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SCALING MUNICIPAL SOLID WASTE-TO-BIOGAS PROJECTS IN INDIA THROUGH A FEEDSTOCK-FIRST RETHINK OF THE VALUE CHAIN

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SCALING MUNICIPAL SOLID WASTE-TO-BIOGAS PROJECTS IN INDIA THROUGH A FEEDSTOCK-FIRST RETHINK OF THE VALUE CHAIN

This paper has been prepared by the Chintan Research Foundation (CRF) as a discussion paper leading to the World Biogas Association (WBA), India Congress 2026.

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Executive Summary

India generates ~1.7 lakh tonnes of municipal solid waste (MSW) each day, with significant potential for biogas and compressed biogas (CBG) production, yet actual deployment remains minimal. The numbers render this gap plain: India has 1,928 registered CBG/Bio-CNG plants, but only 217 are commissioned, alongside 1,744 registered biogas plants, of which 1,282 are functional Galvanizing Organic Bio-Agro Resources Dhan [GOBARdhan] Unified Registration Portal 2026). This study traces where and why this gap exists by dissecting the entire MSW-to-CBG value chain.

The foremost gap that this study identifies is the geographic and seasonal variability of feedstock and the limited attention to this dispersion when planning biogas commercialisation. The analysis finds that for city-based biogas plants, MSW is the most appropriate waste. The key bottleneck, however, is the quality and quantity of the feedstock that reaches the digester. The volume of quality feedstock is significantly eroded by poor source segregation, re-mixing during collection, inadequate processing infrastructure, and fragmented institutional responsibilities. This study concludes that MSW availability does not necessarily translate into bankable feedstock. This understanding, however, remains missing from the policy implementation ecosystem despite the existence of schemes such as GOBARdhan, the Sustainable Alternative Towards Affordable Transportation (SATAT) initiative, the Solid Waste Management Rules, 2016, and the National Bioenergy Programme.

While municipal organic waste remains relevant to the broader GOBARdhan framework, uneven access to capital and credit support for predominantly MSW-based projects could create a specific viability gap. This strengthens the case for convergence with SBM-U and other urban waste-management financing mechanisms. This study identifies three challenges, namely: municipalities lack capital for dedicated segregated-collection fleets; transporters are paid by tonnage, rewarding volume over segregation integrity; and unresolved cost disputes between urban local bodies (ULBs) and operators further erode segregation quality downstream.

In this light, this study argues for a feedstock-first, value-chain approach to CBG deployment, with a focus on matching technology and plant scale to local waste characteristics. The study also draws on lessons from Germany, Sweden, China, and the Indore model to highlight the primacy of reliable demand, adaptive financial support, coordinated institutions, and well-designed public–private partnerships (PPPs). The study identifies the biggest institutional gap as this: three ministries – the Ministry of New and Renewable Energy (MNRE), the Ministry of Petroleum and Natural Gas (MoPNG), and the Ministry of Jal Shakti (MoJS)/Ministry of Housing and Urban Affairs (MoHUA) – all run parallel approval chains with no shared data system. The new Bioenergy for Economy, Environment, and Employment (BioE3) biotechnology policy now adds a fourth touchpoint, the Department of Biotechnology (DBT), without coordinating with existing biogas schemes.

Going forward, India should focus on strengthening segregation and collection systems, improving project finance, integrating waste pickers, ensuring offtake, and aligning ministries more closely, which can in turn help convert India's vast waste resource into a reliable source of renewable energy, renewable carbon, and circular-economy value.

Keywords: *compressed biogas; municipal solid waste; GOBARdhan; SATAT; feedstock supply chain; waste-to-energy; waste segregation; BioE3 policy*

Introduction: India's Energy Transition and Making a Case for Biogas

India's energy system is undergoing a structural transformation driven by two simultaneous imperatives: ensuring energy security and meeting decarbonisation commitments. While the 'electrification first' strategy has gained worldwide consensus, electricity currently accounts for only a fraction of India's final energy consumption, an estimated 21 per cent as of 2025, projected to rise to nearly 60 per cent by 2070 under the National Institution for Transforming India (NITI) Aayog's (2026) net zero scenario. Significant portions of transport, fertiliser production, industrial process heating, long-distance freight, aviation, shipping, and several chemical industries continue to depend on energy-dense molecular fuels. The structural nature of this molecular dependence was made explicit in March 2026, when the Ministry of Petroleum and Natural Gas (MoPNG) invoked the Essential Commodities Act, 1955, to ration natural gas during the West Asian crisis (MoPNG 2026). Domestic piped gas and transport compressed natural gas (CNG) were held at 100 per cent of historical consumption while other sectors absorbed cuts, but fertiliser plants still had guaranteed a protected 70 per cent of their six-month average supply, underlining how load-bearing gas remains for fertiliser production (MoPNG 2026).

Consequently, striking a balance between energy security and decarbonisation in the Indian context requires a framework of 'electrons wherever possible and molecules where indispensable'. Among renewable molecules, biomethane, commercially marketed as compressed biogas (CBG) in India, occupies a distinctive position because it simultaneously addresses energy security, waste management, methane mitigation, nutrient recycling, and rural income generation. This explains why the government has built an increasingly wide set of fiscal and regulatory incentives specifically around it, including central financial assistance, customs duty concessions on plant machinery, and the inclusion of CBG financing under Reserve Bank of India (RBI Priority Sector Lending (RBI 2020).

Biogas is a combustible gas mixture produced by the microbial anaerobic degradation of organic matter, such as cow dung and agricultural residues, under oxygen-free (anaerobic) conditions. Typically, raw biogas contains approximately 50-70 per cent methane (CH_4), 30-50 per cent carbon dioxide (CO_2), and trace quantities of hydrogen sulphide (H_2S), moisture, ammonia, siloxanes, and other impurities. This molecule can substitute for fossil fuels such as liquefied petroleum gas (LPG), CNG, and diesel in both heat and power generation and as a vehicle fuel. Owing to its relatively low methane concentration and presence of contaminants, raw biogas has limited applications and is primarily used for decentralised cooking, heating, or electricity generation.

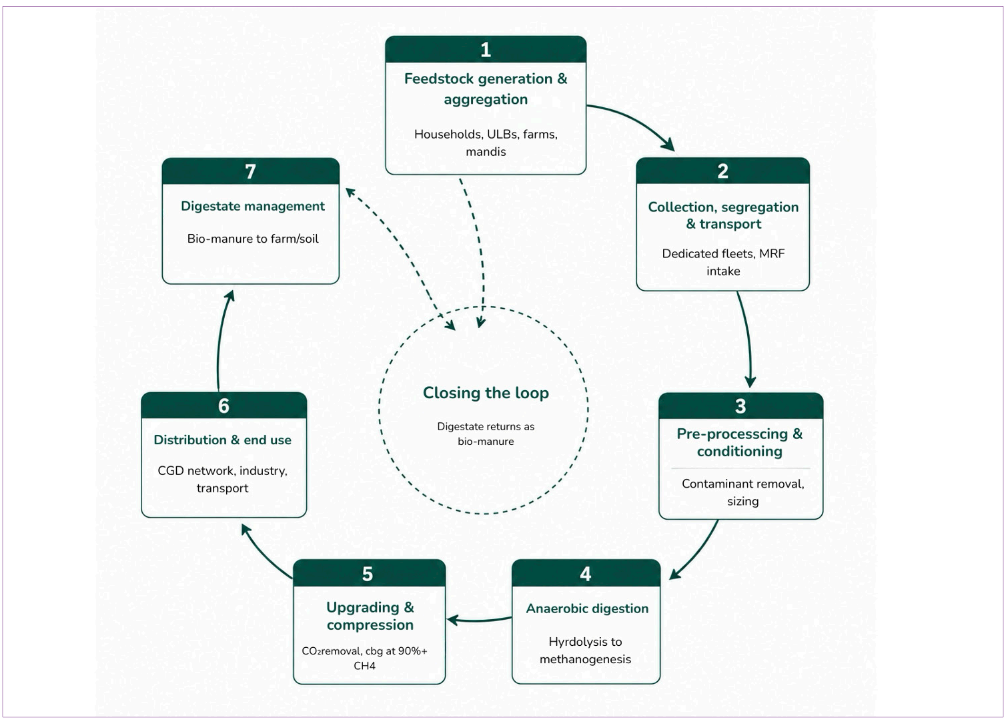
CBG, also referred to as biomethane or Bio-CNG, is produced by upgrading raw biogas through the removal of CO_2, H_2S, moisture, and other contaminants, thereby increasing methane purity to approximately 95-98 per cent (IOCL, SATAT Scheme FAQ). The purified gas is subsequently compressed to high pressure (typically 200-250 bar), enabling storage, transportation, and utilisation in applications traditionally served by CNG. As biomethane meets the quality specifications for natural gas, CBG can be injected into natural gas pipelines, supplied through city gas distribution (CGD) networks, or used directly in transport, industrial heating, commercial establishments, and decentralised energy systems. Its chemical similarity to natural gas also permits utilisation without significant modifications to downstream infrastructure or end-use equipment.

Within this broader case for biogas, municipal solid waste (MSW) occupies a distinct position. It is an organic feedstock with immense potential for valorisation into CBG and is directly linked to the sanitation and 'clean cities' mandate that anchors the Swachh Bharat Mission-Urban 2.0 (SBM-U 2.0). It is under this mandate that the government provides additional central assistance (ACA) specifically for MSW-based CBG plants, delineating MSW as a distinct feedstock category from agricultural or cattle-dung-based biogas (MoPNG 2023c). MSW is also the most institutionally under-tapped of India's major feedstock streams relative to its resource base, and the one whose mismanagement carries the most visible public cost - open dumping, landfill fires, leachate contamination, and methane emissions. Biogas production via anaerobic digestion offers a dual solution: waste management alongside renewable energy production. This aligns with Sustainable Development Goal (SDG) 7 (clean energy), SDG 11 (sustainable cities), and SDG 13 (climate action).

Therefore, biogas can be positioned as a strategic energy resource, a renewable source of carbon, a lever for energy security, and a tool for methane mitigation and nutrient recycling, all at once. However, despite schemes such as Galvanising Organic Bio-Agro Resources Dhan (GOBARdhan), Sustainable Alternative Towards Affordable Transportation (SATAT), and the National Bioenergy Programme (NBP), its adoption lags well behind its potential. The scale of this gap, and the government's own diagnosis of it, is visible in the policy record. SATAT was launched in October 2018 with a target of setting up 5,000 CBG plants by 2023–24, but as of 31 October 2022, only 38 CBG plants had actually been commissioned against 3,694 letters of intent (LOIs) issued (MoPNG 2022). This is a substantial gap. In light of this, on 6 August 2026 the Union Cabinet approved a restructured, ten-year ₹23,731 crore GOBARdhan National Circular Bioenergy Scheme, consolidating SATAT and four other CBG-related schemes into a single framework with assured offtake, administered pricing, and dedicated credit guarantees specifically to close the implementation gap between registered capacity and commissioned plants (Press Information Bureau [PIB] 2026a), a signal that the shortfall lies in implementation, not technology.

For this study, the CBG value chain has been dissected in depth to form the analytical framework used to identify at which point of the value chain (Figure 1) – technical, logistical, institutional, or financial – the constraints become binding. This study therefore analyses MSW-to-CBG as a six-stage value chain: (i) feedstock generation and aggregation; (ii) collection,

Figure 1: The CBG Production Value Chain



segregation, and transport; (iii) pre-processing and feedstock conditioning; (iv) anaerobic digestion and biogas capture; (v) gas upgrading and compression; and (vi) distribution and end use. A parallel digestate pathway extends from digestion to biofertiliser processing and agricultural application. For each stage, the analysis considers four dimensions: the principal technical constraint, the institutional actor responsible for managing it, the associated financial or commercial risk, and the policy instrument required to address that risk.

This allows the study to distinguish between constraints that can be solved through engineering and those that require changes in institutional design, contracting, or market architecture. The efficient integration of each stage is essential as it determines overall plant economics, methane recovery, environmental performance, and commercial viability. For MSW specifically, the first two stages – aggregation and segregation– were found to be a binding constraint on the entire chain, as the contamination introduced before the feedstock reaches the digester cannot be economically removed downstream without derating plant capacity or inflating operating expenditure (OPEX).

Problem Statement

- Why does India underutilise biogas potential despite favourable feedstock availability and existing subsidy schemes?
- In the CBG value chain, is the bottleneck technical, logistical, financial, regulatory, institutional, or awareness-driven?
- Should India prioritise decentralised or centralised biogas infrastructure? Does the answer differ for MSW versus agricultural or livestock feedstock?
- Is biogas being deployed in the right sectors and at the right scales?

Research Objectives

- Determine what type of waste makes the most sense for India's biogas production and examine the underlying rationale.
- Map existing waste-to-biogas policies (national and state-level) and identify overlaps and gaps.
- Evaluate the financial viability and subsidy structures for different scales (household, community, and industrial/CBG plants).
- Assess institutional coordination between (ULBs, state nodal agencies (SNAs), and central ministries (Ministry of New and Renewable Energy [MNRE], Ministry of Housing and Urban Affairs [MoHUA], MoPNG).
- Study barriers to farmer and entrepreneur participation (land, capital, and offtake guarantees).
- Benchmark Indian initiatives against successful global models (Germany, Sweden, and China).

Methodology

- A **landscape literature review** of the waste-to-CBG value chain.
- A **policy review:** a comparative analysis of central schemes (GOBARdhan, SATAT, and NBP) against state-level implementation.
- **Stakeholder interviews** with ULB officials, plant operators, farmers, and oil marketing companies (OMCs).
- **Case studies** of successful and failed biogas projects across states.
- **Cross-country benchmarking** of regulatory and incentive designs drawing from European Union (EU) and Chinese models.

Limitations of the study: Data availability on plant-level performance may be limited or inconsistent across states. Political-economy factors (e.g., the informal waste picker economy) may affect implementation feasibility.

Results and Discussions

Feedstock Generation, Aggregation, and Pre-Processing

India possesses one of the world's largest and most diverse biomass resource bases, giving it a significant comparative advantage for large-scale biomethane production. The country generates substantial quantities of agricultural residues, livestock manure, municipal solid waste, food waste, sewage sludge, press mud from sugar mills, distillery spent wash, poultry litter, and agro-industrial residues (Table 1). Much of this biomass remains underused or is disposed of through environmentally detrimental practices such as open burning, uncontrolled decomposition, or landfilling, resulting in considerable methane and particulate emissions. These organic biomasses, though often disposed of as waste, hold residual potential in the form of carbohydrates and nitrogen that can be valorised into biogas via anaerobic digestion, enabling waste-to-energy conversion. Unlike many developed economies that depend on dedicated energy crops, India's feedstock base is dominated by waste-derived biomass, aligning well with principles of the circular economy and resource efficiency. The availability of year-round feedstocks from agriculture, livestock, urban waste streams, and food processing industries provides opportunities for decentralised energy production while easing the burden of waste disposal.

Table 1: India's Feedstock Base Generation in MT/year for CBG: Agricultural Residues, Livestock Waste, Sewage-Derived Feedstocks, and Food-Processing Waste

India's CBG feedstock: from gross generation to usable potential

AGRICULTURAL RESIDUES	Gross crop residue generated ~500-200 MT/yr	Surplus after fodder, fuel & other uses ~230 MT/yr	Biomass power potential from surplus ~28 GW	CBG potential 20 MT/yr
LIVESTOCK WASTE (CATTLE DUNG)	Total livestock population 536.76 Million	Cattle: 193.46M Buffalo: 109.85M Goat: 148.89M Sheep: 74.26M Pigs: 9.06M		CBG potential 25 MT/yr
SEWAGE SLUDGE/ STP-DERIVED FEEDSTOCK	Sewage generated (urban centres) 72,368 MLD	Installed STP capacity (44%) 31,841 MLD	Acutally treated 20,235 MLD	CBG potential 10 MT/yr
FOOD PROCESSING WASTE	Sugar production, FY 2022-23 32.74 MT	Press mud + spent wash generated 11.4 MT	Operational sugar mills 531	CBG potential 2 MT/yr

Note: MT - Million Tonnes; MLD - Million Litres per Day

Source: MNRE; Central Pollution Control Board (CPCB), National Inventory of Sewage Treatment Plants, March 2021

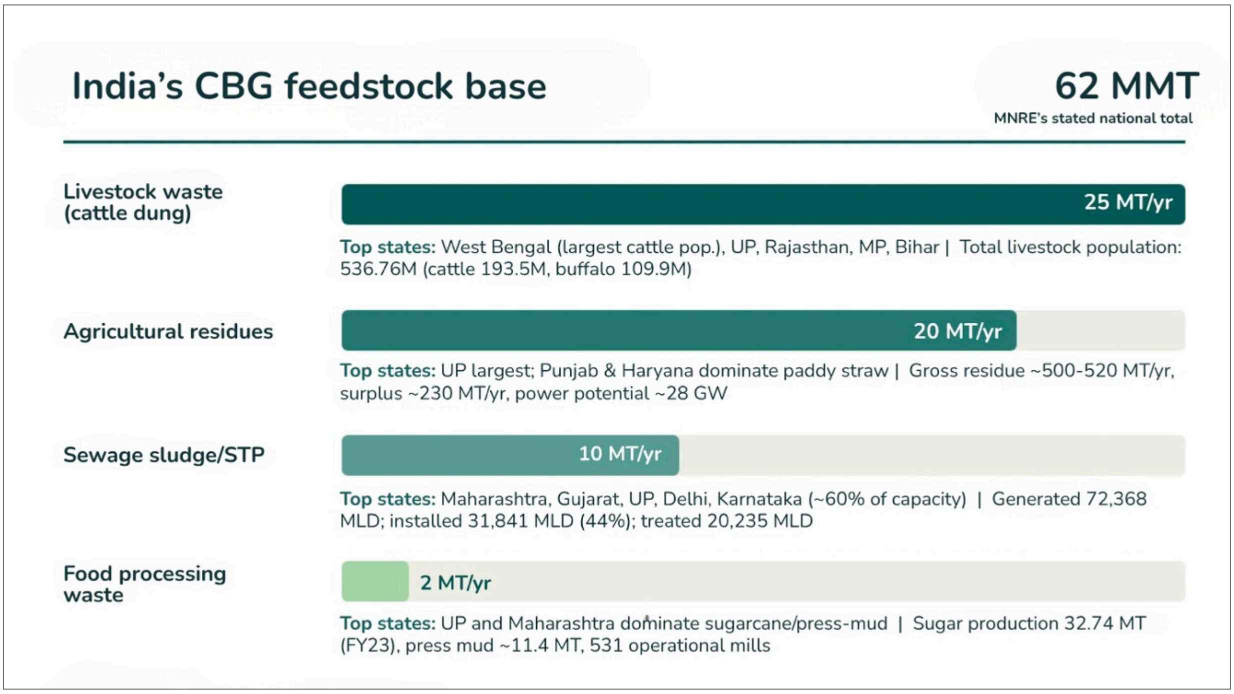
In addition to the variability in feedstock production, geographic distribution also varies significantly across the country (Figure 2). This makes it imperative to analyse the feedstock availability in a particular region for its valorisation. For instance, as per the National Biomass Atlas's state- and crop-wise breakdown, Uttar Pradesh generates the largest gross crop residue volume, followed by Punjab, Haryana, Gujarat, Madhya Pradesh, Karnataka, Andhra Pradesh, and Tamil Nadu as the next tier of surplus-residue states. Punjab and Haryana primarily dominate paddy straw specifically (the feedstock most linked to stubble-burning and to CBG plant-siting decisions). Meanwhile, West Bengal holds the largest cattle population nationally (per the 20th Livestock Census), overtaking the earlier leaders, Uttar Pradesh, Rajasthan, Madhya Pradesh, and Bihar. For sewage treatment plants (STPs), Maharashtra, Gujarat, Uttar Pradesh, Delhi, and Karnataka were found to together account for roughly 60 per cent of India's total installed STP capacity. On the MSW side, only five states/union territories (UTs) (Andaman & Nicobar Islands, Chhattisgarh, Lakshadweep, Odisha, and Tripura) had achieved 100 per cent source segregation as of the same Central Pollution Control Board

(CPCB) assessment, even though 14 states/UTs had achieved 100 per cent collection.

Feedstock Suitability for CBG Deployment in Cities

The above section on national estimates of biomass availability points to India's extensive resource base. However, this does not directly translate to feedstock that can support a commercially viable CBG plant. According to the National Biomass Atlas developed by the Sardar Swaran Singh National Institute of Bioenergy (SSS-NIBE) for the MNRE, India's surplus biomass availability is estimated at 230 million metric tonnes per annum, with an associated biomass power potential of about 28 GW (SSS-NIBE n.d.). This, however, tells us little about whether a specific city's waste stream is bankable. Being bankable means being reliably aggregable, transportable, processable, and deliverable at predictable quality and cost over a plant's operating life. The distinction between resource potential and bankable feedstock is thus central to project-level planning, since spatial concentration, seasonality, moisture, contamination, collection cost, competing uses, and storage requirements determine commercial viability far more than aggregate tonnage does. Feedstock streams differ sharply on these dimensions (Table 2).

Figure 2: India's Feedstock Categories and Their Geographic Distribution



Source: National Biomass Atlas, Livestock Census

MSW, produced about 65 million tonnes annually is abundant in urban centres but carries a very high contamination risk unless source-separated, favouring centralised or cluster-based deployment. Food and hospitality waste is similarly abundant in dense commercial clusters but has very high moisture content, making it better suited to decentralised wet digestion near large generators. Cattle dung is dispersed and best matched to household or community-scale systems. Agricultural residues are seasonal and require aggregation hubs and storage. Sewage sludge is reliably concentrated around treatment plants, favouring centralised processing.

This comparison shows that there is no single optimal feedstock or plant configuration for India; feedstock characteristics should instead determine both technology and spatial scale. This supports the central proposition of this paper that project planning should move from a technology-first to a feedstock-first approach, characterising the available waste stream, its catchment reliability, and competing uses before selecting conversion technology and scale. For MSW specifically, this matters because

Table 2: Comparison of Feedstocks Based on Availability, Seasonality, Contamination Risks, and Aggregability

Feedstock Suitability Profile

Relative rating across five operational dimensions, by feedstock category

Feedstock Category	Availability *Higher = better*	Seasonality *Higher = more fluctuation*	Contamination risk *Higher = more risk*	Aggregation difficulty	Moisture *Descriptive only*
MSW / Organic Fraction	High	Low	Very high	High	High
Food & Hospitality Waste	High	Low	Low-medium	Medium	Very high
Cattle Dung	High	Low	Low	Medium-high	High
Agricultural Residues	Very high	High	Low-medium	High	Low
Press Mud/Distillery Residues	High	Medium-high	Low	Low-medium	High
Sewage Sludge	not rated*	Low	Medium	Low	Very high
Poultry & Livestock Processing Waste	Moderate	Low	Low-medium	Medium	Medium-high

Availability, Seasonality, Contamination Risk, Aggregation Difficulty

Less favourable — More favourable

Source: Authors' own analysis

the usable organic fraction depends on collection and segregation performance, not on total waste generated. A city may generate sufficient waste in absolute terms while failing to generate sufficient bankable feedstock due to contamination, re-mixing, or inadequate source segregation.

In this sense, waste segregation emerges as feedstock infrastructure for a CBG plant, rather than as a parallel municipal service. The analysis consequently frames the principal scaling problem as a value-chain coordination problem. The central question is not whether India possesses the technology to convert organic waste into biomethane, but whether the institutions responsible for generating, collecting, segregating, processing, financing, and purchasing that biomethane are sufficiently aligned to create a predictable and bankable system.

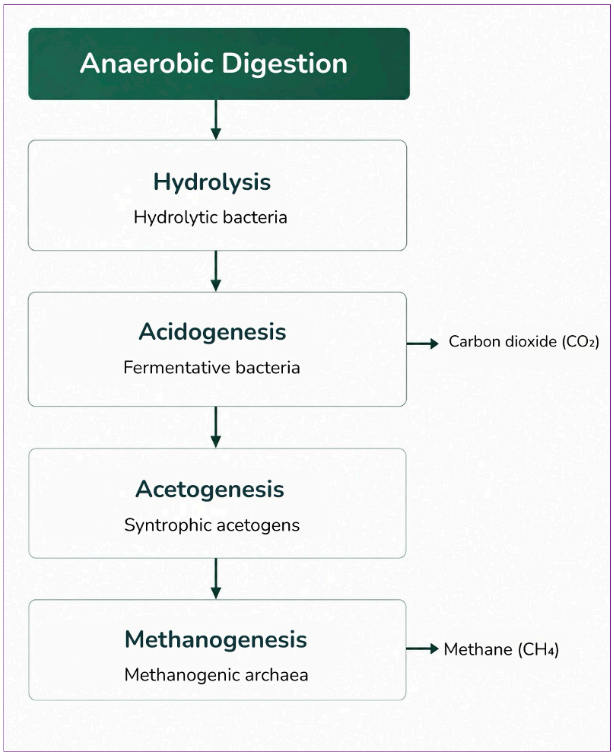
Technical Basis for CBG Production

The technical pathway for conversion of feedstock to CBG upstream requires hydrolysis and anaerobic digestion of the feedstock. Once produced, the downstream steps involve purification, compression, and storage.

Anaerobic Digestion of Organic Feedstock

The production of CBG rests on a sequence of biological and engineering processes that collectively transform heterogeneous organic waste into methane. The process begins with feedstock collection, segregation, size reduction, and homogenisation to ensure uniform substrate characteristics before feeding into anaerobic digesters. Anaerobic digestion comprises four sequential microbial stages: hydrolysis, acidogenesis, acetogenesis, and methanogenesis (Figure 3), during which complex organic polymers are progressively converted into methane and carbon dioxide under controlled mesophilic (30-40°C) or thermophilic (40-60°C) operating conditions (DelaVega-Quintero et al. 2025).

Figure 3: Schematic Representation of the Process of Anaerobic Digestion



The resulting raw biogas is then purified using technologies such as pressure swing adsorption (PSA), water scrubbing, chemical absorption, membrane separation, or cryogenic upgrading to remove carbon dioxide and trace contaminants (Galloni and Di Marcoberardino 2024). Following purification, the biomethane is compressed into CBG for storage, transportation, or injection into gas networks. Simultaneously, the digestion process generates a nutrient-rich digestate in addition to the gas. This digestate can be processed into solid or liquid biofertilizers, thereby closing nutrient loops and enhancing circular resource utilisation (Thomas, Haefele, and Adler 2026).

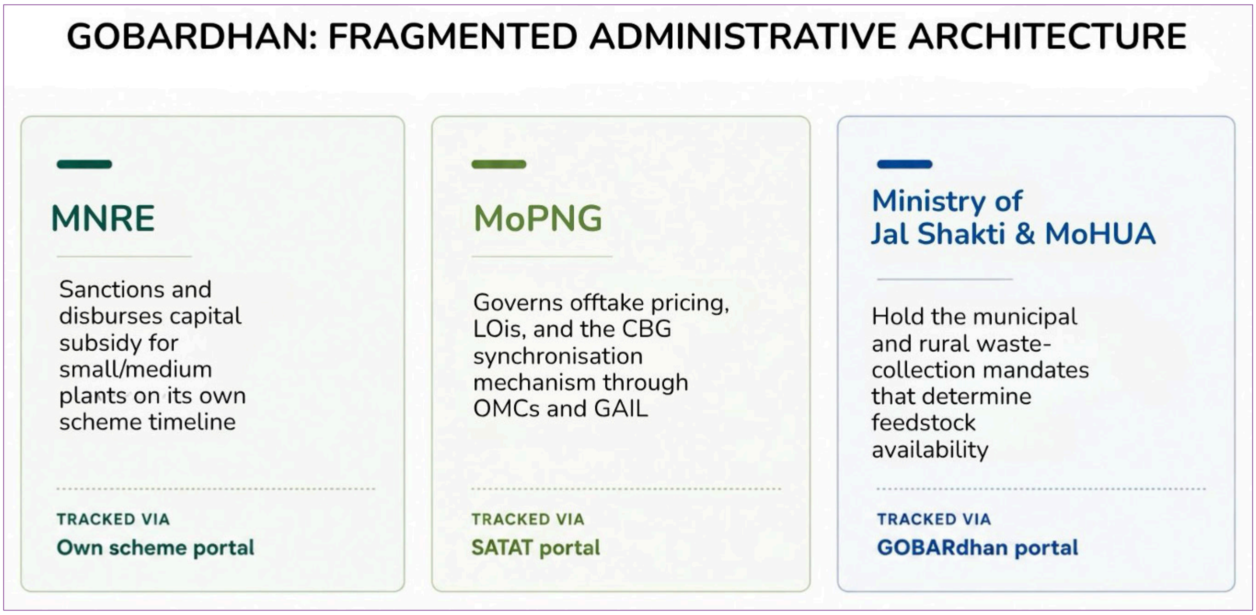
While the process of anaerobic digestion remains broadly similar across all types of organic waste, the value chain diverges significantly for MSW from agricultural or livestock feedstock chains at the very first step. This is because MSW arrives as a mixed and contaminated stream rather than a homogeneous input, unlike single-source agricultural residues or dairy manure. This means segregation quality, not digester technology, is usually the binding constraint on methane yield for MSW-based plants specifically. The Bureau of Indian Standards' (BIS') IS 16087:2016 sets the CBG product-quality specification, requiring a minimum methane content of 90.0 per cent regardless of feedstock source (BIS 2016). Because this output threshold is fixed and feedstock-agnostic, MSW plants, unlike agri- or dairy-fed plants that start from cleaner inputs, must compensate for contamination and heterogeneity earlier in the chain, which places the segregation and pre-processing burden squarely on upstream stages before the gas ever reaches the digester.

Pre-Processing and Hydrolysis of the Wastes

The physical and mechanical preparation of MSW before it enters the digester is where most of the yield and reliability losses reported by Indian CBG operators actually originate. As per the Central Public Health and Environmental Engineering Organisation's (CPHEEO) Manual on Municipal Solid Waste Management, a typical mixed-waste-to-energy line before the biological treatment requires: mechanical screening (trommels) to separate the organic fraction from oversized and rigid contraries such as plastics, textiles, and construction debris by particle size; magnetic and eddy-current separation to remove ferrous and non-ferrous metals ahead of downstream equipment, protecting pumps and mixers from damage; and further segregation and size-reduction steps to homogenise the feedstock before it reaches a digester or composting unit (CPHEEO 2016). Because India's mixed MSW typically arrives wetter and more putrescible than European source-separated organics, moisture and total-solids correction is an additional and locally distinctive requirement, whether through dilution with process water or digestate recirculated for wet digestion, or by retaining higher solids content for dry/high-solids digestion (Breitenmoser et al. 2019).

Indore's plant further illustrates why this stage is extremely decisive. A one-year waste-characterisation survey conducted ahead of the city's Gobardhan Bio-CNG project found that, owing to the city's near-complete source segregation, the wet organic fraction reaching the plant carried 20–30 per cent total solids and 85–90 per cent volatile solids, with only 0.5–-0.9 per cent rejected after

Figure 4: Overview of the Three Ministries Handling the Administrative Architecture for Biogas



pre-processing (Department of Economic Affairs [DEA] n.d.). That reject rate is an order of magnitude below what mixed, unsegregated MSW pre-processing lines typically achieve, and it is the direct, measurable output of upstream segregation quality rather than of any difference in digester design. This further reinforces the paper's broader argument that pre-processing and segregation – not digester technology – are the binding constraint on CBG yield from Indian MSW.

High Solids and Two-Stage Digestion for Indian MSW

High-solids anaerobic digestion (HSAD) operates at 20-40 per cent total solids, compared with under 15 per cent for conventional 'wet' digestion, and is the dominant design choice internationally for source-separated or mechanically segregated MSW organics because it needs a smaller reactor volume per tonne of waste and produces a drier, easier-to-handle digestate – a challenge for the Indian type of MSW.

Two established proprietary formats, DRANCO-type plug-flow dry digesters and Kompogas-type horizontal plug-flow reactors, both run thermophilically at 14-day retention times and are widely deployed on the organic fraction of municipal solid waste (OFMSW) in Europe and Asia. A two-stage configuration comprising an acidogenic (hydrolysis/acidogenesis) reactor feeding a separate methanogenic reactor decouples the fast-acidifying first phase from the slower methanogenic phase, which stabilises the process against the organic-loading shocks typical of MSW whose composition varies day to day; comparative trials on high-moisture MSW have reported roughly 25-30 per cent higher methane yield from two-stage over single-stage digestion at equivalent organic loading (Markphan et al. 2020). For India, where MSW composition is more heterogeneous and wetter than the pre-source-separated organics typical of European HSAD plants, a hybrid configuration, combining high-solids digestion of the coarser organic fraction with a wet, two-stage line for kitchen and hospitality waste, is likely to outperform a single uniform digester design, reinforcing the spatial and technological matching logic set out above.

Odour control is the technology dimension most consistently under-specified in Indian MSW-to-biogas project design, yet it is often the deciding factor in whether a plant retains its social licence to operate near residential areas. Standard mitigation is a combination of negative-pressure enclosure of the tipping and pre-processing halls (so odorous air is drawn into treatment rather than escaping), biofiltration or chemical/wet scrubbing of the extracted air, and covered or in-vessel composting for any digestate that is aerobically finished on site. None of these are exotic technologies, but together they add 5–10 per cent to capital expenditure (capex) that MSW-to-CBG project financing models do not always price in at the detailed project report (DPR) stage – a gap that could be usefully flagged to MNRE and MoHUA for inclusion in future viability-gap-funding (VGF) norms.

Current Policy Architecture for Biogas

India's biogas policy architecture spans at least three ministries, now nominally unified under GOBARdhan. Launched in April 2018 under the biodegradable waste management component of Swachh Bharat Mission-Grameen (SBM-G), the initiative aimed to help villages convert cattle and organic waste into biogas, CBG, and biofertiliser through decentralised systems (Department of Drinking Water and Sanitation [DDWS] 2018). GOBARdhan is now coordinated by the DDWS alongside MNRE, MoPNG, and the Departments of Animal Husbandry & Dairying and Agriculture & Farmers Welfare, spanning MNRE's Waste to Energy Scheme, MoPNG's SATAT scheme, SBM(G) Phase II, and allied agri-infrastructure funds. Over 650 plants had registered on its unified portal (launched February 2021) by mid-2023 (DDWS 2023). Despite convergence under the GOBARdhan brand, the underlying administrative architecture has remained fragmented across the MNRE, MoPNG, Ministry of Jal Shakti (MoJS), and MoHUA (Figure 4). Each ministry maintains its own sanctioning cycle and data system, which produces the plant-count discrepancies seen across official releases and compounds financing and feedstock risk for developers who must satisfy three separate approval chains before a plant becomes bankable. The latest reforms of the GOBARdhan scheme have resolved this by making MoPNG the nodal ministry. However, eligibility and applicability vary across individual support components, making convergence with MoHUA/SBM-U particularly important for MSW-based CBG projects. SBM(G) Phase II, under which GOBARdhan sits, was notified for financial year (FY) 2020-21 to FY 2024-25 with a ₹1,40,881 crore outlay to sustain open-defecation-free (ODF) status and cover villages with solid/liquid waste management, turning biogas conversion into one component of a larger rural sanitation push, rather than a standalone energy scheme (DDWS n.d.).

SATAT, run by MoPNG, functions as CBG's market-pull mechanism: OMCs issue offtake LOIs, and CBG is delivered at 250 bar, priced against CNG's retail rate (Indian Oil Corporation Limited [IOCL] n.d.). MNRE's NBP (notified 2 November 2022, FY 2021-22 to FY 2025-26) disburses capital subsidies via three schemes by plant size: NNBOMP (small), BPGTP (medium), and Waste to Energy (large) (MNRE n.d.; Prime Minister's Office 2022).

The key gap, in all this, remains demand certainty. This is now partly closed via a CBG Blending Obligation (CBO) on city gas distribution (CGD) entities, approved by the National Biofuels Coordination Committee: CBG must reach 1 per cent, 3 per cent, and 4 per cent of CNG/PNG consumption in FY 2025-26 to FY 2027-28, rising to 5 per cent from FY 2028-29. This runs through the CBG-CGD Synchronisation Scheme, under which GAIL co-mingles CBG with domestic gas at a Uniform Base Price for CGDs (MoPNG 2023a; 2023b). Government estimates put potential investment at ₹37,500 crore and 750 new CBG projects by 2028-29 (MoPNG 2023b). The Union Budget 2026-27 further excludes biogas's full value from excise duty calculations on blended CNG (Ministry of Finance 2026).

The MSW-Specific Legal and Contractual Architecture

For MSW-to-CBG projects, the schemes discussed above sit atop a distinct legal foundation that agricultural- or dairy-feedstock plants do not need to navigate: the SWM Rules, 2016, notified by the Ministry of Environment, Forest and Climate Change (MoEFCC) under the Environment (Protection) Act, 1986 (MoEFCC 2016). These rules impose source-segregation duties directly on waste generators, with heightened obligations placed on bulk generators, and assign primary collection and processing responsibility to ULBs (MoEFCC 2016, Rules 4, 15). Rules 15(c) and 15(d) are especially important, as they provide the specific statutory hook for integrating waste-pickers into formal collection systems. For this, local authorities are required to establish a system to recognise organisations of waste pickers or informal waste collectors and to integrate them into solid waste management, including door-to-door collection. This also has to be accompanied by facilitating the formation of self-help groups (SHGs), issuing identity cards, and encouraging their integration into the system (MoEFCC 2016, Rule 15(c)–(d)).

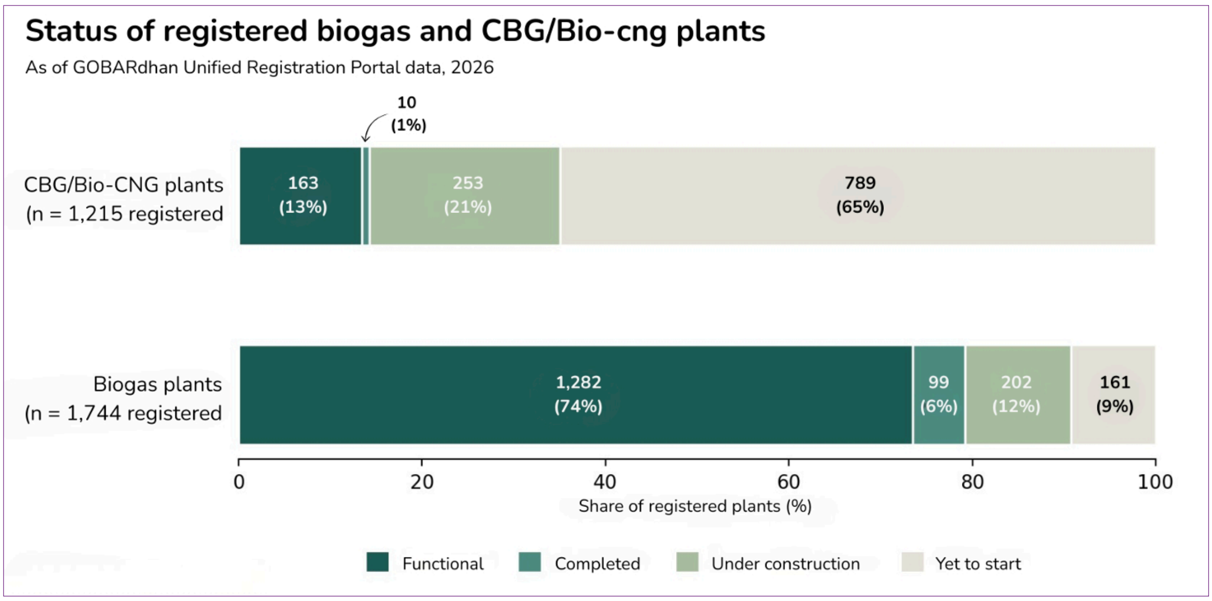
The consultations also converged on a consistent diagnosis: India's MSW management challenge is not primarily one of regulatory design but of implementation. The existing framework, anchored in the SWM Rules, was widely judged by experts as structurally adequate, yet undermined at the operational level by three compounding failures. First, municipalities lack the capital to deploy dedicated segregated-collection fleets, forcing mixed transport even where source segregation has occurred. Second, the prevailing tonnage-based payment structure for transporters creates a perverse incentive: operators are rewarded for volume moved, not for the integrity of segregation maintained, resulting in systematic re-mixing between the collection point and the processing facility. Third, an unresolved dispute over transport responsibility between ULBs and private operators, with ULBs frequently offloading costs onto operators, creates institutional friction that further erodes the quality of segregation.

Compounding this, material recovery facilities (MRFs) established under the Swachh Bharat Mission remain under-scaled relative to the volumes generated, limiting their capacity to correct upstream segregation failures downstream. Taken together, these findings support the experts' framing of waste management reform as a two-decade undertaking rather than a short-term fix, and back their call for an explicit waste hierarchy: composting, biogas, and recycling prioritised, with incineration and landfilling positioned strictly as last-resort options. This hierarchy functions as a corrective lens for capital allocation, redirecting investment away from end-of-pipe disposal infrastructure and toward the segregation and transport systems that determine whether upstream technologies can function at all.

PPP and Financing Architecture

Because MSW-to-CBG projects require the ULB to grant land, waste-supply rights, and often co-location with existing civic infrastructure, they are

Figure 5: Number of Biogas and CBG/Bio-CNG Plants



Source: GOBARdhan portal data

almost universally structured as public–private partnerships (PPPs) rather than pure private investment. In this sense, the Indore model offers India's most extensively documented precedent, recorded on the Government of India's official PPP repository maintained by the DEA (n.d.). Two distinct financing instruments emerge from this record and merit separate treatment rather than being read as a single template.

The first is a viability-gap-funded, small-scale model: Indore's original 15 tonnes per day (TPD) and 20 TPD bio-methanation units were installed under a PPP model at capital costs of ₹6.5 crore and ₹9 crore respectively, backed by VGF of ₹10 crore, aimed at supplying cleaner fuel to public transport (DEA n.d.). This structure suited smaller, mandi-waste-based feedstock streams where private capital alone was insufficient to close the viability gap.

The second, and larger, instrument is a zero-ULB-capital concession. Indore's 550 TPD Gobardhan Bio-CNG plant, inaugurated in February 2022, was structured as a special purpose vehicle (SPV), Indore Clean Energy Pvt Ltd, established by the Indore Municipal Corporation together with Indo Enviro Integrated Solutions Ltd. under a PPP model, with 100 percent capital investment of ₹150 crore contributed by the private partner (Prime Minister's Office 2022). Under this structure, the Corporation purchases a minimum of 50 per cent of the CNG produced to fuel 400 city buses (Prime Minister's Office 2022). The same official PPP record confirms the revenue-sharing terms: the Indore Municipal Corporation made zero capital investment yet earns a premium of ₹2.52 crore annually, while procuring at least 50 per cent of CNG output at ₹5 per kilogram below prevailing market rates (DEA n.d.).

Read together, these two government-documented instruments show that the 'Indore model' is best understood not as one replicable template but as two structurally distinct PPP designs, a subsidy-dependent model for smaller decentralised plants and a fully privately capitalised, premium-and-offtake concession for larger integrated facilities, each suited to a different feedstock scale and municipal risk appetite. This distinction has direct implications for replication: municipalities with limited fiscal space but assured smaller waste streams may find the VGF-subsidised route more feasible, while those able to offer large, reliable feedstock volumes and offtake guarantees can attract fully private capital on Indore's larger-scale terms.

BioE3 and the Clean-Molecule Alignment Question

The Biotechnology for Economy, Environment, and Employment (BioE3) Policy, approved by the Union Cabinet on 24 August 2024, was framed by the Department of Biotechnology (DBT) around six thematic sectors: bio-based chemicals and enzymes; functional foods and smart proteins; precision biotherapeutics; climate-resilient agriculture; carbon capture and its utilisation; and futuristic marine and space research (PIB 2024). Anaerobic digestion and CBG are, however, conspicuously absent from this list. The policy does engage waste-to-value pathways, primarily through carbon capture and utilisation and bio-based chemical synthesis, rather than through biomethane production or blending infrastructure – a gap that matters for MSW-to-CBG project sponsors looking to this policy for support.

What BioE3 offers the biogas sector is, in practice, upstream rather than downstream. The policy is implemented by the DBT jointly with the Biotechnology Industry Research Assistance Council (BIRAC), through a national network of biofoundries, biomanufacturing hubs, and bio-AI hubs that provide start-ups, small and medium-sized enterprises (SMEs), industries, and academia with shared infrastructure and resources for pilot- and pre-commercial-scale biomanufacturing (PIB 2024). Enzyme development sits explicitly within the policy's first thematic sector, and the biomanufacturing hub network is designed to support scale-up of exactly this kind of microbial and enzymatic research and development (R&D). This creates a plausible, if indirect, upstream contribution to MSW-CBG value chains: enzyme and microbial-consortia research that could raise digestion yields, and co-location within a biomanufacturing hub that plausibly extends to digestate-to-biofertiliser upgrading, given the hub network's stated remit over fermentation and biofertiliser-reagent manufacturing.

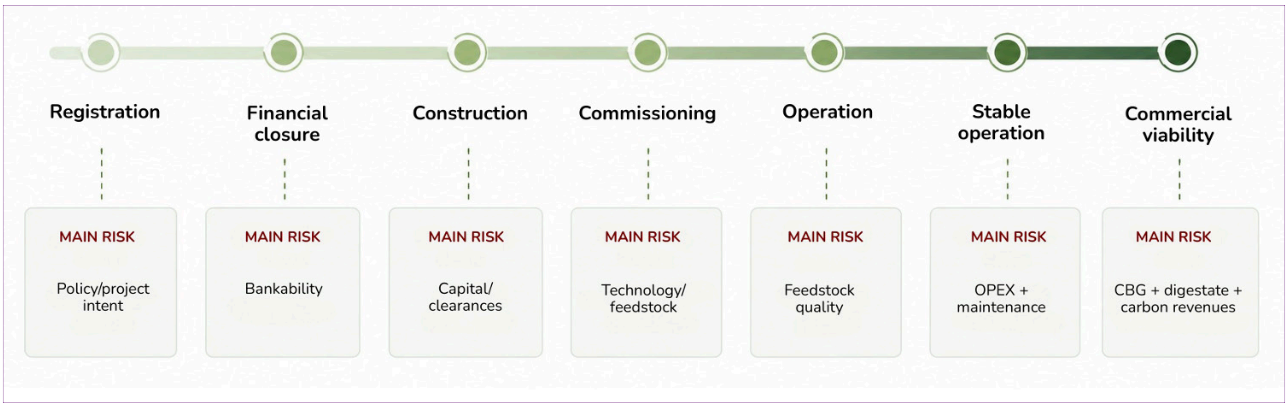
BioE3 offers no coordination with the ministries governing CBG offtake, blending, and feedstock policy. It thus adds a fourth ministry-level touchpoint (DBT, alongside the MNRE and MoPNG) without resolving this coordination gap. Genuine alignment would require an explicit Memorandum of Understanding (MoU) or joint working group between DBT and MNRE/MoPNG directing BioE3-funded R&D toward biomethane-relevant applications.

Current Status of India's Biogas Production

The live data from the GOBARdhan Unified Registration Portal, which is operated by the DDWS, shows 1,744 registered biogas plants nationally, of which 1,282 are functional, 99 are completed, 202 are under construction, and 161 are yet to start, across 569 districts (GOBARdhan Portal 2026). For CBG/Bio-CNG, 1,215 plants are registered, with only 163 functional and 10 completed, 253 under construction, and 789 yet to start, across 220 districts (GOBARdhan Portal 2026) (Figure 4).

This sits close to the Cabinet's own aggregate: as of 6 August 2026, 1,928 plants were registered, including 217 commissioned, producing 0.4 million metric standard cubic metres per day (MMSCMD), and 339 under construction (PIB 2026a). The large share of CBG projects still yet to start (789 of 1,215, roughly two-thirds) is the single most telling feature of these data. It suggests the binding constraint lies not in generating policy interest but in the transition between registration, financial closure, feedstock assurance, construction, and commissioning. Registrations can build a large nominal project universe without a commensurate rise in commercially available biomethane, pointing to a pipeline-to-performance gap. Programme success should therefore be assessed across successive stages – registration, financial closure, construction, commissioning, stable operation, and capacity utilisation – each representing a distinct potential failure point (Figure 5).

Figure 6: CBG Product Stages from Registration to Commercial Viability with Corresponding Failures at Each Stage (Author's analysis)



This is also consistent with the historical record under SATAT, launched in October 2018 with a target of 5,000 CBG plants producing 15 million metric tonnes (MMT) annually by 2023–24 (Prime Minister's Office 2022). Commissioning fell far short: by 31 October 2022, Oil and Gas Marketing Companies had issued 3,694 LOIs, but only 38 plants had been commissioned (MoPNG 2023b). The subsequent expansion of financial support, blending obligations, and restructuring into the unified GOBARdhan framework can therefore be read as a policy response to this intention-to-deployment gap (PIB 2026a). India's next phase of biogas policy should therefore be evaluated less by registration numbers and more by how effectively projects move through the pipeline: commissioning rates, feedstock utilisation, capacity utilisation, downtime, digestate sales, and project-level financial performance.

Table 3: Comprehensive Overview of the MSW-CBG Value Chain, Principal Constraints, Key Institutional Actors, Major Consequences for the Project, and Policy/Financial

Value-Chain Stage	Principal Constraint in MSW-to-CBG	Key Institutional Actor(S)	Consequence for Projects	Policy/ Financial Response
Feedstock Generation and	Fragmented and variable organic-waste supply	Households, commercial generators, ULBs	Uncertain feedstock availability	Segregation mandates, aggregation contracts
Collection, Segregation and Transport	Re-mixing of segregated waste; inadequate dedicated fleets	ULBs, private collection operators, waste pickers	High contamination and loss of usable organics	Performance-linked collection contracts, dedicated transport systems
Pre-Processing and Conditioning	Plastics, metals, inert material, moisture variability	Plant operators, MRF operators	Higher OPEX, equipment damage, lower digester loading	MRF investment, pre-processing standards, VGF support
Anaerobic Digestion	Feedstock variability, loading shocks, inappropriate technology selection	Plant developers/ operators	Lower methane yield, instability, downtime	Feedstock-specific technology selection and operational standards
Upgrading and Compression	Energy consumption and contaminant removal	Plant developers/ operators	Higher operating costs; quality non-compliance	Technology optimisation, quality standards, financing support
Distribution and End Use	Demand uncertainty and price risk	OMCs, CGD entities, industrial/ transport users	Weak project bankability	CBG blending obligations, offtake agreements, market development
Digestate Management	Variable quality and limited market demand	Plant operators, farmers, fertiliser agencies	Loss of potential secondary revenue	Quality standards, market development assistance, assured demand

Source: Authors analysis

Analytical Synthesis: Where Does the MSW-to-CBG Value Chain Break?

From the sections discussing various facets of the MSW-to- CBG value chain, it is clear that a technically efficient digester cannot compensate for unreliable feedstock quantity, excessive contamination, and weak aggregation systems. Conversely, improvements in upstream waste management can substantially improve the performance and economics of downstream biological and gas-upgrading systems. Based on a synthesis of principal constraints in the value chain, key institutional actors for each segment, and the consequences that attach to each, this study has compiled the appropriate policy and financial responses to mitigate them (Table 3).

Cross-Country Benchmarking: Germany, Sweden, and China

India's MSW-to-CBG trajectory has been benchmarked against three structurally different biogas/biomethane markets: Germany, Sweden, and China. This is done to pin down which policy design choices are transferable and which are conditioned on country-specific institutional or resource endowments.

Germany

Germany's biomethane sector is governed through a centrally administered auction and assured offtake mechanism. Germany's energy regulator, the Bundesnetzagentur (Federal Network Agency), sets an annual ceiling price for biomethane installations competing in auctions under the Renewable Energy Sources Act (EEG). In its official English-language press release, the Bundesnetzagentur confirmed that a ceiling of 23.13 cents per kilowatt hour (kWh) will apply to biomethane installations in the 2026 auctions, the highest possible price ceiling within the limits of its statutory scope, after no bids were submitted in the previous year's biomethane auctions (Bundesnetzagentur 2026). This willingness to lift the price ceiling by the maximum legally permitted margin after a failed auction round illustrates a regulator actively recalibrating price signals to keep a competitive market functioning, a tool India's administered CBG pricing under GOBARdhan does not yet employ in the same adaptive way.

On production scale, the International Energy Agency's (IEA's) Renewables 2025 report states that biogas production, used primarily for electricity and combined heat and power (CHP) generation, is highly concentrated in Germany, accounting for 53 per cent of EU production, while Germany also accounts for 29 per cent of EU biomethane production (IEA 2025). Germany's feedstock base, however, remains dominated by energy crops and agricultural co-substrates rather than MSW, which limits direct comparability to India's MSW-oriented programme design.

Sweden

Sweden offers the clearest waste-to-transport-fuel precedent among the three, and is comparatively the most policy-relevant to MSW-linked CBG, given its historic reliance on sewage sludge and organic waste rather than energy crops. The IEA Bioenergy Technology Collaboration Programme's Sweden country report, prepared with the Swedish Energy Agency, notes that in Sweden, biogas and biomethane use is already equivalent to 21 per cent of total gas consumption, a substantially higher share than in most European countries, reflecting both strong biogas deployment and Sweden's relatively low reliance on natural gas overall (IEA Bioenergy 2024).

The IEA's official Energy Policy Review: Sweden 2024, conducted jointly with the Swedish government, further documents that Swedish refineries have already begun converting production toward biofuels, and forest-industry combined heat and power generation, fuelled by biomass by-products, has been incentivised through Sweden's participation in the EU Emissions Trading System (IEA 2024). Sweden's biogas is predominantly upgraded and used as vehicle fuel rather than for grid blending, a demand-side structure shaped by sustained public investment in gas-vehicle refuelling infrastructure. This suggests that assured offtake and price certainty, while necessary, are not sufficient without matching investment in end-use infrastructure – a lesson directly relevant to India's city gas distribution network build-out under GOBARdhan.

China

China offers the most institutionally comparable case to India in terms of scale ambition and multi-ministry coordination, and is useful precisely because it demonstrates a coordination model India currently lacks. China's State Council, through its official English-language news portal, reported that the goal for the country's annual biogas output is set at over 10 billion cubic metres by 2025, and over 20 billion cubic metres by 2030, according to a guideline jointly released by the National Energy Administration and nine other central departments (The State Council of the People's Republic of China 2019). This joint issuance by ten central government bodies is itself a notable institutional design feature: rather than housing biomethane policy within a single nodal ministry, China built in cross-ministerial ownership from the outset, in marked contrast to the fragmented DBT-MNRE-MoPNG landscape discussed earlier in this paper for India.

This 2030 target of 20 billion cubic metres is independently confirmed in the open-access, peer-reviewed literature: an MDPI Sustainability article on China's biogas sector notes that the purification of biogas into biomethane is a vital aspect of energy recovery via biogas, with China targeting over 20 billion cubic metres of biomethane per year by 2030, though biogas energy recovery is currently constrained by the high cost of gas production, cumbersome management, and limited policy support (Wang et al. 2023). This last point, cost and management complexity limiting the realisation of an ambitious central target, mirrors the registration-to-commissioning gap documented for India's own CBG pipeline.

Read together, these three cases suggest that India's institutional fragmentation across the DBT, MNRE, and MoPNG is not a universal feature of national biogas policy design. China's ten-ministry joint guideline demonstrates that formal cross-ministerial ownership can be established at the outset rather than retrofitted. Germany's auction-based ceiling-price mechanism offers a market-tested, adaptively recalibrated alternative to flat administered pricing for de-risking project finance. Sweden's experience shows that offtake certainty must be matched by demand-side infrastructure investment, not treated as sufficient on its own. None of the three, however, offers a waste-to-CBG feedstock model as MSW-centric as India's emerging GOBARdhan framework, which means India's implementation challenge – converting registered MSW-based projects into commissioned, operating plants – remains a comparatively unprecedented policy problem internationally.

Synthesis, Challenges, and Way Forward

India's biogas sector is held back not by a lack of technology or policy but by weak implementation. Although the SWM Rules, 2016 provide a clear framework for waste segregation and collection, gaps in implementation continue to weaken the quality and reliability of feedstock for biogas plants. Municipalities often lack the capital for dedicated segregated-collection systems, while tonnage-based payments to transporters create little incentive to maintain segregation. At the same time, unresolved cost-sharing disputes between ULBs and plant operators can push costs downstream, further denting feedstock quality.

While 14 states/UTs reported 100 per cent waste collection, only five achieved 100 per cent source segregation. At the national level, only 54 per cent of daily MSW generated was processed. Financing remains another constraint as banks continue to view CBG projects cautiously owing to relatively thin margins. Under SATAT, the gap between ambition and deployment has also been significant, with only 40 plants operational against the target of 5,000 plants at the time of the 2022 Parliamentary Committee review.

The challenge is therefore systemic. Feedstock aggregation and financing are the immediate bottlenecks, while fragmented responsibilities across the MNRE, MoPNG, MoHUA/MoJS, and other institutions create a deeper structural constraint. The introduction of DBT under BioE3 adds another institutional stakeholder, making coordination even more important. This study also shows that solutions work best when matched to local feedstock, geography, and institutional capacity, rather than applied uniformly. Indore demonstrates this particularly well through its wet-dry waste segregation model that is aligned with local feedstock characteristics and collection systems, enabling more reliable supply to processing facilities. The approach also highlights the importance of integrating existing waste-management systems. Waste pickers, for example, already play a critical role in segregation and should be formally integrated into municipal systems rather than displaced. The way forward should therefore focus on strengthening the systems around biogas plants, rather than simply increasing plant capacity.

Therefore, going forward, the following priority areas have emerged:

- Treat segregation as feedstock infrastructure: Link source-segregation targets and municipal performance to reliable feedstock supply contracts.
- Fix transport incentives: Move away from tonnage-based payment systems and resolve ULB-operator cost-sharing disputes.
- Strengthen offtake certainty: Reinforce CBG purchase obligations and develop blended-finance mechanisms, drawing on Germany's adaptive pricing approach and Sweden's demand-side experience.
- Improve institutional coordination: Establish a joint MNRE–MoPNG–MoHUA/MoJS–DBT working group, drawing on China's more coordinated, multi-ministry approach.
- Match plant models to feedstock geography: Use decentralised systems where feedstock is dispersed and centralised plants where large, consistent MSW streams are available.
- Replicate successful PPP models: Adapt Indore's approach through VGF for smaller municipalities and zero-capital concession models for larger cities.
- Account for overlooked costs: Incorporate odour control, MRF expansion, and other essential infrastructure costs into VGF norms.
- Build monitoring, reporting and verification (MRV) and carbon-market readiness into plant design: Ensure that plants are designed from the outset to measure emissions reductions and participate in carbon-certification mechanisms.

Ultimately, India's biogas challenge turns less on building new capacity, and more on building the systems that let existing and future plants operate reliably. Reliable feedstock, viable financing, assured offtake, and coordinated institutions will determine whether India's biogas ambitions translate into a functioning circular bioeconomy.

Conclusion

India has the feedstock base, the technology, and even the policy architecture needed to scale MSW-to-CBG production. What it lacks is coordinated execution. The binding constraint is not digester technology but upstream segregation and aggregation, compounded by fragmented institutions, misaligned transport incentives, and thin project financing. Closing this gap requires treating segregation as feedstock infrastructure, aligning ministries under a single coordination mechanism, and matching plant models to local waste characteristics rather than applying uniform templates. Indore shows that this can be done at scale. The task now is deliberate replication. •

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Annexure I

Name	Organisation	Designation
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Mr Dhiraj Santdasani	C40 Cities	Technical Advisor, Waste and Methane
Mr Naim Keruwala	C40 Cities	Regional Director, South and West Asia
Mr Lav Kumar	Centre for High Technology (CHT)	Additional Director
Mr Suneel Pandey	TERI (The Energy and Resources Institute)	Senior Fellow & Director, Environment & Waste Management (Circular Economy & Waste Management) Division
Prof. Arun Kansal	TERI School of Advanced Studies	Professor & Director, ICWMR (Centre for Waste Management and Research)
Dr Atul K.	TERI School of Advanced Studies	Scientist, Department of Natural and Applied Sciences
Prof. O. P. Agarwal	ISPP, Artha Global (formerly CEO, WRI India)	Professor of Practice / Distinguished Fellow / Senior Fellow
Dr Dilip Kumar Khare	World Biogas Association (WBA) India (formerly Advisor, MNRE)	Technical Advisor & Founding Director
Mr Rajnath Ram	NITI Aayog	Adviser (Energy)
Prof. Jagan Shah	TRIPC IIT Delhi	Professor of Practice

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