GHG Platform INDIA

Briefing Paper

Status of Waste to Energy and Potential GHG Emissions Impacts for India

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The GHG Platform India is a collective civil society initiative providing an independent estimation and analysis of India's Greenhouse Gas (GHG) emissions across key sectors, namely, Energy, Industry, Agriculture, Livestock, Forestry, Land-use and Land-use change, and Waste. The platform comprises notable civil society groups in the climate and energy space in India- Council on Energy, Environment and Water (CEEW), Center for Study of Science, Technology and Policy (CSTEP), ICLEI Local Governments for Sustainability-South Asia, Shakti Sustainable Energy Foundation, Vasudha Foundation and World Resources Institute-India.

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Introduction

Achieving 100% scientific solid waste management (SWM) is one of the major objectives of the Swachh Bharat Mission (MoHUA, 2018). Solid waste processing investments in India are primarily focused on waste to compost initiatives and waste to energy (WTE) projects. The suggested National Action Plan for SWM, 2015[1] and the Municipal Solid Waste Management Manual, 2016[2] also considers WTE as a critical component to be implemented in the waste management hierarchy before disposal.

Of the total municipal solid waste (MSW) generated in urban areas of India, only 21% was reported to be processed as of September 2017 (MoHUA, 2019). Given the inadequate processing of waste and presence of only a few sanitary landfills in India, almost 79% of MSW is estimated to be dumped unscientifically in open landfills or burned. Based on GHG Platform India estimates, GHG emissions from disposal of MSW amount to 11.67 million tonnes of CO_2 equivalent (tCO_2e) for year 2015 (Kolsepatil et al., 2019). Through enabling support of the Swachh Bharat Mission, the percentage of MSW processed is reported to have risen to 56% as of June 2019, with WTE being a key contributor to this development (MoHUA, 2019). Given the increasing trend of waste generation and its changing characteristics in Indian cities, it is important to assess the status and impacts of efforts to augment MSW processing infrastructure.

This brief focuses on how implementation of WTE can help realize the country's goals on scientific processing and disposal of MSW. It discusses the potential GHG emission impacts from adopting different WTE technologies under the Swacch Bharat Mission and beyond. The analysis presented aims to highlight the potential for improved waste management and GHG emission mitigation that WTE offers and to emphasize that tapping this opportunity, as best possible, is crucial. While this brief primarily compares GHG emission impacts of prevalent WTE technology options in India, the intent is not to recommend or promote a particular WTE technology. WTE technology selection should be done to fit local conditions and will depend on various factors as outlined in the next section.

Waste to Energy Technologies

WTE is one of the various routes or solutions that can be employed for scientific treatment and processing of different MSW fractions (see Table 1). WTE is placed at tier four in the Integrated Solid Waste Management (ISWM) hierarchy recommended by the Municipal Solid Waste Management Manual, 2016 and can be the preferred option for energy recovery from waste where material recovery is not possible (see Figure 1).

Any processing technology/facility that converts waste into biogas, syngas, ethanol, electricity, liquid fuel or any other fuel is considered as WTE (Planning Commission, 2014). WTE includes a number of technologies of various scales and complexity including the use of household kitchen waste to generate cooking gas to the collection and utilization of methane gas from landfills. WTE is an efficient way of waste processing as it can efficiently reduce the quantum of waste to be disposed (saving space), reduce

[1] Available at https://smartnet.niua.org/content/bb2809a2-ee6a-4b99-86fa-9574bd67ff73
[2] Available at http://cpheeo.gov.in/cms/manual-on-municipal-solid-waste-management-2016.php

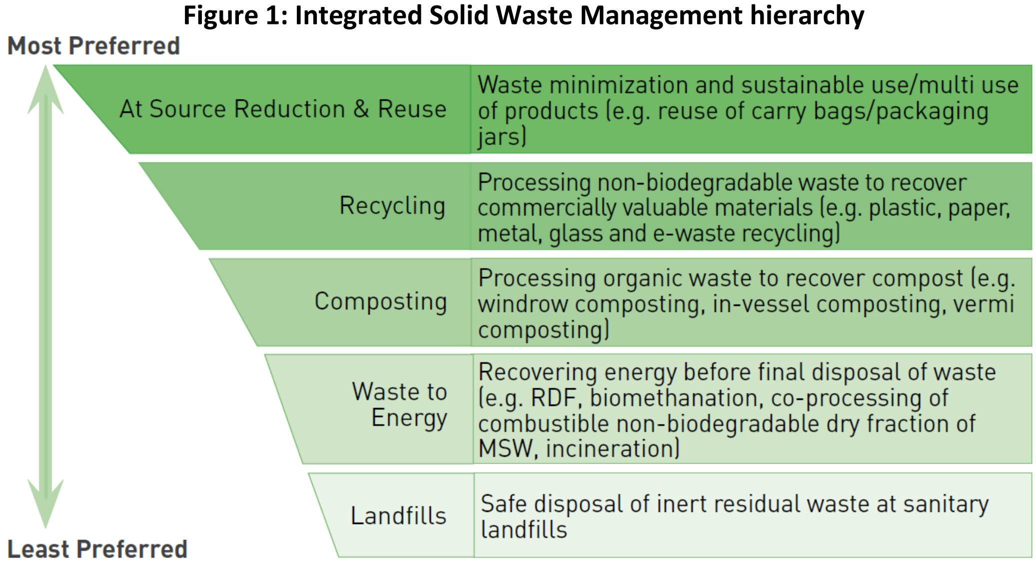
GHG emission from MSW and generate power (alternate energy), thereby helping to move towards a more circular economy.

Table 1: Routes for scientific treatment and processing of key MSW factions

Typical constituent fractions of MSW	**Biodegradable Waste (food waste, garden/yard waste)**	**Combustibles (plastics, wood, rags, cloth, leather, rubber)**	**Inerts + Rejects from processing of organic and combustibles**	**Recyclables/inorganic/E-waste (metals, glass and construction & demolition waste, electronic & electrical items)**
Treatment/processing options	Composting and WTE (Bio-methanation)	WTE (RDF)	Scientific Landfill	Recycling, Reuse, Alternate Building Materials, Scientific Landfill
	WTE (Mass burn Incineration)			

Source: Author's compilation

Figure 1: Integrated Solid Waste Management hierarchy



Source: CPHEEO, 2016

The WTE technologies that are primarily in practice at present for municipal level MSW processing in India include incineration, RDF for co-processing[3], and bio-methanation (anaerobic digestion). Table 2 below provides comparative costs for the three WTE technologies and their basic requirements for operation and processing of waste in developing countries such as India (GIZ, 2017).

Bio-methanation is a WTE technology that can help process biodegradable fractions of waste such as wet food waste, garden/yard waste from street sweepings, vegetable wastes from markets and animal manure in anaerobic digesters to generate biogas. Biogas produced from bio-methanation of organic wastes has a calorific value of 5,000 - 6,000 kilocalories per cubic meter (kcal/m^3) depending on the methane percentage (CPHEEO, 2016). Owing to its high calorific value, biogas can be used as fuel for power generation through either internal combustion engines or gas turbines.

[3] Co-processing of RDF as a fuel in industries

WTE technology options such as refuse derived fuel (RDF) processing and incineration are usually practiced for processing of non-biodegradable & non-recyclable waste fractions with comparatively higher calorific value but can also cover combustible waste fractions such as soiled cloth, contaminated plastic, multilayer packaging material, pieces of rubber, leather, and wood among many other materials which end up in landfill sites (MoHUA, 2018). This also includes materials of low market value in systems where even intense recycling is practiced (GIZ, 2017). Such waste accounts for about 17-20% of the total MSW generated (MoHUA, 2018).

RDF derived from combustible waste fractions, is usually in the form of pellets or fluff produced by drying, shredding, dehydrating and compacting of solid waste. RDF can be used as an energy source in a number of ways - as a fuel for either steam or electricity generation or as alternate fuel in industrial furnaces or boilers (co-processing or co-incineration of waste in cement, lime, and steel industry and for power generation). Segregation of waste into combustibles and non-combustibles is a pre-requisite for RDF technology (MoHUA, 2018).

Incineration is a waste treatment process that involves combustion of waste at very high temperatures in the presence of oxygen and results in the production of ash, flue gas, and heat. The potential for energy generation depends on the composition, density, moisture content, and presence of inert in the waste. In practice, about 65%–80 % of the energy content of the organic matter can be recovered as heat energy, which can be utilized either for direct thermal applications or for producing power via steam turbine generators. Mass-burn incineration systems refer to incinerators designed to typically burn mixed and largely untreated domestic waste, without prior sorting or processing. The primary goal of mass burn incineration is to reduce MSW volume and mass and also make it chemically inert in a combustion process without the need of additional fuel. Incineration is an option especially where other better options of processing of waste are not feasible and land for landfilling and other waste processing methods is scarce. Incineration of MSW generates large volumes of flue gases and also bottom ash. Flue gases consist of particulates of heavy metals, and a wide range of organic and inorganic compounds. Thus it is important to control these air emissions through appropriate operating conditions and flue gas treatment technology in incinerators. Bottom ash should be tested for heavy metal concentrations, suitably stabilized and disposed in a sanitary landfill (GIZ, 2017).

Table 2: Costs and input processing material requirements for WTE technologies

Technology Type	Design capacity (Tonnes/annum)	Initial cost (Million INR)	Capital cost per tonne (INR)	O&M cost per tonne (INR)	Requirements
Incineration	150,000	5,775	4,235	2695	Average LCV: 1,627 Kcal/Kg, Minimum LCV: 1,450 Kcal /Kg
RDF co-processing	50,000	1,925	1,925	1540	Desirable LCV: 2389 – 3,582 Kcal/Kg
Anaerobic digestion (Bio-methanation)	150,000	1,540	1,463	1155	Desirable material: Organic waste

Source: Author’s compilation and analysis based on GIZ, 2017

Selection of a particular WTE technology should factor in multiple criteria such as chemical and physical characteristics of waste (moisture content and calorific value), waste composition and available quantity of waste streams, availability of land, environmental considerations, social factors, capital investment, duration of treatment, and market for products recovered. WTE plants have been operating successfully in many developed countries, but lower calorific value of mixed MSW (because of presence of high organic content and mineral content), substantial seasonal variations in composition, lower recovery rates of investments in existing business models, inadequacies in capacity of local authorities and prevalent MSW management systems, are some of the critical factors affecting the adoption of the technology and success of WTE plants in India (GIZ, 2017).

Status of WTE and Policy Scenario in India

In India, 259 MW of grid connected/captive power in total was generated by WTE plants as of 2017 (MoHUA, 2019). Most of these plants are operated through processing of industrial and agricultural waste. MSW accounts for only 26% of the total power generation from WTE plants. As of end-2017, there were only seven functional WTE plants in India for processing of MSW, spread across four states of Maharashtra, New Delhi, Telangana and Madhya Pradesh with an overall power generation capacity of 88.5 MW (MoHUA, 2018).

Considering the advancement in processing technologies and the need for augmentation of scientific processing, treatment, and disposal of MSW, national level policies and programs have placed emphasis on WTE. The Municipal Solid Waste Management Manual, 2016 highlights energy recovery from waste as a necessary component in the hierarchy of waste management. It advices each state in the country to consider the option of WTE to handle MSW components that cannot be processed instead of landfilling such waste fractions, especially in large cities generating more than 1000 TPD of waste (CPHEEO, 2016).

MSW management is one of the priority focus areas of the Swachh Bharat Mission campaign launched in 2014. Swachh Bharat Mission has set a target of achieving 100% scientific management of all MSW by October 2, 2019. To boost processing of MSW, viability gap funding/grant of 35% of total capital cost has been offered to all solid waste management projects by the Government of India. For the period from 2014 to 2017, funds of over INR 21,230 million have been released by the Ministry of Housing and Urban Affairs (MoHUA) for SWM (MNRE, 2017). Almost all the funding provided under the grant is for WTE and waste to compost projects. Under the Swachh Bharat Mission, another 48 plants are proposed/under construction with a capacity of 411 MW. About 132 waste to compost facilities are also being built and commissioned in around 25 states under the Mission, with a combined waste processing capacity of more than 7,300 TPD.

The Swachh Survekshan has also placed due importance on MSW processing and disposal in its scoring system, and thereby the scoring of cities' share based on scientific processing and disposal has been increased from 20% to 25% in the 2018 Swachh Survekshan. Scientific processing of MSW is also a key element of the star rating system of Swachh Survekshan (MoHUA, 2019).

In addition to infrastructure development support, policy support has been provided to promote WTE processing in India. The Ministry of Power has revised the Tariff Policy, 2006, making it mandatory for state-owned power distribution utilities to purchase power from WTE plants. The Central Electricity Regulatory Commission (CERC) has notified a generic tariff of INR 7.04 per kWh for sale of power from WTE facilities and of INR 7.90 per kWh for RDF facilities (MoHUA, 2018). To promote WTE processing and the usage of MSW based RDF in industries, the MoHUA has formulated 'Guidelines on Usage of Refuse Derived Fuel in Various Industries' (MoHUA, 2018). These guidelines outline the potential for using different grades of RDF and segregated combustible fractions for energy generation across different industries and the suggestive maximum and minimum pricing of the materials.

Emission Reduction Potential of WTE

As noted earlier, seven WTE plants were operational across cities in four states as of end-2017. The total power generation capacity of these WTE plants amounted to 88.5 MW (see Table 3). Considering the average quantity of MSW processed by these facilities, around 7,840 TPD of MSW is being converted to energy every day in these seven plants. **These seven currently functional WTE plants are estimated to help achieve a potential GHG emission reduction of about 0.67 million tonnes of CO_2e of GHG emission annually** that would be otherwise generated through dumping of the said MSW in their absence.

Table 3: Details and GHG emission impact of presently operational WTE facilities

State	Location of Waste to Energy Facility	Installed energy generation capacity (MW)	Avg. quantity of MSW processed per day (TPD)	Avg. mass of MSW processed to generate 1 MW of power (Tonnes)	State-wise avg. GHG emission per tonne of MSW disposed from GHG Platform India estimates[4] (kg of CO_2e per tonne of MSW)	Estimated annual GHG emission reduction from avoided MSW disposal (tonnes of CO_2e)[5]
Maharashtra	Pune, Maharashtra	10	700	70	233.6	61,759
	Solapur, Maharashtra	3	400	133		35,291
Delhi	Okhla, New Delhi	16	1950	122	240.7	166,289
	Gazhipur, New Delhi	12	550	46		46,902
	Narela- Bhavana, ,New Delhi	24	2000	83		170,553
Telangana	Karim Nagar, Telangana	12	1100	92	241.7	88,173
Madhya Pradesh	Jabalpur, Madya Pradesh	11.5	1140	99	219.6	100,153
Total		**88.5**	**7,840**	**92 (avg.)**	**-**	**669,120**

Source: Author's compilation and analysis based on MoHUA documents

[4] *State-wise values of 'average GHG emission per tonne of MSW disposed' based on solid waste disposal GHG emission estimates prepared for 2005-2015 by the GHG Platform India*

[5] *The GHG emission reduction estimated represents emissions avoided from disposal of MSW and does not include potential emission reduction due to energy generation in the WTE facilities*

Under the Swachh Bharat Mission, significant investments are being made to support development of MSW based WTE plants all over the country. Considering the fact that the Ministry of New and Renewable Energy (MNRE) is promoting various technology options for setting up projects for recovery of energy from urban MSW and the NITI Aayog has proposed creation of a Waste to Energy Corporation of India as a nodal agency to setup the facilities through public-private partnership, understanding of the GHG emission reduction potential while considering different WTE routes for achieving 100% MSW processing capacity in India is helpful.

As of end-2017, about 48 WTE facilities spread across 23 states were at different stages of construction or tendering under the Swachh Bharat Mission, with a cumulative power generation capacity of about 411 MW as noted earlier. Based on the performance and MSW volumes being processed in currently operational WTE facilities[6], it is estimated that these WTE plants which are being constructed, can potentially process an average of 37,803 TPD of MSW per day once commissioned.

For the proposed WTE facilities of 411 MW, no information is available on the specific processing technologies to be adopted and the type of MSW (from bio-degradable waste and combustible fractions) that will be processed in these facilities scheduled to come up across states. Thereby, in order to estimate the GHG emission impacts (noted in Box 1 below), three scenarios that entail adoption of different WTE technology options viz. mass-burn incineration, bio-methanation, and RDF co-processing for combustible waste fractions have been considered in this analysis as indicated below:

1. **Mass-burn incineration technology** is adopted wherein biodegradable waste (food waste, garden/yard waste) and dry combustible fractions (paper, wood, non-recyclable plastics, rags/textile, leather, rubber)) are together burnt at very high temperatures to generate power.
2. **RDF co-processing** is adopted wherein the dry combustible fractions including paper, textile, rags, leather, rubber, non-recyclable plastic are recovered as RDF or combusted and utilized to generate power.
3. **Bio-methanation technology** is adopted wherein biodegradable waste undergoes anaerobic digestion to produce biogas which can be tapped to generate power.

As seen in Box 1, **potential GHG emission reduction from avoided MSW disposal due to adoption of mass-burn incineration technology in upcoming/under construction WTE projects under Scenario 1 amounts to 1.96 million tCO_2e per year. If RDF co-processing is adopted in these proposed WTE projects, GHG emission reduction of 0.39 million tCO_2e annually can be achieved potentially while opting for bio-methanation as the technology choice in the proposed projects can reduce emissions by 1.30 million tCO_2e per year.**

It should be noted that Scenario 2 and Scenario 3 that look at adoption of RDF co-processing for dry combustible waste fractions and at use of bio-methanation to utilize bio-degradable waste respectively are not mutually exclusive, given that these technologies help to process different waste streams and may well be implemented in tendem. The analysis of GHG emission impacts presented here has assessed the potential GHG emission reduction from adoption of RDF co-processing and bio-

[6] On an average, 92 TPD of MSW is processed to generate 1 MW of power in the existing WTE facilities as given in Table 1.

methanation to the extent possible with available volumes of different waste fractions. Also while composting is a much adopted solution for processing of biodegradable fractions of waste, it does not fall under the purview of waste to energy and is thereby not considered in the comparative analysis of GHG impacts.

As noted earlier, significant MSW processing capacity augmentation is driven by the Swachh Bharat Mission, with about 411 MW capacity of WTE facilities and 7,300 TPD of composting capacity was proposed/to be commissioned as of end-2017. However, the existing and proposed/sanctioned MSW processing infrastructure would help process only about half of the total MSW generated. It is estimated that about 78,254 TPD of the remaining MSW generated (as of 2017) will not be covered by currently operational and upcoming MSW processing facilities, and thereby could be dumped in disposal sites, leading to GHG emissions. Thus, there is a need to establish new processing infrastructure, in addition to what is planned, in order to address this unprocessed waste quantum. This will also enable achievement of goals of 100% treatment and processing of MSW.

Box 1 presents the potential GHG emission impact if additional WTE facilities are put in place to process the leftover quantum of MSW, for which no processing capacity exists or is proposed as of end-2017. In this case as well, the GHG emission impact analysis has been carried out using the same three scenarios[7] of WTE technology options viz. mass-burn incineration, RDF co-processing, and bio-methanation. **Implementing additional mass-burn incineration based WTE facilities to cater to leftover unprocessed MSW across the states can help realize potential GHG emission reduction of 2.99 million tCO_2e annually. On the other hand, adopting RDF co-processing could mitigate GHG emissions by 0.51 million tCO_2e per year while opting for bio-methanation in additional WTE facilities can lead to 2.43 million tCO_2e of emission reduction annually.** Again it is important to note that RDF co-processing and bio-methanation can be implemented in tandem to process corresponding combustible fraction and bio-degradable fraction and thereby Scenario 2 and Scenario 3 that explore their respective adoption are not mutually exclusive.

Box 1: Potential Impact on Emissions from increased MSW processing through Waste to Energy facilities

MSW Processing Status for India (as of September 2017)	
Total MSW generation	154,034 tonnes per day
Percent of waste that is processed	21.0%
Baseline GHG emissions from MSW disposal as per GHG Platform India estimates (2015)	11.67 million tonnes of CO_2e

[7] Emission impact has been estimated for three scenarios that compare adoption of three WTE technology options, given that there is limited clarity to interpret the composition of the leftover unprocessed waste and to ascertain specific processing technologies,.

Operational WTE projects (as of end-2017)			
Installed energy generation capacity	88.4 MW		
Estimated total MSW processed on average	7,840 tonnes per day		
Potential GHG emission reduction due to avoided solid waste disposal	0.67 million tonnes of CO_2e		
Under-construction/proposed WTE projects (as of end-2017)			
Proposed energy generation capacity	411 MW		
Estimated total MSW to be processed by proposed plants on average	37,803 tonnes per day		
Scenario of WTE technology adoption in proposed projects	**Scenario 1**: Mass-burn incineration technology adopted	**Scenario 2:** RDF co-processing adopted to the extent possible	**Scenario 3:** Bio-methanation technology adopted to the extent possible
Potential GHG emission reduction due to avoided solid waste disposal[8]	1.96 million tonnes of CO_2e	0.39 million tonnes of CO_2e	1.30 million tonnes of CO_2e
WTE Potential in addition to existing/proposed WTE projects			
Total unprocessed MSW quantum not covered by existing or proposed projects	78,254 tonnes per day		
Total MSW that can be processed to generate energy, excluding assumed 30% fraction of inert waste and recyclables	54,778 tonnes per day		
Scenario of WTE technology adoption in new additional projects	**Scenario 1**: Mass-burn incineration technology adopted	**Scenario 2:** RDF co-processing adopted to the extent possible	**Scenario 3:** Bio-methanation technology adopted to the extent possible
Potential GHG emission reduction due to avoided solid waste disposal[9]	2.99 million tonnes of CO_2e	0.51 million tonnes of CO_2e	2.43 million tonnes of CO_2e

Source: Author's analysis

Note: Detailed calculations can be referred to in Tables 5 and 6 in the Annexure

[8] *The GHG emission reduction estimated does not include potential emission reduction due to energy generation in the WTE facilities*

[9] *The GHG emission reduction estimated does not include potential emission reduction due to energy generation in the WTE facilities*

Way Ahead

It is seen that given existing plans and policy scenario for development of solid waste processing infrastructure in the country, WTE holds significant potential for strengthening waste management capabilities and generating clean energy while also contributing to India’s climate mitigation goals under its NDC, across all the technology options assessed in this document. Considering that WTE technology selection depends on the composition of waste to be treated and given the limitations in information available on specific technologies utilized and waste fractions treated for proposed/upcoming WTE facilities analyzed in this document, the actual GHG emission reduction potential realized may range between the lowest and highest values estimated across the scenarios.

Although the GHG emission reduction potential of WTE technologies is well established in this brief, the financial feasibility and preference of material recovery for recycling and reprocessing need to be well assessed before implementation of WTE facility as recommended in the ISWM waste treatment and processing hierarchy. It is important to bear in mind that most of the existing waste processing treatment facilities have encountered significant problems during operation or operate at throughputs far below their capacity. This has led to inadequate processing/treatment/disposal systems for MSW, resulting in larger quantum of waste being sent to disposal sites.

Establishing an integrated waste management system with segregated waste collection to ensure availability of the right type and quality of waste and co-ordination with other departments for efficient utilization of the energy product (electricity/ RDF) are critical elements for the successful operation of any WTE facility. To tap the complete potential of WTE in the country, there is a need to steer efforts towards developing planned infrastructure for processing of waste dumped in smaller cities as well, beyond the major cities generating more than 1000 TPD of waste.

Annexures

Table 4: State-wise GHG emission for every tonne of MSW disposed and contribution of different waste constituents to emissions

State/Union Territory	Avg. baseline GHG emission per tonne of MSW disposed based on GHG Platform India emission estimates for 2005-2015 (kg of CO_2e per tonne) (A)	Reported bio-degradable fraction as per state-level MSW composition (%) (B)	Reported rags fraction as per state-level MSW composition (%) (C)	Reported paper fraction as per state-level MSW composition (%) (D)	Reported average inert/recyclables fraction as per national-level MSW composition (%) (E)	Estimated avg. kg of GHG emission per tonne of biodegradable MSW disposed (kg CO_2e) (2005-15) (F)	Estimated avg. GHG emission per tonne of dry waste (rags and paper) disposed (kg CO_2e) (2005-15) (G)
Andaman & Nicobar	251.9	48	5	10	30	147	104
Andhra Pradesh	298.1	53	4	7	30	200	98
Arunachal Pradesh	232.9	52	4	7	30	156	76
Assam	250.3	54	4	8	30	163	87
Bihar	236.1	52	2	4	30	186	50
Chandigarh	261.0	57	2	4	30	211	50
Chhattisgarh	186.4	51	3	6	30	134	53
Dadra & Nagar Haveli	182.8	72	3	5	30	147	35
Daman & Diu	125.6	30	4	8	30	65	60
Delhi	233.6	54	3	5	30	173	61
Goa	246.5	62	3	6	30	183	64
Gujarat	199.0	44	2	4	30	148	51
Haryana	214.4	42	4	8	30	127	87
Himachal Pradesh	331.7	43	7	13	30	162	170
Jammu & Kashmir	240.4	57	4	7	30	169	72
Jharkhand	177.1	45	3	6	30	123	54
Karnataka	242.8	52	4	8	30	158	85
Kerala	222.0	65	3	6	30	168	54
Madhya Pradesh	240.7	53	3	6	30	172	69
Maharashtra	241.7	53	4	6	30	169	73
Manipur	257.7	60	4	6	30	187	71

State/Union Territory	Avg. baseline GHG emission per tonne of MSW disposed based on GHG Platform India emission estimates for 2005-2015 (kg of CO_2e per tonne) (A)	Reported bio-degradable fraction as per state-level MSW composition (%) (B)	Reported rags fraction as per state-level MSW composition (%) (C)	Reported paper fraction as per state-level MSW composition (%) (D)	Reported average inert/recyclables fraction as per national-level MSW composition (%) (E)	Estimated avg. kg of GHG emission per tonne of biodegradable MSW disposed (kg CO_2e) (2005-15) (F)	Estimated avg. GHG emission per tonne of dry waste (rags and paper) disposed (kg CO_2e) (2005-15) (G)
Meghalaya	243.5	63	3	6	30	182	62
Mizoram	229.2	54	4	7	30	155	74
Nagaland	217.8	57	4	8	30	146	71
Odisha	243.7	50	2	4	30	185	58
Puducherry	243.1	50	5	8	30	152	91
Punjab	206.0	57	3	6	30	152	54
Rajasthan	186.7	46	2	4	30	141	46
Sikkim	223.9	46	5	10	30	129	94
Tamil Nadu	25.5	49	3	6	30	18	7
Telangana	219.6	53	4	7	30	147	72
Tripura	216.9	59	3	5	30	168	49
Uttar Pradesh	195.2	46	3	5	30	139	56
Uttrakhand	218.8	51	4	7	30	149	70
West Bengal	218	50	2	4	30	166	52

Source: Author’s analysis

Notes: *1. State-wise values of ‘average GHG emission per tonne of MSW disposed’ in column A are based on National and State-level estimates prepared for 2005-2015 by the GHG Platform India. Available at http://www.ghgplatform-india.org/waste-sector*

2. Percent values of different MSW fractions in columns B, C and D are based on information reported for cities in NEERI and CPCB study in 2005. Values for paper and rags has been estimated from state-level data reported for total recyclable material based on national-level data reported for 2005 in CPHEEO Manual on Municipal Solid Waste Management-2016.

3. Percent values of inert MSW fractions in column E are based on national-level information reported for 2017.

4. The cumulative value of GHG emission per tonne of MSW in column A has been further broken down by particular degradable fraction (i.e. compostable/bio-degradable matter, and paper & rags) in columns F and G. This apportionment helps to assess GHG emission impact that is contributed by specific degradable constituent, given that these specific fractions can be processed through different WTE routes. The values in columns F and G have been calculated based on value in column A, the reported composition values in columns B, C and D and the corresponding degradable organic content (DOC) values for these fractions as per the 2006 IPCC Guidelines.

Table 5: State-wise potential GHG emission impact of under-construction/proposed WTE projects

State/Union Territory	Total MSW generation reported by SBM as of Sept 2017 (TPD) (A)	Estimated biodegradable waste generated based on state-specific MSW composition (TPD) (B)	Estimated dry/combustible waste generated based on state-specific MSW composition (TPD) (C)	Estimated inert/ recyclables generated that can be processed through routes other than WTE (TPD) (D)	Reported % of MSW processing achieved as on Sept 2017 (E)	Total design capacity of upcoming or under-construction WTE facilities (MW) (F)	Estimated avg. waste to be processed by upcoming or under-construction WTE facilities (TPD) (G)	Processing capacity of proposed composting facilities to treat biodegradable waste (TPD) (H)	Under-construction/proposed Waste-to-Energy projects					
									Scenario 1 (Mass-burn incineration adoption)		Scenario 2 (RDF co-processing adopted to maximum extent)		Scenario 3 (Bio-methanation adopted to maximum extent)	
									Total wet and combustible waste potentially utilized to generate energy in proposed WTE capacity (TPD) (I)	Potential GHG emission reduction from mass-burn incineration (tCO_2e/yr) (J)	Total combustible dry waste potentially utilized to generate energy in proposed WTE capacity (TPD) (K)	Potential GHG emission reduction for RDF co-processing (tCO_2e/yr) (L)	Total wet waste potentially utilized to generate energy in proposed WTE capacity (TPD) (M)	Potential GHG emission reduction for bio-methanation (tCO_2e/yr) (N)
Andaman & Nicobar	115	55	25	35	23%	-	-	-	-	-	-	-	-	-
Andhra Pradesh	6,440	3,425	1,083	1,932	8%	53	4,876	455	4,421	360,789	1,083	34,831	2,970	195,321
Arunachal Pradesh	181	94	33	54	15%	-	-	-	-	-	-	-	-	-
Assam	1,134	609	185	340	7%	-	-	-	-	-	-	-	-	-
Bihar	2,271	1,175	415	681	40%	10	920	-	920	59,462	415	6,802	920	56,281
Chandigarh	340	194	44	102	100%	-	-	-	-	-	-	-	-	-
Chhattisgarh	1,850	951	344	555	3.0%	10	920	90	830	42,372	344	5,935	830	36,525
Dadra & Nagar Haveli	35	25	-	11	0%	-	-	-	-	-	-	-	-	-
Daman & Diu	23	7	9	7	0%	-	-	-	-	-	-	-	-	-
Delhi	10,500	5,714	1,636	3,150	52%	-	-	-	-	-	-	-	-	-
Goa	240	148	20	72	52%	5	460	-	240	16,195	20	415	148	8,896
Gujarat	10,145	4,482	2,619	3,044	28%	13.5	1,242	649	593	32,294	1,242	20,849	593	28,803
Haryana	4,514	1,899	1,261	1,354	1%	28.5	2,622	82	2,540	149,091	1,261	36,111	1,816	75,943
Himachal Pradesh	342	147	92	103	25%	1.7	156	-	156	14,203	92	5,156	147	7,812
Jammu & Kashmir	1,792	1,015	239	538	2%	6.5	598	33	565	37,192	239	5,627	565	31,349
Jharkhand	2,350	1,061	584	705	15%	23	2,116	8	2,108	102,189	584	10,311	1,053	42,662
Karnataka	10,000	5,184	1,816	3,000	38%	20	1,840	651	1,189	79,044	1,816	50,470	1,189	61,808
Kerala	1,576	1,027	76	473	50%	10	920	-	920	55,904	76	1,350	920	50,831
Madhya Pradesh	5,079	2,700	855	1,524	14%	56	5,152	-	5,079	334,657	855	19,291	2,700	152,586
Maharashtra	26,820	14,201	4,573	8,046	10%	11.5	1,058	2388	-	-	1,058	25,323	-	-
Manipur	176	106	18	53	50%	2	184	-	176	12,418	18	411	106	6,473

State/Union Territory	Total MSW generation reported by SBM as of Sept 2017 (TPD) (A)	Estimated biodegradable waste generated based on state-specific MSW composition (TPD) (B)	Estimated dry/combustible waste generated based on state-specific MSW composition (TPD) (C)	Estimated inert/ recyclables generated that can be processed through routes other than WTE (TPD) (D)	Reported % of MSW processing achieved as on Sept 2017 (E)	Total design capacity of upcoming or under-construction WTE facilities (MW) (F)	Estimated avg. waste to be processed by upcoming or under-construction WTE facilities (TPD) (G)	Processing capacity of proposed composting facilities to treat biodegradable waste (TPD) (H)	Under-construction/proposed Waste-to-Energy projects					
									Scenario 1 (Mass-burn incineration adoption)		Scenario 2 (RDF co-processing adopted to maximum extent)		Scenario 3 (Bio-methanation adopted to maximum extent)	
									Total wet and combustible waste potentially utilized to generate energy in proposed WTE capacity (TPD) (I)	Potential GHG emission reduction from mass-burn incineration (tCO_2e/yr) (J)	Total combustible dry waste potentially utilized to generate energy in proposed WTE capacity (TPD) (K)	Potential GHG emission reduction for RDF co-processing (tCO_2e/yr) (L)	Total wet waste potentially utilized to generate energy in proposed WTE capacity (TPD) (M)	Potential GHG emission reduction for bio-methanation (tCO_2e/yr) (N)
Meghalaya	268	168	20	80	58%	-	-	-	-	-	-	-	-	-
Mizoram	239	130	38	72	4%	-	-	10	-	-	-	-	-	-
Nagaland	342	197	43	103	17%	-	-	-	-	-	-	-	-	-
Odisha	2,460	1,225	497	738	2%	11.5	1,058	493	565	37,687	497	9,521	565	34,396
Puducherry	495	247	99	149	20%	-	-	-	-	-	-	-	-	-
Punjab	4,100	2,354	516	1,230	10%	11.5	1,058	386	672	37,877	516	9,207	672	33,471
Rajasthan	6,400	2,912	1,568	1,920	16%	25	2,300	1056	1,244	63,566	1,568	23,783	1,244	57,412
Sikkim	89	41	21	27	67%	-	-	41	-	-	-	-	-	-
Tamil Nadu	15,272	7,468	3,222	4,582	28%	4	368	173	195	1,362	368	901	195	1,156
Telangana	7,371	3,921	1,239	2,211	51%	42.2	3,882	2	3,880	233,255	1,239	29,366	3,880	187,950
Tripura	421	247	48	126	45%	-	-	-	-	-	-	-	-	-
Uttar Pradesh	15,500	7,142	3,708	4,650	13%	43	3,956	288	3,668	195,983	3,708	68,541	3,668	167,365
Uttrakhand	1,400	719	261	420	0.7%	11	1,012	419	593	35,513	261	6,003	300	14,661
West Bengal	8,675	4,376	1,697	2,603	6%	12	1,104	160	944	56,364	1,104	18,933	944	51,453
Total (All India)	**154,034**	**77,702**	**30,123**	**46,210**	**21.0%**	**411**	**37,803**	**7,386**	**31,497**	**1,957,416**	**18,364**	**389,137**	**25,425**	**1,303,153**

Source: Author's analysis

***Notes**: 1. Values of 'Total Waste generation' in column A and 'Reported % of MSW processing achieved in column E are based on data reported under Swachh Bharat Mission as of September 2017.*

2. Values of quantities of different waste fractions in columns B, C and D are calculated using composition values in Table 4 and reported waste generation in column A.

3. Values of 'Total design capacity of upcoming or under-construction WTE facilities (MW)'in column F are as reported for end-2017. The values of 'Estimated avg. waste to be processed by upcoming or under-construction WTE facilities (TPD)'in column G have been calculated based on average figure of 92 TPD of MSW processed to generate 1 MW of power in the existing WTE facilities as given in Table 1 of this document..

4. Values of 'Processing capacity of proposed composting facilities to treat biodegradable waste' in column H are as reported for end-2017.

5. Values in columns I, K and M represent the quantities of waste that can be processed in the respective WTE technology. This quantum has been estimated based on the *designed waste processing capacity of upcoming/under-construction facilities in column G and the total generated/available quantities of waste fractions in columns B, C and D. Since WTE facility cannot process quantities beyond the generated/available quantities of corresponding waste fractions, in cases where the designed waste processing capacity of WTE facilities in column G exceeds the generated/available waste quantum in columns B, C and D as of 2017, the waste that can be utilized in the WTE plants is based on the generated quantities of waste fractions. Further, the capacity of proposed composting facilities in column H has been factored in and deducted to arrive at the waste that can be utilized in mass-burn incineration and bio-methanation.*

6. The GHG emission reduction values in columns J, L, and N are estimated by using the values of 'average GHG emission per tonne disposed' from Table 3 and the corresponding quantities of waste processed quantum of waste in columns I, K and M in the 3 scenarios. In the GHG emission reduction estimation, process rejects are assumed to be 25% of total waste processed in mass-burn incineration. For RDF and bio-methanation, process rejects are assumed to be 10%.

7. The GHG emission reduction estimated represents emissions avoided from disposal of MSW and does not include potential emission reduction due to energy generation in the WTE facilities.

Table 6: State-wise GHG emission impact of WTE potential in addition to existing/proposed WTE projects

State/Union Territory	Total MSW generation reported by SBM as of Sept 2017 (TPD) (A)	Total MSW quantum for which no processing capacity exists or is proposed (TPD) (B)	Total MSW that can be utilized for energy generation, excluding 30% inerts/recyclables (TPD) (C)	Waste to Energy potential in addition to existing/proposed Waste to Energy projects					
				Scenario 1 (Mass-burn incineration adoption)		Scenario 2 (RDF co-processing adopted to maximum extent)		Scenario 3 (Bio-methanation adopted to maximum extent)	
				Total wet and combustible dry waste potentially utilized to generate energy (TPD) (D)	Potential GHG emission reduction from mass-burn incineration (tCO2e/yr) (E)	Total combustible dry waste potentially utilized to generate energy (TPD) (F)	Potential GHG emission reduction for RDF co-processing (tCO2e/yr) (G)	Maximum biodegradable waste quantum that can go to bio-methanation (TPD) (H)	Potential GHG emission reduction potential from bio-methanation (tCO2e/yr) (I)
Andaman & Nicobar	115	89	62	62	4,274	25	858	55	2,687
Andhra Pradesh	6,440	593	415	415	33,904	415	13,366	415	27,319
Arunachal Pradesh	181	154	108	108	6,865	33	817	94	4,838
Assam	1,134	1,055	738	738	50,592	185	5,306	609	32,602
Bihar	2,271	443	310	310	20,024	310	5,076	310	18,953
Chandigarh	340	-	-	-	-	-	-	-	-
Chhattisgarh	1,850	785	549	549	28,035	344	5,935	549	24,166
Dadra & Nagar Haveli	35	35	25	25	1,226	-	-	25	1,186
Daman & Diu	23	23	16	16	554	9	184	7	146
Delhi	10,500	5,040	3,528	3,528	225,641	1,636	32,716	3,528	200,214
Goa	240	-	-	-	-	-	-	-	-
Gujarat	10,145	5,413	3,789	3,789	206,460	2,619	43,972	3,789	184,145
Haryana	4,514	1,765	1,235	1,235	72,512	1,235	35,369	1,235	51,646
Himachal Pradesh	342	100	70	70	6,363	70	3,915	70	3,720
Jammu & Kashmir	1,792	1,125	788	788	51,840	239	5,627	788	43,695

State/Union Territory	Total MSW generation reported by SBM as of Sept 2017 (TPD) (A)	Total MSW quantum for which no processing capacity exists or is proposed (TPD) (B)	Total MSW that can be utilized for energy generation, excluding 30% inerts/recyclables (TPD) (C)	Waste to Energy potential in addition to existing/proposed Waste to Energy projects					
				Scenario 1 (Mass-burn incineration adoption)		Scenario 2 (RDF co-processing adopted to maximum extent)		Scenario 3 (Bio-methanation adopted to maximum extent)	
				Total wet and combustible dry waste potentially utilized to generate energy (TPD) (D)	Potential GHG emission reduction from mass-burn incineration (tCO2e/yr) (E)	Total combustible dry waste potentially utilized to generate energy (TPD) (F)	Potential GHG emission reduction for RDF co-processing (tCO2e/yr) (G)	Maximum biodegradable waste quantum that can go to bio-methanation (TPD) (H)	Potential GHG emission reduction potential from bio-methanation (tCO2e/yr) (I)
Jharkhand	2,350	-	-	-	-	-	-	-	-
Karnataka	10,000	3,709	2,596	2,596	172,597	1,816	50,470	2,596	134,960
Kerala	1,576	-	-	-	-	-	-	-	-
Madhya Pradesh	5,079	-	-	-	-	-	-	-	-
Maharashtra	26,820	20,692	14,484	14,484	958,422	4,573	109,449	14,201	787,731
Manipur	176	-	-	-	-	-	-	-	-
Meghalaya	268	113	79	79	5,252	20	407	79	4,699
Mizoram	239	219	154	154	9,635	38	917	130	6,606
Nagaland	342	284	199	199	11,847	43	1,004	197	9,456
Odisha	2,460	860	602	602	40,149	497	9,521	602	36,643
Puducherry	495	396	277	277	18,444	99	2,972	247	12,335
Punjab	4,100	2,246	1,572	1,572	88,644	516	9,207	1,572	78,334
Rajasthan	6,400	2,020	1,414	1,414	72,256	1,414	21,446	1,414	65,261
Sikkim	89	-	-	-	-	-	-	-	-
Tamil Nadu	15,272	10,455	7,319	7,319	51,011	3,222	7,887	7,319	43,301
Telangana	7,371	-	-	-	-	-	-	-	-
Tripura	421	232	162	162	9,622	48	768	162	8,960
Uttar Pradesh	15,500	9,241	6,469	6,469	345,607	3,708	68,541	6,469	295,141
Uttrakhand	1,400	-	-	-	-	-	-	-	-
West Bengal	8,675	6,890	4,823	4,823	288,065	1,697	29,100	4,376	238,565
Total (All India)	**154,034**	**78,254**	**54,778**	**54,840**	**2,985,882**	**26,030**	**506,422**	**53,174**	**2,426,510**

Source: Author's analysis

Notes: *1. Values of 'Total Waste generation' in column A are based on data reported under Swachh Bharat Mission as of September 2017.*

2. Values in column B denote leftover unprocessed waste quantum estimated from' Total waste generation' in column A and deducting MSW processing quantities of proposed WTE and composting facilities .

3. Values in columns D, F and H represent the quantities of waste that can be processed in the respective WTE technology. This quantum has been estimated based on the 'Total MSW that can be utilized for energy generation' in column C and the total generated/available quantities of waste fractions indicated in Table 5. Since WTE facility cannot process quantities beyond the generated/available quantities of corresponding waste fractions, in cases where the MSW that

can be utilized for energy generation in column C exceeds the generated/available waste quantum as of 2017, the waste that can be utilized in the WTE plants is based on the generated quantities of waste fractions.
4. The GHG emission reduction values in columns E, G, and I are estimated by using the values of 'average GHG emission per tonne disposed' from Table 3 and the corresponding quantities of waste processed quantum of waste in columns D, F and H in the 3 scenarios. In the GHG emission reduction estimation, process rejects are assumed to be 25% of total waste processed in mass-burn incineration. For RDF and bio-methanation, process rejects are assumed to be 10%.
5. The GHG emission reduction estimated represents emissions avoided from disposal of MSW and does not include potential emission reduction due to energy generation in the WTE facilities.

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