Circular Waste Solutions India NAMA

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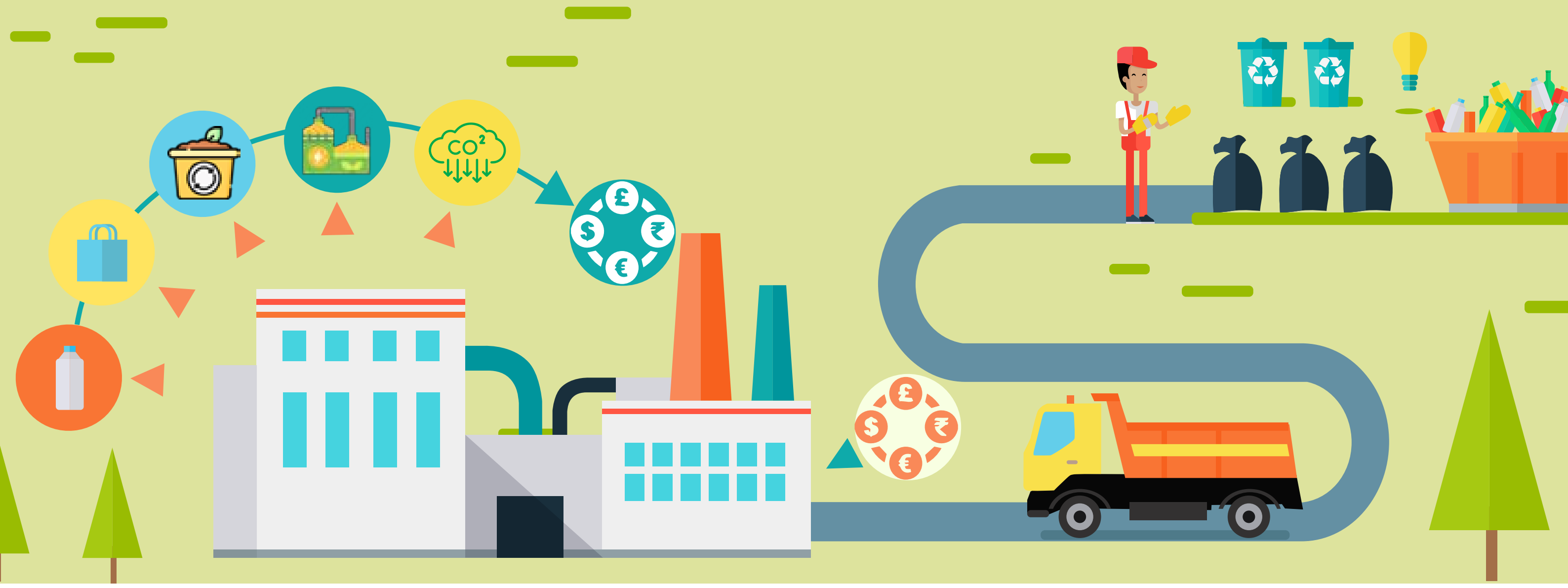
ICLEI
Local Governments for Sustainability
SOUTH ASIA

Handbook for Biomethanation, Composting, Material Recovery Facility and Low Value Plastic Recycling: Current Practices & Business Models



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Acknowledgements

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Abbreviations

AFD	Agence Francaise de Development
ANN	Ambikapur Nagar Nigam
BOO	Build Own Operate
BOOT	Build Own Operate Transfer
BOT	Build Operate Transfer
BWG	Bulk Waste Generator
C&T	Collection and Transport
CAPEX	Capital Expenditure
CBG	Compressed Bio Gas
CBO	Community based Organization
CCMC	Coimbatore City Municipal Corporation
CFA	Central Financial Assistance
CFA	Credit Facility Agreement
CGD	City Gas Distribution
CIWMCL	Coimbatore Integrated Waste Management Company Limited
CNG	Compressed Natural Gas
CPCB	Central Pollution Control Board
CPHEEO	Central Public Health and Environmental Engineering Organisation
CSR	Corporate Social Responsibility
CSTR	Continuous Stirred Tank Reactor
DBO	Design Build Operate
DBOOT	Design Build Own Operate Transfer
DBOT	Design Build Operate Transfer
DEA	Department of Economic Affairs
EBIDTA	Earnings Before Interest, Taxes, Depreciation, and Amortization
EHS	Environment Health and Safety
EPC	Engineering, Procurement, and Construction
EU	European Union
FC	Finance Commission
FCO	Fertilizer Control Order
FMC	Fertilizer Marketing Company
FMCG	Fast-moving Consumer Goods
FOM	Fermented Organic Manure
GHG	Green House Gas
GMC	Gas Marketing Company

GPRA	General Pool Residential Accommodation
GTS	Garbage Transfer Station
HDPE	High Density Polyethylene
IMC	Indore Municipal Corporation
IRR	Internal Rate of Return
JNNURM	Jawaharlal Nehru National Urban Renewal Mission
KfW	Kreditanstalt fur Wiederaufbau
LDO	Liquid Diesel Oil
LDPE	Low Density Polyethylene
LVP	Low Value Plastic
MDA	Market Development Assistance
MLP	Multi Layered Plastic
MNRE	Ministry of New and Renewable Energy
MOAFW	Ministry of Agriculture & Farmers' Welfare
MOCF	Ministry of Chemicals and Fertilizers
MOEFCC	Ministry of Environment, Forest and Climate Change
MOF	Ministry of Finance
MOHFW	Ministry of Health and Family Welfare
MOHUA	Ministry of Housing and Urban Affairs
MOHUA	Ministry of Housing and Urban Affairs
MOPNG	Ministry of Petroleum and Natural Gas
MRF	Material Recovery Facility
MRF	Material Recovery Facility
MSW	Municipal Solid Waste
MSWM	Municipal Solid Waste Management
NBCC	National Buildings Construction Corporation
NBFC	Non-Banking Financial Company
NGO	Non-governmental Organization
NIUA	National Institute of Urban Affairs
NPV	Net Present Value
O&M	Operation and Maintenance
OBP	Ocean Bound Plastic
OMC	Oil Marketing Company
OPEX	Operational Expenditure
OWC	Organic Waste Converter
PET	Polyethylene terephthalate
PIBO	Producers, Importers, and Brand Owners
PIL	Public Interest Litigation
PP	Polypropylene
PPE	Personal Protective Equipment
PPP	Public Private Partnership
PS	Polystyrene

PWP	Plastic Waste Processor
R&D	Research and Development
RDF	Refuse Derived Fuel
RDF	Refuse Derived Fuel
ROI	Return on Investment
SATAT	Sustainable Alternative Towards Affordable Transportation
SBM	Swachh Bharat Mission
SCF	Segregated Combustible Fraction
SCM	Smart Cities Mission
SDG	Sustainable Development Goals
SHG	Self Help Group
SLF	Sanitary Landfill
SPV	Special Purpose Vehicle
TPD	Tonnes per Day
ULB	Urban Local Body
UMC	Udaipur Municipal Corporation
VPSA	Vacuum Pressure Swing Adsorption

1. Introduction

Urban India generated about 1.60 lakh tonnes per day (TPD) of solid waste in 2020-2021 (CPCB, 2022), which is expected to increase to 4.5 lakh TPD in 2030 and 11.95 lakh TPD by 2050 (MoHUA, 2021). Though strategically, holistic Solid Waste Management (SWM) starts with adopting reduction and reuse, followed by practicing source segregation, appropriate processing of different fractions is required to handle the huge quantum of waste in a scientific manner. India's flagship programme, Swachh Bharat Mission (SBM) - Urban 2.0, makes it imperative to focus on scientific and sustainable processing to reduce the disposal of inert and process rejects in landfills to 20% or less of total Municipal Solid Waste (MSW) generated.

Urban Local Bodies (ULBs) are obligated to carry out SWM as one of the 18 functions listed in Schedule XII following the 74th Constitutional Amendment Act,1992. In the last decade, Municipal Solid Waste Management (MSWM) in India has undoubtedly undergone a sea change in technological advancement, especially in solid waste processing. Since the launch of SBM-Urban, MSW processing has increased from 18% in 2014 to 70% in 2021 (PIB, 2021).

However, ULBs are facing significant challenges in providing comprehensive and scientifically sound waste management services due to insufficient budgets and funding, and a lack of technical expertise, exacerbated by the sheer volume of waste to be managed. Typically, MSWM costs are covered by the general budget and funds allocated from property taxes. Most waste processing systems are capital-intensive, so financing a high-end scientific processing system increases the financial burden on Urban Local Bodies (ULBs), considering that only 5% of the total waste management budget is estimated to be earmarked for safe disposal, while 95% is spent on collection and transportation[1] (Nepal, M.et al., 2023). Although financial assistance under several national schemes, such as SBM, Smart Cities Mission, Waste to Energy Programme, etc., could be leveraged to cover capital expenditure (CAPEX), funding for operations and maintenance (O&M) of the processing plants is not budgeted properly. In the absence of a scientific processing system, open dumping of waste continues, leading to greenhouse gas (GHG) emissions, groundwater and soil pollution from leachate generation, and deterioration of air quality in the vicinity. Further, with more than 10,000 hectares of urban land estimated to be locked in open dumpsites in India (CPCB, 2019), open dumping of waste is not viable.

Hailed as a significant enabler, private sector involvement was introduced in the late 1990s to establish a scientific and sustainable waste processing system, and to transfer financial responsibilities and improve efficiency in solid waste processing. However, the private sector has encountered several obstacles, including difficulties in obtaining segregated feedstock and ensuing operational challenges. Further, inadequate financial planning has impeded the viability and long-term sustainability of private sector involvement. Hence, there is a need to understand and generate awareness about the key drivers and barriers to various MSW processing business models, and to develop the capacity of key decision-makers and implementers to understand the economics and finances behind SWM infrastructure. This would enable the stakeholders to make well-informed decisions while selecting the appropriate business model.

1. https://link.springer.com/article/10.1007/s10640-021-00640-3?utm

In this context, ICLEI – Local Governments for Sustainability, South Asia (ICLEI South Asia), with support from GIZ India, has developed this publication titled 'Handbook for Biomethanation, Composting, Material Recovery Facility and Low Value Plastic Recycling: Current Practices & Business Models'. This handbook is designed for ULBs, planners, decision-makers, and business developers. It serves as a valuable resource to grasp the current state of affairs regarding biomethanation, composting, Material Recovery Facility (MRF), and Low Value Plastic (LVP) recycling technologies. It takes into account the on-ground challenges and provides crucial recommendations to consider before establishing a processing facility.

1.1. Methodology

The overall objective is to develop a practical handbook on current practices and business models for MSW processing, including biomethanation, composting, MRF, and LVP recycling. The handbook would potentially enable key stakeholders to contribute to India's progress on the SBM and global commitments, including UN Sustainable Development Goals (SDGs) 11, 12, 13 and 14. Among these SDGs, the handbook specifically targets 11.6 on reducing the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management, and 12.5 on substantially reducing waste generation through prevention, reduction, recycling, and reuse.

The methodology adopted consists of the following stages:

Desktop research on current practices and business models: Detailed desktop research was conducted to understand the MSW processing scenario in India, private sector participation, and existing business models adopted for the four processing technologies. Specific data on waste processing businesses, such as the plant capacity, technology adopted, type of business model, type of feedstock, and output recovered, etc. was collated for a list of processing plants using the four technologies operational in the country.

Further, relevant information on appropriate national policies, programmes, guidelines, and fiscal incentives that play a crucial role in ensuring the successful implementation and operation of the waste processing plants was researched and included in the handbook.

Interviews with waste processing businesses: Waste processing businesses within the network of ICLEI South Asia and GIZ India, identified through desktop research, were approached for interviews to capture on-ground information on technical, infrastructural, operational, and financial models adopted for their processing plants. Further, data was gathered on factors constraining the overall functioning of the plant, obstacles within the market, and key factors contributing to the successful operation of the plant. Virtual interviews were conducted with the companies, firms, and non-governmental organisations (NGOs) listed in Table 1.

Despite sincere efforts to capture various types of waste processing businesses in the four technologies pertaining to capacity, centralised vs. decentralised model, type of contract (EPC, PPP-DBOT, DBFOT, CSR funded, etc.) and so on, this handbook is limited to three cases for each technology, reflecting case-specific ground realities. It must be noted that though the success of the centralised Bio-CNG and MRF plant in Indore has been highlighted as exemplar of the impact of widespread source segregation on plant efficiency, the case of Indore is unique and is not to be considered as representative of other technology- and finance-intensive centralised plants in India. Moreover, evidently, it was difficult to capture sensitive financial information, especially the Break-even Point, Return on Investment (ROI), Internal Rate of Return (IRR), etc.

Table 1: Waste Processing Entities Interviewed

Processing Technology	Company/Firms/NGOs Interviewed
Composting	1) Green Planet Waste Management Pvt. Ltd, New Delhi 2) Balancing Bits, Gurugram, Haryana 3) UPL Environmental Engineers Ltd. Coimbatore, Tamil Nadu
Biomethanation	1) Mahindra Waste to Energy Solutions Limited, Udaipur, Rajasthan 2) Carbonlites, Bengaluru, Karnataka, and Siddipet, Telangana
Material Recovery Facility	1) Saahas Waste Management Private Limited, Bengaluru, Karnataka 2) ReCity Network Private Limited, Puducherry
Low Value Plastic Recycling	1) The Shakti Plastic Industries 2) PYROGREEN Energy Private Limited, Mumbai, Nashik and Chennai 3) UFlex Limited, Noida, UP

Development of business models handbook: The information gathered from desktop research and interviews with ten waste processing organizations was thoroughly analysed to create a detailed handbook. This handbook features successful case studies and practical business models tailored for four specific waste processing technologies. The collated data was further analysed to understand key factors that influence the feasibility, desirability, viability, scalability, sustainability, and adaptability of a solid waste processing plant, looking at various strengths and weaknesses. The handbook includes a section on recommendations and suggestions to strengthen current business practices across the waste processing landscape.

The handbook does not offer prescriptions, but rather presents the suggestions identified from the selected business models. The ground reality may vary widely on a case-to-case basis, depending on business formats for the proposed processing plants.

2. Business Models for Processing Municipal Solid Waste

In India, the business potential of MSW was primarily explored through Public-Private Partnership (PPP). Prior to the introduction of the PPP model[2], financial constraints of the ULBs, their lack of technical and managerial capacity, and dealing with the informality of the waste business made it difficult for them to construct and operate high-investment processing plants on a long-term basis on their own, especially considering the huge quantum of waste generated. The late 1990s saw increased public interest in the environmental and health concerns emerging from littered, unprocessed, and openly dumped waste, evident from several Public Interest Litigations (PILs) on MSWM. This gave impetus to PPPs as an obligatory reform under the flagship Jawaharlal Nehru National Urban Renewal Mission (JnNURM). The objective was to enhance the efficiency of MSW processing businesses through advanced technology, financing, operational expertise, and established business networks.

What is PPP?

The World Bank defines Public-Private Partnership (PPP) as a long-term contract between a private party and a government entity, for providing a public asset or service, in which the private party bears significant risk and management responsibility, and remuneration is linked to performance (The World Bank, n.d.).

PPPs that aim at financing, designing, implementing, and operating public sector facilities and services have three main characteristics: a) long term service provisions (sometimes up to 30 years), b) transfer of risks to the private sector, and c) different forms of long-term contracts drawn up between legal entities and public authorities, where Special Purpose Vehicles (SPVs) come into play.

PPPs in processing MSW support local governments in several aspects, such as:

- leveraging technical expertise and resources offered by the private sector to develop and manage large, centralised processing plants.
- exploring technical innovations of the private sector's research and development (R&D);
- distributing risks between public and private stakeholders, while still ensuring a high-quality public service.
- accessing capital that is more often readily available with the private sector.
- bringing together the skills and capacities of both private and public sectors for the public good in a way that ensures commercial benefits for all parties (CAF, 2018); and
- using innovative legal entities such as SPVs.

Initially, India's PPP model for managing MSW focused primarily on the Engineering, Procurement and Construction (EPC) contract. Under this arrangement, the contractor was responsible for project execution and delivery within agreed timeframes and budgets. Concurrently, management or lease contracts were employed for the O&M of processing plants. Under this arrangement, the disconnect between the EPC and management/ lease contractors, and the management contractors' limited expertise often led to the model's failure. Further, the capital financing risk remains with the government; this is unfavourable in view of budgetary constraints.

This PPP model gradually evolved into a more integrated variant with well-defined roles and responsibilities and financial implications, as executed in present times. For most of the PPPs in the waste processing sector,

2. Large-scale PPP intervention in MSWM sector was initiated in the mid-1990s

the entire responsibility of processing and disposing the waste lies with the concessionaire. In this setup, the ULB is responsible for regular supply of pre-decided quantities of segregated feedstock. Depending on the specific model, CAPEX can be borne by the ULB through national or state-level grants, ULB budget, or grants from donor agencies, or it can be entrusted to the concessionaire. Similarly, the risk of revenue generation can be borne solely by the concessionaire in the form of sale of the end-product. It can also be shared with the ULB in the form of a tipping fee or shared user charges.

Table 2: Indicative types of PPP-based business models for MSW processing

Type of PPP	Asset ownership	Design	Build	Capital Financing	O&M
Build-Own-Operate (BOO)	Private (no obligation to transfer)	Government/ Third party	Private	Private	Private
Build-Operate-Transfer (BOT)	Private (transfer to government after concession period)	Government / Third party	Private	Private	Private
Build-Own-Operate-Transfer (BOOT)	Private (transfer to government after concession period)	Government / Third Party	Private	Private	Private
Design-Build-Operate (DBO)	Government	Private	Private	Government	Private
Design-Build-Own-Operate-Transfer (DBOOT)	Private (transfer to government after concession period)	Private	Private	Private	Private
Design-Build-Finance-Own-Operate-Transfer (DBFOT)	Private (transfer to government after concession period)	Private	Private	Private	Private
Design-Build-Finance-Own-Operate-Transfer (DBFOT)	Private (transfer to government after concession period)	Private	Private	Private	Private

Source: Adapted from CPHEEO Municipal Solid Waste Management Manual and Toolkit for Public Private Partnership Frameworks in Municipal Solid Waste Management


Photo by John Cameron on Unsplash

Despite its advantages however, the PPP model may also contribute its own share of risk to the system in terms of:

- lack of sufficient transparency and openness in the procurement process, thereby compromising on selection of the most efficient concessionaire, and in turn impacting project performance.
- lack of competition due to absence of stringent eligibility and qualification criteria, and following the Least Cost (L1) bidder selection approach; and
- shortcomings and leniency in the tender evaluation process, and vague contract agreements.

Additionally, while bringing in private capital and experience, PPPs also involve transfer of valuable public assets and land to the private entity for the entire project duration, thus preventing direct revenue generation from the assets by the ULB. PPPs usually involve long concession periods, especially for large scale facilities, during which the ULB is legally obliged to handover pre-defined quantities of waste to the concessionaire and not pursue any other form of major waste processing system. Involvement of various stakeholders, and uncertainties regarding under-performance of the contractor are other inherent risks involved in a PPP contract. It is important to understand various risks inherent to these business models both from a public and private point of view. However, it is to be noted that the risk allocation depends on the specific terms and conditions of the contract on a case-to-case basis. Hence, the risk allocation matrix (Table 3) is not exhaustive; it provides ULBs and officials with a possible framework to review and analyse project-specific risks.

Table 3: Indicative risk allocation to involved entities under PPP models

Type of Risk	Risk Allocation (depends on contract structure)
Design risk such as fault in design, non-consideration of ground realities.	• BOO, BOT, BOOT – Design risk is channelled to private contractor from third party design agency • DBO, DBOOT, DBFOT: Private contractor
Construction risk – Fault in design, cost variations between the Detailed Project Report and the actual construction cost, and construction inefficiency could deter construction. Construction risk might also emerge from the government due to delayed land transfer and non-cooperation in granting regulatory approvals, therefore deterring construction activities.	• All models – Private contractor, other than the asset transfer delay and non-cooperation regarding grant of regulatory approval, for which the government is responsible
Financial risk corresponds to capital finance sharing. When the private contractor is entirely financing the project, their risk increases in terms of debt burden if the required CAPEX is underestimated at the design stage.	• All models – Government and private contractor, depending on capital share
Operational risk by private contractor; partially attributable to the government, depending on the quality and quantity of waste supplied to the facility.	• All models – Private contractor and Government, depending on the terms related to quality and quantity of feedstock to be supplied
Delayed asset transfer risk and contractor not maintaining the plant in an appropriate condition, if not supported by a detailed agreement.	• BOO, DBO – Government. • BOT, BOOT, DBOOT, DBFOT – Government and private contractor
Revenue generation risk due to low quality, quantity and poor offtake of end-products; non-payment of tipping fee in timely manner.	• All models – Private contractor. It could be partially transferred to government when tipping fees/ user fees/buy-back of end-product is considered as a source of revenue

Type of Risk	Risk Allocation (depends on contract structure)
Environmental risk arising from non-compliant establishment and operation of plant.	• All models – Private contractor

Source: Adapted from CPHEEO Municipal Solid Waste Management Manual, Toolkit for Public Private Partnership Frameworks in Municipal Solid Waste Management and interviews conducted for the project

Other than the project-specific risks mentioned above, there are risks related to the overall environment within which the project is implemented, which are borne by the government. These include political risk (change in government policy, etc.), financial risk (inflation and currency risk, etc.) and legal or regulatory risk (changes in law, legal processes, and bureaucratic procedures) etc.

Processing costs

MSW processing entails a variety of costs, which could be broadly divided into the following components:

- **Planning and design expenditure:** Pre-feasibility assessment and planning, including quantification and characterisation of waste; determining coverage area; market research
- **Capital expenditure:** Land, civil work; cost of equipment, logistics in procuring equipment; designing and construction interest on debt capital, if any
- **Operating expenses:** Labour; utilities; business development; marketing; recurring maintenance of equipment and necessary upgrades; cost of Personal Protective Equipment (PPE); Environment, Health, and Safety (EHS) equipment and procedure; monitoring and testing of end-product; transportation of end-product to off-takers, if applicable; disposal fee, if applicable; training and capacity building of operating personnel

Revenue Streams

MSW processing generates different sources of revenue, given below:

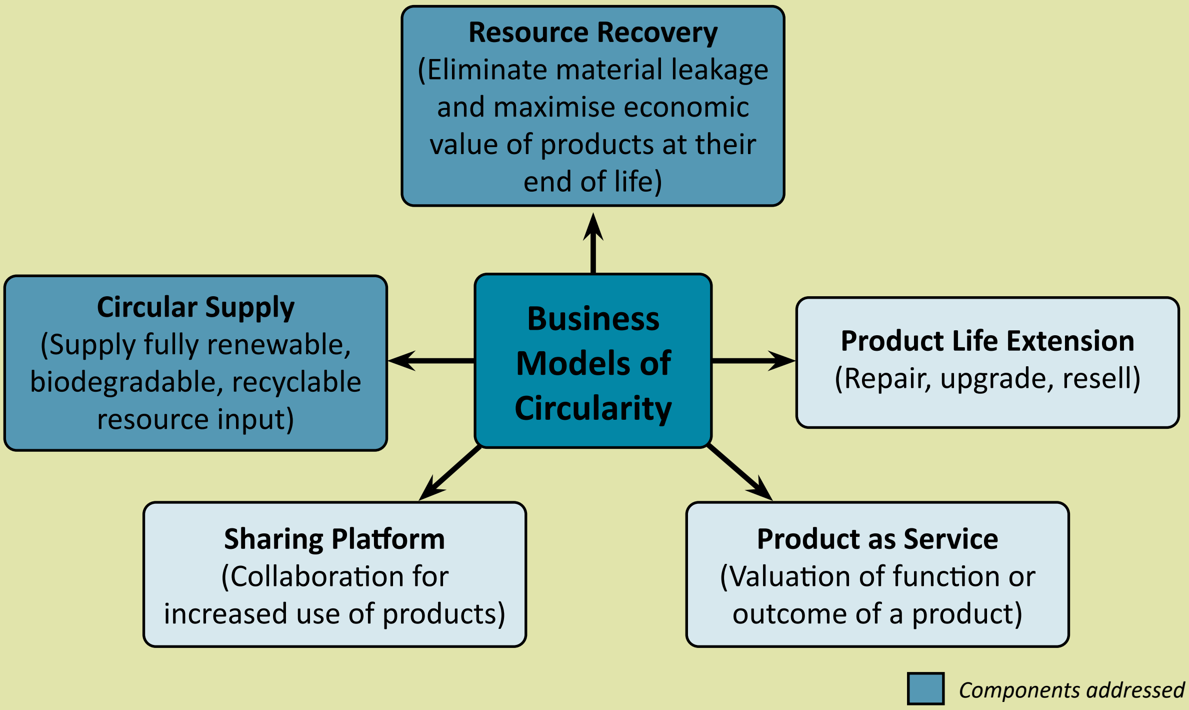
- Sale of end-products such as city compost, Bio-CNG, Fermented Organic Manure (FOM), recyclables, Refuse Derived Fuel (RDF), recycled plastic granules and products manufactured from recycled plastics
- Carbon credits trading
- Extended Producer Responsibility (EPR) credit exchange
- Other plastic credit exchange
- Tipping fee

Circular economy: foundation of business model in MSWM

Business viability of an MSW processing plant inherently relies on the paradigm shift from linear (cradle to grave) to a circular economy (cradle to cradle) approach. The concept of a circular economy in waste management emphasises converting the waste resource to its original form, without impacting its quality or integrity in the process (Circular Economy in Municipal Solid and Liquid Waste, MoHUA, 2021). The Ministry of Housing and Urban Affairs (MoHUA) has assessed resource recovery potential from different waste fractions by adopting a circular economy as follows (MoHUA 2021):

- Compost – INR 3,650 million per annum
- Bio-CNG – INR 16,790 million per annum
- Dry waste recycling – INR 118,360 million per annum
- Construction & Demolition (C&D) waste – INR 4,160 million per annum

The transition from a linear to a circular economy requires a joint effort by stakeholders across the MSW value chain. Relevant industry, technology and/or service providers can contribute to the transition by developing sustainable processing technologies, their suitable installation and operation, circular product design and recycling, and pioneering innovative circular economy business models. The circular economy revolves around a combination of business models that expand beyond recycling and emphasises resource efficiency through reduction and reuse (Figure 1). Resource Recovery and Circular Supply are the two components addressed while discussing the specific waste processing infrastructure highlighted in this handbook.



Sharing Platform: It involves using under-utilised consumer assets more intensively, either through lending or pooling. For e.g. Airbnb platform where property owner lists the property as usually a temporary rented accommodation (OECD 2019).

Product Life Extension: It entails product designing to increase durability, reuse and repair, and/or refurbishing and remanufacturing to provide an entire new service life; thereby materials embedded in the product remain in the economy for longer, and thereby potentially reduce the extraction of new resources (OECD 2019) For e.g. Furbicle re-manufacture furniture and renewe appliances, which are restored to an almost new condition and sold with a warranty (Grant Thoroton, 2021).

Circular Supply: It involves the replacement of traditional production inputs with bio-based, renewable, or recovered materials. This model warrants a strategic sourcing decision, thereby reducing environmental impact of their product lifecycle (OECD, 2021) For e.g. a city gas distribution entity deciding to source a certain portion of its gas supply from organic waste to BioCNG production plant before laying a new pipeline in a city. Thus, the circular supply model also contributes to resource recovery.

Product as Service: It offers new ways to customers to use or access a product rather than the traditional ownership model. For e.g. cloth rental or furniture rental service businesses offer the use of or access to their products on a service basis rather than selling them as individual items for customers to own (OECD 2021).

Figure 1: Business Models of Circularity

2.1. Key Factors for Successful Business Model of Municipal Solid Waste Processing Plants

Key Factors	Parameters
Market Demand	An adequate demand for end-products is most important to ensure the self-sustenance of the facilities. Subsidising use of these end-products such as city compost, Bio-CNG, FOM, RDF, and recycled plastic products, while disincentivising conventional products such as chemical fertilizers, conventional fuel in transport sector, conventional fuel in cement industry, virgin plastic packaging, etc. in respective cases will enhance use of these substitutes in these industries. Additionally, suitable branding/certification/ labelling (for e.g., Harit Maha City Compost in Maharashtra (MPCB, n.d.) following relevant national standards will encourage usage of the end-products.
Institutional and Governance	Support of ULBs is required in establishing a comprehensive baseline for scientific decision-making on the type of processing system required, realistic design capacity, and technical specifications. ULBs shall allocate encumbrance-free land following the appropriate siting criteria for each type of processing plant carried out by themselves or in coordination with the state government. Proactive role of ULBs in facilitating relevant approvals will expedite setting up of plants. Simultaneously, ULBs need to ensure supply of segregated feedstock as per the design capacity. Overall, ULBs need to stay aligned with the objective of the projects for their successful commissioning and implementation.
Policies and Regulatory Instrument	Policy and regulatory instruments have a key role to play right from planning and commissioning to operation of the plant. Relevant policies or regulations setting targets for waste processing and minimised landfill disposal act as the major driving force in planning for waste processing plants. Designated grants for setting up waste processing infrastructure, formulating standards for end-products and their assured offtake support financial sustainability. For example, the Sustainable Alternative Towards Affordable Transportation (SATAT) initiative by the Ministry of Petroleum and Natural Gas (MoPNG) ensures long-term offtake of Bio-CNG at the rate of INR 46/kg + GST, to be paid by Oil/Gas Marketing Companies (OMCs/GMCs) to CNG producers. Further, defined roles of ULBs and their stringent enforcement of source segregation, and collection and transport of waste to designated treatment facilities, is integral to their successful operation.
Rationing Tariff Structure	Appropriate financial planning considering all phases of implementation should be conducted for proposed processing facilities. Capital investments in many cases are supported by national programmes, schemes, international donor agencies or Multilateral Development Banks (MDBs). Nevertheless, a diligent estimation of OPEX vis-à-vis revenue generation needs to be undertaken, considering all probable, but locally contextualised options. In case of ULBs with low levels of source segregation, the financial risk could be partially shared with the ULB through tipping fee per tonnage of feedstock supplied. Prior financial planning explaining market strategies for end-products, forecasting pricing, and identifying guaranteed off-take points will help optimise the business model. Project operators should discuss the quantum and price of off-take with potential customers to develop marketing strategies, while also comparing with the price of available conventional products and considering any fall in demand of end-products due to unavoidable circumstances.

Key Factors	Parameters
Technical	Robust feasibility assessment at the planning stage, consisting of quantification and physico-chemical characteristics of feedstock, is of utmost importance to design the capacity and appropriate technical specifications of processing facilities. Viability of technologies such as composting, which is dependent on specific moisture content and Carbon: Nitrogen (C/N) Ratio, or the calorific value for a potential RDF plant, should be assessed at the planning stage itself to ensure efficient operations. Selection of an appropriate technology provider is another crucial aspect of a successful processing project. ULBs' preference for the Least Cost (L1) bidder due to budgetary constraints is likely to compromise selection of the most efficient bidder, who might be more expensive. Hence, ULBs should aim for a two-stage bidding process and prioritise selection of technically sound bidders through a technical to financial approach of 80:20 or 60:40, as appropriate. Successful operation of a waste processing plant is initiated at the point of waste generation itself. Segregation of waste at the point of generation, followed by segregated collection and transport without contamination till the processing facility, determines the quality and quantity of feedstock. These will influence the requirement for pre-processing, efficiency of processing, and subsequently the quantity or quality of the end-product, which is a significant source of revenue. As experienced in Bengaluru, 15 decentralised biomethanation plants in the city are almost defunct, primarily due to poor waste segregation (Ahluwalia & Utkarsh, 2018).

Source: Adapted from Kaza, Yao, & Stowell, 2016; Kawai, Liu, & Gamaralalage, 2020

3. Composting

Composting is a biological process involving controlled decomposition of organic waste, typically in aerobic conditions, resulting in the production of a stable humus-like product, i.e., compost (CPHEEO, 2016). Compost produced from biodegradable MSW helps restore organic matter in the soil, provides specific nutrients, and reduces the requirement of chemical fertilizers.

3.1. Types of Composting

MSW is composted using a varied level of mechanisation, depending on the quantum of available feedstock, land, and finances. The quality of feedstock, as influenced by the extent of source segregation, should also be considered a major decisive factor for selection of the appropriate technology. For example, when strict source segregation is not practiced, manually aerated windrow composting tends to be more viable than vermicomposting or in-vessel composting. The problems of mixed waste can also be minimized by setting up small-scale decentralised plants targeting specific generators such as vegetable markets, hotels, etc., where contamination tends to be low. Table 4 presents an overview of different types of composting facilities.

Photo by Conscious Design on Unsplash

Table 4: Types of MSW Composting

Parameters	On-site Composting	Vermicomposting	Aerated Windrow Composting	Aerated Static-pile Composting	In-vessel Composting
Description	Small scale - in the premises using bin or pit	Composting in pits where worms process organic matter	Composting in rows in open environment, regularly turned or aerated	Composting with static piles of organic materials that are aerated internally with blowers	Composting in a machine that processes organic materials and requires compost to mature outside the machine
Scale	Small / decentralised/ up to 20 TPD	Small / centralised or decentralised / up to 50 TPD	Large / centralised / up to 500 TPD	Large / centralised / up to 500 TPD	Medium / centralised / up to 300 TPD
Requirement of source segregation	High	Very high	High	Very high	Very High
Land requirement	Low	2 hectares for 50 TPD	8 hectares for 500 TPD, including buffer zones	5 hectares for 500 TPD (less land required given faster processing rates and effective pile volumes)	4 ha for 500 TPD (limited land required due to faster processing rates)
Time	6 - 8 weeks	8 - 10 weeks	8 weeks	5 weeks	4 weeks (3 - 5 days in vessel, 3 weeks to mature outside)
Temperature	Not temperature sensitive	Temperature sensitive (20-40°C)	Not temperature sensitive		
Energy Input	Low		Moderate	Moderate (2 - 3 hours of aeration)	High
Financial Requirement	Moderate	Moderate (exotic worms could be expensive)	Moderate	Expensive	Very expensive
Labour	Semi-skilled/Labour intensive			Skilled/Not labour intensive	
Market Potential	• Quality compost compliant with Fertilizer Control Order as amended from time to time • Co-marketing of compost with chemical fertilizers in the ratio of 3 to 4 bags:6 to 7 bags by the fertilizer companies				

Source: Adapted from CPHEEO, 2016; Kaza, Yao, & Stowell, 2016

3.2. Financing of Composting Plants

The initial investments of composting plants are funded through national programmes, schemes such as SBM Urban 2.0, 15th Finance Commission (FC) grants, Smart Cities Mission, etc., or grants from donor agencies, among others. Nevertheless, a financially viable business model needs to be established to cover the O&M costs and ensure long-term sustainability.

The table below provides the indicative cost of equipment required for setting up a 100 TPD Windrow composting plant for MSW.

Table 5: Indicative Cost of Equipment, CAPEX of 100 TPD Windrow Composting

Component	Estimated Cost (INR Lakhs)
Civil Works (pads, drains, platform, sheds)	1231
Weigh Bridge	6.5
Conveyor belts and trommel – 50, 20 and 4 mm	95
Wheel loaders	45
Backhoe loader	79
Packing machine	0.2
Dumper trucks	84
Excavators	52.5
Wheel barrows	0.2
Turbo vents	8
Sky lighting sheets	9
Laboratory equipment	2.4
Workshop equipment	5
Fire Fighting Equipment	9
Total Estimated CAPEX	**1626.8 (INR 16 crores)**

Source: Model Design document for 100 TPD Windrow Composting Plant, MoHUA, 2025

Table 6: Indicative cost of OPEX of 100 TPD Windrow Composting (Annual)

Component	Estimated Cost (INR Lakhs/year)
Manpower (25–30 staff)	85
O&M and Repairs	82
Tools, PPE, Training	2
Total Annual OPEX	**169 (Approx. 1 crore and 70 lakhs)**

Source: Model Design document for 100 TPD Windrow Composting Plant, MoHUA, 2025

The business model for composting could be centred around the ULB, with the engagement of a private entity. MSW composting primarily generates revenue from selling compost. Additionally, tipping fee and carbon credits could also be accounted for as sources of revenue generation. It is estimated that a 50 TPD windrow composting plant has the potential to incur a net benefit of INR 8,750 per day (Table 7).

Table 7: Indicative economic benefit of composting

Process	Capacity (TPD)	Output (TPD)	Rate/Tonne (INR)	Revenue (INR per day)	O&M Cost (INR per day)	Net Economic Benefit (INR per day)
Windrow Composting	50	7.5	2,500	18,550	10,000	8,750

Source: MoHUA, 2021

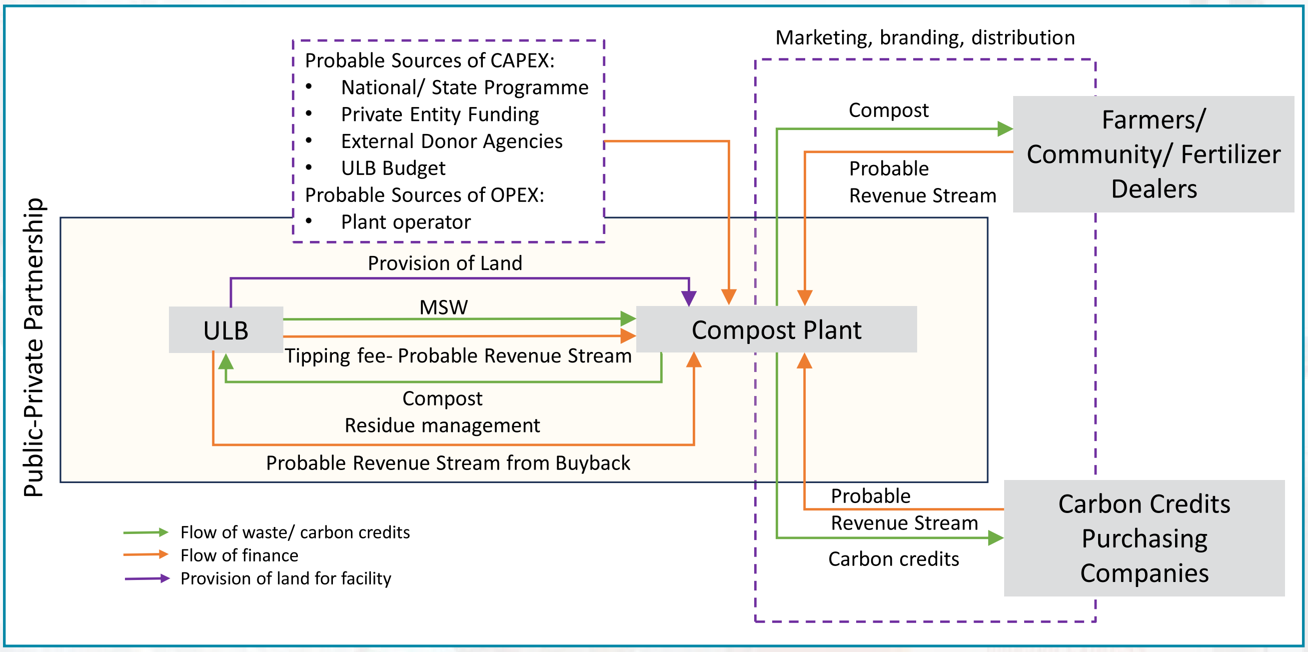


Figure 2: Indicative Financing Arrangements for MSW Composting

3.3. Overview of Composting in India

Biodegradable fraction amounts to 40-60% of MSW generation in India (MoHUA, 2021). Moisture content and C/N Ratio of MSW fraction of different cities in India suggests it is amenable to composting. In 2022, 2,285 functional compost plants (centralised) with the capacity to process 71,682 TPD waste were operational in India. 73 compost plants are under construction, with approximate input capacity of 1,084 TPD (PIB, 2023).

Composting from decentralised plants in India varies from as low as 1 or less than 1 TPD capacity to hundreds of TPD capacity depending on the situation locally. NGOs and community-based organisations (CBOs) have initiated various small scale decentralised composting schemes often with international assistance. Tamil Nadu and Odisha have adopted the model of Micro Composting Centres (MCCs) for all ULBs across the state. MCCs are self-help groups (SHG) operated decentralised composting units ranging from 2 to 5 TPD capacity and requiring only up to 600 sqm of area for each unit (Commissionerate of Municipal Administration, Govt. of Tamil Nadu). SHGs are trained to operate small-scale composting centres to produce compost in four weeks and are provided social security measures. This decentralised system with low CAPEX became self-sustainable through revenue generation from sale of compost, as seen in Dhenkanal in Odisha. In 2021, Dhenkanal Municipal Council generated INR 0.08-1.5 million between February and July in revenue only from MCC against monthly expenditure of INR 0.042-0.054 million over the same duration for MCC and MRFs together, becoming self-sustaining to operate the facilities and compensate the SHG members (Biswas, Chaudhary, Singh, & Tewari, 2021).

Composting is a widely accepted solution for on-site processing of wet waste for Bulk Waste Generators (BWGs) as observed in Delhi-NCR, Varanasi, Surat etc. Here, several waste processing businesses have enabled setting up and operating on-site composting units at residential societies, hotels, malls, hospital premises etc. In case of inadequate space at the BWG premises, the waste is transported to the small-scale off-site plant operated by the waste processing business. Though BWGs are responsible for on-site wet waste treatment in accordance with SWM Rules, 2016, their contribution to CAPEX is important for these relatively smaller businesses to achieve financial viability.

PPP based large-scale centralised composting plants are one of the oldest forms of waste processing businesses in India. However, as unanimously agreed by various businesses, reliance on city compost as exclusive source of revenue cannot be financially viable due to miniscule market demand of city compost. Thus, large-scale compost plants need to rely on tipping fee as primary source of revenue generation and/or explore diverse revenue streams by planning for integrated solutions consisting of composting, MRF, RDF processing, recycling units, and sanitary landfills (SLFs) as practiced in Hyderabad, Coimbatore, Bengaluru etc.

The Policy on Promotion of City Compost, 2016, gave a major impetus to MSW composting in India. While city compost production surged by 71% from 2016-17 to 2017-18, sale of compost doubled during this time and has since been increasing to match production (MoCF, 2020). However, discontinuation of the Market Development Assistance (MDA) under the Policy on Promotion of City Compost in 2021 hindered progress in this regard. Despite awareness of the benefits of bio and organic fertilizers, farmers tend to use relatively inexpensive chemical fertilizers.

3.4. Case Studies

Decentralised MSW-based Compost Units by Balancing Bits

The Story

In 2017, the Municipal Corporation of Gurugram (MCG) contracted out an end-to-end MSWM system to a selected concessionaire for 22 years. However, following limited success of this approach to waste management, MCG changed gears and brought in a policy framework directing Bulk waste generators to adopt on-site processing of wet waste, aligned with the SWM Rules, 2016. Balancing Bits began its operations as a social enterprise with the aim of creating sectoral impact in early 2018, before MCG's shift in approach to MSWM. However, the change in approach made things favourable for Balancing Bits. They were empanelled as an MSW processing service provider by MCG and began by offering composting solutions to BWGs such as commercial complexes and malls, as well as residential societies. Their service area gradually expanded to 35 BWGs within the National Capital Region (NCR) and subsequently spread to cities like Varanasi and Chandigarh.

Technical and Financial Modalities

Bulk waste generators were initially brought into the model, with MCG promoting and pushing for decentralised waste management by them. For quicker adaption of decentralised waste management by BWGs, the municipal corporation also declared waiver of user charges for collecting other MSW fractions and guaranteeing off-take of compost at INR 5/kg but could not keep up with its promises.

The compost units are operated primarily on Business to Business (B2B) model between Balancing Bits and Resident Welfare Associations (RWAs), or any other BWG level associations, as applicable. In residential areas, the RWA provides land within their premises, pays for CAPEX collected as a one-time charge from households, and retains ownership of the equipment. OPEX is covered through user charges from households. Incoming source segregated feedstock is processed through one of the following pathways, using equipment and models developed by Balancing Bits:

- **Non-mechanized Composting:** Sorted biodegradable waste (kitchen waste) is composted using natural microorganisms-based processes, without any mechanised pre-processing.
- **Semi-mechanised Composting:** Sorted biodegradable waste (kitchen waste) is crushed and dried through centrifugal force, which reduces their volume by up to 50%, and further composted naturally using microorganisms-based processes.
- **Off-site Composting:** Sorted biodegradable waste (kitchen waste) is pre-processed on-site through a semi-mechanised process and then transported to off-site natural composting units. This process is adopted in case of unavailability of space within the BWG's premises. With expandable capacity of up to 4 TPD, the off-site composting units are set up on privately leased land.

RWAs utilise the compost from on-site units for self-consumption in 95% cases and have authority to sell the surplus. Further, in the absence of buyers, Balancing Bits helps identify off-takers. Balancing Bits is planning to sell 50% of the compost produced from off-site units through online marketplaces. While online marketplaces offer rates of up to INR 50/kg, wholesale or direct sale to farmers yields INR 2-3/kg. Rest of the compost is consumed by respective RWAs proportionately.

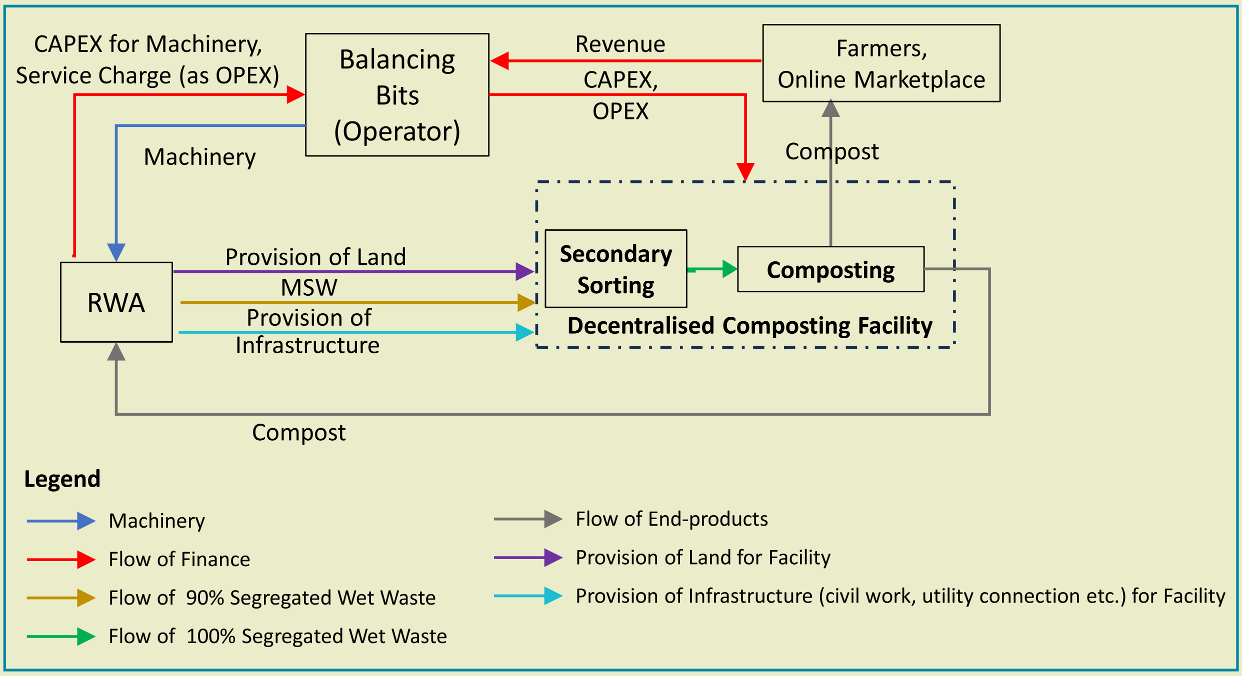


Figure 3: Typical Operational and Financial Model of Decentralised Compost Unit by Balancing Bits

Facility Highlights - Technical	
Type of facility	Decentralised compost facility
Location	Residential societies in Gurugram
Land ownership	Respective RWAs 1,000 - 2,200 sq. feet
Business model	B2B model Technology provider - Balancing Bits Ownership - RWA O&M - Balancing Bits
Concession period	1 - 3 years (renewal rate - 95%)
Owner of facility	Respective RWA
Year of establishment	2017
Designed capacity	0.2 - 1 TPD Off-site unit - up to 4 TPD
Type of feedstock	90% segregated wet waste
Targeted generators	Primarily individual BWG – residential society, commercial complex, mall

Facility Highlights - Financial	
CAPEX	Initially bootstrapped INR 1,600 - 1,700/HH charged to pay CAPEX
OPEX	• 75 - 80% human resource • 20 - 25% consumables, electricity (INR 85/HH/month is considered as service charge to cover OPEX)
Source of Revenue	• Margins on CAPEX (machines, setup, etc.) • Service charge • Sale of compost and carbon credits[3]
Break Even	Making profit within 1 - 1.5 years

Key Insights

- **Source segregation** is crucial to ensure regular operation of the plants. Decentralised facilities, due to their limited coverage area, allow for better control and direct feedback mechanisms, enabling them to receive well-segregated waste and produce high-quality compost.
- **Adopting a B2B model** is an efficient approach of the decentralised model for securing regular flow of feedstock and funds, instead of dealing with individual generators.
- **BWG-specific decentralised model should be promoted** as a service to facilitate their adherence to the SWM Rules, 2016. However, financial support from BWGs is also required in this regard to mitigate operational and financial risks.
- **Benefits promised to BWGs** by ULB such as property tax rebate, guaranteed buy-back of compost, etc. **should be duly passed on to them** to set an example for others.
- **18% GST on waste management services escalates costs for BWGs.** Many residential societies are unable to offset the GST, which deters RWAs from adopting on-site processing.
- **Decentralised composting units** should explore diverse revenue streams such as service charge, sale of compost through online marketplaces, providing services to manage horticulture waste and/or expanding into biogas technology, Carbon Credits, Green Credits, etc. This is because the existing market ecosystem does not support waste processing businesses relying solely on compost. Heavily subsidised chemical fertilizers and low off-take and awareness regarding city compost render it unviable.
- **Start-up ecosystem in MSWM sector could be encouraged.** Financing supported by innovative mechanisms such as the Risk Sharing Facility (RSF) by Small Industries Development Bank of India (SIDBI) and GIZ should be prioritised.
- **Administrative and policy level volatility i**mpact long term sustainability, especially in the case of small businesses.
- **The government should encourage and promote a prescriptive model** for environmentally compliant and holistic waste processing with its associated impact, instead of focusing on profit-centric technologies.

Contributor: Rahul Khera, Balancing Bits

3. Gold Standards carbon credits issued in 2019 - yet to be monetised

Decentralised-integrated MSW-based Compost Units by Green Planet Waste Management Pvt. Ltd.

The Story

Established in 2010 in New Delhi, Green Planet Waste Management Pvt. Ltd. (GPWMPL) operationalised decentralised and integrated MSW processing in the form of a Compost, Green Pellet, Waste to Oil processing system installed at the General Pool Residential Accommodation (GPRA) Complex in New Moti Bagh in 2013. The initiative was replicated in other places like Safdarjung Hospital in 2021, where GPWMPL set up a compost and manual MRF. In July 2023, a 3 TPD compost and dry waste sorting unit was also set up to cater to the waste generated at the Central Vista in New Delhi.

Technical and Financial Modalities

The plant at New Moti Bagh operates on a Design-Build-Finance-Operate (DBFO)-based PPP model. It is based on a contract between NBCC (India) Limited (formerly National Buildings Construction Corporation Limited) and GPWMPL and built on 4,000 sq. feet of land provided free-of-cost by NBCC. A separate private entity is authorised to collect and transport MSW to the processing facility. Depending on its nature, incoming feedstock is manually sorted and processed category-wise through one of the following technologies:

- **Composting:** Incoming biodegradable waste (kitchen waste) is fed into the Organic Waste Converter (OWC), followed by a 10-to-15-day cycle of curing/processing to produce organic manure.
- **Green Pellet Making Unit:** Garden/horticulture waste is passed through a shredder followed by cyclone heating and drying. The shredded and dried fraction is extruded into biomass pellets. At 3,400 Kcal/kg net calorific value, these biomass pellets could potentially replace wood (3,500 Kcal/kg net calorific value).
- **Waste to Oil Processing:** Mixed plastic waste is processed using Polycrack – a heterogeneous catalytic process that converts all types of waste into useful resources such as gas, Liquid Diesel Oil (LDO), water, carbon and power.

Along with CAPEX, GPWMPL was responsible for OPEX for the first seven years. NBCC was responsible for OPEX for the last three years. However, despite a dedicated catchment area, the plant is operating at lesser than design capacity and yielding insignificant revenue for GPWMPL from the sale of compost. The green pellets and oil are consumed internally in the plant. Due to poor capacity utilisation and inadequate revenue generation, the facility could not generate profit even after 10 years of operation. Thus, while setting up a similar MSW processing facility in Safdarjung Hospital, GPWMPL secured CAPEX funding from Ministry of Health and Family Welfare (MoHFW). This led to the 4 TPD plant generating profits in the order of INR 0.05 million/month within 3 months of operation only through sale of segregated dry waste, and despite handing over the compost to, and sharing the profit with MoHFW.

Facility Highlights - Technical		
Type of facility	Compost-Green Pellet-Waste to Oil processing facility	Composting and manual MRF
Location	New Moti Bagh	Safdarjung Hospital

Land ownership	NBCC (India) Limited	MoHFW, Govt. of India
Business model	Design-Build-Finance-Operate (DBFO)	Design-Build-Operate (DBO)
Concession period	3 years (renewal after every 3 years)	1 year (extendable up to 3 years)
Owner of facility	NBCC (India) Limited	MoHFW, Government of India
Year of Establishment	2013	2021
Design Capacity	3 TPD • 1.5 TPD composting • 1.4 TPD green pellet making • 0.1 TPD waste to oil	4 TPD • 1 TPD composting • 3 TPD manual MRF
Type of feedstock	Mixed Municipal Solid Waste	Mixed Solid Waste (non-biomedical fraction)
Targeted generators	Gated community (498 households)	Safdarjung Hospital Premises
Facility Highlights - Financial		
CAPEX[4]	INR 8 million	Ministry of Health and Family Welfare (MoHFW) funded
OPEX	INR 0.16 million/month • 12% maintenance • 80-82% salary	INR 0.155 million/month
Source of Revenue	Compost – INR 0.015 million/month • Buy-back agreement with NBCC – up to 8 Tonnes/month at INR 5/kg • At present, maximum up to 3 Tonnes/month could be generated and sold	Segregated dry waste (25% profit sharing with MoHFW in addition to handing over produced compost)
Break Even	Not yet achieved • Profit generation is possible when CAPEX is borne by government/BWGs	Within 3 months (Net profit - INR 0.050 million/month)

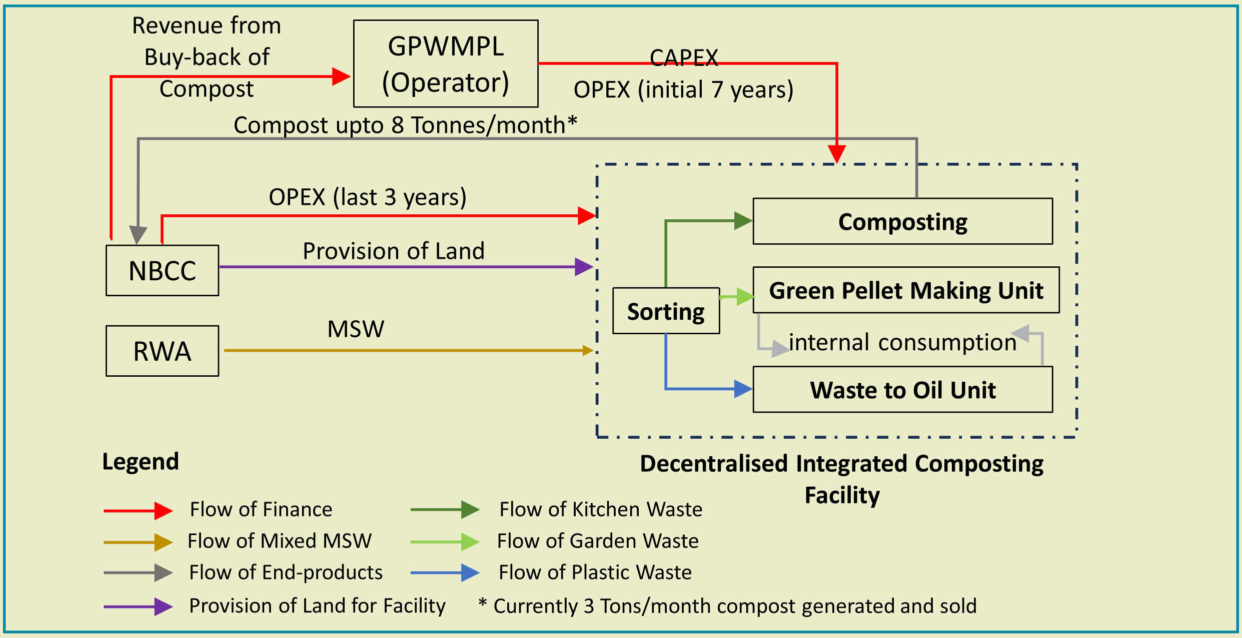


Figure 4: Operational and financial model of decentralised compost-green pellet-waste to oil processing unit at GPRA complex

4. Value in 2013
5. In case of BWG specific unit

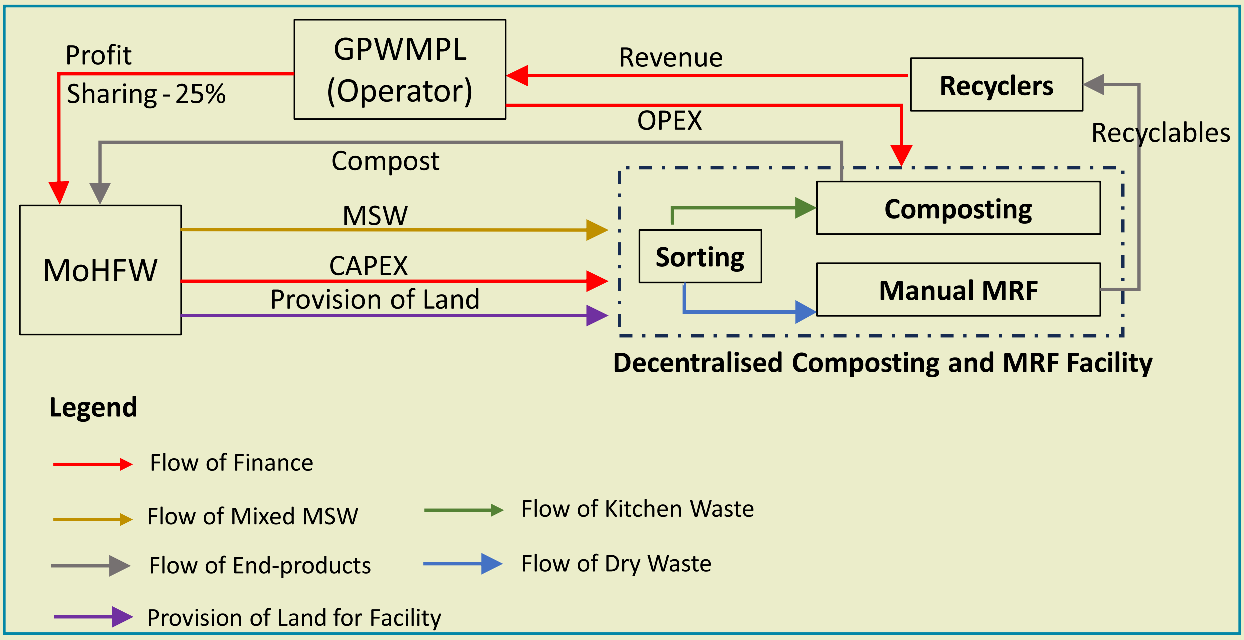


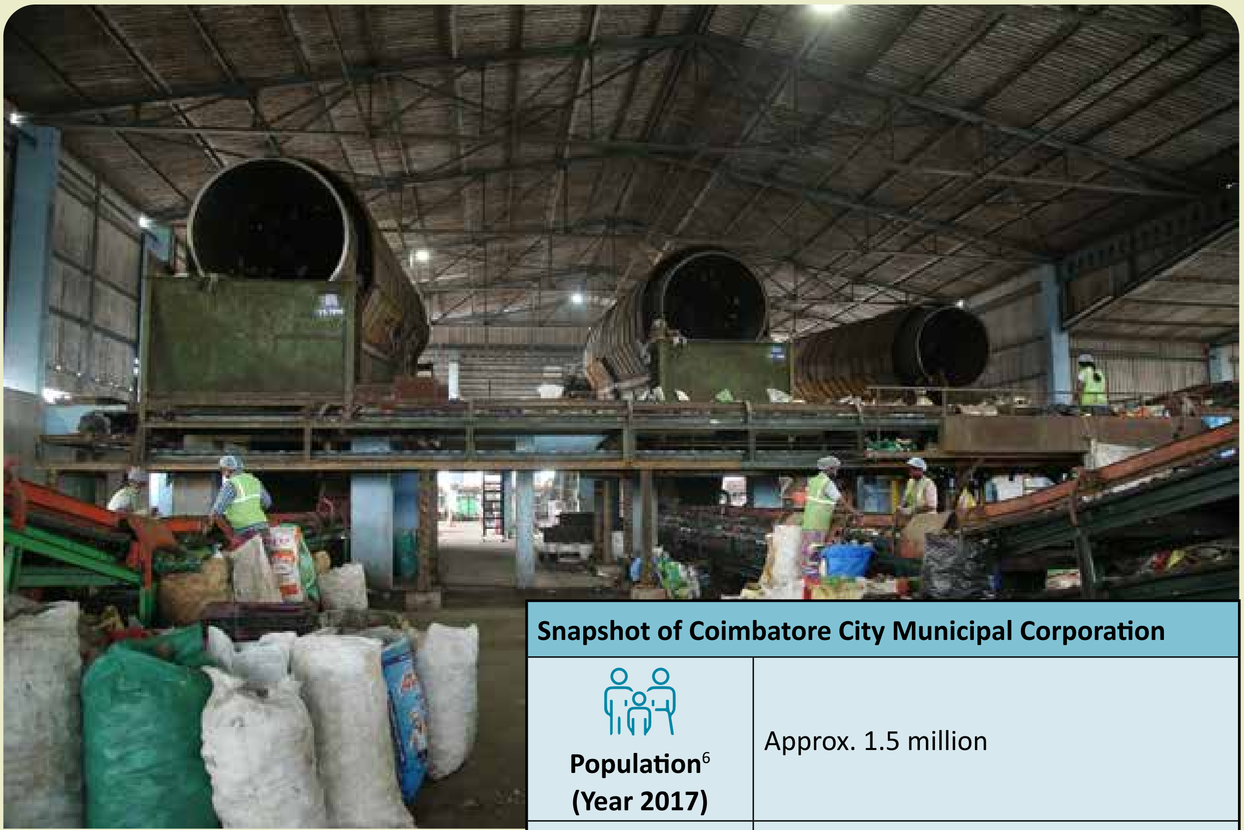
Figure 5: Operational and financial model of decentralised compost-manual mrf processing unit at Safdarjung Hospital

Key Insights

- **Source segregation** is crucial to ensure regular operation of a plant.
- **CAPEX of a decentralised facility that offers limited scope for revenue generation, should be provided by the government or generator (in case of a BWG-specific unit)** to reduce the financial burden on the operator.
- **The government needs to ensure a smooth process of approvals and procurements when funding the CAPEX, to enable timebound installation and commissioning of the WM facility.**
- **A minimum contract period of five years** is required for operational stability. Long-term contracts incentivise private operators to install automated systems such as sorting machines that cut down the labour cost.
- **Guaranteed off-take at a minimum of INR 20/kg** is required for a composting facility to be financially viable. Usually buy-back is agreed upon at lower than market prices (INR 5/kg). With achievement of merely 25% compost production rate from the total input, a miniscule output is generated. The corresponding revenue therefore becomes unviable at the buy-back price.
- **Bulk waste generators should come forward in funding CAPEX** to ensure financial viability. The SWM Rules, 2016 mandate BWGs to process wet waste on-site to the extent feasible.
- Small-scale plants supported by government schemes tend to be more sustainable and reach their break-even point much sooner.

Contributor: Rajesh Mittal, Green Planet Waste Management Pvt. Ltd.

Integrated Processing and Disposal Facility by UPL Environmental Engineers Ltd.



Snapshot of Coimbatore City Municipal Corporation	
Population[6] (Year 2017)	Approx. 1.5 million
Total MSW Generation[7] (Year 2016)	Approx. 855 TPD
Components of Engagement	• Transfer stations • Transportation of MSW from transfer station to processing and disposal site • Closure of existing dumpsites • Processing and disposal facility

The Story

Starting with hazardous waste management, UPL Environmental Engineers Ltd. (UPLEEL) gradually expanded into MSWM services with Coimbatore City Municipal Corporation (CCMC). CCMC conceptualised an integrated MSWM facility under the aegis of the Jawaharlal Nehru National Urban Renewal Mission (JnNURM), and selected UPLEEL as the concessionaire for executing the project.

Technical and Financial Modalities

The integrated solid waste processing and disposal facility was established through a PPP BOOT model involving the city corporation and UPLEEL. CCMC prepared a Detailed Project Report (DPR) for the facility

6. https://southasia.iclei.org/wp-content/uploads/2022/04/Coimbatore_CRCAP.pdf , retrieved in October 2023
7. https://smartnet.niua.org/sites/default/files/resources/climate_resilient_city_action_plan_coimbatore.pdf , retrieved in October 2023

and selected UPLEEL for its implementation through a tender process. Under the 20-year concession agreement, a Special Purpose Vehicle (SPV) named Coimbatore Integrated Waste Management Company Limited (CIWMCL) was set up to establish four transfer stations[8], undertake secondary transport of MSW from transfer stations to integrated WM facility, set up an integrated processing and disposal facility, and shut down the existing dumpsite. CCMC leased out the land to UPLEEL at a token rate and is responsible for supplying waste up to the transfer stations.

CIWMCL transports segregated wet waste in tipper vehicles and rest of the mixed waste in compactors from transfer stations up to the processing facility. The incoming waste is pre-processed through a 25mm trommel. Fractions of less than 25mm reach windrow composting pads and is further sorted through 16mm and 4mm trommels. Waste over 16mm size goes for processing as RDF, while that less than 16mm is composted. Subsequently, composting end-product of more than 4mm is rejected as inert residue, and that less than 4mm is considered as final compost output. Materials over 25mm and 16mm are processed into RDF, shredded and directly dispatched, or aggregated into Segregated Combustible Fraction (SCF) and dispatched for co-processing.

250 unskilled labourers employed across the facility for manual segregation support in recovery of a minor quantity of high-value recyclables such as glass, metal, cardboard, etc. About 20 to 25% reject is generated from the entire processing system and sent for disposal at the Sanitary Landfill (SLF).

Compost and RDF are the primary end-products generated from the system. The compost proved to be a good source of revenue as long as Market Development Assistance (MDA) was being provided. However, currently compost is being sold at INR 700 to 900/Tonne to fertilizer companies. Despite not being a profitable source, compost still generates some revenue, whereas CIWMCL has to pay cement companies for disposing the RDF fraction.

Facility Highlights - Technical	
Type of Facility	Integrated Solid Waste Management Facility
Land Ownership	Coimbatore City Municipal Corporation
Business Model	Build Own Operate Transfer
Concession Period	20 years
Owner of Facility	Coimbatore Integrated Waste Management Company Limited
Year of Establishment	2011
Design Capacity	600 TPD
Type of Feedstock	• Primarily mixed waste • 20-25% segregated wet waste
Catchment area	Centralised Facility – 100% of area under CCMC
Facility Highlights - Financial	
CAPEX	INR 680 million Central:State:Private (50:20:30) 30% private share is obtained as debt.

8. Three transfer stations are currently operational

OPEX	INR 35-40 million/month Key O&M components: • Transportation - 45-50% • Processing - 25-30% • Disposal - 20-30% • GST - 18%
Source of Revenue	Tipping fee[9] - INR 48.6 million/month (estimated from INR 2,700/ Ton tipping fee) Compost[10] - INR 1.2 million/month (on estimated price of INR 0.8/ kg compost)

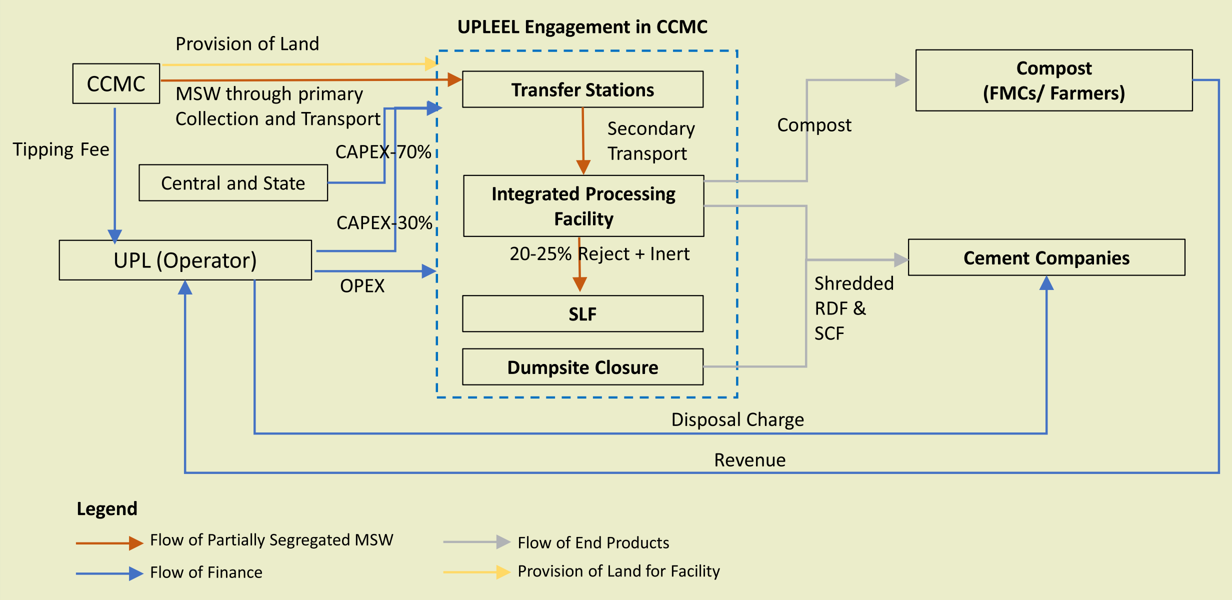


Figure 6: Operational and financial model of integrated MSWM facility in Coimbatore

Key Insights

- **Currently, neither compost nor RDF is a significant source of revenue,** in the case of CIWMCL. Compost enabled revenue generation under the MDA regime of the Ministry of Chemicals and Fertilizers, Department of Fertilizers (MoCF-DOF). But since its discontinuation, guaranteed off-take quantum or price is not provided to compost producers.
- **Mismatch between demand and supply of RDF** compelled CIWMCL to pay a disposal fee to cement industries instead of considering it as a source of revenue. Initially, CIWMCL could sell the RDF to cement industries within 100 km, who paid the transportation cost. Gradually, once bioremediation started, cumulative RDF generated from the integrated facility and closure of the dumpsite became larger than the demand from cement industry clusters, especially within 100 km.

9. ICLEI South Asia estimated monthly tipping fee based on data provided by UPLEEL in October 2023: Total MSW 600 TPD × Tipping fee INR 2,700/Ton × 30 days
10. ICLEI South Asia estimated monthly revenue from compost based on data provided by UPLEEL in October 2023: Total MSW 855 TPD-Wet waste-52% (445 TPD) × Compost 12% (53 TPD) × INR 800/Ton × 30 days

- Tipping fee-based integrated MSWM facilities require **commitment from the respective ULBs to pay the fees regularly.** As this is the key source of revenue for private operators, long outstanding periods create a financial burden on them.
- **CIWMCL could not achieve break-even after the 12th year (initially planned at 10th year)** due to negligible revenue generation.
- **Absence of a single-window clearance system, prolonged government approval processes, lack of a priority lending mechanism, high GST, and inadequate facilitation by the ULB** further delay and deter financial viability of large-scale plants.

Contributor: Dhanasekaran PD, UPL Environmental Engineers Ltd.

4. Biomethanation

4.1. Overview of Biomethanation in India

Biomethanation has emerged as a promising renewable technology using the anaerobic digestion process to convert agricultural, animal, industrial, and municipal biodegradable waste into energy resources, including biogas and nutrient-rich manure. The process generates a mixture of gases (known as biogas), i.e., methane (CH4), carbon dioxide (CO2), hydrogen sulphide (H2S), moisture, and organic manure. Biogas can be used for heating, electricity, and vehicular transportation. To optimise the usability of biogas (especially for vehicular transportation), it undergoes a purification process to remove impurities such as H2S, CO2, and water vapour. Purified biogas is then compressed, resulting in Compressed Biogas (CBG) with methane (CH4) content exceeding 90%. CBG is considered a clean source of energy.

Like composting, biomethanation is a particularly viable solution for the management of MSW in India, primarily due to the significant presence of organic matter and moisture content within MSW (CPHEEO, 2016). India is acknowledged as one of the emerging markets for this biogas energy source. In 2021, the biogas market in India was valued at approximately $1.40 billion, and is projected to grow to $2.25 billion by 2029 at a CAGR (Compound Annual Growth Rate) of 6.3% (Fortune Business Insights, n.d.). However, at present the country has only 99 functional biomethanation plants designed to manage municipal biodegradable waste across different cities. Collectively, these plants have a combined capacity to process 2,288 TPD of municipal solid waste (Nath, 2023). Of the 99 plants, 18 are classified as large-scale facilities, and the largest is at Indore with a total capacity of 550 TPD (Nath, 2023).

Several small-scale biomethanation plants based on the PPP model have been set up across India. Commercial bulk waste generators, especially those belonging to the hospitality sector (hotels, restaurants, malls) with adequate financial resources, prefer biomethanation over composting facilities to avoid the possibilities of nuisance (odour, flies) created by composting units. However, biomethanation is a cost-intensive process and warrants certain scale and concession periods to operate sustainably. Financial aspects for a small-scale plant, such as viability gap funding (VGF) and profit-sharing, need to be factored in judiciously while considering total CAPEX, OPEX, potential assured revenue streams, etc. to determine long-term sustainability. A comparison of biomethanation-cum-Bio-CNG plants of various capacities ranging from 25 to 500 TPD shows that despite higher capital investment and higher OPEX, the larger the capacity, the faster is the timeline to achieve break-even. This is because larger plants have a higher potential for revenue generation (MOHUA, 2021). Hence, wherever applicable, biomethanation technology should be chosen in relatively larger capacity, while complementing with assured off-take of end-products to optimise financial viability.

4.2. Financing of Biomethanation Plants

In the fiscal budget for 2023-2024, the Government of India introduced an ambitious proposal to establish 500 biogas facilities under the Galvanizing Organic Bio-Agro Resources Dhan (GOBARdhan) scheme. The scheme is designed to harness the potential of biomethanation technology for generating methane gas from organic waste materials (Prasad, 2023). The idea is to promote sustainable waste management practices to generate renewable energy and explore the GHG mitigation potential of biomethanation. The project will involve the establishment of 200 CBG plants at the local body level, including 75 in urban areas and 300 in communities or clusters. Further, India embarked on an initiative called Sustainable Alternative Towards Affordable Transportation (SATAT) to harness the economic potential of biomass, specifically in the production of CBG and bio-manure. By March 2023, India successfully operationalised 58 CBG plants under the SATAT scheme and issued a letter of intent to 3,694 potential investors for establishing similar plants (Jain, 2023).

Setting up a biomethanation plant for municipal solid waste is cost-intensive; the cost can vary widely depending on factors such as the scale of the plant, location, technology used, and local regulations. The table below provides indicative details of the equipment required to set up a 100 TPD Bio-CNG plant based on MSW. This plant will involve anaerobic digestion of organic waste and subsequently capturing Bio-CNG from the methane generated.

Table 8: Suggestive electro-mechanical equipment for a 100 TPD BioCNG plant is listed below

List of Electro-mechanical Equipment	Unit Cost (in Lakhs)	Quantity	Total Cost (in Lakhs)
1. Weighing and Receiving Station- 40 T (6 cells)	7	1	7
2. Pre-sorting Line: 1			
a. Grab Crane- 5 T	4	1	4
b. Conveyor Belt	8	2	16
c. Trommel	18	2	36
d. Conveyor Belt for Trommel 10TPH	8	6	48
e. Disk separator 20TPH	150	1	150
f. Wind sorter 20TPH	250	1	250
g. Magnetic Sorting 10TPH	2	2	4
h. Eddy Current Sorting 2 TPH	2	2	4
3. Processing			
a. Shredder 5TPH	6	5	30
b. Crusher 5 TPH Rhino 75HP	15	2	30
c. Hopper With Rotary Valve 15TPH, 40RPM	5	1	5
d. Food Waste Tank Mixer (2HP,100RPM)	1	2	2
e. Submersible Cutter Pump to CSTR, 8Cum/h, 15m head	1.5	4	6
f. CSTR and UASB Agitator, 11 KW each	15 each	6+4	150
g. Gas Holder Double membrane 1900 m3 capacity	0.01	1900	19
h. Sludge Pump 10 HP , 7.5 KW; 450 LPM @15 m head	1.5	2	3
4. Gas Purification System			
a. Dehumidifier 600 m3/hr	8	2	16
b. Scrubber Equipment 600 m3/hr 2 stage	96	1	96
c. Condensate Separator 600 m3/hr	10	1	10
d. Biogas Analyser	3.5	2	7
e. Gas Dryer, H2S, Co2	20	1	20
f. Biogas Flow Meter	0.4	2	0.8
5. Gas Compression System			

List of Electro-mechanical Equipment	Unit Cost (in Lakhs)	Quantity	Total Cost (in Lakhs)
a. Gas Compression unit capacity -500 cum/hr, Pressure bar - 250 bar, Maximum flow rate -3650 cum/hr	25	2	50
b. Pressure Cum Vacuum Reducing Valve -50 mm to 500 mm WC Vacuum -25 mm WC to 40 mm WC	0.2	6	1.2
6. Temperature Gauge	**0.09**	**8**	**0.72**
7. Pressure Gauge	**0.25**	**8**	**2**
8. Flame Arrestor	**0.45**	**1**	**0.45**
9. Gas Flare	**4**	**2**	**8**
10. Bottling System2			
a. LCV mounted with 3 KL CNG cascade	55	3	165
b. DP structure for grid interfacing	10	1	10
c. CNG Filling Post	25	2	50
11. Auxiliary Infrastructure			
a. Piping	20	1	20
b. Overhead tank 6 KL	0.4	3	1.2
c. Pumps	1.5	2	3
d. DG Sets	32	1	32
e. Pipeline to STP	0.02	500	10
f. Metering set, 500 kVA unit substation	12	1	12
Total Cost			**1279.37**
Total CAPEX for Electro-mechanical Equipment			**INR 12.8 Cr.**

Source: Adapted from South Pole Carbon Asset Management Ltd. (South Pole), 2022

An efficiently operated biomethanation plant can generate revenue through various streams such as the following:

- **Sale of biogas:** The biogas can be sold to industrial users, power plants, or residential customers for cooking and heating.
- **Electricity generation:** Biogas can be utilised to produce electricity which can be sold to the grid or used to run the plant.
- **Sale of heat:** Biomethanation plants can utilise the heat generated during the biogas production process. This heat can be sold to industries or used for district heating systems, providing a revenue source.
- **Generation of vehicle fuel:** Biogas can be pressurised and purified into CBG/CNG that can be used as fuel for transportation. Revenue can be generated by selling the CBG to Gas Marketing Companies (GMCs) or fleet operators.
- **Sale of organic fertilizer:** The residue of the anaerobic digestion process can be processed into fermented organic manure (FOM), which can be sold directly to farmers or to the fertilizer industry.
- **Sale of carbon credits:** Biomethanation technology has the potential to mitigate GHG emissions. The revenue can be generated by participating in a carbon offset programme or selling carbon credits.

It is important to note that the revenue potential of a biomethanation plant is generally dependent on plant capacity and efficiency, quality and availability of feedstock, market demand for the final product, and applicable policies and regulations. Table 9 presents the indicative economic benefits of a biomethanation plant.

Table 9: Indicative Economic Benefits of a Biomethanation Plant (50 TPD capacity for a population of 2.50 lakh)[11]

Process	Capacity (TPD)	Output	Rate/ton (INR)	Revenue (INR per day)	O&M Cost (INR per day)	Net Economic Benefit (INR/ day)
Biomethanation	50	Biogas – 1.5 TPD (3% of Input)	46,000 (Biogas)	69,000	30,000 (@ INR 20,000/ Tonne of gas)	51,500
		Compost from dried slurry – 5 TPD (10% of input)	2,500	12,500		

Source: MoHUA, 2021

11. Circular Economy for Municipal Solid and Liquid Waste, MoHUA

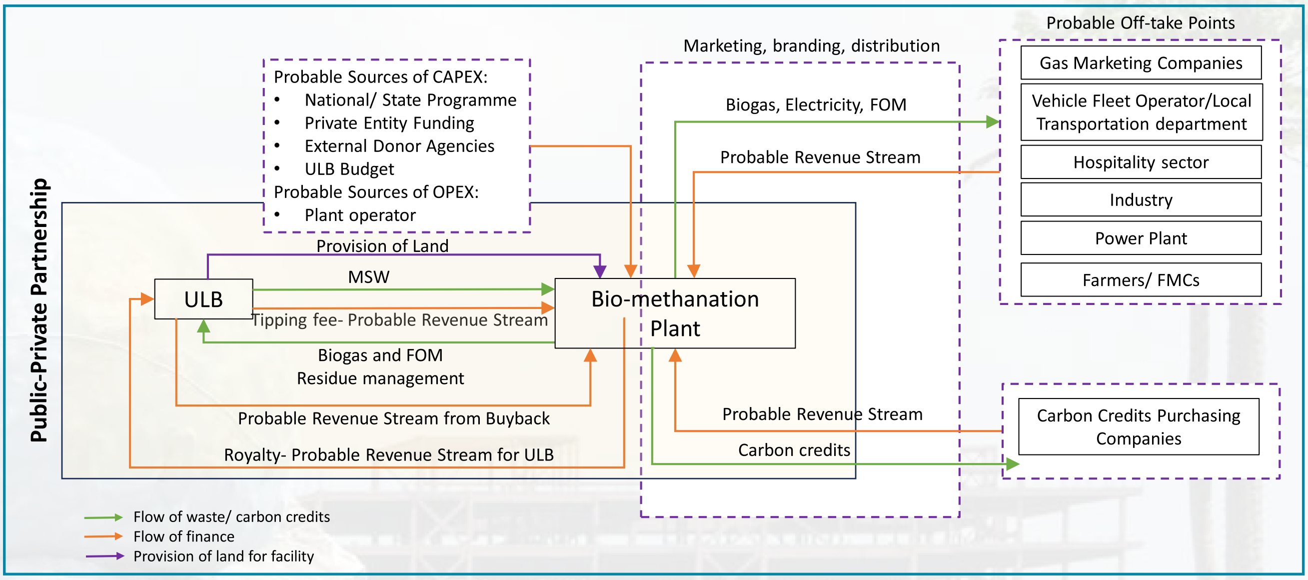


Figure 7: Indicative financing arrangements for MSW-based biomethanation plants

4.3. Case Studies

Decentralised Bio-CNG Plant by Mahindra Waste to Energy Solutions Limited

The Story

Udaipur, also known as the city of lakes, produces an estimated 220 Tonnes of mixed MSW daily, from domestic, commercial and institutional sources, and street sweeping. Currently, the Udaipur Municipal Corporation (UMC) has set up two biomethanation plants with the capacity to process 20 and 2 TPD of organic MSW.

Snapshot of Udaipur Municipal Corporation	
Population (Year 2021)[12]	Approx. 0.58 million
Total MSW Generation[13]	220 TPD

Technical and Financial Modalities

In 2021, Udaipur established a 20 TPD decentralised biomethanation facility for municipal organic waste through a PPP model via viability gap funding. Under this arrangement, a portion of the funding is contributed by the municipal corporation or state/national government, and the remainder is covered by the private firm involved in the project. UMC and Mahindra Waste to Energy Solutions Limited entered a 20-year concession agreement for the project. UMC supplies segregated wet waste primarily from commercial generators such as hotels, canteens, and bulk waste generators like vegetable and fruit markets.

The biomethanation facility in Udaipur is a fully automated plant, utilising a combination of both aerobic and anaerobic digesters that work on the CSTR principle. Two-stage digester systems enhance the digestion efficiency of the plant. A gravitational feeding mechanism is employed to minimise electricity consumption, and an advanced water sealing technology is utilised to prevent gas leakage. The plant provides Mahindra Waste to Energy Solutions Limited revenue from three key sources: 60% from the sale of Bio-CNG to hotels, 30% from the sale of FOM, and 10% from the sale of carbon credits.

Facility Highlights - Technical	
Type of facility	Decentralised Bio-CNG Plant
Land ownership	Udaipur Municipal Corporation
Business model	Viability Gap Funding-based Design-Build-Own-Operate-Transfer (DBOOT)
Concession period	20 years
Owner of facility	Mahindra Waste to Energy Solutions Limited
Year of Establishment	2021
Designed capacity	20 TPD

12. https://earth5r.org/sustainable-waste-management-in-indore-a-case-study/#:~:text=Indore%2C%20with%20a%20population%20of,metric%20tons%20of%20waste%20daily.

13. ICLEI South Asia

Type of feedstock	Segregated wet waste from hotels and vegetable markets; feedstock received daily is only half the plant's capacity.
Targeted generators	Commercial units (hotels, canteen, etc.) and BWGs (vegetable and fruit markets)
Replicability	Replicated in Udaipur based on the experience of Indore
Facility Highlights - Financial	
CAPEX	INR 125 million • INR 85 million – Viability Gap Fund from Udaipur Municipal Corporation • INR 40 million – Mahindra Waste to Energy Solutions Limited
OPEX	• INR 1 million/month
Source of Revenue	Three sources of revenue at present: • 60% Biogas (Biogas to Bio-CNG) • 30% Organic Manure • 10% Carbon Credits
Break Even	Impacted due to inadequate feedstock received by the plant

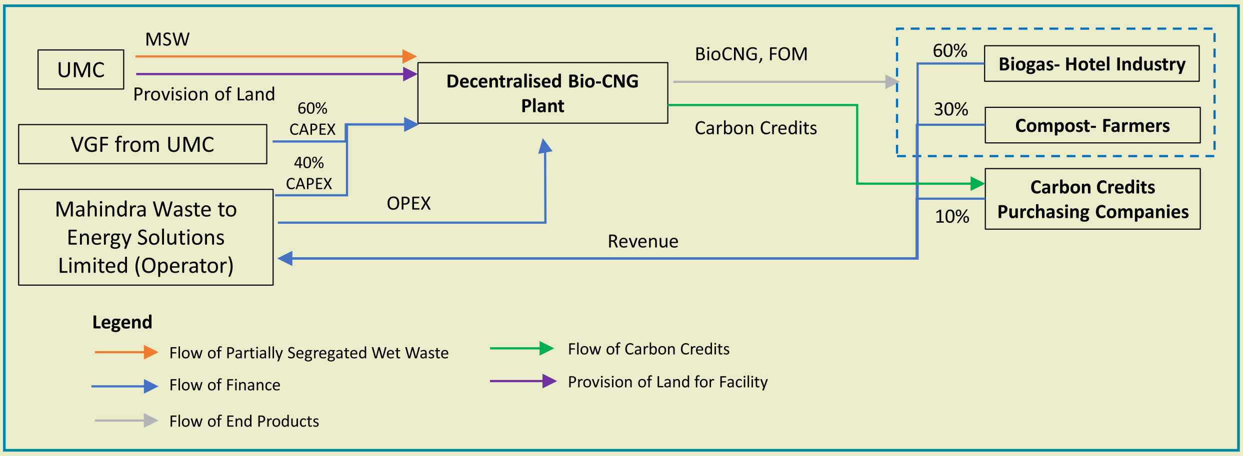


Figure 8: Operational and financial model of decentralised Bio-CNG plant – Udaipur

Key Insights

- **Maintaining a consistent and sufficient supply of high-quality feedstock** is crucial for operating a plant at its maximum capacity. An insufficient feedstock supply not only hinders the plant's efficiency but also has a detrimental effect on overall financial performance.
- The **quality of waste** is equally essential for the sustainable operation of the plant.
- Incentives such as SATAT for assured off-take of Bio-CNG by oil and gas marketing companies, and market development assistance for FOM, play a pivotal role in stimulating the growth of the Bio-CNG market and boosting revenue.
- **Government support and subsidies** are critical in the establishment of high-cost Bio-CNG plants and encouraging more private players to enter the field by safeguarding their investments.

Contributor: S. Sundhara Babu, Mahindra Waste to Energy Solutions Limited

Decentralised Municipal Solid Waste based Bio-CNG Plant by Cabonlites

Photo credit: https://www.carbonlites.com/

Snapshot of host Urban Local Bodies		
	Bengaluru	**Siddipet**
Population	13 million (2020)[14]	0.040 million (2011)[15]
Total MSW Generation	4500 TPD (2022)[16]	47 TPD (2021)[17]
Components of Carbonlites' engagement	Bio-CNG Plant	

The Story

ULBs currently spend around INR 20 to 30 billion annually on MSW transportation, which is expected to come down significantly with decentralised treatment facilities being set up at strategic locations across the city.

In this context, Carbonlites (Indian arm of Carbon Masters, UK) set up MSW-based decentralised biomethanation plants in the cities of Bengaluru and Siddipet. The facilities undertake scientific processing of wet waste into Bio-CNG and bio-fertilizer, thus enabling circular economy principles. The facilities also reduce the burden of MSW transportation and landfill management costs of the respective ULBs. To scale up the initiative, contracts have been awarded for setting up 11 more plants of 5 TPD capacity each in Bengaluru.

14. https://site.bbmp.gov.in/departmentwebsites/swm/, retrieved in Sep 2023
15. Census of India, 2011
16. https://nammakpsc.com/articles/bbmp-solid-waste-management/, retrieved in Sep 2023
17. http://www.indiaenvironmentportal.org.in/files/file/waste-management-Telangana-report-NGT-2021.pdf, retrieved in Sep 2023

Technical and Financial Modalities

Established in 2022, the decentralised Bio-CNG plants operate on a DBO-based PPP model established between the ULBs and Carbonlites. Land for the facility was provided by the ULBs free of cost. The ULBs are also responsible for collecting and transporting segregated waste up to the processing facility in both the cities, with Carbonlites having the right to reject feedstock if it is mixed and contaminated.

Both the plants are equipped with a pre-treatment unit, followed by a temperature-controlled anaerobic digester that operates based on the CSTR principle. Input feedstock is pre-processed into pulp up to slurry consistency. Slurry is fed into the CSTR for anaerobic digestion to produce biogas, which contains 60% methane. The remaining 40% consists of moisture, CO2 and hydrogen sulphide. The raw biogas is further purified into CBG, containing 98% methane. The digestate is aerobically composted in the presence of a proprietary mix of bacteria, and sun dried to be converted into bio-fertilizer. The unique Bengaluru model features a fully functioning biogas plant housed inside a refurbished shipping container, referred to as 'Carbonlites in a Box'. The 25 TPD plant at Siddipet produces 0.2 Tonnes of Bio-CNG and 4 to 5 Tonnes of bio-fertilizer per day.

Facility Highlights - Technical	
Type of facility	Bio-CNG Plant
Land ownership	ULB
Business model	Design--Build-Operate (DBO)
Concession period	10 Years
Owners of facilities	ULBs
Year of establishment	2022
Design Capacity	**Siddipet** - 25 TPD **Bengaluru** - 10 TPD
Type of feedstock	99% segregated wet waste
Catchment Area	**Siddipet** - City level **Bengaluru** - Specific RWAs in Koramangala
Facility Highlights - Financial	
CAPEX'	• **Siddipet** – INR 55 million (ULB – INR 45 million, Carbonlites – INR 10 million) • **Bengaluru** – INR 25 million (ULB – INR 10 million, CSR fund – INR 15 million)
OPEX	• **Siddipet** - INR 0.1 million/month[18] • **Bengaluru** - INR 0.042 million/month[19]
Source of Revenue	**Bio-CNG** • CNG cylinders sold to hospitality sector – off-take by 50 hotels and restaurants • Fuel replacement of Carbonlites' transportation fleet[20]

18. ICLEI South Asia estimated monthly OPEX of the plants based on annual OPEX shared by Carbonlites in July 2023 i.e., INR 12 lakh/ annum for Siddipet plant.
19. ICLEI South Asia estimated monthly OPEX of the plants based on annual OPEX shared by Carbonlites in July 2023 i.e. INR 5 lakh/ annum for Bengaluru plant.
20. Indirect revenue as cost savings on fleet fuel

	Bio-Fertilizer • Directly sold to farmers • Engagement of Farmer Producer Organization (FPO) • Setting up organic manure store in govt. market yard **Carbon Credits** • Registration underway for a portfolio of 60,000-70,000 tonnes/annum
Payback Period	2-3 years
Earnings Before Interest, Taxes, Depreciation, and Amortization (EBIDTA)	Positive after 12-15 months of operation
Internal Rate of Return	Projected upward of 18-20%

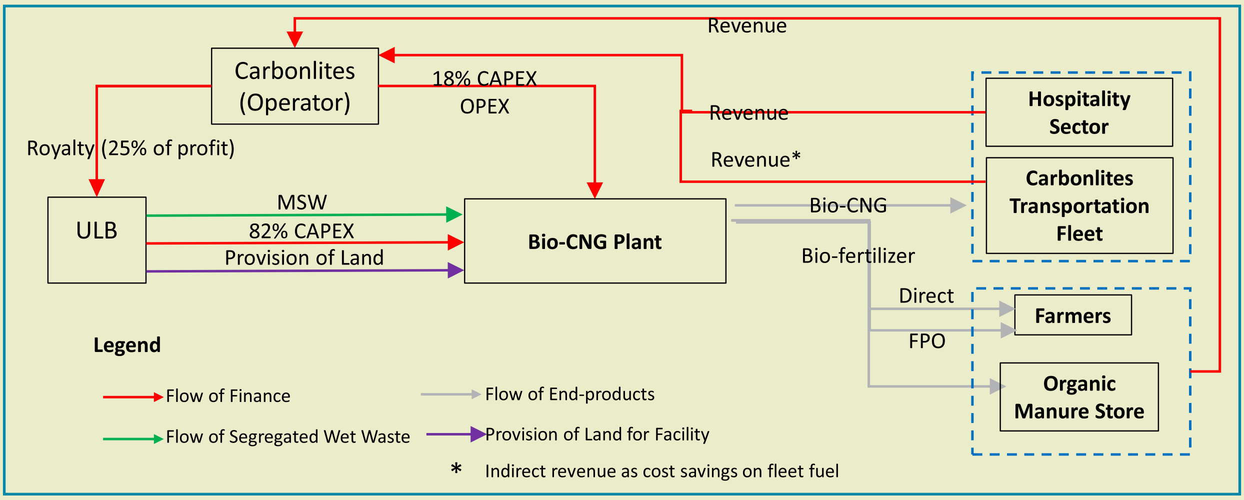


Figure 9: Operational and financial model of decentralised Bio-CNG plant in Siddipet

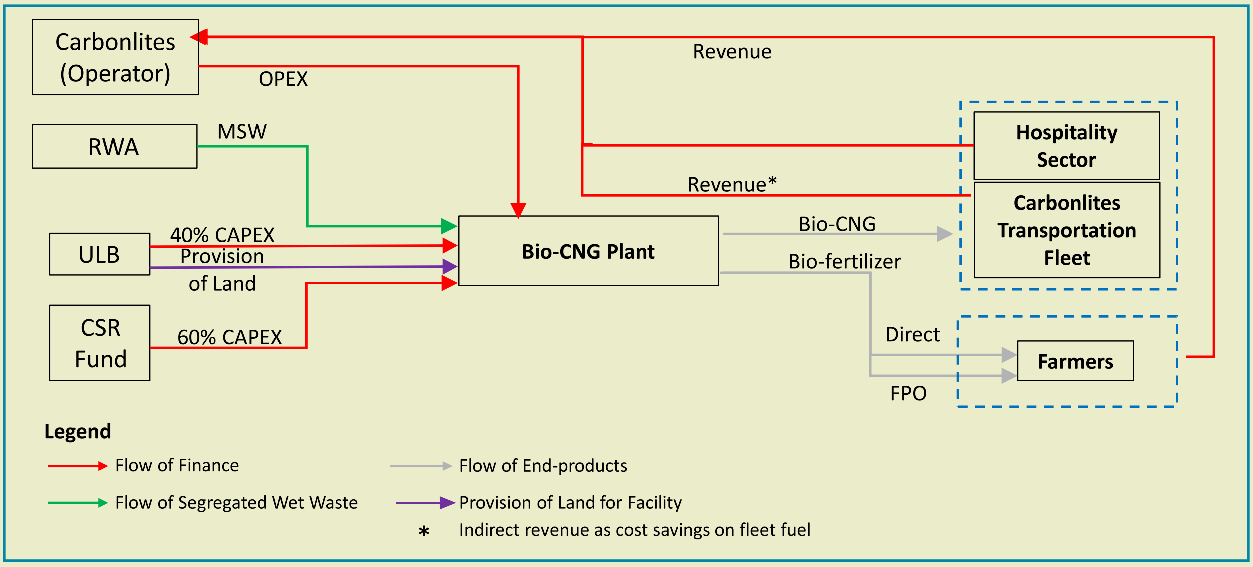


Figure 10: Operational and financial model of decentralised Bio-CNG plant in Bengaluru

Photo credit: https://www.carbonlites.com/

Key Insights

- **While designing and planning for project finance, the operator must factor in an initial window of one to two months** until the plant can start operating at the designed capacity. Machinery must be equipped with **back-up systems** to factor in biological breakdown for one to two months after every eight to10 years of operation.
- High moisture content in feedstock during **monsoons** cause **an increase in OPEX by 15 to 20%.** Further, seasonal factors such as **lack of sunshine for solar drying** and **reduced off-take of manure by farmers except during Rabi and Kharif seasons,** impact financial viability. The facility's storage capacity should be designed depending on quantum and frequency of off-take.
- Viability gap funding (VGF) in the form of **tipping fee from ULB is required.** On the other hand, **profit sharing with ULB is unviable, especially for small-scale plants,** due to their CAPEX and OPEX-intensive nature. Profit sharing for a **large-scale plant (such as 500 TPD) could be explored, depending on the availability of VGF (50%), project capacity, regular processing, and sale of end-product. However, carbon credits could potentially be channelised to the ULB when it is responsible for 100% CAPEX.**
- For the long term, debt and equity financing can make a Business more viable.
- Other external factors determining financial viability are as follows:
  - User charges should be formulated and levied proportionately to enable recovery of collection and transportation costs, and a major part of the processing cost.

- There should be commitment from generators to hand over segregated waste to authorised collection agencies.
- Dedicated collection of wet waste five days a week and dry waste thrice a week enables easier segregation across the value chain, as experienced in Siddipet.
- Distributing payment to primary collection and transport agencies based on the quality of waste would encourage segregated collection and transportation up to the processing facility.
- There should be agreement with the ULB on getting assured quantum and quality of feedstock.
- Potential off takers should be present within 50 to 60 km of the plant's location.
- There should be a stable project supervising team representing the ULB administration for at least 10 to 15 years.
- The ULB should be actively engaged to facilitate different clearances such as PESO (Petroleum and Explosive Safety Organization) approval, fire license, Pollution Control Board (PCB) clearances, etc.

Contributors: Som Narayan & Shubham Joshi, Carbonlites

5. Material Recovery Facilities

A Materials Recovery Facility (MRF) is a unit where non-biodegradable (recyclable and combustible) solid waste can be temporarily stored by the local body, or any person or agency authorised by them. The MRF facilitates segregation, sorting and recovery of materials from various components of waste by authorised informal waste pickers, recyclers or any other work force engaged by the local body for the purpose, before the waste is taken for processing or disposal.

5.1. Types of Material Recovery Facilities

In terms of composition of input feedstock, MRFs could be classified into two categories:

Clean MRF: This is a facility that receives source-segregated or commingled dry waste (recyclable and combustible materials primarily separated from mixed solid waste stream, but with some fraction of inert and wet waste still present). The incoming material typically goes through manual or automated pre-sorting, followed by segregation into various streams to the extent possible. Clean MRFs are recommended for ULBs with high levels of source segregation, and segregated collection and transport systems.

Dirty MRF: This is a facility that receives mixed waste, which is segregated manually or mechanically to separate the recyclable and combustible materials from the wet and inert fraction. A dirty MRF should be equipped with a robust pre-sorting facility to enable efficient material recovery. Issues of leachate generation and emission of a foul odour are common challenges in operation of dirty MRFs (Asian Development Bank, 2013). Dirty MRFs are not an ideal solution as the recyclables in the incoming waste can be so highly contaminated with organic waste that the outputs might not be suitable for recycling plants.

Depending on the scale of operations, type of operations and the level of mechanisation in the facility, MRFs may be classified as manual, semi-automatic or mechanised.

Table 10: Types of MRF Systems

	Manual	Semi-automated	Automated
Description	These facilities will take care of both dry waste stream and wet waste fraction. These proposed facilities can also segregate the mixed waste.	These can also be used as waste transfer stations on addition of some compaction equipment and hook loaders. Compaction of the segregated waste/ inert fraction will help reduce transportation costs, air pollution and GHG emissions by reducing the number of trips of trucks.	Automated MRFs cannot segregate mixed waste if the mixed component is more than 20% of the total received waste (CPHEEO, 2020). Each municipal zone with more than 250 TPD of waste generation can benefit from one MRF to optimise segregation, transportation costs and sustainability. Automated MRFs are recommended only for million plus cities.
Population	Up to 1 lakh	1 - 10 lakh	More than 10 lakhs

	Manual	Semi-automated	Automated
Waste Generation	Up to 40 TPD	About 200 - 400 TPD	More than 500 TPD
Waste Composition	Dry waste – less than 50% Wet waste – more than 50%	Dry waste – 50 - 55% Wet waste – 45 - 50%	Dry waste – more than 60% Wet waste – less than 40%
Requirement of Source Segregation	No	Medium	High
Land	1,500-4,000 sqm (approx.)	6,000-10,000 sqm (Approx.)	10,000-20,000 sqm (Approx.)
CAPEX	INR 1.5 - 4.5 million per facility, excluding cost of land	INR 45 - 60 million per facility, excluding cost of land	100 TPD: INR 180-200 million* 200 TPD: INR 240-260 million* 300 TPD: INR 290-310 million* **Excluding cost of land*
OPEX	INR 1.5-2.3 million per year	INR 6-8 million per year	INR 6.5-8 million per month
Manpower	10 - 18 per MRF	25 - 30 per MRF	35 - 50 per MRF
Energy input	Low	Medium	High
Market potential	The type of input feedstock determines the type of end-product. High level of segregated feedstock will yield higher recovery of recyclables. Recyclables are to be channelised to registered recyclers. Uptake of RDF needs to be ensured by cement industries as per the SWM Rules, 2016, and Guidelines on Usage of Refuse Derived Fuel in Various Industries, MoHUA, 2018.		

Source: Adapted from CPHEEO, 2020

An MRF consists of a combination of processing units in varying degrees of mechanisation (Figure 11). Generally, a semi-automated or automated MRF follows the 2-unit processes described below:

- **Pre-sorting:** Waste sorting or processing through manual or mechanical techniques is essential to separate bulky or large pieces and packets of waste. Manual sorting results in higher labour costs and lower processing rates. Manual sorters remove bulky waste as it passes along on a conveyor belt that carries the pre-sorted waste to the mechanised sorting unit of the facility. Mechanical bulky waste sorters can also be used, depending on the expected character of the incoming waste stream.
- **Mechanical sorting:** Mechanical processes use principles of electromagnetics, fluid mechanics, pneumatics, etc. to segregate the different waste streams. These include trommel/ballistic separator, magnetic separator, air classifier, optical sorter, etc.

MRF, especially semi-automated or automated, is a capital-intensive facility. OPEX of automated MRF is more than 10 times that of semi-automated MRF (CPHEEO, 2020). Therefore, assured inflow of segregated feedstock as per design capacity will influence the proportion of recoverable recyclable and combustible fractions. Higher proportion of recyclable fraction will enhance revenue generation, thereby ensuring financial viability of an automated MRF.

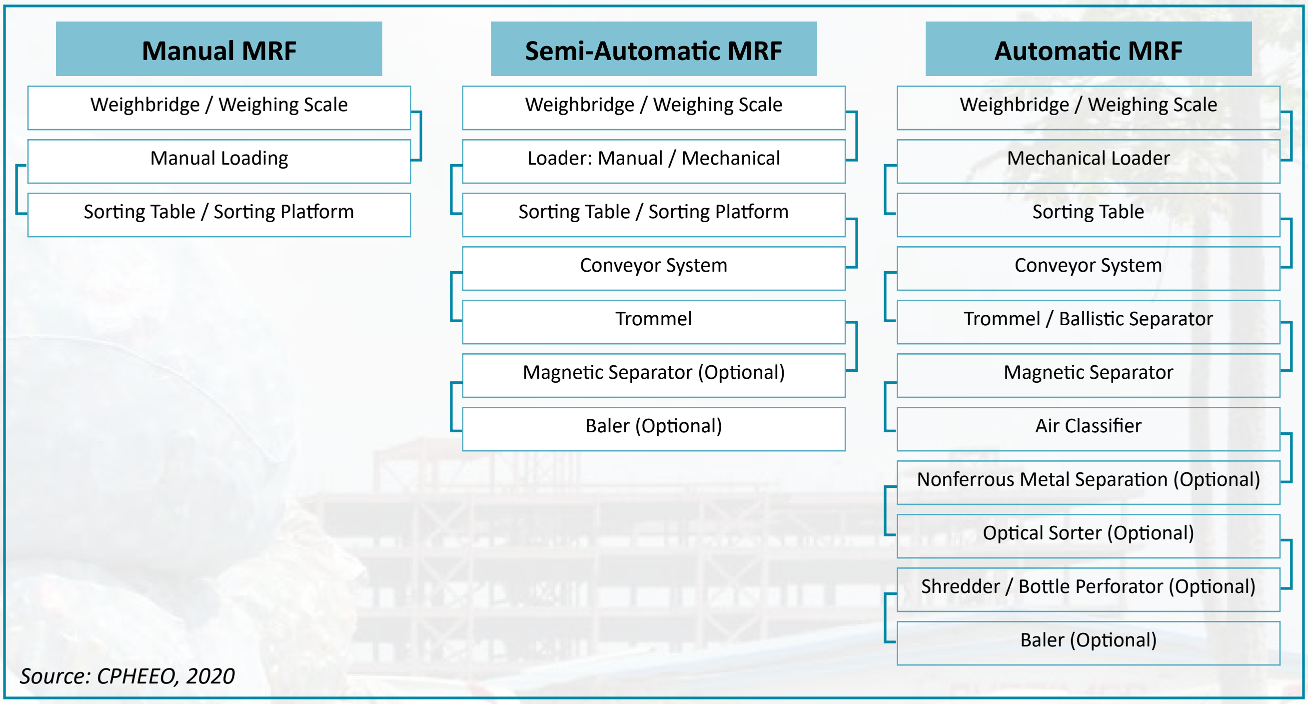


Figure 11: Comparison of process flow in different types of MRFs

5.2. Financing Material Recovery Facility

Though the initial investments of these capital-intensive processing plants are funded through national programmes and schemes such as SBM Urban 2.0, 15th FC Grant, Smart Cities Mission, etc. or grants from donor agencies, among others, a financially viable business model should be established to cover the O&M costs and ensure long-term sustainability.

The table below provides indicative pricing for the equipment required to set up a 100 TPD fully automated MRF. This includes high-end automation such as an AI-based optical Pneumatic Sorter, the requirement of which varies on a case-by-case basis.

Table 11: Suggestive Electro-mechanical Equipment for a Fully-automated 100 TPD MRF

List of Electro-mechanical Equipment	Unit Cost (in Lakhs)	Quantity	Total Cost (in Lakhs)
1. Weighing and Receiving Station- 40 T (6 cells)	7	1	7
2. Pre-sorting Line3 and Processing			
a. Grab Crane- 5 T	4	1	4
b. Trommel	20	2	40
c. Conveyor Belts System	45	1	45
d. Hopper	5	1	5
e. Disk separator 20TPH	150	1	150
f. Density Separator 1.5TPH4	2	1	2
g. Magnetic Sorting 10TPH	2	1	2
h. Eddy Current Sorting 2TPH	2	1	2
i. AI Based Optical Pneumatic Sorter 3 TPH	600	1	600
j. Dryer 1 TPH5	1	1	1

List of Electro-mechanical Equipment	Unit Cost (in Lakhs)	Quantity	Total Cost (in Lakhs)
k. Shredder	30	1	30
h. Baling Machine	40	1	40
3. Vehicles with Loading-Unloading Mechanism	10	2	20
4. Storage Bins	0.3	30	9
Total Cost			**957**
Total CAPEX for Electro-mechanical Equipment			**INR 9.57 Cr.**

Source: Adapted from CPHEEO, 2024, South Pole Carbon Asset Management Ltd. (South Pole), 2022, and Discussion with NEPRA, 2023

The business model for MRFs could be centred around the ULB, with the engagement of a private entity. Key sources of revenue for MRFs are through the following streams:

1. **Sale of recyclables** - High value recyclables such as cardboard, paper, glass, metal and Polyethylene terephthalate (PET), High-density polyethylene (HDPE), and Polypropylene (PP) plastics recovered from MRFs can be sold to recycling industries in shredded or baled form, as per requirements. Although contaminant free recyclables could potentially harness significant revenue for MRFs, generally in India they can recover only up to 10% of the incoming feedstock for recycling.
2. **Sale of RDF** - The major source of revenue from MRFs come from the combustible fraction that is processed as RDF and sold to cement industries. Out of incoming feedstock at an MRF, close to 90% is recovered as RDF.

- **EPR Credit** - Upon registration as a Plastic Waste Processor (PWP), MRF operators can exchange EPR credits with plastic packaging Producers, Importers, and Brand Owners (PIBOs). This enables PIBOs to adhere to their EPR targets as per Guidelines on Extended Producer Responsibility for Plastic Packaging included as Schedule II under the Plastic Waste Management (Amendment) Rules 2022.

  Along with EPR, there are several other plastic credit systems which could be sources of revenue for plastic recovery/ recycling units.

3. **Carbon Credits Trading** - MRFs have the potential to mitigate GHG emissions. Revenue can be generated by participating in a carbon offset programme or selling carbon credits.

The prices of key recyclable materials such as plastics, metal, paper, and glass are determined by the global economy and demand from the manufacturing sector. Table 13 presents the average prices of recyclables prevalent in India in 2025, indicating that the total daily value recovered from dry waste has risen by nearly 2.5 times compared to 2021.

Table 12: Selling price of recyclables from MRF

S. No.	Type of waste	Content in MSW (%)	Generation TPD	Recovery (%)	Recovery TPD	Value (INR/ tonne)	Daily Value Recovery (in INR Cr.)
1	Plastic	15	23,883	80	19,107	10,000	19.11
2	Paper and cardboard	7	11,146	80	8,916	10,000	8.92
3	Glass and ceramics	1	1,592	50	796	10,000	0.80
4	Metal	1	1,592	80	1,274	10,000	1.27
5	Textiles	5	7,961	60	4,777	5,000	2.39
6	Tyres and rubber	1	1,592	80	1,274	10,000	1.27

S. No.	Type of waste	Content in MSW (%)	Generation TPD	Recovery (%)	Recovery TPD	Value (INR/ tonne)	Daily Value Recovery (in INR Cr.)
7	Others (human hair, coconut shell, Tetra pak, footwear)	3	4,777	60	2,866	8,600	2.46

Based on the total MSW generation in 2025 (1,59,222.02 TPD as per SBM Urban 2.0), and using the percentage composition, recovery rates, and INR value per tonne from MoHUA (2021), it is estimated that recovery of dry waste through MRFs could generate approximately INR 36.22 crore in daily revenue.

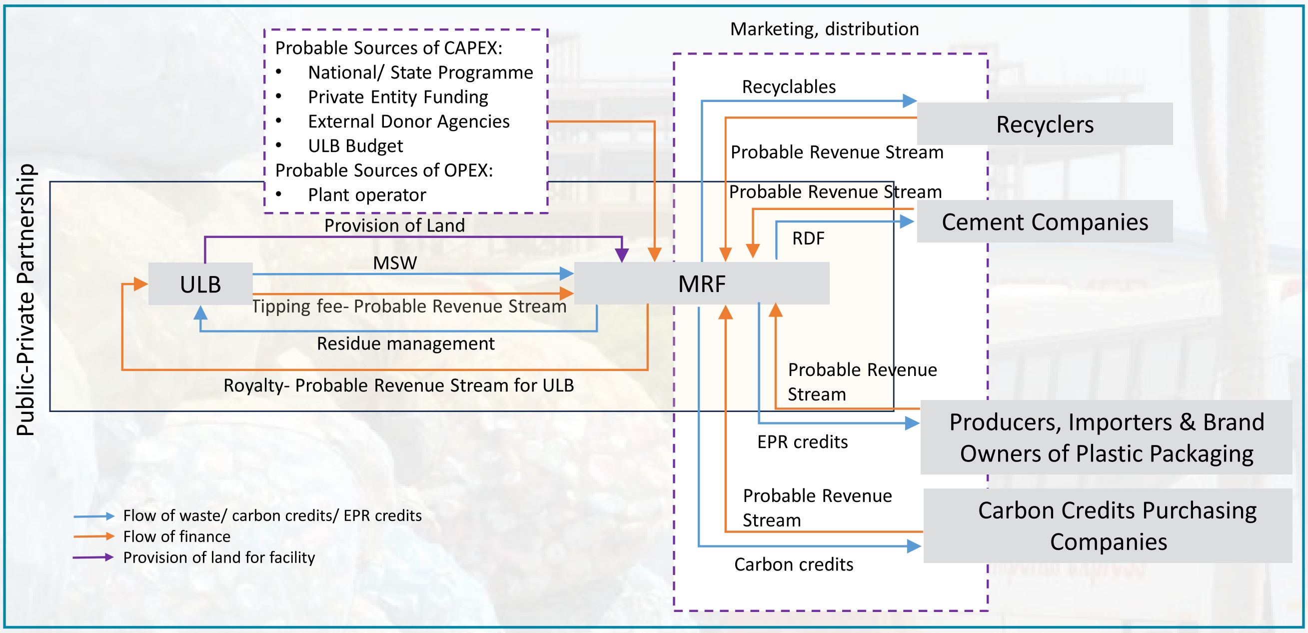


Figure 12: Indicative Financing Arrangements for MRF

5.3. Overview of MRFs in India

The Dry fraction constitutes 30 to 50% of municipal solid waste generation in India (MoHUA, 2021). Setting up MRFs became a priority for ULBs after the SWM Rules, 2016 were published. According to the SBM Urban 2.0 database, more than 5,000 MRFs are installed in urban India. Karnataka, Madhya Pradesh, Maharashtra, Tamil Nadu and Uttar Pradesh are the five states with the maximum number of MRFs (SBM Urban 2.0, 2023).

MRFs in India range from decentralised (as low as 1 or less than 1 TPD capacity), to centralised (hundreds of TPD capacity) units, depending on the local situation. The decentralised model includes community-driven small-scale units which are self-sustaining, as in small towns generating about 50 to 60 TPD of MSW, such as Ambikapur in Chhattisgarh and Alappuzha in Kerala. Informal sector workers, who traditionally play a major role in the collection and recovery of recyclables in India with little or no access to minimum wages, social security benefits, or PPE, are being formally integrated and becoming a driving force in these decentralised business models with assured financial returns.

Ambikapur Nagar Nigam (ANN), in association with women from local SHGs, operate the Solid Liquid Resource Management (SLRM) centres. ANN has an agreement with Swachh Ambikapur Mission Sahakari Samiti, which supervises the women SHG members. They collect segregated waste from all types of generators using vehicles owned by the ULB and segregate it into wet and dry fractions (about 100 sub-categories) at the SLRM centres.

Dry fractions are sold to designated junk dealers daily. User charges collected from generators, and sale of recyclables and compost are the key sources of revenue. In the financial year 2022-23, total revenue generation of INR 35 million was achieved (user charges – INR 18.3 million, sale of recyclables – INR 12.5 million, sale of compost – INR 4 million). Part of the revenue was used to raise the salaries of the women sanitation workers, thereby making the system self-sustaining (Gupta, 2023).

India is also seeing large-scale automated MRFs based on the PPP model gradually being set up. A 300 TPD fully automated MRF operated in Indore by waste management company Nepra has demonstrated the utilisation of high-end technologies such as ballistic separators, magnetic separators, optical pneumatic sorters, etc. It has also shown that the ULB should share the financial risk of such a cost-intensive facility with the private sector, to ensure its stake in the facility's long-term operations and revenue generation.

Photo by Ryan Brooklyn on Unsplash

5.4. Case Studies

Decentralised MRF by Saahas Waste Management Private Limited

The Story

The NGO Saahas is playing a crucial role in the management of dry waste, with a special focus on low value plastics (LVPs). They operate a decentralised semi-automated MRF to serve five ULBs of Bengaluru district, with a capacity to process 12 TPD of dry waste. These ULBs, belonging to the categories of city municipal council, town municipal council, and town panchayat, collaborate to enhance waste management practices. In addition to its partnership with the ULBs, Saahas is extending its services for the specific dry waste management needs of technology companies located in Bengaluru under the **Zero Waste Programme (ZWP).**

Technical and Financial Modalities

Saahas established the MRF in 2015. Initially designed to manage 1 to 2 TPD of dry waste, the plant's capacity was enhanced to manage 12 TPD of dry waste in 2017. Saahas made a capital investment of **INR 6 to 8 million** in the plant, covering its entire establishment cost. The MRF's current responsibility is to manage dry waste collected from different sources, including waste (especially **LVP**) from the five ULBs in Bengaluru district. This initiative receives financial support from a leading international organisation. The recovered LVP is subsequently supplied to cement factories.

The **semi-automated facility** is equipped with two conveyor belts for the primary and secondary sorting of waste. Skilled labourers sort the waste manually as part of the process, and two baling machines are used to compress the sorted materials.

The technology companies that Saahas services under the ZWP produce substantial amounts of dry waste, encompassing diverse plastic types, cardboard and paper. Saahas charges them service fees for collecting and sorting the waste. Valuable recyclable dry waste is sold and rejects from the MRF plant are transported to a landfill site for proper disposal. Additionally, Saahas generates a portion of its revenue from EPR services.

Facility Highlights – Technical	
Type of facility	Decentralised Material Recovery Facility
Land ownership	Rented from private entity
Business model	Privately owned
Owner of facility	Saahas Waste Management Private Limited
Year of establishment	2015
Design Capacity	12 TPD
Type of feedstock	Segregated dry waste
Catchment Area/ Generator	• Technology companies • 5 ULBs, including town municipal council, city municipal council, and town panchayat
Replicability	Pilot MRFs in 4 districts – Udupi, Dakshina Kannada, Ramanagara and Ballari

Facility Highlights – Financial	
CAPEX	INR 6 - 8 million
OPEX	INR 10 per kg of waste • Including rent, human resources, utilities
Source of Revenue	• Sale of waste • Service fee from ZWP client • Funding from international entity for collection of LVPs • Charges for ERP
Break Even	4 years
Profit and Loss	Profit (INR in lakhs): • Year 2022- 107.95 • Year 2023- 228.80 • Year 2024- 104.10

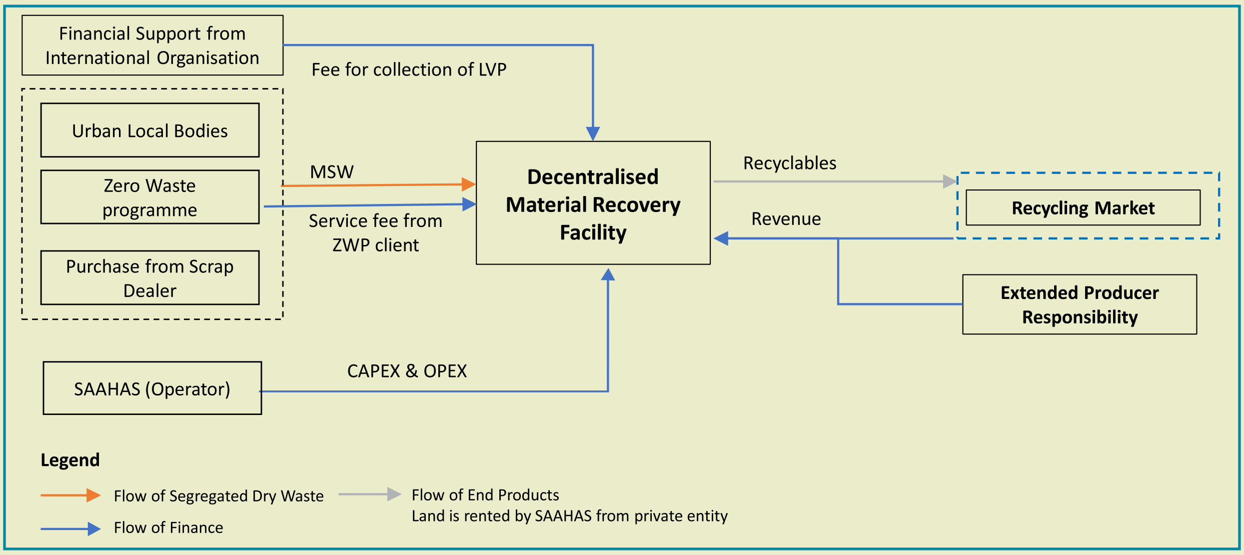


Figure 13: Operational and Financial Model of Decentralised Material Recovery Facility in Bengaluru – SAHAAS

Key Insights

- **Optimal capacity utilisation** is imperative for an MRF to avoid inefficiency. Underutilisation poses challenges in achieving cost-effectiveness within the facility.
- To enhance revenue, the facility requires **segregated feedstock and waste streams** with the highest potential for value addition **prioritised** at the MRF. This approach aims to maximise the recovery of recyclable materials, which can then be sold profitably in the recycling market.
- **Effective data capture** is crucial for the optimal functioning of an MRF.
- **In a rental model, modifying and adapting the MRF can be challenging**, hindering the adoption of innovative technologies and efficient upgrades.

Contributors: Murthy T. and Bhagyashree Vinod Shastri, Saahas Waste Management Private Limited

CSR Funded Decentralised MRF in Puducherry by ReCity Network Private Limited

The Story

Puducherry Municipality, a coastal ULB in the Union Territory of Puducherry, generates 170 MT of MSW per day. Earlier, mixed MSW was collected from the doorstep and disposed into a dumpsite without processing the dry fraction, except recovery of a miniscule share of high-value recyclables through informal value chains.

Snapshot of Puducherry Municipality	
Population	0.244 million (2011)[21]
Total MSW Generation	170 TPD[22]
Components of Engagement	• MRF • Awareness building at points of generation • Digital enabling of collection and transport system • Integration of informal workers into formal value chain, ensuring social security measures for them

In this context, ReCity set up a decentralised MRF called 'Sanitation Park', and initiated an Information Education and Communication (IEC) campaign in Puducherry Municipality, with financial support from Godrej Consumer Products Limited's Corporate Social Responsibility (CSR) funds. The project targeted scientific recovery of non-recyclable fractions by promoting source segregation and ensuring segregated collection and transportation of dry waste, especially non-recyclable fraction, by deploying a digital monitoring system. To scale up the initiative, funds were secured for another 10 TPD MRF catering to the rest of the Puducherry Municipality jurisdiction.

Technical and Financial Modalities

The project aimed to streamline MSWM and build the capacities of 700 waste workers to enable an inclusive and resilient circular economy. The manual MRF recovers non-recyclable fractions from municipal solid waste. Located close to the coastal fishing community, ReCity employs most of the workforce from the neighbouring areas, aligned with its motto of social impact creation. They are also an Ocean Bound Plastic (OBP) certified company.

Facility Highlights – Technical	
Type of facility	Manual Material Recovery Facility
Land ownership	Puducherry Municipality
Business model	CSR-funded Build-Operate-Transfer (BOT)

21. Census of India and discussion with ReCity, July 2023
22. https://recity.in/projects/keep/, retrieved in Sep 2023

Concession period	3 years
Owner of facility	Puducherry Municipality
Year of establishment	2022
Design Capacity	4 - 5 TPD (feedstock supply could reduce to 2 - 2.5 TPD in non-peak tourist season)
Type of Feedstock	Segregated multi-layered plastics, secondary and tertiary packaging materials, and bottle wrappers, along with certain portion of high-value recyclables
Catchment Area	16 wards of 3 zones 32% of ULBs population
Facility Highlights – Financial	
CAPEX	INR 5 million
OPEX	• Approximately INR 0.6 - 1.05 million/month[23] (assumed OPEX of INR 5-7/ kg after maintaining EHS compliances); exclusive of INR 2,000/Tonne of RDF disposal fee payable to cement industries. • The cement companies are expected to provide a detailed certification for the material processed, that includes identification of moisture, and presence of PVC and other banned items.
Source of Revenue	• **Sale of recyclables:** INR 1/kg • **EPR credits:** INR 2 - 4/kg • **Plastic offset:** INR 8 - 10/kg (Plastic offset projects help cover the end-to-end viability gap of the facility's operations . About 90 - 95% of the material at the facility is covered under such projects that pay in the range of INR 8 to 10/ kg for safe and ethical disposal of hard-to-recycle material, and traceability from source to end-of-life with appropriate documentation.)
Break Even	12-15 months

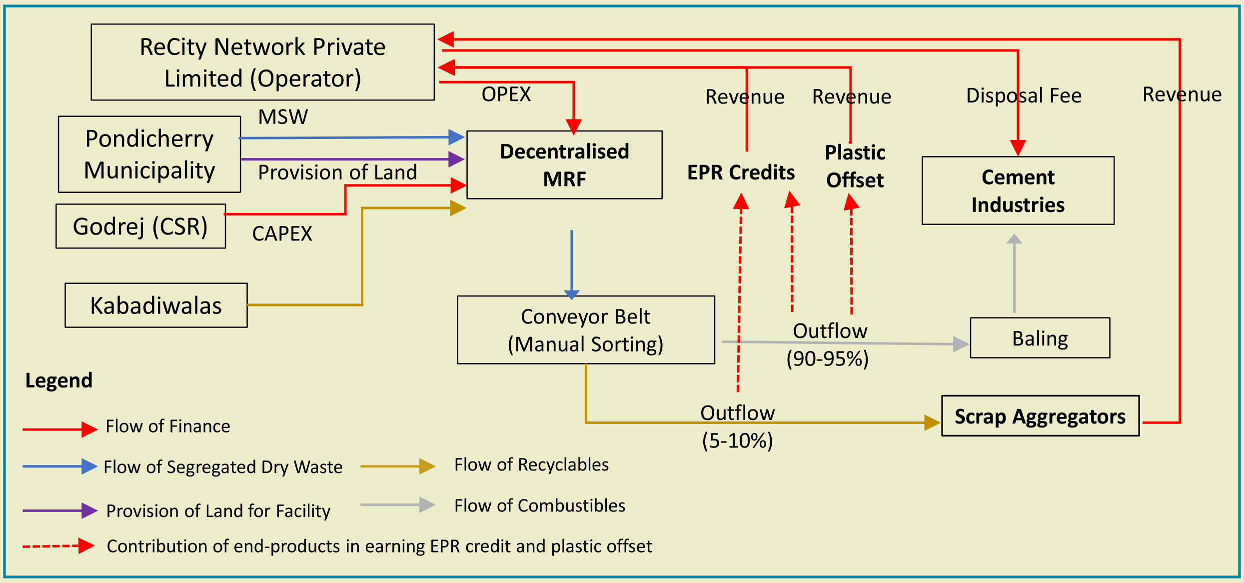


Figure 14: Operational and Financial Model of Decentralised Manual MRF in Puducherry

23. ICLEI South Asia estimated monthly OPEX based on discussion with ReCity in July 2023: Total feedstock handled 4-5 TPD i.e. 4,000-5,000 kg/day x unit OPEX INR 5-7/kg x 30 days

Key Insights

- It is difficult to operate non-recyclable fraction-based MRFs. Their financial viability is influenced by the following factors:
  - **Source segregation and segregated collection and transport** determine the quality of incoming feedstock.
  - **Guaranteed off-take agreement with cement industries** enable sustained revenue generation from non-recyclable RDF fractions.
  - **Revenue generation can be diversified through sources** such as OBP certification
  - **Design capacity should take the fluctuation in inflow into consideration**, especially when the host ULB hosts a large floating population.
  - Storage capacity should be designed to factor in fluctuations in off-take.
  - Engagement of **unskilled workforce requires robust training and capacity building**, thereby having implications in the initial days of operation.
- Setting up decentralised, less capital-intensive MRFs is a **financially viable infrastructure intervention, while utilising CSR funds** aim at social impact creation.
- As an MSW sorting unit, manual MRFs can be a quick-win solution to augment dry MSW recovery infrastructure, **without requiring extensive environmental clearance from pollution control boards.**

Contributor: Bhaskar Lath, ReCity Network Private Limited

Photo credit: https://recity.in/

6. Low Value Plastic Recycling

6.1. Overview of Low Value Plastic Recycling in India

Low value plastics (LVPs) such as Multi-layered Plastic (MLP), Polystyrene (PS), Polyvinyl Chloride (PVC), and Low-Density Polyethylene (LDPE) pose challenges in recycling. Due to their complex composition or additive content, they are difficult to process using conventional recycling methods. Hence, many recycling facilities often do not accept them. Further, their collection is unprofitable for waste pickers, which is why a majority of LVPs either end up in the open or in landfills. Due to their never degrading nature, they turn toxic and affect not only the environment, but humans and animals as well.

Low Value Plastic

Multi-layered Plastic (MLP): MLP consists of different layers of various materials, making separation and recycling more complicated.

Polystyrene (PS): PS, also known as Styrofoam, has a low recycling rate due to its light weight, and bulky and difficult to clean nature.

Polyvinyl Chloride (PVC): PVC contains additives that can complicate the recycling process, and potentially release harmful substances such as chlorine gas, when recycled.

Low-Density Polyethylene LDPE: Although LDPE is technically recyclable, it is often considered an LVP due to several factors, including its low density and low market demand.

According to the 2019-2020 Annual report of the Central Pollution Control Board (CPCB), India generates around 3.4 million tonnes of plastic per annum (CPCB, 2020). Per capita plastic waste generation rose from 700 grams per annum in 2015 to 2,500 grams per annum in 2020 (CPCB, 2020). This indicates a growing trend of higher individual plastic consumption and subsequent waste generation in India. Further, a mere 30% of plastic waste generated in the country is recycled (Aravamudan, 2023). A significant amount of plastic recovery is carried out by the informal sector, indicating the pivotal role played by informal waste pickers in plastic waste management.

Recycling facilities In India prioritise HDPE and PET plastics. These are extensively used in packaging materials including bottles, containers and bags, and hold good market value, making them economically viable for recycling. The recycling rates of PVC, PP, and PS plastics are comparatively lower, and only a limited amount of MLP is recycled in India due to its complex composition (Centre for Science and Environment, 2019). A significant amount of these plastics end up either in open environments or landfill sites. As per a FICCI report, India faces the risk of losing more than $133 billion worth of material value associated with plastic packaging by 2030 due to unsustainable packaging (Accenture, 2020). This underscores the economic significance and potential of effective plastic waste management in the country.

Addressing the issue of LVPs and preventing their accumulation in landfills, open spaces, and water, is a significant concern for the national, state, and local governments in India. To tackle this challenge, the Government of India has been actively promoting sustainable waste management practices, improving recycling infrastructure, and creating awareness about the importance of proper plastic disposal and recycling. Several rules, schemes, and initiatives have been put in place to facilitate sustainable plastic waste management in the country, including the SWM Rules 2016, Plastic Waste Management Rules 2016, Smart Cities Mission, SBM Urban, and so on.

Addressing the issue of LVP and preventing their accumulation in landfills, open spaces, and water is a significant concern for the national, state, and local governments of India. To tackle this challenge, the Government of India has actively been working on promoting sustainable waste management practices, improving recycling infrastructure, and creating awareness about the importance of proper plastic disposal and recycling. Several rules, schemes, and initiatives have been put in place to facilitate sustainable plastic waste management in the country, including the SWM Rules 2016, Plastic Waste Management Rules 2016, Smart Cities Mission, SBM Urban, etc.

6.2. Types of Low Value Plastic Recycling

The recycling landscape of LVP is constantly evolving; there have been advancements in recycling technologies to address these challenges. Some facilities and research institutions are working on innovative recycling processes and techniques to handle LVP more effectively. The key techniques available in the market to recycle LVP are highlighted below:

1) **Energy Recovery:** LVP can be effectively utilised for energy recovery as RDF or Solid Recovered Fuel (SRF). In this process, LVP, along with other non-recyclable waste materials (with good calorific value), are sorted and processed at MRFs. The resulting RDF or SCF serves as a substitute for fossil fuels in the cement industry, or as an input material for Waste to Energy plants or RDF pre-processing facilities, respectively.
2) **Mechanical Recycling (Extrusion):** Mechanical recycling is a common process that involves shredding plastics into smaller pieces and then melting and transforming them into pellets or flakes. However, the mechanical recycling of MLP packaging pose challenges due to its complex composition and contamination. Nevertheless, advancements in recycling technologies have improved the efficiency of MLP recycling.
3) **Chemical Recycling (Pyrolysis):** Chemical recycling, including pyrolysis, is an emerging recycling method that aims to convert LVP polymers back into their original monomers or petroleum products. This process enables the transformation of plastic waste into valuable resources.

6.3. Financing Low Value Plastic Recycling

The business models and cost of establishing recycling facilities dedicated to processing low value municipal plastic waste can be diverse, influenced by factors such as operational scale, target type of plastics and market, location, ULB contracts, and available resources. The initial investments required for capital-intensive processing plants can be financed through various sources, including the following:

- **National Programmes and Schemes:** Funding can be obtained through national programmes like SBM Urban 2.0, 15th Finance Commission Grants, Smart Cities Mission, or other similar government initiatives. The Department of Science and Technology (DST) has also been funding innovative new technologies and initiatives to recycle plastic waste.
- **Grants from International Donor Agencies:** Financial assistance can be sought from donor agencies that focus on environmental sustainability and waste management, such as UNEP (United Nations Environment Programme), Global Environment Facility (GEF), World Bank, etc. These agencies may provide grants or funding opportunities specifically for plastic waste recycling projects.

- **Private Funding:** A private entity itself can invest in the setup of a recycling facility through loans from financial institutions, or partnerships with other private entities interested in supporting environmental initiatives.

LVP recycling facilities rely on various sources of revenue to sustain their operations. The key sources of revenue for such facilities are as follows:

- **RDF:** LVP recycling facilities can process plastic waste into RDF, a type of fuel derived from non-recyclable materials. RDF can be sold to cement factories and power plants for use as a source of energy.
- **Crude Oil:** Recycling processes can transform LVP waste into crude oil through pyrolysis or similar methods. This crude oil can be sold to industries or other businesses for further processing or used as feedstock.
- **Plastic Pellets:** Another common end-product of plastic recycling is pellets. These pellets can be sold to manufactureres of various recycled plastic products such as containers, bags and packaging materials.
- **Manufacturing of Recycled Products:** Some recycling facilities go beyond producing basic raw materials and create value-added products from recycled plastics. These include benches, tiles, recycled plastic bags, and more, which are sold to consumers or businesses.
- **EPR Credits:** Upon registration as plastic waster processors, LVP recycling operators can exchange EPR credits with plastic packaging PIBOs to enable them to adhere to their EPR target as per Guidelines on Extended Producer Responsibility for Plastic Packaging included as Schedule II under Plastic Waste Management (Amendment) Rules 2022.

Along with EPR, there are several other plastic credit systems that could be revenue sources for plastic recovery/ recycling units.

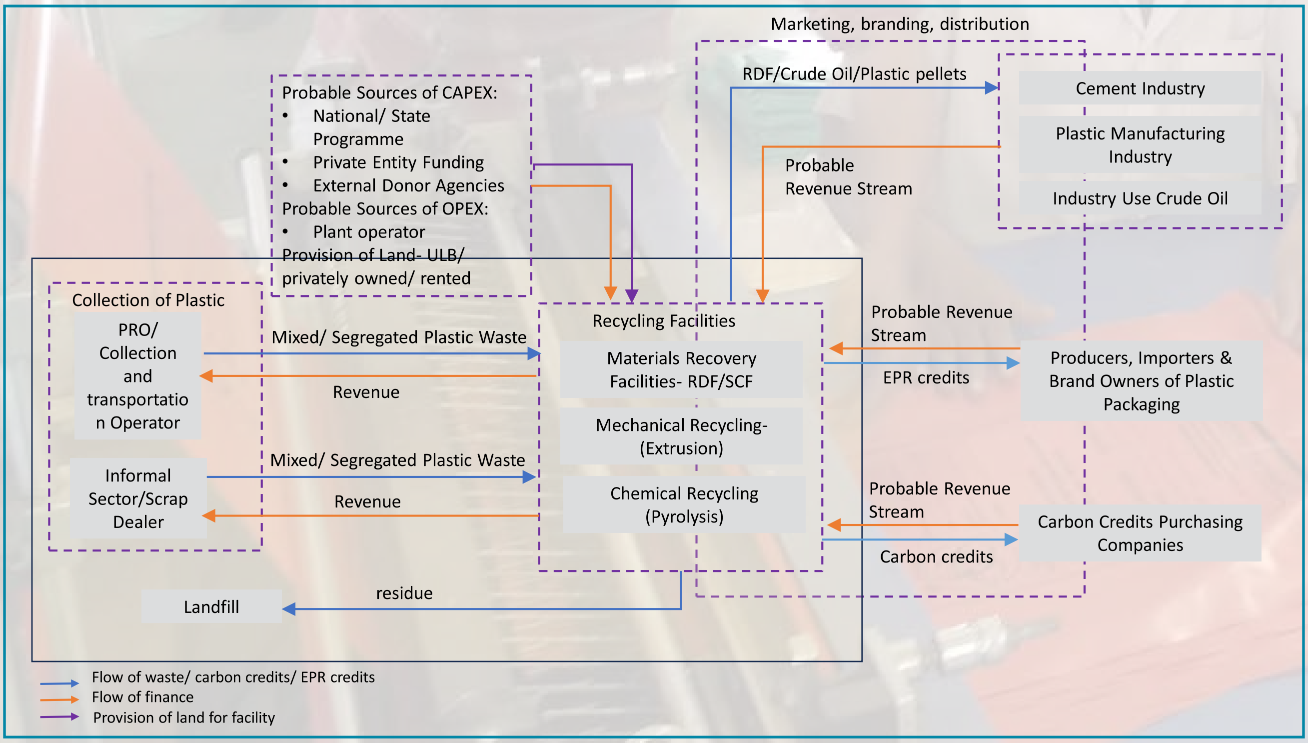


Figure 15: Indicative Financing Arrangements for Municipal LVP Recycling

6.4. Case Studies

Processing of LVP by The Shakti Plastic Industries

The Story

The Shakti Plastic Industries has been widely recognised as a pioneer in plastic waste management, operating in the sector for the last 54 years. Throughout its long history, the company has established its capacity to develop and implement a range of state-of-the-art facilities to process and recycle both high value plastics and LVPs found in MSW. They have established both decentralised and centralised plastic waste processing plants, with capacities ranging from **1 TPD to 200 TPD** in prominent cities including Mumbai, Vadodara, Indore and Bengaluru. The company maintains a nationwide presence in India, operating a network of more than 40 collection centres managed in collaboration with numerous collection partners.

Due to the difficulty in separating and recycling MLPs and their resultant low value in the recycling market, they are frequently not collected by waste pickers, leading to their disposal in drains, open areas, and landfills. To tackle the challenges posed by MLPs, the company has developed and patented an advanced extrusion technology specifically designed for recycling these materials, which are often overlooked by conventional processing facilities.

Technical and Financial Specifications

The unique patented process developed by The Shakti Plastic Industries processes contaminated post-consumer MLPs into high-quality granules or pellets, which are further used in manufacturing new products.

Post-consumer municipal plastic waste is usually contaminated and needs to be washed before being sent for extrusion. The typical process involves sorting, shredding and washing of plastics, followed by extrusion through a heated barrel with a rotating twin-screw by combining heat and mechanical forces, which transforms the shredded plastic waste into pellets. After cooling in a water bath, these pellets are ready to be used in manufacturing new products.

The company sources its feedstock (plastic waste) primarily from ULBs, SHGs, NGOs collecting waste or marine plastics, and aggregators. Additionally, the company offers comprehensive services to recycle post-consumer plastics generated by FMCGs (Fast-Moving Consumer Goods) and pharmaceutical companies, and post-industrial waste. The company collects post-industrial waste from various industrial units using its own vehicles and transports it to multiple processing plants located across the country.

The company primarily sells its end-products (granules and pellets) to manufacturers or exports them. Potential buyers include plastic manufacturing companies that utilise recycled plastic. This helps reduce virgin plastics usage and carbon footprint, aligns with the EPR guidelines, and can help earn plastic credits.

Since 2020, the company has also ventured into producing its own recycled plastic products including tiles, pens, garbage bags, and benches made from MLP. Almost 40 to 50% of the pellets are used for producing in-house recycled products.

Facility Highlights – Technical	
Type of facility	The Shakti Plastic Industries
Land ownership	The company owns the land in most of the plants established by it. However, in cases based on a PPP model, the ULBs assist in providing access to land, water and electricity connections.
Business Model	Recycling facilities are operated using one of the following business models: • Privately managed • EPR compliance for corporates • CSR funds from different companies • PPP model with ULBs – Thane Municipal Corporation (TMC)
Concession period	Concession period with TMC: Minimum 5 years – maximum 15 years
Owner of facility	The Shakti Plastic Industries
Designed capacity	1 TPD to 200 TPD
Type of Feedstock	• LVPs, including MLP and LDPE • High value plastics including HDPE and PP
Facility Highlights – Financial	
CAPEX	CAPEX is contingent on the type of machinery and the country of origin for importation. • For capacity of 500 kg/hour to 4 tonnes/hour the cost is INR 50 - 150 million
Source of Revenue	• Sale of granules/pellets • EPR charges • Sale of products such as tiles, pens, benches, garbage bags, etc. • Recycling of post-industrial waste
Break Even	2- 3 Years

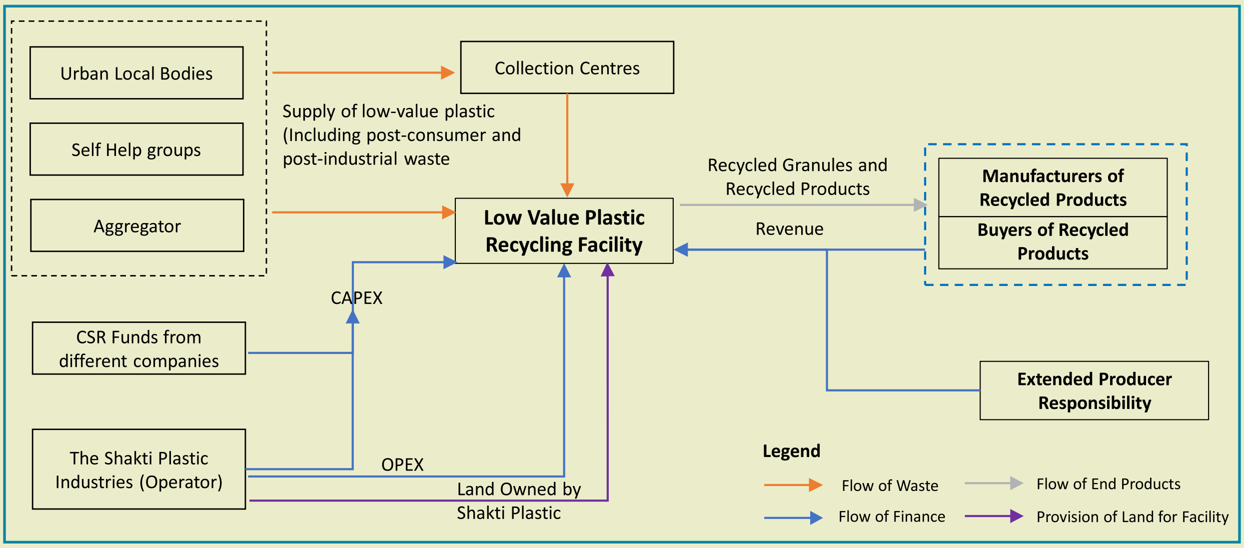


Figure 16: Typical Operational and Financial Model of LVP Recycling Facility by The Shakti Plastic Industries

Key Insights

- Since MSW often contains contaminated plastics that need to be washed before extrusion, a washing line must be installed to ensure the quality of pellets. However, installing a **washing line significantly raises** the overall **capital and operational** expenses of the recycling plant.
- **Sourcing an adequate quantity of feedstock** is critical for the successful operation of a recycling plant.
- **In the absence of source segregation, workers sorting plastics from the mixed waste are exposed to potential health threats.** Also, employing **manual labour** for sorting plastic waste **further increases OPEX** of the plant.
- Establishing a plastic recycling plant requires substantial capital investments. **Support from the government is essential, particularly during the initial stage, establishing clear tenders promoting decentralised MRF** and developing the market potential for recycled products.
- **Government support**, in terms of policy measures, plays a crucial role in promoting the utilisation of recycled plastic granules in manufacturing processes.
- **Fostering market development for the off take of pellets** as well as recycled products is critical for ensuring the long-term sustainability of the facility.

Contributor: Sumedh Kamble, Sustainability & CSR, The Shakti Plastic Industries

Photo by John Cameron on Unsplash

Processing of MLP by UFlex Limited

The Story

UFLEX Limited specialises in the production and distribution of a wide range of flexible packaging items. Their product portfolio includes materials like biaxially oriented polyethylene terephthalate (BOPET) films, biaxially oriented polypropylene (BOPP) films, cast polypropylene (CPP) films, and metallised films.[24] UFLEX initiated plastic recycling in 1996, primarily focusing on recycling the plastic waste generated within its own operations. Subsequently, the company established a plastic recycling facility with a processing capacity of 10 TPD. UFLEX Limited has recently expanded its operations and is now actively involved in accepting municipal plastic waste or post-consumer waste, particularly MLPs. The company is currently engaged in discussions with multiple ULBs to establish recycling plants dedicated to processing MLP waste generated within urban areas.

Technical and Financial Modalities

UFLEX has developed an advanced extruder designed for recycling MLP waste. The device incorporates a dual extruder technology, functioning within a temperature range from 150 to 225°C (ICLEI South Asia, 2021). An air suction pump captures and manages the fumes produced during the melting of inks and adhesives. This comprehensive system is engineered to prevent the emission of harmful gases into the environment. The source of feedstock materials for the company is primarily post-consumer plastic waste acquired from NGOs, and plastic waste generated within its own operations.

The bulk of the finished products manufactured by UFLEX, such as plastic pellets, are primarily sold to plastic manufacturing companies. UFLEX is also actively involved in producing its own recycled products, including items like plastic furniture.

Facility Highlights – Technical	
Type of facility	Decentralised Multi-layered plastic recycling
Land ownership	Uflex Limited
Business model	Privately owned
Owner of facility	UFLEX Limited
Year of establishment	1996
Designed capacity	10 TPD
Type of feedstock	Primarily Multi-layered plastic
Facility Highlights – Financial	
CAPEX	CAPEX • Machinery – INR 220 - 300 million • Civil works – INR 10 million
Source of Revenue	• Sale of granules • Sale of products such as recycled plastic furniture • EPR credits
Break Even	2- 3 Years

24. Source: UFLEX Limited Website

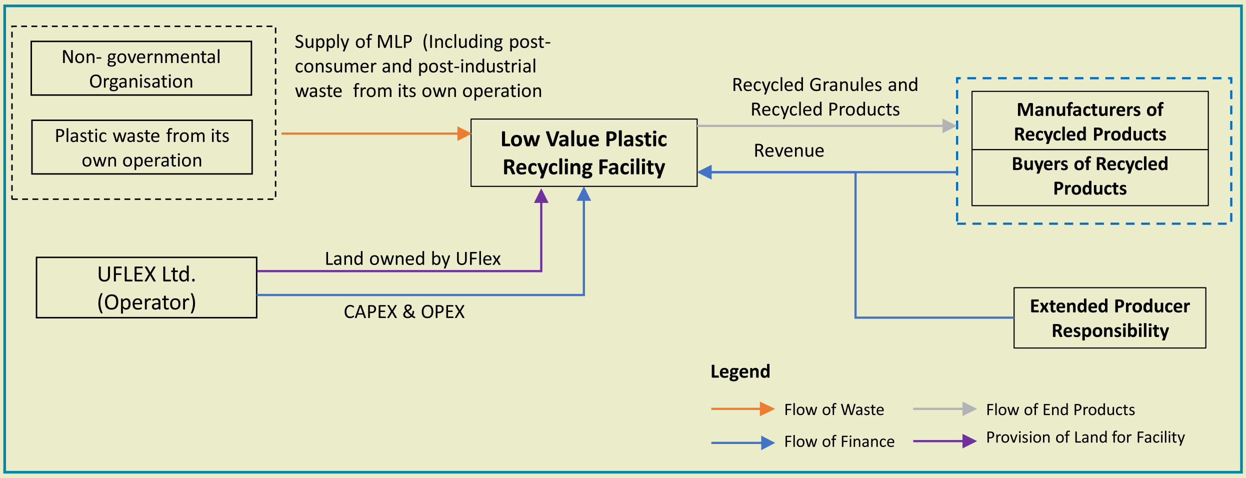


Figure 17: Typical Operational and Financial Model of LVP Recycling Facility by UFlex Limited

Key Insights

- To maintain the continuous and sustainable operation of the plant, it is crucial to ensure a **consistent and timely supply of high-quality feedstock**. Suppliers need to be equipped and trained to provide well-segregated waste that meets stringent quality standards. **It is imperative that impurities do not exceed 4 to 5% of the feedstock**.
- Since MSW frequently includes contaminated plastics, a **washing line is mandatory** for pre-processing and efficiently recycling these plastics.

Contributor: Rahul Dubey, UFlex Limited

Processing of LVP by PYROGREEN Energy Private Limited

The Story

PYROGREEN Energy Private Limited has successfully initiated 13 distinct projects across the country, ranging from 1 TPD to 20 TPD capacity, including in Mumbai (20 TPD), Nashik (10 TPD), and Chennai (5TPD). These projects are dedicated to efficiently processing and recycling LVP materials. PYROGREEN Energy enables brand owners to meet their EPR obligations by employing a scientific approach to process non-recyclable plastic fractions.

Technical and Financial Modalities

PYROGREEN Energy is engaged in recycling MLP, LDPE, and PVC generated in MSW and industrial waste through the innovative application of pyrolysis. To effectively manage PVC in its recycling process, the technology employed by PYROGREEN Energy uses a catalyst that prevents chlorine from being released in its gaseous form. Instead, chlorine is converted into a solid form, thus enhancing the environmental sustainability of the PVC recycling process. The pyrolysis process involves breaking down long polymer chains in an oxygen-free environment, thereby creating compounds with shorter chain lengths. The primary product of the process is liquid oil. Additionally, the process generates gases, wax and char by-products.

The company produces several valuable end-products using the pyrolysis process. These include approximately 45% oil, 20% gas, 10% inert materials, and 25% carbon black. The carbon black boasts of a high carbon content of around 90% and is typically utilised in the cement industry. Further, gas engines often employ the gas produced from the recycling units to generate power. The plants accept LVP waste from various sources, including **NGOs and local vendors**.

PYROGREEN Energy primarily operates within the realm of Engineering, Procurement and Construction (EPC) or turnkey contracts, serving as a technology provider for the establishment of recycling plants.

Facility Highlights – Technical	
Type of facility	Decentralised low value plastic recycling facility
Land ownership	Owned by the project developer/proponent who contracts PYROGREEN Energy
Business Model	Recycling facilities are commissioned using one of the following business models: • Engineering, Procurement and Construction • Operation and Maintenance Contract
Owner of facility	PYROGREEN Energy Private Limited
Designed capacity	1 TPD to 20 TPD
Type of Feedstock	• LVPs including MLP, PVC and LDPE • High value plastics including HDPE and PP

Facility Highlights – Financial	
CAPEX	• INR 25 million for 5 TPD • INR 35 million for 10 TPD • INR 50 million for 20 TPD Extra civil cost is around INR 10 million
OPEX	Approximately INR 0.75 - 1 million/annum for 8 TPD plant
Source of Revenue	• Crude oil • Sale of carbon black • Gas for power generation
Break Even	• 2 - 3 years – 5 TPD • 2 years – 10 TPD • 1 - 1.5 years – 20 TPD
Profit and Loss	Profit (INR in lakhs) • Year 2023 - 58.06 • Year 2022 - 30.35 • Year 2021 - 57.16

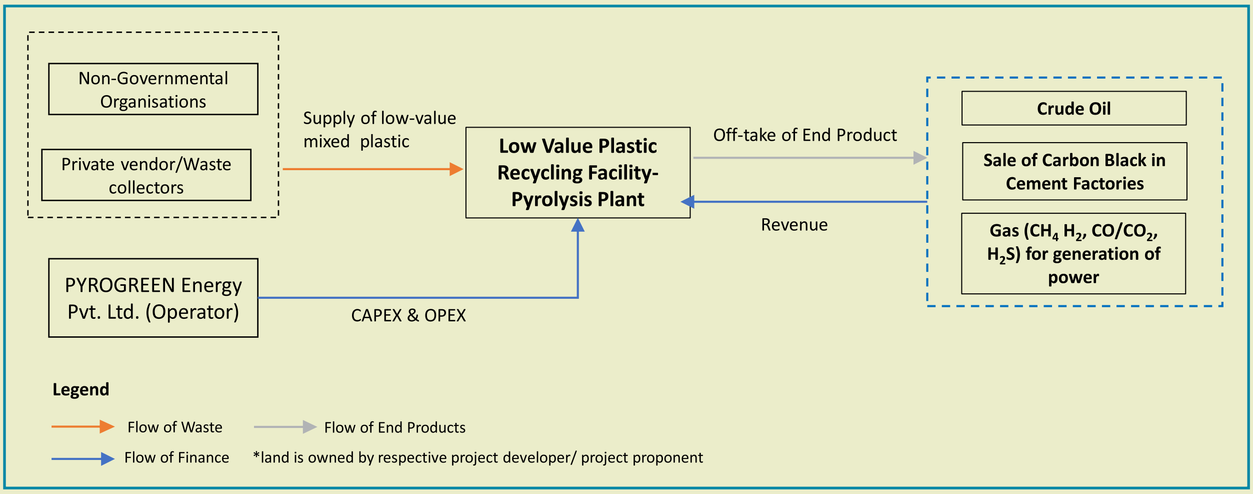


Figure 18: Typical Operational and Financial Model of LVP Recycling Facility Operated and Maintained by PYROGREEN Energy Private Limited

Key Insights

- **Obtaining financial backing for pyrolysis-based facilities becomes more challenging when the Waste to Energy Programme 2022 does not provide Central Financial Assistance**. Attracting private investors under these circumstances can be difficult.
- **Material availability consistently poses a significant challenge**. While the technology is accessible in the market, obtaining the necessary quantity and quality of materials remains a hurdle.
- To enhance the long-term viability of a plant's business operations, **it is essential for the technology to be capable of processing all categories of plastic waste**.
- Selling the oil produced is not a challenge, but identifying potential customers for selling carbon black presents difficulties.

Contributor: Sampath Subramaniam, PYROGREEN Energy Private Limited

7. Supporting Policies and Programmes

Policy/ Programme/ Scheme/ Regulations	Applicable Technology	Key Aspects
SBM Urban 2.0	Composting, Biomethanation, MRF and LVP recycling	With the vision of achieving 'Garbage Free' status for all cities, SBM Urban 2.0 targets 100% scientific management of all fractions of waste, including safe disposal in scientific landfills. The budget allocation under SBM Urban 2.0 for the duration of the mission is as follows: • Establishment of composting facility – INR 35,310 million • Establishment of biomethanation plants – INR 27,180 million • Establishment of MRF-cum-RDF plant – INR 38,420 million SBM Urban 2.0 also recommends dovetailing financial assistance under schemes such as Smart Cities Mission, or 15th FC grant that gives performance-based grants to Million Plus Cities to enhance Service Level Benchmark (SLB), including the MSWM sector. 40% of the grants for non-Million Plus Cities can be utilised based on requirements. The remaining 60% is tied grant, out of which 50%, i.e. INR 248.58 billion, can be utilised for SWM and sanitation purposes.
Waste to Energy Programme – 2022	Biomethanation	It supports the setting up of Waste to Energy projects for generation of biogas/bio-CNG/power/producer or syngas from urban, industrial, and agricultural waste/residue by providing CFA. A total of INR 7,000 million is budgeted for biogas and waste to energy programmes till FY 2025-26. • Biogas – maximum CFA of INR 50 million/project for both existing and new plants • Bio-CNG/enriched biogas/CBG – Maximum CFA of INR 100 million/project for both new and existing plants • Power (biogas based) – Maximum CFA of INR 50 million/project for both new and existing projects • Power (based on biowaste) – maximum CFA of INR 50 million/ project)

Policy/ Programme/ Scheme/ Regulations	Applicable Technology	Key Aspects
Sustainable Alternative Towards Affordable Transportation (SATAT)		MoPNG, under the SATAT initiative, envisages setting up of 5,000 bio-CNG plants by 2023-24, with a production target of 15 million Metric Tonnes (MMT) of bio-CNG from urban, industrial, and agricultural waste, including MSW. The SATAT initiative encourages entrepreneurs to set up bio-CNG plants, produce and supply bio-CNG to OMCs for sale as automotive fuels, with assured off-take at INR 46/kg (from 1.10.2018 to 31.3.2029) plus applicable taxes by OMCs/GMCs. As on 31st Oct 2022, a total of 3,694 letters of intent have been issued by OMCs for addition of 23,868 TPD in bio-CNG capacity.
CBG-CGD Synchronisation Scheme		To ensure off-take of compressed biogas (CBG), MoPNG has issued guidelines for its synchronisation with the City Gas Distribution (CGD) network. As of 2022, 24 Tripartite Agreements have been signed with various CBG producers and CGD entities across the country for supply of biogas/CBG to CGD networks. Subsequently, Uniform Base Price is ensured for supply of both pooled natural gas and biogas through the MoPNG policy guidelines issued in 2022. The procurement price of biogas offered to CBG producers under CBG–CGD Synchronisation Scheme has been revised upwards to INR 1,082/MMBTU (Metric Million British Thermal Unit) plus taxes. Additionally, the producers would receive compression charges / pipeline compression charges / transportation charges, as applicable, for the biogas or CBG supplied. The Ministry of Finance (MoF), through an order in May 2022, made it mandatory for fertilizer companies to offtake fermented organic manure from CBG companies under SATAT as part of the Integrated Nutrient Management programme. The Union Government's Budget of 2023 exempts central excise duty on CBG that is blended with natural gas. This removed the double taxation that CBG producers had to pay earlier for blending it with CNG as, CBG falls under the ambit of GST while CNG does not.
Market Development Assistance for bio-CNG plant derived organic manure		MDA scheme was approved by the Cabinet Committee on Economic Affairs in 2023 in the form of INR 1,500 per MT to support marketing of organic fertilizers, namely, FOM, Liquid FOM or Phosphate Rich Organic Manures (PROM) produced as by-product from biogas or CBG plants set up and registered at the GOBARdhan portal. Registered units can collaborate with Fertilizer Marketing Companies (FMCs), or opt for independent marketing for sale of organic manure compliant with the Fertilizer Control Order (FCO).

Policy/ Programme/ Scheme/ Regulations	Applicable Technology	Key Aspects
City Investments to Innovate, Integrate and Sustain 2.0 (CITIIS 2.0)		MoHUA, with financial support from Agence Francaise de Development (AFD), Kreditanstalt fur Wiederaufbau (KfW), European Union (EU) and the National Institute of Urban Affairs (NIUA), envisages extending financial assistance of up to INR 14.96 billion to 18 selected SPVs promoting Circular Economy with focus on integrated waste management. Each project can avail funding of up to INR 1.35 billion or 80% of the total project cost (90% of total project cost for North-eastern and hilly states). As of October 2023, the application window was pending launch. The allocated funds will be made available by MoHUA to state governments, in accordance with the Credit Facility Agreement (CFA) signed between the funding agencies and the Department of Economic Affairs (DEA). Funds will be transferred to SPVs as a grant by state governments through the Single Nodal Agency (SNA) mechanism. The repayment of the loan and interest incurred will be shared between the central and state governments on a 50:50 basis. Funds allocated to the SPVs will be transferred in the proportion of 10:40:40:10. The fund disbursement mechanism will be detailed in the Quadrilateral Agreement to be signed between MoHUA, respective state governments, SPVs and ULBs.
Guidelines on Usage of Refuse Derived Fuel in Various Industries	MRF and LVP Recycling	The Central Public Health and Environmental Engineering Organisation (CPHEEO), under the aegis of MoHUA, issued guidelines on usage of RDF in various industries in 2018. Accounting for the varying calorific values of different types of RDF have, the guidelines defined minimum and maximum prices for them (RDF I[25], II[26], III[27] and SCF[28]) by assigning a minimum price of INR. 0.4 per 1,000 Kcal/kg calorific value. It also suggested that RDF prices be dynamic and linked with the cost of coal. These guidelines also elucidate the role of various stakeholders, from national to ULB-level as well as cement industries, to facilitate off-take of RDF by cement industries and explore options beyond them.
Draft National Resource Efficiency Policy, 2019	MRF and LVP Recycling	It recognises the importance of MRFs for efficient and economically viable recovery of waste. It aims for a 75% recycling and reuse rate of other plastic packaging materials by 2030.

25. RDF Grade I –for co-processing directly in cement kiln with Net Calorific Value >4500 KCal/kg
26. RDF Grade II –for co-processing directly in cement kiln with Net Calorific Value >3750 KCal/kg
27. RDF Grade III –for co-processing directly or after processing with other waste materials in cement kiln with Net Calorific Value >3000 KCal/kg
28. Input material for the Waste to Energy plant or RDF pre-processing facility with Net Calorific Value>1500 KCal/kg

Policy/ Programme/ Scheme/ Regulations	Applicable Technology	Key Aspects
Solid Waste Management Rules (2016)	Composting, Biomethanation, MRF and LVP recycling	The SWM (2016) Rules were framed under the Environment (Protection) Act, 1986 and govern the duties of all major stakeholders engaged in the management of MSW. These include the Ministry of Environment, Forest and Climate Change (MoEFCC), Ministry of Housing & Urban Affairs (MoHUA) and all other concerned departments, District Collectors, Secretaries in charge of Urban Development in states, pollution control boards, ULBs, waste generators, waste processing facilities, and processed waste utilising facilities (like cement plants using RDF). The Rules also outline the duties of DOF and the Ministry of Agriculture for maintenance of quality and marketing of compost. The Ministry of Power and the Ministry of New and Renewable Energy (MNRE) are also made responsible for facilitating waste to energy infrastructure, purchase of power, and related financial mechanisms. Also, cement or thermal power plants are made responsible for co-processing of high calorific value (>1,500 Kcal/kg) waste.
Fertilizer (Control) Order (FCO), 1985 and its amendments	Composting	FCO, 1985, issued by the Deptartment of Agriculture and Cooperation of the Government of India, recognised city compost as an organic fertilizer and specified its standards under Schedule IV, including minimum nutrient content, maximum permissible impurities, and physical properties. The Fertilizer Inspectors of state governments are empowered under FCO to draw and analyse samples of all fertilizers, including city compost, in notified laboratories. The Order also regulates the procedure for obtaining license/registration as manufacturer or dealer of city compost, and conditions to be fulfilled for trading, etc. Amendments to FCO 1985 in 2020 and 2021 recognise FOM and liquid FOM through respectively, catalysing the establishment of CBG plants.

Policy/ Programme/ Scheme/ Regulations	Applicable Technology	Key Aspects
Plastic Waste Management (PWM) Rules, 2016 (Amendments 2021, 2022, 2023)	MRF and LVP Recycling	The PWM Rules, 2016 introduced by MOECC were introduced to sharpen the interventions and measures taken for plastic waste management in cities and villages. They push for the minimisation of plastic use, and segregation and processing of plastic waste at the local level for viable recycling, re-processing, and treatment of plastic waste. The Rules prohibit carry bags and plastic sheets below 50 microns (amended to 75 microns from September 30, 2021 and 120 microns from December 31, 2022). The Guidelines on Extended Producer Responsibility for Plastic Packaging included as Schedule II under PWM (Amendment) Rules 2022 bring LVPs such as flexible plastic packaging, plastic sachets, carry bags, etc. under the ambit of EPR. Yearly targets for the minimum level of recycling of different categories of plastic packaging collected under EPR are also set for PIBOs. The Guidelines have also set mandatory targets for use of recycled plastic in category-wise plastic packaging manufactured in a year. The amendment makes it mandatory for PIBOs and PWPs to register on the centralised EPR portal developed by CPCB. PWM (Second Amendment) Rules, 2023 provides opportunity for trading of EPR certificates among categories, depending on surplus and deficit. The Central Pollution Control Board (CPCB) shall prescribe the quantum of EPR certificates of categories required to be procured, where surplus exists, for fulfilment of EPR obligation of the category where deficit is present, based on the availability and cost of collection, segregation and processing for different categories of plastic packaging waste.

Approvals to be obtained from concerned authorities to set up and operate various MSW processing plants

Processing Technology	Type of Approval	Concerned Authority	Applicable Phase
Applicable for all four technology-based processing plants	Land allotment and registration	Applicable authority – city / development authority / state government	Before construction
	Authorisation under SWM Rules, 2016 for any processing units of more than 5 TPD capacity. Consent to Establish and Consent to Operate	State Pollution Control Board / State Pollution Control Committee	Before construction or after construction but before operation

Processing Technology	Type of Approval	Concerned Authority	Applicable Phase
	Land conversion and registration (applicable for non-industrial land)	Relevant land-owning authority – city / development authority / state government	Before construction
	Registration as MSME (Micro, Small & Medium Enterprise), as applicable	District Industry Centre	Before construction
	Factory license as per the Indian Factories Act, 1948	State Department of Factories	Before construction
	NOC (No Objection Certificate) and Fire NOC License	State Fire and Emergency Services	Before construction or
	Labour license for entities employing more than 20 labourers on any day of the accounting year as contract labour	State Department of Labour	Before construction
	Industrial Health and Safety (H&S) NOC, H&S License	State Department of Labour and Employment	Before construction or
	Plan submission, NOC and tax payment based on the construction area. Tax payment schedule as applicable	Local administration authorised to approve new construction and levy property tax	Before construction and ongoing subsequently
	Approval to obtain electricity and water connection or dig borewell, as applicable	Local DISCOM / Water Board / Groundwater Board	Before construction
Common MSW Treatment Facility	Environmental clearance	State Expert Appraisal Committee & state-level Environment Impact Assessment Authority	Before construction
Biomethanation and LVP Recycling Plant	Regulating safety of hazardous substances, e.g. compressed gases	Petroleum and Explosives Safety Organization (PESO)	After construction but before operation
MRF and LVP Recycling Plant	Registration as Producer Responsibility Organization	Central Pollution Control Board (CPCB)	During operation

8. Recommendations

India's flagship mission SBM Urban provided a major impetus towards scientific processing of MSW. There are several other enabling policies, frameworks, and practices toward developing financially viable projects. However, existing businesses are laced with multiple challenges ranging from inadequate quantity and quality of feedstock to absence of assured off-take coupled with the inherent risks and challenges in the business model and financial planning.

Moreover, while centralised large-scale processing plants can efficiently handle significant volumes of waste and may have advanced technology for sorting, recycling, and generating revenue from end-products, they require substantial capital investment and can be located farther from the source of waste generation. Therefore, there are several emerging businesses that aim to deal with MSW processing at a decentralised scale. This is also relevant in view of the responsibility of BWGs as elucidated in SWM Rules, 2016. These small-scale facilities are typically located closer to the point of waste generation, reducing transportation costs and emissions. However, the decentralised plants are facing similar issues especially pertaining to capital financing, and sustainable revenue generation to recover the OPEX, at the least. This is more pertinent to the facilities dependent on city compost and RDF as major source of revenue.

Thus, in the context of existing practices and on-ground technical and financial modalities of the plants being referred to, certain recommendations are formulated below that pave direction for each of the stakeholders involved across the value chain for long term viability of the processing plants.

Recommendations are broadly divided into 3 categories:

1) **Project Planning and Design Instrument**

   Objective: Ensure optimum design, technology, and financial allocation and simultaneously selection of the most viable business model that will minimise all categories of risks for both private party and govt. (ULB) or any other dedicated generator

2) **Strengthening Municipal Solid Waste Management Value Chain**

   Objective: Ensure efficient operation of plant by streamlining optimum quantity and quality of MSW and partially shifting operational risk to ULB

3) **Policy and Regulatory Instrument**

   Objective: Strengthen policy and regulatory framework to increase enforcement and adherence, in sync with the existing framework

8.1. Project Planning and Design Instrument

Actor: Project Proponent (ULB or Private Party)

Develop a robust financial model: A well rationalised future projection factoring in conditions such as initial turn-around time, capacity building of unskilled labour force usually employed for manual sorting, seasonal impacts on the quantum and composition of feedstock and off-take of end-products, breakdown of machinery over long-term time frame, and sudden withdrawal of enabling framework such as MDA needs to be duly acknowledged for ensuring long term financial viability.

Financial planning should consider mitigating risk by exploring opportunity of VGF or 100% funding of CAPEX leveraging government schemes. It is more pertinent for decentralised facilities where CAPEX allocation by the dedicated generator would reduce financial burden on the private contractor. Financial risk mitigation is required at the planning stage itself for centralised facilities in both CAPEX and OPEX components, especially in ULBs with minimum extent of source segregation. However, a CSR grant with the aim of impact creation could only be utilised for a small-scale manually operated facility that does not entail high-end automation and associated cost. Additionally, businesses should agree upon a profit-sharing model exclusively for a large-scale plant with due diligence of CAPEX, OPEX, scope of revenue generation and in a ULB which can assure quality and quantity of segregated feedstock specific to the plant. A robust financial model could be developed based on the following steps:

a. **Conducting robust feasibility study:** Proponents of the MSW processing plant should begin with a robust feasibility assessment including identifying types of generators, quantification, and characterisation of waste, and existing MSWM services and infrastructure. This will enable decision making of a centralised or decentralised plant, defining the feasible catchment area, identifying sites for MSW plant and opting for a pilot initiative before scaling up, if required. A latest assessment will help in conceptualising realistic processing technology, design capacity, optimum level of pre-processing requirement, and estimated timeframe for achieving full capacity utilisation. The project proponent, be it ULB or private entity, should conduct the feasibility assessment themselves or outsource to a third-party agency as contextually applicable.

b. **Extensive market assessment:** Proponents of the MSW processing plant should conduct a market assessment (as part of the feasibility assessment) for end-products to identify potential off-takers, distance of the off-take points, off-take capacity, market price for the end-products, responsible entity for bearing transportation cost and buy-back opportunity with the host ULB or dedicated generators, especially for compost and bio-CNG. Assessment of potential off-take capacity will help determine sources of revenue right at the planning stage. Although buy-back entails lesser than market rate for the end-product, it will be inherent in the contractual agreement and ensure bulk sale of the output. Additional market opportunities such as carbon credits, plastic credits such as OBPs credit, and EPR credits should be explored by relevant businesses to maximise revenue generation opportunity, while planning for the project.

   This is applicable especially for aspiring businesses who do not have an established market network, yet and to identify potential off takers within financially viable distance for estimating revenue generation opportunity which could be integrated in the financial model. During the process, the operator should endeavour to establish a network of off-takers which would help later in devising long term off-take agreement regarding guaranteed quantum and price point of end-products.

   The project proponent, be it ULB or private entity, should conduct the market assessment themselves or outsource to a third-party agency as contextually applicable. If it is not included in the feasibility study, the private party should conduct it separately before agreeing on the financial terms and conditions.

c. **Comprehensive and robust agreement between parties:** Both the host ULB or dedicated generator and implementation partner need to formulate a comprehensive agreement that includes assured supply of quantity and quality of dedicated feedstock on regular basis, authority of operator to reject feedstock and provision of penalty for ULB or generator on the pretext of non-compliance with agreed quality and quantity, sustainable contract duration of at least five years for decentralised facility and 10 years for centralised facility, among others. Engagement of the operator in collection and transport system could also be explored to leverage partial control on quality and quantity of feedstock, thereby enhancing operational efficiency and cost-effectiveness. Moreover, any financial transaction between ULB or generator and private contractor pertaining to tipping fee, royalty, profit sharing, off-take of end-product should be conditioned from the viability perspective of entire contract period and annual revision clause could be incorporated if feasible.

Agreement regarding integration of existing informal sector would also be beneficial especially for MRF and LVP recycling for tapping maximum high value recyclable waste. An irrefutable agreement needs to be framed with identified off-takers regarding assured quantum and price of end-product at a defined frequency. The agreement needs to factor in potential off-take capacity including that of buy-back partners as identified through market assessment and calculate optimum off-take quantum to prevent lesser sale later.

d. **Competitive and transparent bidding process:** ULBs should bring in transparency in the procurement process with stringent eligibility and qualification criteria that would facilitate competitive bidding amongst the efficient market players with proven competency. Though L1 approach is preferred especially in completely government financed projects, a strong two stage (Request for Qualification and Request for Proposal) tender evaluation process and selection of bidder through technical:financial approach of 80:20 or 60:40, as applicable, is recommended, to enhance technical efficacy and efficiency.

8.2. Strengthening Municipal Solid Waste Management Value Chain

Actor: Urban Local Body

a. **Implement a streamlined MSW collection and transport system:** A scientific and well planned and well managed MSW collection and transport system coupled with widespread source segregation is the prerequisite for a financially viable processing plant. Hence, while planning for a MSW processing plant, the ULB should conduct robust IEC campaign to ingrain extensive source segregation and operationalise an end-to-end systematic collection and transport system. While source segregation will ensure segregated clean waste enters the value chain, city wide compartmentalised collection and transport will minimise leakage and streamline clean and contamination free segregated waste as per the designed capacity to the processing facility, resulting in efficient recovery and processing. Planning for a processing plant and source segregation should happen simultaneously, to realise the impact of segregation through efficient processing.

b. **Develop and maintain database:** ULBs should develop a comprehensive database on the MSWM practices within the jurisdiction including all decentralised and BWG specific facilities with support from the BWG monitoring cell and organise, monitor, and update it in a systematic manner to enable judicious decision making, especially while planning expansion or setting up new waste processing facility. They should also integrate landfill operation with the central monitoring system to monitor quantum and composition of MSW sent for disposal.

c. **Improve institutional and monitoring mechanism:** While planning for a centralised facility, ULBs should engage a dedicated Project Management Unit (PMU) for extending technical support, facilitating approval process, land clearance and utility connection, and monitoring project progress. Simultaneously, ULBs should set up or strengthen the BWG monitoring cell to assess the present scenario regarding BWG specific processing units, thereby enabling feasible decision making regarding decentralised processing units. ULBs should assess and improve, if required, human resource adequacy and technical skill to enforce and monitor the relevant bye-laws that would result in improved MSWM value chain especially collection and transport system.

d. **Capacity building and awareness generation across stakeholders:** Efficient operation of a wet/dry waste specific processing plant warrants regular flow of segregated feedstock. Thus, ULBs need to ensure that the practice of source segregation is ingrained in the behaviour of citizens through generator specific customised awareness generation. Also, waste collection workers need to be capacitated and sensitised regarding the importance of segregated flow of waste to harness its optimum value.

8.3. Policy and Regulatory Mechanism

Objective	Policy	Regulatory
Adopt source segregation	**State/ULBs** Develop a generator specific robust IEC action plan and implement it	
Enhance responsibility of waste generators towards MSW processing	**State/ULBs** • Revising user charges for non-BWGs and BWGs who are giving waste to authorised collection agency factoring in collection and transportation cost along with other costs associated with processing if the financial agreement between ULB and private contractor entails ULB contributes to project financing	**State/ ULBs** • Formulate stringent byelaws for enhancing BWGs' responsibility by incorporating factors such as incentivising onsite processing, issuing property tax rebate, waiving off user charges for rest of the MSW fractions to be collected as applicable to BWGs engaged in on-site processing, and penalising BWGs in proportion to waste generated in case of non-compliance etc. • BWGs could be mandatorily held responsible for CAPEX of on-site processing facilities, where adequate space is available for on-site system
Augment collection and transport of waste in segregated manner	**State/ULBs** • Linking payment to collection and transport (C&T) agency with both quantity and quality of waste; Quality denotes both composition and applicable physico-chemical parameters for respective processing facilities. While quantity will be decided based on weigh bridge data, approval of quality should be under the discretion of processing facility operator with respect to contractually agreed quality. Quality specific payment and associated penalty to primary and secondary C&T agency could be apportioned to the type of waste received, infrastructure availability, and quality of service provided, as mutually agreed upon between the relevant parties.	

Objective	Policy	Regulatory
	Quality specific payment and associated penalty to primary and secondary C&T agency could be apportioned to the type of waste received, infrastructure availability, and quality of service provided, as mutually agreed upon between the relevant parties.	
Promote minimum generation of process rejects and reduce uncontrolled disposal in SLF	**State/ULB** • Incentivising plants which generate 15%[29] or less process rejects • Introducing Zero Waste to Landfill policy	**State/ ULB** • Mandating waste disposal at SLF not exceeding 20% of total waste generation and consisting of only inert and process rejects
Facilitate land allocation for MSW processing plants	**State/Urban Development Authority/ULB** • Land use plan (Zonal Development Plan/ Land use plan (Zonal Development Plan/ Master Plan) to incorporate designated area for MSW processing over the planning horizon in close coordination with ULB and factoring in future land requirement for the purpose • ULBs can also explore utilising bioremediated dumpsite as practiced in Indore. However, it needs formulating timely action plan to have certain processing capacity in place and gradually adopt a systematic orderly approach to initiate bioremediation and further utilise the land for processing plants in order to minimise the chance of reusing the bioremediated dumpsite for open dumping again.	
Quality check of end-product	**MoEF & CC, MoCF-DOF, CPCB, SPCB -** Setting up a unified portal regarding quality control of city compost and RDF	**MoEF & CC, MoCF, CPCB, SPCB -** Mandating quality check of city compost and RDF at pre-determined frequency and disclosing it on national platform
Enhance off-take of compost	**Ministry of Agriculture & Farmers' Welfare (MoAFW), State Agriculture Departments** Awareness generation among farmers regarding use of city compost and FOM **MoCF-DOF** • Reducing subsidy on chemical fertilizer • Levying penalties on FMCs for non-compliance to off-take of city compost • Reissuance of MDA for city compost	**MOCF-DOF** Mandating quantum and price of city compost offered by FMCs to the city compost complied with FCO, 1985

29. As SBM Urban 2.0 Operational Guidelines recommend disposal at SLF not to exceed 20% of total MSW generation and ICLEI SA's experience indicates presence of about 5% inert in MSW composition

Objective	Policy	Regulatory
Enhance off-take of RDF	**State (SPCB)** Incentives to use RDF in cement kilns and penalties for not using RDF	**MoEF & CC, CPCB -** Mandating off-take of RDF in cement industries at specific price point (INR 0.4/1,000 kcal/kg calorific value) for respective calorific values while mandatorily paying for transportation cost located within 100 km of RDF producer, as elucidated in CPHEEO guidelines
Facilitate LVP recycling	**Ministry of Finance (MoF)** Taxation to reflect environmental cost of virgin plastic products by relatively higher GST rate whereas low or no GST especially on products manufactured with low value recycled plastic would encourage LVP recycling. A common GST rate of 5% on cumulative plastic waste should be revised for different plastic resins especially bringing it down for MLPs, PS, PVCs which are considered difficult to recycle, thereby facilitating its off take by recyclers.	
Facilitate ease of setting up MSW processing plants	**MoEF & CC, CPCB, MoF, Ministry of Micro, Small and Medium Enterprises (MoMSME) -** Setting up unified portal for single window clearance system considering different type of approval required **MoF** - Consider waste management as a priority sector for lending with expedited loan approval process and/or lesser interest rate. This would especially encourage start-ups to venture into MSW processing businesses. **MoF, MoHUA, MoEF & CC** - Promote innovative financing mechanism such as RSF by SIDBI in association with GIZ that provides credit guarantees to loans from commercial banks or non-banking financial companies (NBFCs) towards enhancing waste management activities such as biomethanation, recycling, composting, and RDF for use in cement kilns.	
Facilitate R&D in waste processing technologies	**National and state level research institutes** Leverage different funding mechanisms to conduct R&D to: • enhance domestic manufacturing of waste processing equipment to reduce international dependence • develop innovative LVP recycling technologies • explore opportunity regarding usage of RDF beyond cement industries	

9. Conclusion

In recent years, MSW processing is increasing countrywide leveraging upon SBM Urban 2.0 and other enabling schemes, thus bringing the issue of waste management to the forefront of the nation's development agenda. Simultaneously, the promulgation of the SWM Rules, 2016 and Plastic Waste Management Rules, 2016 including amendments have helped further strengthen this focus and realign the country's commitment to a zero-waste future.

However, the absence of a conducive eco-system comprised of structured project planning, design, and contractor selection process; systematic MSWM infrastructure at collection and transportation level; strong enforcement mechanism; and adequate risk sharing between government and public sector has led to disruption or failure of many of these processing plants.

Hence, despite significant endeavour, a lot remains to be done, especially to ensure long term financial viability of these waste processing plants. This handbook reflects upon existing situational assessment and on-ground learning, success factors and challenges regarding technical, infrastructural, operational, and financial aspects of selected plants. Specifically, the handbook has attempted to identify and formulate some recommendations for key stakeholders to be adopted across the project cycle as well as at the policy and regulatory level, thus creating an enabling environment for financially viable MSW processing businesses. A concerted effort needs to be made by project proponent from the project planning stage to foresee and incorporate multiple financial aspects realistically and substantiate it with a robust agreement for adherence by relevant stakeholders and implementation as forecasted to the optimum extent feasible. Simultaneously, a well-established and well capacitated collection and transportation system will supplement the operational efficiency of processing infrastructure. Lastly, strengthening the existing policy and regulatory framework would provide a major impetus towards sustenance of processing plants.

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