Urban Municipal Solid Waste: Identification of Green Business Potential in India

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Preamble

India, currently the world's second most populous nation, has witnessed a rapid increase in the rate of urbanization and industrialization in the recent past. This growth in the economy has also brought about a corresponding increase in the demands of its citizens, due to rise in purchasing power and exposure to versatile goods and commodities. Consequently, the quantities of solid waste generated from various cities has also risen in an analogous manner, making it imperative to bring about waste management practices which encompass the functions of disposal, collection, recycling, monitoring, and regulation.

The urban solid waste management sector in India requires significant improvement in terms of strategy formation, planning, implementation, and finance. Authorities must devise multi-stakeholder approaches to waste management through adoption of technical, regulatory, and administrative reforms. The growth in the demand of commodities has put an enormous burden on availability of resources such as water, energy, minerals, etc. With the impending resource shortage in our country, it becomes essential to undertake necessary measures in order to efficiently manage the solid waste in cities. Recent initiatives in the Indian context, such as "Smart Cities Mission" and "Swachh Bharat Abhiyan", provide a good opportunity for law makers, industrialists, and citizens to brainstorm, showcase, and develop best practices in the domain of urban solid waste management.

Executive Summary

The domain of waste management in India, remains largely fragmented and unorganized owing to challenges in infrastructure, governance, and lack of cooperation from citizens. Municipal authorities have largely remained detached from processing and recycling of waste, and essentially dump majority of the waste in landfills leading to loss in revenue (through the potential recovery and sale of recyclables) and increase in mountains of waste. Despite rapid urbanization, residents of cities have failed to adopt the practices of segregation of waste at source due to lack of motivation and interest, which leads to the generation of a co-mingled stream of waste from city homes. Consequently, it becomes imperative to undertake immediate measures towards mobilization of resources for comprehensive management of waste in urban India.

The introduction of Solid Waste Management Rules, 2016, has given an impetus to municipal authorities and private concessionaires to engage in waste processing and management activities. Correspondingly, it shall also lead to widespread creation of employment in the areas of waste collection, segregation, transport, processing, and disposal. This report extrapolates the growth of waste management sector till 2030, while simultaneously trying to analyze the potential growth in employment in this sector.

Through a comprehensive examination of the waste management practices prevalent in India and consultation with prominent players from this domain, it is projected that the urban municipal solid waste management sector would provide employment to approximately 6.45 Million people in the country. This would be possible through incorporation and mainstreaming of various waste processing technologies such as waste-to-energy, biomethanation, pyrolysis, composting, and other solid waste recycling techniques.

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Chapter 1

Introduction

- **Background**
- **Urbanization and Solid Waste Generation in India**

Background

Solid waste is defined as discarded, solid fractions, generated from domestic units, trade centers, commercial establishments, industries and agriculture, institutions, public services and mining activities. The Central Public Health and Environmental Engineering Organization, the technical wing of Ministry of Urban Development has classified solid waste in fourteen categories based on source, origin, and type of waste. These include domestic waste, municipal waste, commercial waste, institutional waste, garbage, rubbish, ashes, bulky waste, street sweepings, dead animals, construction & demolition waste, industrial waste, hazardous waste and sewage waste.

As per the World Bank Report of 2012, world cities generated 1.3 billion tons of solid waste per year. This volume is expected to increase to 2.2 billion tons per year by 2025. Globally our modern era has been marked establishing more organized waste collection and landfill programs. A variety of regulations affecting solid waste management have been imposed, and technologies have evolved to improve the waste industry and in turn human health and well-being. In India, Solid Waste Management is one among the basic essential services provided by the municipal authorities in the country to keep urban centers clean. This service is falling too short of the desired level of efficiency and satisfaction resulting in problems of health, sanitation and environmental degradation. Most urban areas in the country are plagued by acute problems related to solid waste. Due to lack of serious efforts by town/ city authorities, garbage and its management has become a tenacious problem and this notwithstanding the fact that the largest part of municipal expenditure is allotted to it.

High population growth rates, rapidly varying waste characterization and generation patterns, growing urbanization and industrialization in developing countries are the important reasons for paying attention towards MSWM as more area is required to accommodate waste. One of the significant problems in urban India is almost no segregation of MSW and disposal of construction and demolition debris (C&D), plastic wastes, commercial and industrial refuses, and e-waste. Bubonic plague epidemic in Surat in 1994 increased awareness on the need for proper SWM systems all over India and kick started measures to properly manage wastes in the country.

As per the Municipal Solid Waste (Management & Handling) Rules 2000 (MSWR) notified by MoEF&CC, Government of India "Municipal Solid Waste" includes commercial and residential wastes generated in a municipal or notified areas in either solid or semi-solid form excluding industrial hazardous wastes but including treated biomedical wastes". These rules have been revised and issued in April 2016 and waste are now categorized as follows:

Source	Typical waste generators	Types of solid wastes
Residential	Single and multifamily dwellings	Food wastes, paper, cardboard, plastics, textiles, leather, yard wastes, wood, glass, metals, ashes, special wastes (e.g., bulky items, consumer electronics, white goods, batteries, oil, tires), and household hazardous wastes.).
Industrial	Light and heavy manufacturing, fabrication, construction sites, power and chemical plants.	Housekeeping wastes, packaging, food wastes, construction and demolition materials, hazardous wastes, ashes, special wastes.
Commercial	Stores, hotels, restaurants, markets, office buildings, etc.	Paper, cardboard, plastics, wood, food wastes, glass, metals, special wastes, hazardous wastes.
Institutional	Schools, hospitals, prisons, government centers.	Same as commercial.
Construction and demolition	New construction sites, road repair, renovation sites, demolition of buildings	Wood, steel, concrete, dirt, etc.
Municipal services	Street cleaning, landscaping, parks, beaches, other recreational areas, water and wastewater treatment plants.	Street sweepings; landscape and tree trimmings; general wastes from parks, beaches, and other recreational areas; sludge.
Process (manufacturing, etc.)	Heavy and light manufacturing, refineries, chemical plants, power plants, mineral extraction and processing.	Industrial process wastes, scrap materials, off-specification products, slay, tailings.

Urbanization and Solid Waste Generation in India

The consequences of burgeoning population in urban centers are more noticeable in developing countries as compared to the developed countries. The population of urban India was 377 million (Census of India, 2011), which accounts for 31% of the total population. Global case histories reveals that when a country's urban population extends beyond 25% of the overall population (as in the present case), the pace of urbanization accelerates (Kumar & Gaikwad, 2004). The population residing in urban regions increased from 18 to 31.2% from 1961 to 2011 respectively (Census of India, 2011).

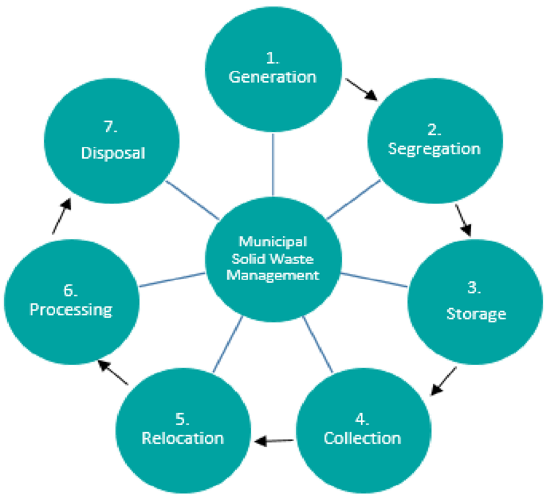
Year	2001	2011	2021	2031
Urban India's Population	286 million	377 million	530 million	600 million
% of total population	28.53%	31.2%	35%	40.76%

Urban population growth for India from 2001 to 2011(Source: Census Report 2011) & from 2021-31(United Nations Report 2014)

With this increasing population, management of Municipal Solid Waste (MSW) in the country has emerged as a severe problem not only because of the environmental and aesthetic concerns but also because of the sheer quantities generated every day.

Status of MSW and Estimates: Generation, Collection and Treatment in India

A solid waste management system (SWM) system includes collection, segregation, transportation, processing and disposal of waste as described below:



In India, majority of Urban Local Bodies (ULB) do not have appropriate action plans for execution and enactment of the MSWR (CPCB Report, 2013). Unfortunately, no city in India can claim 100% segregation of waste at dwelling unit, and on an average only 70% waste collection is observed, while the remaining 30% is again mixed up and lost in the urban environment. Out of total waste collected, only 12.45% waste is scientifically processed and rest is disposed in open dumps (CPCB Report 2013). Environment friendliness, cost effectiveness, and acceptability to the local community are major attributes to achieve efficient solid waste management system. Critical examination of important parameters of MSWM practice with respect to Indian Scenario is delineated below.

MSW GENERATION AND TREATMENT FACILITIES	
Generation (TPD)	133,760
Collection Efficiency	68 %
Total Waste Collected (TPD)	90,957
Waste Lost / Littered (TPD)	42,803
Composition of MSW	
Organic Waste in TPD (51 %)	68,218
Inert & non-organic in TPD (32 %)	42,803
Recyclable in TPD (17 %)	22,739
MSW Treatment Facilities	
MSW Treated / Processed in TPD	25,884
Number of ULBs having treatment / processing facilities	626
1. Composting	279
2. Vermi compost	138
3. Biogas plant	172
4. Pelletization (RDF)	29
5. Waste to Energy	8
Landfilling	
Landfilled	65,489
Total waste to be landfilled	108,292

The Central Pollution Control Board (CPCB) has reported that 1, 33,760 metric tons of waste is generated daily in urban areas in the country (SPCB Response 2012-13). There are several deficiencies in the current system and they do vary across states and cities. In general there is:

(i) Little primary collection at the door step
(ii) Little storage and segregation of recyclables
(iii) Poor secondary storage, mostly by the road side in open spaces or in derelict concrete of bricked in containment areas.
(iv) No regular sweeping of streets
(v) Transportation of waste in open tractors/ trucks
(vi) Little processing of waste; and
(vii) Unscientific disposal of MSW at dumpsites.

In comparison to the levels of the developed world, of 1-2.5 kg capita/day, our per capita average generation of 450 gm/day of MSW is lower. The per capita municipal solid waste generation rate reported for small towns is 200-300 gm/capita, 300-400 gms/capita for medium cities and between 400-600 gms/capita for large cities (2011 CPCB Report). The total quantity of waste currently handled each day in the urban areas in the country is estimated to be 1, 70,000 metric tons i.e. about 62 million tonne per year (2011 CPCB Report).

State-wise generation, collection & treatment (CPCB data as on 06.02.2015) is shown below:

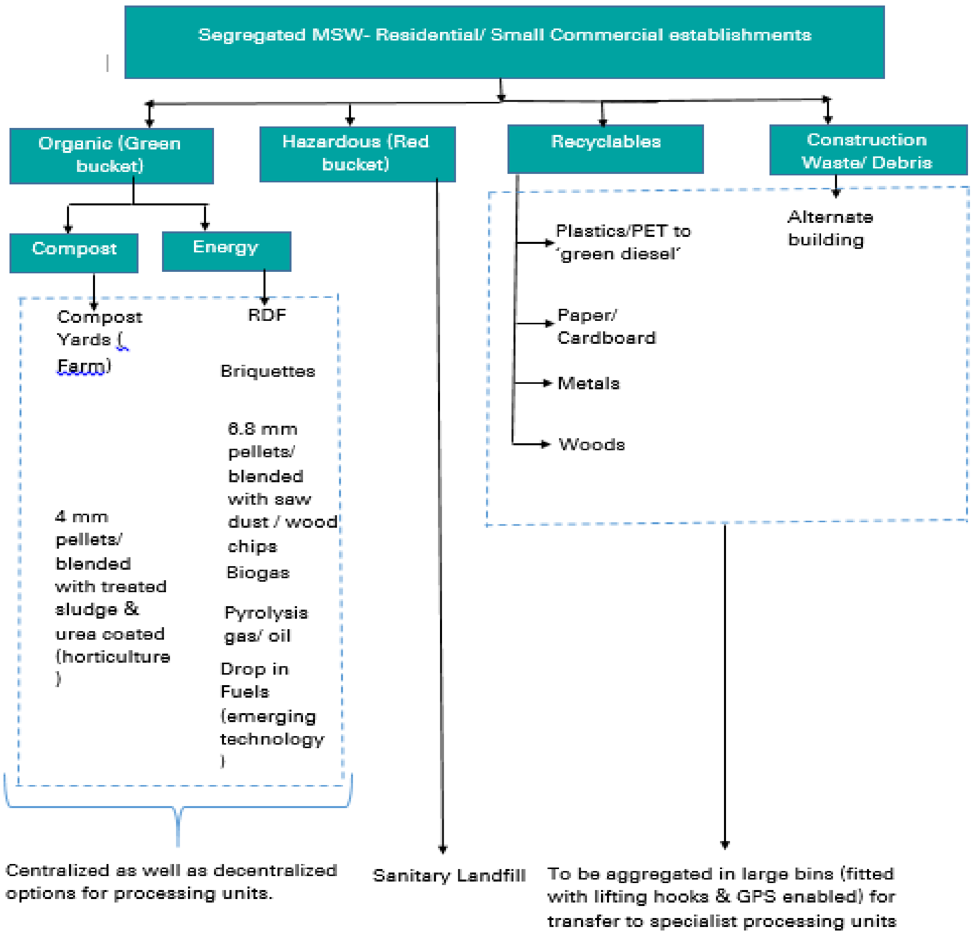
S. No.	States	Quantity generated	Collected(TPD)	Treated (TPD)
1	Andaman & Nicobar	70	70	05
2	AP/ Telangana	11500	10655	3656
3	Arunachal Pradesh	110	82	74
4	Assam	650	350	100
5	Bihar	1670	-	-
6	Chandigarh	340	330	250
7	Chhattisgarh	1896	1704	168
8	Daman Diu & Dadra	85	85	Nil
9	Delhi	8390	7000	4150
10	Goa	183	182	182
11	Gujarat	9227	9227	1354
12	Haryana	3490	3440	570
13	Himachal Pradesh	300	240	150
14	Jammu & Kashmir	1792	1322	320
15	Jharkhand	3570	3570	65
16	Karnataka	8784	7602	2000

17	Kerala	1576	776	470
18	Lakshadweep	21	-	-
19	Madhya Pradesh	5079	4298	802
20	Maharashtra	26,820	14,900	4700
21	Manipur	176	125	-
22	Meghalaya	268	199	98
23	Mizoram	552	276	Nil
24	Nagaland	270	186	18
25	Orissa	2460	2107	30
26	Puducherry	495	495	Nil
27	Punjab	3900	3853	32
28	Rajasthan	5037	2491	490
29	Sikkim	49	49	0.3
30	Tamil Nadu	14532	14234	1607
31	Tripura	407	407	Nil
32	Uttar Pradesh	19180	19180	5197
33	Uttarakhand	1013	1013	Nil
34	West Bengal	8674	7196	1415
35	Total	1,43,449	1,17,644	32,871

State-wise generation, collection & treatment (CPCB data as on 06.02.2015)

Various components of MSW have an economic value and can be recovered, reused or recycled cost effectively. Currently, the informal sector picks up part of the resources from the streets and bins to earn their living. However, a sizeable portion of organic waste as well as recyclable material goes to landfills untreated. Over 81% of MSW annually is disposed at open dump sites without any treatment. With planned efforts to Reduce, Reuse, Recover , Recycle and Remanufacture (5Rs) and appropriate choice of technology, the country can profitably utilize about 65% of the waste in producing energy and/or compost and another 10 to 15% to promote recycling industry and bring down the quantity of wastes going to landfills/ dumps under 20%.

The percentage of wet biodegradable waste is high in Indian waste and is a source of contamination of soil, water and air, if disposed indiscriminately. Biodegradable waste has a good potential for generating biogas, which can serve as fuel, can also be converted to energy as well as to compost which can improve soil health and lead to increased agriculture production. This wet waste must therefore be processed either through bio-methanation or composting technology for generating biogas, electricity or compost for use as nutrient and prevent such wastes reaching the landfill. Considering that reusable and recyclable wastes form 20-25% of the actual waste generated (which does not include the wastes collected by the kabadiwalas / recyclable waste collectors & segregators from source of generation). Plastics, paper and glass constitute 17% of the recyclable wastes. Plastic wastes including composites are high calorific value material and crucial ingredient for MSW based W to E plants. This material also needs to be fully recovered and profitably utilized. Segregation of the non-recyclable dry combustible MSW at secondary storage depots/transfer stations and optimally utilize this material in the form of RDF which can be fed to W to E power plants and as auxiliary fuel in cement and metallurgical industry. Setting up of small to large plastic waste to liquid fuel plants, thereby utilizing the plastic not picked up by kabadiwalas / recyclable waste collectors & segregators and rag pickers, also needs to be encouraged. The following diagram gives an overview of the various categories of waste and end utilization:


Segregated MSW- Residential/ Small Commercial establishments
Organic (Green bucket)
Hazardous (Red bucket)
Recyclables
Construction Waste/ Debris
Compost
Energy
Compost Yards (Farm)
RDF
Briquettes
6.8 mm pellets/ blended with saw dust / wood chips
Biogas
Pyrolysis gas/ oil
Drop in Fuels (emerging technology)
4 mm pellets/ blended with treated sludge & urea coated (horticulture)
Plastics/PET to 'green diesel'
Paper/ Cardboard
Metals
Woods
Alternate building
Centralized as well as decentralized options for processing units.
Sanitary Landfill
To be aggregated in large bins (fitted with lifting hooks & GPS enabled) for transfer to specialist processing units

Chapter 2

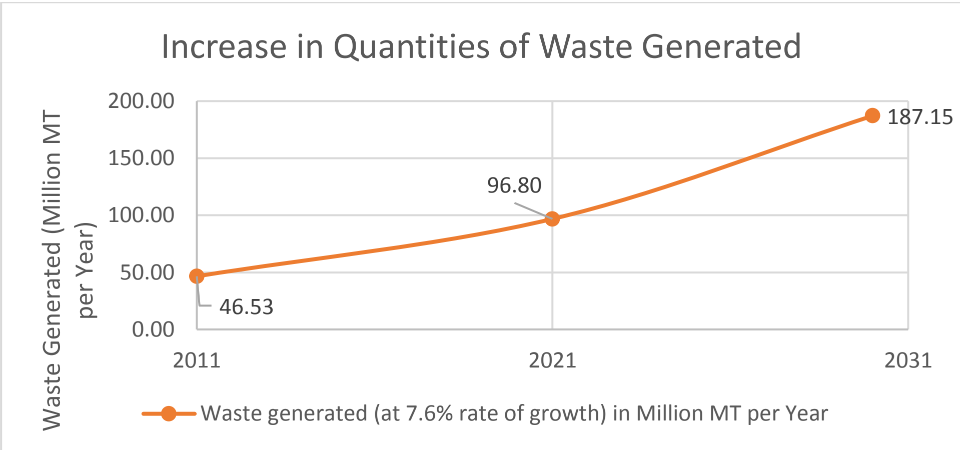
Growth Forecast

Growth in Generation of Waste

According to Census 2011, the total population of India stood at 1.21 billion. Out of this, 377 million (31.16%) of the total population lives in urban areas. The number of cities with one million plus population has increased to 53 from 35 during 2001-2011. Per capita waste generation in cities varies from 0.2 kg to 0.6 kg per day. Generally the collection efficiency ranges from 70% to 90 % in major metro cities while in smaller cities it is below 50%. It is also estimated that the Urban Local Bodies spend about Rs.500 to Rs.1500 per tonne on solid waste for collection, transportation, treatment and disposal. About 60-70% of this amount is spent on street sweeping of waste collection, 20 to 30% on transportation and less than 5% on final disposal of waste, which shows that hardly any attention is given to scientific and safe disposal of waste.

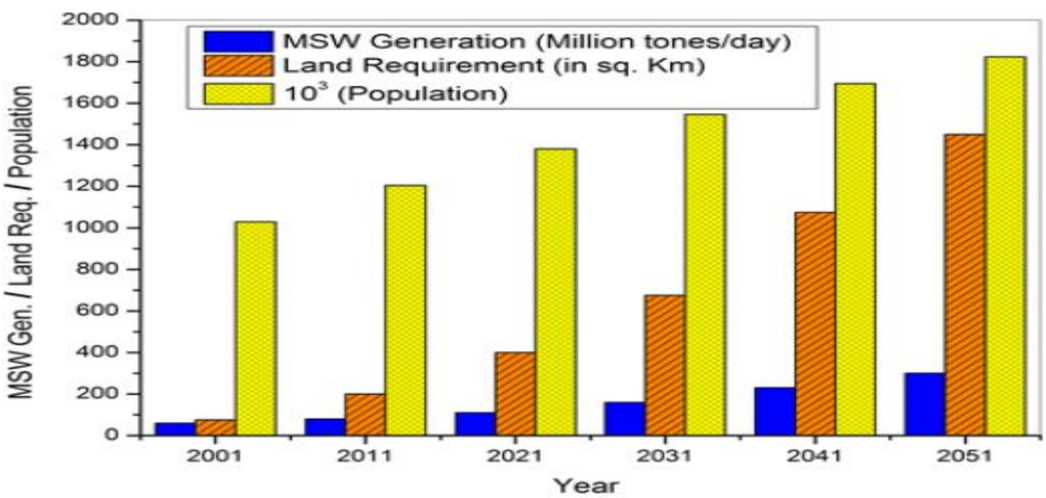
As per the Status Report on Municipal Solid Waste in India (2011) by the Central Pollution Control Board, the net solid waste generation in India stood at 46.53 Million MT in the year 2011. Assuming growth in quantities of waste generated occurs at the Indian GDP growth rate of 7.6 % per annum, projection for total annual waste generation can be projected up to 2030 as under.

GROWTH IN GENERATION OF WASTE			
	2011	2021	2030
Waste generated (at 7.6% rate of growth) in Million MT per Year	46.53	96.80	187.15



Land Requirement

Only about 75-80 % of the municipal waste gets collected and out of this only 22-28 % is processed and treated and remaining is disposed of indiscriminately at dump yards. If cities continue to dump the waste at present rate without treatment, it will need 1240 hectares of land per year. Existing and future land requirement for disposal of MSW along with growth in population and MSW generation is shown in below figure (Source: Joshi & Ahmed 2016)



Chapter 3

Technologies for MSW Treatment & Utilization

- **Technological Solutions**
- **Waste Processing in Indian States**
- **Energy Potential of Waste**

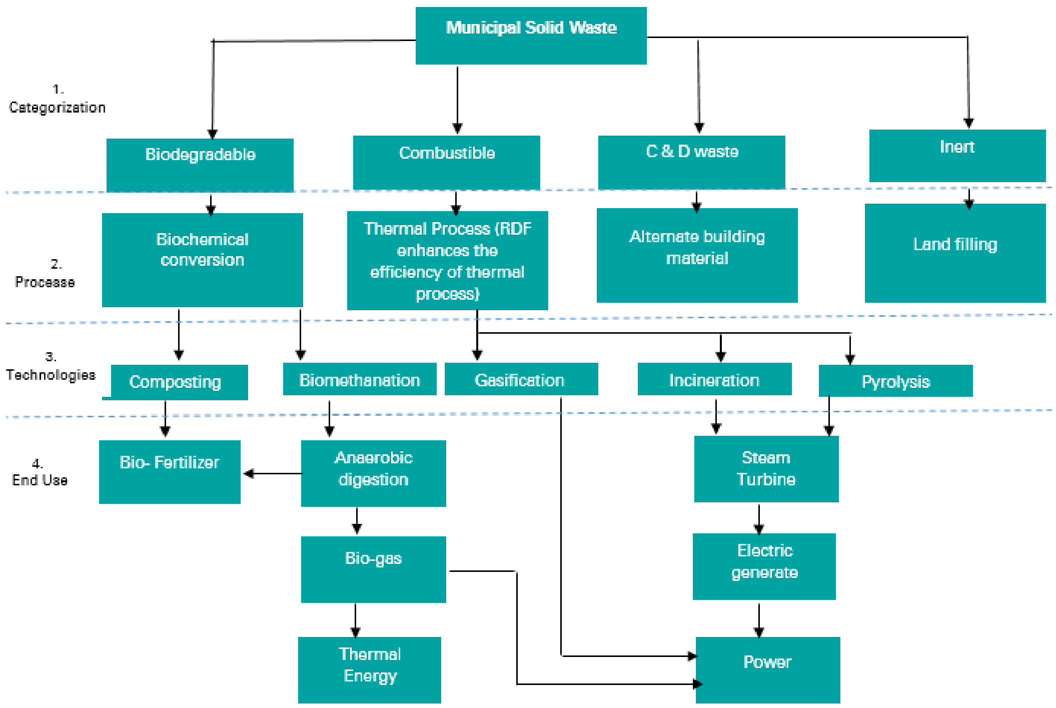
Technological Solutions

Energy recovery in the form of electricity, heat and fuel from the waste using different technologies is possible through a variety of processes, including incineration, gasification, pyrolysis and anaerobic digestion. These processes are often grouped under “W to E technologies”.

(i) Bio-chemical conversion of biodegradable MSW can be categorized into composting, biomethanation and fermentation. Composting is an aerobic process in which biologically degradable wastes are converted through solid state biochemical transformation to yield stable granular material - which could be used as soil conditioners and nutrients. Biomethanation is an anaerobic slurry-phase process that can be used to recover both nutrients and energy contained in biodegradable waste. Biogas can be used either as a source of thermal energy or to generate electricity by using gas engines and turbines.

(ii) Thermal processing of MSW which can be accomplished in several ways including incineration, pyrolysis, gasification and mass burning. Typically, the feedstock could be segregated or un-segregated MSW or refuse derived fuel. Incineration is the complete combustion of waste with the recovery of heat, to produce steam, which in turn produces power through steam turbines. Mass burning of MSW is achieved by burning unprocessed wastes. Pyrolysis uses heat to break down organic materials in the absence of oxygen, producing a mixture of combustible gases (primarily methane, complex hydro, carbons, hydrogen, and carbon monoxide), liquids and solid residues. Gasification is a process that converts organic or fossil based carbonaceous materials into carbon monoxide, hydrogen and carbon dioxide at elevated temperature (500-1800oC) in the presence of limited amount of oxygen – typically called as Syngas at temperature above 900oC along with the conventional fuels like coal without any ill effects for generating heat. Operation of thermal treatment systems involves higher costs and a relatively higher degree of expertise.

Drop-in fuels is an upcoming technology in waste processing. These fuels are produced from various biomass sources that can be produced from several sources of bio-mass i lipids (such as vegetable oils, animal fats, greases and algae) and cellulosic material (such as crop residues, woody biomass, and dedicated energy crops). Researchers are exploring a variety of methods to produce renewable hydrocarbon biofuels. Currently, commercial- scale production of renewable hydrocarbon biofuels is negligible in India. Even in the United States, there were only two commercial facilities with a combined capacity of 167 million gallons per year.



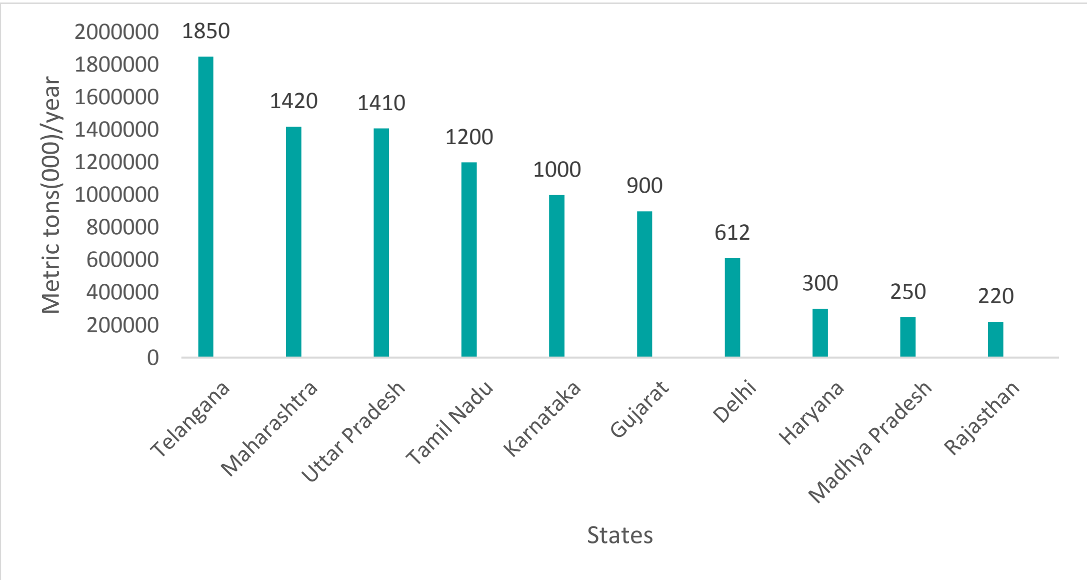
Waste Processing in Indian States

As per information available for 2013-14, compiled by CPCB, municipal authorities have set up 553 compost & Vermi-compost plants, 56 bio-methanation plants, 22 RDF plants and 13 Waste to Energy (W to E) plants in different States in the country.

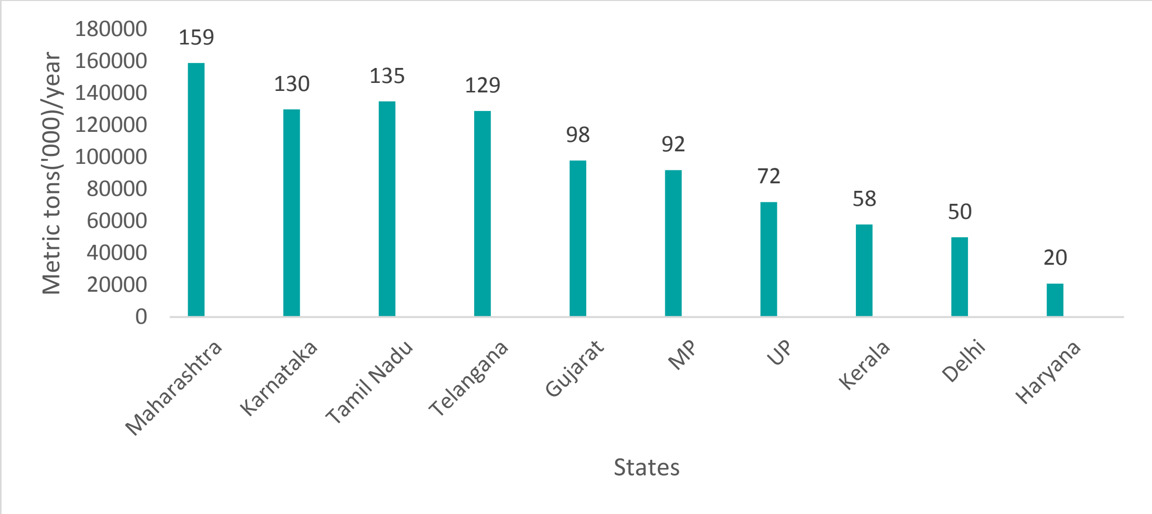
Composting/ Vermicomposting

State	Number of plants (composting/ Vermi composting)	State	Number of plants(Composting/ Vermicomposting)
Andhra Pradesh	32	Madhya Pradesh	4
Chhattisgarh	15	Maharashtra	125
Delhi	3	Meghalaya	2
Goa	5	Orissa	3
Haryana	2	Punjab	2
Gujarat	86	Rajasthan	2
Himachal Pradesh	13	Tripura	13
Karnataka	5	Uttrakhand	3
Kerala	29	West Bengal	9

List of some key composting/ Vermi composting plants in some States



State wise summary of compost plant installed capacity (MoUD Annual Report 2015-16)



State wise compost production potential (Source: MoUD Annual Report 2015-16)

Refuse Derived Fuel

Refuse-derived Fuel (RDF) is another upcoming technology, which can be effectively used to produce power/thermal energy from MSW and reduce Refuse-derived Fuel (RDF) is another upcoming technology, which can be effectively used to produce power/thermal energy from MSW and reduce load on landfill. Status of some key RDF, waste to energy plants and biogas plants are shown in the below table.

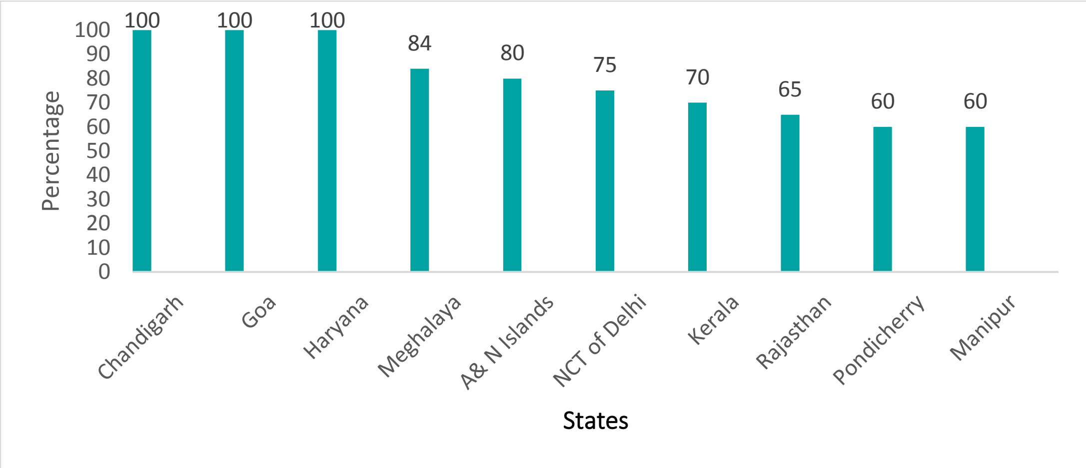
State	No of RDF plants/ waste to energy plants(PP)/ Biogas(BG)	State	No of RDF plants/ waste to energy plants(PP)/ Biogas(BG)
Andhra Pradesh	3- RDF, 4- PP	Delhi(UT)	1-RDF, 1 PP
Chandigarh(UT)	1-RDF	Gujarat	2-RDF
Chhattisgarh	1-RDF	Kerala	2- BG
Maharashtra	19BG		

Waste to Energy plants

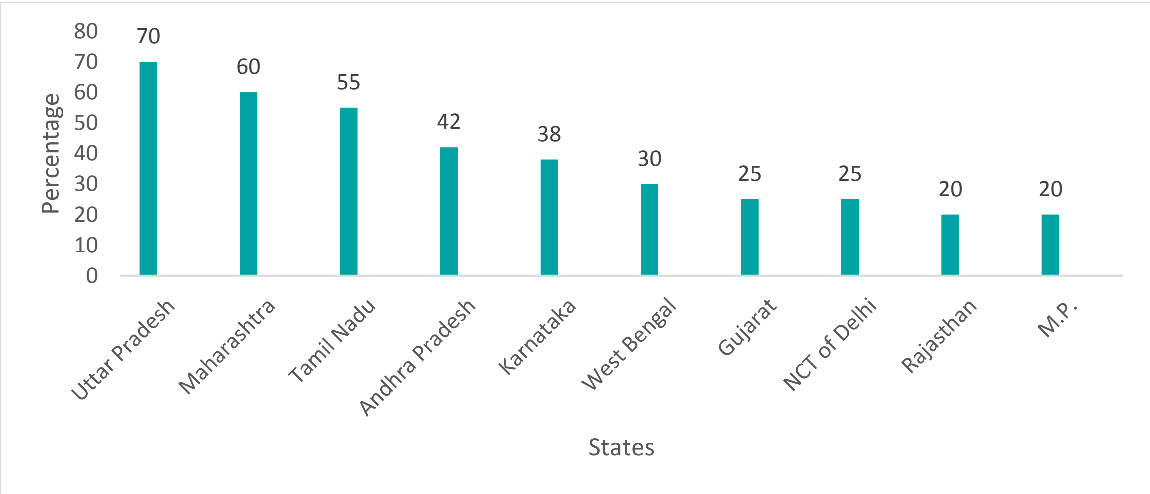
Parameter	Katol, Maharashtra, 2010-14	Bharuch, Ankleshwar, 2006-14	Pune Municipal Corp. 2010-14	Kottayam Medical College	Auro Textile, 2010-14
Capacity	2 MT/day	5MT/day	5 MT/day	2 MT/day	2 MT/day
Quantity of waste processed	800 MT	4000 MT	9000 MT	2000 MT	2000 MT
No. of working days	1200(approx.)	2500(approx.)	1200(approx.)	1400(approx.)	1150
Quantity of biogas generated	60,000 m3	3,20, 000 m3	6,00,000 m3	1,20,000 m3	63, 200 m3
Utility of biogas	Biogas provided free to few families below poverty line	Biogas is provided for boiler	40 KVA generator installed, electricity for captive use and 200 street lights	Hostel Kitchen	Factory kitchen
Quantity of manure generated	50 MT(used for city gardens)	350 MT(Manure is sold)	20 MT(manure not recovered due to space problem)	150 MT(Nearby farmers use it)	70 MT

The above table shows details of five biomethanation plants that were successfully operated by municipalities and private operators.

As per the annual report 2015-16, of the Ministry of Urban development, every state is emphasizing on waste processing and by 31st March, 2016, Chhattisgarh, Goa and Haryana expect to process 100% of its Municipal Solid Waste while other states like Meghalaya, Andaman & Nicobar Islands, Delhi, Kerala, Rajasthan, Puducherry and Manipur have taken significant steps in this direction.



Best Waste processing state/ UTs in percentage, till 31st March, 2016(MoUD, Annual Report 2015-16)



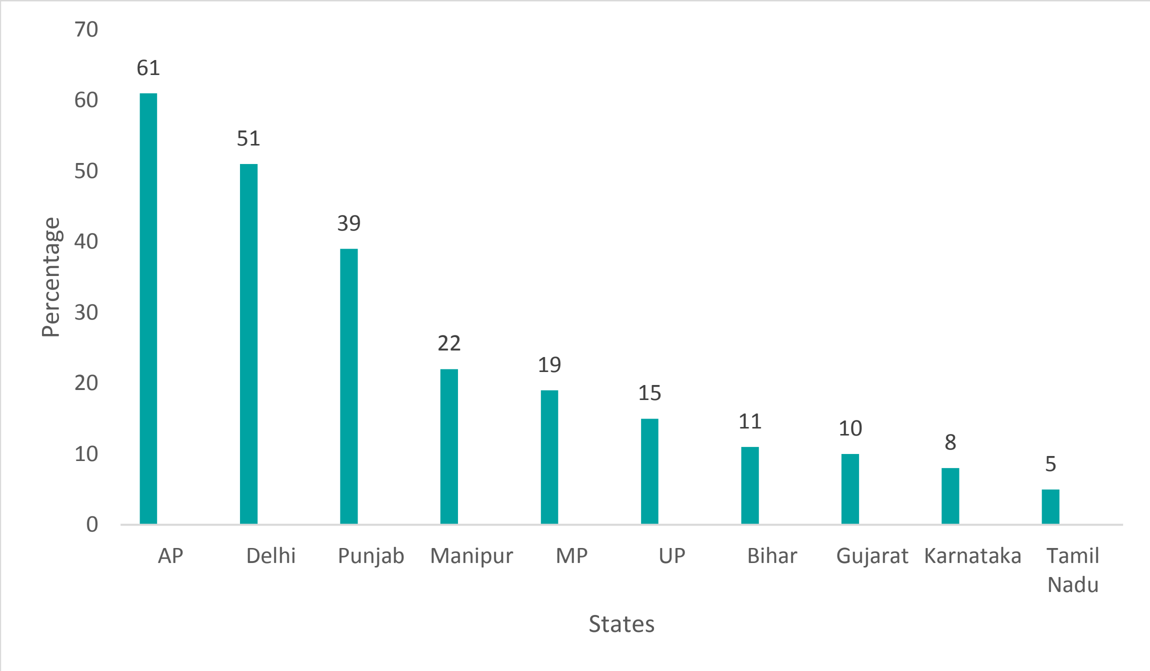
Plastic to Fuel- All around the Globe, companies and individuals are starting to produce fuel from waste plastic. As only 8 % of waste plastic is recycled in the U.S., 15 % IN Western Europe, and much less in developing countries, this reuse of plastic could potentially keep enormous amounts of plastic out of landfills and out of the oceans.

In this process, plastics are shredded and then heated in an oxygen free chamber (known as pyrolysis) to about 400 degree Celsius. As the plastics boil, gas is separated out and often reused to fuel the machine itself. The fuel is then distilled and filtered.

For this technology, the type of plastic converted to fuel is important. Burning pure hydrocarbons, such as polyethylene and polypropylene, a fuel is produced that burns fairly clean.

Success stories

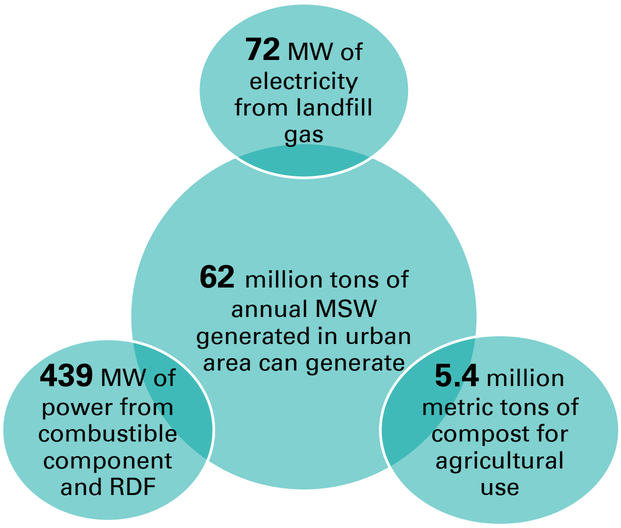
1. In Niagara Falls, NY, John Bordinuil's 'Plastic Eating Monster' can even vaporize thick HDPE plastic into a cleaner burning number to fuel.
2. Cynar in the U.K. converts mixed waste plastics into synthetic fuels that are cleaner and low in sulphur.



State Power Production Capacity of Operations and under construction plants (MoUD, Annual Report 2015-16)

Energy Potential of Waste

As per the report of the task force of erstwhile Planning Commission in 2013, the untapped waste has a potential of generating 439 MW of power from 32,890 TPD of combustible wastes including Refused Derived Fuel (RDF), 1.3 million cubic meter of biogas per day, or 72 MW of electricity from biogas and 5.4 million metric tons of compost annually to support agriculture. The growth of waste to energy plants is a testimony to the fact that waste has a huge energy potential. The diagram below is a depiction of the energy potential from waste.



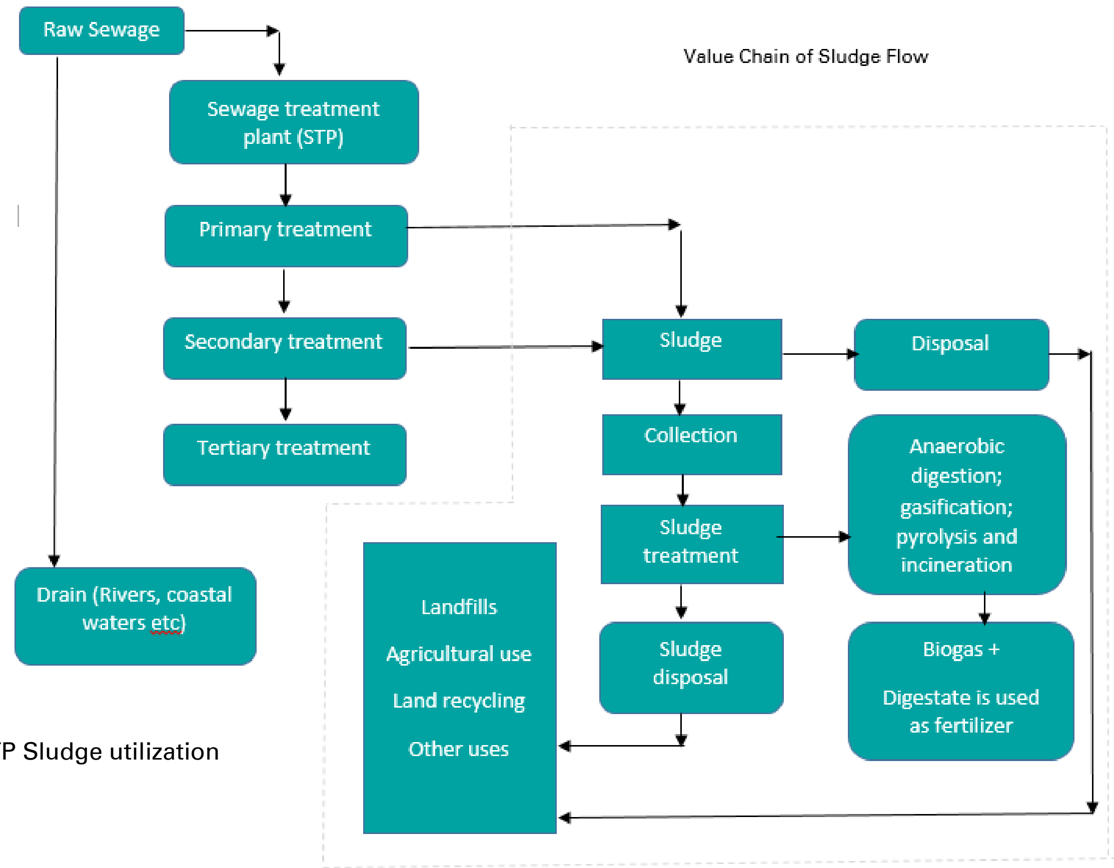
Chapter 4

STP / ETP Sludge Utilization

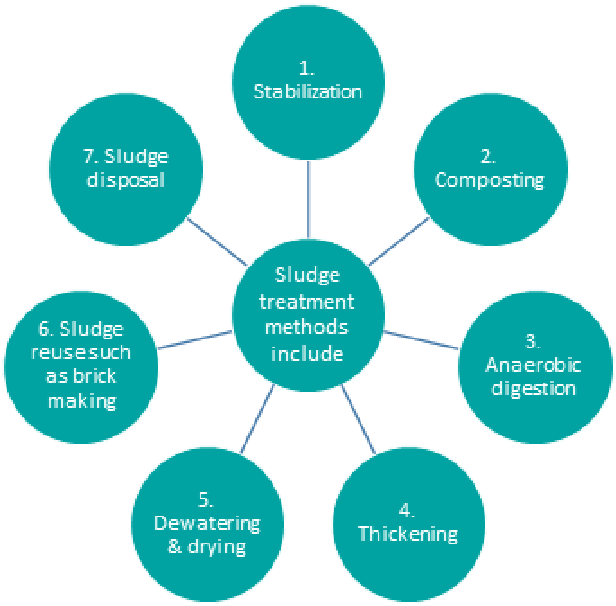
- **Sludge Treatment, Reuse And Disposal**
- **Reuse of Sewage Sludge**

Sludge Treatment, Reuse and Disposal

Sludge is produced from the treatment of wastewater in on-site (e.g. septic tank) and off-site (e.g. activated sludge) systems. This is inherently so because a primary aim of wastewater treatment is removing solids from the wastewater. In addition, soluble organic substances are converted to bacterial cells, and the latter is removed from the wastewater. Sludge is also produced from the treatment of storm water although it is likely to be less organic in nature compared to waste water sludge.



STP/ ETP Sludge utilization



Sludge treatment methods/ Utilization

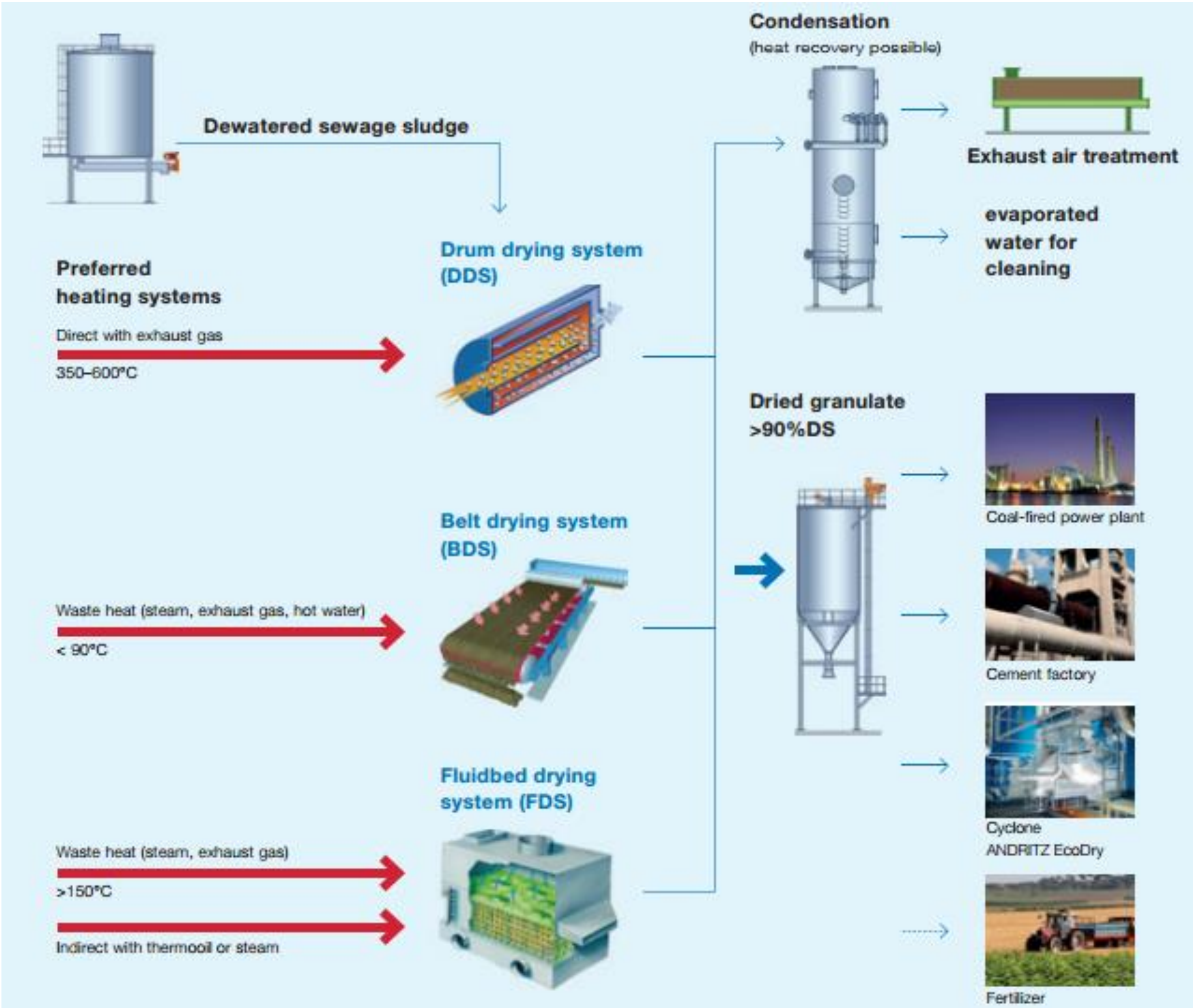
Reuse of Sewage Sludge

Sewage sludge possesses several uses depending on the nature of treatment undertaken. Subjecting sewage sludge to heat results in significant reduction in weight and volume. The following measures are commonly practiced for effective end-utilization of sewage sludge:

- **Thickening:** Thickening is often the first step in a sludge treatment process. Sludge from primary or secondary clarifiers may be stirred (often after addition of clarifying agents) to form larger, more rapidly settling aggregates. Primary sludge may be thickened to about 8 or 10 percent solids, while secondary sludge may be thickened to about 4 percent solids. Thickeners often resemble a clarifier with the addition of a stirring mechanism.
- **Dewatering** and **drying:** Water content of sludge may be reduced by centrifugation, filtration, and/or evaporation to reduce transportation costs of disposal, or to improve suitability for composting. Centrifugation may be a preliminary step to reduce sludge volume for subsequent filtration or evaporation. Filtration may occur through underdrains in a sand drying bed or as a separate mechanical process in a belt filter press. Filtrate and centrate are typically returned to the sewage treatment process. After dewatering sludge may be handled as a solid containing 50 to 75 percent water.
- **Incineration:** Incineration of sludge is less common because of air emissions concerns and the supplemental fuel (typically natural gas or fuel oil) required to burn the low calorific value sludge and vaporize residual water. On a dry solids basis, the fuel value of sludge varies from about 260 cal/g to 980 cal/g of digested primary sludge. Stepped multiple hearth incinerators with high residence time and fluidized bed incinerators are the most common systems used to combust wastewater sludge. Co-firing in municipal waste-to-energy plants is occasionally done, this option being less expensive assuming the facilities already exist for solid waste and there is no need for auxiliary fuel. Incineration tends to maximize heavy metal concentrations in the remaining solid ash requiring disposal; but the option of returning wet scrubber effluent to the sewage treatment process may reduce air emissions by increasing concentrations of dissolved salts in sewage treatment plant effluent.

The Austrian engineering giant Andritz AG has developed state-of-the-art technologies aimed towards gainful utilization of sewage sludge through treatment methods.

The below infographic illustrates the end uses possible from the drying technologies offered by Andritz:



POTENTIAL OF SEWAGE SLUDGE AS ENVIRONMENT FRIENDLY MANURE

Due to exponential population increase in developing world, the wastewater and solid waste generation has tremendously increased and their management has become a serious health and environmental issue. A large amount of sewage sludge generated by sewage treatment plants however, can be re-used after proper segregation and treatment as fertilizer. Several research groups have conducted studies involving chemical analysis of sewage sludge samples subjected to heat treatment over long periods of time. These tests involved analyzing the extent of presence of microbes such as Coliforms and E.Coli, as well as the presence of Nitrogen, Phosphorus, and Organic Matter.

Most studies have come to conclude that sewage sludge possesses great potential for use in greenbelts, forests, and can also be applied for some restricted agricultural purpose after ample heating or sunlight exposure. The chemical parameters in the treated sludge samples were found to be under reasonable limits. Use of sewage sludge further elucidates the concept of circular economy.

Chapter 5

Composting

- **Background**
- **Economics of Composting Business**

Background

Composting is the natural process of 'rotting' or decomposition of organic matter by microorganisms under controlled conditions. Raw organic materials such as crop residues, animal wastes, food garbage, some municipal wastes and suitable industrial wastes, enhance their suitability for application to the soil as a fertilizing resource, after having undergone composting. Composting is a biological process that is optimized when the starting carbon to nitrogen ratio is in the range of 30:1 and the moisture and oxygen levels and temperatures are closely managed and monitored.

Compost is a rich source of organic matter. Soil organic matter plays an important role in sustaining soil fertility, and hence in sustainable agricultural production. In addition to being a source of plant nutrient, it improves the physico-chemical and biological properties of the soil. As a result of these improvements, the soil: (i) becomes more resistant to stresses such as drought, diseases and toxicity; (ii) helps the crop in improved uptake of plant nutrients; and (iii) possesses an active nutrient cycling capacity because of vigorous microbial activity. These advantages manifest themselves in reduced cropping risks, higher yields and lower outlays on inorganic fertilizers for farmers.

Composting may be divided into two categories by the nature of the decomposition process. In anaerobic composting, decomposition occurs where oxygen (O) is absent or in limited supply. Under this method, anaerobic micro-organisms dominate and develop intermediate compounds including methane, organic acids, hydrogen sulphide and other substances. In the absence of O, these compounds accumulate and are not metabolized further. Many of these compounds have strong odors and some present phytotoxicity. As anaerobic composting is a low-temperature process, it leaves weed seeds and pathogens intact. Moreover, the process usually takes longer than aerobic composting. These drawbacks often offset the merits of this process, *viz.*, little work involved and fewer nutrients lost during the process.

Vermicomposting

It is the product or process of composting using various worms, usually red wigglers, white worms, and other earthworms, to create a heterogeneous mixture of decomposing vegetable or food waste, bedding materials, and vermicast, also called worm castings, worm humus or worm manure, is the end-product of the breakdown of organic matter by an earthworm. These castings have been shown to contain reduced levels of contaminants and a higher saturation of nutrients than do organic materials before vermicomposting. Containing water-soluble nutrients, vermicompost is an excellent, nutrient-rich organic fertilizer and soil conditioner. This process of producing vermicompost is called *vermicomposting*. While vermicomposting is generally known as a nutrient rich source of organic compost used in farming and small scale sustainable, organic farming, the process of vermicasting is undergoing research as a treatment for organic waste in sewage and wastewater plants around the world.

Agro-Waste To Manure Process

Primary Segregation	Uploading / Stage 1 Secondary Segregation	Zero Waste Management Centre / Stage 2 Secondary Segregation	Composting Process	Compost Beds	Revenue Potential Options
At Farm / Household Level	Wet items are segregated before it is transferred to common facility	Segregation	Windrow Aerated windrow	Manure Sieving Manure Processing	Sale and Purchase agreements with forest departments, nurseries etc.

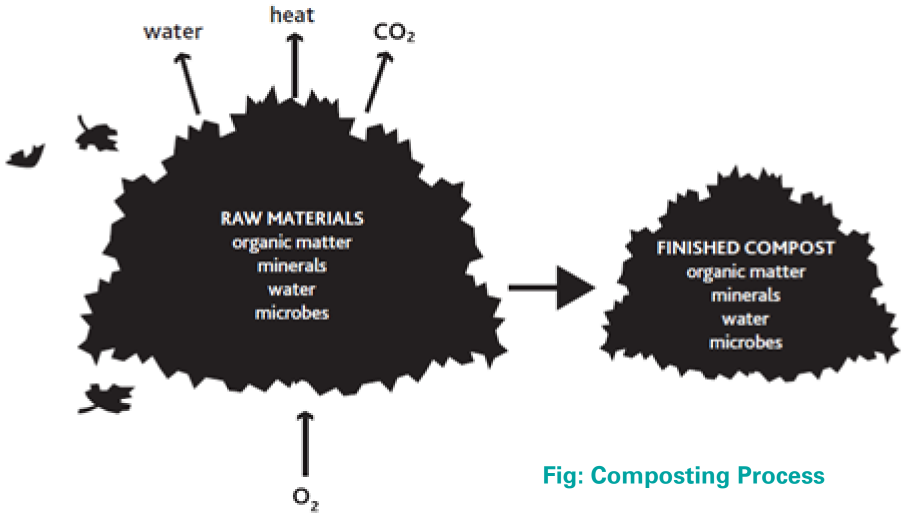


Fig: Composting Process

Composting Technologies and systems for the actual composting phases are described in the **Table** below:

Technology	Description
Windrow	Outdoor composting in piles that rely on mechanical aeration, typically with a compost windrow turner, to optimize the composting process. Windrow facilities with straddle turners (a turner which goes over the top of the pile) are limited in pile height by the height of the turner. Other turner technologies, e.g., elevating face, perform the turning function from the side and therefore pile height is less of a constraint. To optimize the windrow composting process, pile height typically is limited to 3 to 4 meters. Organics to be composted are either premixed prior to being formed into a windrow, or are layered (e.g., typically on a bed of ground yard trimmings, wood chips or sawdust) and then mixed with the turner. To control release of odors when the food scraps in the organics are "fresh," some windrow facility managers create the windrows and then wait for a few days or a week before the first pile turning. In some cases, the windrows are covered with a layer of ground yard trimmings, which acts as a bio-filter during this initial stage. In a windrow, temperature control and oxygen levels are managed via mechanical agitation. Pile temperature and oxygen level need to be taken by a site operator with hand-held monitoring tools. Pile turning introduces oxygen, accelerates physical degradation of feed-stocks and provides an opportunity to adjust the moisture content to the optimum level. Many windrow turners have a watering attachment, which enables moisture to be added to the pile while turning. Generally speaking, the total composting time can be managed by the aggressiveness of the turning regime. More frequent turning breaks particles down more quickly, and provides an opportunity to optimize composting conditions, thus accelerating the composting process. This enables a windrow composting facility to increase its annual throughput capacity.

Enclosed Aerated Windrow	An aerated windrow is essentially a hybrid between a windrow and an aerated static pile. It uses both forced air (to more directly control oxygen levels and temperatures) and pile agitation, which accelerates the physical breakdown of composting materials and thus the composting process. Facilities using aerated windrows typically house them in a building, where the composting hall floor has aeration trenches covered by grates. Process air is directed to a bio-filter outside of the building. Few, if any, facilities solely use aerated windrows by themselves to compost the SSO stream. Typically, aerated windrows are used after initial processing in rotary drums (typically three-day retention time in the drums) or with in-vessel containers.
Aerated Static Pile	Aerated static pile composting is comprised of forcing (positive) or pulling (negative) air through a trapezoidal compost pile. Agitation only occurs when piles are combined or moved to a different area for curing. To better manage odors, piles often are covered with a layer of finished compost or wood chips, which then are incorporated when the piles are moved. The aerated static pile composting method was developed in the early 1970s primarily for composting municipal sewage sludge. For bio-solids, a bulking agent is needed to provide pile porosity to enhance the flow of air and control temperatures. Wood chips were determined to be the optimum bulking agent (although over the years, there has been some experimentation with shredded tires); these are recovered through screening and recycled back into the initial pile mix. One advantage of aerated static pile composting is the ability to capture the process air for odor treatment (typically through a bio-filter). Outdoor aerated static pile operations need to use negative aeration (pulling air down through the pile) in order to direct it to an odor control system. Indoor aerated static piles can use positive aeration, with building air removed and treated through an odor control system.
Rotary Drums	Rotary drums (also called digesters) are included in this section because a number of the solid waste composting systems in North America utilize a drum as the first stage of composting. Rotary drums are not, in and of themselves, a composting technology. They must be used in tandem with another composting method. Rotary drums are popular because they serve several purposes: blending, size reduction without shredding, and screening. Over the three day retention time, the composting process is initiated, providing some degradation of feed-stocks, particularly food waste. Air is fed into the drum to aerate the material; process air typically is treated through a bio-filter. As material exits the drum, it passes through a screen, removing contaminants. Proponents of drums over mechanical shredding of composting feed-stocks cite a better ability to sort contaminants, especially plastic, as it has not been reduced to small pieces that can keep passing through screening systems.
Anaerobic Digestion	Anaerobic digestion (AD) is the biological breakdown of organic materials in the absence of oxygen. In the process, biogas containing methane and carbon dioxide is produced. This biogas can be used as a fuel to generate energy. The material remaining after digestion is a partially stabilized organic material, which can then be aerobically cured and used as compost. Anaerobic Digestion Equipment: Proprietary equipment with a pulping system to pulverize or machinate the in feed materials into a consistent size feedstock for the anaerobic digestion chamber or silo. Vendors offer

	systems of various throughput capacities, with abilities to directly inject liquids (e.g., manures, sludge's, etc.). One and two stage anaerobic digestion systems are available, where the solids are pressed from the liquids and processed in a separate system. All facilities processing SSO treat process air through a bio-filter. Materials typically are premixed before being loaded in the silos; all curing of materials are done in a separate structure (open-sided or enclosed). At some installations, aeration is provided in the curing phase.

Economics of Composting Business

Compost Yards: They are used for preparation of compost from separated solids from biogas plant effluent. Separated solid from biogas plant effluent (about 30% dry solids) will be composted. There will be custom built vats, compost shifters, vibratory sieves, bagging system etc. to produce assured quality compost estimated to be 2000 No × 50 Kg bags per month.

Roof mounted Solar PV Plant: (200 KW, 300,000 KW/year) will function as captive power plant depot cum compost yard adopting net metering scheme. Some power will also be supplied to school or other community centers in nearby village as part of community support activity.

Economics: The capital cost ranges shown below are per throughput ton assuming a minimum of 50,000 throughput tonnes per year.

Composting Technique	Economics
Windrowing	\$40 - 60 per throughput ton
Enclosed Windrowing	\$100 - \$150 per throughout ton
Anaerobic Digestion	\$500-\$700 per throughput ton

Note: "throughput" is the maximum rate of production

Chapter 6

Construction and Demolition Waste

- **Analysis of C&D Waste Management in India**
- **Construction and Demolition Waste Management Rules, 2016**

The construction industry has gained very fast growth in recent decades due to the increase in the population, increase in the IT sector and increase in the industrialization and also introduction of new infrastructure projects resulted in the increase of construction industry drastically, due to which the demand for construction materials is huge for the construction activities which results in the generation of huge amount of construction waste. Construction material wastage resulted in the huge financial setbacks to builders, contractors, regionals authorities and also to the country. The production of waste due to the demolition of structures is more than the wastage which occurs during construction of structures, so there is need of management of Construction and Demolition (C&D) wastes, as distinct from Municipal Solid wastes, is a relatively new subject in India.

Analysis of C&D Waste Management in India

The construction industry in India is booming. Already at 10 per cent of the GDP, it has been growing at an annual rate of 10 per cent over the last 10 years as against the world average of 5.5 per cent per annum. Almost 70 per cent of the building stock in India is yet to come up. The built-up area is expected to swell almost five times from 21 billion sq ft in 2005 to approximately 104 billion sq ft by 2030. (Source: Centre for Science and Environment, 2014).

Globally, cities generate about 1.3 billion tonne of solid waste per year. This volume is expected to increase to 2.2 billion tonne by 2025, says a 2012 report by the World Bank. Building materials account for about half of all materials used and about half the solid waste generated worldwide.

As per the estimates of Centre for Science and Environment (CSE), since 2005 India has newly constructed 5.75 billion sq m of additional floor space with almost one billion sq m in 2013 itself. If (according to the Technology Information, Forecasting and Assessment Council's, or TIFAC's, thumb rule) a new construction generates 40-60 kg of C&D waste per sq m, then taking an average of 50 kg per sq m, India must have generated 50 million tonne (MT) of C&D waste in 2013. Over the last eight years, it would have produced 287 MT of this waste.

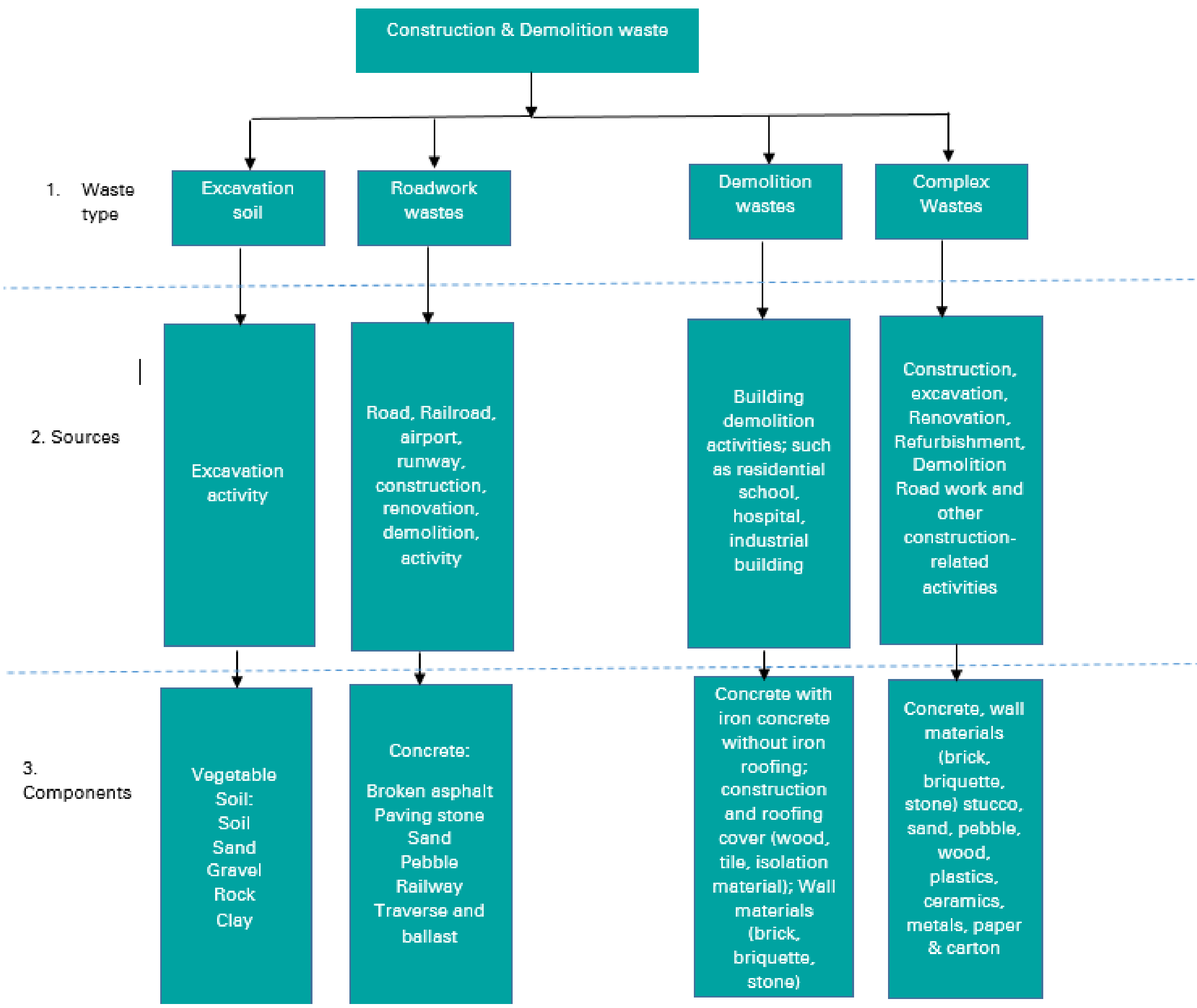
This estimate only accounts for new construction. Demolition and renovation/repair-related waste of the older stock generates additional waste. The waste produced per sq m of demolition is 10 times that generated during construction: as per TIFAC, 300-500 kg of waste per sq m. If it is assumed that five per cent of the existing building stock gets demolished and rebuilt completely annually, then about 288 MT more of C&D waste would have been generated in 2013 alone because of demolitions.

TIFAC also says building repair produces 40-50 kg per sq m of waste. Assuming that one-third of the existing building stock underwent some sort of repair or renovation in 2013, India must have generated an average of 193 MT of C&D waste just from repair and renovation in that year.

Thus, the total C&D waste generated in India just by buildings in one year — 2013 — amounts to a humungous 530 MT, 44 times higher than the official estimate. A lot of this waste is being used by land sharks to illegally fill up water bodies and wetlands around urban centres for real estate development. The rest is just being dumped into rivers and open spaces.

Status of C&D Waste Reuse in India

Construction agencies like CPWD say that Indian laws permit the use of only naturally sourced building material. The IS: 323-1970 Indian standard specification related to aggregates for concrete, laid down by the Bureau of Indian Standards (BIS), stipulates that concrete can be made only with naturally accessed materials.



Components of C & D waste

Though a number of innovative cost-effective recycled building materials, components and construction techniques have been developed and are available, Indian housing and building agencies have not adopted them in their construction practices. Lack of standardization, not listing these techniques and material in the Indian Standard Codes and/or the Schedule of Rates (SOR), poor policy push and lack of awareness are the key barriers.

INNOVATIVE STEPS TAKEN IN GUJARAT FOR C&D WASTE REUSE

Architects in India have already taken steps to reuse waste in their buildings. There is the example of a school building in Rajkot designed by Ahmedabad based architect Surya Kakani that has been built from the debris of Bhuj earthquake. The institute of Rural Research and Development (IRRAD) building in Gurgaon has innovatively recycled and utilized its own construction waste in the building itself. But these are limited steps and they will have to be encouraged with policy and fiscal support. This is particularly relevant for the infrastructure necessary for development such as roads, flyovers, pavements, etc. In fact, the attempt to use recycled material from the Burari centre in New Delhi during the Commonwealth Games faced opposition as these materials are not backed by standards as yet standards as yet.

Construction and Demolition Waste Management Rules, 2016

The Government of India notified the Construction & Demolition Waste Management Rules, 2016 on March 29, 2016. According to these rules the local bodies will have to utilize 10-20% material from construction and demolition waste in municipal and government contracts. These rules also indicate that cities with a population of more than one million will commission processing and disposal facility within 18 months from the date of final notification of these rules, while cities with a population of 0.5 to 1 million and those with a population of less than 0.5 million will have to provide these facilities within two years and three years respectively. Large generators of waste will have to pay relevant charges for collection, transportation, processing and disposal, as notified by the concerned authorities.

Duties of waste generators	Duties of service providers and contractors
• Every waste generator shall segregate construction and demolition waste and deposit at collection centre or handover it to the authorized processing facilities • Shall ensure that there is no littering or deposition so as to prevent obstruction to the traffic or the public or drains. • Large generators (who generate more than 20 tons or more in one day or 300 tons per project in a month) shall submit waste management plan and get appropriate approvals from the local authority before starting construction or demolition or remodeling work, • Large generators shall have environment management plan to address the likely environmental issues from construction, demolition, storage, transportation process and disposal / reuse of C & D Waste. • Large generators shall segregate the waste into four streams such as concrete, soil, steel, wood and plastics, bricks and mortar, • Large generators shall pay relevant charges for collection, transportation, processing and disposal as notified by the concerned authorities;	• The service providers shall prepare a comprehensive waste management plan for waste generated within their jurisdiction, within six months from the date of notification of these rules, • Shall remove all construction and demolition waste in consultation with the concerned local authority on their own or through any agency.

C&D WASTE MANAGEMENT PORTAL

A web or mobile app based platform can be created which requires producers of C&D waste to upload details and evidences pertaining to generation of this waste. This measure shall allow C&D waste receiving centers and regulatory authorities to be updated with the waste generation and disposal activities of producers, thus avoiding the indiscriminate dumping of C&D waste in lakes and unauthorized places. Such a system will also enable more stringent and effective enforcement of punitive measures.

These rules are aimed towards addressing the indiscriminate disposal of C&D waste and enable channelization of the waste for reuse and recycling in gainful manner. These rules have been introduced on the line of concept of **Extended Producer Responsibility,** with a vision of putting in place an institutional framework for C&D waste management system.

Chapter 7

Business Potential

- **Business Opportunities in Solid Waste Management**
- **Business Opportunities in Emerging Markets**

Business Opportunities in Solid Waste Management

In various steps of the process flow of solid waste management, there are various use and users which is specified in the below table:

Segregation of dry waste, re-usable etc	▪ Recycling companies ▪ Rag pickers ▪ Other informal sector participants
Segregation of wet wastes and processing	▪ Farmers ▪ Fertilizer companies, Agro market enterprises ▪ Other informal sector participants
Transport and Logistics	▪ Engineering, Procurement, Construction(EPCs) ▪ Locomotive manufacturing companies(Heavy & Light) ▪ Private vehicle service stations, transport agencies ▪ Part time workers under contract
Storage & Secondary collection	▪ EPCs ▪ MSW junk shop owners ▪ Logistics Services
Recycling of waste	▪ EPCs ▪ Material Recovery Facility(MRF) operators ▪ Intermediate material processing cottage units ▪ Environmental engineering companies
MSW waste to energy recovery	▪ Technology providers and fabricators ▪ Independent power producers and captive power producers ▪ Service technicians ▪ Producers and dealers of MSW derived RDF pellets
Management of wastes at landfills	▪ EPCs ▪ Civil Engineering developers

Smart Bins:

A Chennai based company, specializing in manufacturing of state of art 10 foot tall dustbins, has been engaged to provide as many as 64 large bins at 32 strategic locations in Amritsar.

Its operation would turn entire garbage lifting and dumping procedure into a mechanical affair. Initially as a part of the pilot project, groups of two dustbins each have been installed. The project is a part of the proposed mechanical sweeping.

In India the green businesses would come under 3 broad categories as mentioned below:

1. Entrepreneurial group of waste handlers	2. MSW transporters	3. Waste processing and recycling units
They would collect waste from households segregated wet waste+ dry waste & hazardous waste in pre- designated containers. The waste so collected would then be aggregated & transferred to smart bins	Ward wise they would transfer the waste from smart bins to customised waste transport vehicles & transport (a) dry waste to recycling units (b) wet waste to processing units (c) Hazardous waste to sanitary landfills	There are multiple technology options such as waste to energy processing units such as gasification, incineration, pyrolysis, biomethanation, composting

Disruption in waste management Industry: A start up with a difference

Rubicon Global is a cloud based, full-service waste management recycling company. It works with customers to find inefficiencies and cost- savings in their waste stream and to develop new and innovative ways to reduce, re-use and recycle waste.

<u>The services of Rubicon includes</u>

1. On-demand trash pickup and it has developed a mobile application to provide the service.
2. Their global network of haulers competes for their customers (businesses, group of households) so that their customers get the best prices on waste and recycling services. All their haulers are vetted, insured and regularly monitored for performance, and they work with their vendors to bring the latest technology to customers.
3. They offer the most cost effective disposal solutions; transport waste safely; and find new uses for materials, including recycling and converting waste into energy. Their vendor network includes cardboard, construction & demolition waste, electronics waste, food waste, electronics, food waste, grease & oil, hazardous materials, pallets, paper, plastic, metal & glass and universal waste

<u>Business Model</u>

Founded by Morris and Lane Moore in 2008, Rubicon has created a virtual marketplace where thousands of small, local haulers can bid on portions of huge national contracts. This fosters competition between haulers, driving down the price of service. Rubicon also monitors the ebb and flow of their waste stream to cut down on unnecessary pickups. When Rubicon saves customers money, it takes a cut of those savings. Then, it catalogs the waste and scours its extensive database of recycling opportunities to find ways to resell the often valuable materials that get locked up in that waste. Again, the more Rubicon can sell off, the more it gets paid.

BUSINESS MODEL: RUBICON GLOBAL

Overview: Rubicon Global is a cloud-based, full-service waste and recycling company focused on sustainability. It works with customers to find inefficiencies and cost-savings in their waste stream and to develop new and innovative ways to reduce, re-use and recycle waste. Rubicon has developed a mobile application to provide on-demand trash pickup.

Key Partners
- Small scale waste management enterprises
- Food services & restaurants
- Retail storefronts
- Construction companies
- Leisure & Hospitality sector
- Industries

Key Activities
- Customized waste pickup as per user's schedule
- Serving as an interface between garbage haulers and waste generators
- Collaborate with handlers of cardboard, C&D waste, electronics, food waste, grease & oil, hazardous material, pallets, paper, plastic, metal, glass, and all other sorts of waste
- Route optimization and navigation services to waste haulers for comfortable movement
- Collect feedback, suggestion and information
- Analyzing consumer demand and traffic

Key Resources
- Data centers
- Customer and hauler apps
- Pricing algorithm
- Routing algorithm
- Employees
- Application platform

Value Proposition
- Known as the "Uber of Trash"
- Environmentally conscious disposal of waste
- Diverting significant volumes of waste from disposal in landfills
- Judicious use of environmental resources
- Creation of green jobs
- Service on request
- Enhancement in source segregation
- Sustainable business recognition to high volume users
- In-depth waste generation and disposal statistics provided through detailed analytics

Relationships
- Social engagement
- Customer service
- Review rating and feedback system
- Incentives for
- Dedicated service for large scale waste generators
- Identify and retain frequent / large-scale users of application
- Attract more citizens

Channels
- Website
- Mobile App for Android
- Mobile App for iOS
- Stores
- Social Media (Facebook, Twitter)
- Online Advertisement
- Regional Sales and Support Teams
- Conferences

Customer Segments
- Small and large scale industries
- Internet Users
- Mobile device owners
- Restaurants
- Domestic consumers

Cost Structure	Revenue Streams
➢ Staff ➢ IT Infrastructure ➢ Operational Expenditure ➢ Capital Expenditure ➢ Brand Promotion	× Service registration fees × Usage fees for both haulers and customers × Ad Revenue: Google Websites × Advertising campaigns

Business Opportunities in Emerging Markets

PET BOTTLE REUSE

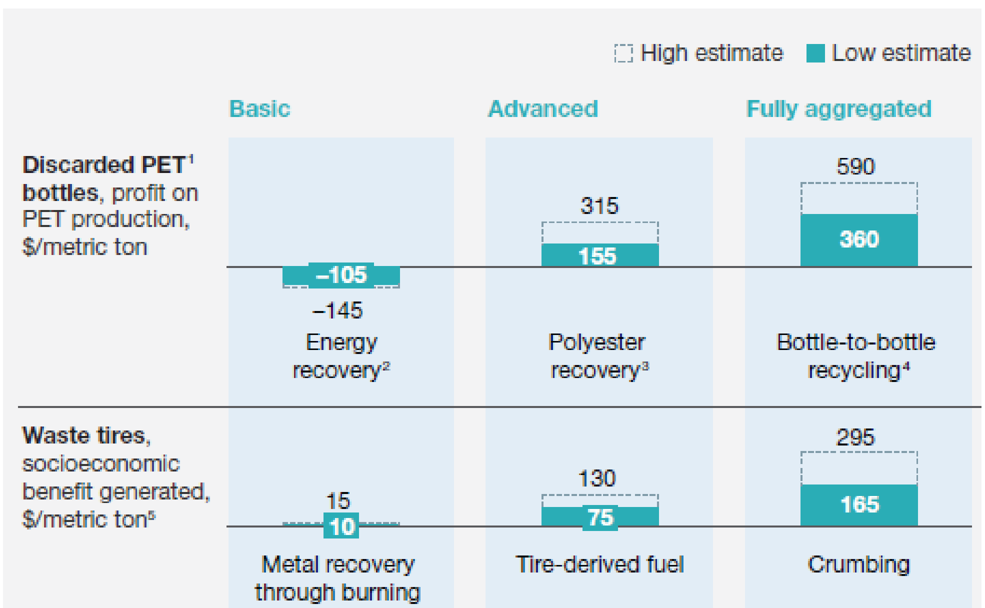
For PET bottles a cost must be assigned so that recovery happens through incentive route.

The PET-bottle-collection system that requires the lowest level of aggregation—collecting PET bottles as part of mixed waste—allows for energy recovery via incineration, yet its economic yield is low. In the United Kingdom, a gate fee is required to be paid by the collector to cover operations. At the next level, recovering the bottles' material value via a mixed-recyclables or mixed-plastics stream could yield approximately $150 to $300 per metric ton.

In India, Coke collects all pet bottles for recycling in Delhi region and converts into tents, T-shirts and other useful materials.

EXTRACTION OF METALS FROM WASTE TYRES

Similarly, metals are commonly extracted from tyres in small backyard operations where tires are burned in open fires—posing great risks to health and environment. Aggregating tires to feed them as fuel into industrial processes (rather than just backyard fires) could increase the value extracted from old tires tenfold. And when initiatives to organize the tyre-waste flow cover not only collection but also the processes to recycle specific materials (not just using tyres as industrial fuel), the value extraction from tires could see a further doubling.



<u>Bobbilli Town excels in smart waste management: Times of India Report, July 23rd 2016</u>

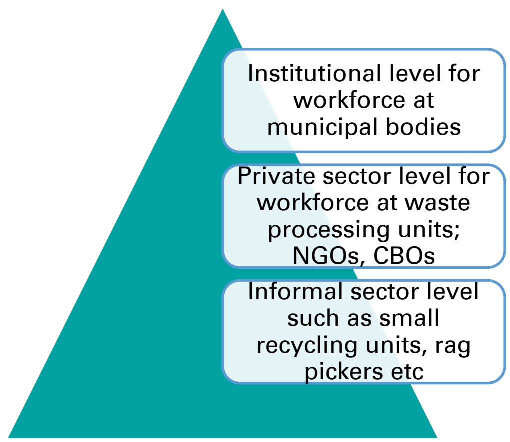
In 2008-09, Bobbilli town in Vizianagram district was filthy and unhygienic like most other Indian towns. But now the situation has transformed due to a scientific and sustainable solid waste management system in place, which not only collected household and commercial waste door to door, segregated and processed them but also made optimum use of waste products for producing Vermi-compost, biogas and electrification in an 8.5 acre solid waste management (SWM) park.

Chapter 8

Job Potential Estimation

Projections of Workforce

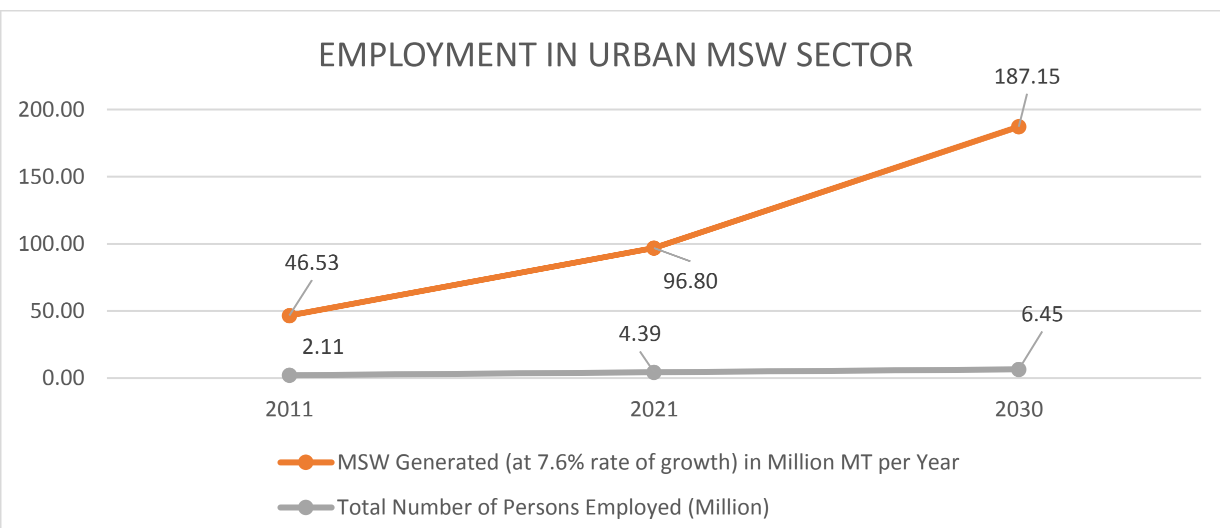
Today managing waste (urban and rural) from collection, transportation, processing and disposal requires a workforce that has to be trained. Through this report we have tried to map all the job roles required in solid waste management sector through research and validate through stakeholder consultations. In our preliminary research, we tried to identify green jobs across different levels in the process flow of solid waste management.



Institutional level for workforce at municipal bodies- Sweepers, Sanitary supervisors, Sanitary sub- inspector, Sanitary Inspector, Sanitary officer, Chief Sanitary Inspector, Public Health, Environmental engineer/ Civil engineering to be deployed as executive engineer, superintending engineer, Chief engineer, Head of SWM department.

Private sector level for workforce at waste processing units; NGOs- Entrepreneurs, Maintenance engineers, supervisors, technicians, Chemists, Education and Awareness Manager

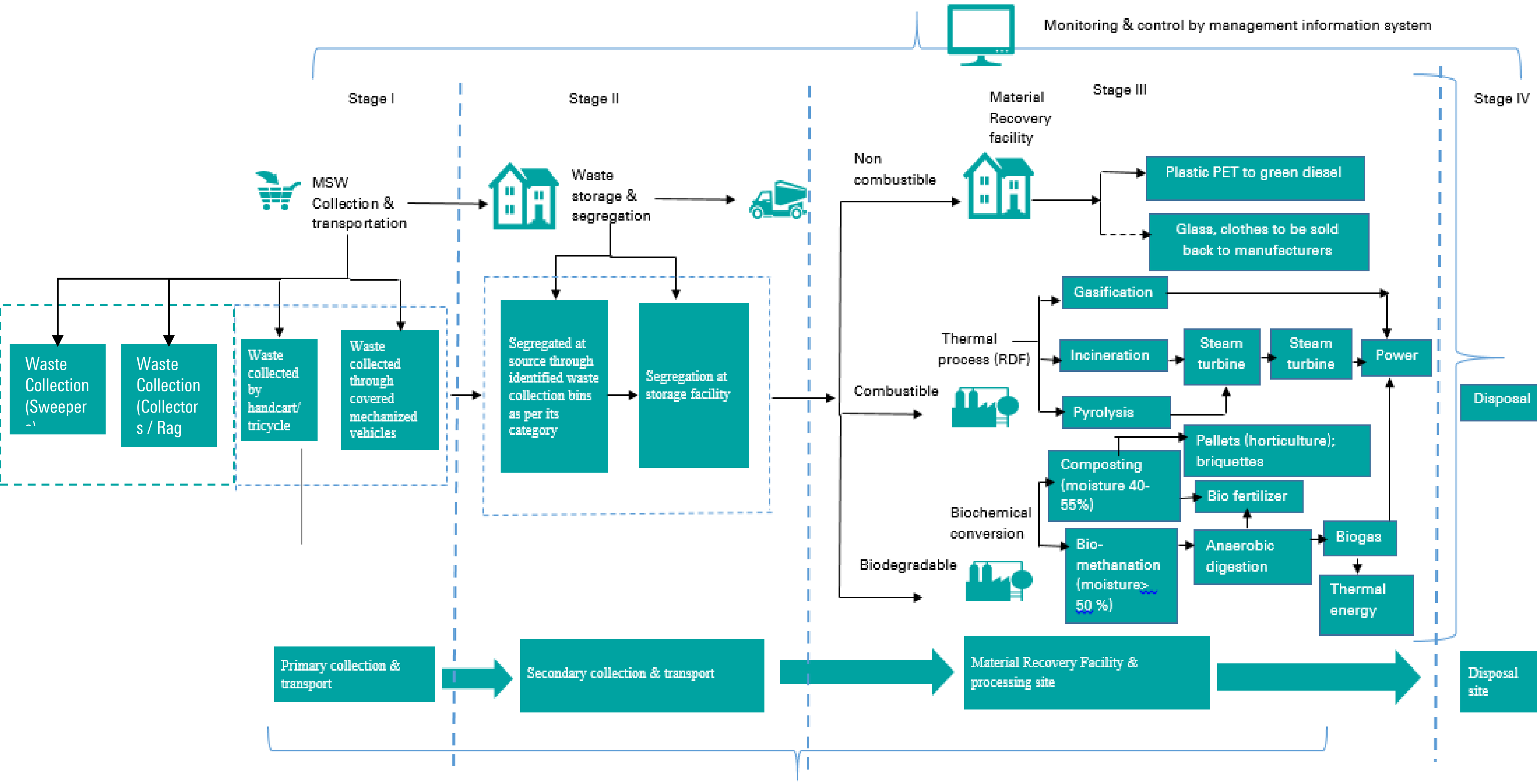
Through stakeholder consultation and secondary research, it has been possible to estimate the growth in number of jobs in the domain of urban municipal solid waste management encompassing the activities of waste collection, segregation, transportation, storage and processing. The following figure gives an account of the overall job creation in the urban municipal solid waste management sector (details in annexure – I).



Chapter 9

Process Mapping

The urban municipal solid waste management process begins with the manual collection of waste from various point sources, followed by its transportation to a storage and segregation facility. Depending on the nature of the waste, it is then sent to recovery facilities or waste to energy plants for conversion to electricity. The following illustration shows the detailed process flow of urban waste:



Chapter 10

Occupational Mapping

- **Occupational Job Roles**
- **List of Job Roles**

Occupational Job Roles

Management of Urban Solid Waste can be classified into the following sectors:

- Administration
- Logistics
- Operations
- Sales and Marketing

The following tables highlights the key activities involved in each sector and the key distinct job roles.

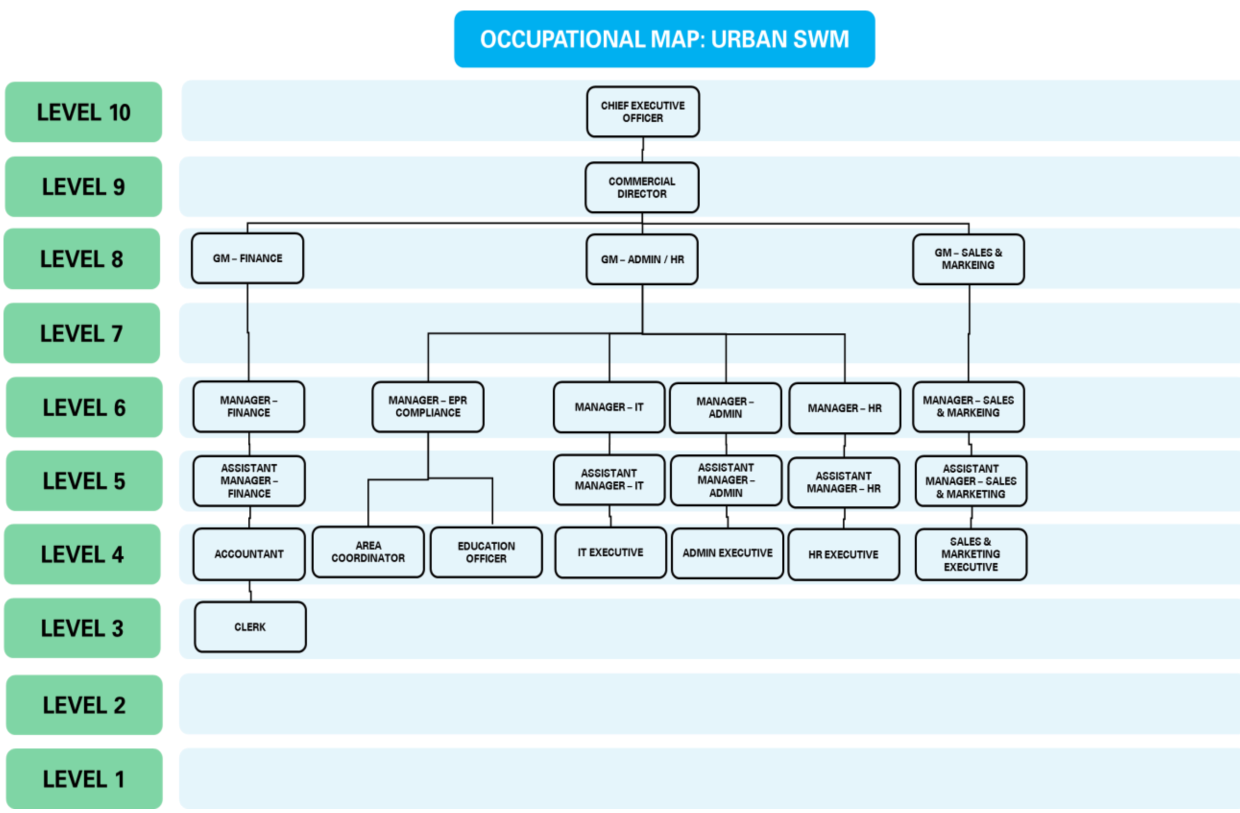
Stages	Sector	Activities involved	Key Job Roles
1	Administration	To provide administrative support in areas of business such as information management systems, human resources, payroll, communication, and compliance. This department shall aim to keep all other functions of the business operating in a swift manner.	○ Managing Director ○ General Manager ○ DGM – Admin / HR ○ Manager – EPR Compliance ○ Area Coordinator ○ Education Officer ○ Manager – IT ○ Assistant Manager – IT ○ IT Executive ○ Manager – Administration ○ Assistant Manager – Administration ○ Administration Executive ○ Manager – HR ○ Assistant Manager – HR ○ HR Executive
2	Logistics	Waste collection and transport - To collect solid waste from different point sources and facilitate its movement to collection/storage facilities prior to its end processing.	○ DGM – Logistics ○ Manager – Collection and Transport ○ Fleet Supervisor ○ Hauler – Truck / Compactor ○ Supervisor – Waste Collection ○ Waste Collector / sorter ○ Sweeper ○ Rag Picker ○ Recyclable waste collector & segregator
		Maintenance - To attend to wear and tear and other maintenance of transport vehicles involved in movement of solid waste.	○ Manager – Maintenance ○ Maintenance Supervisor ○ Denter ○ Painter ○ Mechanic
		Purchase - To buy raw materials, spare parts, other services and goods as required for operation, from external sources.	○ Manager – Purchase ○ Store Supervisor ○ Purchase Executive ○ Helper - Store
3	Operations	To carry out end use operation of solid waste through composting, production of Refuse Derived Fuel, or generation of power through incineration. This is followed by	○ DGM – Operations ○ Manager ○ Operator ○ EHS Supervisor ○ Asset Maintenance Supervisor ○ Landfill supervisor ○ Welder

		disposal of remaining waste in landfill.	○ Fitter ○ Electrician ○ Mechanic ○ Operator – Weigh Bridge ○ Helper ○ Compost Yard Entrepreneur ○ Dry Waste Center Entrepreneur ○ Segregated MSW Collector & Aggregator ○ Safai Karamchari (Sweeper, Dry)
4	Sales and marketing	To develop promotional plans and selling strategies for the sale of products (such as compost).	○ DGM – Sales & marketing ○ Manager – Sales & marketing ○ Assistant Manager – Sales & marketing ○ Sales & marketing executive

Occupational Map

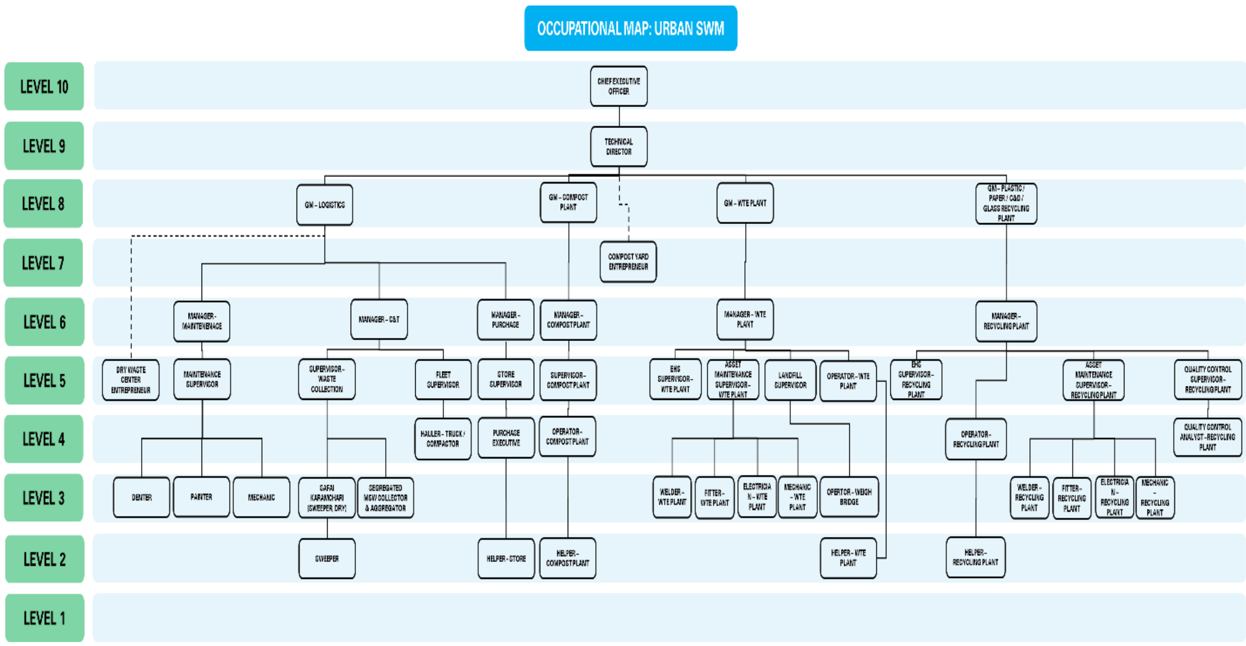
In this section, the occupational map for the Urban MSW sector has been split into two parts – one illustrating the commercial and administrative activities pertaining to waste management operations; the other illustrating the technical operations of various recycling facilities.

Occupational Map: Urban MSW (Commercial)



Occupational Map: Urban MSW (Technical)

In this representation, the job roles for various recycling facilities namely plastic, paper, glass, and C&D are represented by common illustrations, as these fields may be said to have similar technical level job roles.



List of Job Roles

The following list comprises of various job roles which are expected to be generated in the Urban MSW sector. These job roles have been classified into General and Critical depending upon their significance in this sector. The job roles marked in Yellow color have been selected for preparation of Qualification Packs by the Skill Council for Green Jobs.

Sector: Urban MSW			
S.No	Title	Critical /General	NSQF Levels
1	Chief Executive Officer	General	10
2	Commercial Director	General	9
3	Technical Director	General	9
4	GM - Finance	General	8
5	Manager - Finance	General	6
6	Assistant Manager - Finance	General	5
7	Accountant	General	4
8	Clerk	General	3
9	GM - Admin / HR	General	8

10	Manager - EPR Compliance	Critical	6
11	Area Coordinator	General	4
12	Education Officer	General	4
13	Manager - IT	General	6
14	Assistant Manager - IT	General	5
15	IT Executive	Critical	4
16	Manager - Admin	General	6
17	Assistant Manager - Admin	General	5
18	Admin Executive	General	4
19	Manager - HR	General	6
20	Assistant Manager - HR	General	5
21	HR Executive	General	4
22	GM - Logistics	General	8
23	Manager - Maintenance	General	6
24	Maintenance Supervisor	General	5
25	Denter	General	3
26	Painter	General	3
27	Mechanic	General	3
28	Manager - C&T	Critical	6
29	Dry Waste Center Entrepreneur	Critical	5
30	Supervisor - Waste Collection	Critical	5
31	Sweeper	Critical	2
32	Segregated MSW Collector & Aggregator	Critical	3
33	Safai Karamchari (Sweeper, Dry)	Critical	3
34	Fleet Supervisor	Critical	5
35	Hauler - Truck / Compactor	Critical	4
36	Manager - Purchase	General	6
37	Store Supervisor	General	5
38	Purchase Executive	General	4
39	Helper - Store	General	2
40	GM - Sales & Marketing	General	8
41	Manager - Sales & Marketing	General	6
42	Assistant Manager - Sales & Marketing	General	5
43	Sales & Marketing Executive	Critical	4
44	GM - Compost Plant	General	8
45	Compost Yard Entrepreneur	Critical	7
46	Manager - Compost Plant	General	6
47	Supervisor - Compost Plant	Critical	5
48	Operator - Compost Plant	General	4
49	Helper - Compost Plant	General	2
50	GM - WTE Plant	General	8
51	Manager - WTE Plant	Critical	6
52	EHS Supervisor - WTE Plant	Critical	5

53	Asset Maintenance Supervisor - WTE Plant	Critical	5
54	Welder - WTE Plant	General	3
55	Fitter - WTE Plant	General	3
56	Electrician - WTE Plant	General	3
57	Mechanic - WTE Plant	General	3
58	Landfill Supervisor	Critical	5
59	Operator - Weigh Bridge	General	3
60	Operator - WTE Plant	Critical	5
61	Helper - WTE Plant	General	2
62	GM - Plastic Recycling Plant	General	8
63	Manager - Plastic Recycling Plant	General	6
64	EHS Supervisor - Plastic Recycling Plant	General	5
65	Operator - Plastic Recycling Plant	General	4
66	Helper - Plastic Recycling Plant	General	2
67	Asset Maintenance Supervisor - Plastic Recycling Plant	General	5
68	Welder - Plastic Recycling Plant	General	3
69	Fitter - Plastic Recycling Plant	General	3
70	Electrician - Plastic Recycling Plant	General	3
71	Mechanic - Plastic Recycling Plant	General	3
72	Quality Control Supervisor - Plastic Recycling Plant	General	5
73	Quality Control Analyst - Plastic Recycling Plant	General	4
74	GM - Paper Recycling Plant	General	8
75	Manager - Paper Recycling Plant	General	6
76	EHS Supervisor - Paper Recycling Plant	General	5
77	Operator - Paper Recycling Plant	General	4
78	Helper - Paper Recycling Plant	General	2
79	Asset Maintenance Supervisor - Paper Recycling Plant	General	5
80	Welder - Paper Recycling Plant	General	3
81	Fitter - Paper Recycling Plant	General	3
82	Electrician - Paper Recycling Plant	General	3
83	Mechanic - Paper Recycling Plant	General	3
84	GM - Glass Recycling Plant	General	8
85	Manager - Glass Recycling Plant	General	6
86	EHS Supervisor - Glass Recycling Plant	General	5
87	Operator - Glass Recycling Plant	General	4
88	Helper - Glass Recycling Plant	General	2
89	Asset Maintenance Supervisor - Glass Recycling Plant	General	5
90	Welder - Glass Recycling Plant	General	3
91	Fitter - Glass Recycling Plant	General	3
92	Electrician - Glass Recycling Plant	General	3
93	Mechanic - Glass Recycling Plant	General	3

94	Quality Control Supervisor - Glass Recycling Plant	General	5
95	Quality Control Analyst - Glass Recycling Plant	General	4
96	GM - C&D Recycling Plant	General	8
97	Manager - C&D Waste Recycling Plant	General	6
98	EHS Supervisor - CDW Recycling Plant	General	5
99	Operator - CDW Recycling Plant	General	4
100	Helper - CDW Recycling Plant	General	2
101	Asset Maintenance Supervisor - CDW Recycling Plant	General	5
102	Welder - CDW Recycling Plant	General	3
103	Fitter - CDW Recycling Plant	General	3
104	Electrician - CDW Recycling Plant	General	3
105	Mechanic - CDW Recycling Plant	General	3
106	Quality Control Supervisor - CDW Recycling Plant	General	5
107	Quality Control Analyst - CDW Recycling Plant	General	4

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Annexure – I: Estimation of Job Potential in Urban MSW Sector

Growth in MSW Generated

According to a CPCB report of 2011, the waste generated in 2011 stood at 46.53 Million MT. Assuming that the quantity of waste generated grows at the rate of 7.6% per annum till 2030, the following table shows the projections for waste generation till 2030.

Year	MSW Generated (at 7.6% rate of growth) in Million MT per Year
2011	46.53
2021	96.80
2030	187.15

According to "What a Waste – A Global Review of Solid Waste Management", World Bank, 2012, the approximate composition of solid waste in lower-medium income countries is given for 2012 and projected for 2025. The same can be equated to the Indian context to obtain figures for different constituents of solid waste from 2011-2030.

YEAR	ORGANIC (MILLION MT)	PAPER (MILLION MT)	PLASTIC (MILLION MT)	GLASS (MILLION MT)	METAL (MILLION MT)	OTHER (MILLION MT)	TOTAL URBAN MSW (MILLION MT)
2011	27.45	4.19	5.58	1.40	0.93	6.98	46.53
2021	54.43	9.38	12.29	3.57	2.61	14.52	96.80
2030	99.19	18.71	24.33	7.49	5.61	31.82	187.15

Estimating the Number of Jobs in Collection and Transport of Waste

Assuming that 70% of total MSW comprises of household waste, and stating the assumption from Bruhat Bengaluru Mahanagara Palike (BBMP) that 2 persons are required for the collection of 50 Tonnes per Year of household waste.

Year	Household Waste Generated in Million MT per Year	Persons Employed in Household Waste Collection in Million
2011	32.57	1.30
2021	67.76	2.71
2030	131.00	5.24

According to the BBMP, 2 persons are required for collection of 500 Tonnes per Year of waste from bulk generators.

Year	Waste Generated by Bulk Generators in Million MT per Year	Persons Employed in Household Waste Collection in Million
2011	13.96	0.06
2021	29.04	0.12
2030	56.14	0.22

It is assumed that 2 persons may be required for the transportation of 600 tonnes per year of waste from primary collection points to segregation / disposal facilities in India.

Year	Waste Generated in Million MT per Year	Persons Employed in Transportation of Waste in Million
2011	46.53	0.16
2021	96.80	0.32
2030	187.15	0.62

Estimating the Number of Jobs in Segregation of Waste

Based on stakeholder consultations with M/S Ramky Ltd, it is considered that 20 persons are required for segregation, storage, and warehousing of 1825 Tonnes per year of MSW. These figures are provided only up to 2021 considering the assumption that a major fraction of the waste generated by 2021 would be segregated and would not require further efforts prior to processing and disposal.

Year	Waste Generated in Million MT per Year	Persons Employed in Transportation of Waste in Million
2011	46.53	0.51
2021	96.80	1.06

Estimating the Number of Jobs through Processing of Waste

According to "What A Waste - A Global Review of Solid Waste Management", World Bank - 2012, typical MSW disposal methods for Lower Middle Income countries are as under:

Method of MSW disposal	Percentage (%)
Dumps	48.81
Landfill	11.03
Compost	2.17
Recycled	5.24
Incineration	0.22
Others	32.53

Assuming that similar pattern is followed in India, the following table gives the approximate yearly breakup of organic waste by disposal method. As per consultations with M/S Ramky Ltd, it is understood that 20 and 15 persons are required for composting and incineration operations respectively (1825 TPY), which is used to arrive at total number of persons employed through processing of organic waste.

Year	Total organic waste generated (Million MT)	Total organic waste towards compost production (Million MT)	Total organic waste towards incineration (Million MT)	Total employment through processing of organic waste (Million)
2011	27.45	0.60	0.06	0.01
2021	54.43	1.18	0.12	0.01
2030	99.19	2.15	0.22	0.03

According to the National Small Industries Corporation, a 3650 TPY paper recycling plant gives employment to 12 persons. As indicated by "What A Waste - A Global Review of Solid Waste Management", World Bank - 2012, we can assume that 5.24% of Waste paper is recycled in India.

Year	Total paper waste generated (Million MT)	Total paper waste towards recycling (Million MT)	Total employment through processing of paper waste (Million)
2011	4.19	0.22	0.05
2021	9.38	0.49	0.12
2030	18.71	0.98	0.24

According to the National Small Industries Corporation, a 109.5 TPY plastic recycling plant gives employment to 7 persons. As indicated by "What A Waste - A Global Review of Solid Waste Management", World Bank - 2012, we can assume that 5.24% of Waste plastic is recycled in India.

Year	Total paper waste generated (Million MT)	Total paper waste towards recycling (Million MT)	Total employment through processing of paper waste (Million)
2011	5.58	0.29	0.02
2021	12.29	0.64	0.04
2030	24.33	1.27	0.08

Due to unavailability of computational data for processing of metal, glass, and C&D, these have not been included in the estimations of overall job potential.

The overall creation of employment in the Urban MSW sector is as under:

Year	MSW Generated (at 7.6% rate of growth) in Million MT per Year	Total Number of Persons Employed (Million)
2011	46.53	2.11
2021	96.80	4.39
2030	187.15	6.45