment of loan installments will be fixed based on the cash flow with suitable moratorium period.
4	Punjab National Bank	PNB has developed a new loan scheme for financing of BioCNG projects. The minimum designated capacity of a single BioCNG plant shall be 2.0 TPD of BioCNG. Eligible beneficiaries would be entrepreneurs who have been awarded LOIs by OMCs for supply of compressed biogas under SATAT Scheme. Following are the key information regarding the financing scheme • **Nature of facility:** Working Capital/Term Loan/Non-fund based limit • **Margin:** Term Loan (minimum 30% of the Project Cost), Working Capital (minimum 25%) and Non-fund based limit (minimum 15% cash margin) • **Interest rates and charges:** A concession of 0.25% on card rate shall be applicable. Collateral-linked concession shall be applicable. • **Loan tenure and repayment:** Term loan repayable in 12 years. The overall door-to door tenor (moratorium + repayment tenor) shall not exceed the tenor of offtake agreement, which is 15 years and may be extended on mutual consent.

S.No.	Source Detail	Details
5	Indian Renewable Energy Development Agency Ltd. (IREDA)	IREDA is a GOI enterprise under MNRE. It has been established as a Non-Banking Financial Institution for promoting, developing and extending financial assistance for setting up projects relating to new and renewable sources of energy and energy efficiency/conservation. Private sector companies, Central Public Sector Undertaking (CPSU), state utilities, and joint sector companies are eligible to avail the financing facility. Following are the key information regarding the financing facility • **Project funding:** Maximum of up to 50% of the project cost • **Financing mode:** Project financing, equipment financing, loans for manufacturing, financial intermediaries, financing of commissioned projects including takeover of loans from other banks/FIs, additional/bridge loan against SDF loan, loan against securitization

6	Green Climate Fund	The Green Climate Fund (GCF) is a global fund that was created in 2014, to support the efforts of developing countries to limit or reduce their greenhouse gas (GHG) emissions and adapt to climate change. Following are the key information regarding the fund
		• **Total fund value:** USD 10.3 billion
		• **Financing mode:** Grants, equity, loans, guarantees, result-based payments
		• **Eligibility:**
		  ○ Project should be ready for scaling up and having the potential for transformation, promoting a paradigm shift to low-emission and climate-resilient development.
		  ○ The request for financing to the GCF of up to USD 10 million of the total project budget.
		  ○ The environmental and social risks and impacts for the project are classified as minimal to none.



8. Supply Chain Logistics for Biomass and BioCNG in India

8.1. Biomass supply chain logistics

Long term and reliable supply of quality feedstock (biomass) for the BioCNG project is critical for plant operation and project viability. The average feedstock cost for a project may vary based on the type of feedstock, location of procurement, and quality of pre-treatment. Transport of feedstock from source to the plant location and connectivity of these locations are other key aspects of biomass supply chain. For seamless operation of BioCNG plant, it is preferable to have on-site depot, catering to more than 45 days of daily consumption and feedstock availability within 25 km radius of the plant vicinity.

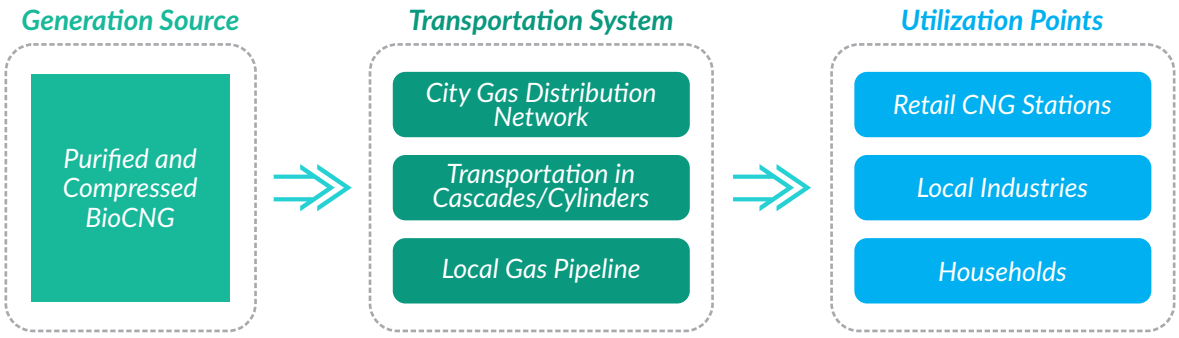
BioCNG plants based on MSWs face the challenge of collection, segregation and transportation of wastes. With the recent advancements in the automation and data exchange, waste collection can be optimized. A number of waste management solutions track the movement of compactors and waste-collection vehicles on a nearly real-time basis, whereas, some are using Internet of Things (IoT) sensors to recognize the types of waste to ensure the quality etc.

Biomass supply chain in India is unorganized (mainly for agriculture residues) with limited participation and involvement of farm producer organizations (FPOs), biomass aggregators, village level entrepreneurs (VLEs) and biomass processing companies, among others. Punjab Renewable Energy Systems Private Limited (PRESPL), Thermax Onsite Energy Solutions Limited (TOESL), A2Z Green Waste Management Limited, Prabodh Engicon Private Limited, and Ecogreen WTE are some of the biomass processing companies involved in the biomass supply chain in India.

8.2. BioCNG supply chain logistics

Upgraded and purified biogas or BioCNG can be transported from the point of generation to utilization point/retailing outlets using city gas distribution network, local gas pipelines or vehicle to transport cascades/cylinders. It is generally stored in high pressure cylinders at 250 bar pressure. The expansion of existing City Gas Distribution (CGD) network from existing 100 cities to 400 cities is planned for the next three-four years. BioCNG can be injected in the CGD network (including PNG network) in specified geographical areas as per standards and protocol. At the utilization points of BioCNG i.e. Retail Outlet/ Standalone Selling Point, there is a requirement to create the infrastructure such as equipment for dispensing the BioCNG. The dispensing equipment will be installed and maintained by one of the CGD company, whereas, the BioCNG nozzles will be staffed and operated by CGD Company or its authorized service representative. A broad overview of the supply chain logistics for BioCNG in India is given in Figure 14.

Figure 14: Broad overview of the Supply Chain Logistics for BioCNG in India



9. Approvals and Permits Required to set up BioCNG Projects

The setting up of BioCNG projects requires number of administrative approvals and permits from various approving authorities including central government and state government departments. An indicative list of approvals and the corresponding approving authority is presented below in the Table 16.

Table 16: Indicative List of Approval for BioCNG Projects and Corresponding Approving Authorities

S.No.	List of Items	Approving Agency/Authority
1	No objection certificate (NOC) for setting up the project	Local municipality cooperation/gram panchayat
2	Capital subsidy	MNRE, GOI through State Nodal Agencies (SNA)
3	Electricity and water connections	Utilities/distribution company and jal board
4	Taxes	Revenue Department
5	Change of Land Use (CLU), if required	State Town Planning Board
6	Consent to establish and consent to operate	State Pollution Control Board
7	Explosive substance license - Consent to establish and Consent to operate	Petroleum and Explosives Safety Organization (PESO)
8	Certificate of incorporation of Project SPV, if required	Ministry of Corporate Affairs
9	Factory license	Indian Factories Act, 1948 from Chief Inspector of Factories
10	Labour license	Department of Labour
11	Gas supply agreement, if required	GAIL/IOCL/HPCL/BPCL/IGL/other OGMCs
12	NOC from Fire Department	State Fire and Emergency Services
13	NOC for forest clearances, if required	State Forest Department
14	Certificate of Manufacture of Mixture of Fertilizers/ Micronutrient mixtures/ Bio-fertilizers/ Organic Manures, if required	Department of Agriculture

9.1. Procedures to Approval/Consent to Establish from Petroleum and Explosives Safety Organization (PESO)

Petroleum and Explosives Safety Organization (PESO) is a government organization created to regulate and monitor the manufacturing, import, export, transport, possession, sale and use of explosives, petroleum products, and compressed gases. PESO provides approval/licences under various acts/rules of explosive/petroleum/inflammable for various premises/units/vehicles. Brief process for securing PESO certification in India is outlined as follows:

- Preparation of application documents such as Memorandum of Articles in case of public/ private sectors or registered partnership deed in case of the partnership company, NOC from District Authority, layout plan of the plant, project report, and test reports
- Application at PESO authority
- Checking of application documents by PESO
- Factory audit
- Issuance of PESO certificate

9.2. Procedures to Approval/Consent to Establish from State Pollution Control Board (SPCB)

Application for Consent to Establish (CTE) for any industry from SPCB is mainly an online process now. More specific details on the process can be found on website of SPCBs. Following are the indicative list of documents required for approval.

- Copy of attested Sale Deed/Lease Deed or any other relevant documents as proof to ensure possession of the site/factory.
- Copy of attested Memorandum of Articles in case of public/private sectors or registered partnership deed in case of the partnership company.
- Layout plan showing the location of various process equipments, utilities, generator, effluent treatment plants, etc.
- Sketch showing the distance of water bodies, roads, existing/proposed residential areas, agricultural lands, and other sensitive areas.
- The detailed manufacturing process for each product along with a detailed process flowchart. Material, water and wastewater balance of the process.
- Land use certificate.
- Sewage Treatment Plant (STP) and or Effluent Treatment Plant (ETP) proposal.
- Air pollution control measures proposal which must contain the details regarding fuels used, sources of emission, characteristics, concentration and quality of pollutant, odour/noise-causing operations and its specific odour/noise control measures.
- Industries attracting Environment Impact Assessment (EIA) notification shall submit environmental clearance obtained from the MOEF/SEIAA along with the EIA Report (If applicable)

9.3. Industrial Classification of BioCNG Projects

As per the Centre Pollution Control Board (CPCB) classification of industrial sectors, a compressed/ refined biogas production from bio-degradable waste industry is broadly an orange category industry (Pollution Index 50). However, plants/industry with zero waste water discharge from digester and feed slurry to digester having Volatile Organic Fraction with more than 75% to be considered as Green category industry[20].

[20] https://cpcb.nic.in/openpdffile direction.php?id=UHVibGljYXRpb25GaWxlLzM3NzdfMTU4ODU3NzUwM19tZWRpYXBob3RvMzcyMi5wZGY=

10. Enablers and Opportunities

GOI and MOPNG have created an enabling ecosystem for accelerated deployment of BioCNG projects in India through various policy and regulatory provisions, and provisions under SATAT Scheme. Table 17 highlights the key enablers and provisions for BioCNG projects in India.

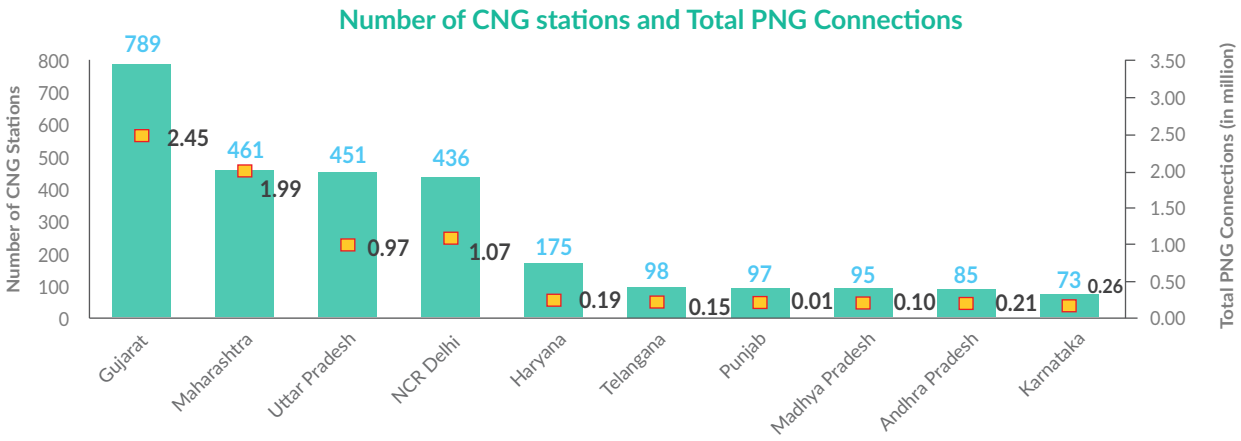
Table 17: Key Enablers and Provisions for BioCNG Projects in India

Assured Offtake of BioCNG	OGMCs in India have issued number of LoIs to setup BioCNG projects. OGMCs are also executing long term commercial agreements to offtake BioCNG/compressed biogas (IS 16087:2016 standard, compressed at 250 bar) at an assured base price of ~USD 0.64 USD (INR 48.3) per kg of BioCNG (all taxes inclusive). The assured price shall remain valid till 31 March 2024 and with a periodic revision provision post 31 March 2024 till 31 March 2029. Additionally, an amount of ~USD 0.03 (INR 2) per kg of BioCNG towards cost of setting up of infrastructure e.g. booster compressor, dispensing unit, etc. at retail outlet and ~USD 0.007 (INR 0.50) per kg of BioCNG towards electricity charges for operation of booster compressor, dispensing unit, etc. at retail outlet, shall be provided to OMCs or applicant, as per whosoever sets up infrastructure at retail outlet.
Facilitate Offtake/Demand Generation of Biomanure	To promote the manure produced from BioCNG plants, FOM and digested biogas slurry have been included under FCO 1985. OGMCs are facilitating the marketing of Biomanure produced from the BioCNG plants. OGMCs have entered into an agreement with National Agricultural Cooperative Marketing Federation of India Ltd. (NAFED) in this regard.
Large CGD network across India	India has ~19,998 km long natural gas transportation pipeline (also called CGD network) across India. This large CGD network covers over 402 districts across 27 states and union territories in India and has a potential to cover 53% of country's area and 71% of country's population[21]. Figure 15 presents the details of gas infrastructure in India[22].

[21] https://pib.gov.in/PressReleasePage.aspx?PRID=1739017
[22] https://pngrb.gov.in/pdf/GAS_INFRASTRUCTURE_MOI_17032021.pdf

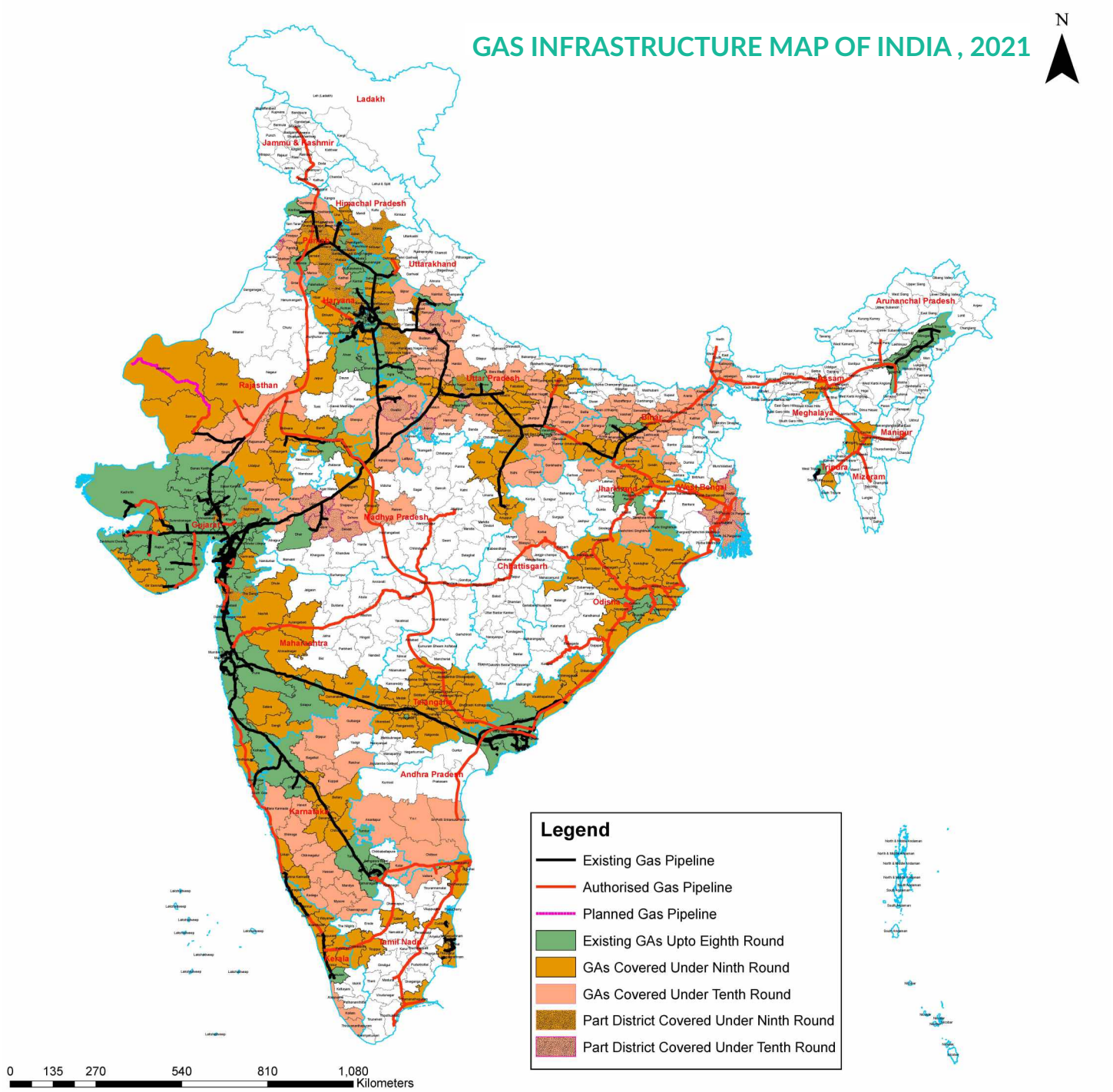
Large Network of CNG Gas Stations (Demand Points)	India has more than 3143 CNG gas stations nationwide. India also has ~8 million PNG connections in domestic, commercial, and industrial categories with 99.4% connections alone in domestic segment. Figure 16 highlights the statewise distribution of CNG gas stations and PNG connections for select states in India[23].
Facilitation/Support from OGMCs	OGMCs are facilitating project developers in design, erecting, construction, commissioning of the BioCNG plants. OGMCs have also entered into MOU with various state governments for facilitating setting up of BioCNG plants. A policy guideline has been issued for synchronization of BioCNG produced by plants under SATAT Scheme in the CGD network.
Priority Sector Lending	BioCNG projects have been included as a fresh category eligible for finance under priority sector (as per the revised PSL guidelines issued by Reserve Bank of India). This would enable better credit penetration for setting-up of BioCNG projects/plants.
MNRE Incentive Scheme	MNRE, through its waste-to-energy program, is promoting setting up of BioCNG projects using urban, industrial, agricultural waste and MSW. The scheme offers CFA in the form of back-ended subsidy for installation of waste-to-energy projects. For instance, CFA of ~ USD 0.54 million (i.e. INR 4 crore) can be provided to setup a 4.8 TPD BioCNG plant with maximum CFA - ~ USD 1.33 million (Rs 10 crore) per project.
Other Fiscal Incentives	GOI has provisioned various fiscal incentive mechanisms to promote the deployment of BioCNG projects in India. These include 100% foreign equity through automatic approval route to attract Foreign Direct Investment (FDI), concessional customs duty, Accelerated Depreciation (AD), and concessional Goods and Service Tax (GST) of 5%, among others.

Figure 15: Statewise distribution of CNG gas stations and PNG connections for select states in India



[23] PPAC's Snapshot of India's Oil & Gas data, Abridged Ready Reckoner May, 2021

Figure 16: Detailed information of Gas Infrastructure in India



11. Barriers and Challenges

Despite the support from government, various enabling mechanisms are in place, and an ambitious target to promote the BioCNG projects, on-ground implementation of the projects have significant challenges and issues. Table 18 summarizes the key challenges faced by the BioCNG projects in India.

Table 18: Summary of Challenges in Implementation of BioCNG Projects in India

Feedstock Availability	Quality of Feedstock (including multiple feedstocks)	Technology Challenges	BioCNG and by-products' Market Challenges	Financing, and Implementation Challenges
No formal market for trading of feedstock Uncertainty of long-term regular supply of feedstock Demand supply mismatch - requirement of large storage facility Unorganized biomass value chain – lack of sufficient collection, processing and transportation facility	Variation in quality of feedstock throughout the year Some projects are designed to take multiple feedstock – optimal operation is a challenge and may also affect the quantity and quality of BioCNG Source segregation is important – receiving non-segregated waste is an operational challenge	Technologies are sensitive to the quality of feedstock – slight change in feedstock quality will significantly impact the BioCNG production rate Capital intensive technologies – high upfront project cost	Year-on-year variation in feedstock price – established feedstock pricing mechanism is required Base price of BioCNG offtake should be linked with feedstock cost variation – mitigates the economic viability risks Create market demand for by-products such as Biomanure etc.	There are schemes by public sector banks to finance BioCNG project, but less private sector banks are financing BioCNG project that too at high cost of debt. Lack of access to infrastructure i.e. road network and CGD network near project sites. Large set of approvals are required from PESO, pollution control board, MNRE - subsidy disbursement etc.

12. Recommendations

12.1. Ensuring Sustainable Supply of Biomass

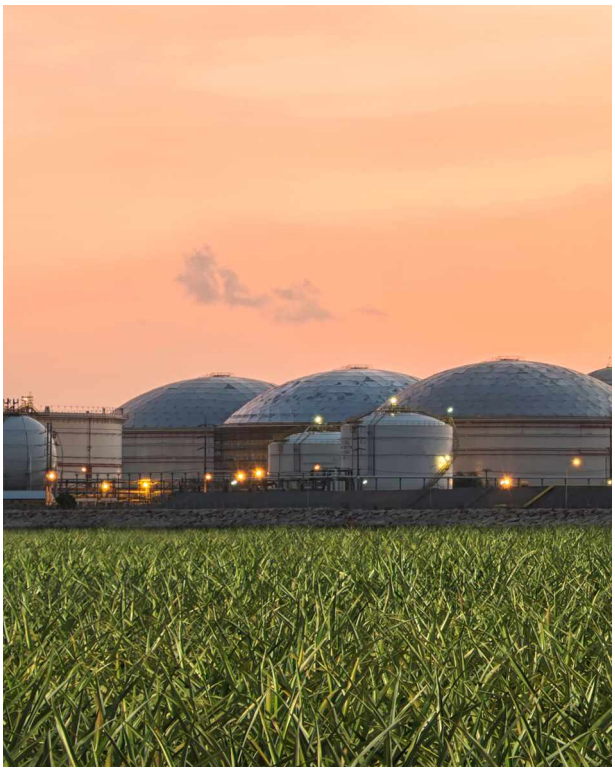
Bioenergy sector in India is matured enough to create market for providing various energy needs on sustainable and commercially economic terms. However, scaling various bioenergy programs and activities require logistic support such as large storage facilities, collection, processing and transportation facilities for sustainable biomass supply chain. Hence, it is imperative to organize the value chain by creating a mechanism or a market place to match biomass demand and supply for a BioCNG plant. An organized platform such as Biomass Depot/banks can be helpful in achieving the required logistical support. The Biomass Depot can ensure balance between the demand and supply at a guaranteed quantity, quality, and price.

In order to minimize the risk of deviation in supply, there is a need to have standardized contracts for the supply of biomass to the projects. These standardized contracts may be signed between the project owner and biomass processing companies or farmer producer organization etc. Further, it is imperative to have an enforcement mechanism through regulatory cover to the project and the biomass supplier, to ensure the effective implementation of contracts.

12.2. Selecting Technologies which are Proven at Medium to Large Scale and Partnerships to Obtain Operational Efficiency of the Project

In India, a large number of BioCNG technology players are available in market, but majority of the players have limited track record of BioCNG projects. Hence, it is important to assess and select a technology using various technical parameters. It has also been observed that the plant performance or production rate of BioCNG is one of the critical challenges associated with the technology and its optimal operation. In order to achieve the operational efficiency and desired product output, project owner may tie up with technology providers to get a guaranteed output of the BioCNG from the plant.

While there is a need to upscale the proven and matured technologies, the research and development in related technologies is required. R&D support would specifically be required to demonstrate technologies which can process multiple feedstocks simultaneously, considering the huge but intermittent availability of some of the key feedstocks such as agriculture residues.



12.3. Access to Affordable Finance and Production Cost Based Pricing of BioCNG

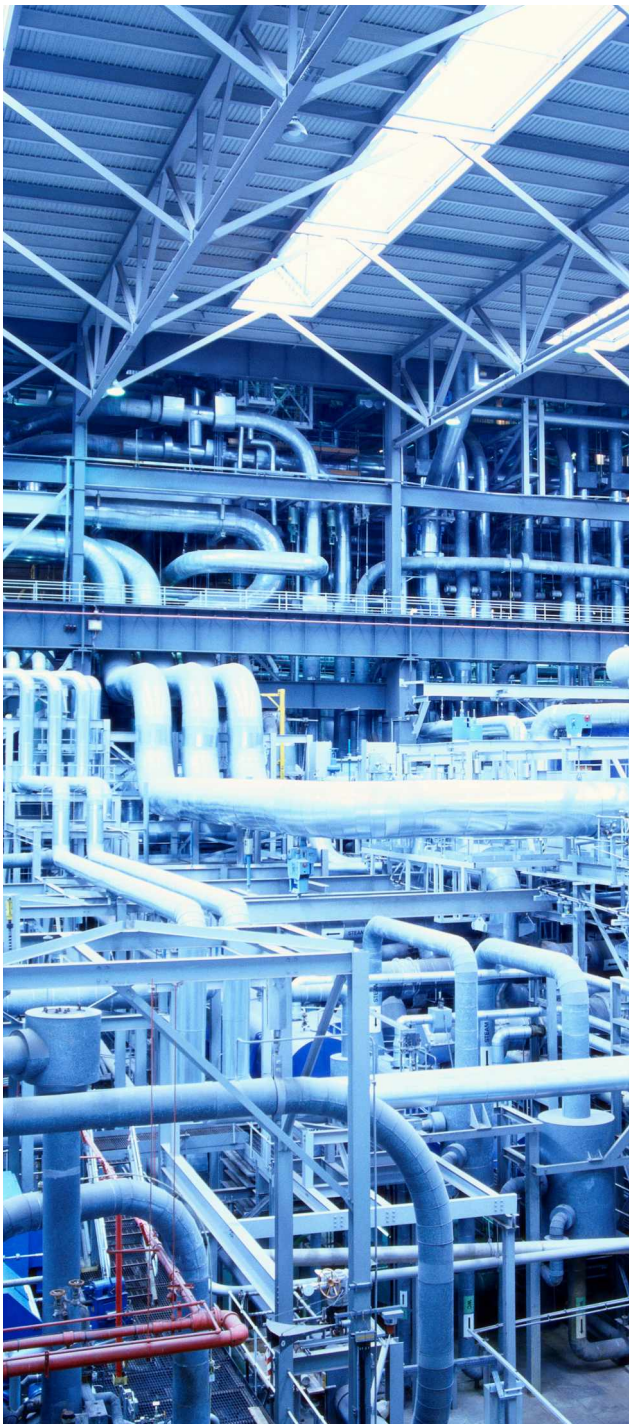
Large scale BioCNG projects are capital intensive due to high CAPEX cost and high upfront project cost. Considering the financial appetite of the existing BioCNG sector players (mainly technology providers) in India, there is a need to mobilize public and private funds at affordable rates. Though there are schemes by public sector banks such as SBI, BOB, Punjab National Bank (PNB) and Canara Bank to finance BioCNG projects, but they have high cost of financing. Also, there are limited private sector banks who are are financing BioCNG projects and that too at high cost of debt.

Oil and gas companies in India are mandated to facilitate the deployment of BioCNG projects under the SATAT Scheme, OGMCs are not only one of the key stakeholders in the BioCNG value chain (as BioCNG offtaker), but also have high financial appetite. OGMCs can be one of the investors and can be the project owner of the BioCNG projects by infusing 100% equity to the projects. OGMCs or other investors may develop or innovate business models through tie ups with biomass suppliers and technology providers to ensure sustainable supply of biomass and operational efficiency for guaranteed BioCNG output, respectively.

Currently, in India, OGMCs are the key offtakers of the BioCNG produced from projects deployed under SATAT Scheme. The offtake price of BioCNG is fixed at ~USD 0.64 (including taxes) per kg till 31 March 2024 and with periodic revision provision post 31 March 2024 till 31 March 2029. Considering the cost of production of BioCNG varies with type of feedstock and the technology adopted, it is suggested to have production cost linked pricing of BioCNG instead of a fixed offtake price.

12.4. Ensuring Infrastructure for Efficient BioCNG Transportation to the Demand Centers

As per the EOIs from OGMCs for production and supply of BioCNG, producer has to deliver BioCNG which is compressed at 250 bar to their existing or new retail outlet/standalone selling point, through cascades (within 25 km, an indicative maximum distance). Further, there would be the requirement of the equipment for dispensing BioCNG which shall be installed and maintained by public sector oil marketing companies. CGD network is another way in which the BioCNG can be transported to the demand center of public sector oil marketing companies. In order to optimally transport the BioCNG using these transport mechanisms, it would require road connectivity between the production site and demand center, and CGD network up to a reasonable point/distance from the project site.



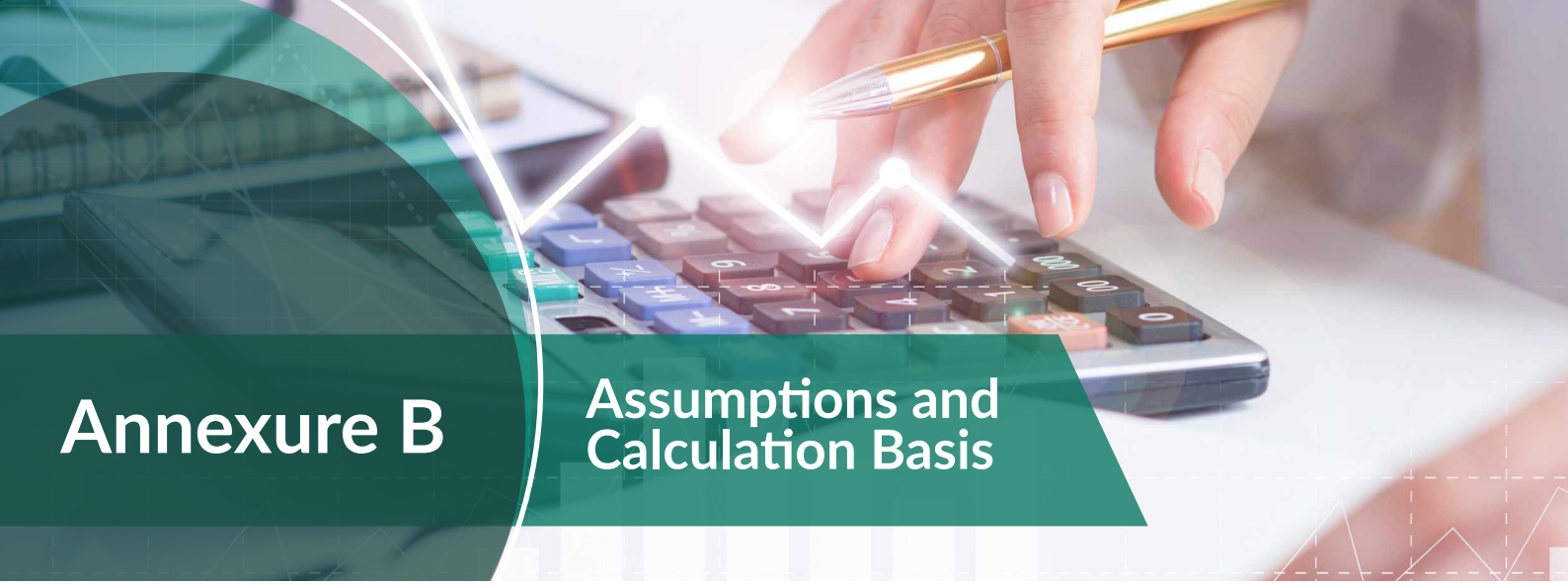
Annexures

Annexure A

List of Global and Indian Companies of BioCNG/Bioenergy Sector

S.No.	Company Name	Type of Business
1.	Praj Industries	Technology Developer
2.	KIS Group	Technology Developer
3.	Novozymes	Technology Developer
4.	BWSC	Engineering, procurement, and construction (EPC)
5.	Wartsila	Engineering, procurement, and construction (EPC)
6.	Orsted	Engineering, procurement, and construction (EPC)
7.	Leafiniti Bioenergy (Nirani Groups)	Engineering, procurement, and construction (EPC)
8.	IOT Biogas Pvt Ltd	Engineering, procurement, and construction (EPC)
9.	XEMX Projects	Engineering, procurement, and construction (EPC)
10.	CNM Energy Solution Pvt Ltd	Engineering, procurement, and construction (EPC)
11.	Sampurn Agri Ventures	Engineering, procurement, and construction (EPC)
12.	Carboneu Pvt Ltd	Engineering, procurement, and construction (EPC)
13.	Cities Innovative Biofuels Private Limited	Engineering, procurement, and construction (EPC)
14.	Bharat Biogas Energy Limited	Engineering, procurement, and construction (EPC)
15.	CEF Budhana Energy Private Ltd	Engineering, procurement, and construction (EPC)
16.	Solika Energy Pvt. Ltd.,	Engineering, procurement, and construction (EPC)
17.	T R Mega Foods and Beverages LLP	Engineering, procurement, and construction (EPC)
18.	Suvidha Infracon Pvt Ltd.	Engineering, procurement, and construction (EPC)
19.	ENGIE	Engineering, procurement, and construction (EPC)
20.	SLPP Renew	Engineering, procurement, and construction (EPC)

S.No.	Company Name	Type of Business
21.	Carbon Clean	Engineering, procurement, and construction (EPC)
22.	Verbio Vereinigte BioEnergie AG	Engineering, procurement, and construction (EPC)
23.	Green Elephant	Engineering, procurement, and construction (EPC)
24.	Biogasclean	Original Equipment Manufacturer (OEMs)
25.	Landia	Original Equipment Manufacturer (OEMs)
26.	BHS Sonthofen	Original Equipment Manufacturer (OEMs)
27.	MSA Bio-Energy Pvt. Ltd.	Original Equipment Manufacturer (OEMs)
28.	Aim-Green Bio-Energies	Original Equipment Manufacturer (OEMs)
29.	Arunagreen	Original Equipment Manufacturer (OEMs)
30.	Grassroots Energy Inc.	Original Equipment Manufacturer (OEMs)



Annexure B

Assumptions and Calculation Basis

1. Data/Information used for Assumption and Calculation for the Sugar Industry:

   In 2018-19, total production of sugarcane in India was ~400 million tonnes (MT). Around 275 MT (~70% of total production) of sugarcane is used to produce ~33 MT of sugar. Generally, 1 tonne of sugarcane produces 120 kg (12%) sugar, 250 kg (25%) bagasse, and 36 kg (3.6%) press mud. Sugar Bagasse has captive usage in the sugar industries, hence assumed that around 40% of the total bagasse is available as surplus. The same basis has been used for the data presented in Figure 10 (Surplus bagasse and press mud generated from sugar industries)

2. Residue to Crop Ratio of 2.5 and Agriculture Residues (AR) Surplus Factor of 20 % is used to arrive at data presented in Figure 8 (Statewise estimated potential of surplus agriculture residues).

3. Fruit and vegetable waste generated is around 20% of the total fruit and vegetable produced. This is assumed to arrive at data presented in Figure 9 (Statewise estimated potential of fruit and vegetable waste).

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