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Low Carbon Action Plan for the Waste Sector of Bihar

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Abbreviations

AMRUT	Atal Mission for Rejuvenation and Urban Transformation
BAU	Business As Usual
BOD	Biological Oxygen Demand
BPIU	Block Project Implementation Unit
BSPCB	Bihar State Pollution Control Board
BSWSM	Bihar State Water & Sanitation Mission
BUIDCO	Bihar Urban Infrastructure Development Corporation Ltd
BVM	Bihar Vikas Mission
COD	Chemical Oxygen Demand
CSE	Centre for Science and Environment
CSWAP	City Solid Waste Action Plan
DWSC	District Water Sanitation Committee
DWWM	Domestic Wastewater Management
FC	Finance Commission
FSSM	Faecal Sludge & Septage Management
FSTP	Faecal Sludge Treatment Plant
GOBARDHAN	Galvanizing Organic Bio-Agro Resources Dhan
GP	Gram Panchayat
GHG	Green House Emission
GHGPI	Green House Gas Platform India
GWM	Grey Water Management
INDC	Intended Nationally Determined Contribution
LSBA	Lohiya Swachh Bihar Abhiyan
MGNREGS	Mahatma Gandhi National Rural Employment Guarantee
MLD	Million Litre per Day
MODWS	Ministry of Drinking Water & Sanitation
MOEFCC	Ministry of Environment Forest and Climate Change
MOHUA	Ministry of Home and Urban Affairs
MOUD	Ministry Of Urban Development

MPR	Monthly Progress Report
MSL	Mean Sea Level
NGT	National Green Tribunal
ODF	Open Defecation Free
OSS	Onsite Sanitation System
RDD	Rural Development Department
SLB	Service Level Benchmark
SRTW	Safe Reuse of Treated Water
STP	Sewage Treatment Plant
SAAP	State Annual Action Plan
SDG	Sustainable Development Goal
SBM	Swachh Bharat Mission
UD&HD	Urban Development and Housing Department
ULB	Urban Local Body
WSP	Waste Stabilisation Pond

Executive Summary

Why Act

The Greenhouse Gas (GHG) emissions from the waste sector contributed almost 4% of the total GHG emissions of India in 2018; out of which as much as 57% is contributed by domestic wastewater while 12% is contributed by solid waste disposal activities (GHGPI, 2022). Methane is the primary GHG emitted from the waste sector which accounts for 83.8% of the cumulative waste sector emissions in 2018 while Nitrous Oxide (N_2O) constitutes the remaining 16.2% of the sectoral emissions (GHGPI, 2022). It is envisaged that with increasing urbanization and exponential population growth, the quantum of waste and domestic wastewater generation will also increase, therefore further intensifying emission. Moreover, it is also indicated that the waste sector presents the largest potential for methane mitigation in the country in comparison to the fossil fuel and agriculture sector (United Nations Environment Programme and Climate and Clean Air Coalition, 2021).

It is estimated that with a population of 121.3 million (2020), the state of Bihar generates approximately 6,272 MLD of wastewater and 31,537 TPD of solid waste. With the growing population and urbanisation, the state is also witnessing an exponential demand for provision of basic services, including waste and domestic wastewater management. Lack of scientific and holistic solid waste and domestic wastewater management systems is also reflected in the static proportion of GHG emissions (5.55%) from the waste sector over the years (2011- 2018) with an increase in volume of absolute emissions (GHGPI, 2022). It is therefore critical to strengthen the technical, institutional and financial capacities of the local and state government, to be able to identify and mainstream low-carbon options while planning, designing, implementing, and financing solid and liquid waste management systems.

It is in this context that ICLEI South Asia seeks to support the State Government of Bihar in strengthening their solid waste and domestic wastewater management systems through a baseline assessment, gap analysis and formulation of short-term low carbon action plan to be implemented within 2030.

Premise of Low Carbon Action Plan for Waste Sector in Bihar

A comprehensive baseline report on existing solid waste and domestic wastewater management systems for both urban and rural areas was prepared. Based on the primary and secondary data, coupled with ground-truthing, existing gaps and issues were identified for the overall waste in the sector in the state.

Key issues identified in the domestic wastewater and solid waste management system

The key gaps in terms of infrastructure and service provisioning, institutional and monitoring mechanisms and policy and regulatory framework have been identified and are highlighted below:

- Domestic wastewater management system
    - Lack of access to Individual Household Latrine (IHHL); presence of insanitary toilets in both urban and rural areas.
    - Usage of toilets not an ingrained behaviour amongst the populace.
    - At present only 12% of sewage generated from the urban areas collected; out of which hardly 25% treated scientifically; Rural areas have negligible coverage of centralised sewer network.
    - Existing and proposed Sewage Treatment Plants (STPs) based on aerobic technology that consumes more electricity as compared to anaerobic systems; have no potential of methane recovery; generate higher amount of sludge, which if not processed scientifically, releases additional methane.
    - Unscientifically designed septic tanks, posing threat to public and environmental health; leads to enhanced GHG emissions.
    - Absence of scientific management of faecal sludge and septage generated from septic tanks across the state.
    - Lack of data across sanitation pathway hinders future planning and implementation.

- Solid Waste Management
    - Source segregation not widely practiced across the state.
    - Littering prevalent, leading to stagnation in water bodies and increased GHG emissions in the long run.
    - Lack of a robust primary collection system; Collection and transportation of mixed waste results in low waste recovery, inefficient processing and increased GHG emissions.
    - Erratic routing of collection and transport vehicles may lead to increased indirect GHG emissions.
    - Only 29% of solid waste processed in the urban areas; remaining dumped in the open, thereby posing a threat to public and environmental health, leads to enhanced GHG emissions.
    - Only 6% of waste is processed in rural areas; Indiscriminate dumping of waste can also turn into a potential source of GHG emissions in future.

GHG Emissions

The baseline information was used to prepare GHG emissions inventory for the waste sector in the state. was prepared as well. Brief findings of GHG emissions inventory for the waste sector with base year 2016 and reporting year 2020 is prepared. Some of the key highlights from the emission inventory includes:

- The total aggregated GHG emissions from the waste sector in Bihar for the year 2020 are estimated to be 8.20 million tCO_2e, representing an increase of 23.2% (or 1.54 million tCO_2e) from 2016.
- GHG emissions from domestic wastewater treatment and discharge emissions grew by 7.1% (or 0.45 million tCO_2e) to 6.69 million tCO_2e in 2020 from 6.25 million tCO_2e in 2016.
- The contribution of solid waste disposal and biological treatment of waste to GHG emission is estimated to be around 0.38 million tCO_2e in the year 2020. Emissions from solid waste disposal and treatment have increased at 7.6% CAGR from the base year 2016.

Further, using the baseline information and GHG emissions inventory, two scenarios were developed:

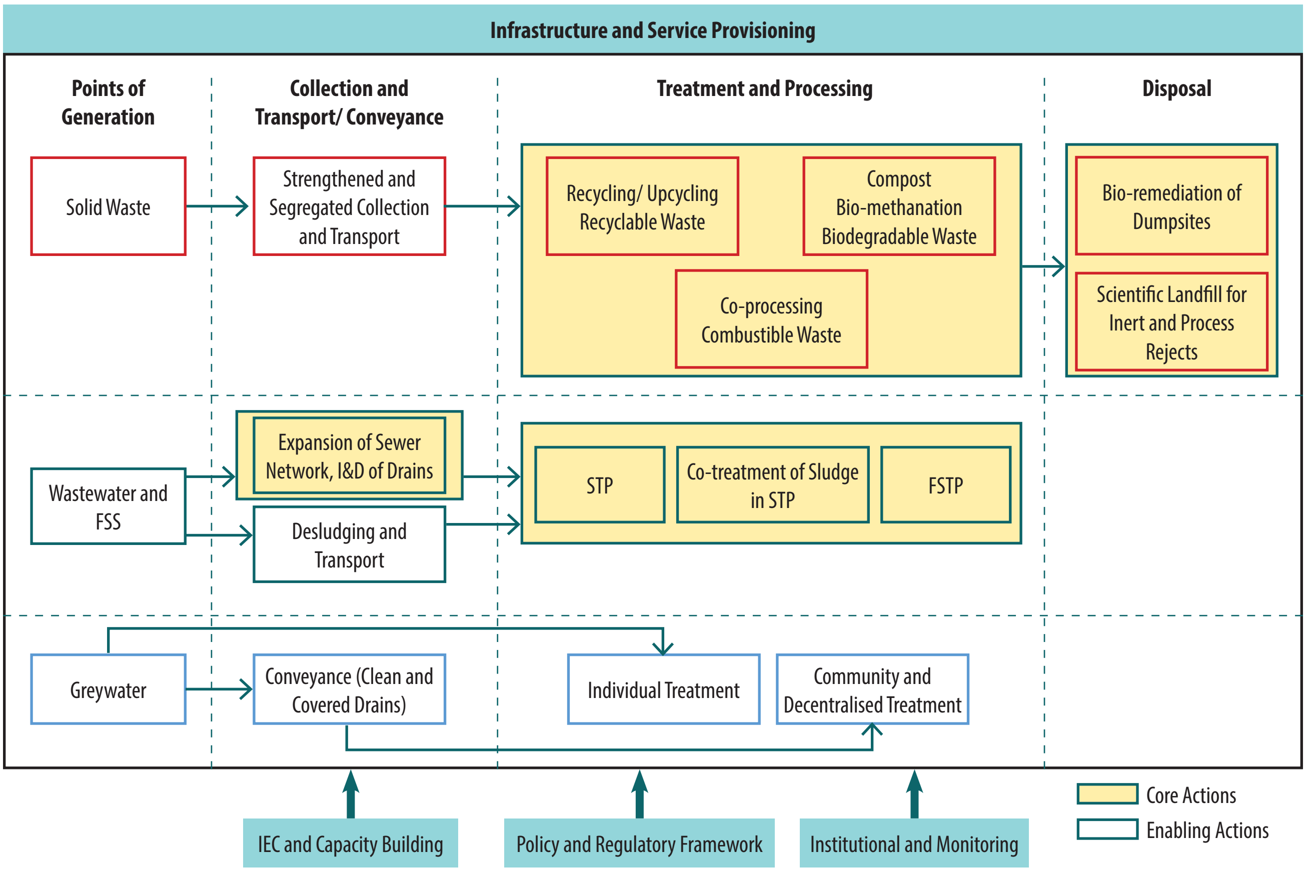
1. Business as Usual (BAU 2070) Scenario and,
2. Low Carbon Pathway 2070 (LCP 2070) Scenario.

Based on the baseline situation and GHG emissions inventory, Low Carbon Action Plan (LCAP) for the waste sector is developed with the vision to support the state of Bihar in strengthening the existing waste management services, promote a sustainable sanitation pathway and enhance the overall mitigation potential. The proposed LCAP adopts a holistic and scientific approach to maximise resource utilisation, improve efficiency and enhance social well-being, thereby also promoting a circular economy. The LCAP recommends core and enabling actions for strengthening the waste management system in the state, identified in discussion with key stakeholders, and are in-sync with the existing national and state level programmes, projects and schemes. The proposed actions are aligned to the state government's goal of pursuing climate resilience and low carbon development. The figure below presents the overall LCAP for the waste sector for the state government of Bihar.

The proposed LCAP recommends short-term low carbon measures which should be implemented by 2030 to be able to achieve the national and state level goals as well as contribute to the overarching Low Carbon Pathway 2070 scenario.

The proposed core actions are primarily technology-based and locally contextualised having direct GHG emissions mitigation potential. In addition to the core actions, enabling actions focusing on the behavioural change, institutional, financial, and legal aspects are also identified and proposed. It is believed that enabling actions will play a critical role in ensuring successful implementation of core actions, thereby reducing overall GHG emissions. The actions also promote building the technical and institutional capacity of all the major stakeholders across the waste and sanitation value chain, to ensure a scientific and sustainable domestic wastewater and solid waste management system.

The proposed interventions are in consonance with the present national level programmes, policies, frameworks such as Swachh Bharat Mission (SBM)- Urban and Grameen Phase I and Phase II, Atal Mission for Rejuvenation and Urban Transformation (AMRUT) 2.0, Municipal Solid Waste Management Manual by the Central Public Health and Environmental Engineering Organisation (CPHEEO, MoHUA), National Framework on Safe Reuse of Treated Water among others and such compliance is highlighted across the LCAP.



Overall Low Carbon Action Plan for the Waste Sector in Bihar

The core actions proposed for enhancing the domestic wastewater management system in the state is briefly presented in the table below:

Core actions for enhancing the domestic wastewater management system in the state

Target	Strategy	Actions
100% access to scientific, universal, and economical toilets achieved by 2025	1. Achieve state wide access to scientific, universal, and economical toilets	1.1. Construction of toilets 1.2. Retrofit toilets
All wastewater from 52% piped sewer-based toilets is safely collected and conveyed by 2025 in urban areas. All faecal sludge and septage from 30% septic tank-based toilets shall be safely collected and transported by 2025 in urban areas as indicated in enabling actions. All wastewater from 1% piped sewer-based toilet is safely collected and conveyed by 2025 in rural areas. All faecal sludge and septage from 25% septic tank-based toilets shall be safely collected and transported by 2025 in rural areas as indicated in enabling actions.	2. Strengthening safe collection and conveyance of wastewater to suitable treatment facility	2.1. Expansion of centralised sewer network 2.2. Maximise interception and diversion (I&D) of open drains

Target	Strategy	Actions
Treatment of 100% collected wastewater and faecal sludge by 2025 from both urban and rural areas preferably by adopting low carbon options. Safe reuse of 50% of treated used water by 2025 in both urban and rural areas. Enhance reuse of treated sludge (biosolids) by 2025 in both urban and rural areas.	3. Maximise treatment and reuse of treated wastewater and faecal sludge by adopting efficient and scientific treatment technology with suitable methane capture mechanism and use of alternative energy source wherever feasible	3.1a. Strengthen and ensure operation and maintenance of aerobic STPs 3.1b. Enhance sewage treatment capacity using anaerobic secondary treatment technology integrated with methane recovery mechanism 3.2. Integrate faecal sludge cotreatment with sewage treatment plants 3.3. Recommend establishment of Faecal Sludge Treatment Plants (FSTPs) at strategic locations across the state 3.4. Deploy and integrate renewable energy (such as solar) to meet part of the energy demand of treatment plants

Core actions for enhancing SWM system in the state

Target	Strategy	Actions
100% safe and contained collection and transport of faecal sludge and septage achieved by 2025	4. Strengthening safe and contained collection and transport of faecal sludge and septage to suitable treatment facility	4.1 Operationalise scheduled desludging by empanelment of desludging operator
At least 80% reuse, treatment and safe disposal of greywater generated from rural areas by 2025 100% reuse, treatment and safe disposal of greywater generated from rural areas by 2030	5. Enhance reuse, treatment, and safe disposal of greywater in rural areas. Reuse to be preferred wherever possible.	5.1. Setting up individual and community level grey water management facilities to reduce untreated disposal of grey water 5.2. Cleaning and covering of open drain 5.3. Remediation of eutrophic water bodies

The recommended core and enabling actions are envisaged to reduce waste sector emissions by 15.3% by 2030 with respect to BAU forecast levels. Moreover, waste sector emissions is expected to reduce further by 59.6% by 2070 with respect to BAU 2070 scenario.

The recommended actions in the LCAP are also prioritized basis its GHG emissions mitigation potential, suitability in local context (cost, technology, and skill intensiveness) and time frame of impact realisation. Considering the existing scenario of waste and domestic wastewater management in the state, diligent local level planning and implementation in line with the proposed recommendation over the subsequent seven years will serve as a foundation for successfully moving towards the low carbon pathway.

1. Background

The Greenhouse Gas (GHG) emissions from the waste sector contributed ~4% of total GHG emissions of India in 2018; out of that ~57% is contributed by domestic wastewater and 12% is contributed by solid waste disposal activities (GHGPI, 2022). Methane (CH_4) is the primary GHG emitted from solid waste disposal, domestic wastewater, and industrial wastewater and accounts for 83.8% of the cumulative waste sector emissions in 2018 while Nitrous Oxide (N_2O) emissions make up the remaining 16.2% of emissions from the sector (GHGPI, 2022). With increasing urbanization and exponential population growth, the quantum of waste and wastewater generation will also increase, further intensifying emission. At the same time, specifically for emission of methane, the waste sector is assessed to have the largest potential for mitigation in India as per the United Nations Environment Programme and Climate and Clean Air Coalition in comparison to fossil fuels and agriculture sector. (United Nations Environment Programme and Climate and Clean Air Coalition, 2021).

Therefore, it is critical to strengthen capacities and governance processes to mainstream low-carbon options while planning, designing, implementing, and financing solid and liquid waste management systems. Timely intervention should be made to adopt appropriate short and long-term efficient solutions across the value chain including generation, collection, transportation, processing/treatment, and disposal that will ultimately lead to overall reduction in GHG emission. This would facilitate achieving overall climate compatible urban development that are not only aligned with the targets of national programmes such as Swachh Bharat Mission (SBM) and Atal Mission for Rejuvenation and Urban Transformation (AMRUT) but also with global commitments such as Sustainable Development Goals (SDGs) especially SDG 6, 7, 11, 12, 13. It will also contribute to India's updated Intended Nationally Determined Contribution (INDC)[1] and the Long-Term Low Emission Development Strategy of India through innovative solid and liquid waste management aimed towards a sustainable and climate resilient urban future.

In this context, ICLEI South Asia seeks to support the State Government of Bihar in strengthening their solid waste and domestic wastewater management systems through a baseline assessment, gap analysis and formulation of short-term action plan to be implemented within 2030. The action plan aims to improve the overall public health, hygiene, and environment and subsequently support policy-makers in developing long term low-carbon and climate resilient sectoral strategies.

1. India's INDC aims to reduce the emissions intensity of its GDP by 33 to 35 per cent by 2030 from 2005 level and to achieve about 40 per cent cumulative electric power installed capacity from non-fossil fuel-based energy resources, amongst others.

2. Methodology

The process for the Low Carbon Action Plan (LCAP) development was initiated with establishing a comprehensive baseline and gap analysis of the existing situation; strategies and actions were formulated to bridge the identified gaps and challenges in the system. The process was integrated with continuous interaction and engagement with key stakeholders to ensure validation and consultation on the development of strategies and to further improve the acceptability of the document. Further, the actions were prioritized contextualised to local situation to ensure phase-wise and target-oriented planning and implementation. Figure 1 demonstrates the methodology adopted in the project to prepare the LCAP.

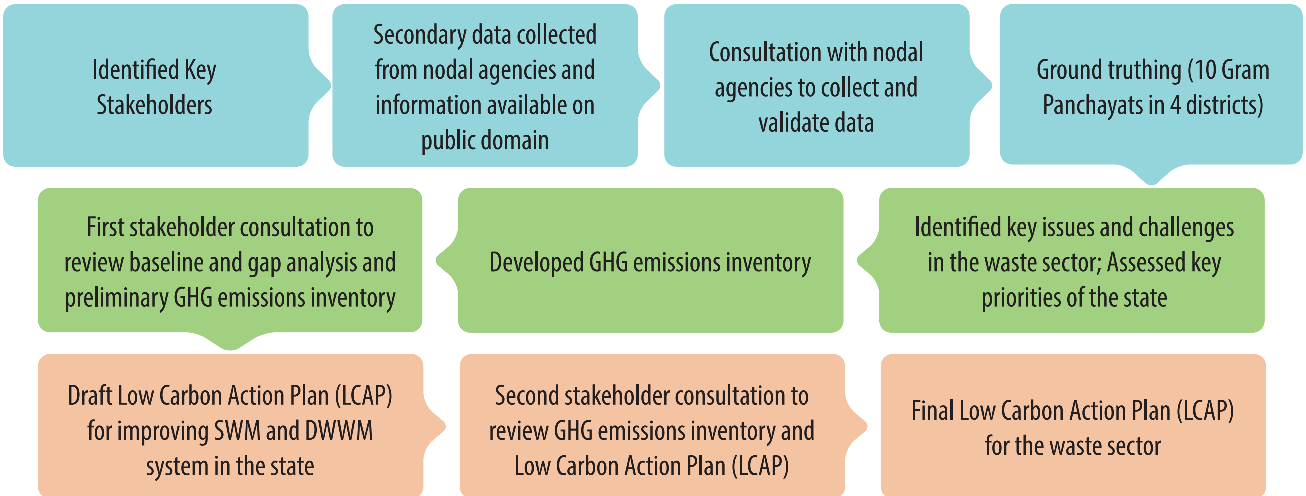


FIGURE 1: **Methodology Adopted for Developing LCAP**

The main steps in the methodology adopted for developing the low carbon action plan for the waste sector are elaborated below.

2.1. Identify Key Stakeholders

The key stakeholders involved in managing domestic wastewater and solid waste in the state across the vertical and horizontal levels of governance including administrative agencies, parastatal bodies, pollution control board, academia, private sector and political representatives such as Urban and Rural Local Bodies, District Water and Sanitation Committees (DWSC), Block Project Implementation Units (BPIU), Bihar Urban Development and Housing Department (BUD&HD), Bihar State Pollution Control Board (BSPCB) etc., were identified and engaged through one-to-one discussion and several rounds of meetings. The list of key stakeholders engaged in the process is provided in Table 1 below.

TABLE 1: **Types of Stakeholders Involved in SWM and DWWM in Bihar**

Core (Primary and Targeted) Stakeholders	• Waste and wastewater generators • DWSC- District Consultants • BPIU- Block Coordinators • 8406 GPs- Sanitation Supervisors, Mukhiyas • Ward Committee-Swachhata Mitra • 142 ULBs • Private agencies involved in collection and transport of MSW and desludging of toilet • Private entities involved in O&M of MRFs, recycling and processing facilities, landfill and STPs • Informal sector • Waste recyclers and processors

Enabling Stakeholders	• BSPCB- Bihar State Pollution Control Board • BUD&HD- Bihar Urban Development and Housing Department • BUIDCO- Bihar Urban Infrastructure Development Corporation • BVM- Bihar Vikas Mission • BSWSM- Bihar State Water and Sanitation Mission • RDD- Rural Development Department • DWSC- District Water and Sanitation Committee (District Magistrate) • BPIU- Block Project Implementation Unit (Block Development Officer) • NGOs involved in IEC such as Aga Khan Foundation and Wildlife Institute of India (WII), • NGOs involved in WASH activities (One Drop)
Supporting Stakeholders	• Shakti Foundation • World Bank • UNEP • Research Institutes such as Centre for Science and Environment (CSE)

2.2. Developing Database

Developing Data Templates – Data templates were developed to capture the state wide Urban Local Body (ULB) and district specific information pertaining to solid waste and wastewater generation and infrastructure and service provisioning across the value chain to assess the baseline. The templates were developed in discussion with the state government and aligned with the indicators from the Service Level Benchmarking (SLB) and Swachh Survekshan.

Desktop Research- Desktop based research were undertaken across relevant websites such as Atal Mission for Rejuvenation and Urban Transformation (AMRUT), Swachh Bharat Mission (SBM), and Namami Gange Portal, Bihar Urban Development and Housing Department (UD&HD), Bihar Vikas Mission (BVM), Bihar Urban Infrastructure Development Corporation (BUIDCO) and Bihar State Pollution Control Board (BSPCB) websites and other published studies/reports from the Ministry of Housing and Urban Affairs (MoHUA) and Ministry of Environment Forest and Climate Change (MoEFCC) were also explored to get an understanding of the existing waste sector in the state.

Primary Data Collection – Further, template specific data were collected from the abovementioned departments and collated to establish the existing Solid Waste Management (SWM) and Domestic Waste Water Management (DWWM) value chain in the state. Additionally ground truthing was also conducted in 10 GPs and 1 ULB to understand the waste management practices and implementation of schemes like Lohiya Swachh Bihar Abhiyan (LSBA).

2.3. Baseline Assessment and Gap Analysis

The collected data set was analysed and key challenges were identified pertaining to infrastructural; regulatory; and institutional and monitoring aspects in SWM and DWWM sector. Priorities were identified with respect to the state vision, its policies, and strategies. The analysis was thus documented in the Baseline and Gap Analysis Report attached as Annex 1.

2.4. Develop GHG Inventory and GHG Emissions Scenario

Simultaneously, the emission estimation for the three waste sub-sectors i.e. domestic wastewater, industrial wastewater and solid waste were also conducted as per the 2006 IPCC Guidelines.

Activity data collected from different departments were used along with appropriate emission factors derived from national (NATCOM & BUR) and international sources (IPCC) to calculate the baseline GHG emissions inventory. The detailed methodological approach is provided in Annex 2.

GHG emissions inventory was used as the baseline information for developing the sectoral scenarios. A series of in-person discussions with relevant state departments were carried out to gather information on existing/planned waste sector related projects and policies. During these departmental consultations in-depth discussion with the nodal officers were undertaken to understand the possible future trends for sectoral parameters such as adoption of anaerobic technology for wastewater treatment, etc.

This process was supplemented by extensive literature review to similar waste sector emissions modeling/ studies to understand the methodological approach and assumptions used to develop forecasting scenarios.

Based on the in-person discussions and secondary literature, sectoral growth rates (per capita waste generation, per capita water supply etc.) and waste flow assumptions (forecasted service delivery like household level sewer connections, septic tanks, STP capacity, etc.) were determined.

These growth rates and waste flow assumptions were fed into the emission forecasting tool developed in-house. The resultant scenarios developed included (1) Business As Usual (BAU 2070) Scenario and (2) Low Carbon Pathway 2070 (LCP 2070 scenario).

Through stakeholder consultations, the scenarios developed and the assumptions used to model (forecast) the BAU and LCP 2070 scenarios were validated. Based on these reviews and consultations, the assumptions were refined and the scenarios finalised. The detailed methodological approach is provided in Chapter 10.

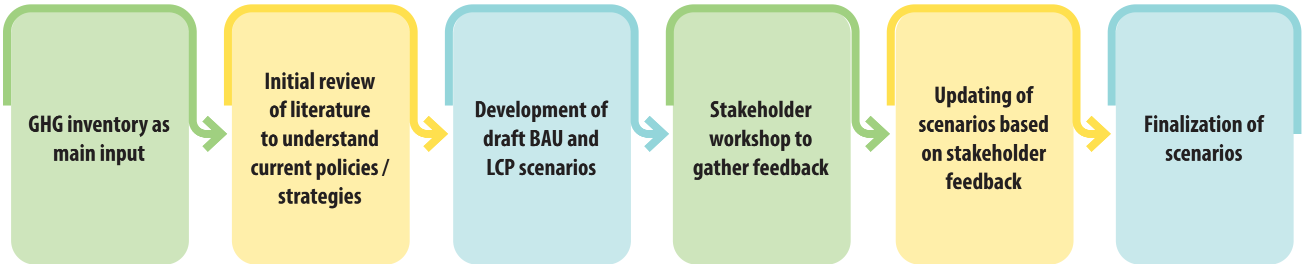


FIGURE 2: **A step-by-step process of GHG emissions forecasting scenario development for Bihar's waste sector**

2.5. Preparing Low Carbon Action Plan

Based on the gaps and issues identified in the sector, and aligned with the GHG inventory and GHG emissions scenario, core actions were suggested for improving waste management services (including domestic wastewater and solid waste) in the state factoring in direct GHG emissions mitigation potential. Simultaneously, other enabling actions were also proposed that would facilitate GHG emission mitigation by efficient implementation of the proposed core actions.

Short-term low carbon measures were formulated for implementation till 2030 to achieve the phase wise targets as identified under the overarching Low Carbon Pathway 2070 scenario.

3. Overview of Waste Sector in Bihar

3.1. Domestic Wastewater and Grey Water Management

3.1.1. Existing Domestic Waste Water Management Practices in Urban Area

Domestic wastewater management in urban Bihar is executed through Bihar Urban Infrastructure Development Corporation (BUIDCO) constituted under Bihar Urban Development and Housing Department (BUD&HD) channelising finances of national schemes such as Namami Gange and Atal Mission for Rejuvenation and Urban Transformation (AMRUT). Under SBM Urban, out of a targeted total 3.86 Lakh Individual Household Latrine (IHHL) and 23,591 community toilet seats, ~94% IHHL and ~88% community toilet seat construction is achieved till date, as per information provided by BUD&HD and BSPCB. As per data from National Sample Survey Office (NSSO), Census 2011 and Ministry of Housing and Urban Affairs (MoHUA), it is estimated that urban areas in Bihar have 93.37% coverage of household toilet of different typologies. In 2021, 132 ULBs had been declared Open Defecation Free (ODF) and out of them 24 had been declared Open Defecation Free + (ODF+) (SBM Urban, 2022). However, scientific construction of the septic tanks cannot be assured and it is reported that supernatant from the septic tank is discharged to the roadside drains further leading to pond/sumps. This causes bad smell, unhygienic conditions, and breeding of disease-causing vectors.

Till 2015-16, 8.12% toilets in Bihar are connected to sewer network (MoHUA, 2019). Further, the Namami Gange targeted to provide 1,46,801 House Service Connections (HSCs) out of which 96,591 HSCs are already being given. Thus, urban Bihar is estimated to have 11.9% sewer network coverage at present. Out of the targeted 1747.92 km of sewer network under Namami Gange, 856.54 km has been laid out till date.

1,551 MLD sewage is generated from urban areas of the state[2] and 188 MLD is collected through piped sewer system. Out of this, 71 MLD is treated in 4 STPs in Bihar as of September, 2022. Additionally, 23 new STP projects of 533.5 MLD capacity are at different stages of construction.

A survey undertaken by BSPCB in 2019 shows that out of the 500 open drains sampled, 44 drains demonstrated high BOD load (>100 mg/l), similar to BOD load of raw sewage, indicating that sewage and supernatant from septic tanks is flowing through open drains and ultimately discharged into waterways or open land. These drains with high BOD load are concentrated in 27 ULBs of Bihar and flow into the river Ganga and other water bodies, polluting them. A total of 262 drains discharging into Ganga and its tributaries are planned to be intercepted and diverted; till now interim measures have been adopted in few drains in Patna. Moreover, some of the drains also discharge in the low-lying areas. The stagnant sewage concentration in these drains and at the depressions can lead to an oxygen deficit environment, thereby contributing to increased methane emissions.

In terms of Faecal Sludge and Septage Management (FSSM), emptying of toilet system is not regularised in the state. Mainly private operators cater to the desludging requirement on demand and the service charge varies widely depending on the quantum of withdrawn sludge and the distance to be covered. There is no government order or notification pertaining to empanelment of the desludging operators and capping of service charge. Due to the absence of any dedicated disposal sites, private operators practice illegal dumping of faecal sludge into water bodies, disregarding the threat posed to health and environment.

3.2. Existing DWWM and GWM Practices in Rural Area

Domestic waste water management in rural Bihar is supported by the SBM-Gramin and LSBA schemes, as well as World Bank supported Neer Nirmal Pariyojana, Namami Gange (Ganga Gram) and Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS).

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2. Sewage generation = Projected Population 2021*135 lpcd water supply*80%

At the beginning of SBM Gramin in 2014, only 3.96 million out of 16.15 million total HHs in rural Bihar had individual toilets (SBM Gramin, 2022). As observed through community interaction; most of the IHHL built prior to implementation of SBM are septic tank-based systems with no assured quality of construction.

12.17 million toilets were constructed under the mission between 2014-2022; thereby expanding the toilet coverage in rural areas. All villages in rural Bihar are declared ODF during the process. Most of the IHHL constructed under SBM Gramin are Twin-Pit system attributed to its low cost, ease of building, low water consumption features. But ground truthing exercises revealed presence of single pit toilets which require regular emptying thus incurring more expenditure for the household.

In spite of extensive toilet construction, functionality and regular usage of toilets is debatable as observed during the ground truthing exercise. Toilet functionality is affected by faulty construction of pipes and chambers, absence of Y junction or poorly built structure. Out of total HHs having IHHL, 82% are functional,[3] of which around 91% toilet usage is reported in National Annual Rural Sanitation Survey (NARSS) 3rd Round, 2019-2020. Many HHs refrain from incurring expenditure for retrofitting of toilets and resort to open defecation. Moreover, newly built HHs (often due to family division) do not have access to independent toilets.

Apart from IHHL, till date, 9857 Community Sanitary Complexes (CSCs) have been constructed in 7830 villages (SBM Gramin, 2022) to cater to households without IHHL primarily due to land constraints. **Khagaria district** has the highest coverage of CSCs with 63.64% out of 231 villages equipped with at least 1 CSC, while **Banka** and **Arwal districts** have lowest coverage of CSCs (less than 10% of villages). A comprehensive on-ground survey for Open Defecation Implementation Plan (ODIP) is being carried out in GPs in order to identify present dependency on CSCs and assess future requirements.

As per estimate, 4324 cubic metre[4] of faecal sludge is generated by rural population in the state. But there is no treatment of faecal sludge generated from rural areas. Septic tank and single pit toilets that require desludging in 3-5 years interval are served by private tankers, operational at the district level. Charges vary depending on the quantity of sludge withdrawn and the distance covered for providing the service. However, there is no information regarding the disposal of emptied sludge.

As estimated, total 4015.66 MLD greywater[5] is generated from rural areas of Bihar. As reported in NARSS 2019-2020, 70.6% HHs practice safe disposal of greywater, primarily reusing in kitchen garden (29.1%). Drain construction was started in Bihar under Panchayati Raj Department under the aegis of Saat Nishchay Scheme since its inception. According to NARSS 2019-2020, a mix of open and closed drains could be observed in GPs to convey grey water[6] generated from 30.6% households while another 10.9% HHs are disposing grey water through soak pits.

According to data obtained from Lohiya Swachh Bihar Abhiyan (LSBA) 2022, under the first phase of the programme, grey water management was initiated through household level intervention where 298 individual soak pits were constructed in 10 GPs of a few selected districts; Begusarai having the highest number of units. Community Soak Pits (CSPs) were constructed in 12 GPs; Samastipur having highest number of CSPs.

Till date, 13,820 individual soak pits and 13,174 CSPs have been constructed under LSBA Phase 1 and 2 combined; Paschim Champaran district has the highest numbers of individual soak pits whilst Purnia district has the highest numbers of CSPs. Magic soak pits[7] are also set up in a few GPs (LSBA, 2022).

In case of unavailability of any treatment mechanism, the drains are connected to small water bodies and pits; these gets eutrophic[8] when silted

3. As per SBM G Phase II Operational Guidelines, Functional toilet denotes i) pan/seat is not completely broken ii) pan is not completely choked iii) pits/tanks are completely covered iv) pipes are not completely broken or open. A toilet is considered as non- functional if any of the parameters stated above, is found to be compromised

4. Sludge generation = Sludge Accumulation Rate 0.00021 m^3/c/d (CPHEEO Manual) * population dependent on septic tank and single pit toilet

5. Greywater generation = population * 55lpcd water supply * 67.5% (Operational Guidelines for the Implementation of Jal Jeevan Mission, 2019)

6. Wastewater from bathrooms and kitchen that has no faecal contamination is called greywater

7. A magic pit is a covered, porous-walled chamber that allows water to slowly soak into the ground. Pre-settled effluent from a collection tank is discharged to the underground chamber, SBM Grameen Phase II: Operational Guidelines

8. Eutrophication is a natural process that results from accumulation of nutrients in water bodies. Algae that feed on nutrients grow into unsightly scum on the water surface. USGS, 2019

and contaminated water flows into it continuously. Moreover, the drains can potentially carry blackwater from insanitary toilets. Using pond water for household chores is a common practice in rural areas, thus health hazard from using contaminated water is possible. Also, eutrophic lakes can potentially emit 50% more methane than comparable non-eutrophic lakes (Li., 2021).

3.3. Existing SWM Practices in Urban Area

Bihar has 142 Urban Local Bodies that are responsible for management of municipal solid waste generated in their areas. Estimated municipal solid waste generation in the urban areas (including Nagar Nigam, Nagar Panchayats and Nagar Parishad) of Bihar was around 4,863.13 TPD in 2020[9]; it increased to 4,967.36 TPD in the year 2021[10]. Segregation at source is restricted to only few areas in certain ULBs such as Patna and Muzaffarpur.

Door-to-door collection system is practiced in Urban Bihar using tricycles, compartmental auto tipper, auto tippers without compartments, pushcarts, tractors etc. The coverage of the door-to-door collection in urban areas is 77%[11]. Total waste collection efficiency is around ~80%[12] considering total waste collected as against the quantity of total waste generated.

Coloured community bins[13] are provided for secondary storage of waste. Total 313088 green colour, 307651 blue colour and 435 black colours containers are placed for secondary storage of waste (BSPCB, 2021). Except Patna no other ULB is equipped with transfer station or transfer point.

Out of the MSW collected, 1458 TPD waste are being processed that includes processing of wet waste primarily through composting and processing of dry waste primarily through MRFs. Rest of the 3509 TPD waste is disposed of into 130 dumpsites covering 10 Nagar Nigams, 53 Nagar Parishads and 67 Nagar Panchayats. Out of these, bio-remediation of 26 dumpsites are underway to reclaim 1.92 million tons legacy waste spread across 172.5 Acre. Currently 80 sanitary landfill sites are also being identified in the state.

3.4. Existing SWM Practices in Rural Areas

Under LSBA Phase -1, 36 Gram Panchayats were selected for pilot interventions for solid and liquid waste management. The program has been rolled out to all Gram Panchayats in the second phase. As reported in National Annual Rural Sanitation Survey (NARSS), 3rd Round, conducted in 2019-2020 no solid waste was visible in 95.2% of surveyed HHs and minimal level of littering could be observed for 79.9% of surveyed villages.

Till now, 39,18,021 twin bins (LSBA, 2022) are distributed to HHs in GPs to promote segregation and safe storage of waste at source encompassing ~10% of total rural households. However, during the field visits, it was observed that most households are using the bins for other purposes. Despite door-to-door IEC campaign, households still do not segregate waste (except households of Bishunpur GP). Moreover, domestic hazardous waste getting mixed with the waste stream poses a health risk to the Swachhata Mitras and the local community.

As per information from LSBA Authority, the total waste generated from rural Bihar (considering 0.250 kg/c/d waste generation and 108.17 million population [The Technical Group on Population Projections, 2019]) is estimated at 27,041.5 TPD. SBM G 2.0 mobile application is being used for doorstep quantification of waste generation. However, at present, the data is captured based on eye estimation.

A door-to-door collection service is provided by all gram panchayats but it is yet to achieve 100% coverage in most of the GPs. Each ward is equipped with one tri-cycle and two Swachhata Mitras who are responsible for door-to-door collection from 7:00 AM onwards to collect and bring the waste to the collection and segregation shed or Waste Processing Unit (WPU). It is estimated from the data provided by LSBA Authority from 36 pilot GPs, that on an average 1,272 kg of waste is collected per day from each GP by the Swachhata Mitras. Around 44,306 Swachhata Mitras (LSBA, 2022) are engaged till now in the door-to-door collection services. E-rickshaws are being used for secondary collection and, for providing primary collection services in the wards located far away from the WPUs. Additionally, 12,258 Community bins (separate bins for wet

9. Estimated amount of waste generated = Urban Population (Census Projection, 2020)* 333 gm/c/d waste generation
10. Estimated amount of waste generated = Urban Population (Census Projection, 2021)* 333 gm/c/d waste generation
11. Estimated D2D coverage = No. of households covered under D2D service as per BSPCB data*100/ total HHs (Projected population 2021/HHs size from Census 2011)
12. Estimated waste collection efficiency = Waste collected as per BSPCB data*100/ total waste generated (Projected population 2021* 333 gm)
13. Green colour container- for bio degradable waste or wet waste, Blue colour container- for recyclable waste or dry waste, Black colour container- for other waste

and dry waste) are also placed at strategic locations in the GPs (LSBA, 2022) till the time of report preparation.

As reported in NARSS 3rd Round, 71.3% surveyed HHs handover waste to designated primary waste collector or process it on-site; the rest dispose it off indiscriminately.

Waste Processing Units (WPUs) have been being set up for treatment and processing of waste. WPUs have waste collection and segregation sheds, a storage facility for dry recyclables (such as cardboard, paper, plastic, metal, etc.) segregated by the Swachhata Mitras and compost unit. Non-recyclable dry waste such as multi-layered plastic and thermocol is being dumped in open areas.

Till date, 123 WPUs are constructed in GPs across 24 districts; most of them in **Supaul, East Champaran and Jamui**. Additional 847 WPUs are being set up across GPs of all districts. (LSBA, 2022). Apart from WPUs, individual 883 compost pits are also constructed till now; most of them being in **Samastipur, Supaul and Begusarai districts**. However, the total capacity of these WPUs and compost pits are not known. Also, quantity of feedstock for the compost pits within these WPUs are not defined or tend to be negligible as most of the households prefer to feed organic waste to the cattle. It was also observed that many Gram Panchayats are yet to receive No-Objection Certificate for setting up WPUs or compost pits. Waste is dumped in open spaces in most of the GPs.

3.5. Existing Policy and Regulatory Structure for Management of Waste in Bihar

In Bihar, solid waste and domestic waste water management infrastructure are facilitated primarily through various national level schemes and programmes under Ministry of Housing and Urban Affairs and Ministry of Jal Shakti; which are supported by several policy and legislative framework. At the state level, Chief Minister's 'Saat Nishchay Yojana' for a developed Bihar under the programme of Good Governance was initiated in mission mode through Bihar Vikas Mission for the period from 2015 to 2020; further extended as Saat Nishchay Yojana (SNY) 2 till 2025.

- SBM/ SBM 2.0 Urban, AMRUT/AMRUT 2.0 and Namami Gange are the key national level prorammes supporting waste sector in urban areas. BUD&HD is implementing SBM/ SBM 2.0 Urban and Smart Cities Mission directly whereas Bihar Urban Infrastructure Development Corporation (BUIDCO) is the nodal agency for implementation of AMRUT and Namami Gange.
- SWM and DWWM activities in rural areas are supported by SBM Gramin Phase I and II, partially through Ganga Gram initiative of Namami Gange and Lohiya Swacch Bihar Abhiyan (LSBA) under SNY. Rural Development Department is implementing these schemes through Bihar Rural Livelihood Promotion Society.

Administrative hierarchy wise the institutional set up for implementation of relevant schemes and programmes in both urban and rural areas are indicated in Figure 3.

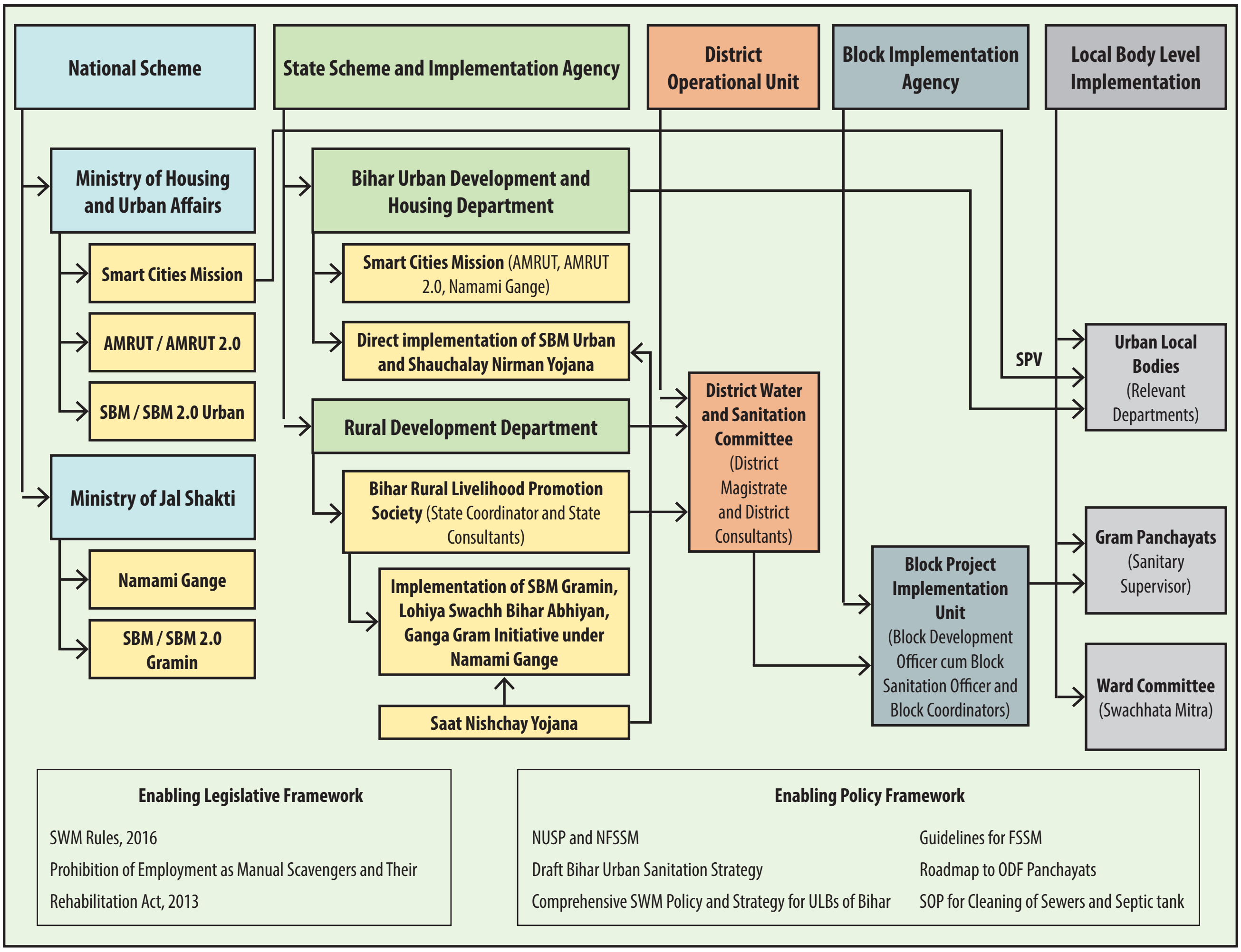

FIGURE 3: **Institutional Set up for Management of Waste Sector in Bihar**

4. Trends and Analysis of GHG Emission from SWM and DWM System

4.1. Overview of the Sector

The emission estimation for the four waste sub-sectors i.e., domestic, and industrial wastewater, biological treatment of solid waste and solid waste disposal was done as per the equations outlined in Volume 5: Waste as per the 2006 IPCC Guidelines. Annex 3 provides a snapshot of data sources for Waste Sector GHG Emissions Inventory. The overall emission estimates for waste sector for the state are provided below for the base year (2016) and the reporting year (2020).

TABLE 2: Aggregated GHG emission estimates for the Waste sector for 2016 and 2020

IPCC ID	Source Category	GHG Emission (Million tCO_2e) based on Global Warming Potential values from IPCC Second Assessment Report (SAR), 1996 Technical Summary[14]		
		2016	2020	Percent change (2016-2020)
4	Waste	6.66	8.2	23.2%
4A	Solid Waste Disposal	0.26	0.34	32.3%
4A2	Unmanaged Waste Disposal Sites	0.26	0.34	32.3%
4B	Biological Treatment of waste	0.004	0.036	838%
4D	Wastewater Treatment and Discharge	6.40	7.83	22.40%
4D1	Domestic Wastewater Treatment and Discharge	6.25	6.69	7.1%
4D2	Industrial Wastewater Treatment and Discharge	0.15	1.14	652.9%

- The total aggregated GHG emissions from the Waste sector in Bihar in the year 2020 are estimated to be 8.20 million tCO_2e, representing an increase of 23.2% (or 1.54 million tCO_2e) from 2016.
- GHG emissions from domestic wastewater treatment and discharge emissions grew by 7.1% (or 0.45 million tCO_2e) to 6.69 million tCO_2e in 2020 from 6.25 million tCO_2e in 2016.
- GHG emissions from industrial wastewater treatment and discharge in 2020 is estimated to be 1.14 million tCO_2e. Industrial wastewater-related emissions increased at the rate of 49.7% CAGR between 2016 to 2020.
- The contribution of solid waste disposal and biological treatment of waste to GHG emission is estimated to be around 0.38 million tCO_2e in the year 2020. Emissions from solid waste disposal and treatment have increased at 7.6% CAGR from the base year 2016.

4.2. Trend in Aggregated GHG emissions

The treatment and discharge of domestic wastewater is the largest source of GHG emissions in Bihar's waste sector, contributing to 81.58% of the aggregated state-level emissions from the sector in 2020. With a share of 13.84% in 2020, industrial wastewater treatment and discharge was the second largest contributor to the total waste sector GHG emissions. Solid waste disposal and biological treatment accounted for remaining 4.58% of Bihar's cumulative waste sector GHG emissions in 2020.

From 2016 to 2020, GHG emissions from all three source categories portray an increasing trend with the total emissions from the waste sector rising at a CAGR of 4.26%. The trend of the overall aggregate emissions is observed to be quite steadily rising.

14. https://www.ipcc.ch/ipccreports/sar/wg_I/ipcc_sar_wg_I_full_report.pdf

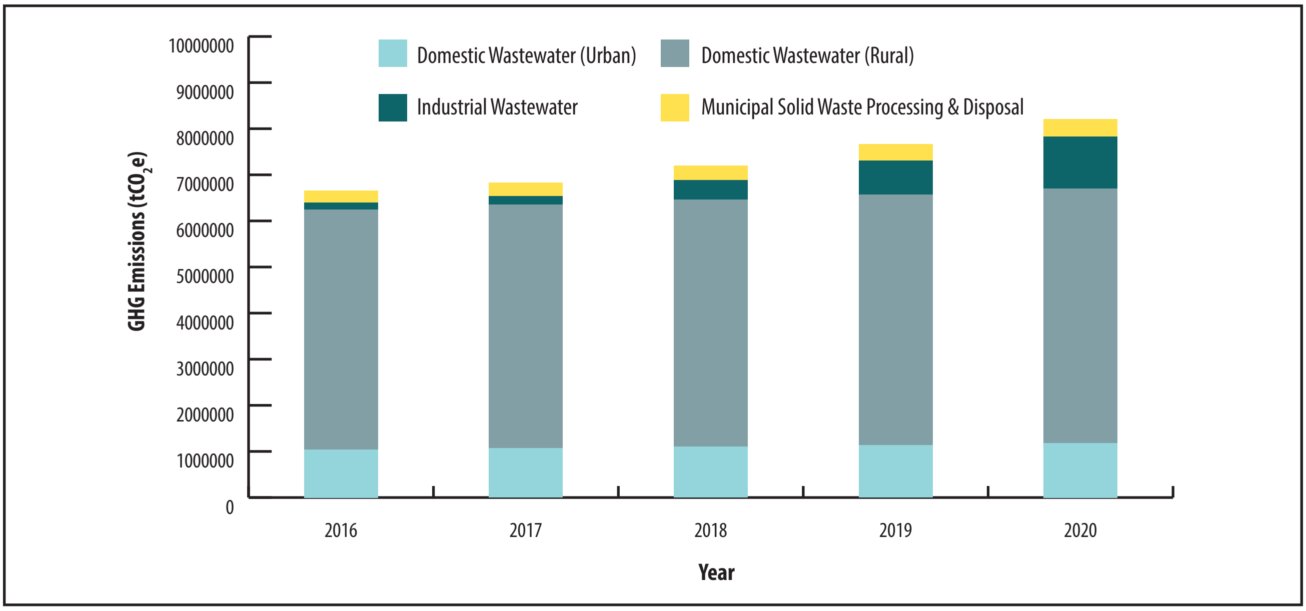

FIGURE 4: Trend of GHG Emissions from Waste Sector

The above graph in Figure 4 shows a varying trend for the overall GHG emissions from the waste sector during the assessment period. The aggregated GHG emissions during the assessment period (2016-2020) increased from 6.66 million tCO_2e in 2016 to 8.20 million tCO_2e in 2020. A linear increasing trend can be observed for the aggregated sectoral emissions.

4.3. Trend in GHG emissions by Type of GHG

The source categories covered in the assessment for the waste sector results in emissions of two GHGs, CH_4 and N_2O. CH_4 is the primary GHG emitted from the waste sector and accounts for 77% of the total cumulative emissions in 2020. The remaining 23% of the emissions resulted from the emission of N_2O gas, which occurs due to the presence of protein content in domestic wastewater and from its disposal in water bodies.

The total CH_4 emissions from the waste sector in the year 2020 amounted to 6.29 million tCO_2e, while N_2O emissions amounted to 1.90 million tCO_2e. This can be observed in Figure 5 below. CH_4 emissions from the waste sector increased with a CAGR of 5.2%, while N_2O emissions increased with a CAGR of 1.4%.

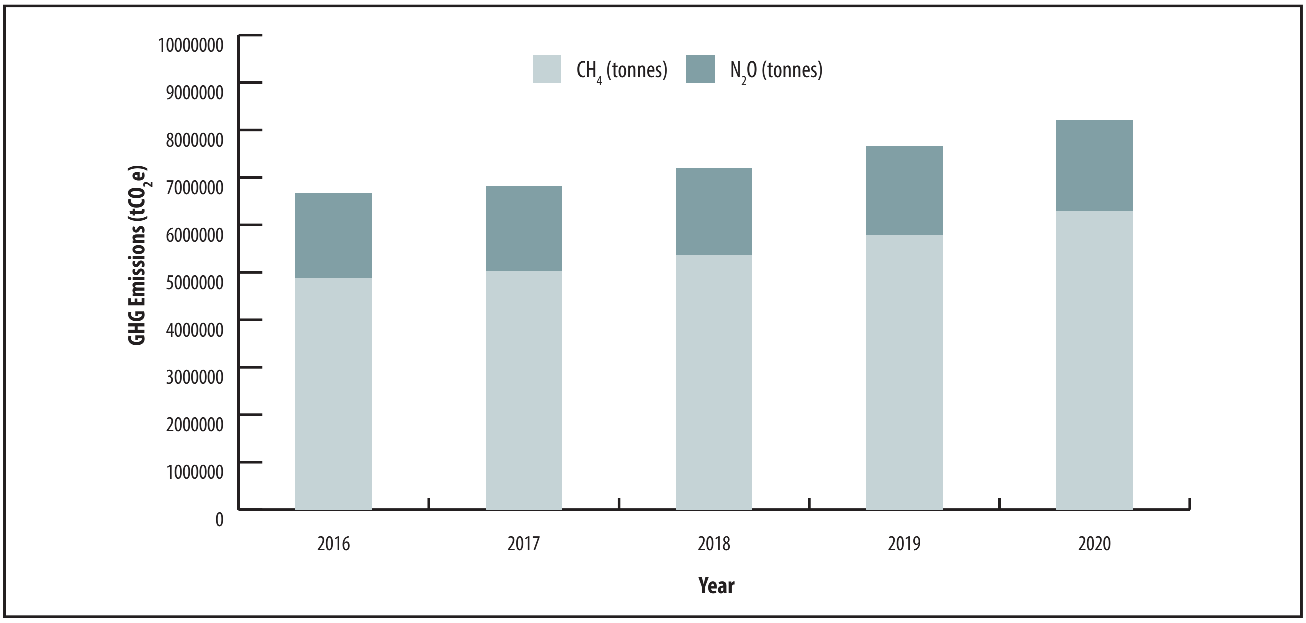

FIGURE 5: Trend of Gas-wise emissions estimates for Waste Sector, 2016-2020

4.4. Trend of GHG emissions from Source Categories

4.4.1. 4A Solid Waste Disposal

GHG emissions from disposal of solid waste is observed to have increased steadily between 2016 and 2020. Solid waste disposal contributed to cumulative GHG emissions of 0.34 million tCO_2e in 2020, as against 0.26 million tCO_2e in 2016. The emissions from solid waste disposal grew at a CAGR of 5.8% from 2016 to 2020. Rising trends in GHG emissions are primarily due to changes in the total quantum of solid waste, its composition, and the method of disposal and characteristics related to the disposal site. In the short-term for the reporting period, the rise in solid waste disposal emissions is driven by increasing waste generation rates, growing population and inadequate levels of waste processing over the emission estimation period, resulting in a higher quantum of solid waste going to disposal sites.

4.4.2. 4B Biological treatment of solid waste

In 2020, biological treatment of solid waste (composting) contributed to GHG emissions of 0.036 million tCO_2e, up from 0.00386 million tCO_2e in 2016. During the same period, emissions from this source category increased at a CAGR of 56.5%. The primary reason for the significant increase can be attributed to increasing composting capacity addition across the state, especially in the urban areas. These installations have been mostly undertaken as part of Swacch Bharat Mission.

TABLE 3: Trend of GHG emission estimates by source categories

Source Category	Emissions in Million tCO_2e				
	2016	2017	2018	2019	2020
4. Waste (Total from Waste Sector)	6.66	6.83	7.20	7.66	8.20
4A2. Unmanaged Waste Disposal Sites	0.26	0.28	0.31	0.33	0.34
4B Biological Treatment of waste	0.00386	0.00704	0.01065	0.02686	0.03617
4D1. Domestic Wastewater Treatment and Discharge	6.25	6.35	6.46	6.57	6.69
4D2. Industrial Wastewater Treatment and Discharge	0.15	0.18	0.42	0.74	1.14

4.4.3. 4D1 Domestic Wastewater Treatment and Discharge

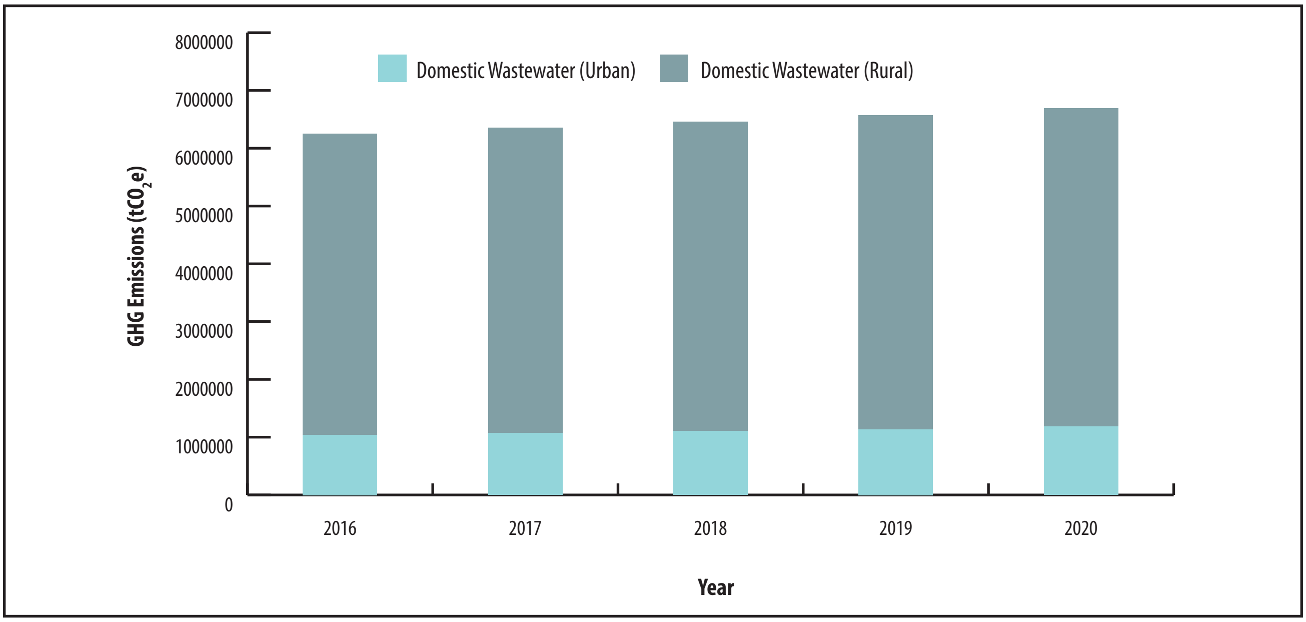

FIGURE 6: Trend of GHG Emissions from Domestic Wastewater Treatment and Discharge, 2016-2020

In 2020, domestic wastewater treatment and discharge contributed to GHG emissions of 6.69 million tCO_2e, up from 6.25 million tCO_2e in 2016. During the same period, emissions from this source category increased at a CAGR of 2.6%. The trend of GHG emissions from domestic wastewater discharge and treatment is shown in Figure 6 below.

Emissions from rural domestic wastewater in 2020 contributed an estimated 82% of the state aggregate domestic wastewater emissions, while the urban domestic wastewater contributed the remaining 18%. CH_4 emissions from domestic wastewater are estimated to be substantially larger than N_2O emissions, accounting for 76.9% of the total GHG emissions. N_2O emissions account for the remaining 23.1%.

Growth of domestic wastewater emissions is driven by increased volumes of wastewater to be treated in both urban and rural regions due to population growth. Dependence of the population on discharge/treatment systems with high GHG emission generation potential such as septic tanks, inadequately managed aerobic treatment plants, and untreated discharge of domestic wastewater is leading to higher emissions.

The rural population, however, accounted for 88.71% and 87.96% of the aggregated population of Bihar in the year 2011 and 2020 respectively. This corresponds to a significantly higher per capita emissions from urban areas. The per capita GHG emissions from domestic wastewater for the urban population in 2016 is estimated to have been 77.86 kg CO_2e/person, as compared to an estimated 51.65 kg CO_2e/person for the rural population. As a result, per capita GHG emissions from the urban household wastewater sector are approximately 50.75% greater in 2016, than the rural domestic wastewater sector.

4.4.4. 4D2 Industrial Wastewater Treatment and Discharge

GHG emissions estimates for industrial wastewater include 16 industrial sub-sectors, with potentially high wastewater generation including

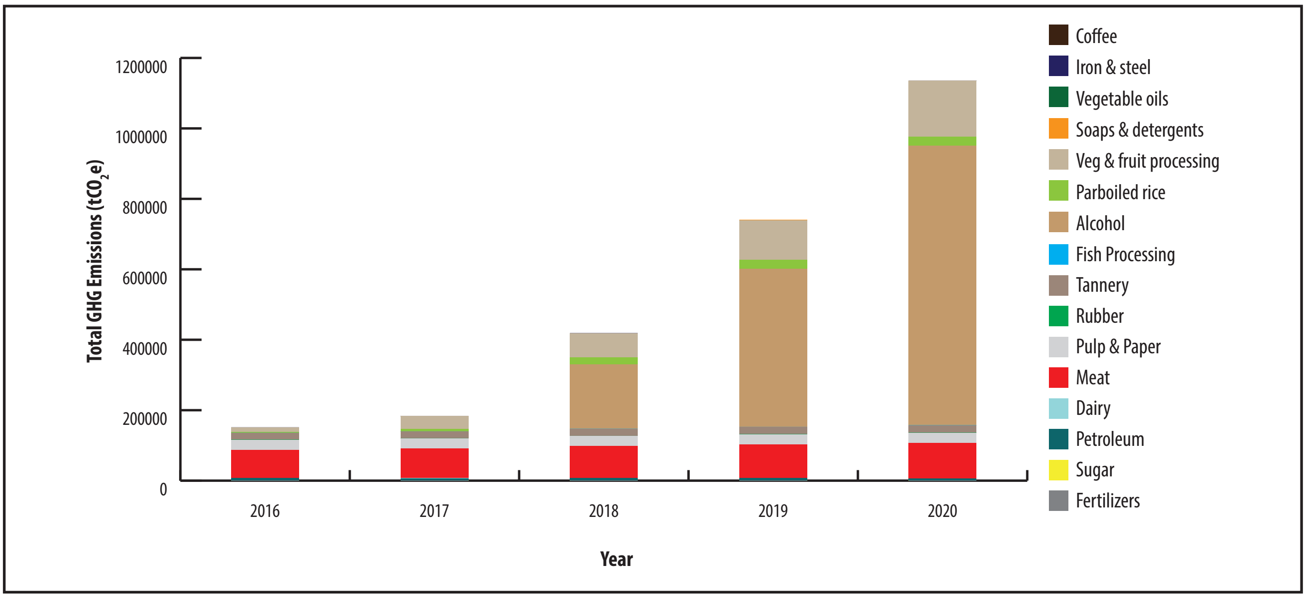

FIGURE 7: Trend of Industrial Wastewater Emissions, 2016-2020

fertilizers, sugar, petroleum, dairy, meat, pulp & paper, rubber, tannery, fish processing, alcohol (breweries & distilleries), parboiled rice, vegetable & fruit processing, soaps & detergents, vegetable oils, iron & steel and coffee, were considered while estimating emission generation. Production activity in all 16 sectors results in the generation of wastewater with significant organic load and potential to release CH_4 emissions, which is dependent on the type of wastewater treatment. The cumulative GHG emissions from industrial wastewater treatment and discharge has significantly increased from 0.15 million tCO_2e in 2016 to 1.14 million tons CO_2e in 2020, at a CAGR of 49.7%. The trend of industrial wastewater emissions can be seen in Figure 7 below.

The above graph shows that, distillery and breweries sub-sector emerged as the significant contributor (70%) in the industrial wastewater GHG emissions. This is primarily due to high organic load in the effluent discharged from distillery and breweries (The Indian BUR III report ascertains this to be 84 COD kg/m^3). The other significant contributors were vegetable and fruits processing, meat industry, par-boiled rice (rice mills) and tanneries. The growth in industrial wastewater-related emissions stems from higher levels of industrial activity (i.e. Industrial production) across state. The sudden jump in the source category emissions from 2018 onwards is primarily due to availability of industrial production data (from 'Online Consent Management & Monitoring System").

5. Low Carbon Action Plan

5.1. Vision and Objectives

Low Carbon Action Plan for waste sector is promulgated with the vision to support Bihar to ensure holistic solid waste management and a sustainable sanitation pathway and integrate low carbon solutions into waste sector. These will enable GHG emission mitigation and contribute to the state level goal of pursuing climate resilience and low carbon development.

In order to achieve this vision, the following primary actions are proposed:

1. To reduce GHG emission from inappropriately contained, or openly discharged and resultant stagnation of human excreta by achieving state wide access to and usage of sustainable toilet system and strengthening collection and conveyance of human excreta.
2. To reduce GHG emission induced by lack of source segregation, unsegregated and unplanned waste collection and transport and indiscriminate disposal of waste by encouraging waste reduction, adopting source segregation, and achieving state wide coverage of door-to-door collection and transport of segregated waste to appropriate processing facilities in segregated manner.
3. To reduce GHG emission and optimise methane recovery by promoting reuse and providing enhanced, safe, hygienic, and low carbon treatment, processing, and disposal facilities of solid waste, grey water, waste water, faecal sludge and septage, integrated with methane recovery mechanism.

All these actions are expected to cumulatively contribute to GHG emission mitigation by reducing the quantum of unmanaged solid waste and domestic wastewater, maximising treatment efficiency and subsequent methane recovery.

5.2. Concept of Low Carbon Action Plan in Waste Sector

The Action Plan highlights the importance of a holistic solid waste and domestic wastewater management system in the state, with suitable infrastructure to reduce sectoral GHG emission supported by efficient SWM and DWWM planning, operation, and monitoring.

The plan proposes mitigating quantifiable GHG emission through infrastructure interventions and better service provisioning through core strategies while identifying the enablers to facilitate successful implementation of these core actions. Specific actions have been formulated in sync with the state level vision and goals for waste sector under the overarching national level framework. For each strategy, implementation jurisdiction, key implementation agencies, ball park cost, source of funding and mitigation potential of actions are tabulated in Annex 4.

In case of solid waste, dumpsites are the key source of emission. Thus, concept of low carbon actions are in tandem with Integrated Waste Management Hierarchy and Circular Economy that prioritises waste reduction and reuse at source followed by maximum recovery, treatment, and processing of solid waste; thereby minimising disposal to dumpsite. For Bihar, the plan proposes processes such as composting, biomethanation, setting up Material Recovery Facilities (MRFs) and closure of dumpsites. ULBs are categorised in 2 types based on population size (Population upto 50,000 and more than 50,000). Concept of urban-rural linkage has been incorporated as applicable to rationalise use of resource and economic viability based on the experience of ICLEI South Asia.

Nature of existing and proposed projects in Bihar has been the guiding force to formulate actions for domestic wastewater management. As cost and technology intensive centralised wastewater management system has been adopted in the state, strategies and actions are built around the same especially in urban area to optimise the use of existing and proposed infrastructure. Recommendations on urban-rural clustered approach have been factored in the realm of FSSM, wherever feasible.

The overall concept of the LCAP is demonstrated in Figure 8.

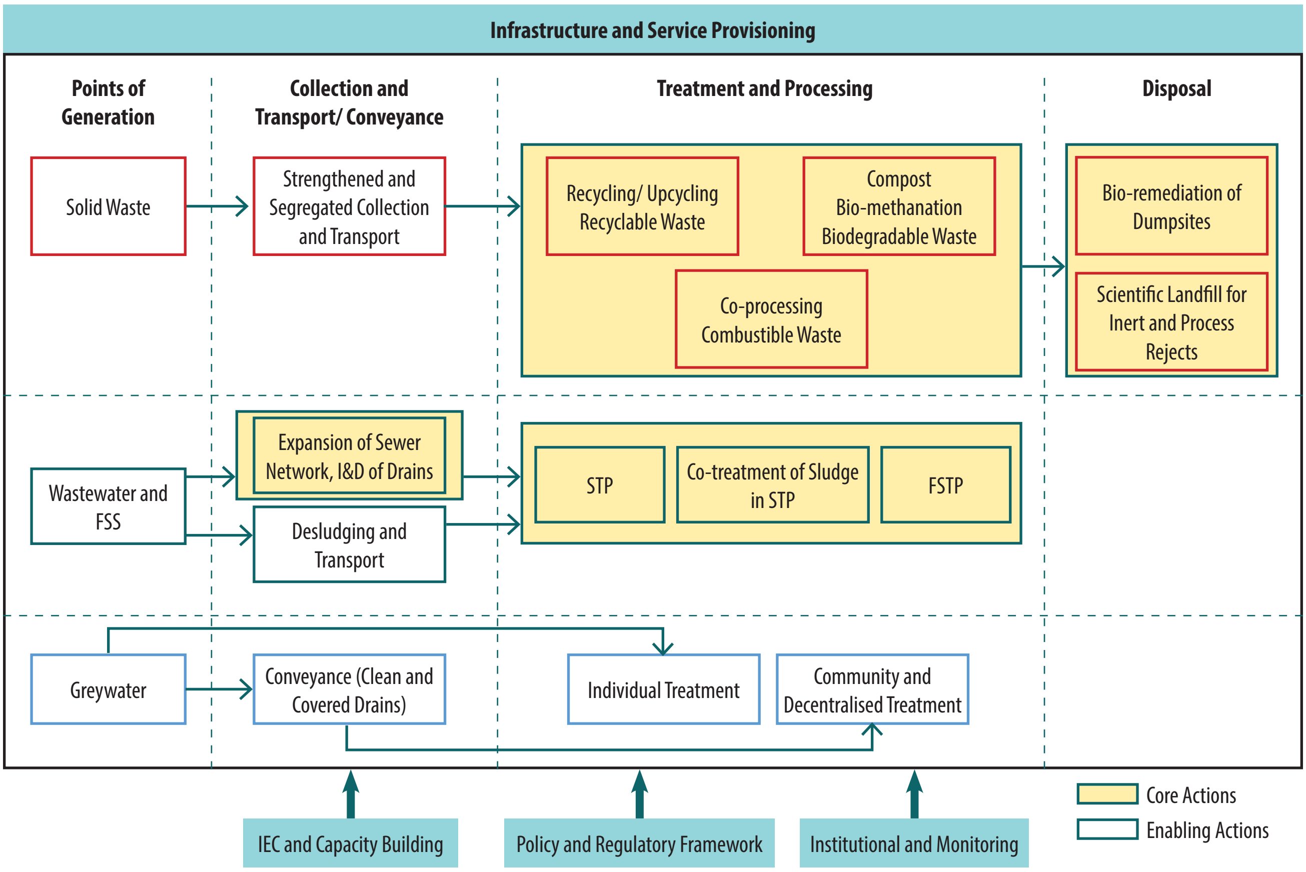

FIGURE 8: Concept of LCAP for Waste Sector

6. Domestic Wastewater – Infrastructure and Service Provisioning Strategies and Actions

In the domestic wastewater sector, the LCAP has identified a number of infrastructure and service provisioning strategies and actions that are discussed in this chapter. Table 4 below gives an overview of the actions and strategies for the wastewater sector.

TABLE 4: Overview of Infrastructure and Service Provisioning Strategies and Actions

Target	Strategy	Actions
Core Strategies		
100% access to scientific, universal, and economical toilets achieved by 2025	1. Achieve state wide access to scientific, universal, and economical toilets	1.1. Construction of toilets 1.2. Retrofit toilets
All wastewater from 52% piped sewer-based toilets is safely collected and conveyed by 2025 in urban areas. All faecal sludge and septage from 30% septic tank-based toilets shall be safely collected and transported by 2025 in urban areas as indicated in enabling actions. All wastewater from 1% piped sewer-based toilet is safely collected and conveyed by 2025 in rural areas. All faecal sludge and septage from 25% septic tank-based toilets shall be safely collected and transported by 2025 in rural areas as indicated in enabling actions.	2. Strengthening safe collection and conveyance of wastewater to suitable treatment facility	2.1. Expansion of centralised sewer network 2.2. Maximise interception and diversion (I&D) of open drains
Treatment of 100% collected wastewater and faecal sludge by 2025 from both urban and rural areas preferably by adopting low carbon options. Safe reuse of 50% of treated used water by 2025 in both urban and rural areas. Enhance reuse of treated sludge (biosolids) by 2025 in both urban and rural areas.	3. Maximise treatment and reuse of treated wastewater and faecal sludge by adopting efficient and scientific treatment technology with suitable methane capture mechanism and use of alternative energy source wherever feasible	3.1a. Strengthen and ensure operation and maintenance of aerobic STPs 3.1b. Enhance sewage treatment capacity using anaerobic secondary treatment technology integrated with methane recovery mechanism 3.2. Integrate faecal sludge cotreatment with sewage treatment plants 3.3. Recommend establishment of Faecal Sludge Treatment Plants (FSTPs) at strategic locations across the state 3.4. Deploy and integrate renewable energy (such as solar) to meet part of the energy demand of treatment plants
Enabling Actions		
100% safe and contained collection and transport of faecal sludge and septage achieved by 2025	4. Strengthening safe and contained collection and transport of faecal sludge and septage to suitable treatment facility	4.1 Operationalise scheduled desludging by empanelment of desludging operator
At least 80% reuse, treatment and safe disposal of greywater generated from rural areas by 2025 100% reuse, treatment and safe disposal of greywater generated from rural areas by 2030	5. Enhance reuse, treatment, and safe disposal of greywater in rural areas. Reuse to be preferred wherever possible.	5.1. Setting up individual and community level grey water management facilities to reduce untreated disposal of grey water 5.2. Cleaning and covering of open drain 5.3. Remediation of eutrophic water bodies

6.1. Core Strategies

6.1.1. Toilet System

Target: 100% access to scientific, universal, and economical toilets achieved by 2025[15] thereby optimising GHG emission mitigation right from the beginning of the sanitation pathway.

Strategy 1: Achieve state wide access to scientific, universal, and economical toilets

Action 1.1. Construction of toilets

Both urban and rural areas have a small fraction of households without access to individual toilets, who depend on community toilets or resort to open defecation. There are also newly built households in rural areas without access to individual toilet. Hence, ULBs and GPs are recommended to identify households without toilets that might include new independent households and households hitherto dependent on community toilet that want to avail the facility of individual toilet now.

For a need assessment, ULBs are recommended to conduct a gap analysis to evaluate the number of households requiring new construction. The updated data can also be linked to the property tax assessment. External agency can be hired to conduct the gap analysis for which SBM 2.0 and/ or 15th Finance Commission financial assistance can be utilised. In rural areas, a gap analysis survey to evaluate the number of households requiring new construction can be integrated with the currently on-going survey to assess dependency on community toilets.

ULBs are recommended to identify any household with land constraint and ensure their accessibility to community toilets within 500 m distance through the same process. Households beyond any of the community toilet coverage area should be provided with separate community toilet or shared toilets between 2/3 households. ULBs shall also ensure that every public place (bus stops, petrol pumps, metro stations, market places, religious and tourist locations, health centres, citizen centres) has at least one Public Toilet / Urinal available within 500 metre distance and that the facilities are kept clean, functional, and open for public use. Similarly, GPs should ensure that villagers without individual toilet owing to land constraint have access to Community Sanitary Complex (CSC), especially ODF plus villages having more than 100 households should be equipped with at least 1 CSC in an easily accessible and acceptable location.

Being located on Ganga flood plain with seasonal fluctuation of water table, selection of toilet is crucial in Bihar for its long-term sustenance and efficacy. Selection of toilet typology need to be decided based on different factors as indicated in Figure 9.

Additionally, considering the presence of some of the tourist spots of international repute in Bihar, respective local bodies are recommended to set up Public Toilets in those areas to cater to the floating population with feature such as hand dryer/paper napkin, sanitary napkin vending machine etc.

Bio-gas Linked SULABH Toilet

Local bodies are also recommended to explore opportunity for bio-gas linked toilets especially for Community Sanitation Centres/ public toilets such as the SULABH model. The capital expenditure of such a toilet may be contributed through SBM and/or 15th FC grants whereas operation and maintenance costs would be the responsibility of the private operator through pay and use cost recovery model. The generated bio-gas can be sold to the community as cooking fuel or used for heating/electricity requirements of the toilet complex, resulting in cost recovery. Most importantly it has the potential to reduce GHG emission through methane capture and reduce conventional energy consumption. A bio-gas linked public toilet (SULABH model) used by about 2,000 persons per day would produce approximately 60 m3 of biogas which can run a 10 kilovolt-ampere (KVA) gen set for 8 hrs a day, producing 65 kilowatt hour power (Gebrezgabher & Natarajan, 2012) which is estimated to be sufficient to operate a public toilet complex (power requirement in a public toilet complex is ~9 kW).

15. Target aligned with SBM Urban and SBM Gramin

Action 1.2. Retrofit toilets

Availability of toilets itself does not ensure its scientific functioning. In many cases, the septic tanks are found to be constructed inappropriately and without soak pits; thus, supernatant is discharged into open drain. Twin pits are often built disregarding the distance between pits, depth and lining of pits, absence of Y-junction, faulty pipes, and chamber and in many cases built as single pit altogether. In worst case, the toilets are entirely connected with open drain.

Section Criteria for Toilets

Soil Conditions		
Normal / sandy, permeable	→	Twin pit toilet
Semipermeable	→	Modified twin pit toilets
Impermeable	→	Ecosan toilet / biogas linked toilet / vermiculture based toilet / septic tank

Hard Strata		
>1.2 m	→	Twin pit toilet
0.75 to 1.2 m	→	Modified twin pit toilets
<0.75 m	→	Ecosan toilet / biogas linked toilet / vermiculture based toilet / septic tank

Ground Water Table		
> 3 m depth	→	Twin pit toilet
Seasonal high water table	→	Modified twin pit toilets
Permanent high water table / water logged condition	→	Ecosan toilet / biogas linked toilet / vermiculture based toilet / septic tank

FIGURE 9: **Selection Criteria for Toilets (Department of Drinking water and Sanitation, 2021)**

Low-Cost Eco-San Toilet for Rural Areas

While construction of new toilets, Gram Panchayats can consider the option of Eco-San i.e. 'Urine Diversion Dehydration Toilet' (UDDT) suitable for flood prone areas where the containment is built on raised platforms and sealed completely; thus the degradation process does not get disrupted due to waterlogging. Excreta stored in sealed chambers is converted into compost in 6-8 months and used as farm manure. Approximately Rs. 20,000-30,000 (Moudgil, 2019) is required to construct an Eco-San as against the designated subsidy of Rs. 12,000 for a twin pit toilet, preferred under SBM. However, since many of the twin pit toilets are rendered dysfunctional within 1-2 years of construction, it is recommended to spend some additional amount initially and ensure sustainable long-term usage of the toilets.

EcoSan Toilet in Kedia Village, Bihar

- As Eco-San is not a preferred technology under SBM, third party such as NGO's intervention, and persuasion is required to convince administration to consider these under the purview of SBM incentives as well. For example, World Neighbors is working with 2,500 households in Madhubani district to equip them with a flood resistant toilet system i.e. Eco-San.
- The third-party organisation should work in tandem with the entity involved in IEC and Capacity Building in the specific area and should be well-versed with local socio-economic and cultural set-up.
- Construction of toilet should be followed by one year of monitoring of toilet usage, trouble shooting, demonstrating compost formation, and sending compost for testing for contamination, if any.

However, it is to be noted that successful implementation and scaling up Eco-San toilet primarily depends on external funding or subsidies as it does not have any inherent business model. A meagre profit can be earned through replacing expensive chemical fertilizer with compost and urine in the farmland owned/ used by the household. On the other hand, some income can be generated for households who decide to sell their manure in the market rather than use it as a fertilizer in the farm.

Both Urban Local Bodies (ULBs) and Gram Panchayats (GPs) are recommended to immediately identify the dysfunctional toilet units, especially those built prior to SBM through the same ground level assessment planned be conducted as a prerequisite to construction of toilets. The extent and nature of retrofitting need to be assessed through the decision tree as indicated in the Figure 10. Funding for toilet retrofitting is restricted to financing motivation and awareness creation activities amongst the populace. Hence, financial status of households and viability to expend for retrofitting need to be assessed and the monetary requirement should be considered under government/ external funding judiciously.

6.1.2. Collection and Conveyance of Waste Water

Target: All wastewater from 52% piped sewer-based toilets is safely collected and conveyed by 2025 in urban areas. All faecal sludge and septage from 30% septic tank-based toilets shall be safely collected and transported by 2025 in urban areas as indicated in enabling actions.[16]

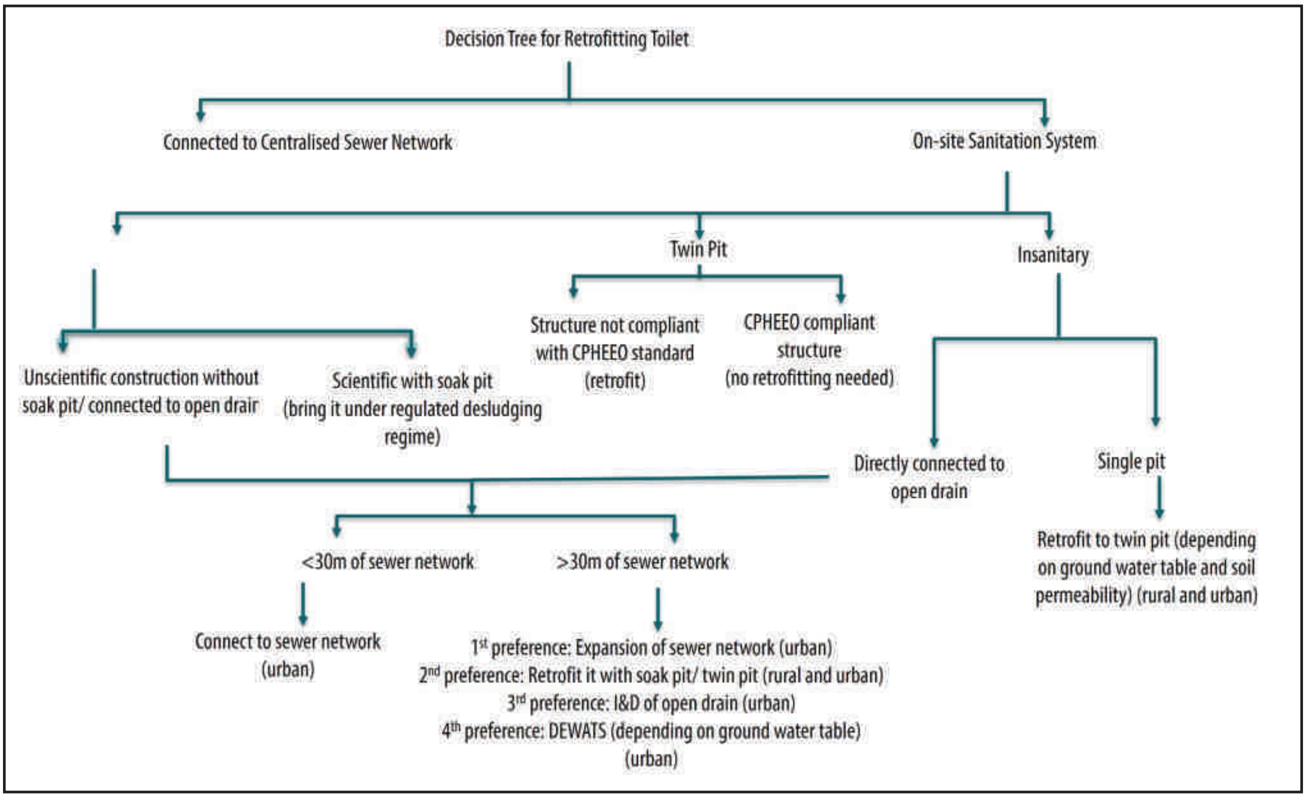

FIGURE 10: Decision Tree for Toilet Retrofitting (ICLEI South Asia, 2022)

Future Scenario of Degree of Utilisation of Toilet System to Mitigate GHG Emission

Toilet Typology	Urban			Rural		
	Baseline-2020	LCP-2025	LCP-2030	Baseline-2020	LCP-2025	LCP-2030
Piped Sewer	12%	52%	60%	1%	1%	5%*
Septic Tank	66%	30%	25%	19.5%	25%	25%
Twin Pit	14%	18%	15%	62.5%	74%	70%
Others	8%	–	–	17%	–	–

*As centralised sewer network is not targeted for rural areas under national and state schemes, only 1% coverage of centralised sewer network is considered in rural areas of Bihar.

All wastewater from 1% piped sewer-based toilet is safely collected and conveyed by 2025 in rural areas.[17] All faecal sludge and septage from 25% septic tank-based toilets shall be safely collected and transported by 2025 in rural areas as indicated in enabling actions.

Strategy 2: Strengthening safe collection and conveyance of wastewater to suitable treatment facility

Action 2.1. Expansion of centralised sewer network

At present only 11.9% households are connected to centralised sewer network limited to only 23 ULBs, additional ~50,000 Households will be provided with HSCs by the end of 2024; thus, a total ~14% urban households will come under the purview of centralised network. It is recommended that ULBs should expand the coverage of centralised sewer network by establishing HSCs to all the properties (including new construction) within the buffer of (<30m) existing network and lay new sewer network in unserved areas.

Through the gap analysis survey as indicated in Action 1.1., ULBs should identify the unserved households and extend the sewer network to provide HSCs by pooling financial support from central schemes, private funding and beneficiary household as well.

Stagnant Open Drain in Patna

16. Twin pit toilet converts faecal matter into compost. Hence, separate collection and treatment mechanism is not applicable for twin pit toilets. Aligned with AMRUT 2.0 and SBM Urban 2.0 Operational Guidelines.
17. As centralised sewer network is not targeted for rural areas under national and state schemes, only 1% coverage of centralised sewer network is considered in rural areas of Bihar.

In-depth techno-economic feasibility analysis based on the following indicative parameters need to be conducted before considering expansion of centralised sewer network:

- Population density
- Design period and respective projected population, expected sewage volume and quality
- Landuse- land availability for STP w.r.t. STP siting criteria
- Topography- slope, terrain, and geological conditions
- Depth of groundwater table and its seasonal fluctuation affecting construction, sewer infiltration and structural design
- Soil bearing capacity
- Water supply reliability, augmentation steps, drought conditions
- Prospect of adding FSS into the sewerage network for co-treatment (as elaborated in Action 3.2)
- Prospect of revenue flow through reuse in agriculture, farm forestry, non-potable urban usage and industries

Centralised sewer network is not a primary focus area under national and state level schemes applicable for rural areas. However, considering the economic advancements and enhanced standard of living, a minor share of piped sewer network is envisaged to be laid in rural areas as well by 2025 and subsequently by 2030.

Action 2.2. Maximise interception and diversion (I&D) of open drains

A survey conducted by BSPCB in 2019 indicates that 500 open drains carrying sewage are channelled across Bihar and discharged into river and other low-lying areas. Right now, I&D is planned to be undertaken under Namami Gange programme only for the 262 drains connected to Ganga and other tributaries but it is not fully implemented; interim measures are implemented in only a few drains in Patna.

ULBs are recommended to tap all drains including those connected to low lying areas using financial assistance from AMRUT 2.0, SBM (for ULBs with <1 lakh population) and 15th Finance Commission grants. This is crucial in mitigating potential GHG emissions arising due to anaerobic degradation of the BOD load upto 220 mg/l in stagnant depressions. Primary, secondary, and tertiary drains are to be demarcated along with measurement of width to set up appropriate interception structure such as coarse screen, grit chamber, fine screen and settling basin etc. before linking with the sewer network.

Apart from the mechanical I&D, biological in-situ treatment such as bioremediation or phytoremediation should also be considered after robust physico-chemical and financial feasibility assessment. This is pertinent considering that the state aims to provide 100% access to scientific toilet system by 2025 to stem the flow of human excreta through open drains.

6.1.3. Treatment, Reuse and Disposal of Waste Water

Target: Treatment of 100% collected wastewater and faecal sludge and septage by 2025 from both urban[18] and rural areas preferably by adopting low carbon options.

Safe reuse of 50% of treated used water by 2025 in both urban and rural areas.[19]

Enhance reuse of treated sludge (biosolids) by 2025 in both urban and rural areas.

Strategy 3: Maximise treatment and reuse of treated wastewater and faecal sludge and septage by adopting efficient and scientific treatment technology with suitable methane capture mechanism and use of alternative energy source wherever feasible

18. Target aligned with AMRUT 2.0 and SBM Urban 2.0 Operational Guidelines
19. Target aligned with National Framework on Safe Reuse of Treated Water, 2021

Action 3.1. a. Strengthen and ensure operation and maintenance of aerobic STPs

Action 3.1. b. Enhance sewage treatment capacity to be able to process generated wastewater using anaerobic secondary treatment technology integrated with methane recovery mechanism.

At present about 4.5% of the total generated sewage is treated at the 4 operational STPs in Bihar which are functioning at 65% of installed capacity. Even with 100% capacity utilisation of the existing STPs and upon commissioning of all the under construction STPs, installed capacity cannot match the wastewater generation from the urban areas. Thus, it is recommended to increase capacity of the sewage treatment infrastructure in proportion to the increased amount of wastewater that will be collected through expanded sewer network.

Centralised sewer network is not a primary focus area under national and state level schemes applicable for rural areas, therefore, there is no STPs or any plans for STPs for rural areas in near future. However, considering the economic advancements and enhanced standard of living, it is envisaged that, STPs will be installed in rural areas as well by 2025 and subsequently by 2030.

All the installed STPs are aerobic, mostly Activated Sludge Process (ASP) and Sequential Batch Reactor (SBR) based. Though treatment efficiency of both technologies is similar in well managed and operationed systems, aerobic technology does not have the potential of methane recovery.

Although direct GHG emission is less from a well-managed aerobic STP, operational efficiency and management is debatable in the first place. On the other hand, the anaerobic treatment generates methane gas which can be recovered as a source of energy and it can be accounted towards reduction of GHG emissions. Through anaerobic treatment process, methanation of 1 kg COD can produce about 3,300 kcal of energy (KOBAYASHI, 2013). It is to be noted that anaerobic STPs are effective towards emission mitigation only when integrated with methane recovery technique. Anaerobic system has the following advantages as against aerobic system.

Aerobic System	Anaerobic System
Higher indirect GHG emission. Aerobic decomposition requires a proportionate volume of dissolved oxygen to the volume of organic matter in the waste water. The electricity required to supply sufficient dissolved oxygen accounts for the major proportion of electricity requirement. **For treating 1 MLD of sewage, 153.7-302.5 kWh of energy is essential** (IITs, 2010)	No need of additional oxygen and therefore does not require additional electricity for supplying oxygen. Although both aerobic and anaerobic treatments use electricity for stirring and pumping operations, these operations require very little power. Thus, anaerobic treatment is energy-saving, creating an opportunity for mitigation of indirect GHG emission from consumption of electricity in aerobic system. **For treating 1 MLD of sewage, upto 130 kWh of energy is essential** (IITs, 2010).
The amount of sludge generation from **1 MLD sewage treatment is 210-315 kg** (KOBAYASHI, 2013 and as estimated by ICLEI South Asia).	The amount of sludge generation from **1 MLD sewage treatment is 15-80 kg** (KOBAYASHI, 2013 and as estimated by ICLEI South Asia). Reduced cost of sludge treatment and quantum of proportionate GHG emissions.

Bio-gas based power generation from STPs in Chennai (CPHEEO, 2021)

Chennai has been one of the forerunners in India regarding bio-gas based power generation from STPs. Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB) has commissioned 8 biogas plants at 3 STPs with a cumulative treatment capacity of 610 MLD. In spite of conventional aerobic ASP based technology, the STPs are upgraded to integrate anaerobic decomposition of thickened sludge in the absence of air in the closed dome type digesters.

Bio-gas engine in the range of 625-1064 kW can generate power using methane content of the bio-gas. Normally bio-gas is composed of 60% to 65% Methane and 25 to 30% CO_2 with trace amount of other gases such as H2S. The average electrical energy production from bio-gas is about 2 KWh/m3. Thus, total 7022 kW gas engines are installed generating 4.5 lakh kWh power per day, catering to more than 92% of the in-house energy requirements as of September, 2022. This has resulted in cost savings through power production to the tune of is Rs. 64 Crores till September, 2022.

Introducing DEWATS

Only 12% of urban Bihar and only 1% of rural Bihar is connected to piped sewer network. In addition to the large volume of uncollected wastewater, even collected wastewater is not treated completely. Current STP capacity only accommodates 43% of collected wastewater. Hence, DEWATS could be installed to cater to the collected but untreated wastewater (upto 100 KLD) generated from small communities as a cost-effective solution.

However, it is to be noted that more than 8m depth to ground water level and low porosity and permeability of soil are prerequisites for setting up DEWATS (NIUA, 2017). Bihar exhibits seasonal fluctuation of ground water level and only a few patches in the central, southern and south-western part of the state has consistent depth to ground water in the range of more than 5 m (CGWB, 2020). Also, historically, the groundwater is reported to be contaminated in Bihar. Thus, planning for DEWATS needs robust hydrogeological assessment of the area and most likely to be restricted to a few patches in the central, southern and south-western part. Considering the target of low carbon solution, anaerobic digestion based DEWATS with bio-gas capture system is recommended as the most effective and economically viable technology choice.

Considering the existing pattern of technology preference in Bihar, efficient operation, and management of existing and proposed aerobic STPs should be prioritised by incorporating interventions such as effective performance management through IT systems; improving aeration, pumping, and motor efficiency; and also designed preferably with gravity flow; amongst others. This will lead to improvements in service delivery to achieve Methane Correction Factor (MCF) 0 as against MCF 0.3 for not well-managed aerobic systems.

Simultaneously, ULBs, GPs, along with BUIDCO, UD&HD, RDD, DWSC and BPIU are recommended to channelise and integrate future funds for anaerobic treatment processes. Design of any new anaerobic STP should be mandatorily equipped with methane capture mechanism to effectively contribute to GHG emissions mitigation.

Open disposal of faecal sludge

Future Scenario of Sewage Treatment in Bihar

	Urban			Rural		
	Baseline-2020	LCP-2025	LCP-2030	Baseline-2020	LCP-2025	LCP-2030
Volume of wastewater treated in STPs (MLD)	80	1000	1400 (100% aerobic)	0	85	295 (100% anaerobic)

Action 3.2. Integrate faecal sludge cotreatment facility with both aerobic and anaerobic sewage treatment plants

At present, 88% of urban Bihar and close to 100% of rural Bihar is dependent on On-site Sanitation System (OSS). Faecal Sludge and Septage (FSS) emptied from these OSS are disposed openly disregarding the threat to the health and environment. As the concept of setting up FSTP is still in early stages in Bihar, co-treatment in existing STPs based on clustered approach is proposed for treatment of FSS.

STPs shall be equipped to accommodate feasible amount of sludge collected from economically viable catchment zone (preferably within 25km as recommended by CPHEEO) including both urban and rural areas.

The main decisive factors for planning co-treatment are:

1. Access to infrastructure for decanting and pre-treatment that will determine the level of improvement required to enable co-treatment (like creation of a decanting facility) and those that can be easily undertaken in a short period of time at minimum cost
2. Quantum of functional sewage flow and BOD concentrations - physico-chemical parameters of sewage is to be analysed to assess the feasibility of accommodating additional sludge for treatment
3. Spare capacity of STP especially the bio-gas unit in case of anaerobic plant - usually provisioning co-treatment will require high financial investment when the STPs are operating at close to 100% installed capacity
4. Distance of point of sludge withdrawal is recommended to be within 25km distance from STP- Respective ULBs in coordination with STP operator should demarcate the buffer of 25km and notify the empanelled desludging operators designated in those areas to empty the toilets and dispose the collected sludge into respective STPs mandatorily.
5. Volume to be treated and characteristics of faecal sludge and septage particularly COD, BOD, TSS - it is recommended that comprehensive physico-chemical analysis of withdrawn sludge is conducted consisting of samples from residential, other establishments and community and public toilets as the first step for feasibility assessment. This will determine the mechanism for addition of faecal sludge and septage into an STP for co-treatment as depicted in the Figure 11.

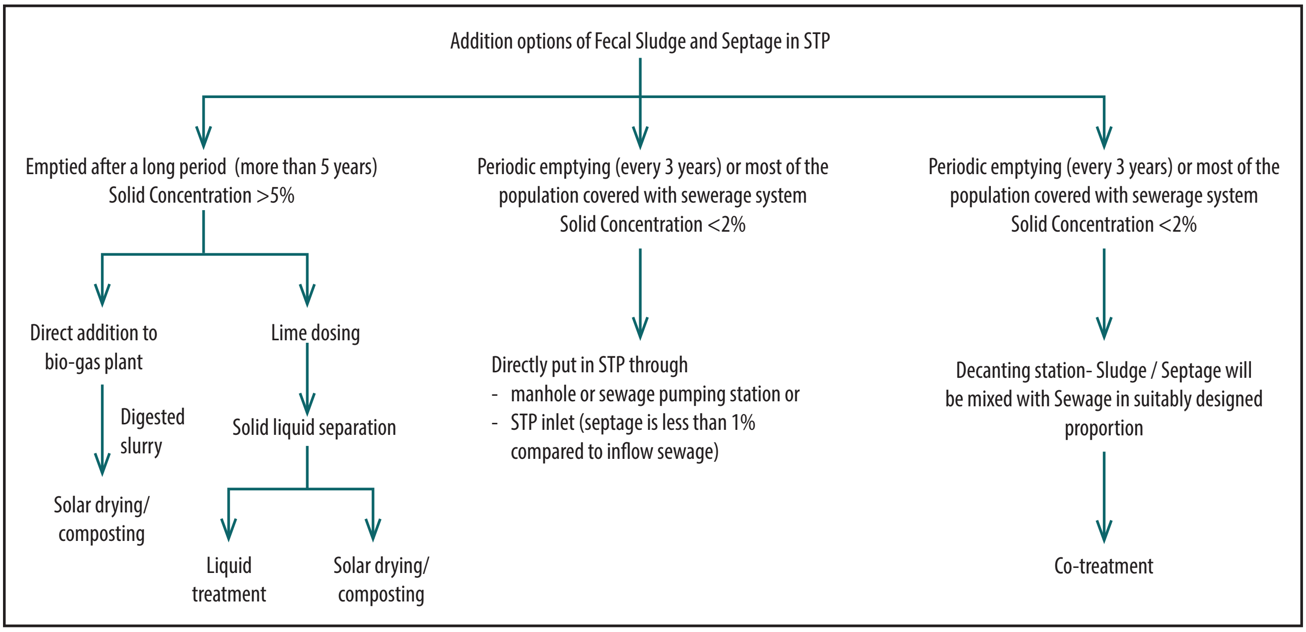

FIGURE 11: Addition Options of FSS in STP for Co-treatment (Adapted from (CPHEEO, 2020)

Considering the prevailing practice of demand driven emptying and recommended scheduled emptying practice that is expected to be widespread only after few years of implementation, additional decanting unit at the sewage pumping station is likely to be the most viable solution for addition of FSS into STP.

An analysis of the various scenarios suggests that at present the operational STPs are not feasible to handle the total sludge generated from toilets based on the unutilised BOD loading capacity of the existing STPs. However, the entire portion of the withdrawn sludge will not belong to the 25km buffer zone of all these STPs. Also, the volume and characteristics of sludge will vary widely depending on desludging frequency.

Assessment of future scenario suggests that upon successful commissioning of all planned STPs, unutilised BOD loading capacity will be more than the estimated sludge BOD load. Thus, co-treatment of faecal sludge is possible in these STPs from the context of sludge accommodation capacity. But in most likelihood, all this sludge will not be generated within all of the STP catchment area.

Hence, following parameters need to be assessed to check feasibility for co-treatment.

- Catchment area analysis for individual STP
- Monitoring of volume and characteristics of inflow sewage in each STP
- Physico-chemical analysis of the emptied sludge from identified area

It is to be noted that additional decanting facility needs to be set up to enable co-treatment once 100% capacity utilisation is attained in STP. Table 5 shows the potential increase in the capacity for co-treatment of sludge in STPs.

TABLE 5: Potential for Co-treatment of Sludge in STP

Parameters	Baseline-2020	LCP-2025	LCP-2030
STP Installed Capacity (MLD) (Urban+Rural)	80	1000	1400
Functionality (%)	59	90	90
Designed BOD Loading Capacity (kg/day)	14,400	1,80,000	2,52,000
Functional BOD Loading Capacity (kg/day)	8,460	1,62,000	2,26,800
Unutilised BOD Loading Capacity in STP (kg/day)	5,904	18,000	25,200
Estimated Sludge Available for Co-treatment (m3)	6,363	7,769	4,395
BOD Load of Estimated Sludge Available for Co-treatment (kg/day)	12,726	15,538	8,790

Action 3.3. Recommend establishment of Faecal Sludge Treatment Plants (FSTPs) at strategic locations across the state

Setting up standalone FSTP is of lesser priority due to high CAPEX and OPEX. But evidently, co-treatment of FSS in STP depends on multiple factors and many of it can be assessed appropriately only after commissioning and operation. Hence, it is recommended to establish FSTPs for both rural and urban areas on clustered basis prioritizing the population beyond catchment area feasible for co-treatment (>25 km from STP).

Planning and designing an FSTP is determined by the following factors, amongst others:

- Estimated FS Generation - Accurate estimation of faecal sludge is important as it will determine the complete management mechanism right from reception unit, pre-treatment, treatment modules, size of treatment unit, area required for treatment upto the end-use of the treated products and by-products.
- FS characteristics - Sludge is characterised into two groups High and Low strength depending on the source and physico-chemical properties, as mentioned in the FSM Book by Linda Strande and paper published by Strauss, 1996. Different technology can accommodate different physico-chemical strength. For eg. Anaerobic Baffle Reactor with Anaerobic Filter can permit maximum BOD and COD load of 600 mg/l and 1500 mg/l respectively.[20] Thus, FS characteristics especially BOD and COD is crucial for factoring in specific technology choice. A comprehensive laboratory analysis is recommended to identify the most viable technology in the local context.
- Faecal Sludge Feeding Rate - It is important to clearly define the rate at which the faecal sludge will be fed into the treatment system. The faecal sludge feeding into the treatment system depends on the capacity and discharge arrangement of the desludging trucks. The treatment modules shall be designed considering the flow rate at which sludge is being discharged from the truck into the treatment plant.
- Retention Time - In order to ensure the effective treatment of sludge as well as sludge water, it is necessary to provide adequate retention time for each of the treatment module proposed.

20. Collated from: https://sswm.info/sites/default/files/reference_attachments/EAWAG%20SANDEC%202008%20Module%205%20FSM%20Lecture.pdf, https://www.susana.org/_resources/documents/default/3-3439-7-1540380071.pdf, Discussion with CDD, 2021

An independent faecal sludge treatment plant can be broadly classified into five stages.

- Pre-treatment Screening and Sludge Stabilisation
- Solid-liquid separation – dewatering the faecal sludge into solid and liquid streams
- Solid treatment – to meet bio-solid standards
- Effluent (liquid) treatment –to meet discharge standards
- Tertiary Treatment

Technology options targeted for each of the treatment module can be broadly categorised into 3 groups.

Mechanical Treatment	Treatment technology is predominantly based on mechanical equipment characterised by higher energy requirements, and presence of multiple mechanical/electromechanical parts in the treatment process.
Biological (Passive) Treatment	Technology used is primarily gravity based natural and biological process consuming less energy, no chemicals and having very few moving/ mechanical parts.
Thermal Treatment	The technology used for solid-liquid separation or effluent treatment can be either a mechanical or passive treatment system. But, for treating solids, a pyrolizer (thermal unit) is used.

Hence, options of a mix of passive and mechanical treatment (focus on anaerobic technology) is recommended to be adopted for minimised energy consumption while capturing methane and subsequent energy production. The different technologies used for different FSTP modules are shown in Table 6.

TABLE 6: Treatment Technologies for Different FSTP Modules

Treatment Module	Mechanical and Chemical	Biological (Passive)
Pre-treatment Screening and Sludge Stabilisation	Mechanical screen and grit chamber Lime stabilisation	
Solid-liquid separation	Screw press Anaerobic Stabilisation Reactor	Unplanted drying bed Settling/ Thickening Tank
Solid treatment	–	Unplanted drying bed Solar Drying using Greenhouse Roofing Aerobic Composting
Effluent (liquid) treatment	–	Anaerobic Baffle Reactor (ABR) with Integrated Settler and Anaerobic Filter (AF) Horizontal Planted Gravel Filter (HPGF)
Tertiary Disinfection	UV treatment / Sand Carbon Filter (SCF)/ Chlorination	Polishing Pond

Future Scenario of Treatment of Sludge in Bihar

Type of Intervention	Baseline-2020	LCP-2025	LCP-2030
Sludge treatment capacity (FSTP)	0	100 KLD (urban +rural together)	2,930 KLD (urban +rural together)
Sludge treatment capacity (co-treatment)	0	7,769 KLD (urban +rural together)	4,395 KLD (urban +rural together)

Action 3.4. Deploy and integrate renewable energy (such as solar) to meet energy demand of treatment plants

Apart from the direct GHG emission from treatment plants, potential indirect emissions due to electricity consumption is important to account for while devising a low carbon action plan. This is more pertinent for aerobic treatment facilities where energy consumption is higher than anaerobic plant as it requires electricity supply throughout the process (Alicat Scientific). Table 7 gives an overview of electricity requirements for existing aerobic treatment technologies adopted in India. Considering the daily power requirement for Activated Sludge Process (ASP), Moving Bed Biological Reactor (MBBR) and Sequential Batch Reactor (SBR) technology for aerobic technology and Up flow Anaerobic Sludge Blanket (UASB) technology which is an anaerobic technology, the average daily power consumption for aerobic treatment technology is 153.7-302.5 kWh/d/MLD and anaerobic treatment technology is upto 125.7 kWh/d/MLD.

TABLE 7: **Assessment of Energy Consumption across Aerobic and Anaerobic Wastewater Treatment Technology**

Energy requirement - kWh/d /MLD	ASP[*a]	MBBR[*b]	SBR[*a]	UASB+ASP[*b]	MBR[*a]	WSP[**b]
Average Technology Power Requirement - Secondary Treatment + Secondary Sludge Handling	180	220	150	120	300	2
Average Technology Power Requirement - Tertiary Treatment + Tertiary Sludge Handling	1	1	1	1	1	1
Average Non-Technology Power Requirement - Secondary Treatment	4.50	2.50	2.50	4.50	2.50	2.50
Average Non-Technology Power Requirement -Tertiary Treatment	0.20	0.20	0.20	0.20		0.20
Total Daily Power Requirement (average)	**185.70**	**223.70**	**153.70**	**125.70**	**302.50**	**5.70**

Note : Sludge Treatment: * Thickener + Centrifuge; ** Drying Process | **Processing type Type:** a = Aerobic; b = Anaerobic-Aerobic;
ASP: Activated Sludge Process | **MBBR:** Moving Bed Biological Reactor | **SBR:** Sequential Batch Reactor | **UASB:** Upflow Anaerobic Sludge Blanket | **MBR:** Membrane Bio Reactor | **WSP:** Waste Stabilization Pond

Source: IITs, 2010

Thus, ULBs along with Bihar Urban Infrastructure Development Corporation (BUIDCO), Bihar Urban Development and Housing Department (BUD&HD), and Bihar Renewable Energy Development Agency (BREDA) are recommended to explore use of renewable sources of energy such as solar energy etc. in the STPs especially aerobic STPs to potentially reduce the indirect CO_2 emissions. Scope of using solar energy should be explored while planning and designing FSTPs as practiced in FSTPs in Wai, Sinnar and Bhubaneswar.

Following parameters need to be assessed for successful application of solar energy for STP operation.

- Electrical energy demand of all the electrical equipment's in different units of STP baed on number of different equipment, rated power consumption and daily operation hour (capacities of the electrical equipment are to be validated from the treatment unit user manuals)
- Location of installation, amount of sunlight available, number of load to be connected, number of hours of usage for each load, available modules in the market and the efficiency, peak watt of the module etc.
- Battery sizing to incorporate power supply and supply the loss of energy by the inverter (other parameters to consider - system capacity of battery, depth of discharge (DoD) and, number of autonomy days (no sunshine days)
- Inverter power capacity (should be higher than the total connected load), and efficiency of the inverter
- PV module size and number
- Area requirement

A study on the potential application of solar power for decentralised STP (300 KLD with average daily inflow of 250 KLD) in Delhi (Singh, 2016) shows 50.06% of the electrical energy used by the STP can be replaced by solar energy (after excluding the blowers used in extended aeration unit).

Future Scenario of Deploying Solar Energy in STPs

	Baselin-2020	LCP- 2030
Total Installed STP Capacity (MLD)- Urban	80	1400
Solar Power (MWp)	0	11.34 (20% of total electricity demand)

Optimise reuse of treated wastewater and sludge

National Framework on Safe Reuse of Treated Water, 2022 recommends potential reuse of treated water in industries, agriculture, municipal uses (such as toilet flushing, maintenance of public avenues and parks, fire-fighting, environmental flows, aquifer recharge, construction, vehicle exterior washing, non-contact impounds, public amenities, golf courses, toilets, parks, and gardens in the divider of highways and other important roads). Use of treated wastewater in 14 industrial sectors is also recommended by CPCB; where the level of treatment will be determined based on the requirement of the industry or plants (CPCB, 2021). Other applications of treated wastewater include growing forest tree species and tree cover in urban areas. It also facilitates the year-round utilization of wastewater. Similarly, treated wastewater can be used to produce commercial non-food crops and flowers. (Indian Institute of Technology, Bombay, NITI Aayog, National Mission for Clean Ganga, Royal Danish Embassy, India, Innovation Centre Denmark, 2022). However, the treated water should meet the quality standards of designated reuse as indicated in Annex 5.

Apart from the treated water, STPs can also produce bio-solids by recovering nutrients from sludge and produce high quality compost. Similar resource recovery happens from FSTP as well. However, the use of bio-solid should be compliant to US EPA standards for bio-solids and Solid Waste Management Rules, 2016. Energy recovery is also possible from treatment plants, given the use of anaerobic technology with gas capture mechanism. Generated renewable energy can be used for heating or electricity generation that will reduce energy costs and greenhouse gas (GHG) emissions.

Thus, it is recommended that parallel to developing State Level Policy on Safe Reuse of Treated Water, and awareness generation amongst stakeholders as indicated in Strategy 9 and 10, BUD&HD, BUIDCO and RDD are advised to conduct statewide mapping of potential reuse of treated water, bio-solids and energy with due support from local bodies while enhancing treatment infrastructure. Also, as it can be observed from the case studies, revenue generation from STPs/FSTPs is still not a widespread practice in India due to various socio-economic reasons. Hence, BUIDCO, BUD&HD and RDD should also integrate specific component of reuse at the tendering stage itself to mandate and ensure optimum reuse, once the project is commissioned on ground.

Compendium of Recycle and Reuse of Wastewater In 54 Million Plus Cities by MoHUA exhibits success stories of recycle and reuse of wastewater for industries, irrigation and agricultural purposes in 32 cities that translates to reuse of only 17.77% of total wastewater generation. Moreover, monetisation of treated water was possible only in 11 cities. Gwalior and Nashik being two of them to have achieved 100% recycle and reuse of wastewater by discharging secondary treated wastewater in canals and rivers and diverting it for irrigation purpose. (CPHEEO, 2021)

On the other hand, snapshot of 29 FSTPs across India indicates that bio-solids, treated water and energy from 15 FSTPs are utilised and with increasing operational efficiency, extent of reuse is expected to increase. Out of the processed products, monetization is mostly practiced in cases of nutrient recovery (bio-solids). The revenue from compost sales covers part of the operating cost, which varies from as low as 6% to the entire cost recovery, plus profits generated in case of co-composting with solid waste (Rao, Velidandla, Scott, & Drechsel, 2020).

6.2. Enabling Strategies

6.2.1. Collection and Transport of Faecal Sludge

Target: 100% safe and contained collection and transport of faecal sludge and septage generated from septic tanks by 2025, to increase efficiency in treatment and processing and optimising GHG mitigation.[21]

Strategy 4: Strengthening safe and contained collection and transport of faecal sludge and septage to suitable treatment facility.

Action 4.1. Operationalise scheduled desludging by empanelled desludging operators

The emptying and transportation of faecal sludge from on-site systems in the state is carried out solely by private operators on demand. Households or establishments call them to empty the septic tanks and the withdrawn sludge is disposed in the open away from human habitation.

To regularise desludging, a scheduled desludging regime at a frequency of 3 years is recommended to be operationalised in a clustered approach for both ULBs and GPs as advised by CPHEEO.

ULBs are recommended to anchor all desludging operation through empanelled operators in the new system. They should identify the GPs within 10km (or any distance based on economic viability) distance and the empanelled operators should be mandated to provide desludging services within the demarcated rural jurisdiction as well. The call centre number should also be circulated within those GPs to encourage villagers to avail the service.

Tentative implementation steps to regularise desludging can be as follows:

- State level regulation on empanelment of desludging operators need to be issued as practiced in states such as Andhra Pradesh, Tamil Nadu etc. In accordance to the state order, ULBs must regulate desludging operators by establishing a system of licensing, which will permit them to legally empty septic tanks within the designated jurisdiction, facilitate the enforcement of health and safety standards and the prevention of open dumping of emptied sludge.
    - Through the licensing system, the desludging operators have to enter an agreement with the ULB specifying the condition of operation and maintenance, worker's safety, working hours, and also renewal of license by submitting vehicle details, RC book, company details, details of the owner and worker's life insurance and safety disclaimer along with designated fee. Following the verification of all these documents and collection of registration fee, a license shall be issued by the ULB through which the operators will be permitted to desludge septic tanks, and mandated to use manifest system (technology enabled or manual as applicable) for track emptying and disposal. Subsequently, ULBs should establish a system for penalizing operators that operate without valid permits/licenses.
- Administration and political wings are sensitized towards advantages and benefits of implementing scheduled desludging and a Council Resolution made for implementing scheduled desludging.
- A geospatial survey to capture the data of the properties targeted for scheduled desludging, recording information on toilet typology, last date of desludging, width of the access road to the property and the access point to the containment that will determine the proposed desludging schedule and infrastructure requirements for desludging.
- Unique reference number for each septic tank system through RFID tag, property tax assessment number, etc. to ensure that all households/ establishments are covered under this scheme.
- Options for revenue collection (user charge/surcharge on property tax) discussed and legal procedures initiated.
- Creating a ring-fencing mechanism (such as an ESCROW account) to hold special funds raised.
- Private operators empanelled and brought under the proposed mechanism.
- A centralised monitoring system established at the ULB level especially for bigger ULBs (pop. >50,000) to formulate desludging schedule of geo-tagged properties and identify rationalised route plan, communicating to operators, monitoring the emptying event and transportation route. For smaller ULBs (pop. <50,000), a manual manifest system can be used and manually integrated with the geo-database/ property tax database. Nodal officer shall be assigned to monitor the system.
- All ULBs equipped with a call centre facility to cater to the request of contingent desludging.

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21. Target aligned with AMRUT 2.0, and SBM Urban 2.0 Operational Guidelines

A brief snapshot of the scheduled desludging system is shown in Figure 12. Systematic operationalisation and implementation of scheduled desludging will enable optimum utilisation of OSS i.e. septic tank suited to local context and reduce the chances of premature withdrawal of FS and consequential leakage of methane gas or overburdening treatment facility with inadequately digested sludge. Adequately digested sludge will also ensure input of FS with appropriate physico-chemical characteristics as per the designed parameter; thereby optimising efficiency of the treatment plant. Additionally, rationalised routing will potentially reduce vehicular CO_2 emissions.

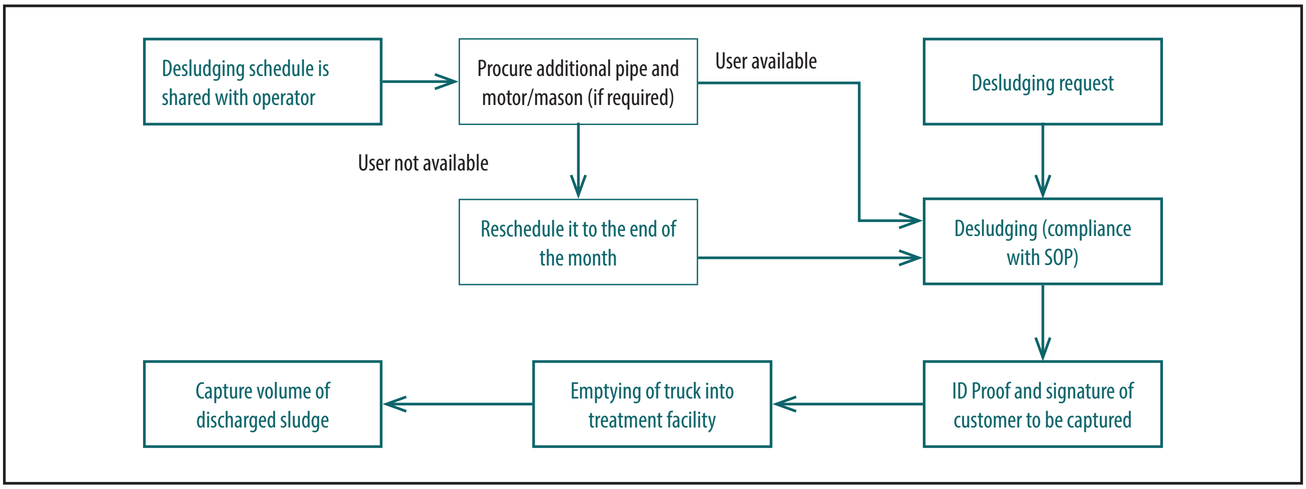

FIGURE 12: Proposed System of Scheduled Desludging (ICLEI South Asia, 2022)

Scheduled Desludging of Septic Tanks in Wai, Maharashtra (Frontiers in Environmental Science, 2019, Vol 7)

Wai Municipal Council was the first ULB in India to operationalise scheduled desludging in 2018 through City Government Resolution for FSSM Intervention. Moving from a complaint redressal system of demand-based emptying to a regular service-oriented emptying system, scheduled desludging ensured that septic tanks are regularly cleaned on a pre-determined schedule as per the recommended desludging cycle of 3 years. Property tax data has been used to create a baseline and the city has been divided into 3 zones targeting 1/3 septic tank to be cleaned annually as per ODF++ Guidelines. Considering the target, requirement of the total desludging vehicles has been calculated based on baseline data.

The service provider (private facilities management company) has been selected through tendering. ULB uses the revenue generated through collection of sanitation tax to pay private operators based on the targeted number of desludging achieved and compliance to safety standards such as use of appropriate PPE, cleaning of spillage, disposal at the designated site etc. In this Performance Linked Annuity Model (PLAM), an Escrow account is being maintained by a third-party bank where the ULB has to maintain a balance equivalent to 3 months' worth of payment to operator.

In case of emergency desludging, property owners must first inform the ULB instead of calling the private operator directly. The local government inspects and verifies these requests before asking private operators for desludging. About 20% of desludging is done in response to emergency requests.

Each step of the schedule desludging of septic tank and movement of desludging truck from household to the FSTP is being monitored digitally. This concept of scheduled desludging has increased 7-8 septic tank desludging per month to 7-8 septic tanks desludging per day and it also ensures the safety of sanitation workers engaged in desludging activities and the convenience of the residents. Based on the success of this model it is being implemented in more than 30 ULBs in Maharashtra.

6.2.2. Greywater Management

Target: At least 80% reuse, treatment, and safe disposal of greywater by 2025[22]

100% reuse, treatment, and safe disposal of greywater by 2030

Strategy 5: Enhance reuse, treatment, and safe disposal of greywater in rural areas. Reuse to be preferred wherever possible.

Action 5.1. Setting up individual and community level facilities to treat maximum greywater generated in rural area

Individual and community level facilities are required for treatment of greywater, after its reuse. These facilities are available sparsely in GPs in the first place, while some of the community soak pits are rendered non-functional due to road laying and other small scale construction activities. Adequacy of these facilities cannot be assessed due to lack of information on its capacity.

Hence, GPs, especially for villages having less than 5000 population, are recommended to focus on household level soak pit/ leach pit/ magic pit based on land availability followed by construction of community level soak pits where household level construction is not possible due to land constraints. GPs should judiciously assess the existing infrastructure gaps and continuously monitor the progress through SBM Grameen 2.0 App to adopt necessary measures.

Reuse of Greywater in Kitchen Garden

Action 5.2. Cleaning of open drain and covering it

GPs have both covered and open drains and open drains were observed to be blocked with littered waste during the ground truthing exercise. Moreover, supernatant from septic tank or human excreta from insanitary toilets is sometimes discharged into the drains, leading to stagnation. BOD of exclusively greywater is 100-300mg/l whereas BOD can go upto 150-400 mg/l if supernatant is mixed with greywater (CPHEEO, 2020). Hence, long term stagnation of supernatant or human excreta mixed greywater in drains or pits can create an anaerobic environment and subsequently results in GHG emission.

22. Aligned with SBM Grameen Phase II Operational Guidelines

Regular drain cleaning is recommended in all GPs, coupled with covering the drains to reduce the scope of littering. The issue of mixing of supernatant or human excreta is expected to be resolved through toilet retrofitting.

Action 5.3. Remediation of eutrophic water bodies

Due to absence of adequate greywater management facility, drains also convey greywater and flow into ponds/ small depressions (pits). These ponds/ pits were found eutrophicated in a few instances. Cleaning and upgradation of drains should be followed by remediation of the eutrophic water bodies in order to restore it in its original state. Thus, GPs are recommended to assess and monitor the waterbodies; physico chemical analysis of the water samples will be required to analyse the extent of eutrophication and the required degree of remediation.

- Villages where individual or community level treatment will suffice the treatment requirement, the water bodies can be remediated to its purified stage using technology such as floating rafter machine and its subsequent maintenance should be ensured by community and GP.
- Decentralised treatment systems in and around the water body will be required for villages where adequate individual or community level treatment facilities are not feasible; especially in villages with more than 5000 population. In this context, waterbody remediation should be integrated with setting up DEWATS such as waste stabilisation ponds or constructed wetlands.

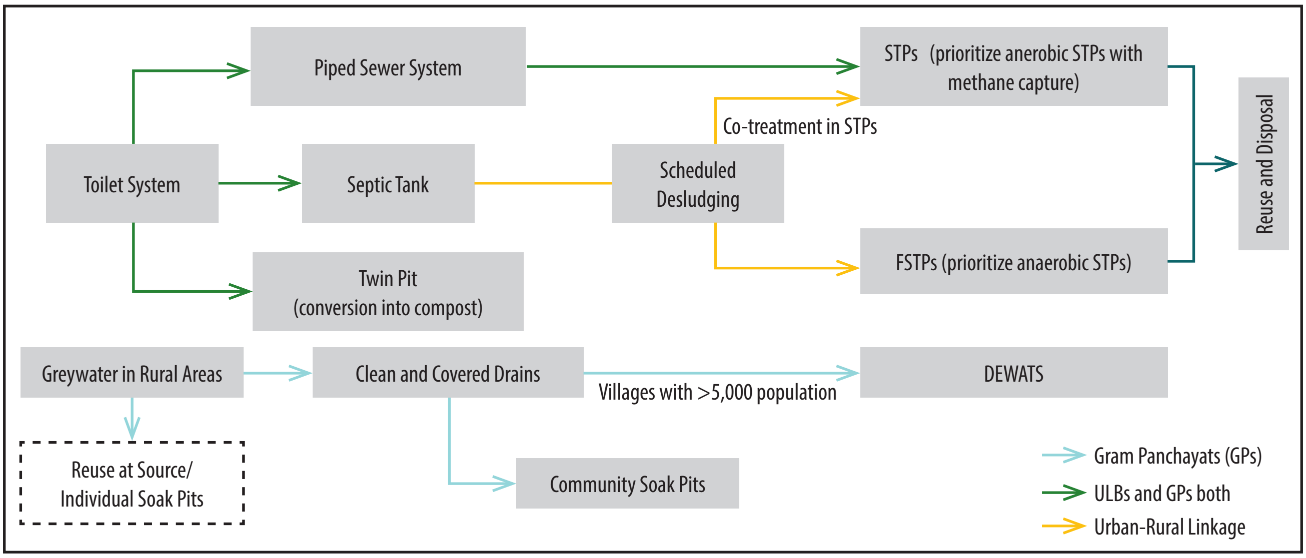

FIGURE 13: Proposed Flow of Domestic Wastewater and Greywater Management Value Chain in Bihar

Eutrophicated Waterbody

7. Solid Waste Management- Infrastructure and Service Provisioning Strategies and Actions

In the domestic solid waste sector, the LCAP has identified a number of infrastructure and service provisioning strategies and actions that are discussed in this chapter. Table 8 below gives an overview of the actions and strategies for the solid waste sector.

TABLE 8: Overview of Infrastructure and Service Provisioning Strategies and Actions

Target	Strategy	Actions
Core Strategies		
100% processing of solid waste in urban areas by 2025 At least 80% processing of solid waste in rural areas by 2025 Immediate bioremediation of legacy waste Scientific capping of the dumpsite and Landfill Gas (LFG) recovery where bioremediation is not possible.	1. Enhance, promote, and ensure scientific treatment, processing, and disposal of solid waste and use of alternative energy source wherever feasible	1.1. Strengthen the existing composting facilities and enhance the overall processing capacity to process biodegradable waste
		1.2. Introduce bio-methanation to enhance overall biodegradable waste processing capacity
		1.3. Upgradation of existing MRFs; and setting up additional MRFs
		1.4. Bio-remediation of legacy waste Scientific capping of dumpsite and simultaneously promoting Landfill Gas (LFG) recovery where bio-remediation is not possible
		1.5. Develop Scientific Sanitary Landfill with Landfill Gas (LFG) capture mechanism
		1.6. Deploy and integrate renewable energy (such as solar) to meet some part of energy demand of treatment plants
Enabling Strategies		
100% source segregation, segregated collection, and transport in urban areas by 2025 At least 80% source segregation, segregated collection, and transport of solid waste in rural areas by 2025	2. Ensure source segregation and segregated primary collection and transport thereby reducing leakage of waste	2.1. Source segregation
		2.2. Strengthening primary collection system
		2.3. Enhance street sweeping efficiency
	3. Strengthen secondary storage, collection, transport of solid waste for enhanced treatment and processing efficiency down the value chain thereby minimising solid waste disposal at landfill site	3.1. Phase-wise removal of community bins
		3.2. Setting up and/ or upgradation of transfer stations with pre-sorting facility
		3.3. Strengthen and enhance secondary transport system

7.1. Core Strategies

7.1.1. Solid Waste Treatment, Processing and Disposal

Target: 100% processing of solid waste in urban areas by 2025[23]

At least 80% processing of solid waste in rural areas by 2025[24]

Immediate bio-remediation of legacy waste[25]

Scientific capping of the dumpsite and Landfill Gas (LFG) recovery where bio-remediation is not possible.

Strategy 1: Enhance, promote, and ensure scientific treatment, processing, and disposal of solid waste and use of alternative energy source wherever feasible

Action 1.1. Strengthen the existing composting facilities and enhance the overall processing capacity to process biodegradable waste

Most of the ULBs in Bihar is equipped with composting facilities, catering to approximately 50% of the total biodegradable waste generation. However, these are operating only at half of their installed capacity. As composting is the most proven and cost-effective technology to treat biodegradable fraction of MSW, ULBs are recommended to optimise the efficiency of the existing facilities and parallely install additional plants.

Under Lohiya Swachh Bihar Abhiyan (LSBA) Scheme, GPs in Bihar are setting up composting units. This process should be streamlined further capturing the capacity of the units, and ensuring strengthened operation and monitoring.

- With reference to the prevailing practice, decentralised units especially pit composting or vermi-composting can be set up in all categories of ULBs focusing on generators such as vegetable markets, hotels, institutions etc.
- Centralised windrow or vermi-composting facilities can be set up in large ULBs (pop. >50,000) to process segregated biodegradable waste.
- Integrated pit or vermi-composting and manual MRF could be set up together for smaller ULBs (pop. <50,000) as indicated in the Action 6.3. as well.

Performance efficiency of the compost units across the state should be enhanced through promoting source segregation, capacity building of operators and overall institutional strengthening and robust monitoring mechanism.

Future Scenario of Composting of Solid Waste

Type of Processing (TPD)	Urban			Rural		
	Baseline-2020	LCP-2025	LCP-2030	Baseline-2020	LCP-2025	LCP-2030
Composting	632	1430	1808	1600	7928	8870

Action 1.2. Introduce bio-methanation to enhance overall biodegradable waste processing capacity

At present, a single 1 TPD bio-methanation plant is located in the state. The CPHEEO Municipal Solid Waste Management Manual considers bio-methanation as one of the most technically sound treatment processes for biodegradable waste and reducing open disposal. It also has potential to generate bio-gas, bio-CNG and/ or electricity through methane capture. It directly contributes to GHG emission mitigation through avoidance of open disposal and replacing conventional fuel/ energy requirements and also incurring economic benefit. Hence it is recommended that more

23. Target aligned with SBM Urban 2.0 Operational Guidelines
24. Target aligned with SBM Grameen Phase II Operational Guidelines
25. Target aligned with SBM Urban 2.0 Operational Guidelines

bio-methanation plants should be set up both in urban and rural areas to cater to the biodegradable waste fraction.

- Centralised units can be installed in bigger ULBs (pop. >50,000)) to process segregated biodegradable waste.
- Decentralised units can be set up in all categories of ULBs to treat waste from vegetable and fruit markets, hotels, institutions, community halls etc.
- Wet waste in GPs can be processed using bio-methanation through individual household, cluster, community, or commercial model depending primarily on its quantum.

ULBs are recommended to obtain Central Financial Assistance (CFA) under Waste to Energy Programme, 2022 along with the SBM U 2.0 and 15th FC grant to set up Bio-methanation plants. Financial sustainability requires that the biogas is sold out for cooking or used for electricity generation while the slurry is collected, dewatered and marketed as organic manure (upon enhancement). The biogas production ranges from 50-150 m3/ton of wastes (CPHEEO, 2016), depending upon the composition of waste. Produced biogas can be used for cooking or to produce electricity and heat. Biogas may also be cleaned by removing CO_2 and H2S. The resulting methane enriched biogas (Compressed Bio Gas- CBG) containing more than 90% methane (CH_4) has properties almost similar to CNG and hence a vehicle running on CNG can straightway be filled with CBG without any modification in the vehicle (SATAT FAQs, 2022). CBG can be transported through cascades or through pipelines to the fuel station networks of Oil Marketing Companies (OMCs) under SATAT scheme that assures offtake of CBG at a minimum price of Rs 46/ Kg + applicable taxes by OMCs (SATAT FAQs, 2022). The alternative green transport fuel can be sold to Bihar State Road Transport Corporation (BSRTC) to be used in CNG fuelled buses. PPP model in the development and operation of bio-gas and/or bio-CNG plants should be encouraged, especially since revenue generation is possible through its output. CSR assistance can also be brought in for installation of small-scale bio gas plants at decentralised level. In rural areas bio methanation unit can be set up in line with GOBARDHAN scheme. Bio methanation would result in stabilised sludge which can be used as a soil conditioner and fertiliser. Bio methanation also helps to reduce the amount of waste going to landfill thus extending the life of existing landfills. There is less odor and less bird menace in bio-methanation facilities.

The overall performance and economic viability of the bio methanation plant is greatly influenced by extent of segregated feedstock along with following characteristics:

- physical- size of constituents, moisture, and density
- chemical- volatile solids, fixed carbon content, inerts, calorific value, C/N ratio (Carbon/Nitrogen ratio), and toxicity
- homogeneity of feedstock
- sustainable demand for the generated biogas

FIGURE 14: Advantages of Biomethanation- (left) use of biogas as source of lighting, (top right) use of biogas as cooking fuel, (bottom right) use of CBG as fuel

TABLE 9: Future Scenario of Bio methanation of Solid Waste

Type of Processing (TPD)	Urban			Rural		
	Baseline- 2020	LCP-2025	LCP-2030	Baseline- 2020	LCP-2025	LCP-2030
Bio-methanation	1	1430	1808	0	3050	3411

Decentralised Bio-methanation Plant in Coimbatore

The pilot project of a 1.5 TPD bio methanation facility, set up in Coimbatore City Municipal Corporation (CCMC) is a successful example of reuse of biogas coupled with emission mitigation potential through decentralised MSWM. Built under the CapaCITIES project, funded by the Swiss Agency for Development and Cooperation (SDC), the plant produces 165 m3 biogas per day from waste collected from local markets, hotels and households, which in turn is used to generate 7 kW power per day to light up the compound area of the plant and some part of street lighting.

In addition to direct electricity generation and related GHG emissions reduction, the facility has helped to avoid at least 1 trip per day to final disposal site thereby avoiding 2 litre of fuel consumption per day and 1.5 TPD waste disposal. Thus, the bio methanation unit could result in 1.11 tCO_2e/day emission reduction and cost reduction of Rs. 344/ day by replacing conventional grid electricity.

CCMC is in the process of scaling up this technology at the municipal level by installing 100 TPD centralised bio-CNG plant with potential to generate approx. 6,500 cum per day of methane that can be converted into 3,900 kg per day of CNG. It is expected to reduce approx. 8705 tCO_2e emissions in a year that can earn Rs. 200 per unit in carbon credits.

Centralised Bio-CNG plant in Indore

In order to strengthen waste to wealth and circular economy in MSWM, Indore Municipal Corporation (IMC), the cleanest city in India for 6 consecutive years, has set up a 550 TPD centralised Bio-CNG plant to process segregated wet waste. Set up in PPP mode between IMC and EverEnviro Resource Management Pvt. Ltd., the project has unique features such as a fully automated pre-treatment unit and separation hammer mill technology for the preparation of bio-slurry feed to run digesters. Besides, the anaerobic digesters, mounted with agitators, work on Continuous Stirred Tank Reactor (CSTR) principle. Also, Vacuum Pressure Swing Adsorption (VPSA) technology has been used to ensure high-quality recovery of bio-CNG fuel from raw biogas. The plant generates 17,000 kg of Bio-CNG and 100 tons of organic manure per day.

Out of the bio-CNG generated from this plant, 50% gas is sold to IMC at Rs. 5 lesser than market rate to run approximately 400 city buses and the remaining 50 percent gas is sold to Avantika Gas Limited under SATAT scheme. 6 CNG stations are spread across the city to be used by city buses. Additionally, pipelines are being laid out to supply gas to GAIL. Thus, an estimated 16,000 litre of fossil fuel usage could be avoided in a day by use of Bio-CNG generated from this plant; thereby contributing to 1,30,000 tCO_2e emission mitigation in a year. Thus, the plant could earn carbon credit worth of Rs. 5.5 Crore in a year.

In addition to bio-CNG, solid organic manure generated in the plant is sold to different marketing companies selected through tendering process. Liquid waste is sent to STP and reused on-site after suitable treatment. Bio-efficacy test has been conducted for the same. In addition to these direct benefits, 20% of the plant's electricity consumption is contributed by solar energy.

As discussed with plant operator; since inauguration, the plant is running at 96% efficiency to date. However, efficiency of the plant depends on extensive source segregation practice followed in Indore. Only 1% reject is generated from the plant that reflects the impeccable quality of feedstock that goes in to produce bio-CNG. For Bihar, due to limited extent of source segregation, absence of detailed characterisation of MSW, and lack of a robust primary collection system; state wide adoption of economically viable large-scale bio-gas/bio-CNG projects should be rationalised by comprehensive technical and financial feasibility analysis.

Action 1.3. Upgradation of existing MRFs and setting up additional MRFs

MRFs are only recently being set up across the state in urban areas, total 57 MRFs are operational at 655 TPD capacity. Apart from catering to only half of the dry waste generated in urban areas, these are completely manual MRFs without any machineries involved in sorting and completely dependent on manual segregation and without basic facilities such as weighing scale and sorting platform.

It is recommended that existing MRFs in small ULBs (pop. <50,000) should be equipped with basic facilities such as weighing scale, sorting platform, safety, and protective equipment and in larger ULBs (pop. >50,000) manual MRFs should be upgraded into semi-automated/ automated facility.

Along with provisions for sorting recyclables, MRFs should have provision for sorting SCF (Segregated Combustible Fractions)/RDF (Refuse Derived Fuels) and shred it as per industry requirement. Also, it shall be ensured that outputs (recyclables and non-recyclables) from all MRFs are streamlined as per the value chain and market demand. MRFs especially the smaller ones could be also linked with aggregators to streamline recovered fractions to relevant uptake points.

Establishing strong market linkage with registered recyclers and cement plants with assistance from state government (BSPCB, BUD&HD) and obtaining competitive price for the recovered items through optimum quality control will determine the environmental and economic sustenance of MRF.

As mentioned above, depending on population and waste generation, ULBs can have different types of MRF as indicated in Table 10.

TABLE 10: Type of MRF Systems (adapted from CPHEEO Advisory 2020)

Population	Upto 50,000	More than 50,000
Waste Generation	Upto 20 TPD	More than 20 TPD (limited to maximum of ~180 TPD [except Patna])
Type of MRF	**Manual MRF cum Solid Liquid Resource Management (SLRM) Center** - These facilities will take care of both dry waste stream as well as wet waste fraction. These proposed facilities can also segregate the mixed waste.	**Semi-automated MR**F - These can also be used as waste transfer stations with addition of some compaction equipment and hook loaders. Compaction of segregated waste/ inert will help in reducing the cost of transportation, reducing air pollution and release of greenhouse gases (GHGs) by reducing the number of trips of trucks. **Automated / fully mechanized MRF** - has limitation in segregation of mixed waste hence it is required that automated MRFs will receive only dry waste. Each of the municipal zone of the city having waste generation more than 250 TPD can have 1 MRF to optimize segregation, transportation cost and sustainability. However, automated MRFs are recommended only for million plus cities.

Apart from population size and quantity of waste generation, factors such as quality and quantity of incoming waste, whether the incoming waste is source separated dry waste stream or mixed waste stream, and desired quality of end products determine configurations of an MRF.

An MRF will consist of a combination of processing units in varying degrees of mechanization as indicated in the Figure 21. But generically, a semi-automated or automated MRF will follow the 2-unit processes as below:

- **Pre-sorting:** Waste sorting or processing through manual or mechanical techniques is essential to separate out bulky/ large pieces and packets of wastes. Manual sorting results in higher labour costs and lower processing rates. Manual sorters remove bulky waste as the waste passes along a conveyor belt, which carries the pre-sorted waste to the mechanized sorting unit of the facility. Mechanical, bulky waste sorters can be also used as per characterisation of expected incoming waste stream.
- **Mechanical sorting:** Mechanical processes based on principles of electromagnetics, fluid mechanics, pneumatics, etc., are used to segregate the different waste streams. These include trommel/ballistic separator, magnetic separator, air classifier, optical sorter etc., as indicated in the Figure 15.

FIGURE 15: Comparison of Process Flow in Different Types of MRF (CPHEEO, 2020)

Material recovery in rural areas is facilitated through Waste Processing Units (WPUs) which are equipped with a collection and segregation shed. Collected waste is sorted into recyclables and non-recyclables; recyclables are sold to Kabadiwalas and non-recyclables are dumped openly. Construction of WPUs is currently taking place under LSBA, but that does not prevent the scattered dumping of non-recyclable fractions. Thus, urban-rural linkage needs to be established to maximise recovery of dry waste from rural areas.

ULB level MRFs (pop. >50,000 ULBs) should be developed and operated in a manner to collect and store non-recyclable fractions from nearby GPs. Clustered approach should be followed while designing these MRFs where nearby GPs should be demarcated and linked with that particular MRF based on dry waste generation and transport cost ensuring financial viability.

Alternatively, block level MRFs could be set up, as is being planned in Nalanda district to recover dry recyclables from all GPs in the district. The MRFs should be equipped with cleaning machine, compressing machine, and shredding machine.

Open Disposal of Waste in GPs (left), Construction of WPU in Progress (right)

Future Scenario of Processing of Dry Waste in Bihar

Type of Processing (TPD)	Urban			Rural		
	Baseline-2020	LCP-2025	LCP-2030	Baseline-2020	LCP-2025	LCP-2030
Recycling	48.6	744	940	66	4878	5459
Co-processing	583.5	458	579	-	1219	1365

Material recovery Facility in Indore

To move towards the *'zero waste to landfill'* city, Indore Municipal Corporation, in PPP mode with Nepra Resource Management Private Ltd. has set up 300 TPD fully automated Material Recovery facility (MRF) to scientifically manage and maximise economic return from the dry waste generated in the city.

The incoming waste is screened into 3 categories; upto 50mm, 50-300mm and more than 300mm. Key functioning and automation of the MRF revolves around 50-300mm materials. This is separated into 2D (paper and plastic films) and 3D component (types of plastic resins and metals) through Ballistic Machine. Subsequently, different items are sorted through Magnetic Separator and Optical Pneumatic Sorting techniques and undergoes manual quality check and colour sorting on the platform afterwards. Another round of inspection takes place once separated items are released into dedicated bunker and subsequently, each material is dispatched in accordance to its usage.

Success of the State-of-the-Art MRF in Indore begins with the extensively adopted source segregation. Due to the flow of segregated waste right from the point of generation, a clean MRF could be managed efficiently. However, in spite of approximately 100% source segregation, only 10% of incoming waste could be recovered as recyclable i.e. the most valuable fraction. Due to limited extent of source segregation, lack of MSW characterisation, and absence of robust primary collection system; successful implementation of automated or semi-automated MRF in Bihar will depend on establishing strong source segregation followed by a robust technical and financial viability assessment.

Action 1.4. Bio-remediation of legacy waste. Scientific capping of dumpsite and Landfill Gas (LFG) recovery where bioremediation is not possible

There are total 104 functional dumpsites in Bihar with a large quantum of legacy waste. Bioremediation is underway in only 26 dumpsites. Rest of the dumpsites will continue to be a significant source of GHG emission. Thus, it is recommended that all dumpsites are to be remediated in the state immediately to comply with the provisions under Solid Waste Management Rules, 2016.

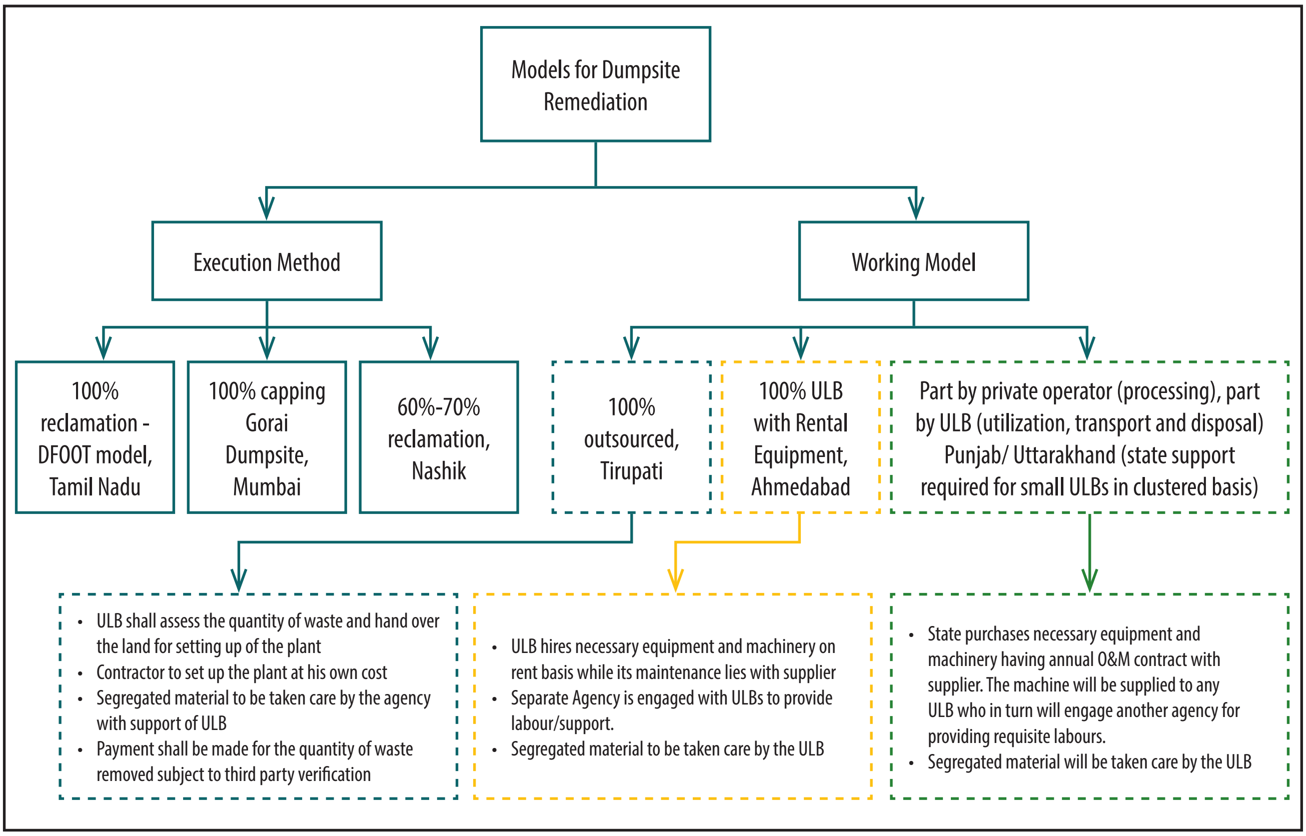

FIGURE 16: Types of Bioremediation Implementation Models (CPHEEO, 2020)

As the economic efficiency of the dumpsite reclamation exercise depends on use of recovered and segregated material, quantification and characterisation of legacy waste should be the premise of initiating reclamation.

Larger ULBs can adopt 100% outsourced model whereas cluster of smaller ULBs can be prepared at the state level to remediate existing dumpsites following the 3rd type of working model as indicated in the Figure 24. Dumpsite reclamation should be done in accordance to the developmental milestone of treatment and processing facilities of wet and dry waste and proposed scientific landfill so that the dumping of inert and process rejects can be continued in the scientific landfill.

Dumpsite remediation can be primarily of 2 types:

- **Bioremediation and Bio-mining:** 100% reclamation of dumpsite or bioremediation cum bio-mining is the excavation of old dumped waste and make windrow of legacy waste thereafter stabilization of the waste through bio-remediation i.e. exposure of all the waste to air along with use of composting bio-cultures. This is followed by screening of the stabilized waste to recover all valuable resources (like organic fines, bricks, stones, plastics, metals, cloths, rags etc.) and its sustainable management through recycling, co-processing, road making etc.
- **Capping:** Where reclamation is not viable, the dumpsite should be capped scientifically to prevent further damage to the environment. Capping a landfill involves three layers: an upper vegetative (top soil) layer, a drainage layer and a low permeability layer comprised of a synthetic material overlaying two feet of compacted clay. Leachate collection and treatment and gas collection and control facility which collects and extracts gas from within and from the top of the landfill and then treats it and uses it for energy recovery respectively are integral part of capping of dumpsite.

Closed dumpsites may be used for development of local markets, urban parks, office, commercial, or institutional space (after ascertaining safety and assessing requirement of relevant controls- which should be taken up 3 years after complete cessation of leachate generation).

Functional Open Dumpsite vs. Bioremediated Dumpsite and Post-closure Usage as Park

Large dumpsite with legacy waste is not evident in rural areas; scattered disposal of waste takes place that does not contribute to GHG emission. However, these small garbage dumps need to be cleared and the waste could be recovered and channelled to WPU and subsequent value chain. If it is not in recoverable condition, the entire dumped waste can be transported to nearby ULB level functional dumpsite or sanitary landfill. Once cleared, these points need to be maintained subsequently by factoring in socio-cultural aspects such as painting rangoli on ground or wall painting that can be integrated with IEC action plan.

Action 1.5. Develop Sanitary Landfill with Landfill Gas capture mechanism

SWM Rules, 2016 defines sanitary landfilling as a means for the final and safe disposal of residual solid waste and inert wastes on land in a facility designed with protective measures against pollution of ground water, surface water and fugitive air dust, wind-blown litter, bad odour, fire hazard, animal menace, bird menace, pests or rodents, greenhouse gas emissions, persistent organic pollutants slope instability and erosion.

Sanitary landfills can be constructed for large ULBs (pop. >50,000) on individual basis and 100% privatised development and O&M contract whereas state supervised model could be adopted on clustered basis for smaller ULBs (pop. <50,000)), designed preferably for next 20 years for disposal of the following fractions:

- inert waste
- commingled waste (mixed waste) not found suitable for waste processing
- pre-processing and post-processing rejects from waste processing sites

While designing SLF, urban-rural linkage needs to be considered to cater to the inert and process rejects generated from rural areas. In this process, nearby GPs within economically viable distance should be identified and clustered together; from which inert and process rejects would be collected by the landfill operator; frequency should be decided depending on quantum of generation. Relatedly, the SLF should also be able to cater to the process rejects from the block level MRFs.

Construction of sanitary landfill should precede bio-remediation or capping of functional dumpsites so that the dumping of inert and process rejects can be continued in the sanitary landfill.

The essential components of a MSW landfill include:

- liner at the base and sides of the landfill which prevents migration of leachate or gas to the surrounding soil
- leachate collection and control facility which collects and extracts leachate from within and from the base of the landfill and then treats the leachate
- gas collection and control facility (optional for small landfills) which collects and extracts gas from within and from the top of the landfill and then treats it or uses it for energy recovery
- final cover at the top of the landfill which enhances surface drainage, prevents infiltration of water and supports surface vegetation
- surface water drainage system which collects and removes all surface runoff from the landfill site.

Basic steps to design, implement and operate a sanitary landfill can be adopted from Municipal Solid Waste Management Manual, CPHEEO, 2016.

Reclamation of Pirana Dumpsite in Ahmedabad[26]

Reclamation of Pirana is one of the recent cases of dumpsite reclamation and landfill gas capture in India. Operational since 1980, 84 hectare Pirana dumpsite accommodated 10 lakh tons of legacy waste at the time of reclamation and stood tall at a height of 22m.

During the reclamation process of Pirana dumpsite, bio-mining technique has been used. Parallelly, bio reactor had been used for the mixed incoming waste to avoid mixing with legacy waste.

The outputs derived through biomining are used for different purposes:

- RDF to Abellon Clean Energy free of cost, utilized as fuel in Bio-mass Gasification and also to 3 other plants of similar type
- C & D waste transported to be reused and made into paver blocks, precast walls, manhole covers and many more products
- Semi Compost transferred to the existing MSW compost plants for further treatment and selling to farmers

Pirana dumpsite reclamation contributed to estimated 483 million tCO_2e emissions reduction per year. In additional to GHG emission mitigation, the process has led to several socio-economic benefit in terms of material recovery, green job creation, enabling liveable situation in the neighbourhood.

Future Scenario of Waste Disposal in Sanitary Landfill in Bihar

Parameters	Urban (Urban-Rural Linkage)	
	LCP-2025	LCP-2030
SLF Design Capacity (TPD)	9080 (Urban + Rural)	9335 (Urban+ Rural)
Methane Capture	-	10%

Explore Opportunity of Setting up Construction and Demolition Waste Processing Plant

MSW in Urban Bihar consists of 29% inert (sand, stone and dust) i.e. 2,098 Tons of inert fraction is generated per day. However, at present there is no C&D waste processing plant in the state. Ministry of Urban Development (MoUD) vide its circular dated 28th June, 2012 stated all states to set up C&D waste recycling facilities in all cities with population of over 1 million. Also, SBM Urban 2.0 Operational Guidelines recommend setting up C&D waste treatment plant in Patna, Muzaffarpur and Gaya. Apart from these, rest of the ULBs are also recommended to conduct comprehensive need assessment for setting up C&D waste processing plant to reduce the burden on SLFs.

Action 1.6. Deploy and integrate renewable energy (such as solar) to meet energy demand of treatment plants

Apart from the direct GHG emission from treatment plants, potential indirect emissions due to electricity consumption is important to account for while devising the low carbon action plan. This is more pertinent for energy intensive processes such as bio-methanation or automated MRFs. Conventional energy consumption by these facilities could be reduced by installation of solar panel; thereby reducing dependence on the electricity grid and saving O&M cost. It is especially recommended in small towns and cities with limited funds for solid waste management but with potential climatic condition to harness solar power.

The following figures demonstrate how the SWM value chain may be improved to better service delivery in urban and rural areas.

26. Compiled from https://niua.in/c-cube/sites/all/themes/zap/pdf/landfill-remediation.pdf and https://www.globalmethane.org/expo-docs/india10/postexpo/landfill_asnani.pdf , accessed on November, 2022

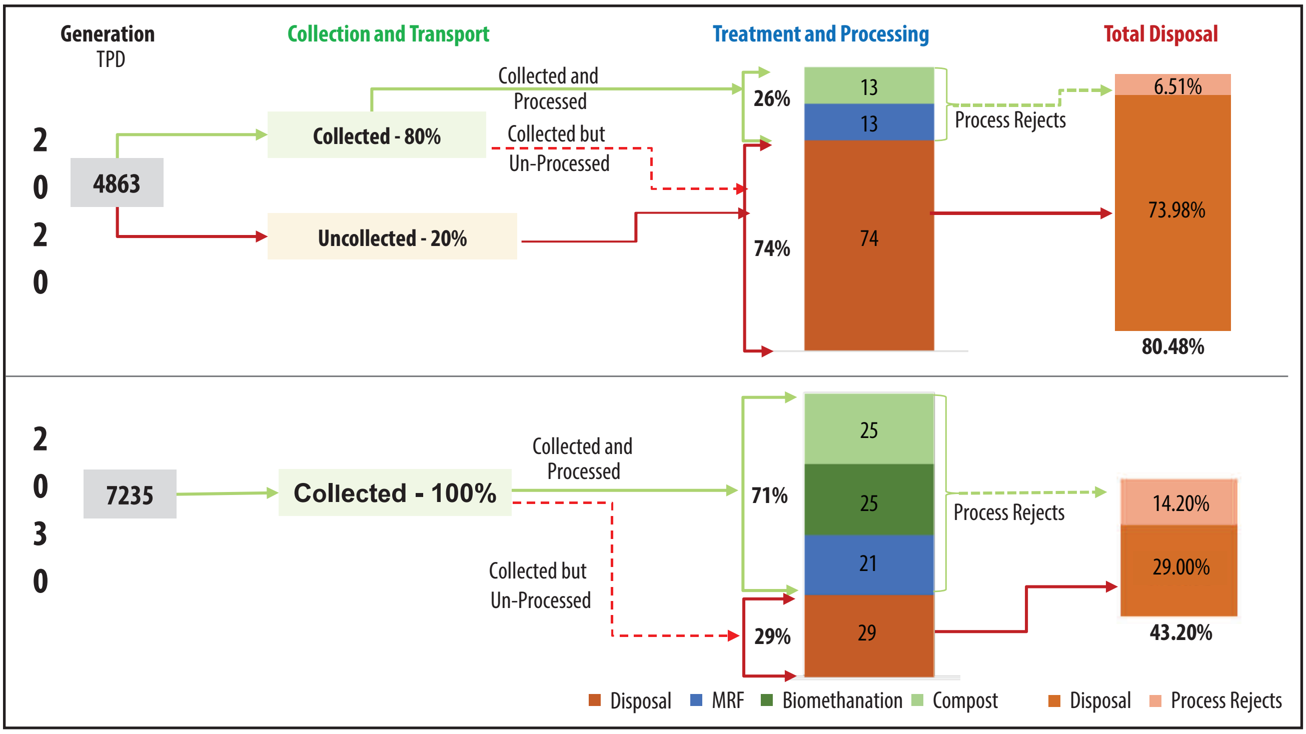

FIGURE 17: Improvements in Service Level Across the SWM Value Chain in Urban Areas

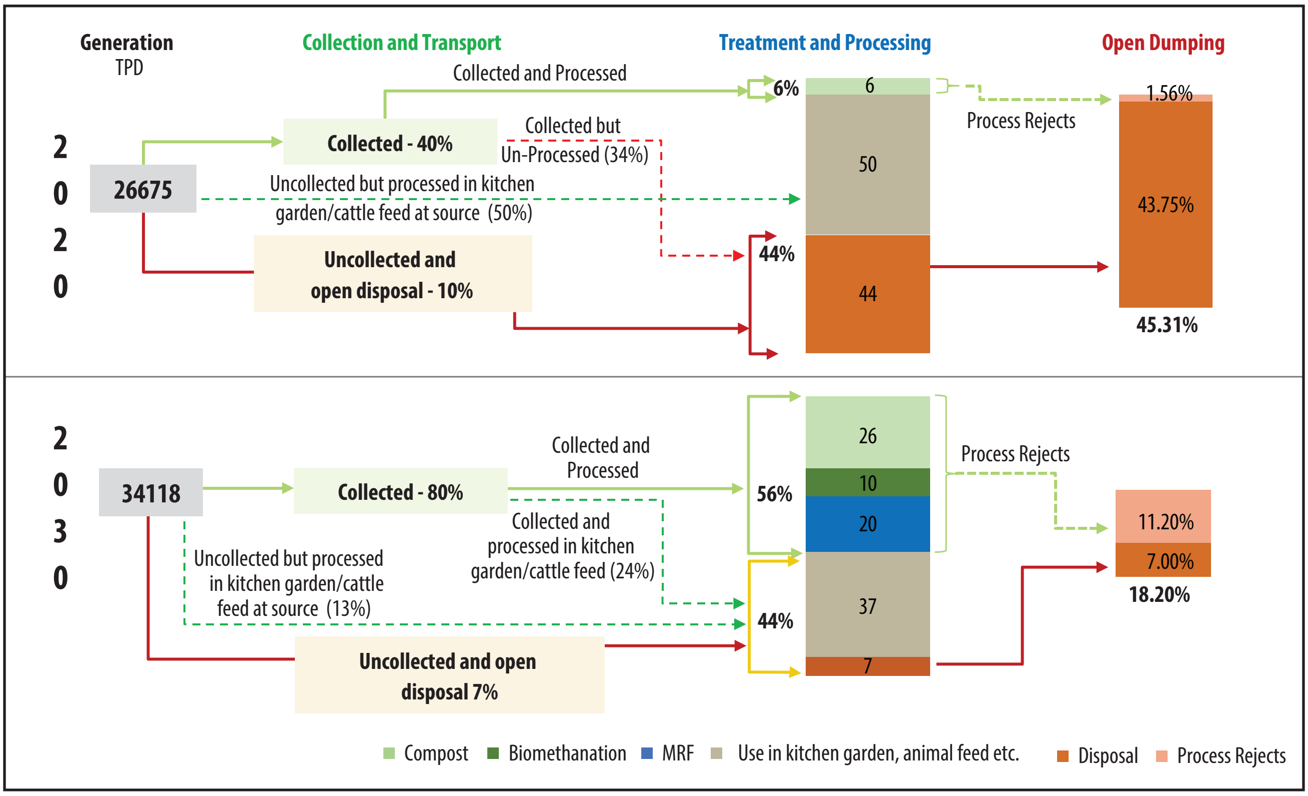

FIGURE 18: Improvements in Service Level Across the SWM Value Chain in Rural Areas

7.2. Enabling Strategies

7.2.1. Solid Waste Collection and Transport System

Target: 100% source segregation, segregated collection, and transport in urban areas by 2025.[27]

At least 80% source segregation, segregated collection, and transport of solid waste in rural areas by 2025.[28]

Strategy 2: Ensure source segregation and segregated primary collection and transport thereby reducing leakage of waste

Action 2.1. Source segregation

Source segregation is the first step towards implementing low carbon actions in SWM system. This would facilitate segregated waste collection and transport enabling ease of recovery, treatment and processing that will help in mitigating GHG emission. At present, extent of source segregation across Bihar is limited to only 10-20% in most of the areas with a few exceptions.

Apart from conducting IEC campaign and enforcement of byelaws and stringent monitoring, both ULBs and GPs are recommended to complete the distribution of color coded (green for wet waste and blue for dry waste) dust bins to households wherever not yet distributed. Households should be encouraged to store domestic hazardous waste in segregated manner wrapped securely in paper. This will reduce contamination of valuable waste fractions and disposal of mixed waste in landfill.

Action 2.2. Strengthening primary collection system

At present, door to door collection efficiency in urban areas is not yet 100% and the system is still not well established in most of the rural areas. Lack of door-to-door collection increases instances of open dumping or burning of waste and subsequently, highly contaminated, and untreated fractions increase burden on landfill. Hence, both ULBS and GPs should strategically plan its infrastructure as well as human resource to be able to provide for this service.

Segregated Primary Collection in Some Areas in Patna

27. Target aligned with SBM Urban 2.0 Operational Guidelines
28. Target aligned with SBM Grameen Phase II Operational Guidelines

Primary collection in the urban areas can be through a mix of motorized (door to door collection in auto tippers and other vehicles as per requirement) and non-motorized conveyance system. Non motorized i.e. tri-cycle, push cart or e-rickshaws is recommended for areas inaccessible by large vehicles such as narrow lanes, slums, hilly terrain etc.

- Auto tippers can directly bring the waste to transfer stations or processing facilities depending on the available infrastructure.
- Waste collected through push carts, tri-cycle, e-rickshaws should be brought to designated collection points and transferred to secondary transportation vehicles and further streamlined directly to processing facility or to transfer stations depending on available infrastructure.
- In rural areas, door to door collection can be continued in the tri-cycle/ e-rickshaws as practiced at present and should be brought to the WPU.
- In order to ensure ease of segregated collection and transport and subsequent processing, auto tippers should be closed and compartmentalised and tri-cycle, push carts, or e-rickshaws should be provided with 4-8 bins, wherever not yet introduced.

For new procurement, CNG auto-tippers and e-rickshaws should be considered to factor in low carbon options. Retrofitting existing vehicles with CNG fuelled engine can also be considered by ULBs.

Action 2.3. Enhance street sweeping efficiency

In ULBs, street sweeping should be done on daily basis (at least once a day). Twice a day sweeping is required for commercial areas with high floating population. GPs should decide their frequency of sweeping depending on street density. The system of using pushcarts for street sweeping is suggested to be continued but it is necessary to have a well-planned, time-bound system for street sweeping including adequate staffing and equipment.

The existing beat routes in urban areas need to be optimized according to CPHEEO Manual as mentioned below:

- High density roads: 1 person per 300–350 running meters of road length
- Medium density roads: 1 person per 500 running meters of road length
- Low density roads: 1 person per 750–1,000 meters of road length

Mixed Waste Collected through Street Sweeping indicating Presence of Littering

Each street sweeper shall also continue drain cleaning (upto 18 inch depth) parallelly to remove silt. Further, it needs to be ensured that street sweepings and drain silt are not mixed with household wastes to avoid contamination. Options of designating separate street corner bins (black bins) could be explored to store street sweepings waste and drain silt separately in line with CPHEEO Manual. Depending on the type of road and activity on the road, the size of the bins may be decided.

Dedicated vehicles can be deployed for collecting street sweeping waste that need to be transported directly to designated scientific landfill site. In case a transfer station is available in the ULB, collected street sweeping waste can be brought in to transfer station instead of transferring directly to SLF; depending on comparative distance vis-à-vis transportation cost. From transfer stations, it can be subsequently transferred to the sanitary landfill; preferably recommended through compactors to reduce the secondary transportation cost.

It is to be ensured that only inert fraction is disposed off in scientific landfill.

Street sweeping waste in rural areas can be stored in WPUs and the inert fraction and process rejects from a cluster of GPs should be transported to nearby ULB level SLF in aggregated manner as discussed in Action 6.5.

Strategy 3: Strengthen secondary storage, collection, transport of solid waste to the treatment and processing facilities thereby minimising quantum of solid waste disposal at landfill site

Action 3.1. Phase-wise removal of community bins

It has been observed that community bins are prone to overspilling and littering and always tend to turn into Garbage Vulnerable Points (GVPs). In rural areas, the bins were also found to be redundant. Hence, phased removal of community bins in both urban and rural areas is recommended after strengthening coverage and efficiency of primary collection system. However, twin litter bins should be retained or new bins should be placed at 50 m distance where public pathway is there around the waterbody or the waterbody is accessible for the public (for eg. Ganga and other tributaries ghats in Bihar).

Action 3.2. Setting up and/ or upgradation of transfer stations

At present, transfer stations are present only in Patna. However, for any ULBs where the distance from collection area to disposal site is more than 15km or 30mins away, transfer stations are recommended to save transportation time and fuel. Transfer stations should be made only when the cost of direct haul in collection vehicles would outweigh the cost of supplemental haul in large bulk-haul transfer vehicles plus the cost of the supporting transfer system infrastructure at the transfer station and disposal site.

However, considering the limited extent of source segregation, transfer station with a pre-sorting line might be recommended depending on available finance in spite of a negative cost-benefit ratio with reference to the cost comparison indicated above. Pre-sorting line will enable segregation of incoming mixed waste. Segregated wet and dry waste will be streamlined to designated processing facilities; this will optimise efficiency of the processing facilities.

Situational Comparison Between Manual and Automated Transfer Station

Existing manual transfer stations such as in Patna shall be upgraded in the similar manner as well. For ULBs which are equipped with disposal facility located within 15km distance, additional transfer station is usually not required.

Action 3.3. Strengthen and enhance secondary transport system

ULBs should strengthen secondary transport system to collect the waste at collection points and transfer stations and transport it to processing facilities in segregated manner. Type of secondary transport vehicles need to be decided based on the type of secondary storage infrastructure and quantity of waste to be transported, travel distance, road widths, road conditions etc.

8. Other Enabling Strategies for Solid Waste and Wastewater Sector

8.1. IEC and Capacity Building

Target: All major stakeholders are aware of the impact of mismanaged solid waste and domestic wastewater on the environment and public health and have adopted holistic practices thereby supporting the implementation of proposed scientific solid waste, domestic wastewater and greywater management system in the state.

Strategy: Create awareness and capacitate relevant stakeholders across the solid waste and waste water sector value chain to support implementation of scientific solid waste, domestic wastewater and greywater management system leading to GHG emission mitigation

A successful and sustainable awareness and behaviour change campaign is seen as an essential part of a successful low carbon action plan for waste sector as many potential solutions will require the users to change their current practices and adopt behavioural change such as practicing source segregation, construction of scientific toilets, regular use of toilet and its scheduled cleaning, etc.

In order to ensure the support and participation of all stakeholders, public awareness campaigns should be undertaken by the local bodies and civil society. ULBs as well as GPs in coordination with Block Project Implementation Unit (BPIU) and District PIU and District Water and Sanitation Committee (DWSC) should plan information and public awareness campaign in line with the ongoing programme such as SBM Urban 2.0 and SBM Grameen Phase II, targeting appropriate groups, and disseminating key messages through direct communication channels and mass media campaigns. The programme should also be able to cater to the need of capacitating relevant stakeholders, training and raising awareness of the opportunities and threats. Sensitization and capacity building on the following components is proposed:

I. Toilets system and emptying of toilets

- Awareness regarding importance of sustained toilet use behaviour, maintaining and cleaning toilets
- Educating on construction quality of toilets
- Awareness regarding adverse impacts of mixing of grey water and black water
- Understanding the requirement of periodic desludging in compliance with Standard Operating Procedures (SOPs)
- Sensitization towards the roles and responsibilities of desludging service providers
- Regular and timely payment of defined user charges

II. Grey Water Management

- Prioritizing reuse of grey water in kitchen garden
- Proactive participation in setting up and O&M of household or community level grey water treatment units, wherever applicable
- Awareness to ensure discharge of greywater into conveyance system such as closed drains, small bore pipe systems, etc. where reuse or household level treatment is not possible

III. Solid Waste Management

- Minimizing waste generation
- Open dumping and burning of waste
- Difference between biodegradable and non-bio degradable fraction and source segregation
- Reuse and upcycle of non-biodegradable fraction
- Sensitization regarding the role of waste collectors
- Diligent payment of user charges

- Establishing and operating household or community level decentralized waste processing units
- Economic and environmental benefits of treated products (compost/ biogas etc.)

IV. Training and Capacity Building Programme

- Capacity building of waste collectors to monitor source segregation, report non-compliance and ensure segregated collection and transport of waste, thereby increasing treatment and processing potential
- Capacity building of operators of different solid waste processing facilities to ensure efficient functioning, thereby reducing quantum of waste reaching landfill and resultant emissions
- Capacity building of masons engaged in toilet construction, specifying scientific construction methods to reduce emissions
- Capacity building of desludging service providers regarding SOP and compliance to desludging schedule
- Capacity building of STP operators to improve functioning of especially aerobic STPs, thereby reducing emission
- Capacity building of sanitation workers at different administrative level (State/ Local Body level) for holistic strengthening of value chain

TABLE 11: Recommended IEC Tools for Various Stakeholders

Target Group	IEC Tool	Frequency
Households/RWAs/Commercial units/street vendors (Applicable for ULBs and GPs)	Door–to-door campaigns- Illustrative campaigns using pamphlets	Quarterly
	Pledge for source segregation, use of toilets, reuse of greywater in kitchen garden as applicable	One time- to be monitored quarterly during door-to-door distribution of pamphlets
	Award and recognition for practicing source segregation, reuse of grey water in consistent manner	Annual- shall be awarded after a month of initiating IEC campaign and monitored during quarterly door to door campaign
	One-to-one meetings/ FGDs with relevant authorities	Quarterly
Educational institutions- to act as Agent of Change (Applicable for ULBs and GPs)	Awareness-raising programmes through interactive sessions with students	Annual/Biennial
	Illustrative Handbooks	One time
Hotels/Restaurants/ Malls/ Vegetable Markets/Office- Institutes/Temples/ Community Halls/ Park (Applicable for ULBs only)	One-to-one meetings to be held with designated authority	Biennial
	FGDs for extending technical support in constructing on-site waste collection/ processing centres	Annual/Biennial
	Award and recognition- Star/ Responsible Generator award for practicing source segregation and managing waste as per legal and policy framework	Annual- shall be awarded after a month of initiating IEC campaign followed by quarterly monitoring
Mass Awareness (Applicable for ULBs only)	Screening of audio-visual (AV) clips before movie shows in multiplexes	Continuous
	Screening of messages and AV clips on LED screens installed across the city	Continuous
	Workshops and conferences for citizens on different forums and platforms involving renowned universities/ research institutes	Biennial

Target Group	IEC Tool	Frequency
Mass Awareness (Applicable for ULBs and GPs)	TV, radio, print, media (Hindi and regional/ local languages)	Once in 2-3 hours throughout the day (TV/ Radio) Once in a week (print media)
	Circulation of notifications on social media (WhatsApp, Facebook, Twitter etc.)	Weekly- Designated day in a week for sharing notifications (can be considered Swachhta K Din- Day of Cleanliness)
	Installation of banners/ sculptures and wall painting at prominent landmarks	Regular
	Mass clean-up drives, marathons, cyclothons, rallies/ fairs and melas etc.- bringing in brand ambassadors for impactful drive in different parts of ULB/ GP on rotational basis	Quarterly
	Dance/ Drama/ Street Play etc. in local dialects	Regularly - preferably on Sundays/ holidays/ festivals of local or national importance
Mass Awareness and Tourists/ Floating Population (State Level)	Advertisements on public transport, on the back side of tickets for inter-city service- in collaboration with BSRTC	Continuous
	Banner and advertisements specifically designed for tourists and floating populations in tourist locations, bus stands, railway stations and airport	One time

TABLE 12: Recommended Tools for Capacity Building

Method	Tools	Recommended frequency
Inter-personal Communication (IPC)	FGD with waste collectors	Quarterly
	FGD with masons	Quarterly
	FGD with desludging service providers	Bi-annual
Training Programme	Classroom training sessions with sanitation staff, District, Blocks and GPs level functionaries and Community Approaches to Sanitation (CAS) training of Swachhagrahis	Quarterly
	On-ground demonstration with masons, desludging service providers, waste collectors and treatment unit operators	Quarterly
Exposure Visit	Visits of sanitation staff/ treatment/processing facility operator on rotational basis to best practice cases	Annual

For successful implementation of IEC and capacity building programmes, a robust need assessment is recommended for each ULB. ULBs can obtain third party assistance for the same, if required. Subsequently, relevant private party (NGOs/ CBOs/ other institutions) can be engaged through a transparent bidding process for development and implementation of IEC and Capacity Building actions suited to local context. The plan will define target groups, target areas such as wards/zones/HHs/ other establishments with time lines. It will also include identification of suitable IEC and capacity building method and tools for each target group, frequency and resources required for implementation. The plan will also identify supporting administrative, management and policy level interventions accelerating the process to get desired outcome.

District level detail IEC plan need to be prepared encompassing all gram panchayats under its jurisdiction. Relevant agencies should be engaged by state for implementation of the IEC and capacity building plan.

Additionally, State Government (such as UD&HD, BSPCB, RDD etc.) can facilitate state level mass awareness campaign in association with specific stakeholders such as Bihar State Road Transport Corporation or Bihar State Tourism Development Corporation amongst others targeting bus terminus or tourist places respectively to maximise the extent of awareness creation.

8.2. Institutional and Monitoring Mechanism

Target: All policy and regulatory framework enforced and a robust institutional and monitoring system is in place to support and sustain the proposed scientific solid waste, domestic wastewater, and greywater management system, optimising GHG emissions mitigation

Strategy: Ensure policy and regulatory framework is enforced through carrot and stick approach and a strong institutional and monitoring mechanism is in place to ensure good governance and the long-term sustenance of the proposed scientific solid waste, domestic wastewater, and greywater management system

Different institutions are involved, directly and indirectly, throughout the waste sector value chain and play various roles in its management and mitigation of GHG emission. It is important to ensure that an efficient institutional structure is in place and the capacity exists for regulating and monitoring the solid waste and wastewater management system at different levels of government (urban/ rural local body, block, district, and state) and in other allied institutions. Strategic actions for improving institutional processes are shown in Table 13.

TABLE 13: Strategic actions for institutional improvement

Target Component	Recommended action
Institutional Strengthening and Monitoring Parameters- ULBs/ GPs	
Centralized facility for monitoring and regulation for large ULBs (pop. >50,000) For other smaller ULBs (pop. <50,000) indicated parameters can be mapped and monitored manually with respect to property tax id etc.	● Monitoring Components: ○ Digital Door Numbering of all establishments/Property Tax record/ Geocoordinate of all establishments to be tagged with toilet typology ○ GPS tagging of all vehicles involved in solid and liquid waste sector ○ Route mapping of all vehicles ○ Mapping extent of sewer network ○ Monitoring all treatment plants (input, output, quality of processed products and by-products, process rejects, environmental control mechanism etc.) ● Recruitment of agency for establishing facility could be done through Design-Build-Operate-Transfer (DBOT) model ● Training of all stakeholders to monitor the parameters and report to central control and command facility
Grievance redressal system ● Technology enabled for large ULBs (pop. >50,000) ● Manual for other smaller ULBs (pop. <50,000) and GPs	● Establish grievance redressal system either technology enabled or manual (telephonic complaint register/ through D2D vehicles) suited to local context
Immediate response to grievances (both ULBs and GPs)	● All stakeholders to be made aware of the grievance redressal system ● Grievance to be redressed as soon as possible (preferably within 24 hours)

Target Component	**Recommended action**
Enforce and monitor on-site waste processing by Bulk Waste Generators (BWGs) (ULBs)	• All ULBs should adopt Model Bihar MSWM By-Laws • Relevant penalties should be incorporated for non-compliance to the provision of on-site treatment of wet waste • Nagar Nigams are recommended to set up dedicated BWG cell to enforce and monitor compliance to MSWM By-Laws
Ensure collection of designated user charges (both ULBs and GPs)	• Regular collection of notified user charges
Waste audit (both ULBs and GPs)	• Capacity building of ULBs/ GPs to prepare for waste audits and to develop all required documents • Engage third party experts • ULBs/ GPs to take corrective action based on audit data
Institutional Strengthening and Monitoring Parameters- ULBs/ GPs/ State	
Strengthen institutional capacity (ULBs, GPs, Blocks, Districts, State)	• Assess institutional capacity • Ensure adequate human resource availability
Strengthen engagement of cement industries for co-processing of non-recyclables (State)	• Engagement of cement industries for co-processing of non-recyclables waste (SCF/ RDF) at the state level as recommended under CPHEEO Guidelines on Usage of RDF in various Industries, 2018 • State should implement guidelines of using SCF/RDF in cement industries, based on the financial viability, developed in consultation and mutual agreement between ULBs, MRF operators and cement plants, with proper monitoring and documentation
Facilitate research and development for use of anaerobic technology in STPs and FSTPs (State)	• Facilitate R&D on increasing performance efficiency, and assessing feasibility to leverage financial assistance under different national and/or state level schemes and programmes
Strengthen the value chain to ensure uptake of processed products and by-products (State)	• Financial viability of treatment and processing units depend on the offtake of treated products. Thus, value of the outputs generated through technology/ processes at initial stages in the state such as use of RDF in cement plant, bio-gas/ bio-CNG, recycled plastic granules or pellets, treated wastewater etc need to be strengthened.
Institutionalise and enforce policy measures such as Green Protocol to reduce waste generation(State)	• As a policy initiative, a green protocol should be developed and implemented in the state, to be followed during festivals and mass gatherings in the state such as sports competitions and college festivals, exhibitions, events in offices, hotels and institutions, as well as political, state and other community events. The green protocol will act as a guideline designed to restrict generation of waste especially that of single use plastics during events and encourage the use of reusable, biodegradable, eco-friendly materials.
Institutionalise and enforce policy measures such as Policy on Safe Reuse of Treated Water (State)	• State level policy on safe reuse of treated water should be formulated wherein timebound targets for collection and treatment of used water and safe reuse of treated water is provided aligned with the national targets. Targets should be linked directly to establishment of STPs, e.g. 50% reuse within 5 years of establishing an STP and 100% within 10 years effectively leading to 'zero discharge'. As part of the policy, state should introduce mandatory use targets appropriate to the local context as a regulatory measure or as part of incentive programmes especially for industrial purposes. For this, state should incorporate lessons from implementation experiences gained from other states. Similarly, state can also consider designation of associated 'no-freshwater' zones. The policy should also lay out the guiding principles governing the planning, design, implementation, and monitoring of SRTW programmes/projects in the state.

9. Prioritization of Recommended Low Carbon Actions for Waste Sector

Formulated strategies and actions are prioritized further to ensure phase-wise and target-oriented planning and implementation. Though all recommended actions are crucial to move ahead on the low carbon pathway, the prioritization exercise defines the preliminary focus areas to initiate the process with due recognition to the cohesiveness of actions across the value chain.

With reference to the targeted low carbon pathway, each action was ranked based on GHG emissions mitigation potential, applicability to local context pertaining to cost, technology, policy and regulatory framework and skill requirement, and temporal scale of impact as defined in Table 20. Ranks for all parameters were multiplied to calculate score of each action. Based on the quartile range of scores, actions were categorised into high, medium, and low priority groups.

TABLE 14: Methodology Adopted for Prioritizing Actions

Parameters	Sub-parameters	Explanation	Rank
GHG Emissions Mitigation Potential	–	Based on direct emission reduction and indirect emission avoidance through use of products and by-products (when an action will contribute to direct emission reduction through another action, it is considered as Estimated Elsewhere- EE)	1= No, 2= Yes
Applicability in Local Context	Indicative cost of intervention	Range for cost of intervention varies widely from that of collection and transport to setting up treatment plant. Hence, actions are ranked factoring in ballpark cost, various national manual/ guidelines/advisories that indicate cost comparison of different actions such as CPHEEO Manual, Advisory on On-Site and Off-Site Sewage Management Practices etc. and experience of ICLEI SA.	1= Low, 2= High
	Technology intensive	Depending on various national manual/guidelines/advisories such as CPHEEO Manual, Advisory on On-Site and Off-Site Sewage Management Practices etc. and experience of ICLEI SA.	1= Yes, 2=No
	Policy and regulatory framework	Based on availability of national and state level policies that can support respective actions	1= No, 2= Yes
	Skill required for O&M	Depending on various national manual/guidelines/advisories such as CPHEEO Manual, Advisory on On-Site and Off-Site Sewage Management Practices etc. and experience of ICLEI SA.	1= High, 2= Low
Is there an immediate impact or over the time?	–	Impact of the interventions are categorised into two groups. There are interventions which will start showing impact right after the operation starts and it will inevitably be continued over longer time frame. Another category of interventions are primarily the soft measures; taking long time to reflect its impact.	1= Over the time 2= Immediate to Short term and to be continued in the long term as well

TABLE 15: Prioritization Scoring for Low Carbon Actions

Sector	Domestic Wastewater and Greywater Management		Solid Waste Management	
Score	High >16		High >10	
	Medium 8-16		Medium 5-10	
	Low <8		Low <5	

Range of score was adjusted separately for domestic wastewater and solid waste management sector to integrate and rationalise functioning and O&M of each sector. Source segregation, IEC, capacity building and institutional strengthening are crucial aspects of human resource intensive solid waste management activities recurring daily round the clock. These demand side oriented actions are, therefore, more important in SWM system as compared to proposed centralised sewer system focused DWWM system that emphasise more on infrastructure provisioning or supply side of continuum. Hence, range of score was adjusted to prioritise actions with relevance to each value chain. The prioritization matrix for the low carbon actions from wastewater and solid waste sectors are consolidated in Annex 6.

Key findings from the prioritized actions of the wastewater sector are:

- Out of the infrastructure and service provisioning actions for domestic wastewater and grey water management, access to a scientific toilet is of highest priority along with focus on expansion of piped sewer network, efficient O&M of existing and proposed aerobic STPs, optimum utilisation of STPs by provision of sludge co-treatment, integrating renewable energy with STPs/FSTPs to reduce dependency on conventional energy and setting up individual or community level grey water management facilities. Construction and retrofitting toilet have the highest score with high rank for all parameters. Rest of the actions under high priority category have obtained lesser score owing to their skill or cost intensive nature. However, all of these actions need to be simultaneously planned and implemented with high priority to incorporate low carbon solutions across the entire value chain.
- In spite of having GHG emissions mitigation potential, addition of sewage treatment capacity with anaerobic technology, setting up FSTPs are categorised as medium priority along with operationalising scheduled desludging due to cost, technology and skill intensive nature or realisation of impact only over long term. Besides, as opposed to the current trend of existing and proposed aerobic STPs, setting up anaerobic STPs is a necessary yet farfetched solution and treatment of faecal sludge can be achieved through co-treatment in STPs as well instead of setting up standalone FSTPs.
- Other greywater management solutions such as cleaning and covering open drains, remediation of eutrophicated water bodies are ranked as low priority owing to no direct GHG emissions mitigation potential and higher degree of cost and technology intensiveness as compared to high priority individual or community level GWM facilities.
- Enabling actions such as IEC and capacity building, institutional strengthening measures such as grievance redressal or monitoring mechanism, introducing and enforcement of policy measures etc. are of medium to low priority primarily due to no direct GHG emissions mitigation potential or reflectance of impact over long term. However, these are crucial for streamlining implementation and harnessing

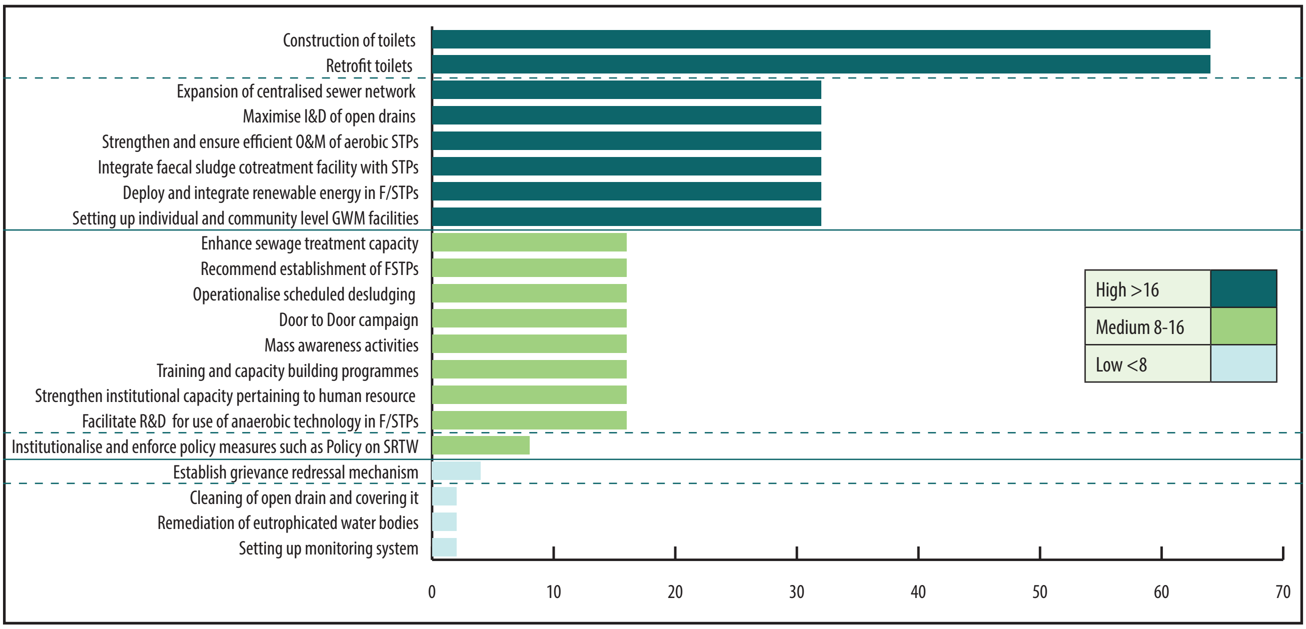

FIGURE 19: Prioritized Action for Domestic Wastewater Management System

optimum impact from core actions; thus, should be aligned with the ground level requirement and relevance.

Key findings from the prioritized actions of the solid waste sector are:

- High priority actions for solid waste management revolves around enhance and strengthening treatment and processing infrastructure thereby reducing open dumping of waste i.e. one of the key sources of GHG emissions from waste sector. However, performance efficiency of treatment facilities depends on quality of feedstock and thus it should be supplemented by extensive source segregation and robust primary and secondary collection and transport system. Hence, these should be adopted with high priority as well.
- In spite of having no direct GHG emissions mitigation potential and realisation of impact over longer time frame, enabling actions such as IEC, capacity building, monitoring Bulk Waste Generators (BWGs) and strengthening institutional capacity etc. are considered as high priority due to its high degree of influence on impactful implementation of core low carbon actions.
- Though bio-methanation has direct GHG emissions mitigation potential and several other benefits, it is a technology, cost, and skill intensive process. Moreover, negligible extent of source segregation will reduce efficiency of bio methanation plant; thereby generating large quantum of process rejects. Hence, use of bio-methanation technology along with strengthening engagement of cement industries for co-processing of recyclables and C&D waste processing plant are treated as medium priority.
- Sanitary Landfill is a technology, cost, and skill intensive solution and also least preferable in Integrated Waste Management Hierarchy. Thus, developing Sanitary Landfill with LFG capture system, along with soft measures such as waste audit, grievance redressal and monitoring system are considered as low priority action areas. However, similar to domestic waste water management system, these are crucial for streamlining implementation and harnessing optimum impact from core actions; thus, should be aligned with the ground level requirement and relevance.

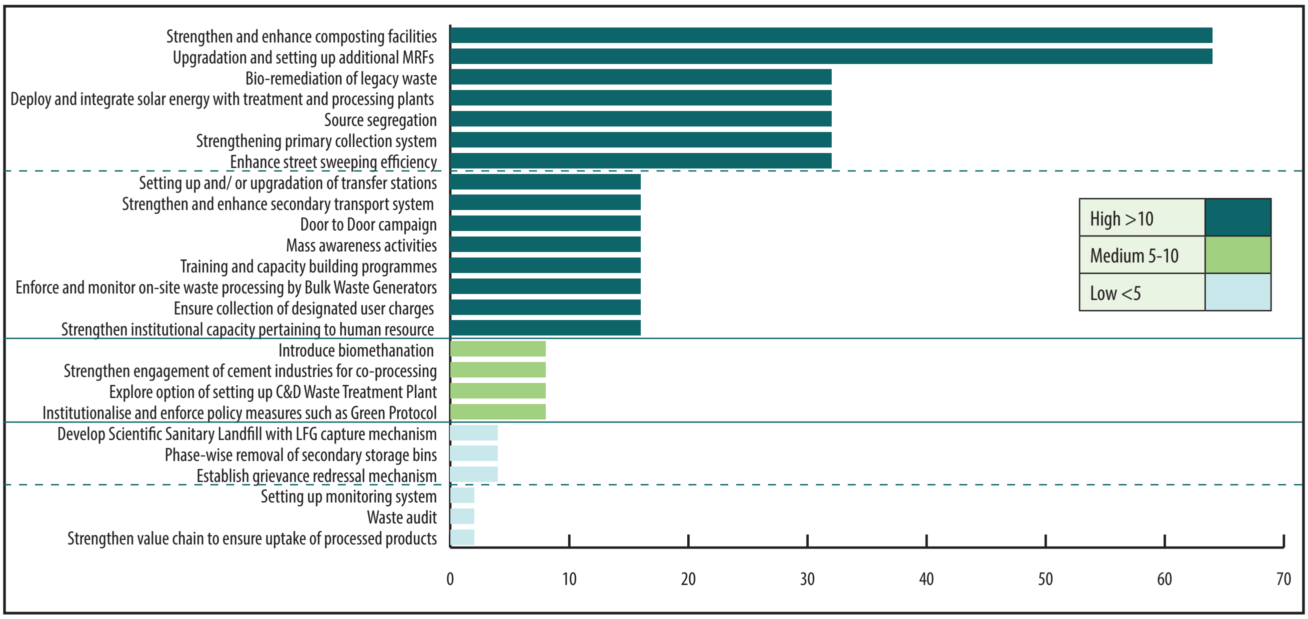

FIGURE 20: **Prioritized Action for Solid Waste Management System**

10. Mitigation Scenarios through Postulated Strategies

10.1. GHG Emissions Scenario Development – Approach and Methodology

Waste sector GHG emission forecasting is an estimation of a state's future greenhouse gas (GHG) emissions based on several assumptions about how the activities in that state that contribute to those emissions may vary over time.

Having an understanding of how its GHG emissions might develop in the future can help a Bihar state to:

- Establish a baseline scenario and define a net-zero or GHG reduction target.
- Estimate the impacts of mitigation measures on future GHG emissions.

It's important to understand that while GHG emission forecasting tries to offer a reliable assessment of future GHG trends at a given moment in time, it cannot predict the future. Overtime, sectoral information and assumptions will vary; thus, the forecasting assessment and findings should be updated to reflect this new information.

What is a Scenario - According to the Intergovernmental Panel on Climate Change (IPCC): "A plausible description of how the future may develop based on a coherent and internally consistent set of assumptions about key driving forces (e.g., rate of technological change, prices) and relationships." (IPCC Data Distribution Centre Glossary)[48]. To put simply, a scenario could be defined as the "big picture" of how we envisage the future in the long term.

While developing the above-mentioned scenarios following broad approach and assumptions were considered:

1. **Sectoral Scope:** (1) Solid waste emissions (excl rural waste disposal) and (2) Domestic waste water (urban and rural). Industrial waste water emissions not included.
2. **Scenario Period:** The forecasting scenario considers 3 time period along with the baseline year (2020). These three time periods are 2030, 2050 and 2070.
3. **Forecasting approach:** Excel based calculation tool; considers baseline and future GHG emissions estimates from the urban service demand for key sectors including solid waste disposal (urban), processing and treatment, domestic wastewater, and its sub-sectors.
4. **Population:** The population projection numbers have been sourced from (1) census projection document (till 2036) and (2) population numbers used in CEEWs GCAM model for long term emissions forecasting exercise for Bihar.

10.2. GHG Emissions Scenario and Results

1. Business As Usual (BAU 2070) – The BAU scenario, presented in Figure 31, represents a forecasting of emissions growth, which considers existing and pipeline of policies and projects related to waste sector in Bihar, without significant change in waste sector related policies, technology, and economics.

The BAU considers baseline and planned waste sector related policies, projects and interventions by GoB to develop short-, medium- and long-term waste sector infrastructure scenario (waste, generation, collection, treatment & disposal).

Steps to develop the BAU scenario

1. Conduct a review of existing and planned waste sector actions (i.e., plans, policies, projects and programmes) that are relevant to GHG mitigation using document review and departmental meetings;
2. Identify existing and planned sector actions from the national and state government that will impact waste sector activities and emissions;

29. https://www.ipcc-data.org/guidelines/pages/glossary/glossary_s.html

3. Develop implementation assumptions for the BAU (existing and planned) scenario that have been or will be implemented after the base year (detailed assumption and service demand provided in Annex 7);
4. Develop the BAU scenario by entering the implementation assumptions (activities and scale) into emissions scenario model;
5. Verification of implementation assumptions through stakeholder consultations;
6. Update the model scenario to reflect changes to implementation assumptions.

The BAU scenario indicates that if no climate action is taken, Bihar's waste sector emissions by 2070 will be more than double than the baseline year levels (2020). Total GHG emissions could increase from 70,66,407 (or 7.06 million) tCO_2e in 2020 to 1,56,91,501 tCO_2e or (15.69 million) tCO_2e in 2070. It is expected that DWW sector would still continue (as in the baseline year) to be the dominant source of GHG emissions from the waste sector contributing to 88% of the total forecasted GHG emissions. While MSW would contribute to the remaining 12% of the total emissions.

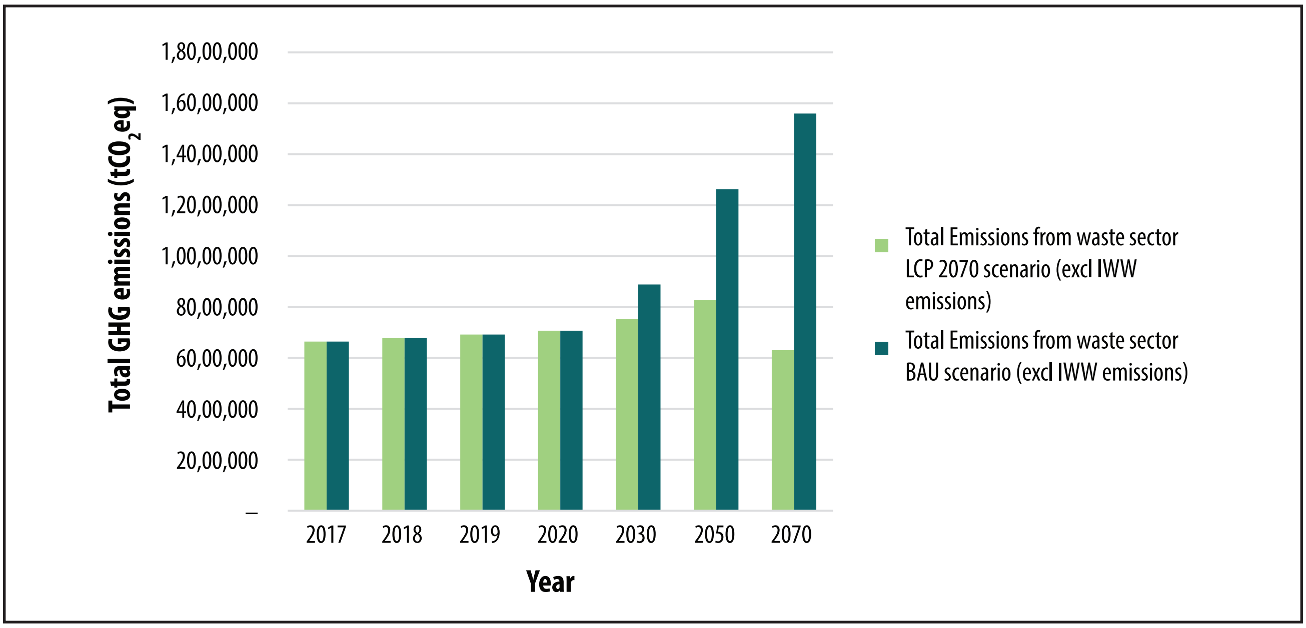

FIGURE 21: **Bihar's emissions by scenarios - BAU and LCP2070**

Low Carbon Pathway 2070 (LCP 2070 scenario) – Expands upon LCAP 2030 actions. Scenario considers waste sector strategies and interventions that have to be undertaken to significantly bring down the waste sector-related emissions by Bihar in line with 2070 target. The scenario includes strategies and actions that are ambitious yet necessary to reduce emission from waste in line with Bihar's 2070 target. The scenario expands on the implementation of existing and planned actions and also identifies new strategies and actions that reduce additional sources of GHG emissions.

Steps to develop the LCP 2070 scenario

1. Identify the major emission sources and activities and consider key strategies and actions that could address these sources/activity types;
2. Identify actions that could feasibly be used to implement strategies;
3. Develop implementation assumptions for the ambitious LCP strategies (detailed assumption and service demand provided in Annex 7);
4. Develop the LCP scenario by entering the implementation assumptions into emissions scenario model;
5. Organize consultation to meet with relevant Government of Bihar (GoB) departments/agencies, other parastatal agencies and experts to review/verify the feasibility and scale of the strategies;
6. Update the model scenario to reflect changes to implementation assumptions.

In the LCP2070 scenario, Bihar's total emissions by 2070 is expected to be 6.3 million tCO_2e in 2070. Increased actions prescribed under LCP2070 scenario will reduce future emissions below BAU forecast levels:

- 2030: 15.3% decrease from BAU
- 2050: 34.4% decrease from BAU
- 2070: 59.6% decrease from BAU

Table 23 presents these figures in more detail. Some of the key interventions with high mitigation potential include MSW recycling, DWW and Fecal Sludge treatment using anaerobic treatment with methane recovery option.

TABLE 16: Bihar's waste sector GHG emissions by scenario (tCO_2e)

GHG emissions (tCO_2 eq)[49]	2020 (Baseline)	BAU Scenario			Low Carbon Pathway		
		2030	2050	2070	2030	2050	2070
Solid Waste Disposal & Treatment	**376021.99**	**545697.95**	**1090843.80**	**1941143.54**	**5,41,261.26**	**2,27,019.09**	**-3,71,759.52**
Composting (Urban)	36174.31	75295.42	200557.52	394079.21	1,04,577	80,223	26,272
Composting (Rural)		197258.60	549421.67	998453.39	5,12,872	4,39,537	3,32,818
Biomethanation (Urban)		-364.79	-27983.51	-45821.11	-1,824	-5,597	-10,997
Biomethanation (Rural)		-13761.61	-71868.79	-145117.52	-3,440	-14,374	-29,024
Waste to Energy		-90964.84	-116301.47	-122423.00	–	–	–
Recycling (Urban)		-7719.52	-27758.41	-60603.36	-62,721	-1,15,660	-1,81,810
Recycling (Rural)		-5148.61	-28680.69	-52120.87	-1,64,755	-2,29,446	-2,77,978
RDF (Urban + Rural)		681.14	1591.41	2382.88	-1,66,663	-2,76,016	-5,89,228
Waste Disposal (FOD) - Urban	339847.68	390422.15	611866.08	972313.91	3,23,216	3,48,351	3,58,187
Domestic Waste Water	**6692988.30**	**8323296.84**	**11533085.82**	**13655815.22**	**69,84,224**	**80,55,512**	**66,73,796**
Treatment & Discharge (Urban)	961225.26	931454.34	1791739.14	3809291.15	5,58,891	9,06,525	-1,278
Treatment & Discharge (Rural)	3839723.83	5208933.47	7173708.03	7191649.62	46,05,775	52,43,103	49,15,105
RE integration in WW treatment		0.00	0.00	0.00	-13,245	-35,972	-17,765
N_2O emissions (Urban)	221394.26	294058.47	442845.08	569316.00	2,64,653	3,98,561	5,12,384
N_2O emissions (Rural)	1670644.95	1881037.53	2066584.33	1967981.02	16,92,934	18,59,926	17,71,183
Methane Recovery from FSTP plants	0.00	7813.03	58209.24	117577.42	-1,24,784	-3,16,631	-5,05,834
Total Emissions from waste sector	7069010.29	8868994.78	12623929.62	15596958.76	75,25,485	82,82,531	63,02,037
Waste Disposal (FOD) - Urban	339847.68	390422.15	611866.08	972313.91	3,23,216	3,48,351	3,58,187
Total Emissions from waste sector (mil tCO_2eq)	7.07	8.87	12.62	15.60	7.53	8.28	6.30

30. Industrial wastewater emissions are excluded due to lack of robust data for sector;s long term forecasting

11. Way Forward

This action plan outlines the key actions the state needs to implement for waste sector in short term to move towards the low carbon and climate resilient future over longer time frame. The actions are envisaged to help the state enable its local governments to achieve the targeted waste segregation, and collection and treatment efficiency of waste and wastewater as outlined in central government programmes and improve governance of overall service delivery mechanism.

While the Action Plan outlines several infrastructural measures that need to be undertaken to reduce emissions and improve overall service delivery, there are crucial regulatory or policy measures that can support the reduction of emissions and improvement in services.

All stakeholders need to work together on the following aspects to successfully implement the Low Carbon Action Plan.

- Formulate new policy and/or incorporate relevant changes in the existing policy framework enabling implementation of the recommended actions such as local policies for waste segregation and segregated collection with fines for non-compliance.
- Inculcate behavioural change among residents through IEC regarding waste management for both solid and liquid wastes and capacity building of stakeholders for optimum use of new infrastructure and their operation and maintenance.
- Develop time bound implementation plan in line with local bodies and state budget. Where state funds are insufficient, state should identify external funding for the implementation of actions.
- Develop impact timeline based on implementation phase of all mitigation interventions and effective monitoring and evaluation methodologies that measure expenditure and climate linked and service linked outcomes of such expenditure.

Over time, the local bodies, block, district, and state authorities need to move beyond implementation and also continue to monitor the progress of this plan, evaluate the impact of the suggested actions and build its knowledge in order to develop new actions or policies as and when needed. BSPCB, BUD&HD and RDD should spearhead a coordinating action and partnership between multiple stakeholders involved across the administrative hierarchy and private sphere.

The state must recognise the need of fast paced change in service delivery due to population increase and shifts in urban-rural divide. Although the targeted scale of service delivery is defined till 2070 as part of the low carbon pathway in the Action Plan, new technologies and innovations that adapt to the changing landscape and cater to the need of waste sector can significantly alter the carbon trajectory. In order to meet the changing infrastructure and service demand in the waste sector, market innovators, start-ups, research and development institutes, public bodies and industry need to be actively engaged to seek out new ideas and opportunities. This means that the Action Plan should not be treated as a static document, but should be reviewed and revised at regular intervals. In subsequent decades, state needs to update the strategies and actions to align with the altered demographic dynamics and evolved knowledge, business models and technologies.

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Annex 1:

Baseline Assessment of Waste Sector

Bihar, India

Local Governments for Sustainability
SOUTH ASIA

Contents

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Abbreviation

AMRUT	Atal Mission for Rejuvenation and Urban Transformation
BOD	Biological Oxygen Demand
BPIU	Block Project Implementation Unit
BSPCB	Bihar State Pollution Control Board
BSWSM	Bihar State Water & Sanitation Mission
BUIDCO	Bihar Urban Infrastructure Development Corporation Ltd
BVM	Bihar Vikas Mission
COD	Chemical Oxygen Demand
CSE	Centre for Science and Environment
CSWAP	City Solid Waste Action Plan
DWSC	District Water Sanitation Committee
FC	Finance Commission
FSSM	Faecal Sludge & Septage Management
FSTP	Faecal Sludge Treatment Plant
GOBARDHAN	Galvanizing Organic Bio-Agro Resources Dhan
GP	Gram Panchayat
GHG	Green House Emission
GHGPI	Green House Gas Platform India
IHHL	Individual House hold Latrine
LSBA	Lohiya Swachh Bihar Abhiyan
MGNREGS	Mahatma Gandhi National Rural Employment Guarantee
MLD	Million Litre per Day
MODWS	Ministry of Drinking Water & Sanitation
MOEFCC	Ministry of Environment Forest and Climate Change
MOHUA	Ministry of Home and Urban Affairs
MOUD	Ministry Of Urban Development
MPR	Monthly Progress Report

MSL	Mean Sea Level
NGT	National green Tribunal
NDC	Nationally Determined Contribution
ODF	Open Defecation Free
OSS	Onsite Sanitation System
RDD	Rural Development Department
SLB	Service Level Benchmark
SRTW	Safe Reuse of Treated Water
STP	Sewage Treatment Plant
SAAP	State Annual Action Plan
SDG	Sustainable Development Goal
SBM	Swachh Bharat Mission
SBM	Swachh Bharat Mission
SPV	Special Purpose Vehicle
TSS	Total Dissolved Solids
UD&HD	Urban Development and Housing Department
ULB	Urban Local Body
WII	Wildlife Institute of India
WSP	Waste Stabilisation Pond

1. Background

The Greenhouse Gas (GHG) emissions from the waste sector contributed ~4% percent to the total GHG emissions of India in 2015; out of that ~63% is contributed by domestic wastewater and 12% is contributed by solid waste disposal activities (GHGPI, 2022). Methane (CH4) is the key contributor which is emitted from decomposition of degradable organic components of the waste and wastewater. With increasing urbanization and exponential population growth, the quantum of waste and wastewater generation will also increase, leading to increase in the emission. Therefore, it is critical to strengthen capacities and governance processes to mainstream low-carbon options while planning, designing, implementing, and financing waste management services. This would facilitate achieving climate compatible urban development that are not only synced with the targets of national programmes such as Swachh Bharat Mission (SBM) but also with global commitments such as Nationally Determined Contributions (NDCs) and Sustainable Development Goals (SDGs).

As per the United Nations Environment Programme and Climate and Clean Air Coalition (United Nations Environment Programme, 2021), the largest potential for methane mitigation in India is in the waste sector. A close assessment of the existing situation of sanitation and municipal solid waste management can help to identify gaps and suggest measures for efficient system including collection, transportation, treatment, processing and disposal of solid waste and domestic wastewater that will lead to overall reduction in GHG, especially methane emissions.

With the above objective in mind, ICLEI South Asia seeks to support the state government of Bihar in strengthening their municipal solid waste and domestic wastewater management profile through baseline assessment, gap analysis, emission inventory and formulation of short-term action plan to be implemented within 3-5 years. This is aimed at improving the overall public health, hygiene, and environment; and subsequently supporting policy-makers in developing low-carbon sectoral strategies. In this report, the baseline assessment and gap analysis of municipal solid waste and domestic wastewater is presented.

2. Methodology

The following methodology was adopted for baseline assessment and gap analysis.

A. Identify key stakeholders

The key stakeholders involved in managing domestic wastewater and municipal solid waste in the state across the vertical and horizontal levels of governance including administrative agencies, parastatal bodies, pollution control board, academia, private sector and political representatives such as Urban and Rural Local Bodies, District Water and Sanitation Committees (DWSC), Block Project Implementation Units (BPIU), Bihar Urban Development and Housing Department (BUD&HD), Bihar State Pollution Control Board (BSPCB) etc. were identified and engaged through one-to-one discussion and several rounds of meetings. All identified stakeholders are listed below in Section 5.

B. Developing database

Developing Data Templates – Data templates were developed to capture the state wide ULB and district specific required information to assess the existing situation. The templates were developed in discussion with the state government and aligned with the Service Level Benchmarking (SLB) and Swachh Survekshan indicators.

Desktop Research- Desktop based research were undertaken across relevant websites such as Atal Mission for Rejuvenation and Urban Transformation (AMRUT), Swachh Bharat Mission (SBM), and Namami Gange Portal, Bihar Urban Development and Housing Department (UD&HD), Bihar Vikas Mission (BVM), Bihar Urban Infrastructure Development Corporation (BUIDCO) and Bihar State Pollution Control Board (BSPCB) websites and other published studies/reports from the Ministry of Housing and Urban Affairs (MoHUA) and Ministry of Environment Forest and Climate Change (MoEFCC) were also explored for capturing overview of the existing waste sector in the state.

Table 1: List of Reference Secondary Database

S. No.	Departments/Agencies	Reports/ Types of Data
State Level		
1.	Urban Development and Housing Department (UD&HD), Govt. of Bihar	Summary on urbanisation in Bihar and service provisioning in urban areas
2.	Bihar Urban Infrastructure Development Corporation Limited (BUIDCO)	List of proposed projects on STPs
3.	Bihar Vikas Mission (BVM)	● Summary of Lohiya Swacch Bihar Abhiyaan and Shauchalay Nirmaan (shahri kshetra) Yojana ● Facilities provided under these two schemes (2018-2019) ● Status of ODF declaration
4.	SBM Gramin ODF+ Portal	● Districts wise village level coverage of ODF+ indicators and assets ● A Roadmap to ODF Panchayats in Bihar
5.	Nagar Seva Bihar	● City Development Plan (CDPs-27 ULBs) ● City Sanitation Plan (CSPs- 30 ULBs)
6.	District Administration	● District Environment Plan for Kaimur ● District Environment Plan for Aurangabad
National Level and others		
S. No.	**Departments/Agencies**	**Reports/ Types of Data**
1.	Central Pollution Control Board	● Annual Report on Status of Implementation of MSW Rules- Status of solid waste management in urban areas including generation, extent of source segregation, coverage of door-to-door collection and collection efficiency, treatment/ processing facilities (as of 2019-2020). ● National Inventory of Sewage Treatment Plants- Domestic wastewater: sewage generation; no. of STPs installed and operational capacity, treatment technology (2021)

S. No.	Departments/Agencies	Reports/ Types of Data
2.	National Mission for Clean Ganga (NMCG)	State level Monthly progress Reports (MPR)- State level urban areas' information on sewage and solid waste generation, coverage of solid waste management and sewage treatment infrastructure (Feb, 2022)
3.	National Sample Survey Office (NSSO)	● 68th round of National Sample Survey (NSSO)- State-wise distribution of protein intake (2011-2012) ● 76th round of National Sample Survey (NSSO)- 2018-toilet typology
4.	National Family Health Survey (NFHS)	National Family Health Survey - 5 - Access to sanitation facilities (urban and rural) (2019-2020)
5.	National Annual Rural Sanitation Survey (NARSS)	National Annual Rural Sanitation Survey Round 3- Rural population practicing solid and liquid waste management; using safe, functional & hygienic toilets and living in ODF verified villages (2019-2020)
6.	Sustainable Sanitation Alliance (SUSANA)	Shit Flow Diagram (SFDs- 6 ULBs, Rajgir; Jamalpur, Buxar, Bodhgaya; Patna, Katihar)- ULB specific information across the value chain of faecal sludge management (toilet system, transport, processing, and disposal)

Primary Data Collection – In addition, data were collected from the abovementioned departments and collated to establish the existing Municipal Solid Waste Management (MSWM) and Domestic Waste Water Management (DWWM) value chain in the state encompassing waste and wastewater generation, waste segregation practice, collection and transport, treatment processing and disposal practice.

Ground Truthing in Selected Gram Panchayats

- To assess the progress of the prestigious Lohiya Swachh Bihar Abhiyan (LSBA) and co-relate the on-ground situation corresponding to the data reported, a ground truthing exercise was undertaken in **10 Gram Panchayats (GPs) spanning over 4 districts in the state.**
- These were selected out of 36 GPs listed under LSBA Phase 1 implementation and in consultation with BSPCB and LSBA state level implementation agency.
- Team of ICLEI-SA visited the GPs along with respective District Consultants and carried out observational assessment and interacted with communities to identify pertinent sectoral challenges.

District	Block	Gram Panchayat
Muzaffarpur	Gaighat	Dahila Patsharma
	Sakra	Bishunpur
	Kanti	Raj Saine
Begusarai	Chhourahi	Ajani
	Chhourahi	Ekamba
	Chhourahi	Narayan Piper
Nalanda	Giriyak	Raitar
	Chandi	Sartha
Samastipur	Patori	Hetanpur
	Mohanpur	Dharnipatti East

Figure 1: Map Indicating Districts of GPs Selected for Ground Truthing[1]

C. Analysis, Assessment and Report Preparation

The collected data set was analysed and key challenges were identified pertaining to infrastructural, regulatory, and institutional and monitoring aspects in MSWM and DWWM sector. Priorities were identified with respect to the State vision and various policies and strategies and the analysis was thus documented in a report.

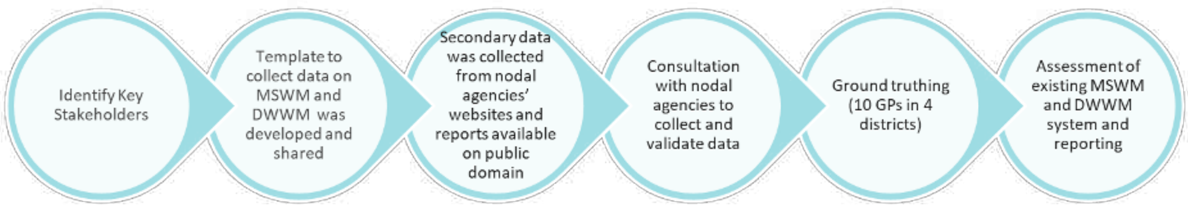


Figure 2: Methodology Adopted for Baseline Assessment

3. State Profile

Bihar is located in the eastern part of the country (between 83°-30' to 88°-00' longitude). This land-locked state lies mid-way between the humid West Bengal in the east and the sub- humid Uttar

[1] Source: http://www.onefivenine.com/india/villag/state/Bihar

Pradesh in the west which provides it with a transitional position in respect of climate, economy, and culture. River Ganga flowing through the middle from west to east, divides Bihar state into two unequal halves: North Bihar and South Bihar. Lying at 173 feet above Mean Sea Level (MSL), Bihar extends for an area of 94,163.00 sq. kms; out of which only 1.16% area comes under urban category and the rest belongs to rural area (State Profile, 2022). Bihar state is divided into 9 divisions comprising of 38 districts; these are further divided into sub-divisions (101), Community Development (CD) Blocks (534) and Panchayats (8,406).

As per the Census 2011, Bihar was the third most populous state of India with a total population of 104.10 million and the most densely populated state. Nearly 89% of Bihar's population lived in rural areas. As per Census of India 2011 though the state accounts for 8.6% of India's total population, it has only 3.1% of country's total urban population; thus, Bihar had the second lowest rate of urbanisation at 11.3% as compared to national average of 31.2%. Population growth in the decade (2001-2011) was 25.42%; reduced from the previous decade's growth rate of 28.43%. As per the Report of the Technical Group on Population Projections, in 2021, Bihar has population of 123.08 million; 12.12% consists of urban population (The technical Group on Population Projections, 2019).

At present there are total 142 Urban Local Bodies (ULBs) in Bihar consisting of 12 Nagar Nigams, 49 Nagar Parishads and 81 Nagar Panchayats. 44% of the urban population of Bihar resides in the Nagar Nigams[2], 32% resides in Nagar Parishads[3] and 24% resides in Nagar Panchayats[4]. (Government of Bihar, 2022)

The dominance of rural population is also reflected in the economy of Bihar state. With ~80% of people employed in agriculture, it is one of the strongest economic sectors in the state. Bihar is the fourth largest producer of vegetables and the eighth largest producers of fruits in India (IBEF Bihar, 2022). Food processing, dairy, sugar, manufacturing, and healthcare are some of the fast-growing industries of the state.

Despite a consistent economic growth, infrastructure and service provisioning especially in terms of municipal solid waste management and domestic waste water management in the state has not been able to perform in consonance with the growing demand. Out of 28 states, Bihar has ranked 19 in Swachh Survekshan, 2021 whereas the capital city Patna ranked 44th out of 48 cities in the more than 10 lakhs population category. As indicated in the Monthly Progress Report (MPR, June 2022) of Bihar for National Green Tribunal (NGT), only 4.5 % (71 MLD) of sewage generated from urban areas is treated; rest of the 95.5% (1480 MLD) of sewage reaches waterways untreated. Merely 11.5% of solid waste generated from urban areas is treated and rest of it is disposed in open dumpsite as indicated by BSPCB. Though all Gram Panchayats (GP) are declared Open Defecation Free (ODF), ground truthing[5] in a few selected GPs indicates otherwise. There is a certain level of progress in terms of municipal solid waste management; however liquid waste; especially domestic waste water management at GPs are at a nascent stage. Detail baseline situation of MSWM and DWWM in the state of Bihar is discussed in the chapters below.

[2] towns with more than 2 lakh population
[3] towns with population between 40,000 and 2,00,000
[4] towns with population between 12,000 and 40,000
[5] Conducted by ICLEI-SA in June-July, 2022

4. Institutional Set-up

In Bihar, solid waste and domestic waste water management infrastructure are facilitated primarily through various National level schemes and programmes under Ministry of Housing and Urban Affairs and Ministry of Jal Shakti; which are supported by several policy and legislative framework. At the State level, Chief Minister's 'Saat Nishchay' for a developed Bihar under the programme of Good Governance was initiated in mission mode through Bihar Vikas Mission for the period from 2015 to 2020; further extended as Saat Nishchay 2 till 2025.

- SBM/ SBM 2.0 Urban, AMRUT/AMRUT 2.0 and Namami Gange are the key National level prorammes supporting waste sector in urban areas. BUD&HD is implementing SBM/ SBM 2.0 Urban and Smart Cities Mission directly whereas Bihar Urban Infrastructure Development Corporation (BUIDCO) is the nodal agency for implementation of AMRUT and Namami Gange.
- Rural area SWM and DWWM activities are supported by SBM/ SBM 2.0 Gramin and partially through Ganga Gram initiative of Namami Gange. Rural Development Department is implementing these schemes through Bihar Rural Livelihood Promotion Society.

Administrative hierarchy wise institutional set up for implementation of relevant schemes and programmes in both urban and rural areas are indicated in Figure 3.

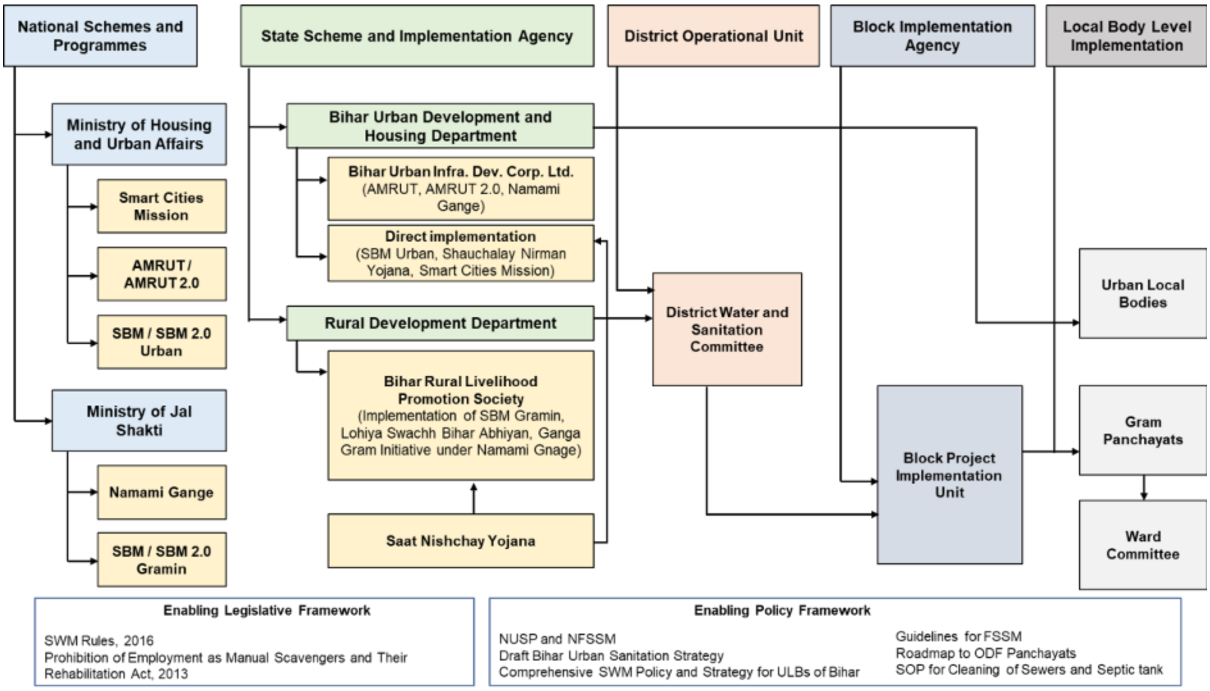


Figure 3: Institutional Set up for Management of Waste Sector in Bihar

5. Stakeholder Mapping

MSWM and DWWM in Bihar includes various stakeholders, interacting and coordinating based on overlapping objectives and goals. The interactions and relationships between the stakeholders influence overall management and implementation of MSWM and DWWM projects and programmes. The stakeholders are divided into four different categories based on their roles and functions.

1. Core (Primary and Targeted Stakeholders)

- Directly impacted by mismanaged solid waste and wastewater and will get benefitted from intervention strategies

- Their practices are contributing to mismanaged solid waste and wastewater and their behaviour change is directly targeted
- **Accountable and responsible** to manage MSW and DWW in a sustainable and efficient manner

1. **Enabling Stakeholders**

- Create enabling conditions for behaviour change and bring in benefits and sustaining the improvements over time
- To be **consulted** and to extend **support** for improving MSWM and DWWM

2. **Supporting Stakeholders**

- Development partners or funding agencies whose strategies are aligned with the target to manage MSW and DWW in a sustainable manner
- to be **informed** and to **respond** to the requirement of the city

Stakeholders are identified and categorised in the following manner:

Table 2: Types of Stakeholders Involved in MSWM and DWWM in Bihar

Types	**Core (Primary and Targeted) Stakeholders**	**Enabling Stakeholders**	**Supporting Stakeholders**
List of Stakeholders	• Waste and wastewater generators • DWSC- District Consultants • BPIU- Block Coordinators • 8406 GPs- Sanitation Supervisors, Mukhiyas • Ward Committee-Swachhata Mitra • 142 ULBs • Private agencies involved in collection and transport of MSW and desludging of toilet • Private entities involved in O&M of MRFs, recycling and processing facilities, landfill and STPs • Informal sector • Waste recyclers and processors	• BSPCB • BUD&HD • BUIDCO • BVM • BSWSM • RDD • DWSC- District Magistrate • BPIU- Block Development Officer • NGOs involved in IEC such as Aga Khan Foundation and Wildlife Institute of India (WII), • NGOs involved in WASH activities (One Drop)	• Shakti Foundation • World Bank • UNEP • Research Institutes such as Centre for Science and Environment (CSE)

6. Policy Framework

6.1. National Level

6.1.1. National Urban Sanitation Policy (NUSP)

Erstwhile the Ministry of Urban Development (MoUD) published the "National Urban Sanitation Policy" in 2008 with the goal to transform urban India into community-driven, totally sanitized, healthy and liveable cities and towns. NUSP initiated the pathway to providing safe sanitation services;

thereby enabling opportunity to mitigate GHG emission from waste sector in the long run. As recommended under NUSP, Bihar Urban Sanitation Strategy had been drafted in 2010.

6.1.2. National Faecal Sludge and Septage Management (FSSM) Policy

National Faecal Sludge and Septage Management (FSSM) Policy, published in 2017, has created an enabling environment for regulation of on-site sanitation systems, leading to the opportunity for mitigation of GHG emissions from inappropriately treated or untreated or uncollected faecal sludge and septage from on-site systems. Guided by the policy, Guidelines for Faecal Sludge and Septage Management in Bihar has been drafted under the aegis of Bihar UD&HD in 2018.

6.1.3. National Framework on the Safe Reuse of Treated Water (NFSRTW)

Ministry of Jal Shakti published the NFSRTW in 2021 with the vision of widespread and safe reuse of treated used water in India. Till date, no state specific policy has been conceptualised in Bihar considering the Safe Reuse of Treated Waste (SRTW) approach.

6.2. State Level

6.2.1. Draft Bihar Urban Sanitation Strategy

Aligned with the NUSP recommendation, state level sanitation strategy was laid out in 2010. This is one of the very first strategic frameworks focusing on moving towards Open Defecation Free (ODF) urban areas in the state. To fulfil the objectives of encouraging cities to prevent open defecation, provide potable water in adequate quantity and safely manage waste water as elucidated in the strategy, holistic approach has been planned to be implemented across waste sector as per the ~30 City Sanitation Plans (CSPs) that had been developed in the subsequent years.

6.2.2. Roadmap to ODF Panchayats

Bihar State and Water Sanitation Mission (BSWSM) prepared a step-by-step guide to support the rural communities in eliminating the practice of open defecation. The roadmap elaborates the role of district and block level functionaries and emphasise on the community engagement across planning, implementation and sustainability phase while moving towards achieving and sustaining ODF status.

6.2.3. Guidelines for Faecal Sludge and Septage Management in Bihar

As recommended in NFSSM Policy, 2017, Bihar UD&HD has framed FSSM guidelines for the state drawing from provisions and specifications as elucidated in relevant standards, manual and policies such as National Building Code 2005, Indian standard code of practice for installation of septic tanks (IS: 2470) - Bureau of Indian Standards (1986), National Urban Sanitation Policy 2008, CPHEEO Manual on Sewage and Sewerage Treatment 2013, Advisory note on Septage Management (issued by Ministry in 2013), National FSSM Policy 2017 etc. The guidelines indicate planning process for FSSM, technology options across the value chain and options to tap funding for implementing FSSM system. It has also indicated FSSM approaches that can be adopted by various tiers of cities and timelines that can be followed for the planning and implementation. However, considering this guideline, no specific FSSM actions are implemented in urban Bihar till date.

7. Schemes and Programmes

7.1. National Level

7.1.1. Atal Mission for Rejuvenation and Urban Transformation (AMRUT) and AMRUT 2.0

27 cities in Bihar were covered under AMRUT with commitment of 1,165 Crores INR as central assistance out of total approved 2,470 Crores INR. However, sewerage and septage management was not considered a priority sector in Bihar as per State Annual Action Plan (SAAP) 2016-2017 and only, 37.74 Crores INR was allocated and channelized for septage management in Katihar (Urban Development & Housing Department, GoB, 2017).

AMRUT program targets the development and improvement of sanitation value chain from collection to treatment of waste water, thereby potentially addressing the GHG emissions from unmanaged or inefficiently managed waste water. AMRUT 2.0 further enhances this effort by focusing on recycle/ reuse of treated used water.

7.1.2. Namami Gange

12 districts from Bihar located on the banks of River Ganga are covered under the Namami Gange scheme consisting of 20 ULBs and 13 GPs on the river bank are promulgated as Ganga Gram[6].

Till date, 30 sewerage infrastructure projects have been sanctioned, which are in various stages of implementation in different towns. These projects aim to treat 651.54 MLD sewage from urban Bihar through setting up STPs, laying sewer network and allied interception and diversion work. At present 4 projects are functional with 109 MLD installed capacity, 21 are under construction and 6 are in the tendering stage. (Department of Finance, GoB, 2021-2022). By facilitating safe treatment of human excreta, this scheme has immense potential to bring additional benefits in terms of health and environment along with contributing to GHG emission mitigation from the domestic wastewater management sector.

7.1.3. *Swachh Bharat Mission* (SBM and SBM 2.0.)- Urban

Various initiatives undertaken as part of SBM-U has led to achieving 100% source segregation and door-to-door collection in 99.6% of urban wards in Bihar as reported under SBM. 67 Material Recovery Facilities (MRFs) and 177 compost plant are also constructed since the inception of SBM-U.[7] The state has also achieved ~94% and ~88% targeted construction of Individual Household Latrines (IHHL) and community toilet seats under the scheme (BUD&HD and BSPCB 2022).

7.1.4. *Swachh Bharat Mission* (SBM Gramin and SBM Gramin 2.0)

Considering the impact of the activities undertaken through SBM Gramin, at the time of reporting[8], 23 villages of Bihar are categorised to be ODF Plus Model[9], whereas 54 villages entitled with the ODF Plus Rising[10] category and 890 villages are ODF Plus Aspiring[11] category.

[6] Ganga Gram

[7] https://sbmurban.org/state-detail?id=BR&i=10

[8] September, 2022

[9] Village sustaining ODF status and having arrangements for SWM and LWM, displaying visual cleanliness at public places and IEC messages on ODF Plus

[10] Villages sustaining ODF status and having arrangements of SWM and LWM

[11] Villages sustaining ODF status and having arrangements of SWM or LWM

Since its inception, SBM is playing a crucial role in optimising treatment of solid waste and focusing on safe and scientific containment of faecal matter, which is an immediate step towards GHG emission mitigation.

7.1.5. Smart Cities Mission (SCM)

4 cities are selected in Bihar (Bhagalpur, Bihar Sharif, Muzaffarpur and Patna) to be developed as Smart Cities and Special Purpose Vehicles (SPVs) are set up in this regard. Except Bhagalpur, 3 other ULBs are undertaking several initiatives in waste sector. Integrated Command Control Centre that will cater to digitalisation of solid waste management system is going to be set up in Patna, Biharsharif and Muzaffarpur. House Service Connections (HSCs), sewerage network, flow meter is going to be installed and Sequential Batch Reactor (SBR) technology based STP is also planned to be set up in Muzaffarpur under SCM and sewerage network is to be laid in the area demarcated for Area Based Development (ABD) in Biharsharif. Thus, SCM will support the state in moving along low carbon pathway by mitigating potential indirect GHG emission through enhanced primary collection system, rationalised routing of collection vehicles and strengthening sanitation pathway.

7.1.6. Galvanizing Organic Bio-Agro Resources Dhan (GOBARDHAN)

Galvanizing Organic Bio-Agro Resources Dhan (GOBARDHAN) scheme, launched in 2018, is still at a nascent stage in Bihar. As of now, division specific agencies are identified for implementation of GOBARDHAN projects in Bihar state. GOBARDHAN scheme is expected to take the state further along low carbon pathway by methane capture and minimising indirect GHG emission from transporting collected waste for centralised treatment.

7.2. State Level

7.2.1. Saat Nishchay- Shauchalay Nirmaan Ghar Ka Sammaan/ Saat Nishchay 2

As part of the Saat Nischay Yojana, Bihar State Government had launched “Shauchalay Nirmaan Ghar Ka Sammaan” in 2016 aligned with the target of SBM. This is being executed in both urban and rural Bihar to ensure 100% toilet coverage for making Bihar ODF, healthy and clean, without any discrimination to any household of the state. To fulfil this Nishchay, two schemes had been started by the state government: Lohiya Swacch Bihar Abhiyaan for rural areas and Shauchalay Nirmaan Yojana for urban areas; discussed below in detail.

Further to Saat Nishchay, Saat Nischay Phase 2 was launched ahead of Bihar Assembly Election in 2020 with the state vision of ‘Swacch Gaon Samriddh Gaon’ and ‘Swachh Shahar Vikshit Shahar’ in terms of solid and liquid waste management along with maintenance and monitoring of the infrastructure created under Phase 1.

7.2.2. Shauchalay Nirmaan Yojana

Executed by the Urban Development and Housing Department and aligned with the objective of SBM Urban, mandate of this scheme was to facilitate construction Individual Household Latrines (IHHL) and Community Sanitation Centre seats for landless urban families and to stop Open Defecation in all 3377 urban wards of 142 ULBs. Till now, 3.65 Lakh IHHL are constructed in urban Bihar[12].

7.2.3. Lohiya Swachh Bihar Abhiyan

Under Lohiya Swachh Bihar Abhiyan (LSBA), a combination of SBM-G and Lohiya Swachh Yojana (LSY), 1.22 Crore IHHL and 8434 CSCs are constructed in rural areas till date; additionally, 1.3 lakh

[12] As per data provided by UD&HD

dysfunctional toilets are also made functional and all insanitary toilets are converted into sanitary toilets (Department of Finance, GoB, 2021-2022). However regular usage and functionality of the toilets are debatable as observed during ground truthing. Moreover, some newly built households do not have access to IHHL. As part of 'Swachh Gaon Humara Gaurav Campaign", one week per month is dedicated towards sustaining ODF status.

7.2.4. Mukhyamantri Gramin Gali-Naali Nishchay Yojana

In order to strengthen the rural infrastructure, this scheme was inaugurated in October 2016 aligned with the Nishchay "Ghar Tak Pakki Gali Naliyan". After implementation of the Pradhanmantri Gram Sadak Yojana, left out habitations having no link, were linked with all-weather connectivity roads and drainage and by-lanes were provided in all GPs under this scheme.

Along with support from various National level schemes, aforementioned state level activities are expected to complement the state's overall effort of low carbon development. In the context of MSWM, though there have been continuous improvements in coverage of door-to-door collection and collection efficiency, treatment and disposal of MSW still remains a big challenge for the state. Subsequently a massive amount of waste is disposed openly in insanitary landfill that are the major source of methane emission. Parallelly in the domestic waste water management sector, by achieving close to 100% coverage of IHHL, Bihar has come a long way of containing the wastewater at source that has potential of mitigating GHG especially methane emission. However, unscientific construction, lack of widespread usage, lack of appropriate wastewater collection system, inappropriate selection of treatment technology and unregulated FSSM system may pose a threat towards the effort.

8. Legal Framework

8.1. Solid Waste Management Rules (2016)

These were framed under the Environment (Protection) Act, 1986, and govern the duties of all major stakeholders including MoEF&CC, MoHUA and all other concerned departments, District Collectors, Secretary in charge of Urban Development in State, Pollution Control Boards, Urban Local Bodies, waste generators, waste processing facilities and processed waste utilising facilities (like cement plants using RDF) in the management of MSW.

Annual Report on Implementation of SWM Rules, 2016 over the years indicate lack of robust data on existing MSWM practices in Bihar. Some information including quantum of waste generation, extent of source segregation and coverage of door-to-door collection is available, however information on waste processing and disposal is largely missing.

9. Financial Assessment

Sewerage was not considered as a priority area for Bihar under AMRUT scheme as indicated in State Annual Action Plan (SAAP) 2016-2017, only 1.5% of total approved amount i.e. 37.74 Crores INR was allocated for sewerage and septage management sector in Katihar (Urban Development & Housing Department, GoB, 2017). Laying of sewer network and setting up STPs was amplified through Namami Gange programme. 6086.18 Crores INR was sanctioned for Bihar for 53 projects, out of which 30 are targeted for setting up STPs, laying sewer network and interception and diversion of open drains (Details of Funds Spent on Namami Gange Programme, 2021).

MSWM and toilet construction activities were two key components where 90% of the funds under SBM Urban were allocated and as of 31st January 2019, ~70% and ~55% funds were released out of total allocated for ODF and SWM components respectively. (MoHUA, 2019)

Along with SBM Urban 2.0, 759 Crores INR is released to non-million plus cities in Bihar for Financial Year 2021-2022 under 15th Finance Commission (FC) grants. Out of the total grant, 60% is tied grant and out of the total tied grant, 50% is earmarked for 'Sanitation Solid Waste Management and attainment of star ratings as developed by the MoHUA (PIB, 2022).

Under SBM Gramin, 5632.86 Crores INR worth financial incentive was provided to Bihar till March, 2022 (Decline in Budgetary Provision of SBM-R, 2022).

Along with SBM Gramin 2.0, 11,736 Crores INR tied grant is allocated to Bihar states for GPs for water and sanitation for the five years 2021–22 to 2025–26 under 15th FC. For effective utilization of the tied grant for water and sanitation, States need to identify nodal departments and set up a system in accordance with the guidelines. Till now, entire allocated amount for FY 2021-22 (2509 Crores INR) (PIB, 2021) is disbursed to Bihar.

User charges are being collected for door-to-door solid waste collection services both in urban and rural areas. But no specific user charges are being collected for sewer network connection.

10. Technological Enabling of SWM/SLWM/DWWM System

An integrated app such as SBM Gramin 2.0 App is available for the Sanitation Supervisors of each GP. All the village level information such as demographic, waste, and grey water generation, SLWM related infrastructure details along with source of funding are to be captured in the App in line with ODF Plus checklists as defined in SBM Gramin Phase 2 guidelines.

11. Existing SWM Practices in Urban Area

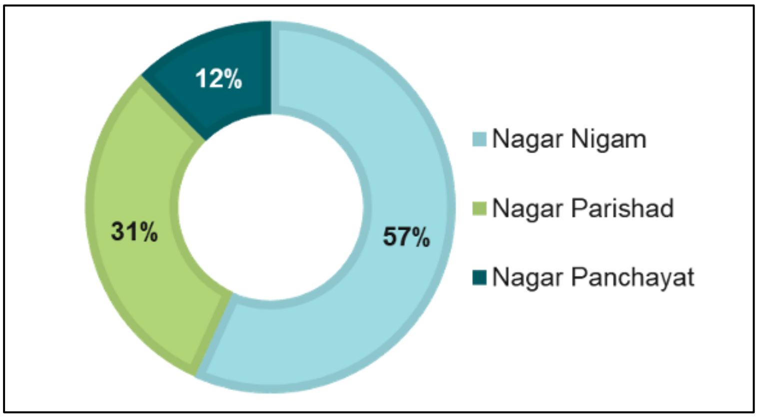
11.1. Solid Waste Generation

Bihar has 142 Urban Local Bodies responsible for management of municipal solid waste generated in the urban areas. Estimated municipal solid waste generation in the urban areas (including Nagar Nigam, Nagar Panchayats and Nagar Parishad) of Bihar was around 4,863.13 TPD[13] in 2020 while it increased to 4,967.36 TPD[14] in the year 2021. Per capita per day waste generation in the urban areas of Bihar is assessed to be 0.333 kg[15] in 2021. Share of MSW generation from different categories of ULBs is demonstrated in the Figure below.

[13] Urban Population (Census Projection, 2020)* 333 gm/c/d waste generation

[14] Urban Population (Census Projection, 2021)* 333 gm/c/d waste generation

[15] Average of per capita per day waste generation reported in Annual Report on Implementation of SWM Rules, 2018-19, 2019-20 and 2020-21



(BSPCB 2021)

Figure 4: Share of Waste Generation from Different Categories of ULBs

11.2. Storage and Source Segregation

Twin bins (14,43,620 green and blue bin each- BSPCB, 2021) are distributed to ~56%[16] of urban households to promote source segregation and safe storage of waste.

- Muzaffarpur Municipal Corporation with support from local volunteers and NGOs has achieved 80% source segregation (CSE Report)
- Patna Municipal Corporation has also started an IEC campaign to create awareness on source segregation. According to the PMC, city has achieved 25% source segregation.
- Munger, Muzaffarpur and Bihar Sharif are identified as model ULBs (CPCB, 2021) with respect to extent of source segregation, commissioning of one of the first MRFs and in general better waste management system in comparison to other ULBs in the state.

Bulk Waste Generators such as vegetable markets, malls, hotels, celebration halls etc. have been identified by most of the ULBs and are mandated to ensure source segregation, scientific processing of biodegradable waste to the extent feasible in the premises itself and handover dry waste to designated waste collectors in accordance to the MSW bylaws.

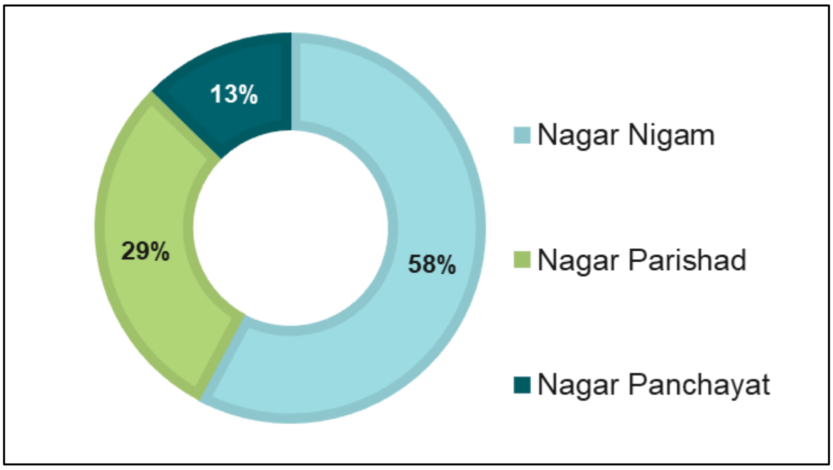
11.3. Primary Collection and Transportation

Tricycles, compartmental auto tipper, auto tippers without compartments, pushcarts, tractors etc. are used for door-to-door collection waste from households and other establishments. The coverage of the door-to-door collection in urban areas is 77%[17]. E-rickshaws are being used for collection of waste from slum pockets or inaccessible areas in some ULBs. Total waste collection efficiency is around ~80[18]% considering total waste collected as against the quantity of total waste generated.

[16] Bins distributed*100/ No. of HHs (projected urban population 2021/ urban HHs size as per Census 2011)

[17] No. of households covered under D2D service as per BSPCB data*100/ total HHs (Projected population 2021/HHs size from Census 2011)

[18] Waste collected as per BSPCB data*100/ total waste generated (Projected population 2021* 333 gm)



(BSPCB, 2021)

Figure 5: Share of Waste Collection from Different Categories of ULBs

11.4. Secondary Storage, Collection and Transportation

Coloured community bins are provided for secondary storage of waste

- Green colour container- for bio degradable waste or wet waste
- Blue colour container- for recyclable waste or dry waste
- Black colour container- for other waste

Total 313088 green colour, 307651 blue colour and 435 black colours containers are placed for secondary storage of waste (BSPCB, 2021). Except Patna no other ULB is equipped with transfer station or transfer point.

11.5. Processing and Disposal of Waste

According to data provided by BUD&HD, 1458 TPD waste are being processed by the ULBs which includes processing of wet waste primarily through composting and processing of dry waste primarily through MRFs. Types of processing facilities are indicated below:

Table 3: Types of Waste Processing Facilities in ULBs

Processing Facilities	Numbers	Installed Capacity (TPD)	Functional Capacity (TPD)
Composting	141	1159	642
Bio-methanation	1	1	1
MRF	57	655	655
RDF	2	12	12
Plastic Recycling	1	5	5

(BUD&HD, 2022)

Rest of the 3509 TPD waste is disposed of into 130 dumpsites located in 10 Nagar Nigams, 53 Nagar Parishads and 67 Nagar Panchayats, out of these bio-remediation of 26 dumpsites are underway to reclaim 1.92 million tons legacy waste spread across 172.5 Acre. Currently 80 sanitary landfill sites are also being identified in the state.

Ground Truthing Observation- Patna Municipal Corporation

- Source segregation and segregated collection of waste is practiced in 2 model wards (8 and 23)
- Street sweeping waste consisted of wet waste and valuable dry fractions such as plastic, paper, cardboard etc. that indicates presence of littering
- E-rickshaws are used for door-to-door collection of waste from slum area
- Waste collection from commercial areas and street sweeping take place in 2-3 shifts. PMC has identified 92 Bulk Waste Generators who are responsible to manage its wet waste and PMC collects only dry waste
- City has 6 transfer points. Only mixed waste or partially source segregated waste reach transfer points. The partially segregated waste too gets mixed during secondary collection at the transfer points
- PMC has installed 22 OWCs (total capacity 19.5 tons) to cater to vegetable market waste
- Patliputra Transfer Point is equipped with:
  - 5 TPD pit composting facility; produced compost is distributed amongst nurseries
  - 10 TPD MRF for manual sorting of dry waste; recyclable waste sold to kabadiwalas
  - Waste cloth reuse/upcycling unit
- 20 TPD Pit composting facility at dumping site is non functional
- Biomining of legacy waste started in Dec 2021 at Ramchak Bariya dumping site. Three private companies i.e. NACOF, Patiya and R.K Enterprises are involved in the biomining process. However, Patiya and R.K. Enterprises have stopped work due to financial crunch
- NACOF has reclaimed 4 lakh cum of legacy waste till date. Compost is being sold to Biosulfur Company and RDF is going to Dalmia Cement.
- Municipal waste collectors monitor source segregation and college interns are engaged for door-to-door IEC campaign by the designated agency



12. Existing SWM Practices in Rural Areas

Under LSBA Phase -1, 36 Gram Panchayats were identified to improve the existing situation of solid and liquid waste management on pilot basis. The program is rolled out to all Gram Panchayats in the second phase.

As reported in National Annual Rural Sanitation Survey (NARSS), 3rd Round, conducted in 2019-2020 no solid waste was visible in 95.2% of surveyed HHs and minimal level of littering could be observed for 79.9% of surveyed villages.

12.1. Storage and Source Segregation

Till now, 39,18,021 twin bins (LSBA, 2022) are distributed to HHs in GPs to promote source segregation and safe storage of waste that consists of ~10% of total rural households. However, during the field visits, it was observed that most households are using the bins for other purposes. Despite door-to-door IEC activities, households are still not practicing segregation of waste (except households of Bishunpur GP). Moreover, domestic hazardous waste getting mixed with the waste stream poses a health risk to the Swachhata Mitras and the local community.

12.2. Generation, Composition, and Collection

The total waste generated from rural Bihar (considering 0.250 kg/c/d[19] waste generation and 108.17 million population (The technical Group on Population Projections, 2019) is estimated at 27,041.5 TPD. SBM G 2.0 mobile application is being used for doorstep quantification of waste generation. However, at present, the data is captured based on eye estimation. 99% of the waste generated in GPs is biodegradable; thus, it can be a good feedstock for composting.

A door-to-door collection service is provided to all gram panchayats but it is yet to achieve 100% coverage in most of the GPs. Each ward is equipped with one tri-cycle and two Swachhata Mitras who are responsible for door-to-door collection from 7:00 AM onwards to collect and bring the waste to the collection and segregation shed or Waste Processing Unit (WPU). *Data obtained from the pilot 36 GPs shows that on an average 1272 kg of waste is collected per day from each GP[20] by the Swachhata Mitras.* Around 44306 Swachhata Mitras (LSBA, 2022) are engaged till now in the door-to-door collection services. E-rickshaws are being used for secondary collection and, for providing primary collection services in the wards located far away from the WPUs. Additionally, 12,258 Community bins (separate bins for wet and dry waste) are also placed at strategic locations in the GPs (LSBA, 2022) till the time of report preparation.

[19] Discussion with LSBA Authority, 2022

[20] Analysis by ICLEI-SA

Table 4: Procurement Solid Waste Management in Rural Areas

Procurement Category	Number
Tricycle-Rickshaw	17,087
Dustbin	39,18,021
Community-Bin	12,258
E-Rickshaw	1212

(LSBA, 2022)

12.3. Processing and Disposal of Waste

As reported in NARSS 3rd Round, 71.3% surveyed HHs handover waste to designated primary waste collector or process it on-site; rest of the 28.7% HHs dispose of solid waste indiscriminately.

Waste Processing Units (WPUs) are being set up for treatment and processing of waste. WPUs have waste collection and segregation sheds, a storage facility for dry recyclables (such as cardboard, paper, plastic, metal, etc.) segregated by the Swachhata Mitras and compost unit. Non-recyclable dry waste such as multi-layered plastic and thermocol is being dumped in open areas.

Till date, 123 WPUs are constructed in GPs across 24 districts; most of them in **Supaul, East Champaran and Jamui**. Additional 847 WPUs are being set up across GPs of all districts. (LSBA, 2022). Apart from WPUs, individual 883 compost pits are also constructed till now; most of them being in **Samastipur, Supaul and Begusarai districts**. However, the total capacity of these WPUs and compost pits are not known. Also, quantity of feedstock for the compost pits within these WPUs are not defined or tend to be negligible as most of the households prefer to feed organic waste to the cattle. In this regard, it was also observed that many Gram Panchayats are yet to receive No-Objection Certificate for setting up WPUs or compost pits. Waste is dumped in open spaces in most of the GPs.

Ground Truthing Observation

- Twin-bin (each 10-litre capacity) is distributed to households but these are not used appropriately and littering was observed
- Despite the door-to-door IEC campaign conducted by different agencies, source segregation level is poor
- Domestic hazardous waste and ash from coal-fueled cooking furnaces mixes with solid waste; leads to difficulty in segregation and further recovery
- Door to door collection service is in place. However, 100 % coverage is not yet achieved
- Waste Processing Units are yet to be set up in most of the GPs. Delay in obtaining NOC and convergence with MNREGA is hindering the process of setting up WPU
- Following clustered approach as postulated under SBM Gramin, GPs are recommended to be linked with nearby MRF facilities for scientific disposal of non-recyclable dry waste. However, this is not an established practice as of now.

13. Gaps and Challenges in Solid Waste Management

13.1. Urban Areas

Gaps are identified with respect to these key activities listed below amongst many others, mandated for ULBs by SWM Rules, 2016:

Requirements as per SWM Rules, 2016	Infrastructural	Institutional and Monitoring	Regulatory
	Waste Generation, Collection and Transport		
• arrange for door-to-door collection of segregated solid waste • direct waste generators to segregate waste at source and hand over the segregated waste to authorized waste pickers or waste collectors authorized by the local body	**Source segregation is not widely practiced in urban areas**. Except Muzaffarpur, extent of source segregation even in the capital city Patna stands maximum at ~25%. **Lack of source segregation and subsequent collection of mixed waste will render difficulty in waste recovery and processing. Ultimately,**	In spite of model SWM bylaws adopted by half of the ULBs, **source segregation is not monitored stringently on ground by waste collectors.**	Model SWM bylaws are not institutionalised across all ULBs that would enforce source segregation; especially at BWG level. **Thus, the opportunity to**

Requirements as per SWM Rules, 2016	Infrastructural	Institutional and Monitoring	Regulatory
● transport segregated waste to respective processing facilities for wet and dry fractions with preference for on-site treatment of wet waste ● create public awareness through information, education, and communication (IEC) campaign on various aspects of SWM ● setup material recovery facilities or secondary storage facilities with sufficient space for sorting of recyclable materials	**the mixed waste ends up reaching open dumpsite and insanitary landfill, in most cases that act as major source of GHG emission.** There is 77% coverage of primary collection service, rest of the waste is streamlined through either informal sector or in most likelihood is either littered or burnt openly and end up reaching dumpsite and waterways. **The littered waste can stagnate waterbodies and lead to oxygen deficit environment; thereby resulting in increased GHG emission.** Moreover, open burning of waste is also potential source of GHG emission especially CO2. **Secondary storage facility is absent in most of the ULBs.** Only Patna has transfer points/ transfer stations where waste is dumped and further transported to dumpsite. However, waste transfer is not yet mechanised from primary collection to secondary transport vehicles. **Due to lack of secondary storage facilities, primary collection vehicles might be travelling longer distances and undertake more trips; increasing indirect GHG (CO2) emissions**	Awareness generating IEC activities are also restricted to only a few model wards that too in Nagar Nigams such as Patna or Muzaffarpur. Moreover, proactive community engagement was not observed either. As route rationalisation system is absent as of now across the ULBs in Bihar, the **unsystematic routing of vehicles can lead to indirect GHG emission especially in the form of CO2**.	**efficiently process the large quantum of waste especially wet waste from BWGs is lost. The mixed waste coming into the MSW stream reduces efficiency of processing facilities and hinders optimum resource recovery.**
	Treatment and Disposal		
● facilitate construction, operation and maintenance of solid waste processing facilities and associated	**Only one bio-methanation facility is set up till date** having potential to capture and utilise methane gas		

Requirements as per SWM Rules, 2016	**Infrastructural**	**Institutional and Monitoring**	**Regulatory**
infrastructure with preference for decentralised facilities ● undertake on their own or through any other agency construction, operation and maintenance of sanitary landfill and associated infrastructure ● allow only the non-usable, non-recyclable, non-biodegradable, non-combustible and non-reactive inert waste and pre-processing rejects and residues from waste processing facilities to go to sanitary landfill ● investigate and analyse all old dumping sites and existing operational dumpsites for their potential bio-mining and bio-remediation; if bio-mining or bio-remediation is not possible legacy waste should be capped scientifically	generated through anaerobic digestion of wet waste. About 3509 TPD MSW is disposed openly in 130 operational dumpsites with a large quantum of legacy waste. **These are major sources of methane emission.** Bio-remediation is undergoing only for 26 dumpsites. Considerable **difference between installed and functional composting facilities c**ould be attributed to technical and operational issues including lack of segregation practices. The untreated wet waste fraction can lead to increased GHG emission when disposed in dumpsite.		

13.2. Rural Areas

Infrastructural	**Institutional and Monitoring**
Source segregation is not widely practiced in rural areas either except a few GPs in certain districts. Domestic hazardous waste getting mixed with the waste stream poses a health risk to the Swachhata Mitras and the local community**. Lack of source segregation and subsequent collection of mixed waste reduces the efficiency of compost and any other waste processing units.**	Though the SBM Gramin 2.0 APP is designed to capture waste generation and other facilities across the value chain, most of the data are integrated based on eye estimation. **Lack of well-defined database deters practical planning and implementation.**

Infrastructural	Institutional and Monitoring
Primary collection system is not well established except pilot GPs under LSBA Phase 1. The uncollected waste is littered, burnt, dumped openly. Dry waste fraction is streamlined through informal sector and part of the littered waste end up reaching waterways. The littered waste can stagnate waterbodies and create oxygen deficit environment. Stagnated water ways and open burning of waste are potential source of GHG emission.	
Most of the waste generated in rural areas are biodegradable in nature. Apart from cattle feed, compost units are the most viable solution. However, compost pits are set up till now only in about 800 GPs out of more than 8,000 GPs. Rest of the waste is dumped indiscriminately. **At present, these dumping points are not significant source of GHG emission due to its aerobic condition. However, if the practice prevails; in long term, these will turn into potential source of GHG emission.** **Waste collection and segregation sheds are built as merely a shed without any additional infrastructure such as weighing machine, fencing, and seating arrangement for sanitary supervisor**. Thus, efficiency of these units are not optimised and security of the segregated valuable fraction is compromised as well in certain instances.	The clustered approach recommended under SBM Gramin is not yet practiced on ground. Nearby MRFs are either established recently, non-functional or functioning inefficiently. **In spite of establishing contract with ULB MRF such as the case of Bihar Sharif in Nalanda District to streamline dry waste from adjacent GPs to Bihar Sharif MRF, the system is not operational in practice.** **Swachhata Mitras of GPs in certain districts are not paid consistently.** This reflected the inefficient fund channelisation system; thereby impacting systematic waste collection and segregation. **Delay in obtaining land clearance and No-Objection Certificate to set up collection and segregation shed, compost unit or WPU in general creates a major barrier against infrastructure improvement.**

14. Existing Domestic Wastewater Management Practices in Urban Area

14.1. Toilet System

Domestic wastewater management in urban Bihar is executed through BUIDCO constituted under BUD&HD channelising finances of national schemes such as SBM Urban, Namami Gange and AMRUT. Under SBM Urban out of targeted total 3.86 Lakh IHHL and 23,591 community toilet seats, ~94% IHHL and ~88% community toilet seat construction is achieved till date[21]. Urban areas in Bihar have 93.37% coverage of household toilet[22]. At the time of reporting, 132 ULBs are declared ODF and out of them 24 are declared ODF+ (SBM Urban, 2022). However, scientific construction of the septic tanks cannot

[21] Data provided by BUD&HD and BSPCB

[22] Estimated by ICLEI-SA

be assured and it is reported that supernatant from the septic tank is discharged to the roadside drains and further this is drained to the nearest depression creating pond/slumps. This causes bad smell, unhygienic condition, and breeding of mosquitoes.

Estimated toilet typology in urban Bihar is demonstrated in the Table below:

Table 5: Toilet Typology in Urban Bihar

Sl. No.	Toilet Typology	Coverage (Number/ %)	Reference
1	Sewer Connected	304030[23] (11.9%)	Considering 8.12% sewer connected data from MOHUA + sewer connected under NMCG
2	Septic tank	1698448[24] (66.48%)	Total Water Closet as per MoHUA Urban Statistics Handbook - Sewer Connected HHs
3	Twin Pit Latrine	364840[25] (14.28%)	IHHL constructed till now
4	Community/Public Toilet	17883[26] (0.70%)	NSS Report 2018
5	Other/No Toilet	169475 (6.63%)	Total HHs- HHs having all other categories of toilet

14.2. Wastewater and Faecal Sludge Collection and Transportation system

Urban Bihar had 8.12% water closet connected to sewer network (MoHUA, 2019) till 2015-16. Further, under Namami Gange, 1,46,801 House Service Connections (HSCs) were targeted to be provided out of which 96,591 HSCs are already being given. Thus, urban Bihar is estimated to have 11.9% sewer network coverage at present.

Out of the targeted 1747.92 km of sewer network under Namami Gange, 856.54 km is laid out till date.

A survey undertaken by BSPCB in 2019 shows that out of the 500 open drains sampled, 44 drains demonstrated high BOD load (>100 mg/l), similar to BOD load of raw sewage. It clearly indicates that sewage and supernatant from septic tanks as indicated earlier is flowing through open drains and ultimately discharged into waterways or open land. These drains with high BOD load are concentrated in 27 ULBs of Bihar and disperse with river Ganga and other water bodies; polluting the aquatic system. A total 262 drains discharging into Ganga and its tributaries are planned to be intercepted and diverted; till now interim measures are adopted in few drains in Patna. Moreover, some of the standing drains (24 out of 500) along with some other drains (a total of ~200 drains) disperse in low

[23] Considering 8.12% sewer connected from MOHUA, 2015-16 + sewer connected under NMCG
[24] Total Water Closet as per MoHUA Urban Statistics Handbook -2019, data reported 2015-16- Sewer Connected HHs
[25] IHHL constructed under SBM
[26] 0.7% access to CT/PT as per NSS Report 2018 https://www.thehinducentre.com/resources/article30979980.ece/binary/Report_584_final_0_compressed.pdf

lying areas. The stagnant sewage concentration along these standing drains and at the depressions can lead to an oxygen deficit environment, thereby contributing to increased methane emission.

Emptying of toilet system is not yet regularised in the state. Mainly private operators cater to the desludging requirement on demand basis and the service charge varies widely depending on the quantum of withdrawn sludge and the distance to be covered. There is no government order or notification pertaining to empanelment of the desludging operators and capping of service charge. Due to absence of any dedicated disposal sites as of now, private operators practice illegal dumping of faecal sludge into water bodies, disregarding the threat posed to health and environment.

14.3. Treatment and Disposal

1,551 MLD sewage is generated from urban areas of the state [27]. Additional 26.85 MLD[28] sewage is estimated to be generated by floating population. Out of the total sewage generated, only 71 MLD is treated in 4 STPs in Bihar. Detail of these 4 STPs that were set up under Namami Gange are given below in the Table. Quality of treated water suggests that STPs are operating efficiently. Additionally, 23 new STP projects of 533.5 MLD capacity are at different stages of construction.

Table 6: Detail of Functional STPs in Bihar

Sl. No.	Name of STP	Installed Capacity (MLD)	Current Capacity Utilisation (MLD)	Technology	Outlet BOD (mg/l)	Outlet COD (mg/l)
1	Beur	35	20	Aerobic	7	23
2	Saidpur	45	33	Aerobic	7	27.5
3	Karmalichawk	4	2	Aerobic	6.3	35.42
4	Pahari	25	16	Aerobic	10.7	38.9

(BSPCB, 2022)

15. Existing Liquid and Domestic Waste Water Management Practices in Rural Area

Liquid and domestic wastewater management is being carried out in rural areas of Bihar through SBM-Gramin and LSBA, dovetailing financial assistance from the World Bank supported Neer Nirmal Pariyojana, Namami Gange (Ganga Gram) and Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS).

15.1. Toilet System

At the beginning of SBM Gramin in 2014 only 3.96 million, out of 16.15 million total HHs in rural Bihar was identified with the availability of IHHL (SBM Gramin, 2022). As observed through community interaction; most of the IHHL built prior to implementation of SBM are septic tank-based system; however, scientific functioning of the septic tanks cannot be guaranteed. Another 12.17 million toilets

[27] Projected Population 2021*130 lpcd water supply*80%

[28] 5% of projected population as floating population*45 lpcd water supply*80%

were constructed under the mission; thereby achieving 82.67%[29] toilet coverage in rural areas. All villages in rural Bihar are declared ODF during the process. Most of the IHHL constructed under SBM Gramin are based on Twin-Leach Pit system attributed to its low cost, ease of building, low water consumption features. But during the ground truthing, presence of single pit toilet was also captured; this requires regular emptying incurring more expenditure for the household. Hence, it is recommended under SBM Gramin Phase 2 primarily to retrofit the single pit toilet into twin-pit based system to ensure its functionality as an optimum on-site sanitation facility.

Table 7: Toilet Typology in Rural Bihar

Sl. No.	Toilet Typology	Number/Percentage Share	Reference
1	Sewer Connected	237933[30] (1.2%)	Census, 2011
2	Septic Tank	3826778[31] (19.3%)	Toilet available untill SBM started- 1.3 lakh toilets which needed retrofitting
3	Twin Pit	12326314[32] (62.17%)	Toilet constructed under SBM+1.3 lakh retrofitted under LSBA as reported in Finance Department Report, 2022
4	Community/Public Toilet	0%	NSSO, 2018
5	Others/No Toilet	3436708 (17.33%)	Total HHs- (all other categories)

In spite of 100% IHHL coverage, functionality and regular usage of toilets is debatable as observed during the ground truthing exercise. Toilets may get dysfunctional due to faulty construction of pipes and chambers, absence of Y junction or poorly built structure. Out of total HHs having IHHL, 82% are functional[33] and out of the population with access to IHHL, 90.7% toilet usage is reported in NARSS 3rd Round, 2019-2020. As retrofitting of toilet is limited to creating awareness and motivating HHs to retrofit the system, HHs refrain themselves from incurring this expenditure and a few HHs still resort to open defecation. Moreover, newly built HHs (due to family division) are yet to get access to IHHL.

Apart from IHHL, till date, 9857 Community Sanitary Complexes (CSCs) are also constructed in 7830 villages (SBM Gramin, 2022) to cater to the households without IHHL primarily due to constraint of land. **Khagaria district has the highest coverage of CSCs as 63.64% out of 231 villages are equipped with at least 1 CSC whereas Banka and Arwal districts have lowest coverage of CSCs (less than 10%**

[29] Estimated by ICLEI-SA

[30] Considering 1.2% sewer connected from Census 2011

[31] Toilet available untill SBM started- 1.3 lakh toilets which needed retrofitting

[32] Toilet constructed under SBM+1.3 lakh retrofitted under LSBA as reported in Finance Department Report, 2022

[33] Functional toilet- These components include i) pan/seat is not completely broken ii) pan is not completely choked iii) pits/tanks are completely covered iv) pipes are not completely broken or open. A toilet is considered as non- functional if any of the parameters stated above, is found to be compromised

of villages). A comprehensive on-ground survey Open Defecation Implementation Plan (ODIP) is being carried out by GPs in order to identify present dependency on CSCs and assess future requirements.

15.2. Grey Water Management System

As estimated, total 4015.66 MLD greywater[34] is generated from rural areas of Bihar. As reported in NARSS 2019-2020, 70.6% HHs practice safe disposal of greywater. It is primarily reused in kitchen garden (29.1%[35]). Apart from that, drains construction was started in Bihar under Panchayati Raj Department and been brought under the aegis of Saat Nishchay Scheme since its inception. A mix of open and closed drains could be observed in GPs to convey grey water[36] generated from households (30.6%[37]). Another 10.9% HHs[38] are disposing grey water through soak pits.

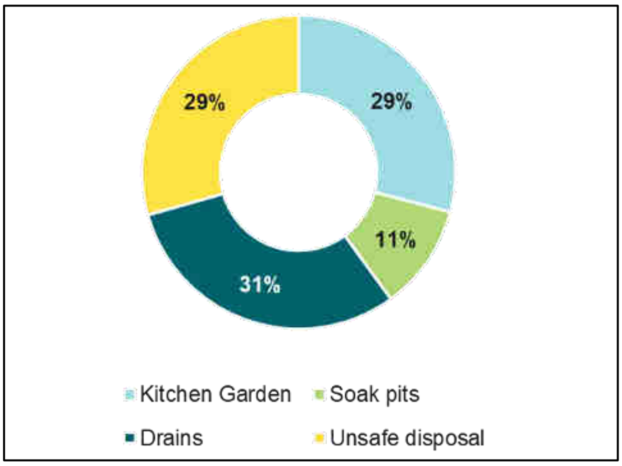


Figure 6: Types of Grey Water Management Practiced in Rural Areas

Under LSBA Phase 1, grey water management was initiated through household level intervention **where 298 individual soak pits were constructed in 10 GPs of a few selected districts; Begusarai having the highest number of units. Community Soak Pits (CSPs) were constructed in 12 GPs; Samastipur having highest number of CSPs [39].**

Till date, 13,820 individual soak pits and 13,174 CSPs are constructed under LSBA Phase 1 and 2 combined; **Paschim Champaran district having highest numbers of individual soak pits whilst Purnia district having highest numbers of CSPs.** Magic Pits are also set up but it is limited to only a few GPs of 19 districts as of now (LSBA, 2022).

In case of unavailability of any treatment mechanism, the drains are connected to small water bodies and pits; these gets eutrophicated[40] when silted and contaminated water flows into it on a long run. Moreover, the drains can potentially carry blackwater from insanitary toilets. Using pond water for household chores is a common practice in rural areas, thus possible health hazard can occur while

[34] Greywater generation= population*55lpcd water supply*67.5% (Operational Guidelines for the Implementation of Jal Jeevan Mission, 2019)
[35] NARSS 2019-2020
[36] Wastewater from bathrooms and kitchen that has no faecal contamination is called greywater
[37] NARSS 2019-2020
[38] NARSS 2019-2020
[39] Data provided by LSBA, 2022
[40] Eutrophication is a natural process that results from accumulation of nutrients in water bodies. Algae that feed on nutrients grow into unsightly scum on the water surface. USGS, 2019

using contaminated water. Also, the eutrophicated lakes can potentially emit 50% more methane than comparable non-eutrophic lakes (Li., 2021).

15.3. Faecal Sludge Management

As per estimate[41], 4278.15 cubic metre of faecal sludge is generated by rural population in the state. But the treatment of domestic waste water from rural areas is at a nascent stage across Bihar. Septic tank and single pit-based toilets that require desludging in 3-5 years interval are catered by private tankers, operational at the district level; each catering to several GPs. HHs are charged for each emptying service that varies widely, depending on the quantity of sludge withdrawn and the distance covered for providing the service. However, there is no clarity regarding the disposal of emptied sludge and it is disposed openly in most likelihood, instances of Not in My Backyard (NIMBY) syndrome are evident as indicated during stakeholder interaction.

Table 8: Comparison of Parameters for Raw Sewage and Faecal Sludge

Sl. No.	Parameters (mg/l)	Raw Sewage	Faecal Sludge
1	BOD	250-400	4,732
2	COD	500-800	27,026
3	TSS	600-1,000	29,746

(CPHEEO, MOHUA, 2020 and Department of Drinking Water and Sanitation, Ministry of Jal Shakti, 2021)

A comparison of effluent parameters between raw sewage and faecal sludge indicates parameters are 100 times higher for faecal sludge as demonstrated in the Table 8. Hence, open disposal of human faeces will contaminate the environment and might create health hazard to the people in close vicinity; especially in case of direct exposure. In this context, considering the requirement to treat the bio-hazardous faecal sludge, exploring opportunity of co-treatment in nearby Sewage Treatment Plant (STP) or construction of district level Faecal Sludge Treatment Plant (FSTP) is being considered under LSBA Phase 2.

Ground Truthing Observation

- Mix of open and close drain was found. Junction chambers are installed at strategic locations to adjust and channelise the flow according to situation
- Except a few individual soak pits or CSPs, drains carrying grey water are connected to nearby talav/pond
- Most of the open drains are found littered and silted as well
- Only in a few places stagnant water was observed; it is not a seasonal phenomenon, depends on drain clogging or topography of the region
- Grey water is used in kitchen garden in some households
- CSPs are mainly constructed at the school and temple premises and it was rendered dysfunctional in few cases due to overlapping and unplanned construction activities

[41] Sludge generation= Sludge Accumulation Rate 0.00021 m3/c/d (CPHEEEO Manual) *population dependent on septic tank and single pit toilet

- Most of the households have access to IHHL. Newly built HHs (due to family division) do not have IHHL yet. Some HHs still resort to open defecation due to unavailability or non-functional IHHL
- Twin Leach Pit toilets are built under SBM G; toilets built prior to SBM have septic tank system
- Functionality of Community Sanitary Complexes (CSCs) is not widespread and requires retrofitting in a few GPs
- An Open Defecation Implementation plan (ODIP) is being prepared for all GPs across Bihar to identify HHs without IHHL, present dependency on CSCs and future requirement
- Muzaffarpur district has started the first toilet clinic for repairing toilets
- IEC campaign was undertaken by Aga Khan Foundation regarding usage of toilet and importance of handwashing in a few districts

Muzaffarpur- Bishunpur GP

- *Few HHs have built adjacent kutcha pits for passage of greywater*
- *Most of public hand pumps are connected to soak pits*
- *First toilet clinic by UNICEF for retrofitting toilets*

Nalanda- Sartha GP

- *Centralised grey water management system is proposed in one of the villages*

Samastipur- Hetanpur GP

- *No linkage between river and pits. But during flood, greywater carrying open drains and pits can be inundated and might contaminate river water*

Figure 7: Observations Regarding Liquid Waste Management in Rural Areas

16. Gaps and Challenges in Domestic Wastewater Management

16.1. Urban Areas

Gaps are identified with respect to these key activities listed below amongst many others, recommended for ULBs as per the Bihar Urban Sanitation Strategy and Guidelines for FSSM in Bihar:

Recommendations as per Bihar Urban Sanitation Strategy, 2010 and Guidelines for FSSM in Bihar, 2018	Infrastructural	Institutional and Monitoring	Regulatory
	Toilet System and Collection and Transport		
● Promoting proper functioning of network-based sewerage systems and ensuring household connections, connections to all other establishments ● All households with individual toilet in non-sewered areas to have safe onsite sanitation system ● Deploying adequate manpower and equipment for collection and transport of faecal sludge ● Licensing of existing desludging service providers ● Implement scheduled desludging ● Capacity building programme for service providers, masons, etc ● Promoting proper usage, regular upkeep and maintenance of household, community and public sanitation facilities ● Baseline data collection and preparation of FSSM strategy and Citywide Sanitation Plan	93.37% IHHL coverage in urban areas but **built quality of toilets especially septic tank-based system with respect to Indian Standard (IS: 2470) code of practice for installation of septic tanks cannot be guaranteed**. As ~67% toilet in urban areas estimated to be septic tank based, inefficient functioning of the same not only contaminates soil and groundwater, **it will also exacerbate methane emission. Moreover, supernatant from the septic tank is discharged to the open drains** and further this wastewater is channelled to the nearest depression creating pond/slumps. This causes bad smell, unhygienic condition, and breeding of mosquitoes and the stagnated condition are potential source of methane emission. **Sewerage network coverage is limited to only 11.9% households.**	**Baseline data pertaining to all components across sanitation pathways are not available, managed or monitored.** As a large section of urban households are dependent on OSS, a well-defined database will be helpful in defining citywide strategy, actions and it's on ground implementation. **Desludging vehicles are not geo-tagged; there is no monitoring mechanism regarding collection and disposal.** This triggers unsafe collection and indiscriminate disposal	**No FSSM related regulation is in place anywhere in urban Bihar** in terms of licensing desludging operators, following safe desludging protocol or implementing scheduled desludging.

Recommendations as per Bihar Urban Sanitation Strategy, 2010 and Guidelines for FSSM in Bihar, 2018	Infrastructural	Institutional and Monitoring	Regulatory
	Further, the BOD load of several open drains indicate the conveyance of raw sewage through it. **Hence, a significant volume of sewage is not collected safely in the first place. It will not only contaminate the waterways, destroy aquatic eco-system and associated health hazards, the sewage flow can create stagnant oxygen deficient condition in the low-lying areas thereby increasing methane emission.**	practices without considering its threat to public health and environment.	
	Treatment and Disposal		
● 100% sewage collected will be treated at the treatment facility to meet the effluent quality standards. All sludge is to be treated as well. ● Promoting recycle and reuse of treated waste water for non-potable applications as much as possible ● Identification of trenching sites for proper disposal of faecal sludge, till the time proper treatment plant is in place ● Operationalising co-treatment at existing STP and/or co-	**Only 4.5% is treated in currently functional STPs**. **Existing STPs in Bihar are based on aerobic treatment technologies with no potential of recovery.** Even though direct methane emission from aerobic system is lesser than anaerobic system[42], higher electricity consumption in aerobic system contributes to indirect CO2 emission. Also, comparatively higher amount of sludge generated from aerobic system (Kobayashi, 2013) will release additional		

[42] Methane Correction Factor: overloaded, not well managed aerobic system- 0.3, different types of anaerobic system- 0.8 (as per 2006 IPCC Guidelines, Vol.5, Chapter 6 Table 6.3)

Recommendations as per Bihar Urban Sanitation Strategy, 2010 and Guidelines for FSSM in Bihar, 2018	Infrastructural	Institutional and Monitoring	Regulatory
composting with municipal solid waste wherever feasible for safe treatment of collected FS ● Implement and operationalise faecal sludge treatment plants with reuse wherever necessary for safe treatment of all the generated FS ● Capacity building of operators	methane if not recovered well. On the other hand, the collected but untreated sewerage flow can still create stagnant oxygen deficient environment in the waterways resulting in increased methane emission. **No existing provision of treating emptied faecal sludge in STPs through co-treatment or in standalone FSTPs.** Thus, open disposal of faecal sludge is a rampant practice that can be a bio-hazard to environment and health.		

16.2. Rural Areas

Infrastructural	Institutional and Monitoring/ Maintenance	Regulatory
Toilet System		
Septic tanks built especially prior to SBM cannot ensure scientific construction and in most cases are not connected to soak pits in compliance to Indian Standard (IS: 2470) code of practice for installation of septic tanks. Poor construction quality of the septic tanks that contribute to 19.3% IHHL in rural area not only contaminate soil and	**No properly maintained data base on typology, usage and functionality of toilets will deter the process of identifying required intervention across the sanitation pathways** such as taking actions for retrofitting non-functional twin-pit or unscientific septic tank and conversion of single pit or insanitary IHHL, if any. Moreover, planning for Faecal Sludge and Septage Management (FSSM) including requirement of emptying toilet, exploring opportunity for co-treatment	

Infrastructural	Institutional and Monitoring/ Maintenance	Regulatory
groundwater, this inefficient anaerobic OSS system exacerbates methane emission. Further, the pit latrines are most efficient in terms of methane emission mitigation, only when sediment is removed regularly for fertilizer. If otherwise, especially in case of wet climate and ground water table higher than latrine, it can potentially lead to enhanced methane emission[43].	and setting up FSTP cannot be earmarked methodically. **This will subsequently contribute to unplanned both direct methane emission from inefficient toilets and indirect CO2 emission during collection and transport of sludge.** Though GPs are declared ODF based on 100% coverage of **IHHL, its usage is not yet ingrained amongst community.** Also, timely retrofitting of dysfunctional toilets is not undertaken; in most likelihood due to financial constraints. This tends to induce practice of OD. **Open defecation especially in depression areas/ small water bodies in long run can lead to oxygen-deficit environment that may allow for anaerobic decomposition to produce methane.** CSCs are not well maintained as observed during ground truthing. **There is lack of community ownership and willingness to maintain these facilities.**	
FSSM		
Toilets are not emptied at any regular interval in compliance to Government advisory norm[44]. This may hinder the anaerobic degradation expected to take place inside the OSS. During emptying, direct methane emission can be fatal. Moreover, when disposed openly, prematurely withdrawn unstabilised sludge can aggravate the pathogenic contamination of environment. Additionally,	**Lack of institutional and technical capacity** for strengthening faecal sludge and septage management for e.g. setting up FSTP. **No monitoring mechanism for desludging operation** induces inappropriate collection and indiscriminate disposal of sludge, disregarding its harmful impact on environment.	**Currently operating desludging vehicles are not government licensed.** Cases of manual scavenging or unscientific/ unsafe emptying procedure might be practiced. Due to the absence of any capping on the price of desludging services, a wide range

[43] Methane correction factor for Latrine in Wet climate/flush water use, ground water table higher than Latrine- 0.7
[44] Advisory Note On Septage Management In Urban India, MoUD, 2013

Infrastructural	Institutional and Monitoring/ Maintenance	Regulatory
when it will be feed into treatment facility, the unit might be overburdened with the BOD load of the premature sludge. As discussed earlier, emptied sludge is not treated anywhere across rural Bihar. Opportunity of co-treatment is limited as well due to inadequate STP capacity. **In the absence of any designated point of disposal, open disposal will not only be hazardous for environment, the vehicles might have to travel a longer distance contributing to unplanned indirect CO2 emission.**		of price is charged for each emptying service.
Greywater Management		
Reuse of greywater is limited to a small fraction of the population and individual and community level treatment facilities are available sparsely. The soak pits can potentially produce methane through the anaerobic degradation of organic compounds present in greywater. **Hence, it is recommended to prioritize reuse of greywater at source.** A mix of open and closed drains are present in the rural areas. **Open drains are prone to littering and siltation that not only obstruct the water flow and create pockets of water stagnation, it also acts as a breeding ground of disease carrying vectors.** Most of the greywater carrying drains are connected	Data on greywater generation and capacity of treatment facilities are recommended to be captured in the SBM Gramin 2.0 App. But this is monitored currently based on eye estimation. **Lack of robust database can lead to non-optimum utilisation of resource while planning for treatment infrastructure.**	

Infrastructural	Institutional and Monitoring/ Maintenance	Regulatory
to waterbodies. Though greywater essentially don't carry faecal matter, unscientifically built toilets can potentially contaminate greywater conveyance system which will subsequently pollute its points of disposal. **Additionally, the stagnant drains and water bodies might lead to anaerobic decomposition of organic matter to produce methane.**		

17. Way Forward

It is understood that improvement of all components across the MSWM value chain and sanitation pathways are crucial for achieving mitigation of GHG emissions. To achieve GHG emission mitigation and reduction, there is need for integrating low carbon solutions in waste and sanitation planning and implementation framework across the system. Along with infrastructure development and service delivery enhancement, ensuring sustainable operation of waste and waste water treatment and processing facilities and monitoring mechanism are pertinent to improve the overall waste sector and reduce emissions. Hence, it becomes crucial to ensure that Bihar state has an easily implementable short term action plan for augmenting low carbon solutions in the waste sector in totality to go forward towards the target of achieving carbon neutrality.

In this regard, a holistic strengthening of waste sector profile is to be conceptualised prioritizing low carbon solutions across the value chain. The action plan will encompass core scalable actions, primarily in terms of infrastructure and service provisioning; that will demonstrate GHG emission mitigation potential in envisaged scenarios. Simultaneously, other enabling actions ranging from infrastructure and service provisioning to IEC and capacity building, monitoring and regulatory framework will be put forth that will facilitate efficient implementation of core scalable actions and lead to overall improvement in the system.

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Annex 2:

Bihar State Greenhouse Gas (GHG) Emissions Estimates for Waste Sector

Final Report

ICLEI
Local Governments for Sustainability
SOUTH ASIA

November 2022

Contents

1. Introduction and Background

1.1 Overview of the sector

India's total GHG emissions for the Waste sector in 2016 are estimated to be 75.23 million tonnes of CO_2e[1]. The waste sector, which includes the GHG emissions from microbiological processes that occur in the organic matter of solid waste under anaerobic degradation, and the anaerobic treatment of domestic and industrial wastewater represented 2.65 per cent of total national GHG emissions in 2016. It was dominated by emissions from wastewater treatment and discharge[1]. More than three fourth (78.9 per cent) of the emissions from the waste sector come from wastewater treatment and discharge, followed by 21.04 per cent from solid waste disposal[1].

With increasing urbanization and exponential population growth, the quantum of waste generation is also increasing, leading to increase in the emission generation. Therefore, it is critical to strengthen capacities and governance processes to mainstream climate considerations while planning, designing, implementing and financing of waste services.

GHG inventories play an important role in identifying key emission sources or *'hotspots'*, evaluating mitigation potential, formulating framework for setting goals and targets for future emission reductions and supporting policy-makers in developing sectoral strategies for emission reductions. With the above objective in mind, ICLEI South Asia developed a State wide GHG emission inventory of the waste sector for Bihar. The following sections provides a complete overview of (1) methodology (2) data sources, and (3) emissions inventory results.

1.2 GHG Coverage

The emission estimation scope covers three GHGs currently: Carbon Dioxide (CO_2), Methane (CH_4), and Nitrous Oxide (N_2O). Activities in the Waste sector lead to emissions of two GHGs, namely CH_4 and N_2O, both of which are accounted for under the estimates reported herein.

The 100-year Global Warming Potential (GWP) values for CO2, CH_4 and N_2O gases, respectively, as provided by the Intergovernmental Panel on Climate Change (IPCC) in its Second Assessment Report, 1996 have been referred to while reporting the emission estimates in terms of CO_2 equivalent (CO_2e) (see Table 1).

Table 1: Global warming potential as per IPCC second assessment reports[2]

Name of the gas	Formula	Global Warming Potential (GWP)	Global Temperature Change Potential (GTP)
		SAR	SAR
Carbon dioxide	CO_2	1	1
Methane	CH_4	21	5
Nitrous oxide	N_2O	310	270

1.3 Key economic sectors covered

As per the IPCC reporting structure, the following source categories and sub-categories under the Waste sector have been considered in the emission estimation. The relevant gases considered under each sub –category is also indicated below.

[1] Biennial Update Report4 to UNFCCC (BUR 3) with estimate for the year 2016
[2] Source: IPCC Second Assessment Report, 1996 and Sixth Assessment Report, 2022

- 4A Solid Waste Disposal
  - 4A2 Unmanaged Waste Disposal Sites: CH_4
- 4B Biological treatment of solid waste – CH_4 and N_2O emissions
- 4D Wastewater treatment and discharge
  - 4D1 Domestic Wastewater Treatment and Discharge: CH_4 and N_2O
  - 4D2 Industrial Wastewater Treatment and Discharge: CH_4

The source categories and sub-categories considered for the state-level estimates are in line with India's national reporting documents i.e., (i) INCCA report[3] with estimates for the year 2007, (ii) 1st Biennial Update Report[4] to UNFCCC (BUR 1) with estimates for the year 2010, (iii) 2nd Biennial Update Report[5] to UNFCCC (BUR 2) with estimates for the year 2014 and (iv) 3rd Biennial Update Report[6] to UNFCCC (BUR 3) with estimates for the year 2016.

1.1. Boundary of GHG estimates

The geospatial boundary of GHG emission estimates for the Waste sector includes the entire State of Bihar, spanning a geographical area of 94,163 sq. km and housing a population of 103 million (as per Census 2011). Within this geographical boundary, emissions of CH_4 and N_2O from the source categories of '4A Solid waste disposal', 4B Biological treatment of solid waste and '4D Wastewater treatment and discharge' are included in this assessment.

The scope of emission estimation from solid waste disposal is limited to the urban areas within India given that rural areas lack the requisite waste management and disposal systems and thereby GHG emission generation can be insignificant in the absence of controlled/semi-controlled anaerobic conditions, in line with India's three national reporting reference documents indicated in section 1.3.

1.4 Reporting Period

ICLEI South Asia is estimating state level emission estimates for the Waste Sector for the period 2020 and 2020 (calendar year).

2. Methodological Approach

The emission estimation for the four waste sub-sectors i.e., domestic and industrial wastewater, biological treatment of solid waste and municipal solid waste was done as per the equations outlined in Volume 5: Waste as per the 2006 IPCC Guidelines[7]. Annex 3 provides a snapshot of data sources for Waste Sector GHG Emissions Inventory. The overall approach and methodology adopted for developing the emissions inventory for the waste sector for the state government of Bihar is discussed below:

2.1. 4D Wastewater treatment and discharge

2.1.1. Domestic Wastewater

The characteristics of the domestic wastewater and consequently the associated GHG emissions vary from place to place depending on factors such as economic status, community food intake, water supply, treatment systems and climatic conditions of the area. Centralized wastewater treatment

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[3] Available at: https://www.iitr.ac.in/wfw/web_ua_water_for_welfare/water/WRDM/MOEF_India_GHG_Emis_2010.pdf

[4] Available at http://unfccc.int/resource/docs/natc/indbur1.pdf

[5] Available at: https://unfccc.int/sites/default/files/resource/INDIA%20SECOND%20BUR%20High%20Res.pdf

[6] Available at: https://unfccc.int/sites/default/files/resource/INDIA_%20BUR-3_20.02.2021_High.pdf

[7] IPCC Guidelines for National Greenhouse Gas Inventories Volume 5 - Waste

systems are usually available in urban areas while rural areas are largely lacking in such treatment systems. Domestic wastewater treatment systems and pathways to be considered for developing the emissions inventory will include information on:

- Centralized treatment plants, septic tanks, pit latrines, open/closed sewers, anaerobic digesters.
- Wastewater collection, type of treatment system, share of population covered by each treatment system type.
- For domestic wastewater related Methane (CH_4) emission estimates, Tier 1 and Tier 2 approach was applied.
- For Nitrous Oxide (N_2O) emission estimates, a Tier 1 approach was followed with Bihar state average protein consumption values over the years.
- The default values of the emission factors as per the 'IPCC's Second Assessment Report (SAR)' were used in the estimates for CH_4 and N_2O emissions.
- Primarily, a top-down approach to estimate CH_4 and N_2O emissions from domestic wastewater, with bottom-up data on sewage treatment plants (STPs) for urban areas.

<u>Methane (CH_4) emissions from Domestic Wastewater-Key parameters for emission estimation</u>

- Fraction of population in urban and rural areas (Bihar State)
- Degree of Utilization of each treatment type (i.e., proportion of resident population using different wastewater treatment/discharge systems – eg. latrines, septic tanks, sewer, none)
- Biochemical oxygen demand (BOD) (i.e., organic content in wastewater)
- Methane Correction Factor (i.e., methane generation potential) based on treatment type used
- Collected/Uncollected fractions of Wastewater
- Methane recovery (if any)
- Sewerage collection and treatment via STPs (aerobic & anaerobic)

<u>Nitrous Oxide (N_2O) emissions from Domestic Wastewater- Key parameters for emission estimation</u>

- State Population
- Average annual per capita protein consumption (kg/person/yr): National Sample Survey Organization (NSSO) surveys
- Other default coefficients from IPCC

A detailed information on the assumptions used in the domestic wastewater related GHG emission estimation is provided at Annex 3.

Domestic Wastewater Estimation – Key Parameters
Bihar State Urban and Rural Population (2016-2020) – the population numbers were considered from Census projection report. (Population Projections for India and States 2011 – 2036 - Report Of The Technical Group On Population Projections – access link: https://nhm.gov.in/New_Updates_2018/Report_Population_Projection_2019.pdf

Average Per Capita Biochemical oxygen demand (BOD) of wastewater in the state -
- The primary factor in determining the CH4 generation potential of wastewater is the amount of degradable organic material in the wastewater
- No state level data available. Hence, the value of BOD is taken to be 45 gm per capita per day – based on India's BUR III national assumption
- Since national estimates are not updated year on year constant values are used across the reporting period.

2.1.2. Industrial Wastewater

GHG emission generation potential from industrial wastewater is based on the concentration of degradable organic matter in the wastewater, the volume of wastewater, and the prevalent aerobic and anaerobic wastewater treatment technologies in different industries. The emission generation from the industrial wastewater will capture data and information such as:

- Methane (CH_4) emission from industrial wastewater were estimated based on the quantity and quality of wastewater produced in industries. Relevant statistics and norms for industrial production[8] and wastewater generation per tonne of product[9] in different industries were used.
- All applicable industries existing in the state of Bihar, belonging to the 16 industrial sub-sectors, with potentially high wastewater generation including Fertilizers, Sugar, Petroleum, Dairy, Meat, Pulp & Paper, Rubber, Tannery, Fish Processing, Alcohol (breweries & distilleries), Parboiled rice, Vegetable & fruit processing, Soaps & detergents, Vegetable oils, Iron & steel and Coffee, were considered while estimating emission generation. Typically, practices and technologies adopted for Methane (CH_4) recovery from wastewater are factored in to estimate Methane (CH_4) recovered and subsequently to be deducted from the cumulative estimates of Methane (CH_4) emission from industrial wastewater. In the case of Bihar State, there was no reliable/robust data available on methane recovery, hence this was not considered in the calculations.
- Industrial production datasets available on a financial year basis were converted to calendar year datasets for a given calendar year by considering 3/4th of the value from the previous financial year (corresponding to 9 months from April to December out of 12 months in a year) and 1/4th from the next financial year (corresponding to 3 months from January to March out of 12 months in a year).
- Detailed information on industrial wastewater and industrial production were sought from the concerned authorities and departments (Bihar State Pollution Control Board, Department of Industries & Bihar Industrial Area Development Authority). In cases, where reliable data was not available, industrial wastewater emission estimates were based broadly on the apportionment of national emission estimates using the state-level information on the economy, industrial activity etc. Past sectoral annual growth rates have been used to back calculate missing data for industries.

[8] For example, 'Bihar State Online Consent Management & Monitoring System" managed by BSPCB
[9] India's 3rd Biennial Update Report to UNFCCC (BUR 3)

- A mix of Tier 1 and Tier 2 approach was followed to estimate Methane (CH_4) emissions from industrial wastewater since of industrial wastewater generation data was arrived at using state-level and national-level data sources.

Emission estimation for each industry sector based on following parameters:

- Industrial production in tonnes
- Wastewater generated per tonne of product
- Organic concentration (i.e., characteristic of wastewater)
- MCF based on broad treatment technology used by sector
- Methane recovery (if any)

Industrial Wastewater Estimation – Key Parameters

- A combination of country specific and default values available at the national level have been used for this coefficient since state-level values are not available.
- Degradable organic component in industrial wastewater (CODi) – COD Kg/M^3 - default and country specific national level values are used for this coefficient in the assessment.
- **Methane Correction factor -** MCF indicates the extent to which the CH4 producing potential is realized in each type of treatment method. Thus, it is an indication of the degree to which the system is anaerobic. The value of the MCF is based on the prevalent wastewater treatment system used in the respective industrial sector.
- Values for applicable treatment types for India based on IPCC 2006 guidelines.

A detailed information on the assumptions used in the industrial wastewater related GHG emission estimation is provided at Annex 3.

2.2. 4A Solid waste disposal

The assessment estimates Methane emissions for Bihar from the disposal of Municipal Solid Waste (MSW), generally defined as waste collected by local municipal governments or other local authorities, typically including Household waste, Garden (yard) and park waste, commercial/institutional waste. MSW includes degradable matter (such as paper, textiles, food waste, straw and yard waste), partially degradable matter (such as wood, disposable napkins, sludge) and non-degradable materials (such as leather, plastics, rubbers, metals, glass, ash from fuel-burning like coal, briquettes or woods, dust and electronic waste).

Anaerobic decomposition of bio-degradable matter present in MSW generates GHGs like methane and nitrous oxide. Methane emissions from municipal solid waste disposal sites are the largest source of GHG emission in the waste sector. The emissions from MSW were estimated by following the below mentioned approach:

- Direct GHG emissions from solid waste was estimated based on parameters such as solid waste generation, its composition and management of the dumpsite sites. None of the urban areas in Bihar practice scientific disposal of waste or have landfill sites.
- Like majority of the country, rural areas in the state largely lack requisite systems for municipal solid waste management and its scientific disposal in landfill sites. Thus, in line with India's NATCOM-II, only disposal of solid waste in urban areas has been considered in the assessment.
- For solid waste disposal emission estimates, both Tier 1 and Tier 2 approaches were used.
- A top-down approach was followed in the collection of secondary activity data and estimation of Methane emissions from solid waste disposal.

- The first order decay (FOD) model outlined in the 2006 IPCC Guidelines to estimate emissions from the decomposition of solid waste in disposal sites over a period of time was used in this assessment. In FOD based estimates, GHG emissions from waste decomposition over a period of 50 years prior to 2016 i.e., from 1965-2015 were also estimated.

Key parameters for emission estimation:

- Urban population
- Per capita solid waste generation (kg/day)
- Waste character (%)
- Proportion of solid waste going to landfill Site (%)
- Degradable Organic Carbon (DOC) – based on waste composition
- Methane recovery (if any)

Municipal Solid Waste Disposal Emissions – Key Parameters

- **Per capita solid waste generation (kg/day) –** Calculated using BSPCB reported data (reported by BSPCB to CPCB in its 2020 annual report i.e., 0.333 kg/day/capita) and national-level average annual growth (waste generation) rate of 1.22% per annum.
- **Proportion of solid waste going to disposal site (%) –** The proportion of waste going to waste disposal site is estimated by deducting the reported data on solid waste processed through treatment routes from the total quantum of waste generated. Reliable state-level information on the quantity or proportion of waste going to landfills is not available for the 1965-2015 period. Therefore, between 1965-2015, it is assumed that 70% of the generated waste went to the landfill during this period, in consonance with the assumption for national-level estimates. In the national-level estimates done by CPCB in its 'Consolidated Annual Review Report on Implementation of Municipal Solid Wastes (Management and Handling) Rules 2000 & 2016', 70% of the generated waste is assumed to have gone to landfills during the 2005-15 period.
- For Bihar, waste processing data is available for only year 2020 (appx 60% of the waste generated in the State). Due to the lack of robust year on year data for waste processing data and in consultation with BSPCB, effective quantum of waste sent for disposal in 2020 assumed to be 79.29% of the total waste generated (including composting rejects).
- **Degradable Organic Carbon (DOC) -** DOC value for each of the constituent degradable fractions of waste has been calculated using the default DOC content from 2006 IPCC Guidelines. Waste characterization Patna city (Singh & Raj, 2018) was utilized as the State urban representative number for the period 2016-2020 (source: Singh, A. and Raj, P., 2018. Segregation of waste at source reduces the environmental hazards of municipal solid waste in Patna, India. Archives of Environmental Protection, 44(4)).

A detailed information on the assumptions used in the municipal solid waste related GHG emission estimation is provided at Annex 3.

2.3. 4B Biological treatment of solid waste

Biological treatment of solid waste involves composting and anaerobic digestion of organic waste, such as food waste, garden (yard) and park waste and sludge. In the state of Bihar, composting is the only biological treatment option being used for waste management.

Composting is an aerobic process and a large fraction of the degradable organic carbon (DOC) in the waste material is converted into carbon dioxide (CO_2). CH_4 is formed in anaerobic sections of the compost, but it is oxidised to a large extent in the aerobic sections of the compost. Composting also produces N_2O emissions. Unmanaged or poorly working composts are likely to produce more both of CH_4 and N_2O. The emissions from biological treatment of municipal waste (composting) were estimated by following the below mentioned approach:

- GHG emissions from biological treatment of solid waste (composting) was estimated using the data collected on the amount and type of solid waste which is treated biologically.
- For composting emission estimates, Tier 1 approach was used.
- The emissions from composting, and anaerobic digestion in biogas facilities, will depend on factors such as type of waste composted, amount and type of supporting material (such as wood chips) used, temperature, moisture content and aeration during the process. In our approach, IPCC default emission factors were utilised.

Key parameters for CH_4 emission estimation:
- Mi = mass of organic waste treated by biological treatment type i, tonnes
- EF = emission factor for treatment i, g CH_4/kg waste treated
- i = composting or anaerobic digestion
- R = total amount of CH_4 recovered in inventory year, tonnes CH_4

Key parameters for N_2O emission estimation:
- Mi = mass of organic waste treated by biological treatment type i, tonne
- EF = emission factor for treatment i, g N_2O/kg waste treated
- i = composting or anaerobic digestion

Biological Treatment of Solid Waste (Composting) – Key parameters
- *Processing (composting) capacity* - For Bihar, waste processing data is available for only year 2020 (appx 60% of the waste generated in the State). Due to lack of robust year on year data for waste processing data and in consultation with BSPCB, total waste processing capacity addition is assumed to grow by around 5% every year. The processing data for previous years was hence back calculated using this assumption. Which provides following numbers - 2016 - 66.71 TPD, 2017 - 121.78TPD, 2018- 184.24TPD, 2019 - 464.52TPD, 2020- 625.68 TPD

A detailed information on the assumptions used in the biological treatment (composting) of municipal solid waste related GHG emission estimation is provided at Annex 3.

3. Quality Control (QC) and Quality Assurance (QA)

Internal quality control (QC) procedures applicable to the emission estimates include generic quality checks in terms of the calculations, processing, consistency, and clear recording and documentation as follows:

- The input activity data for each emission source sub-category were selected from that available in different datasets by duly factoring in its relative time-series consistency and temporal and spatial applicability.
- The input data in the calculation sheets were checked internally for transcription errors on a sample basis for all the three sub-sectors.
- The calculation spread sheets were checked for correct application of formulae, activity and factors and to ensure that calculations are correct. Manual calculations will be carried out for a part of the state emission estimates in all 3 sub-sectors to verify the spreadsheet results.

- The reporting document was checked to confirm all relevant references and secondary sources for activity data and emission factors have been included and cited along with web links in line with the platform's citation policy.
- Emission source categories and sub-categories included and excluded in the emission estimates have been transparently reported in this report. Any known gaps in the state emission estimates along with the rationale of assumptions used to address data gaps have been clearly indicated for each of the sub-sectors in the final report.

Data Verification and Validation - This was undertaken through a two-pronged approach – Local level and State level. At local level, ICLEI team collected and cross verified waste related data and assumptions made to develop the inventory. As part of the field verification, the team visited urban centre and rural areas to collect information on few foundational calculation assumptions such as per capita MSW waste generation, waste characterisation, domestic wastewater characteristics, etc.

At State Level, the collected data, both from primary/secondary sources and field visits were shared with the DEFCC/BSPCB/PMU for inputs. Based on the discussion, final waste sector baseline data was utilised for the emissions estimates.

Once the draft emission estimates and methodology notes are prepared, these were shared with relevant stakeholders and the BSPCB during the 1st consultation process for peer review and feedback. The inputs provided during this stakeholder consultation was used to revise, improve and finalise the GHG emissions inventory.

4. General assessment of completeness

Emissions from the source category '4C Incineration and open burning of waste' was not included in the GHG estimates subject to availability of reliable and robust data for these sources.

Emissions from source category '4A Solid waste disposal' is typically limited to disposal of municipal solid waste in urban areas in this type of State level assessment. Given the lack of solid waste management systems in rural areas, a majority of the solid waste in rural areas does not decompose under controlled/semi-controlled anaerobic conditions and thereby does not contribute to significant GHG emissions.

Further, most of the solid waste disposal sites across Bihar are not scientifically constructed and are inadequately managed as per national government guidance. The sites are also observed to be shallow[10] in general. Therefore, the emission estimates account for the source category '4A2: Unmanaged waste disposal sites', which is deemed applicable for Bihar, like most of the states in India.

Possible emissions from industrial waste and other waste such as clinical waste and hazardous waste considered under this source category were not included, as there was no published information from reliable sources on the generation and management of these solid waste streams in the state is available.

With regard to the industrial wastewater estimates, 16 industry sectors having significant organic load in their effluent and thereby generating significant GHG emission will be included. These sectors were identified based on stakeholder meetings (Department of Industries, BIADA, and BSPCB), secondary

[10] Unmanaged solid waste disposal sites having depths of less than 5 meters are classified as shallow as per IPCC 2006 Guidelines, Vol. 5, Chapter 3: Solid Waste disposal.
Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf

literature including India's National Communication reports, the 2006 IPCC guidelines for National GHG inventories, literature from NEERI and largely include the significant industrial wastewater related GHG emission sources in the Bihar State. Estimates for domestic wastewater cover both the urban as well as rural population in the state and are considered to sufficiently capture the relevant emission sources.

Emissions from manure (animal waste) management and biomass burning in croplands are not included in scope of this GHG estimation methodology. Since these are captured in Agriculture, Forestry and Other Land Use (AFOLU) sector emissions, as prescribed by IPCC 2006 guidelines.

5. Trends and analysis of GHG emissions from Waste Sector

5.1. Overview of the sector

Emission estimates for the waste sector are provided below for the base year (2016) and the reporting year (2020):

Table 2: Aggregated GHG emission estimates for the Waste sector for 2016 and 2020

IPCC ID	Source Category	GHG Emission (Million tonnes of CO_2e) based on Global Warming Potential values from IPCC Second Assessment Report (SAR)[11]		
		2016	**2020**	**Percent change (2016-2020)**
4	**Waste**			
4A	**Solid Waste Disposal**	**0.26**	**0.34**	**32.3%**
4A2	Unmanaged Waste Disposal Sites	0.26	0.34	32.3%
4B	**Biological Treatment of waste**	**0.004**	**0.036**	**838%**
4D	**Wastewater Treatment and Discharge**	**6.40**	**7.83**	**22.40%**
4D1	Domestic Wastewater Treatment and Discharge	6.25	6.69	7.1%
4D2	Industrial Wastewater Treatment and Discharge	0.15	1.14	652.9%

- The total aggregated GHG emissions from the Waste sector in Bihar in the year 2020 are estimated to be 8.20 million tonnes of CO_2e, representing an increase of 23.2% (or 6.66 million tonnes of CO_2e) from 2016.
- GHG emissions from domestic wastewater treatment and discharge emissions grew by 7.1% (or 0.45 million tonnes of CO_2e) to 6.69 million tonnes of CO_2e in 2020 from 6.25 million tonnes of CO_2e in 2016.
- GHG emissions from industrial wastewater treatment and discharge in 2020 is estimated to be 1.14 million tonnes of CO_2e. Industrial wastewater-related emissions increased at the rate of 49.7% CAGR between 2016 to 2020.
- The contribution of solid waste disposal and biological treatment of waste to GHG emission is estimated to be around 0.38 million tonnes of CO_2e in the year 2020. Emissions from solid waste disposal and treatment have increased at 7.6% CAGR from the base year 2016.

[11] 100-year GWP values specified for the 3 GHGs considered for the Waste Sector are CO_2: 1, CH_4: 21, N_2O: 310 as per the IPCC Second Assessment Report, 1996, Technical Summary, Table 4.
Available at https://www.ipcc.ch/ipccreports/sar/wg_I/ipcc_sar_wg_I_full_report.pdf

5.2. Trend in aggregated GHG emissions

The treatment and discharge of domestic wastewater is the largest source of GHG emissions in Bihar's waste sector, contributing to 81.58% of the aggregated state-level emissions from the sector in 2020. With a share of 13.84% in 2020, industrial wastewater treatment and discharge was the second largest contributor to the total waste sector GHG emissions. Solid waste disposal and biological treatment accounted for remaining 4.58% of Bihar's cumulative waste sector GHG emissions in 2020.

From 2016 to 2020, GHG emissions from all three source categories portray an increasing trend with the total emissions from the waste sector rising at a CAGR of 4.26%. The trend of the overall aggregate emissions is observed to be quite steady.

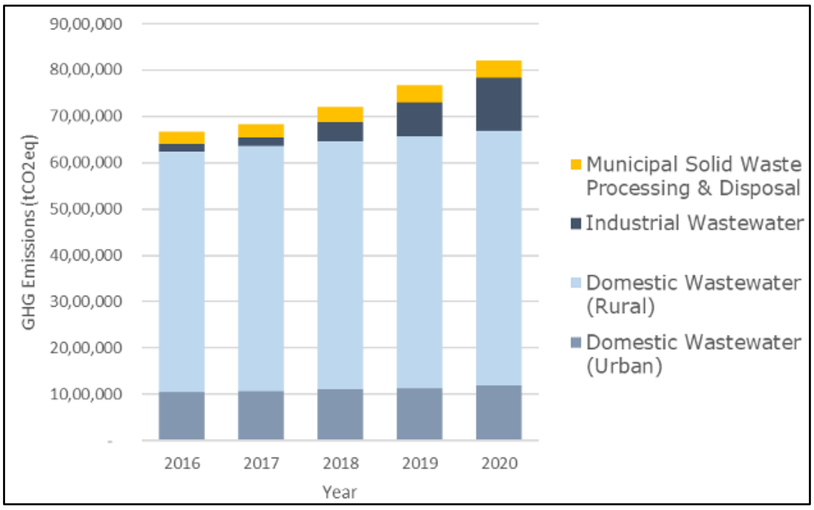

Figure 1: Trend of GHG Emissions from Waste Sector

The above graph shows a varying trend for the overall GHG emissions from the waste sector during the assessment period. The aggregated GHG emissions during the assessment period (2016-2020) increased from 6.66 million tonnes of CO_2e in 2016 to 8.20 million tonnes of CO_2e in 2020. A linear increasing trend can be observed for the aggregated sectoral emissions.

5.3. Trend in GHG emissions by type of GHG

The source categories covered in the assessment for the waste sector results in emissions of two GHGs, CH_4 and N_2O. CH_4 is the primary GHG emitted from the waste sector and accounts for 77% of the total cumulative emissions in 2020. The remaining 23% of the emissions were resulted from the emission of N_2O gas, which occurs due to the presence of protein content in domestic wastewater and from its disposal into waterways, lakes or seas.

The total CH_4 emissions from the waste sector in the year 2020 amounted to 6.29 million tonnes of CO_2e, while N_2O emissions amounted to 1.90 million tonnes of CO_2e. Between 2016 and 2020. This can be observed in Figure 2 below. CH_4 emissions from the waste sector increased with a CAGR of 5.2%, while N_2O emissions increased with a CAGR of 1.4%.

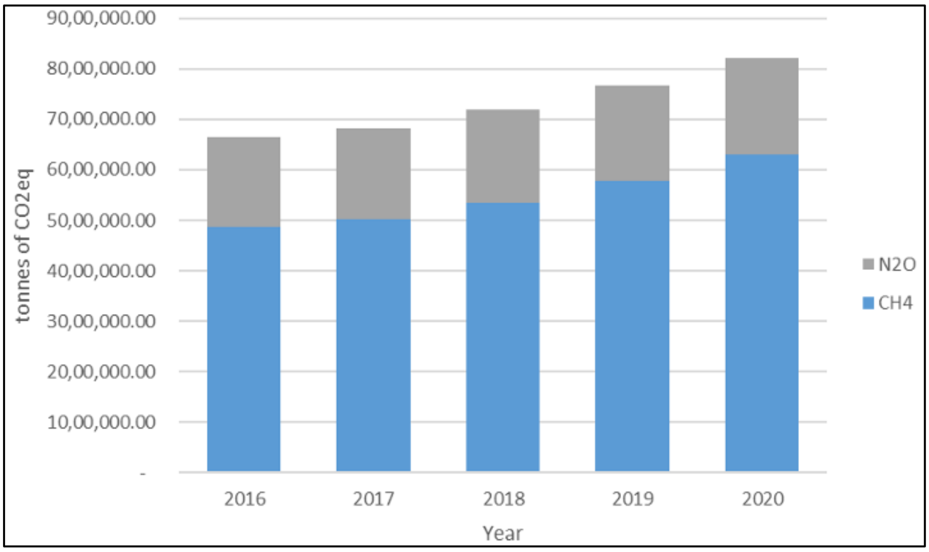

Figure 2: Trend of Gas-wise emissions estimates for Waste Sector, 2016-2020

5.4. Trend of GHG emissions from Source Categories

Table 3: Trend of GHG emission estimates by source categories

Source Category	Emissions in Million tonnes of CO_2e				
	2016	**2017**	**2018**	**2019**	**2020**
4. Waste	6.66	6.83	7.20	7.66	8.20
4A2. Unmanaged Waste Disposal Sites	0.26	0.28	0.31	0.33	0.34
4B Biological Treatment of waste	0.00386	0.00704	0.01065	0.02686	0.03617
4D1. Domestic Wastewater Treatment and Discharge	6.25	6.35	6.46	6.57	6.69
4D2. Industrial Wastewater Treatment and Discharge	0.15	0.18	0.42	0.74	1.14

5.4.1. 4A Solid Waste Disposal

GHG emissions from disposal of municipal solid waste is noticed to have increased steadily between 2016 and 2020. Solid waste disposal contributed to cumulative GHG emissions of 0.34 million tonnes of CO_2e in 2020, as against 0.26 million tonnes of CO_2e in 2016. The emissions from solid waste disposal grew at a CAGR of 5.8% from 2016 to 2020. Rising trends in GHG emissions are primarily due to changes in the total quantum of solid waste, its composition, and the method of disposal and characteristics related to the disposal site. In the short-term for the reporting period, the rise in solid waste disposal emissions is driven by increasing waste generation rates, growing population and inadequate levels of waste processing over the emission estimation period, resulting in a higher quantum of solid waste going to disposal sites.

5.4.2. 4B Biological treatment of solid waste

In 2020, biological treatment of solid waste (composting) contributed to GHG emissions of 0.036 million tCO2e, up from 0.00386 million tCO2e in 2016. During the same period, emissions from this source category increased at a CAGR of 56.5%. The primary reason for the significant increase can be attributed to increasing composting capacity addition across the State, especially in the urban areas. These installations have been mostly undertaken as part of Swacch Bharat Mission.

5.4.3. 4D1 Domestic Wastewater Treatment and Discharge

In 2020, domestic wastewater treatment and discharge contributed to GHG emissions of 6.69 million tCO_2e, up from 6.25 million tCO_2e in 2016. During the same period, emissions from this source category increased at a CAGR of 2.6%. The trend of GHG emissions from domestic wastewater discharge and treatment is shown in the figure below.

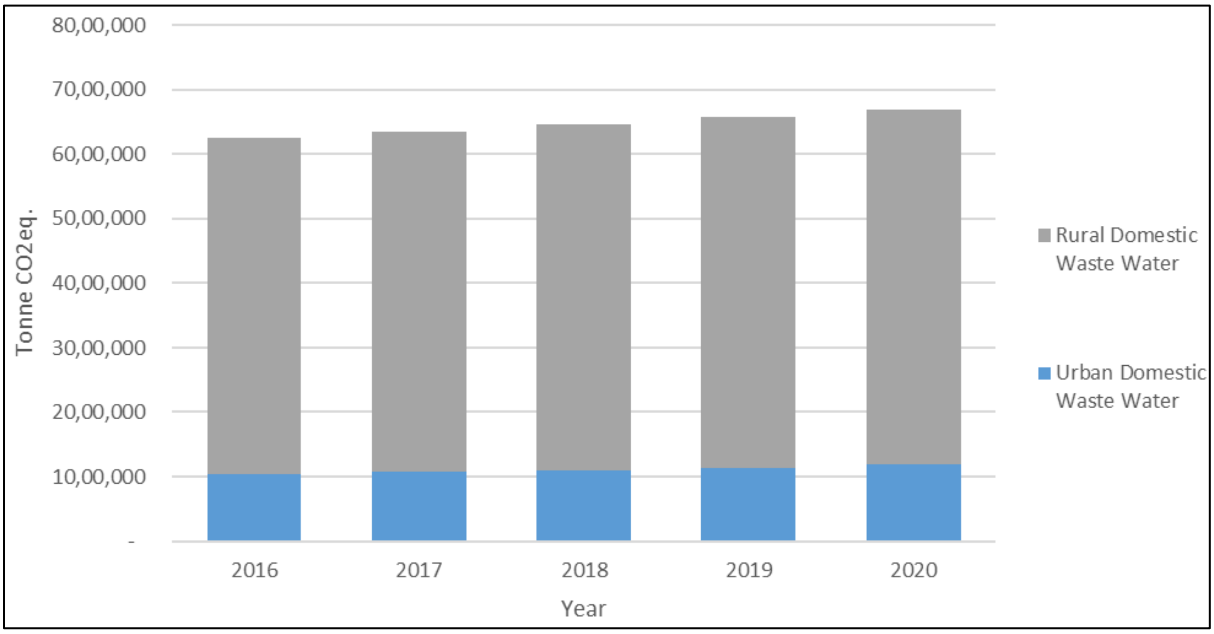

Figure 3: Trend of GHG Emissions from Domestic Wastewater Treatment and Discharge, 2016-2020

Emissions from rural domestic wastewater in 2020 contributed an estimated 82% of the state aggregate domestic wastewater emissions, while the urban domestic wastewater contributed the remaining 18%. CH_4 emissions from domestic wastewater are estimated to be substantially larger than N_2O emissions, accounting for 76.9% of the total GHG emissions. N2O emissions account for the remaining 23.1%.

Growth of domestic wastewater emissions is driven by increased volumes of wastewater to be treated in both urban and rural regions due to population growth. Dependence of the population on discharge/treatment systems with high GHG emission generation potential such as septic tanks, inadequately managed aerobic treatment plants, and untreated discharge of domestic wastewater is leading to higher emissions.

The rural population, however, accounted for 88.71% and 87.96% of the aggregated population of Bihar in the year 2011 and 2020 respectively. This corresponds to a significantly higher per capita emissions from urban areas. The per capita GHG emissions from domestic wastewater for the urban population in 2016 is estimated to have been 77.86 kg CO_2e/person, as compared to an estimated 51.65 kg CO_2e/person for the rural population. As a result, per capita GHG emissions from the urban household wastewater sector are approximately 50.75% greater in 2016, than the rural domestic wastewater sector.

5.4.4. 4D2 Industrial Wastewater Treatment and Discharge

GHG emissions estimates for industrial wastewater include 16 industrial sub-sectors, with potentially high wastewater generation including Fertilizers, Sugar, Petroleum, Dairy, Meat, Pulp & Paper, Rubber, Tannery, Fish Processing, Alcohol (breweries & distilleries), Parboiled rice, Vegetable & fruit processing, Soaps & detergents, Vegetable oils, Iron & steel and Coffee, were considered while estimating emission generation. Production activity in all 16 sectors results in the generation of wastewater with significant organic load and potential to release CH4 emissions, which is dependent on the type of wastewater treatment. The cumulative GHG emissions from industrial wastewater treatment and discharge has significantly increased from 0.15 million tonnes CO2e in 2016 to 1.14 million tonnes CO_2e in 2020, at a CAGR of 49.7%. The trend of industrial wastewater emissions can be seen in the figure below.

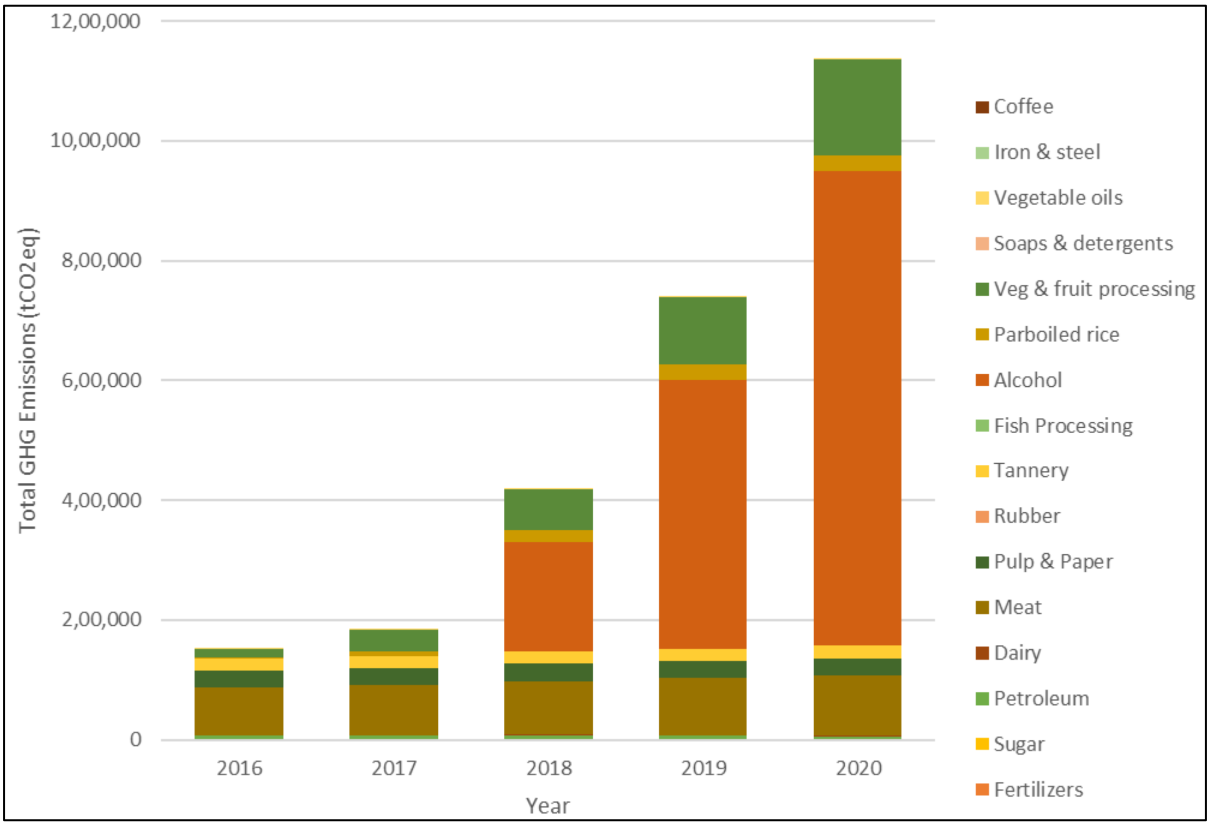

Figure 4: Trend of Industrial Wastewater Emissions, 2016-2020

As seen in the Figure above, distillery and breweries (70%) sub-sector emerged as the significant contributor in the industrial wastewater GHG emissions. This is primarily due to high organic load in the effluent discharged from distillery and breweries (The Indian BUR III report ascertains this to be 84 COD kg/m3). The other significant contributors were vegetable and fruits processing, meat industry, par-boiled rice (rice mills) and tanneries.

The growth in industrial wastewater-related emissions, which in turn stems from higher levels of industrial activity (i.e. Industrial production) across state. The sudden jump in the source category emissions from 2018 onwards is primarily due to availability of industrial production data (from 'Online Consent Management & Monitoring System").

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Annex 3:

Data Sources and Assumptions for Waste Sector GHG Emissions Inventory

IPCC ID	GHG source & sink categories	Data Sources
4A2	Unmanaged Waste Disposal Sites	• Urban Development & Housing Department (UD&HD), Government of Bihar • Bihar State Pollution Control Board (BSPCB) • Municipal Corporations, Bihar • SBM (Urban) Cell, Government of Bihar • Detailed project reports and literature for Bihar's cities • Central Pollution Control Board (CPCB) • National Environmental Engineering Research Institute (NEERI) • Central Public Health and Environmental Engineering Organization (CPHEEO) • IPCC 2006 Guidelines on national emission inventories
4B	Biological treatment of solid waste	• Urban Development & Housing Department (UD&HD), Government of Bihar • Bihar State Pollution Control Board (BSPCB) • Municipal Corporations, Bihar • SBM (Urban) Cell, Government of Bihar • Detailed project reports and literature for Bihar's cities • Central Pollution Control Board (CPCB) • National Environmental Engineering Research Institute (NEERI) • Central Public Health and Environmental Engineering Organization (CPHEEO) • IPCC 2006 Guidelines on national emission inventories
4D1	Domestic wastewater treatment and discharge	• Urban Development & Housing Department (UD&HD), Government of Bihar • Bihar State Water & Sanitation Mission (BSWSM) • Rural Development Department • Public Health Engineering Department (PHED), Government of Bihar • IPCC 2006 Guidelines on national emission inventories Central • Central Pollution Control Board (CPCB) • Census of India • National Sample Survey Office (NSSO)

IPCC ID	GHG source & sink categories	Data Sources
		• National Environmental Engineering Research Institute (NEERI)
4D1	Industrial wastewater treatment and discharge	• Department of Industries, Government of Bihar • Regional Office of Bihar State Pollution Control Board (SPCB) • Bihar Industrial Area Development Authority • Bihar Industries Association • Bihar State Water & Sanitation Mission (BSWSM) • Bihar Chamber of Commerce and Industries • Department of Fertilizers, Ministry of Chemicals and Fertilizers, Government of India • Directorate of Sugarcane Development, Ministry of Agriculture, Government of India • Department of Agriculture, Cooperation & Farmers Welfare, Ministry of Agriculture & Farmers Welfare, Government of India • Department of Animal Husban, Government of India dry, Dairying and Fisheries, Ministry of Agriculture • Central Pulp & Paper Research Institute (CPPRI) • Rubber Board, Ministry of Commerce and Industry, Government of India • Department of Industrial Policy and Promotion, Ministry of Commerce & Industry, Government of India • National Environmental Engineering Research Institute (NEERI) • IPCC 2006 Guidelines on national emission inventories

Data sources and Assumptions

Solid Waste Disposal

<table>
<tr><th>Methodological Approach</th><th>Source</th></tr>
<tr><td colspan="2">Solid Waste Disposal</td></tr>
<tr><td colspan="2" align="center">Activity Data</td></tr>
<tr><td colspan="2">Urban Population</td></tr>
<tr><td>As projected for years (2016-2020). The census exercise uses Cohort Component Method for making population projections based on fertility, mortality and migration rates.</td><td>Census of India, Population Projections for India and States 2011 – 2036 - Report of The Technical Group on Population Projections (https://nhm.gov.in/New_Updates_2018/Report_Population_Projection_2019.pdf)</td></tr>
<tr><td colspan="2">Mass of Waste deposited (W)</td></tr>
<tr><td>The mass of MSW generated has been estimated using data on urban population and the per capita waste generation. The average proportion of waste going to disposal sites has been applied to calculate the mass of waste that is deposited in dumpsites.
a) Per capita waste generation:
● The per capita numbers have been back-calculated based on the per capita figure reported by BSPCB to CPCB in its annual report i.e. 0.333 kg/day/capita. Considered annual growth rate for the per capita waste generation across different time periods based on reported National-level values of urban per capita generation
b) Proportion of solid waste going to disposal site (%) – The proportion of waste going to waste disposal site is estimated by deducting the reported data on solid waste processed through treatment routes from the total quantum of waste generated. Reliable state-level information on quantity or proportion of</td><td>a) <u>Per capita waste generation</u>:
Decadal National Growth Rate - Per Capita Waste Generation
<table>
<tr><th>Year</th><th>Daily Per capita Waste generation (kg/day)</th></tr>
<tr><td>2016</td><td>0.317</td></tr>
<tr><td>2017</td><td>0.321</td></tr>
<tr><td>2018</td><td>0.325</td></tr>
<tr><td>2019</td><td>0.329</td></tr>
<tr><td>2020</td><td>0.333</td></tr>
</table>
Estimated Per Capita Waste Generation – Bihar
<table>
<tr><th>Year</th><th>Annual Growth rate</th></tr>
<tr><td>1951</td><td>1.1%</td></tr>
<tr><td>1961</td><td>1.0%</td></tr>
<tr><td>1971</td><td>1.5%</td></tr>
<tr><td>1981</td><td>0.7%</td></tr>
<tr><td>1991</td><td>1.2%</td></tr>
<tr><td>2005</td><td>1.2%</td></tr>
</table>
Source: Source: ICLEI South Asia Analysis based on CPCB and TERI Data (TERI (1998): Looking Back to</td></tr>
</table>

<table>
<tr><th colspan="2">Methodological Approach</th><th>Source</th></tr>
<tr><td colspan="2">waste going to landfills is not available for the 1965-2015 period. Therefore, between 1965-2015, it is assumed that 70% of the generated waste went to the landfill during this period, in consonance with the assumption for national-level estimates. In the national-level estimates done by CPCB in its 'Consolidated Annual Review Report on Implementation of Municipal Solid Wastes (Management and Handling) Rules 2000 & 2016', 70% of the generated waste is assumed to have gone to landfills during the 2005-15 period.</td><td>Think Ahead: Green India 2047; India's Second National Communication to the UNFCCC)
b) <u>Annual growth rate of per capita waste generation across different time periods</u>
● TERI (1998): Looking Back to Think Ahead: Green India 2047'

c) <u>Proportion of waste to disposal site:</u>
For Bihar, waste processing data is available for only year 2020 (appx 60% of the waste generated in the State). Due to lack of robust year on year data for waste processing data and in consultation with BSPCB, effective quantum of waste sent for disposal in 2020 assumed to be 79.29% of the total waste generated (including composting rejects - 25% of the rejects is assumed from the composting process.).
<table>
<tr><th>2016</th><th>2017</th><th>2018</th><th>2019</th><th>2020</th></tr>
<tr><td>95.22%</td><td>91.71%</td><td>87.46%</td><td>83.43%</td><td>79.29%</td></tr>
</table></td></tr>
<tr><td colspan="3">Emission Factors</td></tr>
<tr><td>DOC</td><td>● DOC values for the organic portion of the waste have been calculated using the IPCC default values for DOC content for the degradable fractions in waste (i.e. paper, rags, and compostable matter) and reported waste composition data across time periods.
● The waste composition reported for the years of 1971, 1995 and 2005 is assumed to be applicable for time periods of 1965-1994, 1995-2004, and 2005-15, respectively. For</td><td><u>Default DOC content:</u>
● 2006 IPCC Guidelines for National GHG Inventories, Vol. 5, Chapter 2: Waste Generation, Composition and Management Data, Table 2.5[2].
Waste composition from 1971 to 2005:
● Integrated Modeling of Solid Waste in India (March,1999) CREED Working Paper Series no 26 and CPCB, 1999
● CPCB and NEERI (2005), Table 2, pg. 3[3]
● CPHEEO Manual on Municipal Solid Waste Management-2016, Table 1.6[4]</td></tr>
</table>

[2] Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_2_Ch2_Waste_Data.pdf
[3] Available at https://www.cpcb.nic.in./uploads/MSW/Waste_generation_Composition.pdf?&page_id=waste-generation-composition
[4] Available at: http://cpheeo.gov.in/upload/uploadfiles/files/Part2.pdf

<table>
<tr><th colspan="2">Methodological Approach</th><th>Source</th></tr>
<tr><td></td><td>2016 onwards Patna city composition is used as a proxy.

Default DOC content values as per 2006 IPCC Guidelines:
<table>
<tr><th>Component</th><th>Default DOC content values (wet waste)[1]</th></tr>
<tr><td>Paper</td><td>40%</td></tr>
<tr><td>Rags</td><td>24%</td></tr>
<tr><td>Compostable Matter</td><td>15%</td></tr>
</table></td><td>d) Waste composition at the State level is not available (2016-2020). Therefore, the latest and reliable source data for Patna city was utilised as the State urban representative number. Source of the MSW composition numbers - Singh, A. and Raj, P., 2018. Segregation of waste at source reduces the environmental hazards of municipal solid waste in Patna, India. Archives of Environmental Protection, 44(4).</td></tr>
<tr><td>Fraction of DOC that decomposes</td><td>0.5</td><td>IPCC 2006 Guidelines, Vol. 5. Chapter 3: Solid Waste disposal, Equation 3.7[5]</td></tr>
<tr><td>Methane Correction Factor (MCF)</td><td>MCF value taken as 0.4 as applicable for unmanaged shallow solid waste disposal sites with depths of less than 5 meters</td><td>IPCC 2006 Guidelines, Vol. 5. Chapter 3: Solid Waste disposal, Table 3.1[19]</td></tr>
<tr><td>Fraction of CH_4 in generated landfill gas (F)</td><td>0.5</td><td>IPCC 2006 Guidelines, Vol. 5. Chapter 3: Solid Waste disposal, Page 3.15[19]</td></tr>
</table>

[1] As per 2006 IPCC Guidelines for National GHG Inventories, Vol. 5, Chapter 2: Waste Generation, Composition and Management Data, Table 2.5. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_2_Ch2_Waste_Data.pdf

[5] Available at: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf

Methodological Approach		Source
Oxidation factor (OX)	0	IPCC 2006 Guidelines, Vol. 5. Chapter 3: Solid Waste disposal, Table 3.2[19]
Methane Recovery (R)	0	IPCC 2006 Guidelines, Vol. 5. Chapter 3: Solid Waste disposal, Section 3.2.3[19]
Reaction constant (k)	0.84	IPCC 2006 Guidelines, Vol. 5. Chapter 3: Solid Waste disposal, Table 3.3[19]

Domestic Wastewater Treatment and Discharge

Activity Data/Emission Factor Parameter	Methodological Approach	Source
Domestic Wastewater Treatment and Discharge		
Activity data		
State population (P)	• Estimated on the basis of population figures and decadal population growth rates as per Census of India's Report - Population Projections for India and States 2011 – 2036 - Report of The Technical Group on Population Projections. • The exercise uses Cohort Component Method for making population projections based on fertility, mortality and migration rates.	Census of India, Ministry of Home Affairs, Government of India[6]
Per capita biological oxygen demand	• Per capita BOD values for Bihar was not available. The national-level per capita BOD values are used.	MoEFCC. (2021). India: Third Biennial Update Report to the United Nations Framework Convention on

[6] Available at: https://nhm.gov.in/New_Updates_2018/Report_Population_Projection_2019.pdf

<table>
<tr><th>Activity Data/Emission Factor Parameter</th><th>Methodological Approach</th><th>Source</th></tr>
<tr><td colspan="3">Domestic Wastewater Treatment and Discharge</td></tr>
<tr><td>(BOD) in inventory year, g/person/day</td><td>● The value of Biochemical Oxygen Demand (BOD) is taken to be 45 gm per capita per day from ENVIS (Environmental Information System) Centre on Hygiene, Sanitation, Sewage Treatment Systems and Technology.
● Per capita BOD value is assumed to be constant for the reporting period, due to lack of published year-on-year data.</td><td>Climate Change. Ministry of Environment, Forest and Climate Change, Government of India.</td></tr>
<tr><td>Degree of utilization of treatment/ discharge pathway or system, j, for each income group fraction i (Ti,j)</td><td>● Relates to the proportion of resident population using different wastewater treatment/discharge pathways or systems.
● The treatment/discharge pathways or systems are broadly classified by the 2006 IPCC Guidelines into septic tank, sewer, latrine, others and none.[7]

● The degree of utilization of treatment/discharge pathway or system is based on the latrine facility dataset, Census of India (2011), MoHUA's Handbook of Urban Statistics and State level data from National Mission for Clean Ganga program.
● Sewage Treatment Plant (STP): The STP capacity that is operational in the GHG emissions estimation period (2016-20) is identified from BSPCB and STP performance evaluation reports. Based on the technology, the aerobic and anaerobic categorization of STP is done. The STPs that are installed and not operational are considered to be 'collected and not treated'. These values (aerobic STP percent, anaerobic STP percent and collected and not treated) are estimated for the years 2016-2020. The corresponding percentage is multiplied with 'piped sewer' to estimate the emissions from individual discharge pathways.

Rural:</td><td>● 2006 IPCC Guidelines, Vol. 5, Chapter 6: Wastewater Treatment and Discharge, Table 6.5
● Census of India – Availability and type of latrine facility: 2001 – 2011 (For Urban and Rural data)
<table>
<tr><th>Treatment/ discharge type</th><th colspan="5">Share of urban population using treatment/ Discharge pathway or system (%)*</th></tr>
<tr><th></th><th>2016</th><th>2017</th><th>2018</th><th>2019</th><th>2020</th></tr>
<tr><td>Latrine</td><td>5.09%</td><td>6.26%</td><td>7.69%</td><td>9.45%</td><td>11.61%</td></tr>
<tr><td>Public Latrine</td><td>0.00%</td><td>0.14%</td><td>0.28%</td><td>0.42%</td><td>0.56%</td></tr>
<tr><td>Sewer</td><td>8.12%</td><td>8.77%</td><td>9.47%</td><td>10.23%</td><td>11.05%</td></tr>
<tr><td>Septic Tank</td><td>59.46%</td><td>60.80%</td><td>62.17%</td><td>63.56%</td><td>64.99%</td></tr>
<tr><td>Sewer</td><td>8.12%</td><td>8.77%</td><td>9.47%</td><td>10.23%</td><td>11.05%</td></tr>
</table>
● Ministry of Housing and Urban Affairs (MoHUA), Government of India (2019), Handbook of Urban Statistics[10]
● State level data from National Mission for Clean Ganga program in discussion with officials of Department of Urban Development and Housing Department

Sewage Treatment Plant data</td></tr>
</table>

[7] Available at table 6.5 of 2006 IPCC Guidelines, Vol. 5, Chapter 6: Wastewater Treatment and Discharge
[10] https://mohua.gov.in/pdf/5c80e2225a124Handbook%20of%20Urban%20Statistics%202019.pdf

<table>
<tr><th>Activity Data/Emission Factor Parameter</th><th>Methodological Approach</th><th>Source</th></tr>
<tr><td colspan="3">Domestic Wastewater Treatment and Discharge</td></tr>
<tr><td></td><td>The degree of utilization of treatment/discharge pathway or system for rural Bihar is based on the NSSO survey, Annual Rural Sanitation Survey (2019[8] & 2020[9]), Lohia Swacch Bihar Abhiyan.

Piped sewer:

Wastewater treatment facilities are largely absent in rural areas. The rural wastewater that is collected through the sewer network largely does not undergo any treatment downstream of the sewer network. Therefore, the portion of rural domestic wastewater that is collected and conveyed through the sewer network is assumed to not undergo any treatment and decomposes under aerobic conditions, thereby not leading to CH_4 emissions.</td><td><table>
<tr><th>STP Location</th><th>STP Commissioned in (Year)</th><th>STP Installed Capacity MLD</th><th>Technology (UASB /ASP / OP /SBR /MBR/FAB Etc.)</th><th>Aerobic/Anaerobic</th><th>Status</th><th>STP Operational Capacity MLD</th></tr>
<tr><td>Saidpur</td><td>2021</td><td>60</td><td>SBR</td><td>Aerobic</td><td>Operational</td><td>40</td></tr>
<tr><td>Beur</td><td>2020</td><td>43</td><td>SBR</td><td>Aerobic</td><td>Operational</td><td>10</td></tr>
<tr><td>Karmalichak</td><td>2020</td><td>37</td><td>SBR</td><td>Aerobic</td><td>Operational</td><td>37</td></tr>
<tr><td>Pahari</td><td>2021</td><td>0</td><td>SBR</td><td>Aerobic</td><td>Operational</td><td>0</td></tr>
</table>
Degree of utilization of treatment/discharge pathway or system – Rural
<table>
<tr><th>Treatment/ discharge type</th><th>Share of rural population using treatment/ Discharge pathway or system 2016 - 2020 (%)**</th></tr>
<tr><td>Latrine</td><td>62.17%</td></tr>
<tr><td>Public Latrine</td><td>0.00%</td></tr>
<tr><td>Others/None</td><td>17.33%</td></tr>
<tr><td>Septic Tank</td><td>19.30%</td></tr>
<tr><td>Sewer</td><td>1.20%</td></tr>
</table></td></tr>
<tr><td>Fraction of population in income group i (Ui)</td><td>The values of fraction of population in the income group (i.e. fraction of urban and rural population) have been sourced from Census of India's Report - Population Projections for India and States 2011 – 2036 - Report of The Technical Group on Population Projections.</td><td>Census of India, Ministry of Home Affairs, Government of India[11]</td></tr>
</table>

[8] https://jalshakti-ddws.gov.in/sites/default/files/National_Report_NARSS_2018_19.pdf
[9] https://jalshakti-ddws.gov.in/sites/default/files/NARSS_Round_3_2019_20_Report.pdf
[11] Available at: https://nhm.gov.in/New_Updates_2018/Report_Population_Projection_2019.pdf

<table>
<tr><th>Activity Data/Emission Factor Parameter</th><th>Methodological Approach</th><th>Source</th></tr>
<tr><td colspan="3">Domestic Wastewater Treatment and Discharge</td></tr>
<tr><td>Organic Component removed as sludge, kg BOD/year (BOD)</td><td>0</td><td>2006 IPCC Guidelines, Vol. 5, Chapter 6: Wastewater Treatment and Discharge, Equation 6.1[12].</td></tr>
<tr><td>Correction factor for additional industrial BOD discharged into sewers (I)</td><td>• Based on the 2006 IPCC Guidelines, the default values of "I", for collected and uncollected wastewater, have been used for both urban and rural assessment.
<table><tr><th>"I" for Collected Wastewater</th><th>"I" for Uncollected Wastewater</th></tr><tr><td>1.25</td><td>1</td></tr></table></td><td>2006 IPCC Guidelines, Vol. 5, Chapter 6 - Wastewater treatment and discharge, Equation 6.3[32]</td></tr>
<tr><td>Amount of CH_4 recovered in inventory year (R)</td><td>0</td><td>2006 IPCC Guidelines, Vol. 5, Chapter 6: Wastewater Treatment and Discharge, equation 6.1[32]</td></tr>
<tr><td>Annual per capita protein consumption, kg/person/year</td><td>• The values for per capita protein consumption for both urban and rural population have been sourced from the National Sample Survey Office (NSSO) reports on nutritional intake in India 2011-12.

• As the updated year-wise values of per capita protein consumption are not available for urban and rural population, therefore, the available values based on NSSO surveys in 2011-12 have been used[13].</td><td><table><tr><th rowspan="2">State</th><th colspan="2">Protein Intake (kg/person/yr.) 2016-2020, NSSO Report</th></tr><tr><th>Urban</th><th>Rural</th></tr><tr><td>Bihar</td><td>22.23</td><td>22.96</td></tr></table></td></tr>
</table>

[12] Available at: https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf
[13] Available at - https://pib.gov.in/newsite/PrintRelease.aspx?relid=116953

Activity Data/Emission Factor Parameter	Methodological Approach	Source
Domestic Wastewater Treatment and Discharge		
Emission factors		
Maximum CH_4 producing capacity, kg CH4/kg BOD (Bo)	0.6	2006 IPCC Guidelines, Vol. 5, Chapter 6 - Wastewater treatment and discharge, Table 6.2[32].
Methane correction factor (MCF_j)	<u>The following assumptions have been made:</u> ● The portion of urban wastewater that is collected in sewers but is untreated can be handled through 'stagnant sewers' or be discharged into water bodies such as 'sea, lake or river'. The quantity of this untreated wastewater that is discharged into water bodies is unknown and, therefore, the entire portion of collected and untreated urban wastewater is accounted under 'stagnant sewer'. ● Wastewater generated in rural areas is not handled or treated in any way and decomposes under aerobic conditions[14]. Thus, the proportion of rural wastewater that is collected and conveyed through sewer systems is also assumed to not undergo any treatment downstream and decomposes under aerobic conditions, thereby not leading to CH_4 emissions. Thus, the 'flowing sewer' system has MCF value as '0'. ● Rural wastewater that is uncollected and untreated can be either discharged into 'sea, lake or river' or 'to ground'. However, as the quantity of wastewater that is discharged 'to ground' is unknown and, therefore, the entire portion of uncollected and untreated rural wastewater is accounted under 'sea, lake or river discharge'.	2006 IPCC Guidelines, Vol. 5, Chapter 6: Wastewater treatment and discharge, Table 6.3[32].

[14] India's Second National Communication. Available at: https://unfccc.int/resource/docs/natc/indnc2.pdf

<table>
<tr><th>Activity Data/Emission Factor Parameter</th><th>Methodological Approach</th><th>Source</th></tr>
<tr><td colspan="3">Domestic Wastewater Treatment and Discharge</td></tr>
<tr><td></td><td>
<table>
<tr><th>Treatment/ discharge pathway or system (j)</th><th>MCF_j</th></tr>
<tr><td>Anaerobic reactor</td><td>0.80</td></tr>
<tr><td>"Centralized, aerobic treatment plant, I not well managed, overloaded)"</td><td>0.30</td></tr>
<tr><td>"Centralized, aerobic treatment plant well managed"</td><td>0.00</td></tr>
<tr><td>Stagnant sewer</td><td>0.50</td></tr>
<tr><td>Sea Lake or river discharge</td><td>0.10</td></tr>
<tr><td>Flowing sewer (open/closed)</td><td>0.00</td></tr>
<tr><td>Septic system</td><td>0.50</td></tr>
<tr><td>Latrine - Dry climate, groundwater table lower than latrine, communal (many users)</td><td>0.50</td></tr>
<tr><td>Latrine (dry climate, groundwater table lower than latrine, small family (3-5 members))</td><td>0.10</td></tr>
</table>
</td><td></td></tr>
<tr><td>Fraction of nitrogen in protein (F_{NPR})</td><td>0.16</td><td>2006 IPCC Guidelines, Vol. 5, Chapter 6: Wastewater Treatment and Discharge, equation 6.8 and table 6.11[32].</td></tr>
<tr><td>Factor for non-consumed protein added to the</td><td>1.4</td><td>2006 IPCC Guidelines, Vol. 5, Chapter 6: Wastewater Treatment and Discharge, table 6.11[32].</td></tr>
</table>

Activity Data/Emission Factor Parameter	Methodological Approach	Source
Domestic Wastewater Treatment and Discharge		
wastewater ($F_{NON-CON}$)		
Factor for industrial and commercial co-discharged protein into the sewer system ($F_{IND-COM}$)	1.25	2006 IPCC Guidelines, Vol. 5, Chapter 6: Wastewater Treatment and Discharge, table 6.11[32].
Nitrogen removed with sludge (N_{SLUDGE})	0	2006 IPCC Guidelines, Vol. 5, Chapter 6: Wastewater Treatment and Discharge, equation 6.8[32].

Data Sources and Assumptions for Industrial Wastewater Treatment and Discharge

Activity Data/Emission Factor Parameter	Methodological Approach	Source
Industrial Wastewater Treatment and Discharge		
Activity Data		
Industrial Production (Pi)	Production datasets available on financial year basis have been converted to calendar year datasets for a given calendar year by considering 3/4th of the value from the previous financial year (corresponding to 9 months from April to December out of 12 months in a year) and 1/4th from the next financial year (corresponding to 3 months from January to March out of 12 months in a year). **Fertilizers** ● There are no operational fertilizer plants in Bihar, as of now. Hindustan Fertilizer Corporation Ltd. (HFCL) in Barauni is being revived and is expected to be operational in 2022. **Sugar** ● State-wise data on sugar production for years 2016-2020 has been sourced from data complied from Indian Sugar Mills Association **Petroleum**	**Fertilizers** Department of Fertilizers, Ministry of Chemicals and Fertilizers, Government of India, fertilizer Scenario - 2018[15] **Sugar** Year on year production data available at - Indian Sugar Mills Association/Chinimandi website - https://www.chinimandi.com/statistics/statewise-sugar-production-in-india/ **Petroleum:** ● Petroleum Planning and Analysis Cell (PPAC), Ministry of Petroleum and Natural Gas – Production of Petroleum Products[16][17]

[15] Available at: https://www.fert.nic.in/sites/default/files/2019-09/Fertilizers-Scenario-2018.pdf
[16] Available at: http://www.ppac.org.in/WriteReadData/userfiles/file/PT_production_source_H.xls http://www.ppac.org.in/WriteReadData/userfiles/file/PT_production_source_H.xls
[17] Available at: http://www.ppac.org.in/WriteReadData/userfiles/file/PT_crude_H.xls

Activity Data/Emission Factor Parameter	Methodological Approach	Source
	• As the data on production of petroleum products is not available, hence, national-level data on the production of petroleum products has been apportioned, based on corresponding proportions of 'Total volume of Crude Oil processed' by refineries located in the state. **Dairy** • Industrial production data has been compiled from the Bihar Pollution Control Board's "Online Consent Management & Monitoring System" account. The website is hosted by Ministry of Environment, Forest and Climate Change, Government of India. The excel database was downloaded and dairy processing industries were sorted and their production capacities (year on year basis) was estimated. The database list includes industries categorized in two categories - Consent to establish and consent to operate. The calculations estimate production capacity for industries which have received 'consent to operate'. **Meat Industry** • Meat production data has been sourced from Handbook of Statistics on Indian States, published by the Reserve Bank of India. The publication provides data till 2018-19. For the	**Meat:** • State-wise Meat Production, Handbook of Statistics on Indian States, Reserve Bank of India[18] **Rubber:** • Statistics and Planning Department, Rubber Board[19] **Tannery** • Food and Agriculture Organization (FAO)- World Statistical Compendium for raw hides and skins, leather and leather footwear 1999-2015, Table 5, Table 7, Table:9[20] • Handbook of Industrial Policy and Statistics 2008-09, Table 14.2-Table 14.36, Department of Industrial Policy and Promotion, Ministry of Commerce and Industry[21]

18 Available at: https://www.rbi.org.in/Scripts/PublicationsView.aspx?id=20742
19 http://www.rbegp.in/RUBI/LicensingReportsInIndex.do?licensetypepk=1&statepk=0&districtpk=0
20 Available at: http://www.fao.org/3/a-i5599e.pdf
21 Available at: https://eaindustry.nic.in/industrial_handbook_200809.pdf

Activity Data/Emission Factor Parameter	Methodological Approach	Source
	remaining years average annual growth rate of previous years was used to extrapolate the data. **Fish Processing** There are no fish processing facility in Bihar. Information source table 1.5 of Handbook of Fisheries Statistics and BSPCB 'CTO' database. **Pulp & Paper** Industrial production data has been compiled from the Bihar Pollution Control Board's "Online Consent Management & Monitoring System" account. The website is hosted by Ministry of Environment, Forest and Climate Change, Government of India. The excel database was downloaded and paper and pulp industrial units were sorted and their production capacities (year on year basis) was estimated. The database list includes industries categorised in two categories - Consent to establish and consent to operate. The calculations estimate production capacity for industries which have received 'consent to operate'. For Bihar, based on the above mentioned criteria, there is only one paper mill operational in the State. Yearly production values were not available, hence production capacity is taken as the proxy for total production across the years (Indira Paper Mill Private Limited, Patna, 25 MT/day capacity). **Rubber**	

Activity Data/Emission Factor Parameter	Methodological Approach	Source
	Total production data has been sourced from List of Manufacturers available on the Rubber Board's website. The website provides list of licensed manufacturers in the Bihar State along with their production capacities. The licences are provided for every 5 years. The data provided is from 2018 onwards. To cross check the previous year data, year of establishment for manufacturing units were cross checked on the internet. Based on this analysis, it is assumed that production capacities (mentioned on the website) were also valid for 2016 & 2017. **<u>Tannery</u>** ● Tannery Production data is not available for the period 2016 to 2020. The projected production figure is based on the annual average growth rate of tannery production between 2005 and 2015. ● State-wise data on leather processed by states not available. National-level data available on cumulative production of bovine, sheep, lamb, goat and kid skins and hides has been apportioned to each of the states based on the available data for year 2005-06 on corresponding 'Gross Value Added' by the tannery sector. Data on the number of tannery factories is available; however, the data on corresponding 'production or installed capacities' is not known for these tanneries. Hence, 'Gross Value Added' is gauged to be a more appropriate metric to represent the manufacturing activity in the tannery sector for each state and has been used as a basis for apportionment. Data on 'Gross Value Added' is available only for 2005-06, and has been used across the reporting period for apportionment of national production data.	

Activity Data/Emission Factor Parameter	Methodological Approach	Source
	Breweries and Distilleries Industrial production data has been compiled from the Bihar Pollution Control Board's "Online Consent Management & Monitoring System" account. The website is hosted by Ministry of Environment, Forest and Climate Change, Government of India. The excel database was downloaded and industrial units (breweries and distilleries) were sorted and their production capacities (year on year basis) was estimated. The database list includes industries categorised in two categories - Consent to establish and consent to operate. The calculations estimate production capacity for industries which have received 'consent to operate'. For Bihar, based on the above-mentioned criteria, yearly production values for 2017-18 and 2016-17 were not available, hence production capacity for these years were not considered. **Parboiled Rice** Industrial production data has been compiled from the Bihar Pollution Control Board's "Online Consent Management & Monitoring System" account. The website is hosted by Ministry of Environment, Forest and Climate Change, Government of India. The excel database was downloaded and industrial units (Parboiled Rice) were sorted and their production capacities (year on year basis) was estimated. The database list includes industries categorised in two categories - Consent to establish and consent to operate. The calculations estimate production capacity for industries which have received 'consent to operate'.	

Activity Data/Emission Factor Parameter	Methodological Approach	Source
	For Bihar, based on the above mentioned criteria, yearly production values for 2016-17 was not available, hence production capacity for it was back calculated based on the AAGR of the following years (with data). **<u>Vegetable and Fruits Processing</u>** Industrial production data has been compiled from the Bihar Pollution Control Board's "Online Consent Management & Monitoring System" account. The website is hosted by Ministry of Environment, Forest and Climate Change, Government of India. The excel database was downloaded and industrial units (Parboiled Rice) were sorted and their production capacities (year on year basis) was estimated. The database list includes industries categorised in two categories - Consent to establish and consent to operate. The calculations estimate production capacity for industries which have received 'consent to operate'. For Bihar, based on the above mentioned criteria, yearly production values for 2016-17 was not available, hence production capacity for it was back calculated based on the AAGR of the following years (with data). **<u>Soaps and Detergents</u>** Industrial production data has been compiled from the Bihar Pollution Control Board's "Online Consent Management & Monitoring System" account. The website is hosted by Ministry of Environment, Forest and Climate Change, Government of India. The excel database was downloaded and industrial units (Parboiled Rice) were sorted and their production capacities (year	

Activity Data/Emission Factor Parameter	Methodological Approach	Source
	on year basis) was estimated. The database list includes industries categorised in two categories - Consent to establish and consent to operate. The calculations estimate production capacity for industries which have received 'consent to operate'. For Bihar, based on the above mentioned criteria, yearly production values for 2016-17 was not available, hence production capacity for it was back calculated based on the AAGR of the following years (with data). **Vegetable Oils** Industrial production data has been compiled from the Bihar Pollution Control Board's "Online Consent Management & Monitoring System" account. The website is hosted by Ministry of Environment, Forest and Climate Change, Government of India. The excel database was downloaded and industrial units (Parboiled Rice) were sorted and their production capacities (year on year basis) was estimated. The database list includes industries categorised in two categories - Consent to establish and consent to operate. The calculations estimate production capacity for industries which have received 'consent to operate'. For Bihar, based on the above mentioned criteria, yearly production values for 2016-17 was not available, hence production capacity for it was back calculated based on the AAGR of the following years (with data).	
Wastewater generated, m3 /t product (Wi)	• Constant values of wastewater generated per tonne of product have been used for all the years (2016-2020) for all industry sectors due to lack of year-on-year information.	India's Third Biennial Update Report to UNFCCC (BUR 3), Table 2.31[4].

Activity Data/Emission Factor Parameter	Methodological Approach	Source
Chemical oxygen demand (CODi)	• Constant values of chemical oxygen demand (CODi) have been used for all the years (2016-2020) for all industry sectors due to lack of year-on-year information	India's Third Biennial Update Report to UNFCCC (BUR 3), Table 2.31[4].
Organic component removed as sludge (Si)	0.35	2006 IPCC Guidelines, Vol. 5, Chapter 6: Wastewater Treatment and Discharge, Equation Number 6.4[22].
Amount of CH_4 recovered (Ri)	0	2006 IPCC Guidelines, Vol. 5, Chapter 6: Wastewater Treatment and Discharge, Equation Number 6.4[99].
Emission Factors		
Methane correction factor (MCFj)	• Constant values of methane correction factor (MCFj) have been used for all the years (2016-2020) for all industry sectors due to lack of year-on-year information	India's Third Biennial Update Report to UNFCCC (BUR 3), Table 2.31[4].
Maximum CH_4 producing capacity (Bo)	0.25	2006 IPCC Guidelines, Vol. 5, Chapter 6: Wastewater Treatment and Discharge, Equation Number 6.5[99]

[22] Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf

Annex 4 :
List of Core and Enabling Actions

Local Governments
for Sustainability
SOUTH ASIA

For Domestic Wastewater

Actions	Jurisdiction	Key Stakeholders	Mitigation Potential	Mitigation Potential (Unit)	Carbon Credit	Ballpark CAPEX	Ballpark OPEX	Potential Funding	Linkage to SDGs	Reference
Infrastructure and Service Provision: Core Actions										
Achieve state wide access to scientific, universal, and economical toilets										
Construction of toilets	Urban and Rural	ULBs, BUD&HD, BIDA GPs, BPIU, DWSC, RDD			For biogas linked public or community toilets	Rs. 0.02 million for IHHL (SBM Urban Guidelines) Rs. 0.065 million per seat for CT Rs. 0.075 Million per seat for PT Rs. 0.095 Million for 5 seat Brick Masonary (200 users) Rs. 0.18 Million for 10 seat Brick Masonary (400 users) Bio Digester Tank 10 KLD for every 200 users- Rs. 0.174 Million		SBM 2.0 both urban and Grameen, 15th FC, 7 Nishchay 2 (SNY, LSBA), CSR and other grants from international donor agencies, private funding mode for CT/PT	SDG 6.2, 13.2	SBM U 2.0 Operational Guidelines
Retrofit toilets	Urban and Rural	ULBs, BUD&HD, GPs, BPIU, DWSC, RDD			NA	Rs.0.005 Million per IHHL		local Govt. funding, CSR and other grants from international donor agencies,	SDG 6.2, 13.2	https://swachhbharatmission.gov.in/SBMCMS/writereaddata/portal/images/pdf/Advisory%20_on_funding_provision_on_retrofit_to_twin_pit_campaign.pdf
Strengthening safe collection and conveyance of wastewater to suitable treatment facility										
Expansion of centralised sewer network	Urban and Rural	ULBs, BUIDCO, BUD&HD, BIDA GPs, BPIU, DWSC, RDD			NA	Rs. 0.01 million/ capita		AMRUT 2.0, SBM U 2.0 (<1 lakh population), 15th FC, SCM, NMCG, private funding, loans from MDBs	SDG 6.2, 6.3, 13.2	https://icrier.org/pdf/FinalReport-hpec.pdf escalated by cost inflation index https://caclub.in/cost-inflation-index-notified-by-cbdt/
Maximise interception and diversion (I&D) of open drains	Urban	ULBs, BUIDCO, BUD&HD, BIDA			NA	Interception of Nala- Rs. 6 to 10 Million (depending on size of Nala Diversion of Nala- Rs. 0.05 Million/Km	-		SDG 6.3, 13.2	State Mission for Clean Ganga- Uttar Pradesh- Minutes of Meeting- 6th Meeting of NMCG Executive Committee
Maximise treatment and reuse of treated wastewater and faecal sludge and septage by adopting efficient and scientific treatment technology with suitable methane capture mechanism and use of alternative energy source wherever feasible										
Strengthen and ensure operation and maintenance of aerobic technology based STPs	Urban	ULBs, BUIDCO, BUD&HD, STP operators	200.62	tonnes of CO_2e/MLD by optimising efficiency of aerobic STP operation	NA	NA	Rs. 1.25 Million/year/MLD	for new STPs- covered as part of finance for setting up the facility for existing STPs- Local Govt. funding/ grants from international donor agencies also interlinked with monitoring and capacity building	SDG 6.3, 6.6, 13.2	Ready Reckoner on Municipal Used Water Treatment Technologies for Medium and Small Towns (SBM (U) 2.0 operational guidelines)

Actions	Jurisdiction	Key Stakeholders	Mitigation Potential	Mitigation Potential (Unit)	Carbon Credit	Ballpark CAPEX	Ballpark OPEX	Potential Funding	Linkage to SDGs	Reference
Enhance sewage treatment capacity to be able to process generated wastewater while focusing on anaerobic technology based secondary treatment with option of methane recovery	Urban and Rural	ULBs, BUIDCO, BUD&HD, BIDA GPs, BPIU, DWSC, RDD	1530.51	tonnes of CO_2e/MLD by integrating gas capture (100% recovery) with anaerobic system	For anaerobic STPs with methane capture mechanism	WSP: Rs. 3-6 Million/MLD Root Zone Aeration/ Constructed Wetland- Rs. 3-15 Million/MLD Extended Aeration- Rs. 9-20 Million/MLD Aerated Lagoon- Rs. 4-6 Million/MLD ASP: Rs. 8-17 Miillion/MLD SBR: Rs. 15-30 Million/MLD MBBR: Rs. 17-23 Million/MLD Trickling Filter- Rs. 5-8 Million/MLD UASB: Rs. 4-6 Million/MLD DEWATS: Rs. 8-20 Million/MLD - - - - - FAB: Rs. 22 Million/MLD MBR: Rs. 65 Million/MLD	All in per annum basis WSP: Rs.0.6- 0.25 Million/MLD Root Zone Aeration/ Constructed Wetland- Rs. 0.12-0.3 Million/MLD Extended Aeration- Rs. 0.7-1.2 Million/MLD Aerated Lagoon- Rs. 0.15-0.3 Million/MLD ASP: Rs. 0.6-1 Miillion/MLD SBR: Rs. 1-2 Million/MLD MBBR: Rs. 0.8-1.2 Million/MLD Trickling Filter- Rs. 0.2-0.5 Million/MLD UASB: Rs. 0.2-0.35 Million/MLD DEWATS: Rs. 0.2-0.25 Million/MLD - - - - FAB: Rs. 2.14 Million/MLD MBR: Rs. 4.2 Million/MLD	AMRUT 2.0, SBM U 2.0 (<1 lakh population), 15th FC, SCM, NMCG, private funding, loans from MDBs	SDG 6.3, 6.6, 13.2	Ready Reckoner on Municipal Used Water Treatment Technologies for Medium and Small Towns (SBM (U) 2.0 operational guidelines)- September 2022 - - - - - SBM Urban Advisory on Onsite and Offsite Sewage Management Practices- July 2020
Integrate faecal sludge cotreatment facility with both aerobic and anaerobic sewage treatment plants	Urban, and Urban Rural Linkage	ULBs, BUIDCO, BUD&HD, STP operators GPs, BPIU, DWSC, RDD			NA	Rs. 1 million/10 KLD	Rs. 0.01 Million/Month/10 KLD	for new STPs- covered as part of finance for setting up the facility for existing STPs- Local Govt. funding/ grants from international donor agencies	SDG 6.3, 6.6, 13.2	Ready Reckoner on Municipal Used Water Treatment Technologies for Medium and Small Towns (SBM (U) 2.0 operational guidelines)
Recommend establishment of faecal sludge treatment plants (FSTPs) at strategic locations across the state	Urban, and Urban-Rural Linkage	ULBs, BUIDCO, BUD&HD, BIDA GPs, BPIU, DWSC, RDD			For anaerobic FSTPs with methane capture mechanism	Rs. 11 Million for 6 KLD Plant at Devanahalli Rs. 24 million for 20 KLD plant at Phulera	Rs. 0.5 Million per Year for 6 KLD Plant at Devanahalli Rs. 0.7 Million per year for 20 KLD plant at Phulera	AMRUT 2.0, SBM U 2.0 (<1 lakh population), 15th FC, SCM, NMCG, SBM G 2.0, LSBA, private funding, loans from MDBs	SDG 6.3, 6.6, 13.2	Cost Analysis of Faecal Sludge Treatment Plants in India, NIUA, 2019
Deploy and integrate renewable energy (such as solar) to meet some part of energy demand of treatment plants	Urban	ULBs, BUIDCO, BUD&HD, STP/ FSTP operators, BREDA			For indirect GHG emissions mitigation	Capacity (KW)- Capital Cost up to 1 KW- 0.05 Mn Rs 1-2 KW- 0.047 Mn Rs 2-3 KW- 0.046 Mn Rs 3-10 KW- 0.045 Mn Rs 10-100 KW- 0.041 Mn Rs >100 KW- 0.039 Mn Rs	-	for new STPs- covered as part of finance for setting up the facility for existing STPs- Local Govt. funding/ grants from international donor agencies	SDG 12.a, 7.2, 13.2	Benchmark costs for Grid-connected Rooftop Solar Photo-voltaic systems for the financial year 2021-22, MNRE https://mnre.gov.in/img/documents/uploads/file_f-1629353920466.pdf

Actions	Jurisdiction	Key Stakeholders	Mitigation Potential	Mitigation Potential (Unit)	Carbon Credit	Ballpark CAPEX	Ballpark OPEX	Potential Funding	Linkage to SDGs	Reference
Infrastructure and Service Provision: Enabling Actions										
Strengthening safe and contained collection and transport of faecal sludge and septage to suitable treatment facility										
Operationalise scheduled desludging	Urban and Urban Rural Linkage	ULBs, BUIDCO, BUD&HD, GPs, BPIU, DWSC, RDD, private desludging operators, RTO			NA	Existing vehicles are to be reused with adequate retrofitting. Truck Mounted Suction Machines available on GEM ranging from Rs. 0.5 Million to 9 Million	Rs. 0.9 Million per year per vehicle in the first year up to Rs. 1.3 Million per year per vehicle for 10th year	primarily existing vehicles are to be used, interlinked with monitoring system and capacity building AMRUT 2.0, SBM U 2.0 (<1 lakh population), 15th FC, SCM, SBM G 2.0, LSBA (private funding in case of integrated desludging and FSTP business model)	SDG 6.2.	GEM Portal: https://mkp.gem.gov.in/waste-material-handling-and-recycling-systems-truck-mounted-suction-machine/search#/?q[]=cesspool%20vehicle&page=26&_xhr=1 OPERATION AND MAINTENANCE (O&M) ASPECTS OF FAECAL SLUDGE MANAGEMENT IN SMALL TOWNS- publication by CPR: https://cprindia.org/wp-content/uploads/2021/12/Operation-and-Maintenance-O_M-Aspects-Of-Faecal-Sludge-Management-In-Small-Towns.pdf
Enhance reuse, treatment and safe disposal of greywater in rural areas. Reuse to be preferred wherever possible.										
Setting up individual and community level grey water management facilities to treat maximum grey water generated in rural area	Rural	GPs, BPIU, DWSC, RDD			NA	Individual soak pit Rs. 0.0035-0.005 million, Community soak pit- Rs. 0.015-0.02 million (ref. As discussed with LSBA Authority, November, 2022) Phytorid/Reedbed/Wetland/DEWATS: Rs. 3 Million/MLD	Phytorid/Reedbed/Wetland/DEWATS: Rs. 0.3 Million/MLD	SBM G 2.0, LSBA, NMCG- Ganga Gram, CSR and other grants	SDG 6.3	Ready Reckoner on Municipal Used Water Treatment Technologies for Medium and Small Towns (SBM (U) 2.0 operational guidelines)
Cleaning of open drain and covering it					**NA**				**SDG 6.3**	
Remediation of eutrophicated water bodies					NA	Rs. 1-1.5 million for 6 months dredging, desilting Rs. 5-6 million for bioremediation using floating rafter Rs. 0.03-0.05 million/ KLD (ref. experience of ICLEI SA) Rs. 10-15 Million/Acre (Delhi Jal Board)	Delhi Jal Board estimates are inclusive of O & M costs		SDG 6.3, SDG 6.6	https://www.newindianexpress.com/cities/delhi/2022/jan/10/delhi-jal-boards-city-of-lakes-project-completes-three-years-2405070.html

Actions	Jurisdiction	Key Stakeholders	Mitigation Potential	Mitigation Potential (Unit)	Carbon Credit	Ballpark CAPEX	Ballpark OPEX	Potential Funding	Linkage to SDGs	Reference
Soft Measures: Enabling Actions										
Create awareness and capacitate relevant stakeholders across the domestic wastewater and greywater management value chain to ensure implementation of scientific domestic wastewater and grey water management system leading to GHG emission mitigation										
Door to Door campaign	Urban and Rural	ULBs, BUIDCO, BUD&HD, GPs, BPIU, DWSC,RDD			NA	Rs. 20 million for 1 million pop. size ULB (ref. experience of ICLEI SA)		SBM 2.0 both urban and Grameen, 15th FC, LSBA, grant from international development organisations	SDG 6.a	
Mass awareness activities					NA				SDG 6.a	
Training and capacity building programmes					NA	Rs. 10 million for 1 million pop. size ULB (ref. experience of ICLEI SA)			SDG 6.a	
Ensure policy and regulatory framework is enforced through carrot and stick approach and a strong institutional and monitoring mechanism is in place to ensure good governance and the long-term sustenance of the proposed scientific domestic wastewater, and greywater management system										
Centralized monitoring system	Urban	ULBs, BUD&HD			NA	Centralised-Rs. 80 million for 1 million pop. size ULB (only for wastewater module) (ref. experience of ICLEI SA)		SCM, SBM U 2.0, (<1 lakh population), 15th FC	NA	
Establish grievance redressal mechanism	Urban and Rural	ULBs, BUD&HD, GPs, BPIU, DWSC, RDD			NA			SCM, SBM U 2.0, (<1 lakh population) 15th FC, SBM G 2.0, LSBA	NA	
Assess existing institutional capacity and ensure adequate human resource at various levels	Urban, Rural, Block, District, State	ULBs, BUD&HD GPs, BPIU, DWSC, RDD			NA	NA		Respective institution's fund	NA	
Facilitate research and development for use of anaerobic technology in STPs and FSTPs	State	BUD&HD, BUIDCO, BSPCB			NA	NA		National/ State Govt. funds to promote R&D (CSIR/ DST/ Promoting Innovations in Individuals, Start-ups and MSMEs Funding (PRISM)etc.) Grants from international donor agencies	NA	
Institutionalise and enforce policy measures such as policy on safe reuse of treated wastewater	State	BUD&HD, BUIDCO, RDD, BSPCB			NA	NA		NA	SDG 6.3	

For Solid Waste Management

Actions	Jurisdiction	Key Stakeholders	Mitigation Potential	Mitigation Potential (Unit)	Carbon Credit	Ballpark CAPEX	Ballpark OPEX	Potential Funding	Linkage to SDGs	References
Infrastructure and Service Provision: Core Actions										
Enhance, promote, and ensure scientific treatment, processing, and disposal of solid waste and use of alternative energy source wherever feasible										
Strengthen the existing composting facilities and enhance the overall processing capacity to process biodegradable waste	Urban and Rural	ULBs, BUD&HD, compost plant operator in case of existing plant, BIDA GPs, BPIU, DWSC, RDD	=(1.42-0.17)	tCO_2e of emissions mitigated per tonne of waste composted	GHG emissions avoided from open dumping	Vermi Composting: Rs. 0.2 Million to Rs. 0.5 Million for plant capacity 0.1 tonnes per day to 2 tonnes per day In Vessel Composting: Rs. 1 Million to Rs. 20 Million for plant capacity of 0.1 ton/day to 2 ton/day Pit Composting: Rs. 0.025 Million to Rs. 0.3 Million for plant capacity of 0.1 ton/day to 2 ton/day Mechanised Organic Waste Composter: Rs. 0.6 Million to 5 Million for plant capacity of 0.1 ton/day to 3 ton/day Windrow: Rs. 100 Million to Rs. 1100 Million for plant capacity 100 ton/day to 1000 ton/day Aerated Static Pile Composting: Rs. 150 Million to Rs. 1250 Million for plant capacity 100 ton/day to 1000 ton/day	Vermi Composting: Rs. 50,000 to Rs. 0.2 Million per annum In Vessel Composting: Rs. 150/ton of compost Pit Composting: Rs. 300/ton of compost Mechanised Organic Waste Composter: Rs. 100/ton Windrow: Rs. 1000/ton of compost Aerated Static Pile Compost: Rs. 1200/ton	SBM U 2.0, 15th FC, SBM G 2.0, LSBA, private funding, loan or grants from Multilateral Development Banks (MDB) etc.	SDG 11.6, 12.5, 13.2	Waste to Wealth- a ready reckoner for selection of technologies for management of municipal waste- MoHUA- 2017
Introduce Biomethanation to enhance overall biodegradable waste processing capacity	Urban and Rural	ULBs, BUD&HD, BIDA GPs, BPIU, DWSC and RDD	=(1.42-0.02)	tCO_2e of emissions mitigated per tonne of waste treated	GHG emissions avoided from open dumping and methane capture	Rs. 2-3 Million for 1 ton/day to Rs. 400-450 Million for 300 tons/day Rs. 500 million for 500 TPD plant (as discussed with IMC Officials, November, 2022) Rs. 7 million for 5 TPD plant (ref. SWM Practices in Urban India, A compendium, NIUA, 2019)	Rs. 2000/ton Rs. 16 million per month for 500 TPD plant (as discussed with IMC Officials, November, 2022) Rs. 0.067 million per month for 5 TPD plant (ref. SWM Practices in Urban India, A compendium, NIUA, 2019)	Waste to Energy Programme, 2022, SBM U 2.0, 15th FC, SBM G 2.0 (GOBARDhan), Members of Parliament Local Area Development Scheme, Member of Legislative Assembly Area Development Schemes, New National Biogas and Organic Manure Programme, private funding, loan from Multilateral Development Banks (MDB) etc.	SDG 11.6, 12.5, 12.A, 13.2	Waste to Wealth- a ready reckoner for selection of technologies for management of municipal waste- MoHUA- 2017

Actions	Jurisdiction	Key Stakeholders	Mitigation Potential	Mitigation Potential (Unit)	Carbon Credit	Ballpark CAPEX	Ballpark OPEX	Potential Funding	Linkage to SDGs	References
Upgradation of existing MRFs; manual MRFs to be upgraded into semi automated/ automated facility depending on population size Setting up additional MRFs Ensure outputs from all MRFS are streamlined as per the value chain and market demand (for e.g. SCF (Segregated Combustible Fractions)/RDF (Refuse Derived Fuels) to be sold of to nearest cement plants)	Urban and Urban Rural Linkage, and/or block level MRF	ULBs, BUD&HD, MRF operator for existing MRFs, BIDA GPs, BPIU, DWSC, RDD,	"RDF = 1.55 Recycling = 1.4"	"tCO_2e of emissions mitigated per tonne of RDF used to replace industrial coal use in cement factory RDF cal assumption: Grade I RDF calorific value : 4500 kcal/kg. Industrial coal: 3000-4200 kcal/kg. It is assumed that with process eff etc. 1 tonne of RDF can replace 1 tonne of industrial coal (in terms of calorific value basis). 1 tonne of coal produces 1.56 tonnes of CO_2e 1 tonne of RDF production uses 24 kWh (basis - http://swachhbharaturban.gov.in/writereaddata/SBM%20RDF%20Guidelines.pdf?id=hzvkqmkxvkc0xosz) which translates to 0.01 tonne of CO_2eq/tonnes of RDF produced. Net emission reduction is 1.56-0.01 = 1.55 tonnes of CO_2e 1 tonne of RDF used tonnes of CO_2e mitigated per tonne of mixed waste recycling (paper plastic aluminium, steel etc.)"	GHG emissions avoided from open dumping, use of recycled products and use of RDF against alternate fuel	"For Population up to 50,000: (15-20 ton/day in 2-3 facilties of 1,2,5 ton each)- Manual Rs. 0.15-0.3 million per MRF For Population 50,000 to 1,00,000: (35-40 ton/day in 3-5 faciltiies of 1,2,5,10 ton each)-Manual Rs. 0.15-0.45 million per MRF For Population 1,00,000 to 5,00,000: (200 ton/day in 2-3 facilities of 50,75,100 TPD each)-Semi Automatic Rs. 45- 60 million per MRF For Population 5,00,000 to 10,00,000: (200-500 ton/day in 2-3 facilities of 100 TPD each)-Semi Automatic Rs. 60 million per MRF For Population More than 10,00,000: (more than 500 TPD in 2-7 facilities of 100, 200, 300 TPD each)- Automatic Rs. 180-200 Million for 100 TPD Rs. 240-260 Million for 200 TPD Rs. 290-300 Million for 300 TPD"	"For Population up to 50,000: (15-20 ton/day) Rs. 1.5-1.7 million/ year For Population 50,000 to 1,00,000: (35-40 ton/day) Rs. 2-3 million per year For Population 1,00,000 to 5,00,000: Rs. 6- 7 million per year For Population 5,00,000 to 10,00,000: Rs. 7 to 8 million per year For Population more than 10,00,000: Rs. 6.5 to 8 million per year"	SBM U 2.0, 15th FC, SCM, private funding, loan from Multilateral Development Banks (MDB) etc.	SDG 11.6, 12.5, 13.2	SBM - Urban Advisory on Material Recovery Facility (MRF) for Municipal Solid Waste- 2020
"Bio-remediation of legacy waste Scientific capping of dumpsite and simultaneously promoting Landfill Gas (LFG) recovery where bioremediation is not possible"	Urban	ULBs, BUD&HD, BIDA	1.42	tCO_2e of emissions mitigated per tonne of waste disposed in the dumpsite for anaerobic degradation	Direct GHG emissions mitigation	Rs. 180/ ton to Rs. 1200 of clearing legacy waste depending on the size of dump, distance from cement plants, waste characteristics, etc.		SBM U 2.0, 15th FC, private funding, loan from Multilateral Development Banks (MDB) etc.	SDG 11.6, 12.5, 13.2	"LEGACY WASTE MANAGEMENT AND DUMPSITE REMEDIATION TO SUPPORT SWACHH BHARAT MISSION 2.0- toolkit Towards Lakshya Zero Dump Site- collection of case studies- SBM 2.0"

Actions	Jurisdiction	Key Stakeholders	Mitigation Potential	Mitigation Potential (Unit)	Carbon Credit	Ballpark CAPEX	Ballpark OPEX	Potential Funding	Linkage to SDGs	References
Explore option of setting up C&D Waste Treatment Plant	Urban	ULBs, BUD&HD, BIDA			Direct GHG emissions mitigation	"Rs. 230 Million for 500 TPD plant (Ref. Waste to wealth- New Delhi plant) Rs. 55 Million for 100 TPD plant (Prayagraj) Rs. 70 million for 1000 TPD plnat (ref. SWM Practices in Urban India, A compendium, NIUA, 2019)"	Rs. 0.5 million per month for 1000 TPD plant	SBM U 2.0	SDG 11.6, 12.5, 13.2	"Waste to Wealth- a ready reckoner for selection of technologies for management of municipal waste- MoHUA- 2017 https://timesofindia.indiatimes.com/city/allahabad/ups-first-plant-to-convert-construction-waste-into-bricks-starts-ops/articleshow/88327644.cms"
Develop Scientific Sanitary Landfill with Landfill Gas (LFG) capture mechanism	Urban and Urban Rural Linkage	"ULBs, BUD&HD, BIDA, GPs, BPIU, DWSC, RDD"			NA	"Rs. 150 million for 20 TPD inert and reject disposal at 6.25 acre area (ref. SWM Practices in Urban India, A Compendium, NIUA, 2019) Ahmedabad-32 acre landfill site at project cost of Rs. 130 Million Chandigarh- 8 acre landfill site at project cost of Rs. 178.5 Million South Delhi Municipal Corpora-tion- 32.5 acre landfill site at Rs. 423 Million"	Chandigarh site- annual cost Rs. 37.3 Million	SBM U 2.0, 15th FC, private funding, loan from Multilateral Development Banks (MDB) etc.	SDG 13.2	"https://www.indiatoday.in/cities/delhi/story/delhi-news-engineered-landfill-site-to-reduce-waste-garbage-mountains-1944272-2022-05-02 https://www.nswai.org/docs/Landfill%20Site.pdf https://theprint.in/india/sdmc-to-set-up-engineered-sanitary-landfill-site-at-tehkhand/797443/ https://www.hindustantimes.com/cities/chandigarh-news/new-sanitary-landfill-to-cost-chandigarh-mc-3-73-crore-annually-101619463799307.html"
Deploy and integrate renewable energy (such as solar) to meet some part of energy demand of treatment plants	Urban and Rural	ULBs, BUD&HD, treatment plant operator, BREDA	1104	"emissions avoided - $kgCO_2eq$/year/kWp Average solar irradiation in BIHAR state is 1156.39 W / sq.m 1kWp solar rooftop plant will generate on an average over the year 4.6 kWh of electricity per day (consider-ing 5.5 sunshine hours)"	For indirect GHG emissions mitigation	"Capacity (KW)- Capital Cost up to 1 KW- 0.05 Mn Rs 1-2 KW- 0.047 Mn Rs 2-3 KW- 0.046 Mn Rs 3-10 KW- 0.045 Mn Rs 10-100 KW- 0.041 Mn Rs >100 KW- 0.039 Mn Rs"		"for new treatment plants- cov-ered as part of finance for setting up the facility for existing treatment plants- Local Govt. funding/ grants from international donor agencies"	SDG 12.A, 7.2, 13.2	"Benchmark costs for Grid-connected Rooftop Solar Photo-voltaic systems for the financial year 2021-22, MNRE https://mnre.gov.in/img/documents/uploads/file_f-1629353920466.pdf"

Actions	Jurisdiction	Key Stakeholders	Mitigation Potential	Mitigation Potential (Unit)	Carbon Credit	Ballpark CAPEX	Ballpark OPEX	Potential Funding	Linkage to SDGs	References
Infrastructure and Service Provision: Enabling Actions										
Ensure source segregation and segregated primary collection and transport thereby reducing leakage of waste										
Source segregation	Urban and Rural	"ULBs, BUD&HD, GPs, BPIU, DWSC, RDD"			NA	NA		SBM U 2.0, 15th FC, SBM G 2.0, LSBA	SDG 11.6	
Strengthening primary collection system	Urban and Rural	"ULBs, BUD&HD, BIDA GPs, BPIU, DWSC, RDD"			NA	Rs. 0.8 million/ Auto Tipper (ref. experience of ICLEI SA)	Rs. 0.06 million per ton month for 350 SAT vehicle in a million plus city (ref. experience of ICLEI SA)	SBM U 2.0, 15th FC, SCM, SBM G 2.0, LSBA, private funding, loan from Multilateral Development Banks (MDB) etc.	SDG 11.6	
Enhance street sweeping efficiency	Urban and Rural	"ULBs, BUD&HD, BIDA GPs, BPIU, DWSC, RDD"			NA	mainly integrated with salary for street sweeper		SBM U 2.0, 15th FC, SCM, SBM G 2.0, LSBA, private funding, loan from Multilateral Development Banks (MDB) etc.	SDG 11.6	
Strengthen secondary storage, collection, transport of solid waste to the treatment and processing facilities thereby minimising quantum of solid waste disposal at landfill site										
Phase-wise removal of community bins	Urban and Rural	"ULBs, BUD&HD, GPs, BPIU, DWSC, RDD"			NA	Interlinked with other action points		Interlinked with primary collection and secondary storage and transport action	NA	
Setting up and/ or upgradation of transfer stations with pre-sorting facility	Urban	ULBs, BUD&HD, BIDA			NA	Rs. 100 million for 100 TPD transfer station (ref. experience of ICLEI SA)	Rs. 0.5 million per month for 100 TPD transfer station (ref. experience of ICLEI SA)	SBM U 2.0, 15th FC, SCM, private funding, loan from Multilateral Development Banks (MDB) etc.	SDG 11.6	
Strengthen and enhance secondary transport system	Urban	ULBs, BUD&HD, BIDA			NA	Rs. 4 million/ compactor (ref. experience of ICLEI SA)	Rs. 0.0045 million per ton per month for 15 vehicles (compactors and trucks) in a million plus city (ref. experience of ICLEI SA)	SBM U 2.0, 15th FC, SCM, SBM G 2.0, LSBA, private funding, loan from Multilateral Development Banks (MDB) etc.	SDG 11.6	
Soft Measures: Enabling Actions										
Create awareness and capacitate relevant stakeholders across the solid waste management value chain to ensure implementation of scientific solid waste management system leading to GHG emission mitigation										
Door to Door campaign	Urban and Rural	"ULBs, BUD&HD, GPs, BPIU, DWSC,RDD,"			NA	Rs. 20 million for 1 million pop. Size ULB (ref. experience of ICLEI SA)		SBM 2.0 both urban and Grameen, 15th FC, LSBA, grant from international development organisations	NA	
Mass awareness activities	Urban and Rural				NA				NA	
Training and capacity building programmes	Urban and Rural				NA	Rs. 10 million for 1 million pop. Size ULB (ref. experience of ICLEI SA)			NA	
Ensure policy and regulatory framework is enforced through carrot and stick approach and a strong institutional and monitoring mechanism is in place to ensure good governance and the long-term sustenance of the proposed scientific solid waste management system										
Centralized monitoring facility	Urban	ULBs, BUD&HD			NA	"Rs. 80 million for 1 million pop. Size ULB (only for SWM module) "		SCM, SBM U 2.0, 15th FC,	NA	

Actions	Jurisdiction	Key Stakeholders	Mitigation Potential	Mitigation Potential (Unit)	Carbon Credit	Ballpark CAPEX	Ballpark OPEX	Potential Funding	Linkage to SDGs	References
Establish grievance redressal mechanism	Urban and Rural	"ULBs, BUD&HD, GPs, BPIU, DWSC, RDD"			NA			SCM, SBM U 2.0, 15th FC, SBM G 2.0, LSBA,	NA	
Enforce and monitor on-site waste processing by Bulk Waste Generators	Urban	ULBs			NA	NA		interlinked with adequate staff recruitment, and capacity building	NA	
Ensure collection of designated user charges	Urban and Rural	ULBs, GPs			NA	NA		interlinked with adequate staff recruitment, and capacity building	NA	
Waste audit	Urban and Rural	"ULBs, BUD&HD, GPs, BPIU, DWSC, RDD "			NA	NA		"National/ State Govt. funds to promote R&D (CSIR/ DST/ Promoting Innovations in Individuals, Start-ups and MSMEs Funding etc.) Grant from international donors agencies "	NA	
Assess existing institutional capacity and ensure adequate human resource at various levels	Urban, Rural, Block, District, State	"ULBs, BUD&HD GPs, BPIU, DWSC, RDD"			NA	NA		Respective institution's fund	NA	
Strengthen engagement of cement industries for co-processing of non-recyclables as RDF	State	"BUD&HD, Cement Plants, ULBs, BPIU, DWSC,RDD"			NA	NA		NA	NA	
Strengthen the value chain to ensure uptake of processed products and by-products	Urban, Rural, State	"ULBs, BUD&HD GPs, BPIU, DWSC, RDD BSPCB"			NA	NA		"National/ State/ Local Govt. funds to promote R&D (CSIR/ DST/ Promoting Innovations in Individuals, Start-ups and MSMEs Funding etc.) Grant from international donors agencies"	NA	
Institutionalise and enforce policy measures to reduce waste generation such as Green Protocol	State	BUD&HD, RDD, BSPCB			NA	NA		NA	NA	

Annex 5:

Standards for Treated Sewage Effluent and Compost

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Treated sewage effluent discharge standards

Sl. No	Parameters	General norms 1986				MoEFCC Notification, October 2017**	NGT order 2019** (for Mega and metropolitan cities)
		Inland Surface water	Public sewers	Land irrigation	Marine coastal areas		
1.	BOD [mg/L]	30	350	**100**	100	< 30 < 20 (metro cities)	<10
2.	COD [mg/L]	250	–	**–**	250	Not more than 50 (for new STP design)	< 50
3.	TSS [mg/L]	100	600	**200**	100 process water 10% of influent cooling water	< 100 < 50 (metro cities)	< 20
4.	TKN [mg/L]	100	–	**–**	100	Not more than 10 (for new STP design)	< 10
5.	NH3-N [mg/L]	50	50	**–**	50	Not more than 5 (for new STP design)	–
6.	Dissolved phosphorus [mg/L]	5	–	**–**	–	–	<1
7.	Faecal coliform [MPN/100ml]	–	–	**–**	–	< 1000	Permissible < 230

Source: NGT 2019, MoEFCC 1986, 2015 and 2017 & CSE report on Performance study of FSTPs in India 2020

The specified limits of BOD are currently 10 mg/L for edible crops and 20 mg/L for non-edible crops.

Maximum permissible concentration of toxic elements in irrigation waters

Element		Maximum permissible concentration (mg/l)	
		On all soils in continuous use or acidic soils	For short term use of textured alkaline soils
Aluminum	Al	1.0	20.0
Arsenic	As	0.1	2.0
Beryllium	Be	0.1	0.5
Boron	B	0.5	1.0
Cadmium	Cd	0.01	.05
Chromium	Cr	0.10	1.0
Cobalt	Co	0.05	5.0
Copper	Cu	0.2	5.0

Element		Maximum permissible concentration (mg/l)	
		On all soils in continuous use or acidic soils	For short term use of textured alkaline soils
Iron	Fe	5.0	20.0
Lead	Pb	5.0	10.0
Lithium	Li	2.5	2.5
Manganese	Mn	0.20	10.0
Molybdenum	Mo	0.01	0.01
Nickel	Ni	0.20	2.0
Selenium	Se	0.005	0.01
Vanadium	V	0.10	1.0
Zinc	Zn	2.0	10.0

Source: Environment Studies Board, 1973, CPHEEO, 1993

Suggested values for major inorganic constituents in water applied to the land

Problem and Related Constituent	Impact on the land		
	No Problem	Increasing Problem	Severe
Salinity			
Conductivity of Irrigation water (millimhos/cm)	<0.75	0.75-3.00	>3.00
Permeability			
Conductivity of Irrigation water (millimhos/cm)	<0.50	<0.50	<0.20
Sodium Absorption ratio (SAR)	<18.0	18.0-26.0	26.0
Specific Ion toxicity (form root absorption)			
Residual Sodium Carbonate (RSC),(meq/l)	<1.25	1.25-2.5	>2.5
Sodium (Na,%)	(A)	(A)	(A)
Chloride,meq/l	(B)	(B)	(B)
Chloride, mg/l	<142.00	142.00 -355.00	>355.00
Boron, mg/l	<1	1-4	>4
Specific Ion toxicity (form foliar absorption, sprinklers)			
Sodium (Na,%)	(C0<40	(c)40-60	(C)>60
Chloride.meq/l	<250	250-1,000	>1,000
Miscellaneous			
NO_3(mg/l) for sensitive crops	(D)	(D)	(D)
PH	6.5-8.5		

Suggested limits for salinity in irrigation waters

Crop Response	TDS mg/l	EC,mhos/cm
No detrimental effects will usually be noticed	500	0.75
Can have detrimental effect on many crops	500-1,000	0.75-1.50
May have adverse effects on many crops	1,000-2000	1.50-3.00
Can be used for salt tolerant plants on permeable soils with careful management practices	2,000-5000	3.00-7.50

Standards for composting as per SWM Rules 2016

Parameters (1)	Organic Compost (FCO 2009) (2)	Phosphate Rich Organic Manure (FCO 2013) (3)
Arsenic (mg/Kg)	10.00	10.00
Cadmium (mg/Kg)	5.00	5.00
Chromium (mg/Kg)	50.00	50.00
Copper (mg/Kg)	300.00	300.00
Lead (mg/Kg)	100.00	100.00
Mercury (mg/Kg)	0.15	0.15
Nickel (mg/Kg)	50.00	50.00
Zinc (mg/Kg)	1000.00	1000.00
C/N ratio	<20	Less than 20:1
pH	6.5-7.5	(1:5 solution) maximum 6.7
Moisture, percent by weight, maximum	15.0-25.0	25.0
Bulk density (g/cm^3)	<1.0	Less than 1.6
Total Organic Carbon, per cent by weight, minimum	12.0	7.9
Total Nitrogen (as N), per cent by weight, minimum	0.8	0.4
Total Phosphate (as $P_2 0_5$) percent by weight, minimum	0.4	10.4
Total Potassium (as $K_2 0$), percent by weight, minimum	0.4	-
Colour	Dark brown to black	-
Odour	Absence of foul Odor	-
Particle size	Minimum 90% material should pass through 4.0 mm IS sieve	Minimum 90% material should pass through 4.0 mm IS sieve

* Compost (final product) exceeding the above stated concentration limits shall not be used for food crops. However, it may be utilized for purposes other than growing food crops.

Dewatered sludge should satisfy the following criteria (US EPA) while used without any restriction (Class A Bio Solids):

- Faecal coliform density < 1,000 MPN/g total dry solids
- Salmonella sp. Density < 3 MPN/ 4 g of total dry solids
- Helminth egg concentration of < 1/g total solids (WHO, 2006)
- E coli of 1,000/g total solids (WHO, 2006)

Dewatered sludge should satisfy the following criteria (US EPA) while used as Class B Bio Solids (suitable for use on arable land used to grow crops that are not to be consumed raw and to which there will be no public access for more than a year after application and use on forest land and spreading on woodlots).:

- Faecal coliform density < 2,000,000 MPN/g total dry solids

Annex 6 : Prioritization Matrix for Low Carbon Actions in Domestic Wastewater, Greywater and Solid Waste Sector

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Prioritization Matrix for Domestic Wastewater and Greywater Management Sector

Actions (Infrastructure and Service Provisioning)	GHG Emission Mitigation Potential	Applicability in Local Context				Is there an immediate impact or it is over the time?	Prioritization Score
		Cost	Technology Intensive	Policy / Regulatory Framework	Skill Required for O&M		
Construction of toilets	2	2	2	2	2	2	64
Retrofit toilets	2	2	2	2	2	2	64
Expansion of centralised sewer network	2	1	2	2	2	2	32
Maximise interception and diversion (I&D) of open drains	2	2	2	2	1	2	32
Strengthen and ensure operation and maintenance of aerobic technology based STPs	2	2	2	2	1	2	32
Enhance sewage treatment capacity	2	2	1	2	1	2	16
Integrate faecal sludge cotreatment facility with STPs	2	2	2	2	1	2	32
Recommend establishment of FSTPs	2	1	1	2	2	2	16
Deploy and integrate renewable energy in F/STPs	2	2	2	2	2	1	32
Operationalise scheduled desludging by empanelment of desludging operator	1*	2	2	2	2	1	16
Setting up individual and community level grey water management facilities to treat maximum grey water generated in rural area	1**	2	2	2	2	2	32
Cleaning of open drain and covering it	1**	1	1	1	2	1	2
Remediation of eutrophicated water bodies	1**	1	1	1	2	1	2
Actions (Soft Measures)							
Door to Door campaign	1	2	2	2	2	1	16
Mass awareness activities	1	2	2	2	2	1	16
Training and capacity building programmes	1	2	2	2	2	1	16
Centralized facility for monitoring and regulation (primarily for Nagar Nigams and large Nagar Parishads- for other smaller ULBs all of these indicated parameters should be mapped and monitored individually)	1	1	1	2	1	1	2
Establish grievance redressal mechanism	1	2	1	2	1	1	4

Actions (Infrastructure and Service Provisioning)	GHG Emission Mitigation Potential	Applicability in Local Context				Is there an immediate impact or it is over the time?	Prioritization Score
		Cost	Technology Intensive	Policy / Regulatory Framework	Skill Required for O&M		
Assess existing institutional capacity and ensure adequate human resource at various levels	1	2	2	2	2	1	16
Facilitate research and development for use of anaerobic technology in STPs and FSTPs	1	2	2	2	2	1	16
Policy on safe reuse of treated wastewater	1	2	2	1	2	1	8

* Estimated Elsewhere- direct impact is accounted for elsewhere such as FSTP in this case

** Not considered for GHG mitigation potential as BOD is low

High >16		Medium 8-16		Low <8	

Prioritization Matrix for Low Carbon Actions in Solid Waste Management Sector

Actions (Infrastructure and Service Provisioning)	GHG Emission Mitigation Potential	Applicability in Local Context				Is there an immediate impact or it is over the time?	Prioritization Score
		Cost	Technology Intensive	Policy / Regulatory Framework	Skill Required for O&M		
Strengthen and enhance composting facilities	2	2	2	2	2	2	64
Introduce biomethanation to enhance overall biodegradable waste processing capacity	2	1	1	2	1	2	8
Upgradation of existing MRFs and setting up additional MRFs	2	2	2	2	2	2	64
Bio-remediation of legacy waste	2	2	2	2	2	1	32
Develop Scientific Sanitary Landfill with Landfill Gas (LFG) capture mechanism	2	1	1	2	1	1	4
Explore opportunity of setting up C&D Waste processing plant	2	1	1	2	1	2	8
Deploy and integrate renewable energy (such as solar) to meet some part of energy demand of treatment plants	2	2	2	2	2	1	32
Source segregation	1*	2	2	2	2	2	32
Strengthening primary collection system	1*	2	2	2	2	2	32
Enhance street sweeping efficiency	1*	2	2	2	2	2	32

Actions (Infrastructure and Service Provisioning)	GHG Emission Mitigation Potential	Applicability in Local Context				Is there an immediate impact or it is over the time?	Prioritization Score
		Cost	Technology Intensive	Policy / Regulatory Framework	Skill Required for O&M		
Phase-wise removal of secondary storage bins	1	1	2	2	1	1	4
Setting up and/ or upgradation of transfer stations with pre-sorting facility	1*	1	2	2	2	2	16
Strengthen and enhance secondary transport system	1*	1	2	2	2	2	16
Actions (Soft Measures)							
Door to Door campaign	1	2	2	2	2	1	16
Mass awareness activities	1	2	2	2	2	1	16
Training and capacity building programmes	1	2	2	2	2	1	16
Monitoring system (large ULBs (pop. >50,000)- centralised system, for other smaller ULBs (pop. <50,000- manual system)	1	1	1	2	1	1	2
Establish grievance redressal mechanism	1	2	1	2	1	1	4
Enforce and monitor on-site waste processing by Bulk Waste Generators	1	2	2	2	2	1	16
Ensure collection of designated user charges	1	2	2	2	2	1	16
Waste audit	1	1	2	1	1	1	2
Assess existing institutional capacity and ensure adequate human resource at various levels	1	2	2	2	2	1	16
Strengthen engagement of cement industries for co-processing of non-recyclables as RDF	1	2	2	2	1	1	8
Strengthen the value chain to ensure uptake of processed products and by-products	1	1	2	1	1	1	2
Institutionalise and enforce policy measures to reduce waste generation such as Green Protocol	1	2	2	1	2	1	8

*Estimated Elsewhere- direct impact is accounted for elsewhere such as different treatment and processing units in this case

High >10		Medium 5-10		Low <5	

Annex 7:

Scenario Assumptions

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BAU Scenario Assumptions

STRATEGY		ASSUMPTIONS	DATA SOURCE
1	Population	Urban: 2030- 1,93,97,205; 2050- 2,92,11,731; 2070- 3,75,54,230 Rural: 2030- 12,01,35,006; 2050- 13,19,85,204 2070- 12,56,87,770	Census of India Population projection by Technical Group on Population Projection (till 2030) + CEEW Numbers for 2050 and 2070
Solid Waste Sector			
2	Per Capita Waste Generation (kg/c/d) - Urban	• 2030- 0.373 • 2050- 0.475 • 2070- 0.605	Baseline -BSPCB (0.33 kg/c/day) 1.22% per annum increase of waste generation due to lifestyle change
3	Collection Efficiency - Urban	• 2030- 85% • 2050- 90% • 2070- 95%	Calculated by ICLEI SA based on BSPCB data. Expert judgement- 5% per decadal improvement in collection efficiency is considered.
4	Composition – Urban	• Dry: 21% (2030), 22%(2050), 22%(2070) • Wet: 50% (2030), 50%(2050), 49.86%(2070) • Others: 29% (2030), 28%(2050), 28%(2070)	ICLEI SA analysis, Singh, A., & Raj, P. (2019). Sustainable recycling model for municipal solid waste in Patna. Energy & Environment, 30(2), 212-234. and Pandey, M. K. (2014). Solid waste management in Patna.
5	Waste Treatment Urban	• Composting: 18% (2030), 25%(2050), 30%(2070) • Anaerobic Digestion: 0.05% (2030), 2%(2050), 2%(2070) • WtE: 0% (2030), 1%(2050), 2%(2070) • MRF: 16% (2030), 19%(2050), 21%(2070)	Calculation based on BUD&HD and BSPCB dataset. Expert judgement
6	Per Capita Waste Generation (kg/c/d) - Rural	• 2030- 0.284 • 2050- 0.36 • 2070- 0.458	Baseline -Calculated from LSBA Data (0.25 kg/c/day) . 1.22% per annum increase of waste generation due to lifestyle change
7	Collection Efficiency - Rural	• 2030- 50%, 2050- 50%, 2070- 50%	Calculated by ICLEI SA based on LSBA data. Expert judgement
8	Composition – Rural	Dry: 20% (2030, 2050), and 2070) Wet: 73%(2030, 2050), and 2070)	Calculated by ICLEI SA based on Ministry of Jal Shakti Manual on Biodegradable Waste Management in Rural Areas, 2021 Expert judgement

STRATEGY		ASSUMPTIONS	DATA SOURCE
		Others: 7%(2030, 2050), and 2070)	
9	Waste Treatment Rural	• Composting: 10% (2030), 20% (2050), 30% (2070) • Anaerobic Digestion: 0.4% (2030), 1.5% (2050), 2.5% (2070) • Recycling: 0.5% (2030), 2% (2050), 3% (2070) • RDF: 4.5% (2030), 8% (2050), 12% (2070)	Calculation based on LSBA and BSPCB dataset. Expert judgement
9	Process Rejects (urban + rural)	• Compost- 2030- 25%, 2050- 20%, 2070- 15% • MRF- 2030- 25%, 2050- 20%, 2070- 15% • Bio-methanation - 2030- 25%, 2050- 20%, 2070- 15% • WTE- 2030- 0%, 2050- 25%, 2070- 20%	Calculation based on LSBA, UD&HD and BSPCB dataset. Expert judgement
Domestic Wastewater Sector			
10	Protein Intake (kg/capita/year)	• Constant over decades • Urban- 22.3 • Rural- 22.96	State-wise distribution of nutrient intake as per 68th round of NSSO report
11	BOD (gm/capita/day)	Constant over decades: 45	ENVIS (Environmental Information System) Centre on Hygiene, Sanitation, Sewage Treatment Systems and Technology
12	Per Capita Water Supply (lpcd)	• Constant over decades • Urban- 135 • Rural- 55	Calculation based on LSBA and BSPCB dataset. Expert judgement
13	Degree of utilization – urban	• Sewer Connected Toilet: 2030- 30%, 2050- 70%, 2070- 90% • Latrines: 2030- 20%, 2050- 10%, 2070- 2% • Septic tank: 2030- 50%, 2050- 20%, 2070- 8% • PT/ Others/ No Toilet: 0% from 2030 onwards across all decades	BUIDCo, NMCG and BUD&HD data. Expert judgement
14	STP-Installed Capacity (MLD)	• 2030- 500 • 2050- 1546 • 2070- 2920	BUIDCo, NMCG and BUD&HD data. Expert judgement

STRATEGY		ASSUMPTIONS	DATA SOURCE
15	STP-Operational Capacity (MLD)	• 2030- 294 • 2050- 1082 • 2070- 2336	BUIDCo, NMCG and BUD&HD data. Expert judgement
16	Type of Treatment Technology (STP)	• 2030- 100% aerobic • 2050- 80% aerobic, 20% anaerobic • 2070- 65% aerobic, 35% anaerobic	BUIDCo, NMCG and BUD&HD data. Expert judgement
17	Degree of utilization – rural	• Sewer Connected Toilet: 2030- 1%, 2050- 5%, 2070- 7% • Latrines: 2030- 66%, 2050- 50%, 2070- 43% • Septic tank: 2030- 28%, 2050- 45%, 2070- 50% • PT/ Others/ No Toilet: 5% 2030 and 0% onwards across all decades	Census data, LSBA data, National Annual Sanitation Survey – Jal Shakti. Expert judgement
18	STP-Installed Capacity (MLD) - rural	• 2030- 0 • 2050- 203 • 2070- 288	NMCG and BUD&HD data. Expert judgement
19	STP-Operational Capacity (MLD)) - rural	• 2030- 0 • 2050- 119 • 2070- 169	NMCG and BUD&HD data. Expert judgement
20	Type of Treatment Technology (STP) - rural	• 2030- 100% aerobic • 2050- 80% aerobic, 20% anaerobic • 2070- 65% aerobic, 35% anaerobic	NMCG and BUD&HD data. Expert judgement
21	Fecal Sludge Treatment Efficiency (without methane capture) urban + rural	• 2030- 1% • 2050- 5% • 2070- 10%	NMCG and BUD&HD data. Expert judgement

Low Carbon Pathway Scenario Assumptions

STRATEGY		ASSUMPTIONS	DATA SOURCE
1	Population	Urban: 2030- 1,93,97,205; 2050- 2,92,11,731; 2070- 3,75,54,230 Rural: 2030- 12,01,35,006; 2050- 13,19,85,204 2070- 12,56,87,770	Census of India Population projection by Technical Group on Population Projection (till 2030) + CEEW Numbers for 2050 and 2070
Solid waste sector			
2	Extent of source segregation- Urban	• 2030- 100% • 2050- 100% • 2070- 100%	Expert judgement
3	Per Capita Waste Generation (kg/c/d) - Urban	• 2030- 0.373 • 2050- 0.475 • 2070- 0.605	Baseline -BSPCB (0.33 kg/c/day) 1.22% per annum increase of waste generation due to lifestyle change
4	Collection Efficiency - Urban	• 2030- 100% • 2050- 100% • 2070- 100%	Calculated by ICLEI SA based on BSPCB data. Expert judgement- 5% per decadal improvement in collection efficiency is considered.
5	Composition – Urban	Dry: 21% (2030), 22%(2050), 22%(2070) Wet: 50% (2030), 50%(2050), 49.86%(2070) Others: 29% (2030), 28%(2050), 28%(2070)	ICLEI SA analysis, Singh, A., & Raj, P. (2019). Sustainable recycling model for municipal solid waste in Patna. Energy & Environment, 30(2), 212-234. and Pandey, M. K. (2014). Solid waste management in Patna.
6	Waste Treatment Urban	• Composting: 25% (2030), 10%(2050), 2%(2070) • Anaerobic Digestion: 25% (2030), 40%(2050), 48%(2070) • WtE: 0% (2030), 0% (2050), 0% (2070) • Recycling: 13% (2030), 12.5% (2050), 12% (2070) • Combustibles: 8% (2030), 9.5% (2050), 10% (2070) • Methane recovery from sanitary landfill: 10% (2030), 30% (2050), 50% (2070)	Calculation based on BUD&HD and BSPCB dataset. Expert judgement
7	Extent of source segregation- Rural	• 2030- 80%, • 2050- 90%, • 2070- 100%	Expert judgement
8	Per Capita Waste Generation (kg/c/d) - Rural	• 2030- 0.284 • 2050- 0.36 • 2070- 0.458	Baseline -Calculated from LSBA Data (0.25 kg/c/day) . 1.22% per annum increase of waste generation due to lifestyle change

STRATEGY		ASSUMPTIONS	DATA SOURCE
9	Collection Efficiency - Rural	• 2030- 80%, • 2050- 90%, • 2070- 100%	Calculated by ICLEI SA based on LSBA data. Expert judgement- 10% per decadal improvement in collection efficiency is considered.
10	Composition – Rural	Dry: 20% (2030, 2050 and 2070) Wet: 73% (2030, 2050, and 2070) Others: 7% (2030, 2050, and 2070)	Calculated by ICLEI SA based on Ministry of Jal Shakti Manual for Biodegradable Waste Management. Expert judgement
11	Waste Treatment Rural	• Composting: 26% (2030), 16% (2050), 10% (2070) • Anaerobic Digestion: 10% (2030), 30% (2050), 50% (2070) • Recycling: 16% (2030), 16% (2050), 16% (2070) • RDF: 4% (2030), 4% (2050), 4%(2070)	Calculation based on LSBA and BSPCB dataset. Expert judgement
12	Process Rejects	• Compost- 2030- 20%, 2050- 15%, 2070- 10% • MRF- 2030- 20%, 2050- 15%, 2070- 10% • Bio-methanation - 2030- 20%, 2050- 15%, 2070- 10%	Expert Judgement.
Domestic Waste Water			
10	Protein Intake (kg/capita/year)	• Constant over decades • Urban- 22.3 • Rural- 22.96	State-wise distribution of nutrient intake as per 68th round of NSSO report
11	BOD (gm/capita/day)	Constant over decades: 45	ENVIS (Environmental Information System) Centre on Hygiene, Sanitation, Sewage Treatment Systems and Technology
12	Per Capita Water Supply (lpcd)	• Constant over decades • Urban- 135 • Rural- 55	Expert judgement
13	Degree of utilization – urban	• Sewer Connected Toilet: 2030- 60%, 2050- 80%, 2070- 100% • Latrines: 2030- 25%, 2050- 10%, 2070- 0% • Septic tank: 2030- 15%, 2050- 10%, 2070- 0% • No/ Insanitary Toilet: 0% from 2030 onwards across all decades	BUIDCo, NMCG and BUD&HD data. Expert judgement
14	STP-Installed Capacity (MLD)	• 2030: 1400 • 2050: 2660 • 2070: 4056	BUIDCo, NMCG and BUD&HD data. Expert judgement

STRATEGY		ASSUMPTIONS	DATA SOURCE
15	STP- Operational Capacity (MLD)	• 2030: 1260 (90% efficiency) • 2050: 2527 (95% efficiency) • 2070: 4056 (100% efficiency)	BUIDCo, NMCG and BUD&HD data. Expert judgement
16	Type of Treatment Technology (STP)	• 2030: 100% aerobic (60% not well managed, 40% well managed) • 2050: 50% aerobic and 50% anaerobic (50% not well managed, 50% well managed) • 2070: 100% anaerobic with 100% gas capture	BUIDCo, NMCG and BUD&HD data. Expert judgement
17	Degree of utilization – rural	• Sewer Connected Toilet: 2030- 5%, 2050- 15%, 2070- 30% • Latrines: 2030- 70%, 2050- 50%, 2070- 20% • Septic tank: 2030- 25%, 2050- 35%, 2070- 50% • No/ Insanitary Toilet: 0% from 2030 onwards across all decades	SBM Gramin data. Expert judgement
18	STP-Installed Capacity (MLD)	• 2030: 295 • 2050: 918 • 2070: 1659	Expert judgement
19	STP- Operational Capacity (MLD))	• 2030: 266 (90% efficiency) • 2050: 872 (95% efficiency) • 2070: 1659 (100 efficiency)	Expert judgement
20	Type of Treatment Technology (STP)	• 2030- 100% anaerobic with 80% gas capture • 2050- 100% anaerobic with 80% gas capture • 2070- 100% anaerobic with 100% gas capture	Expert judgement
21	Renewable Energy Integration	• 2030- 11.34 MWp (20% of total electricity demand) • 2050- 31.26 MWp (50% of total electricity demand) • 2070- 15.21 MWp (100% of total electricity demand)	Based on data from NMCG, BUIDCo, UD&HD. Expert Judgement
22	Fecal Sludge Treatment Efficiency with methane recovery (urban + rural)	• 2030- 40% • 2050- 70% • 2070- 90%	Based on data from NMCG, BUIDCo, UD&HD. Expert Judgement

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