Waste to Energy

Case study

The second phase of the CapaCITIES project (2019 – 2024)focuses on mainstreaming climate action in Indian cities and states by enhancing their capacities to adopt integrated climate resilient planning, implement concrete climate actions, structure sustainable bankable projects, design innovative finance mechanisms,and develop climate resilience infrastructure. The project is in its 2nd phase and 4 additional cities, two from Tamil Nadu and Gujarat are added. The partner cities are Coimbatore, Tiruchirappalli, and Tirunelveli in Tamil Nadu, Rajkot, Ahmedabad, and Vadodara in Gujarat, Siliguri in West Bengal, and Udaipur in Rajasthan. Gujarat and Tamil Nadu are also receiving state-level technical assistance. The project will focus on planning, implementing, and financing in the areas of biodiversity, energy, transport, waste, and water management, where Switzerland has proven expertise, in close collaboration with Indian experts.

The Phase II of the CapaCITIES project is supporting the on-ground implementation of the climate action scaling up the pilot project implemented in Phase 1. One such project under implementation is scaling up a pilot, 1.5 TPD bio methanation project to 200 tonnes/day (TPD) waste to Bio CNG solution for Coimbatore. The project would significantly reduce GHG emissions which includes methane which is one of the powerful greenhouse gas (GHG), contributing to the formation of ground-level ozone, a serious environmental and health pollutant, and a greenhouse gas that causes one million preventable deaths annually. Methane is also 80 times more potent than carbon dioxide (CO_2) at warming over a 20-year period. In addition, the project will also reduce waste management costs for the city.

Waste to Bio CNG Solution - Coimbatore

Waste to Bio CNG Solution implementation in India

India is rapidly urbanizing. Urban India accounted for 11.4% of the country's population in 1901. This increasedto 28.53% in 2001, surpassed 30% in 2011, and reached 31.16% in 2018. The Government of India is dedicatedto lowering greenhouse gas emissions and ensuring long-term urban development. Cities consume more than two-thirds of global energy and emit more than 70% of global CO2. Cities' carbon footprint will only grow as they are expected to occupy more than 60% of the global population by 2030. As a result, waste generation is significant, and facilities are overburdened. Since many communities lack municipal waste processing facilities or dump sites, open burning or unmanaged landfills are the only options. Door-to-door collection and transportation absorb 80% of Municipal Solid Waste (MSW) budgets (source: (Potential of Bio Compressed Natural Gas (Bio-CNG) | CAG, n.d.)). There are two advantages of using bio CNG: It is a cost-effective method of converting wet waste into energy, as well as a calorific fuel replacement with a lower carbon footprint.
A World Bank report from 2021 shows that India's MSW will reach 543 million tonnes by 2050. This accounts for 13% of global waste and 83% of waste in South Asia. Up to 70% of waste is treated; the remaining is dumped in landfills and illegal sites (MoHUA, 2021). Through "bio methanation," half of the treated organicwaste can be converted to bio-CNG.

CapaCITIES aims to strengthen Indian cities' ability to identify, plan, and implement integrated measures to reduce Greenhouse Gas (GHG) emissions and improve climate change resilience, in line with national priorities.

The Climate Resilient Cities Action Plan (CRCAP) Coimbatore

ClimateResilientCities is a step-by-step action planning process for local governments that addresses climate change adaptation and mitigation. This process builds on ICLEI's Cities for Climate Protection (CCP) campaign, GreenClimateCities (GCC) Programme, and the Asian Climate Change Resilience Network adaptation toolkit.

Coimbatore has conducted an analysis of the city's urban systems' baseline situation. Climate risk was assessed by assessing each system's vulnerability to climate change impacts such as an increase in temperature and precipitation. The vulnerable urban systems were determined such as water, land use, sewage, solid waste, and transportation. For each of these urban systems vulnerabilities was examined.

Fragile urban systems	Climat erisks	Climate fragility statements	Risk*
Water		• There will be an increase in the demand for water. This will lead to more groundwaterextraction lowering the groundwater table • GDP, economy (industry and agriculture) and health will be impacted	Extreme
Land-use		• Change in green-blue cover in the city will be change the microclimate • Increased heat island effects will lead to impacts on health, food and cattle feed production	High
Sewerage		• Overflow of sewage lines and dilution of wastewater will impact the efficient of wastewatertreatment	Extreme
Solid waste		• Decomposition rates in treatment facilities will affected impacting ecosystems, increasingGHG emissions, odour, sanitation and health issues	High
Transport		• Private vehicular volume will increase, increasing the temperature and emissions	High

*** Risk Score (likelihood x consequence)** - Low: 1-4; Medium 5-10; High: 11-20; Extreme: 20-25 Temperature increase Rainfall increase

Figure 1: Climate risk and vulnerability assessment of fragile urban systems in Coimbatore

The city developed 2020-2021 GHG emissions inventories. The 2020-21 inventory shows total GHG emissionsof 29,40,178 tCO2e or 1.46 tCO2e per person.

Sector	Energy use (GJ)	GHG Emissions (tCO2e)
Residential Buildings	69,71,080	9,34,529
Commercial and Institutional Buildings/Facilities	19,38,312	3,24,328
Manufacturing Industry and Construction (i.e., Industrial sector)	66,29,484	10,49,122
Mobile Units (Transportation)	55,86,718	1,98,738
Waste	---	4,33,459
TOTAL	**2,11,25,594.66**	**29,40,178**

Figure 2: Sector-wise energy consumption and GHG emissions (2020-21)

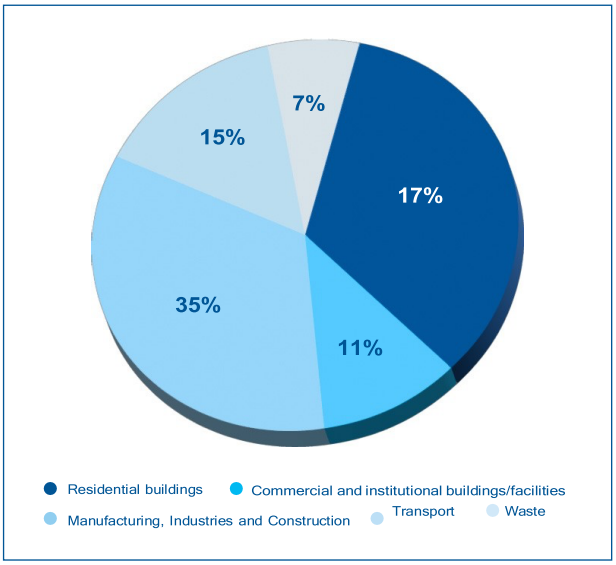


Figure 3: Coimbatore: Sector-wise share of GHG emissions (2020-21)

Energy consumption and GHG emissions overview

The total GHG emissions in the city for 2020-21 is 0.29 million tonnes of CO2e (tCO_2e). Per capita energy consumption in the city is 10.48 GJ, leading to 1.46 tCO_2e per capita GHG emissions.

The energy consumption and GHG emissions in the city from municipal operations, constituting end-uses/ sources such as buildings, wastewater treatment, water supply, street lighting and transport, are 0.3 million GJ and 0.05 million tCO_2e respectively.

Table 1: SWM GHG emissions and overall resilience impact

Sector	Resilience interventions	Total mitigation potential (tCO_2e)	Overall resilience impact
Solid Waste	• 1 bio methanation facilities with a 200 TPD capacity • A 215 TPD waste incineration facility • Create collection and processing facilities based on zones. • Support privately owned, community-driven businesses that manage solid waste in the city • Create and implement user fees	**502770.438** (17.1% of total)	Bio methanation plants and waste incineration facility will benefit40% of the city's population by reducing GHG emissions and improving health and livelihood of vulnerable sections.

Existing Solid Waste Management Situation in Coimbatore

Coimbatore, also called Kovai, is Tamil Nadu's third-largest city after Chennai. It spans 257 sq. km. Coimbatore Municipal Corporation's city sanitation plan reports 16,01 lakhs (1.60 million) for 2011. CCMC reported a 2019 population of 17.99 lakhs (1.79 million) in its City Sanitation Plan (CSP) to Swachh Bharat Mission, Governmentof India (GOI). In 2018, 890 TPD were generated, 850 TPD were collected, and 650 TPD were treated. Per capita waste generation in Coimbatore is between 400-600 gpcd, which is higher than the average for cities of similarsize. So, 500 gpcd per capita was assumed to project the city's daily waste generation. At the current rate, daily waste generation in Coimbatore is set to double over the next two decades. Coimbatore City Municipal Corporation (CCMC), the agency responsible for waste management, would need to improve waste collection, management, and recovery infrastructure. The primary waste collection is managed by CCMC including a door-to-door collection of wet waste and dry waste. The waste is then transported to the transfer station from thereon the waste is transported to the waste management facility at Vellalore for further processing. The waste collection report at 3 main transfer stations is outlined in the table below:

Table 2: Waste Received at Transfer Station

Location	Waste (TPD)	No. of trips of Auto Tipper	Average payload in ton
Vellalore	379	244	1.55
Ukkadam	249	190	1.26
Peelamedu	287	218	1.31
TOTAL	**915***		

* Actual data- assuming a leakage of 10-15%

The average payload carried by the waste collection vehicles is varying between 1.31 to 1.55 tons per trip.

1. Waste Processing

While the collection of waste is managed by CCMC, for the processing of waste, CCMC has made the following arrangements.

- **Private sector agency:** Responsible for secondary transport, treatment, and processing of 400 TPD waste at the Vellalore waste management facility
- **The vermicomposting facility** operated by another private sector agency processing 70 TPD organic waste
- **Bio methanation plant** owned and operated by CCMC - capacity 1.5 TPD – Saibaba colony, Coimbatore- operated by the private sector
- ~490 TPD of mixed waste is dumped directly at the landfill without any further processing resulting ina significant amount of additional and legacy GHG emissions

~120 TPD of organic waste enters CCMC waste collection and transportation informally in absence of a proper waste collection and processing alternative and at present is processed by CCMC.

2. Untreated organic waste

Based on the estimation drawn as per the latest waste characterization testing undertaken in December 2021, the untreated organic waste is computed for 2022:

The current processing of organic waste at the Private Sector Agency involves segregation and primary processing of the waste, post primary processing a major portion of waste goes to the landfill. Additionally, due to latency in the process of vermicomposting and limited offtake, even the vermicomposting is not that effective.

Hence, to reduce emissions from the waste sector and manage the bio-waste in the most efficient model a new waste management solution i.e., setting up of waste to bio CNG plant is proposed through a public-private partnership.

Table 3: Untreated Organic Waste

S.No	Zone	TPD
1	2022 total waste generation	1080
2	2022 waste collection	915
3	Organic waste collected (48% of total collection)	440
4	Total organic waste processed atdifferent facilities*	167
5	**Unprocessed organic waste to landfill**	**272**

* 70 TPD vermin composting+ 96 TPD Private Sector Agency + 1.2 TPD bio methanation

Solution: Setting up waste to bio CNG plant

A waste-to-bio CNG plant is being developed by Coimbatore City Municipal Corporation (CCMC) to process organic waste. Thereby, reducing the associated GHG emissions and optimizing the expenditure of city municipal corporations towards waste management. Table 1 below presents the covenants of the proposed project briefly:

Table 4: Untreated Organic Waste

S.No	Title	Details
1	Problem Statement	1. ~272 TPD unprocessed organic waste is dumped alongsidemixed waste without any segregation at the landfill site at Vellalore resulting in significant GHG emissions/ existing including bulk organic waste 2. ~96 TPD organic waste processed at Private Sector Agency, onlyprimary processing-a part of segregated waste is dumped to mixed landfill resulting in significant GHG emissions 3. Large operating expenditure towards waste management paidby CCMC as tipping fees
2	Solution	Development of organic waste to Bio CNG plant on PPP – DBFOT-Design, Build Finance, Operate, Manage and Transfer
3	Outcomes	1. Reduction in GHG Emission which would result from dumping ofwaste in mixed landfill 2. Operational Savings on account of reduced operatingexpenditure per ton for waste processing

Solution Description

Bio methanation is the natural process of Anaerobic digestion (AD) which breaks down organic matter in the absence of oxygen to release biogas, leaving an organic residue called digestate. Biogas is a mixture of methane, carbon dioxide and water and can be used to produce electricity and heat or used as a natural gas substitute. It will help to reduce the use of fossil fuels and thus reduce CO_2 emissions. The organic waste must be of high quality and source segregated with a low degree of impurities for the Bio methanation technology to work appropriately. Digestate is a nutrient-rich by-product of AD and can be used as a fertilizer and soil improver.

Bio methanation projects have the advantage of alow footprint but require skilled manpower. Wet anaerobic digestion is considered for the project. The solution process chart and plant design parameters have been outlined in the figure below. Given the limited availability of quality segregated a state-of-the-art secondary segregation facility is considered in the plant design.

Table 5: Waste to Bio CNG Plant Design Parameters

1	Waste Management Plant Capacity	200 TPD (phased expansion) Segregated OrganicMunicipal Solid Waste
2	Biogas Generation	Approx. 10000 cum/day, 6500 cum/day methane
3	Equivalent Compressed Biogas (CBG)	Approx. 3900 Kg per day
4	Organic Manure Generated	Approx. 10 Tons/day
5	Fresh Water Required	30-40cum/day (at the initial stage during commissioning the water requirement will be about 100 cum/day)
6	Liquid Organic Overflow	Approx. 100 cum/day (70% - 75% will be recycled back)
7	Area Required	~20,000 sqm (considering expansion of plant to 200 TPDin future)

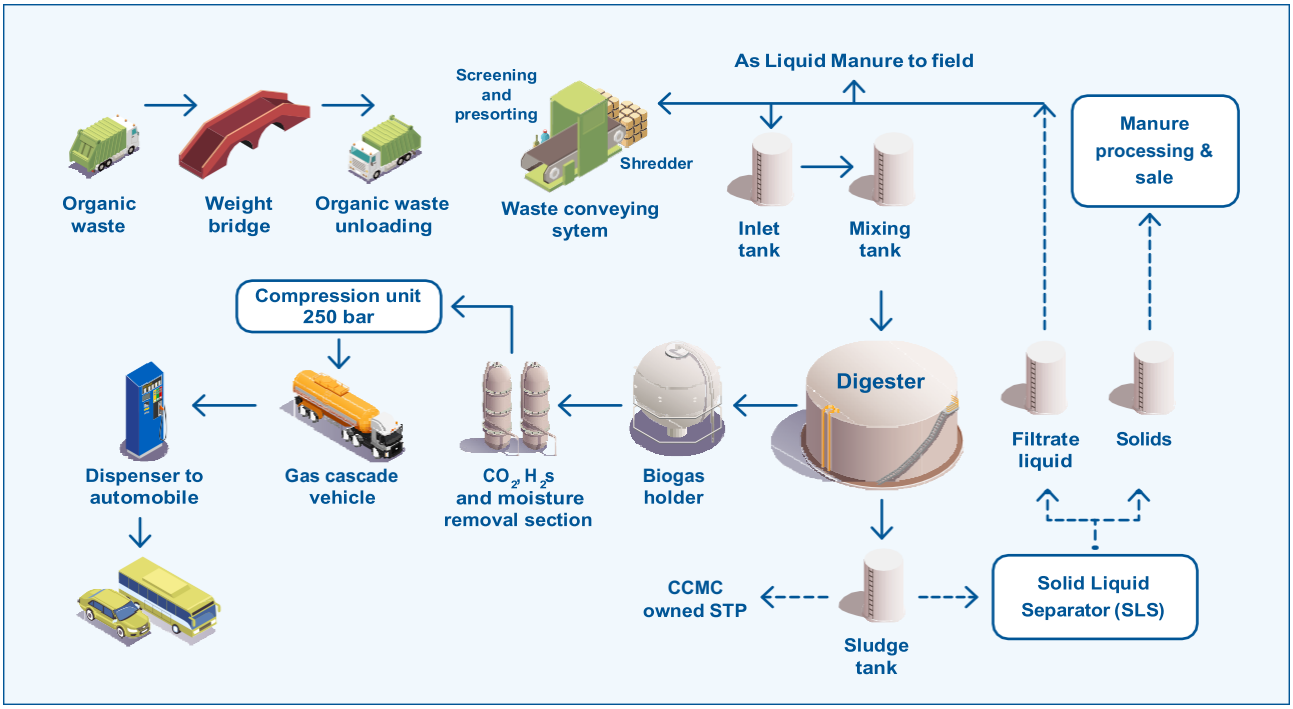


Figure 4: Proposed Waste Management System

The end product bio CNG would be sold by the private developer considering the commercial viability. The developer can leverage the Sustainable Alternative Towards Affordable Transportation (SATAT) initiative of the Ministry of Petroleum, Government of India to sell the Bio CNG at a fixed price to oil marketing companies. Based on the plant location cascading has been considered under the plant design wherein Biogas generated will be purified and compressed into cascades and then transported for commercial purposes.

Implementation Structure

The project has been implemented on a Public-Private Partnership (PPP); the figure below shows a schematicrepresentation of the project implementation structure.

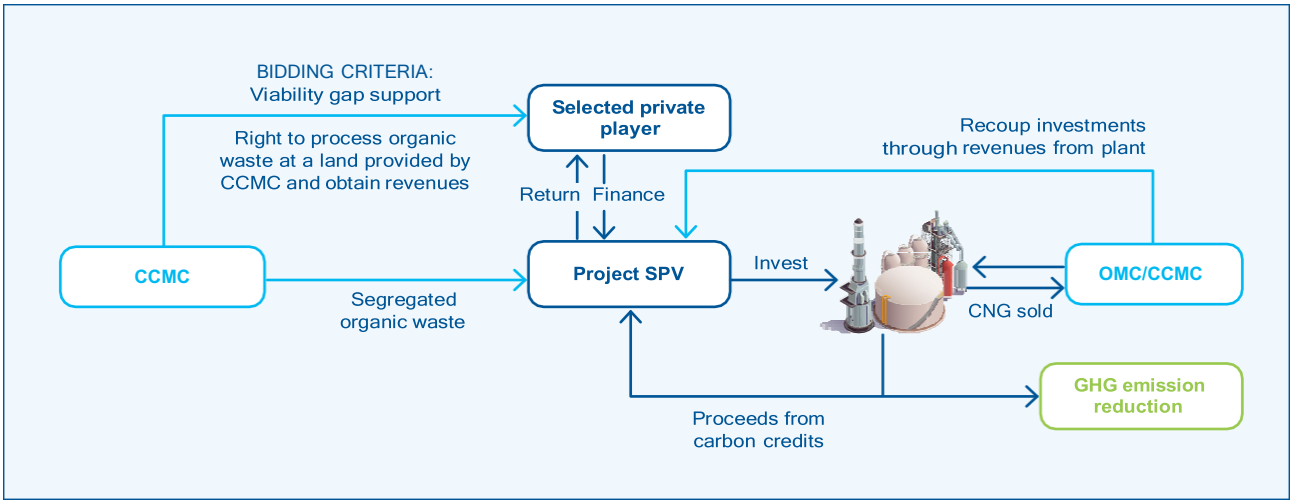


Figure 5: Schematic structure of Project Implementation

The role of each party in the outlined implementation under the Public-Private Partnership (PPP) arrangementhas been summarized in the table below:

Table 6: Role of each party

S.No	Name of Agency	Responsibility
1	CCMC	• Provide land to the private operator at concessional rate of Re 1 • One time Viability Gap support for the project as quoted by theprivate operators in the price bid • Provide 130 to 150 TPD of semi segregated organic waste as perthe agreed quality in the concession agreement • Arrange for further treatment of sludge at STP operated by CCMCat Vellalore Site at no cost to private sector • Arrange for transfer of reject waste from plant site to landfill at noextra cost to private sector
2	Private Sector	• Design, Build, Finance, Operate, Maintain and Transfer (DBFOT) basis the Waste to Bio CNG plant for the concession period basisconcession conditions. • On completion of the concession, the private sector shall transfer the plant at a token Rs. 1 to the CCMC. CCMC shall refurbish theplant and operate it on its own or appoint another private sectoroperator to refurbish and operate the plant. • Sell bio CNG to OMC/ CCMC: CCMC would have first right on bioCNG produced at the plant at a price quoted by OMC • Responsible for carbon project development, registration andvalidation and sharing 50% of net revenues with CCMC

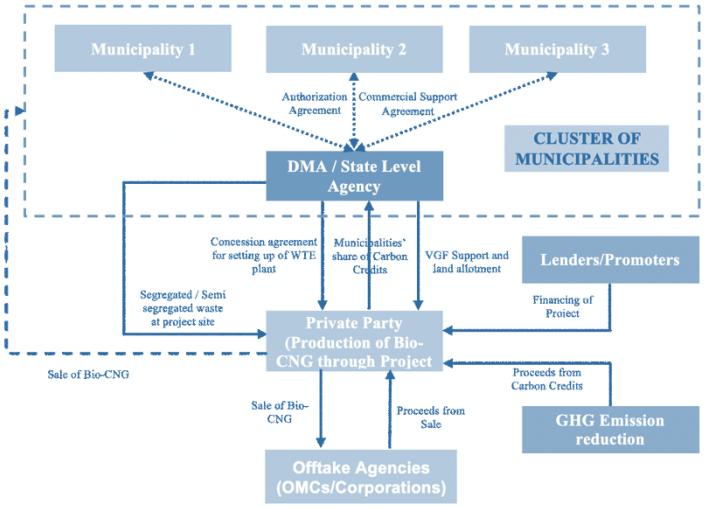
Replication Potential for Municipal Corporations

The model that has been proposed for Coimbatore Municipal Corporation can successfully be replicated for other Municipal Corporations where total unprocessed waste is available. The below table showcases the Municipal Corporations that have the potential for the replication development of waste to Bio CNG on Public Private Partnership (PPP).

Table 7: Replication potential for Municipal Corporations

Name of ULB's (Municipal Corporations)	Total Wet Waste	Total UnprocessedWet Waste	Proposal
Coimbatore	595	363	Ongoing Project
Madurai	364	144	Potential for replication development of waste to BioCNG on PPP with Viability Gap Fund (VGF) Support
Salem	319	164	
Tiruppur	207	46	
Tambaram*	245	74	
Total Excluding Coimbatore 4 Plants		**428 TPD**	

Instead of using composting processes, these Municipal Corporations throughout the state can successfully replicate the same strategy. Despite the fact that composting has comparatively greater advantages in terms of improving soil fertility, water retention, and the delivery of nutrients to plants through manures, there are a number of drawbacks to this waste management strategy, including its effects on climate change, the release of carbon dioxide into the atmosphere, oxygen depletion, and production of unpleasant odours due to the release of hydrogen sulphide produced by the anaerobic activity. Maintaining ambient temperatures, odour control, and the current weather conditions is a common issue faced by Municipal corporations / Municipalities. Composting processes should contain provisions for CO_2 trapping to stop the emission of greenhouse gases as we work to construct infrastructure that is climate resilient.



The above aggregation model of setting up Bio-CNG facilities for identified clusters of municipalities involves implementation risks because the private sector developer must develop a project for many municipalities, unlike Municipal Corporations. To maximize waste capacity, municipalities have been clustered to install Bio-CNG plants. DBFOT private parties will adopt the PPP concept as shown in Figure 6. Because municipalities have independent legal structures and operations, it is advocated that a single point agency, such as DMA or a newly established state-level agency, be established for this specific purpose.

Figure 6: The Implementation Structure for the PPP model

Therefore, it is recommended to use Waste to Bio CNG facilities as a solution for efficient solid waste

management that significantly reduces carbon emissions while also producing renewable energy. City buses may run on this energy, which can also be sold to hotels and hostels for use as green fuel for their vehicles or as cooking gas.

Impact

Biogas is a renewable, environmentally friendly fuel that may be utilized like natural gas for transportation and industry. Bio-CNG emits 48 g CO_2-eq/km, 70% less than motor spirit and 69% less than diesel. The average emission reduction per year for waste-to-bio-CNG plants in various Municipal Corporations over 15 years is 25,183 tCO_2e, estimated from the 100 TPD facility proposed in Coimbatore and an additional 100 tons/day capacity would be added. The average annual emission decrease for a ~428 TPD bio CNG plant in Madurai, Salem, Tambaram, and Tiruppur is 97,020 tCO_2e. The average annual emission reduction for a ~488 TPD bio CNG plant (9 possible clusters of Municipalities) is 1,10,621 tCO_2e.

The development of the proposed plant would positively contribute towards reducing the GHG emissions as below:

- Upstream GHG emissions from methane avoidance due to proper waste processing
- Downstream GHG emission on account of displacement of conventional fuel by Bio CNG

There are anticipated benefits that a city can easily implement by implementing the above strategies. In order to achieve sustainable development by 2030, all member nations, including India, are urged to take urgent action, particularly to reduce the effects of climate change. Out of 17 Sustainable Development Goals (SDG), the following goals are said to have direct and co-benefits by setting up of Bio CNG plant.
These advantages are linked to the Sustainable Development Goals (SDGs), specifically SDGs 7,11,12, and 13, which result in improved well-being and livelihoods, income stabilization, providing a sustainable fuel, reducing global warming, and boosting the local economy by achieving the common goals of bulk waste generators and the Coimbatore City Municipal Corporation (CCMC).

Table 8: Impact/benefit assessment from SDG goals

SDG Goal	SDG Target	SDG Indicator	Impact /Benefit from setting up waste to Bio CNG plant
	By 2030, increase substantially the share of renewable energy in the global energy mix	Renewable energy share in thetotal final energy consumption	Approx. 3900 kg per day of compressed biogas, approx. 10000 KWH/day of electricitycould be generated out of processing 200 tonnes biogasplant.
	By 2030, reduce the adverse per capita environmental impact of cities, including bypaying special attention to air quality and municipal andother waste management	Proportion of municipal solid waste collected and managedin controlled facilities out of total municipal waste generated, by cities	Unprocessed wet waste is source segregated and treatedin controlled facilities i.e., biogas plant.
	By 2030, substantially reducewaste generation through prevention, reduction, recycling, and reuse	National recycling rate, tons of material recycled	Source segregation is most required for operating the plant, therefore organic wasteis segregated which in turn reduce the amount of waste disposed in land fill.
	Integrate climate changemeasures into national policies, strategies, and planning	Total greenhouse gasemissions per year	Greenhouse emissions per year can be reduced from 8994 tCO2e from year 1 to 258483 tCO2e till year 15 for 4 Corporations and 10255 tCO2e from year 1 to 110621 tCO2e to year 15 for 9 clusters of municipalities.

Conclusion and lessons learned

To develop a “bankable” project, all project risks must be identified and allocated to the party that best manages the risk in terms of project structuring. The key success factors from the structuring perspective have been outlined below:

- **The availability of organic waste** is key to the success of a project and has to be ensured through a contractual mechanism in the concession agreement. Penalties are levied on the Authority for non-provision of waste as per pre-determined quality in the Concession Agreement.
- **Segregation of organic waste:** depending on the local compliance and segregation standards, the plant design should consider a separate state-of-the-art segregation facility to ensure quality feedstockand output.
- **Non/low revenue-generating activities:** The private sector should be given an alternative to de-link non-revenue-generating activities like the option to have an in-house Effluent Treatment Plant (ETP) and compost business. In the Coimbatore case, the Corporation is taking upon the responsibility of treatment of sludge and disposal of residue waste in landfill at no cost to the private sector.
- **Pre-arrangement with the Compressed Biogas (CBG) buyers:** The location of the plant should consider the current and proposed expansion of the CBG network of Oil Marketing Companies (OMCs) and City Gas Distribution (CGD) companies. This can significantly reduce the transportation and capital costs required for transportation and storage,
- **Need of Viability Gap Support (VGF):** A one-time VGF support for commercial interest may be required depending on the waste segregation levels, and availability of the CBG/ CGD network in the plant vicinity.