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Project – IUC: Sustainable and innovative cities and region

Sub-project – Baseline study for solid waste management in Kochi

Deliverable – Final report

Acknowledgments

The baseline study for the solid waste management system project has been commissioned as part of the Kochi-Vilnius strategic collaboration under the European Union International Urban Cooperation (IUC)-India program. The study represents the key deliverable of the Urban Cooperation Local Action Plan for the city of Kochi. The report has been prepared by Sundarajan Subramony (JNKE, IUC India project) based on secondary research, stakeholder consultations, case studies and review of recommendations.

I am grateful for the support, expertise and insights provided by Dr. Rajan Chedambath (Director, Center for Heritage, Environment and Development (CHED), Kochi and Simmi S from CHED as well as the IUC India team including Mohit Ganeriwala, Ashish Verma, Suhas Pande, and Panagiotis Karamanos. The discussions held with these stakeholders and the information provided by them was instrumental to the completion of this study.

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1 Executive summary

This chapter is the executive summary of the baseline study and briefly discusses the assignment background, existing status of solid waste management in Kochi, learnings from international and national best practices, conclusion and way forward.

Assignment background

Preparation of study and problem statement: The baseline study for the solid waste management project has been commissioned as part of the Kochi-Vilnius strategic collaboration under the IUC-India program. The study represents the key deliverable of the Urban Cooperation Local Action Plan for the city of Kochi. The report has been prepared by Sundarajan Subramony (JNKE, IUC), based on secondary research, conducting stakeholder consultations, preparing case studies and making final recommendations. The objective of the assignment is to provide baseline information for solid waste management (SWM) in Kochi, by analyzing the current status of SWM and waste treatment facilities in Kochi and by identifying best practices in the SWM domain being followed by various national and international cities. This study can later feed into a detailed feasibility study.

Strategic cooperation between Vilnius and Kochi: Kochi Municipal Corporation (KMC) has entered into a strategic collaboration with the city of Vilnius in Lithuania on SWM. IUC-India is supporting the Kochi-Vilnius city pairing through the provision of exchange visits and the development of a Local Action Plan (LAP) for building efficient, sustainable and climate friendly waste management practices at KMC.

Methodology employed: The baseline study was conceived during the discussion of various stakeholders involved in this strategic collaboration. The study aims to provide a detailed analysis on the existing SWM scenario in the city of Kochi while also clearly laying out the way forward for streamlining and upgrading the SWM value chain in the city. The study is based on: a) secondary research through reports shared by IUC-India team, web search and case studies on SWM and waste treatment facilities in Lithuania, United Kingdom, Sweden and India; and b) stakeholders consultations with officials of the C-HED and IUC-India.

Existing status of solid waste management in Kochi

About Kochi: Kochi is a coastal city that lies in Ernakulam district of state of Kerala. It is the commercial capital and the second largest city of the state. Kochi was a major global spice trading center in the 14th century and is known as the queen of the Arabian Sea for its scenic beauty. Kochi, with an estimated population of 616,866[1], as of 2018 as compared to the population of 580,020[2] in Vilnius as on January 1, 2020 is divided into 74 wards and seven zones for governance and administrative purposes. KMC is the main administrative body for Kochi, under which various departments function for operation and maintenance of urban services.

Solid waste collection: The waste generated in Kochi is segregated into hazardous, biodegradable and non-biodegradable categories. Currently, only 75% of waste, (230 tonnes out of 305 tonnes[3]) generated in Kochi is being collected through door-to-door collection by KMC workers and Kudumbashree (Kerala-based NGO) employees, for treatment and disposal at the Brahmapuram solid waste management facility. The waste is collected by these door-to-door collectors using handcarts and tipper auto-rickshaws and is brought to secondary collection points, from where they load the waste into corporation vehicles, to be carried to the processing and disposal facility at Brahamapuram.

[1] *As per Center for Heritage, Environment and Development data*
[2] *https://www.registrucentras.lt/p/853*
[3] *As per Center for Heritage, Environment and Development data*

Solid waste transportation: Transportation of waste from waste collection points to the Brahmapuram plant for processing/disposal and treatment is carried out by KMC using 83 vehicles, owned by KMC. The waste collected from secondary collection points is loaded into large tipper trucks and compactor trucks for transportation to the waste treatment and disposal facility at Brahmapuram. The operational and transport cost for solid waste produced in the city is borne by KMC.

Solid waste disposal and treatment: As per Center for Heritage, Environment and Development (C-HED) data, of the 305 TPD solid waste generated in Kochi, 230 TPD is collected, of which 130 TPD is processed while 100 TPD is disposed-off at the landfill site. The waste collected is transferred to Brahmapuram facility, wherein the organic fraction of waste is treated in a windrow composting facility and the plastic/non-biodegradable fraction of the waste is tipped at the dumping yard. The dedicated waste management facilities include a) Windrow composting plant, b) Plastic shredding unit and c) Refuse derived fuel (RDF) facility. However, the windrow composting plant is in a dilapidated state and does not have adequate capacity, RDF facility is not operational and the waste dump at the dumping yard is increasing in size beyond capacity.

Future plans: The Kerala State Industrial Development Corporation (KSIDC) in June 2020 has floated a tender for the selection of a private party to manage the entire SWM value chain in the Ernakulam cluster including Kochi city, in an integrated manner. The private party will also be required to develop a waste to energy (WtE) plant with a minimum capacity of processing 300 TPD of waste, at Brahmapuram.

Effect of climate change on SWM activities: High rainfall in Kochi, coupled with clogged drains & canals due to inadequate waste collection and lack of cleaning, leads to flooding in the city which results in accumulation of tons of waste, making it difficult for solid waste collectors to collect such huge quantities of waste. Rainfall and flooding at the landfills leads to inundation, waste solution migration to neighboring areas and physical erosion. Rise in temperature over the years may alter the waste decomposition rate and leachate production rate thus leading to the spread of infectious diseases. Rise in sea levels has various harmful effects on the landfill site, land treatment areas, waste piles and waste storage areas. Additionally, the treatment of solid waste at treatment facilities as well as direct disposal at landfill sites emits greenhouse gases and methane.

Learnings from international and national best practices

Vilnius – city profile: Vilnius, the capital of Lithuania, has an area of 401 km^2. The population of Vilnius is 580,020 as of 2020. The Vilnius municipality is one of the 60 municipalities in the country, has 51 members, provides administrative services, organizes the provision of public services and adopts political decisions. The council committees perform activities related to environment and energy, economy and finance, culture, education and sports, urban planning and development, services and city maintenance, social affairs, health and local government development. Additionally the municipality has 1.6 administrative employees per 1,000 inhabitants.

Learnings from Vilnius: Vilnius has undertaken some efficient initiatives in the field of SWM to combat litter, increase waste collection rates and build an efficient SWM value chain. Drones are used for city surveillance and to monitor landfill sites, a separate maintenance company provides all utility services to the city and service providers for SWM are selected through a tendering process. Additionally, SWM activities are financed through municipal tax levied on homeowners, whereas collection of recyclables is financed by manufacturers and importers. Some other effective practices implemented by the Vilnius municipality are stipulated below:

- Setup of dedicated entity for waste management i.e. Vilnius Waste System Administrator (VASA). The company was setup in 2015 and is wholly owned by the municipal corporation of Vilnius. The aim of the company is to carry out efficient administration of waste management, control and supervise the provision of municipal waste management services, and to create a provision to transfer information to municipal waste holders and authorities of the Vilnius municipality.

- Underground waste container system has been developed in Vilnius as per which all the residents of the city have installed dozens of underground and semi-underground container, having 75% of their depth underground, with separate containers for household wastes, paper, plastics and glass. These bins are economical, reliable and aesthetically more pleasing.
- Deposit recycling facility wherein the recyclable and reusable material is returned back to the point of sale and reverse vending machines by the consumers, in return for a refund, which is deposited by the consumer at the time of purchase.
- Vilnius county waste management center manages the mechanical biological treatment (MBT) plant, operates the Vilnius county regional landfill, and operates 17 bulky waste disposal sites and six green waste composting sites. The MBT plant uses segregated waste, combines re-sorting of mixed utility waste with anaerobic digestion or composting and produces solid recovered fuel.
- Waste to energy (WtE) cogeneration plant is being constructed in Vilinius, which will convert waste into useful heat and electricity. The plant will treat 160,000 tonnes/year of non-recyclable, non-usable waste (after sorting) at the MBT facility, following which the waste will be incinerated for production of electricity and recovery of heat simultaneously, known as cogeneration. The plant is expected to be completed by 2020.

Learnings from other cities: Additionally, the cities of Leeds (UK), Stockholm (Sweden), Indore (India), New Delhi (India) and Hyderabad (India) have also adopted some efficient initiatives and best practices in the SWM domain which are stipulated below.

- Leeds, UK: The Leeds recycling and energy recovery facility (RERF) uses state-of-the art technology to recover 90% of the city's black bin waste (general household waste excluding hazardous waste) to produce ~11 MW of electricity, thus saving EUR 7 million/year as compared to landfill and supplying electricity to ~20,000 households in the UK. It reduces Leed's carbon footprint and increases re-use.
- Stockholm, Sweden: The Stockholm Waste Management Plan 2017-22 addresses the complete value chain of waste management to minimize waste generation and maximize resource efficiency. It has policies to curb waste generation, plans for an underground waste collection/sorting system and waste-to-energy plants to recycle the collected waste. The City of Stockholm was able to process 614,110 tonnes of waste in 2018, generating an energy of 1,641,360 MW. It recycles almost 99% of the household waste generated (through anaerobic digestion or waste to energy plants).
- Indore, India: Indore has been adjudged as the cleanest city in India for the past four years, due to the implementation of some efficient practices such as complete elimination of garbage dumps, 100% waste segregation, zero landfill and conversion of waste to usable products such as compost and fuel. Indore Municipal Corporation (IMC) partnered with NGOs, to run awareness campaigns, contracted private companies to run some waste management operations, used technology and improved municipal capacity to ensure implementation of its waste management plan.
- New Delhi, India: The WtE plant at Ghazipur, New Delhi, processes 2,000 tonnes of waste daily & generates 127 tonnes of refuse derived fuel (RDF plant) and 12 MW of power at the power plant. However the WtE plant is taking more waste than stipulated every month for processing and the waste dumped at the Ghazipur landfill site has risen into a massive garbage dump, which is not being treated at the WtE plant, signifying challenges in its operations. Additionally the landfill is susceptible to fires and a massive fire broke out at the landfill in 2017.
- Hyderabad, India: SWM in Hyderabad is based on an integrated SWM, PPP model wherein the private player Ramko Enviro Engineers Ltd (REEL) is involved in the entire SWM value chain, including the processes of collection, transportation, disposal and processing/treatment. REEL employs some best practices while collecting and transporting waste and has a windrow composting plant, RDF facility, a WtE plant, leachate treatment facility, plastic treatment facility and a landfill for disposal and treatment of waste.

Conclusion and way forward

Need for an efficient SWM: Currently only 75% of waste generated is being collected for treatment and disposal at Brahmapuram, the remaining being dumped in canals and drains. KMC does not generate any revenue from SWM activities but expenses pertaining to SWM activities are borne by the organization. Additionally, the Brahmapuram facility is not functioning scientifically (including the windrow composting plant, RDF facility, and the dumping yard). Thus, there is an imminent need for upgrading and streamlining the SWM value chain in Kochi as stipulated below

- Increase in waste collection rates: The waste collection rate in Kochi needs to be increased from the current 75% to 95-100% in phases, by preventing waste generators from illegally burning/burying their waste or dumping it in drains and canals and increasing coverage of waste collection.
- Revenue from SWM activities: As KMC does not earn any revenue from SWM activities, it needs to formalize and levy user charges on waste generators, thus earning revenue through solid waste collection.
- Cleaning of drains and canals: Drains and canals need to be cleaned regularly and accumulated solid waste needs to be removed to prevent their clogging and to prevent the problem of urban flooding in Kochi.
- Scientific management of landfill site: The landfill site at Brahmapuram needs to be upgraded so that it is able to function scientifically with complete control over methane gas developed in the landfill (to prevent air pollution) and limited access of vectors and flies to the waste. Adequate controls and system should be in place so that leachates and contaminates are not able to flow freely thus polluting water bodies, ground water table, and land. Odor control measures should also be followed.
- Reconstruction of the windrow composting plant: The windrow composting plant at Brahmapuram should be reconstructed so as to have adequate capacity and to improve its dilapidated condition thus significantly reducing the waste dump at the landfill site.
- Plans for a WtE plant: Large quantities of waste currently being dumped at the landfill site would be converted into electricity, by a WtE plant, thus significantly reducing landfill, pollution, greenhouse gases (GHG) and Carbon dioxide (CO_2) emissions. A WtE plant with a minimum capacity of processing 300 TPD of waste is proposed to be built at Brahmapuram, as per a tender floated by the Kerala State Industrial Development Corporation (KSIDC) in June 2020.
- Setup of dedicated entity catering to SWM activities in Kochi: Kochi can also look at setting up of a dedicated company which will be wholly owned by the Kochi municipal corporation and shall be responsible for the entire municipal waste management lifecycle. The setup of an independent organization will reduce the burden of waste management from KMC and also enable the organization to employ waste management experts who are well equipped at tackling the specific waste management challenges faced by Kochi. KMC has earmarked a budget of INR 2 crore (EUR 0.24 million) for the incorporation and other related activities of such a company.

Next steps/way forward: Having established the need for an efficient SWM system in the city of Kochi, and the need to adapt and implement best practices from India and abroad, KMC should undertake or assign a detailed feasibility study in this regard which should cover in detail the following:

- Technical feasibility: The technical feasibility should cover all the technical aspects, including upgrading & streamlining the SWM value chain in Kochi. It should also comprise of identification and assessment of best practices & processes used for solid waste collection, transportation, disposal and processing/treatment, along with an estimation of feasibility and costs related with each new process or best practice thus added to the value chain. For the SWM value chain, the input & output specifications, performance standards, social and environmental assessment, and risk assessment would be conducted.
- Financial feasibility: The feasibility study should cover in detail the user charges that could be levied on different waste generators, thus earning revenue for KMC. The feasibility study should also undertake a

detailed financial assessment of streamlining the SWM value chain covering detailed estimation of capital expenditure, operational expenditure and revenue, sensitivity analysis and value for money analysis.

- Project structure: The study should cover the feasibility of appointing a private player, for integrated SWM and for upgrading and streamlining the SWM value chain in Kochi. This would include roles and responsibilities of various stakeholders, particularly that of the private developer and the implementing agencies, mode of contracting such as Private Public Partnership (PPP) or Engineering Procurement and Construction (EPC), mode of payment and contract duration.
- Bid-process management: The feasibility study should provide details regarding the next steps in project preparation and execution, i.e., bid-process management and would explain in detail the number of stages that will be employed for the procurement process, bidding parameters, appointment of transaction advisors, formation of data rooms and customization of bidding documents.
- Workshop by Vilnius: Selected experts from Vilnius would deliver a workshop cum training to the SWM department of KMC. The workshop is planned to happen in the later part of the year and will focus on transfer of best practices from Vilnius to Kochi.

2 List of acronyms & abbreviations

Abbreviation	Full form
AD	Anaerobic digestion
AMRUT	Atal Mission for Rejuvenation and Urban Transformation
APC	Air pollution control
ATT	Advanced thermal treatment
BPCL	Bharat Petroleum Corporation Limited
C&D	Construction & demolition
CDP	City development plan
C-HED	Center for Heritage, Environment and Development
CO_2e	Carbon dioxide emission
CREDAI	Confederation of Real Estate Developers Association of India
CSP	City sanitation plan
DBOFT	Design, build, finance, operate and transfer
DMO	District medical officer
DST	Department of Science & Technology
EDMC	East Delhi Municipal Corporation
EU	European Union
GCDA	Greater Cochin Development Authority
GHG	Greenhouse gases
GIDA	Goshree Islands Development Authority
HH	Household
IEC	Information, education & communication
IEISL	IL&FS Environmental Infrastructure & Services Limited
IMC	Indore Municipal Corporation
IUC	International Urban Cooperation
JNNURM	Jawaharlal Nehru National Urban Renewal Mission
KMC	Kochi Municipal Corporation
KPWD	Kerala Public Works Department
KSEB	Kerala State Electricity Board
KSERC	Kerala State Electricity Regulatory Commission
KSPCB	Kerala State Pollution Control Board
KWA	Kerala Water Authority
LAP	Local action plan
MBT	Mechanical biological treatment
MoEF&CC	Ministry of Environment, Forests & Climate change (MoEF & CC)

Abbreviation	Full form
MOHUA	Ministry of Housing and Urban Affairs
MSW	Municipal solid waste
MW	Megawatt
PPA	Power purchase agreement
PPP	Public private partnership
RDF	Refuse derived fuel
RERF	Recycling and energy recovery facility
SEIAA	State Environment Impact Assessment Authority
SPM	Single point mooring
SPM	Suspended particulate matter
SRF	Solid recovered fuel
SWM	Solid waste management
TIFAC	Technology information , forecasting & assessment council
TPD	Tonnes per day
ULB	Urban local body
VAATC	Vilnius County Waste Management Center
VASA	Vilnius Atlieku Sistemos Administratorius
WtE	Waste to energy

3 List of tables and figures

4 Introduction

This chapter contains the background of the assignment, city profile of Kochi and the objectives of this baseline study. It also briefly explains the methodology followed in preparation of this study and the limitations of this exercise.

4.1 Assignment background

Baseline study: The baseline study for the solid waste management project has been commissioned as part of the Kochi-Vilnius strategic collaboration under the IUC-India program. The study represents the key deliverable of the Urban Cooperation Local Action Plan for the city of Kochi. The report has been prepared by Sundarajan Subramony (JNKE, IUC), based on secondary research, conducting stakeholder consultations, preparing case studies and making final recommendations. The objective of the assignment is to provide baseline information for solid waste management (SWM) in Kochi, by analyzing the current status of SWM and waste treatment facilities in Kochi and by identifying best practices in the SWM domain being followed by various national and international cities. This study can later feed into a detailed feasibility study.

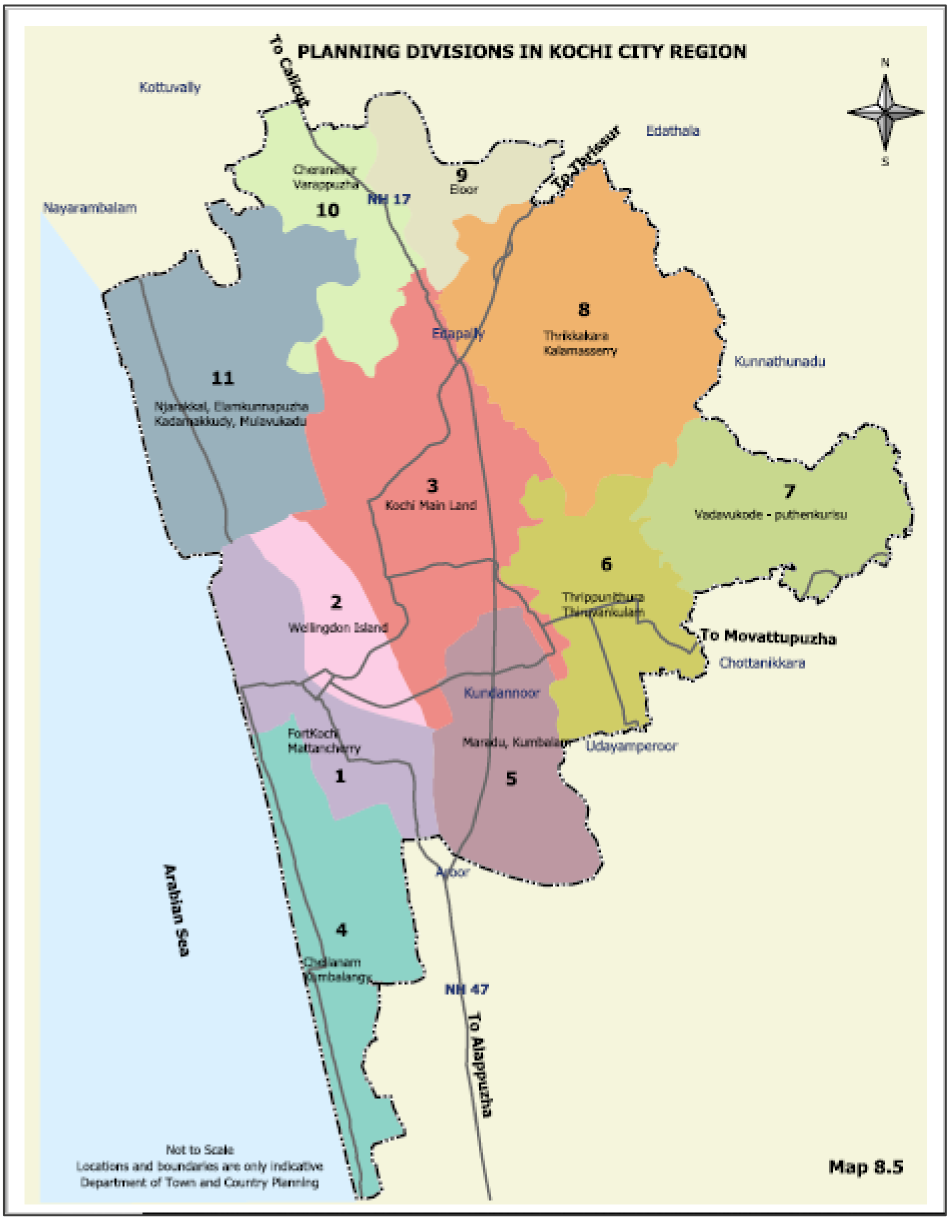
Program objectives: The IUC programme's overall objective is to contribute to improved international urban policy diplomacy and increased decentralised cooperation on sustainable urban development and climate change. The programme has two components: a) City/Sub-national cooperation on sustainable urban development to strengthen European Union (EU) - India cooperation among selected city/sub-national governments as well as between the national level and the EU, on sustainable urban development while contributing to India's Smart Cities Mission, AMRUT and other national and international sustainable urbanisation processes; and b) Cooperation on sustainable energy and climate adaptation and mitigation, and access to clean and affordable energy, through building upon the Global Covenant of Mayors (GCoM) initiative in line with existing India-EU commitments.

Kochi and Vilnius partnership: KMC is in the process of cooperating with the city of Vilnius in Lithuania on SWM. IUC-India is supporting the Kochi-Vilnius city pairing through the provision of exchange visits and the development of a LAP for the efficient, sustainable and climate friendly waste management practices at KMC. Both Kochi and Vilnius officials visited their partner cities and identified three major areas for strategic cooperation, i.e. – a) SWM, b) Transport and c) Tourism. One such initiative under the IUC-India collaboration is to undertake the baseline study that will enable a clear understanding of the current status of SWM and waste treatment facilities in Kochi, with a focus on SWM's effect on climate change and vice-versa. The baseline assessment will also draw insights related to best practices being undertaken by the SWM systems and waste treatment facilities in cities, both in India and abroad (including Vilnius) and then tailoring and implementing them in Kochi in order to achieve an efficient SWM value chain and efficient production of energy from waste.

4.2 Kochi – city profile

Kochi city: Kochi is a coastal city that lies in the Ernakulam district of Kerala. It is the commercial capital of the state. Kochi was a major spice trading center of the world in the 14th century and is known as the queen of the Arabian Sea for its scenic beauty. The city has vast expense of water sheets (22% of city area) in the form of canals & backwaters and has about 48 km of seacoast making the Kochi Harbour a major natural harbour. Kochi is home to Southern Naval Command of the Indian Navy and the state headquarters of the Indian Coast Guard. Commercial maritime facilities include the Port of Kochi, an international container transshipment terminal, the Kochi Shipyard, offshore single point mooring (SPM) of the Bharat Petroleum Corporation Limited (BPCL) Kochi Refinery and the Kochi Marina. Kochi has been hosting India's first art biennale, the Kochi-Muziris Biennale, since 2012, which attracts international artists and tourists. Kochi, with an estimated population of 616,866 in 2018, is divided into 74 wards and seven zones for governance and administrative purposes. 98% of households in Kochi have access to tap water, 97% of households have access to toilet facility within premises whereas 72.4% of households have waste water outlet connected to drainage. Solid waste collection is door-to-door whereas sewerage system is either piped (11.7%) or based on septic tanks (67.2%).

Figure 1: Kochi city region map



Source: Kochi Municipal Corporation

Kochi Municipal Corporation (KMC): Kochi Municipal Corporation came into existence on November 1, 1967. The Corporation has a harbour, railway junction, international airport, naval base and various industries in its command area and its peripheries. It was formed by amalgamating three earlier municipalities of the state, viz. Ernakulam, Mattancherry and Fort Kochi, the Willingdon Island and four panchayats viz. Palluruthy, Vennala, Vytiila and Edappally and the small islands of Gundu deepu and Ramanthuruth. At present, the total area of KMC is 94.88 km^2. For administrative purposes, the city is divided into 74 wards with the corporation headquarters in Ernakulam. Kochi has a high density of available science and technology personnel and a significant number of employable graduates passing out each year from highly graded institutes. The city has a major advantage in terms of low business operating costs (~50% lesser than comparable major cities), lower employee attrition rate, and ~60% lower rental costs. The city's power and water tariff are among the lowest in the country. Major challenges faced by KMC are unavailability of developable land, differential service levels across the city, constrained and overstressed road network, poor walkability and street safety, inefficient integration of multi-modal transport system, over dependency on grants, outward migration of educated population, etc. Kochi is one of the two cities in Kerala (the other being Thiruvananthapuram) selected under the central government's smart city mission and also, one of the nine cities selected from Kerala under the AMRUT scheme.

Greater Cochin Development Authority (GCDA) and Goshree Islands Development Authority (GIDA): The GCDA and GIDA are the development authorities initiating and monitoring the development of Greater Kochi area, mainly in development of infrastructure facilities for the city. The GCDA is the planning and development Authority of the Metropolitan area of Kochi, which is the urban hinterland of Kochi Port. The jurisdictional area of GCDA comprises of Kochi City, six surrounding municipalities and 25 intervening panchayats. The major functions of GCDA are orderly and planned development of the Greater Kochi Region. GIDA's main purpose is the development of the infrastructure facilities of scattered islands in and around Kochi. Kerala Water Authority (KWA) deals with planning, design, implementation, operation and maintenance of water supply projects in Kochi.

4.3 Objectives of the study

Establish a baseline of the current practices to handle solid waste: The study has been prepared by doing extensive secondary research and multiple stakeholder consultations. The study analyses the solid waste generated in Kochi, its types and sources, current practices for segregation, collection, handling, disposing and treating the waste. Additionally, the study captures the policies and legal framework that influence SWM in Kochi, commercial and financial aspects of SWM in Kochi and future plans of KMC with respect to SWM such as the WtE plant at Brahmapuram. The study encapsulates the roles of various government organizations/agencies and other stakeholders in the entire value chain of SWM and the role of private player in the SWM value chain including solid waste treatment and waste-to-energy facilities. The study also estimates the amount of waste that will be generated in Kochi in the next two decades and records the impact of SWM on climate change and vice versa.

Present international and national experience (with a focus on the EU) on similar processes: This report covers multiple case studies from Vilnius (Lithuania), Leeds (the UK), Stockholm (Sweden) and India (Indore, New Delhi and Hyderabad) so as to identify efficient SWM value chains, SWM best practices and waste treatment procedures followed both nationally and internationally. The case studies from the cities of Vilnius and Hyderabad analyze best practices followed throughout the SWM value chain such as segregation, collection, transportation, disposal and waste treatment, including the WtE cogeneration plant yet to be commissioned in Vilnius. The case studies from Leeds and New Delhi focus on the technologies used for waste to energy conversion at the respective WtE plants in both the cities. Lessons from Stockholm include the use of Green IT and the adaptation of waste management plan across the value chain. Key challenges from each city as well as learnings, in the SWM domain, which can be tailored, adapted and implemented in Kochi have been detailed in the study. Additionally drawing in from insights from the four case studies, certain mitigation strategies that KMC could follow, to prevent harmful effects of SWM on the environment have also been detailed in the study.

Set the basis for a more detailed feasibility study: This report is a baseline study for SWM in Kochi and the findings of this report will feed into a detailed feasibility study. The study should cover the technical aspects of upgrading & streamlining the SWM value chain in Kochi, along with identification and assessment of best practices & processes used for solid waste collection, transportation, disposal and processing/treatment, along with an estimation of costs related with each new process or best practice thus added to the value chain. For the SWM value chain, the study should cover in detail the input & output specifications, performance standards, social and environmental assessment and risk assessment. Additionally, the user charges that could be levied on waste generators, detailed estimation of capital and operational expenditure, revenue and sensitivity analysis must be conducted. The study should also focus on the feasibility of appointing a private player for integrated SWM, and should thus focus on roles and responsibilities of various stakeholders, mode of contracting, mode of payment, details of bid process management and contract duration.

4.4 Methodology employed

The study aims to provide a detailed analysis on the existing SWM scenario in Kochi while also clearly laying out the way forward for upgradation and development of existing as well as new facilities. The study is based on: a) secondary research through reports shared by IUC-India and the Centre for Heritage, Environment and Development (C-HED) team, web search and case studies on SWM, and waste treatment facilities in Lithuania, the UK and India b) stakeholder consultations with officials of the IUC-India team and officials of C-HED.

Secondary research: Extensive secondary research was carried out during the preparation of this baseline study which included summarizing, collating and synthesizing the existing research pertaining to the city of Kochi through reports shared by IUC-India and C-HED, procured through web search and also using relevant case studies from Lithuania, the UK and India:

- Documents shared by IUC-India*:* The IUC-India team shared a number of existing studies pertaining to urban infrastructure in Kochi which were imperative in the preparation of this baseline study. Some of these reports included a study on the waste to energy project yet to be commissioned at Brahmapuram, a presentation and a document on data related to SWM as provided by C-HED, and Climate Action Plan (CAP) reports for Kochi prepared by GIZ. In addition to these IUC-India also provided the site visit report of KMC team to Vilnius, report on deposit-recycling system, report on mechanical biological treatment (MBT) plant at Vilnius and a presentation on Vilnius municipality. The documents related to Kochi provide a comprehensive overview of the current situation in Kochi related to the SWM value chain whereas the documents related to Vilnius highlight some of the best practices in the SWM domain being followed in Vilnius which have the potential to be adapted and implemented in Kochi.
- Documents procured through web search: Extensive web search was also carried out in order to undertake secondary research. Various reports and articles related to urban infrastructure in Kochi and current condition related to SWM were referred to while preparing this study. Some of these reports included the City Development Plan, City Sanitation Plan, Smart city plan, Kochi, organisational framework of KMC, Suchitwa mission, EIA/EMP assessment report prepared by L&T[4], Kerala state policy on SWM, Solid waste management rules 2016 and other waste management rules applicable to Kochi. Articles related to SWM as well as effect of climate change on SWM activities in Kochi were also referred. These reports and articles helped in identifying the problems related to SWM sector in Kochi and also helped in understanding the suggestions provided by various stakeholders and strategies developed to implement those suggestions.
- Case studies: As part of an extensive secondary research, 6 case studies including 1 from Vilnius (Lithuania), 1 from Leeds (the UK), 1 from Stockholm (Sweden) and 1 each from Indore (India), New Delhi (India) and Hyderabad (India) respectively related to efficient SWM systems, best practices and waste treatment facilities, were analysed. While case studies from the cities of Vilnius and Hyderabad analyze best practices followed throughout the SWM value chain including activities such as segregation, collection, transportation, disposal and waste treatment including the WtE cogeneration plant yet to be commissioned in Vilnius whereas the case studies from Leeds and New Delhi focus on the technologies and best practices used for WtE conversion at the respective WtE plants in both the cities. The case study

[4] GJ Eco Power Private Limited (GJEP), the private player initially selected for setting up of the waste to energy plant in Kochi. GJEP had further enlisted L&T Infra Engineering to conduct the EIA /EMP assessment[4] for the waste to energy plant. This assessment report was compiled in July 2019. However the concession agreement with GJEP has now been terminated.

from Stockholm include the use of Green IT and the adaptation of waste management plan across the value chain to minimize waste generation and maximize resource efficiency.

Stakeholder consultations: Stakeholder consultations were organized through video conferencing and conference calls. Discussions were held with various stakeholders such as officials of the C-HED such as Dr. Rajan Chedambath and Ms. Simmi S, and officials of IUC- India such as Dr. Panagiotis Karamanos (Team Leader, IUC) and Ashish Verma. Discussions were held to understand the objectives of the study, role of C-HED and KMC, background of solid waste management in Kochi, details of the WtE plant proposed to be setup at Brahmapuram as well as to understand the key points to be captured in the baseline study. Inputs and insights provided by these experts/officials were of great importance in the preparation of this study and these have been further included in relevant chapters of this study.

4.5 Limitations of the exercise

The study aims to provide a comprehensive analysis of the current waste management scenario in the city of Kochi, the future outlook for SWM services and to highlight the best practices related to SWM, followed across India and abroad. However the study is limited in the sense that it is only a baseline study to assess the as-is situation of the SWM lifecycle in Kochi, in addition to the assessment of existing facilities and practices for waste treatment. Additionally, this study relies heavily on secondary sources of information and data collection through stakeholder consultations. In the wake of Covid-19 and the subsequent restrictions laid out by the Government of India, on-ground verification of data and site visits were not feasible.

5 Existing solid waste management

This chapter captures the existing arrangement of SWM in the city of Kochi, covering the entire SWM value chain, including waste generation, segregation, collection, transportation, disposal and waste treatment processes and technologies. The coverage of SWM activities within the city, prevailing waste types and sources of waste have been further explained. It also covers the roles and responsibilities of key stakeholders of the SWM system, policy and legal framework applicable to Kochi SWM, and future plans of KMC, related to SWM. Environmental concerns related to SWM activities are also illustrated

5.1 Solid waste generated in Kochi

Amount of solid waste generated in Kochi: The total municipal solid waste (MSW) generated in the Kochi ULB area is ~305 tonnes per day[5] (TPD) which translates to a waste generation per capita of 0.507 kg/day/head. As per the discussion with C-HED officials, the city does not have established mechanisms to accurately measure the total amount of waste generated in the city and the aforementioned figure for total waste generated has been derived by analyzing collection mechanisms such as number of trucks collecting waste, number of trips made each day etc. Of the 305 TPD of MSW generated in 21 circles in Kochi (comprising one to five wards each), 230 TPD of waste is collected for processing & disposal at the landfill site, resulting in a current waste collection rate of about 75%. Of the 230 TPD of MSW collected, 130TPD is processed while 100 TPD is disposed-off at the landfill site.

Sources of waste in Kochi: The major source of MSW in the city includes domestic waste sources, commercial units, wedding and community halls, hotels, restaurants, markets, institutions, schools, offices, street sweeping, hospitals (non-infectious waste), slaughterhouses, construction and demolition, etc. As per the Draft Kochi Climate Action Plan (CAP) report prepared by GIZ, domestic waste sources such as households and commercial establishments, such as small shops, are the major contributors, generating 57% of the waste in Kochi, followed by hotels and restaurants with a 10% share, markets (vegetables, fruits and meat) with ~7% share and hospitals and health care facilities with a share of 1.5%.

Types of waste in Kochi: As per the Environmental Impact Assessment (EIA)/ Environmental Management Plan (EMP) assessment report prepared by L&T Infra Engineering[6] and dated 2019, organic waste (62.6%) forms a major part of the total waste generated, followed by plastics, paper, textiles, fines and composites which in total contribute ~31% of the waste generated. However, as per C-HED data, based on a study conducted in 2016, the compostable organic waste at collection point formed 79.8% of the total waste generated. The detailed waste composition profile as per EIA/EMP assessment report and C-HED data has been provided in the chart below:

Table 1: Waste composition in Kochi as per EIA/EMP and C-HED data

Type of waste	Composition as per EIA/EMP – 2019 (%)	Composition at collection point as per C-HED data – 2016 (%)
Organics	**62.6%**	**79.78%**
Organic waste	62.6%	79.78%
Recyclables	**25.3%**	**12.61%**

[5] *GIZ Climate Action Plan for Kochi City, 2019*

[6] *GJ Eco Power Private Limited (GJEP), the private player initially selected for setting up of the waste to energy plant in Kochi. GJEP had further enlisted L&T Infra Engineering to conduct the EIA /EMP assessment[6] for the waste to energy plant. This assessment report was compiled in July 2019. However the concession agreement with GJEP has now been terminated.*

Type of waste	Composition as per EIA/EMP – 2019 (%)	Composition at collection point as per C-HED data – 2016 (%)
Plastics	9.9%	4.83%
Paper & cardboard	8.8%	4.87%
Textile	4.6%	-
Glass	1.4%	1.06%
Metal	0.3%	0.35%
Wood	0.3%	-
Rubber and leather	-	1.5%
Others	**12.1%**	**7.61%**
Fines	4.2%	-
Composites	3.3%	-
Biomedical waste	2.0%	-
Inert	1.6%	1.74%
Liquids	0.4%	-
Hazardous HH waste	0.3%	0.28%
Mixed WEEE	0.1%	-
Ash and fine earth	-	1.68%
Others	0.2%	3.91%

Source: EIA/EMP assessment report, C-HED data, CRISIL analysis

As per the EIA/EMP assessment report, the chemical analysis of the waste revealed a low carbon to nitrogen ration of 19:1, whereas the moisture content of the waste stood at an average value of 60%, while the average calorific value was 8.1 megajoules per kilogram (Mj/Kg).

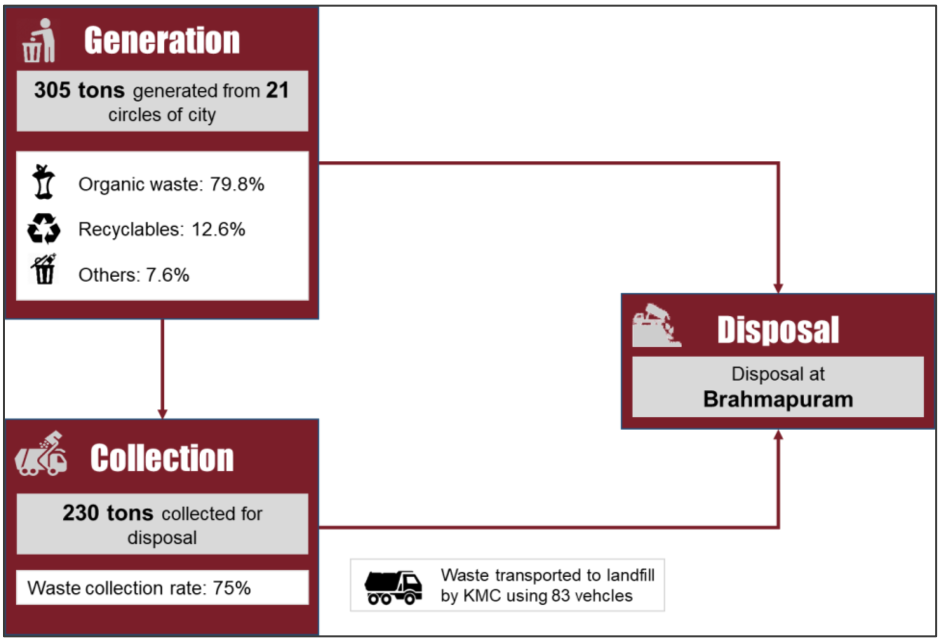
5.2 Prevailing waste collection and waste handling practices

SWM coverage: KMC is responsible for Kochi's municipal solid waste management through two of its departments, namely the Department of Health and the Engineering Department. Solid waste collection, transportation, handling and disposal is looked after by the Department of Health, whereas functions such as planning, vehicle procurement, equipment, site development, setting up of plants for treatment of bio-degradable waste and awarding of annual contracts for large-scale cleaning activities are looked after by the Engineering Department. For the purpose of solid waste collection and transportation, the KMC is divided into 21 circles comprising one to five wards each.

Solid waste segregation (at source): Segregation of waste in Kochi happens at source. For the past 10-15 years, the waste generated in Kochi is being segregated into hazardous, biodegradable and non-biodegradable categories. KMC has provided separate waste collection bins to each household, one for collecting biodegradable waste and the other for collecting non-biodegradable waste. KMC through residents' associations, had requested households to segregate the waste at source itself and deposit the biodegradable and non-biodegradable waste in the respective bins.

Solid waste collection (door-to-door): Kochi city uses a door-to-door method of solid waste collection, wherein permanent and contractual workers employed with KMC, and Kudumbashree employees (Kerala-based NGO engaged in several social activities in Kerala) are responsible for collection of solid waste directly from waste generators such as households. While biodegradable waste is collected daily from households, non-biodegradable waste is collected on a weekly basis. Each door-to door collector covers, on an average ~150 households per day, however, depending upon the efficiency of the collector, this number may rise. These waste collectors collect biodegradable waste from households, in the morning each day, using hand-carts and tipper auto rickshaws (owned by KMC) and by afternoon, they bring all the waste to secondary collection points (KMC has 85 waste collection points spread across the city) from where they load the waste into corporation vehicles to carry the waste for processing/disposal at the Brahmapuram plant. Of the 305 TPD of MSW generated in 21 circles in Kochi (comprising one to five wards each), 230 TPD of waste is collected for processing and disposal at the landfill site, resulting in a current waste collection rate of about 75%.

Figure 2: SWM cycle in Kochi

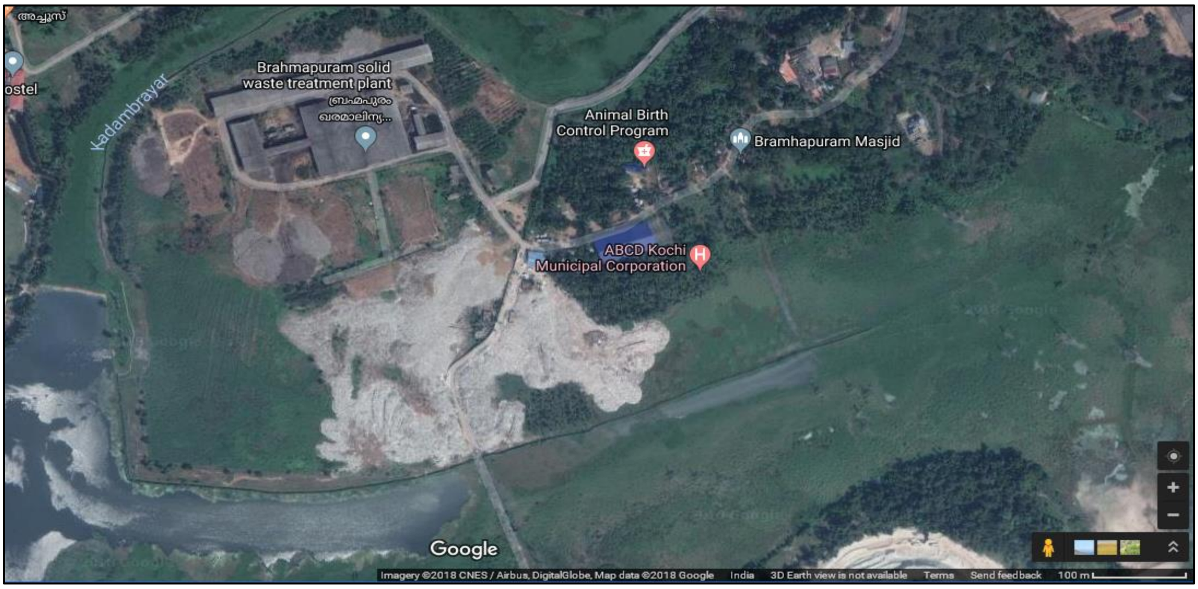


Source: C-HED Data

Solid waste transportation: Transportation of waste from waste collection points to the Brahmapuram plant for processing/disposal and treatment is carried out by KMC using 83 vehicles which are owned by KMC, in addition to 500 handcarts. The detailed breakdown of the vehicles employed in waste collection is provided in Table 2 below. The waste collected from secondary collection points is loaded into large tipper trucks and compactor trucks to transport the waste to the waste treatment and disposal facility at Brahmapuram where the organic component of waste received is treated in a windrow composting facility and the plastic/non-biodegradable component of the waste is tipped at the dumping yard. The operational and transport cost for solid waste management is borne by KMC.

Solid waste treatment at Brahmapuram facility: Of the 305 TPD of solid waste generated in the city, 230 TPD of MSW is collected, and of which 130TPD is processed while 100 TPD is disposed-off at the landfill site. The collected waste from the city is transferred to Brahmapuram waste treatment and disposal facility wherein, the organic component of waste received is treated in a windrow composting facility and the plastic/non-biodegradable component of the waste is tipped at the dumping yard. Brahmapuram is an area located around 20 kilometers from Kochi city. Spread over an area of 110 acres at Brahmapuram this area has been identified as the hub for waste management activities and consists of a a) windrow composting facility, b) RDF facility to convert waste into usable fuel for combustion (not operated since commissioning), c) plastic shredding and bailing unit, d) incineration plant for medical waste, e) septage treatment plant and f) landfill site and g) a plastic dumping yard.

Figure 3: Waste treatment facility at Brahmapuram



Source: C-HED, Google

Revenue from SWM activities: KMC does not charge any user fee for collection of waste but the workers who are responsible for collection of waste charge INR 50-100 per month (EUR 0.6 to EUR 1.2[7]) from each household for waste collection. For example, Kudumbashree workers charge a fee of INR 100 per month (EUR 1.2) per household for waste collection, the fee is paid directly by the household and commercial units to the Kudumbashree workers and does not provide any source of revenue to KMC. It needs to be noted here that although KMC does not generate any revenue from SWM activities expenses, such as salaries, program expenditures etc, pertaining to SWM related activities are borne by the organization. As per the Kerala State Waste Management Policy, 2018, waste generators must pay a user fee for SWM as specified in the by-laws of the local bodies. Therefore, KMC could formalize the user charges for waste to be collected from waste generators and include the same in the by-laws.

Equipment and vehicles: KMC and Kudumbashree workers utilize 583 vehicles, ranging from handcarts to refuse compactors for handling solid waste in the city. The city currently has 13 refuse compactors, 24 covered tippers, 44 mini high-lift tippers, 2 mini trucks and 500 handcarts which are utilized for SWM activities in the city. While handcarts and tipper auto rickshaws are utilized for waste collection activities, compactor trucks and tipper tucks are utilized for transporting waste from secondary collection points to the disposal and waste treatment facility at Brahmapuram.

Table 2: Equipment/Vehicles

Equipment / vehicle	Number
Refuse compactors	13
Covered tippers	24
Mini high lift tippers	44
Mini trucks	2
Handcarts	500
Total	**583**

Source: C-HED data

[7] *Exchange rate of 1 EUR = INR 82.64 as of May 18, 2020*

Figure 4: Vehicles used for SWM handling

Refuse Compactor

Mini high lift tipper

Source: C-HED

Staff employed: The KMC along with its own employees (both permanent and contractual) and Kudumbashree workers, engages 1,284 people for primary waste collection activities in the city. These door to door waste collectors collect waste from various households, using handcarts and tipper auto rickshaws and bring all the waste to secondary collection points from where they load the waste into corporation vehicles to carry the waste for processing/disposal and treatment at the Brahmapuram plant. A detailed breakdown of the number of people engaged under various categories is shown below:

Table 3: Number of people engaged in primary waste collection

Staff	Number of people
Permanent employees	799
Contractual employees	204
Corporation Workers	**1,003**
Kudumbashree workers	**281**
Total workers	**1284**

Source: C-HED data

5.3 Technologies and treatment processes

Windrow composting technique: The waste treatment plant at Brahmapuram was commissioned in 2008 and has a capacity of treating 250 TPD of waste. The plant uses the aerated windrow composting technology and was built at a cost of INR 19 crore (EUR 2.3 million). Windrow composting is the production of compost by piling organic/biodegradable waste into long rows called windrows. These piles or windrows are periodically turned to improve porosity, mix in or remove moisture, allow oxygen flow to the windrow's core and enable heat generation, and to redistribute cooler and hotter portions of the pile. This method is suitable for producing large volumes of compost.

- <u>Standard specifications and size</u>*:* Windrows are trapezoidal and are 6-10 feet high and 6-10 feet wide at the base. The windrows are laid at a distance of 1-3 meters from each other because the space between windrows should be sufficient for the movement of the windrow turning machine. Also windrow dimensions allow conservation of heat generated during composting process, while also maintaining diffusion of air to the deeper portions of the windrow.
- <u>Present status of the windrow composting plant</u>*:* The present status of the Windrow composting plant is as follows: a) The plant is operated by M/s Enviro Green under the operations and maintenance contract,

b) The windrow composting technique converts waste into manure and yields ~20 tonnes of manure per day which is then sold by the contractor, thus earning them revenue. Additionally there is a fee of INR 550/tonne (EUR 6.6 per tonne) paid by KMC to the contractor for processing waste at the composting plant excluding the cost of INR 1.5/kg (EUR 0.2 per kg) for transportation, and c) The plant operated optimally till the first year of its operation but by the nature of being constructed on a wet land, the plants platform sunk and a few columns collapsed. The reconstruction of the plant has not yet commissioned due to the high proposed cost. M/s Enviro Green is entrusted with the operation and maintenance of the waste treatment plant. The plant generates ~20 tonnes of manure each day.

Plastic dumping yard: The plastic dumping yard at Brahmapuram receives ~100 tonnes of plastic waste each day. Around 1% of this plastic waste is suitable for recycling, and is recovered from the waste, the remaining 99% of waste is dumped as a heap at the landfill.

- <u>Standard specification and size</u>: The total spread of plastic waste at Brahmapuram is 300m x 200 m that is 60,000 m^2. The average height of the accumulated waste dump is 3m, volume of waste is 180,000 m^3 and the weight is 68,400 tonne and is spread over 16 acres of land.
- <u>Present status of the dumping yard:</u> The plastic dump at Brahmapuram is increasing in size day by day beyond capacity and is a menace for the municipal corporation. It has seen several fires over the past few years, thus polluting the air and the environment.

5.4 Maintenance procedures

Currently, the Brahmapuram facility receives waste on a daily basis from the city limits through municipal corporation-owned vehicles. The biodegradable waste undergoes windrow composting while the non-biodegradable waste is dumped at the landfill.

Windrow composting plant: The windrow composting facility at the Brahmapuram plant is currently in a dilapidated condition but is operational. The compost plant columns have sunk, by the nature of being constructed on a wet land and needs repair. The windrow composting plant should be rectified and maintained to treat the biodegradable waste at Brahmapuram. Also the capacity of the windrow composting plant needs to be enhanced so that it is able to process all the waste received thus preventing the site from becoming a dump site.

Plastic dumping yard: Almost 99% of the total plastic waste collected from the city is dumped unscientifically at the plastic dumping yard at Brahmapuram, making the dump susceptible to fires. The plastic dumping yard needs to be maintained and the waste must be removed from time to time to prevent the heap from rising and contributing to diseases and fires.

5.5 Commercial/financial aspects

Revenue: KMC had a total revenue of ~ INR 47,572 lakh (EUR 57.1 million) in fiscal 2019 of which ~INR 12,775 lakh (EUR 15.3 million) comprised of various tax revenues. Assigned revenues and compensation (such as vehicle tax compensation), rental income from municipal properties (markets, town halls, stadiums etc), fee and user charges (fee for birth certificate, market fee etc.), sale & hire charges (sale of agricultural products etc), revenue grants, contributions and subsidies (such as maintenance funds, library grants etc), income from investments (dividends, fixed deposits etc.) and interest earned form other major revenue heads. The total revenue in fiscal 2018 was INR 31,389 lakh (EUR 37.7 million). KMC earns a significant amount of its revenue through various grants, contributions and subsidies (~56% in 2019). KMC does not collect any revenue for the door-to-door waste collection activities undertaken by its workers (for SWM activities) as well as by the Kudumbashree workers. These workers however collect a nominal fee of INR 100 (EUR 1.2) per household for the waste collection, which does not add to the revenue earned by KMC.

Table 4: Estimated budgeted revenue and expenditure of pertaining to SWM for KMC

Particulars (INR lakh)	FY18	FY19	FY20
User charges related revenue			
User charges from commercial shops and buildings	-	500	500
User charges for solid waste disposal	-	200	180
Revenue expenses			
Repair & maintenance – treatment plants	2,000	30	430
Repair & maintenance – recreation centers	84	25	167
Repair & maintenance – public toilets	21	50	141
Interest & finance charges			
Interest on loans from HUDCO	367	62	68
Program expenditure			
Health-related programs, sanitation and waste management etc	2020	600	347
Total estimates of budgeted revenue	**0**	**700**	**680**
Total estimates of budgeted expenditure	**4,492**	**767**	**1,153**
Profit/Loss	**(4,492)**	**(67)**	**(473)**[8]

Source: KMC budget documents

Expenses: KMC had total expenses to the tune of ~ INR 44,642 lakh (EUR 53.6 million) in fiscal 2019 which comprised of establishment expenses (salaries, wages, contribution to pension funds etc), administrative expenses (Rent, income tax, insurance etc), operations & maintenance expenses (electricity charges, repair & maintenance charges, environment conservation charges etc), Interest & finance charges (interest on loans, bank charges etc.), program expenses (expenditure on poverty eradication program, education related activities etc.) revenue grants & subsidies (assistance to medical institutions etc.), prior period items and depreciation. The expenses in fiscal 2019 were higher as compared to expenses in fiscal 2018 which were to the tune of INR 30,760 lakh (EUR 36.9 million). KMC spent a total of ~INR 399 lakh (EUR 0.5 million) in sanitation & waste management work as programme expenditure which was less than what they had spent in fiscal 2018 (INR 688 lakh) / (EUR 0.8 million). The operational and transportation cost for solid waste management in the city is borne by KMC. KMC pays the private player INR 550 (EUR 6.6)/tonne for processing of waste. Further KMC incurred an expenditure of INR 3,983 lakh (EUR 4.8 million) for repair & maintenance of drainage network in fiscal 2019 which was more than INR 2,765 lakh (EUR 3.3 million) on the same activity in fiscal 2018.

On account of KMC generating more income than incurring expenses, it had been generating profits in the past two financial years, which were INR 2,030 lakh (EUR 2.4 million) and INR 618 lakh (EUR 0.7 million) in fiscal 2019 and fiscal 2018, respectively.

5.6 Policy and legal framework

Various policies applicable to SWM and waste treatment facilities in Kochi are described below:

Solid Waste Management Rules, 2016: The Union Ministry of Environment, Forests & Climate change (MoEF & CC) revised the Municipal Solid Waste (Management and Handling) Rules 2000 as Solid Waste Management Rules, 2016. With the introduction of the solid waste management rules, 2016 a wider range of stakeholders have been held accountable for the efficient management of the SWM system. The new set of

[8] *Considering that budgeted prior period income and budgeted prior period expenditure is not related to SWM*

protocols define the responsibilities of each member in the value chain and also introduce awareness initiatives, incentives and penalties around the SWM process. They also introduce the criteria for setting up a waste treatment facility, criteria for a waste to energy process, specifications of sanitary landfills, and monitoring for their implementation. The policy explains the roles and responsibilities of stakeholders, and explain the power of ULBs to enforce user charges for SWM services. The policy also allows for incentives such as capital subsidy, co-marketing of fertilizer etc for waste to energy plants. Additionally the policy mandates, that non-recyclable waste having calorific value of 1500 kcal/kg or more shall not be disposed of on landfills and shall only be utilised for generating energy either or through RDF or by giving away as feed stock for preparing RDF.

Kerala State Waste Management Policy, 2018: The Kerala state management policy was formulated with a vision to transform Kerala into a clean, waste-free state and make it an environmentally healthy state by adopting the three principles of a) reduce, b) reuse and c) recyle. The policy envisages “a healthy, prosperous, and resource efficient society in which waste is reduced, reused, recycled and prevented wherever possible and disposed of in an environmentally safe manner”. The policy builds on the basic principles laid out in the SWM rules, 2016. The policy focuses on compliance by waste generators regarding prohibition of disposal of waste on streets, drains and water bodies and explains the processes of segregation, collection and treatment of waste. The policy aims to ensure full door-to-door coverage for waste collection and discourages the use of single use and throw away materials. Additionally the policy explains the process for handling different types of waste such as sanitary waste, garden/horticulture waste, construction/demolition waste etc. It focuses on user charges to be paid by waste generators for SWM services as specified in the bye-laws and postulates that industrial units located within 100 km of WTE plants and RDF plants need to replace at least 5% of their fuel requirement with RDF produced.

Construction and Demolition Waste Management Rules, 2016: The MoEF & CC notified the Construction and Demolition Waste Management Rules in 2016. The rules are an initiative to effectively tackle the issues of pollution and waste management. The construction and demolition waste generated nationally is about 530 million tonnes annually. The construction and demolition waste management rules, 2016 defines construction and demolition waste. The rules apply to every waste resulting from construction, re-modelling, repair and demolition of any civil structure of individual, organization or authority who generates construction and demolition waste such as building materials, debris and rubble.

E-Waste (Management) Rules, 2016: The MoEF & CC notified the e-waste management rules, 2016 in supersession of the e-waste (management and handling) rules, 2011. The policy applies to every consumer, producer, manufacturer, collection centers, dealers, refurbishes, dismantlers and recyclers involved in manufacture, sale, transfer, purchase, storage, collection, and processing of e-waste or electronic & electrical equipment which is listed in Schedule I. It also include parts, components and spares which make the product operational. The protocols superseded the e-waste management rules of 2011. In EWM rules of 2016, e-waste has been defined as whole or in parts of an electrical and electronic equipment discarded as waste by consumer as well as the rejected material from refurbishment, manufacturing and repair.

Plastic Waste Management Rules, 2016: The MoEF & CC notified the plastic waste management rules, 2016 which will now supersede the plastic waste management rules, 2011. The policy defines plastic, compostable plastics, carrybags, virgin plastics, multilayered packaging and all types of plastic waste. It also lists the categories of plastics, lists the roles and responsibilities of prescribed authorities for plastic waste management, the roles and responsibilities of plastic waste generators and producers. The set of protocols explain the modalities of plastic waste management, environmental issues and challenges related with plastic waste and to promote the use of plastic waste in various tasks such as road construction, energy recovery etc.

Bio-Medical Waste Management Rules, 2016: The MoEF & CC notified the bio-medical waste management rules, 2016 to replace the earlier rules, 1998. These protocols define the types of waste which are categorized as bio-medical waste such as human & anatomical waste, treatment equipment such as needles, syringes and other material used in healthcare and in the process of treatment and research. They also explain the waste categories for bio-medical waste and define the ambit of bio-medical waste generators such as blood banks, treatment or immunization processes in hospitals, nursing homes etc. Scientific disposal of such waste for effective disposal by hospitals and other waste generators. The roles and responsibilities of waste generators and producers as well as standards for incinerators and other bio-medical waste handlers are also explained.

Hazardous and Other Waste Management Rules, 2016: India's environment ministry MoEF & CC has issued its revised hazardous and other wastes (management and transboundary movement) rules 2016. The policy explains the type of waste, which by reason of its characteristics would be classified as hazardous waste and helps to distinguish between hazardous and other wastes. Hazardous waste classification, identification and storage & labelling requirements of hazardous waste are explained. Management of such waste, problems associated and importance of proper hazardous waste management is also illustrated. Roles, responsibilities and duties of waste generator and various stakeholders as well as environmentally sound management, management hierarchy, co-processing, disposal and recycling of hazardous waste is explained.

5.7 Waste management policies for Covid-19

Policy coverage: The Central Pollution Control Board, Ministry of Environment, Forest and Climate Change, Government of India has come out with guidelines for handling, treatment, and waste generated during treatment / diagnosis and quarantine of Covid-19 patients. The guidelines are applicable for all stakeholders including isolation wards, quarantine centers, sample collection centers, laboratories, ULBs and common biomedical waste treatment and disposal facilities. These policies are applicable in addition to the Bio-medical waste management rules, 2016 (BMW rules).

Guidelines for Covid-19 isolation wards, sample collection center and labs: Separate colour coded bins/bags/containers should be employed in accordance with the BMW rules. The waste collected from isolation wards needs to be disposed in double layered bags (using 2 bags) to ensure strengths and no leaks. The waste collected should be clearly marked as "Covid-19 waste" thus enabling priority treatment and disposal. The containers, bins and trolleys used for storage of Covid-19 waste should be daily disinfected with 1% sodium hypochlorite solution. The isolation wards should depute dedicated sanitation workers separately for bio-medical waste and general solid waste.

Responsibilities of persons operating quarantine facilities: The waste generated at quarantine facilities is expected to have less quantity of bio-medical waste. The facility managers at these places are expected to ensure separate collection of biomedical waste in yellow bags, ensure collection of biomedical waste through common biomedical waste treatment facilities (CBWTF), door step collection or at designated deposition centers. In case of any difficulty in accessing such facilities the person should contact their respective ULB.

Duties of CBWTF: The CBWTF are responsible for regularly reporting the receipt of waste from isolation wards, quarantine facilities, and testing centers. The operator has to ensure regular sanitization of workers involved in collection and handling of biomedical waste. Personal protection equipment (PPEs) shall be provided to sanitation and workers and dedicated, regularly sanitized, vehicles will be employed for waste collection. The operator shall ensure that Covid-19 waste shall be disposed-off immediately upon receipt at the facility.

Duties of ULBs: Urban local bodies shall be responsible for ensuring safe collection and disposal of biomedical waste. The authorities will arrange necessary security, engage authorized waste collectors and CBWTFs for door to door waste collection. They shall be responsible for creating awareness, providing yellow waste bags, create provisions for PPEs and ensure smooth facilitation of the entire waste management collection and disposal cycle.

UN habitat Covid-19 SWM guidelines: Although there are guidelines for treatment of biomedical waste, these guidelines lack guidance on adapting the existing waste management practices for a pandemic. Keeping this in mind, United Nations Human Settlement Programme has developed a ten point strategy for solid waste management in the context of Covid-19. These guidelines have been presented below:

- Map sources of waste generation to identify changes in generation amounts and flows: Places such as hospitals, home care units, testing labs, and quarantine camps should be identified as they will generate hazardous waste. Additionally, places such as schools commercial units etc. which will see decreased waste generation shall also be identified. The mapping of such sources will enable efficient resource allocation

- Separate infectious waste in households: All potentially infectious waste should be put in clearly identifiable colored bags, ensuring double coverage if possible. If identification of or separation of infectious waste is not possible then all waste from the household should be sealed and handles as residual waste. Waste bags should be distributed to households' especially low income and informal settlements.

- Maintain and expand waste collection services: Human as well as financial resources should be allocated efficiently as per the mapping exercise undertaken by the authorities. Increased and regular waste collection services should be provided to the identified biomedical waste sources, informal settlement and high population density areas. The authorities should promote reduced contact between people especially during door to door collection of waste.

- Ensure safe waste treatment and disposal: On site temporary storage and thermal treatment of infectious waste from identified sources in the city must be ensured. If thermal facilities are not available, adequate and safe sanitary landfill measures must be ensured.

- Protect waste workers, formal and informal: All workers either formal or informal must be properly trained to follow basic hygiene measures. Safe work practices including PPE shall be made available for these workers. The authorities should also consider support for livelihood loss of informal waste workers.

- Regularly communicate with citizens and stakeholders: The new collection schedule and other changes must be effectively communicated to through radio, newspapers, social media and other channels. Citizens should ensure proper disposal of waste in line with guidelines.

- Engage with stakeholders: The authorities must engage with waste stream stakeholders both formal and informal to identify roles and responsibilities. Coordination and collaboration with informal workers, NGOs and waste management operations should be undertaken to strengthen and expand service and coverage.

- Accelerate procurement procedures: The procurement of safety equipment, additional storage bins, collection trucks, should be expedited. A review of central and state funds should be undertaken to review possibility of fund diversion from existing programmes to push Covid-19 related activities

- Application of national and international guidelines for healthcare and medical waste: The guidelines laid out by the respective government shall be followed. In case of absence of government guidelines, the WHO guidelines should be followed.

- Design scenarios and contingency plans: The lesson learned from other countries should be considered and implemented in each phase of planning. The authorities should also conduct risk assessments associated with failure of continued service for instance staff and equipment shortage, closure of recycling, waste treatment and disposal units.

5.8 Key stakeholders

This section introduces the key stakeholders in relation to solid waste management in Kochi. Table 5 below highlights the key responsibilities pertaining to SWM for various stakeholders in Kochi.

State government of Kerala: The state government of Kerala is the prime authority which through its line departments prepares state policies, regulations, bylaws, formulates strategies, policies and regulations, prepares master plan for cities, identifies suitable land for setting up solid waste processing and disposal facilities and streamlines the urban development of the entire state. It also provides funding support for major projects related to various aspects of urban development such as town planning and development, water supply, public health and safety, solid waste management, storm water drainage, sewerage and sanitation etc. All the other stakeholders will need to follow the stipulated guidelines of the Government of Kerala pertaining to SWM activities in Kochi.

Suchitwa Mission: Suchitwa Mission, the Technical Support Group (TSG) in Waste Management sector under the Local Self Government (LSG) Department, Government of Kerala is responsible for providing technical and managerial support to the LSG's of the State, for conceptualizing, action planning, conducting creative workshops & trainings, initiating sector related studies, action research & bringing about papers, conducting monitoring and other such activities in the SWM sector. The mission is also the nodal agency for implementing Swachh Bharat Mission (both Urban & Rural) and Communication and Capacity Development Unit (CCDU) in the State. Suchitwa mission plays a critical role in determining the way the state should proceed to manage its waste, and in this capacity the mission's technical team keeps providing advice on issues such as managing the non-biodegradable legacy waste accumulated at the Brahmapuram plant or advice related to the leachate treatment at the same plant.

Kochi Municipal Corporation (KMC): KMC was formed in 1967 merging municipalities of Fort Kochi, Mattanchery and Ernakulam and is the main administrative body of Kochi city. For the purpose of effective administration, the corporation is divided into different departments, each catering to a different aspect of city's development. KMC is responsible for Kochi's municipal solid waste management, through two of its departments namely, the Department of Health and the Engineering department. Solid waste collection, transportation, handling and disposal is looked after by the health department whereas functions such as planning, vehicle procurement, equipment, site development, setting up plants for treating bio-degradable waste and giving annual contracts for large scale cleaning activities are looked after by the engineering department. For the purpose of solid waste collection and transportation, the KMC is divided into 21 circles comprising of one to five wards each.

Table 5: Responsibility matrix for SWM activities in Kochi

Urban Services	Planning	Implementation	Operations & maintenance	Tariff & revenue
Solid Waste Management	KMC and other local bodies	KMC and other local bodies	KMC and other local bodies, private sector initiatives such as CREDAI Clean City Kochi	KMC

Source: Kochi City Sanitation Plan

Kudumbashree: Kudumbashree is a Kerala based NGO, which is engaged in several social activities in Kerala and its workers along with KMC employees are responsible for collecting waste from waste generators through door-to-door waste collection method using hand carts and tipper auto rickshaws, which are owned by KMC. Kudumbashree workers are involved in only primary waste collection, for which they charge a fee of INR 100 per household. Secondary waste collection and transportation of waste is done by KMC workers.

Enviro Green (Solid waste processing): The windrow composting plant at the Brahmapuram facility is operated by Enviro Green under the operation and maintenance contract. At this plant the processed waste is converted into manure which is then sold by the contractor, thus earning him revenue. Additionally there is a fee of INR 550/tonne paid to the contractor excluding the cost of INR 1.5/kg for transportation. Thus Enviro Green being associated with the waste processing facility at Brahmapuram is a key stakeholder in planning for SWM activities in Kochi.

5.9 Future plans

Waste to Energy (WtE) plant: A waste to energy plant, based on advanced thermal gasification technology was to be taken up on public private partnership (PPP) basis wherein the private player, GJ Eco Power Pvt. Ltd. (GJEP) was supposed to design, build, finance, operate and transfer (DBFOT) the facility for 20 years. The plant proposed to have a waste processing capacity of 500 TPD of unsegregated waste. However the plans for the proposed WtE plant have been stalled and the concession agreement with GJEP has been terminated as the private party, GJEP failed to meet the conditions precedent, related to financial close, even after four years of signing the concession agreement. GJEP failed to produce the financial plan, financing documents for the project and failed to demonstrate financial close. GJEP further asked for modified arrangements such as conversion of concession agreement into lease agreement and provision of 100 percent government guarantee. Because of the above mentioned reasons, the concession agreement with GJEP has been terminated.

Fresh tender for integrated SWM: The Kerala State Industrial Development Corporation (KSIDC) has floated a fresh tender for integrated solid waste management for the Ernakulam cluster in June, 2020. Under the project, the selected private party will be required to look after the entire value chain of SWM in the cluster including Kochi city, including segregation, collection, transportation, processing and disposal. The project will also involve the development of a waste to energy plant of minimum 300 TPD, processing capacity on DBFOT basis at Brahmapuram.

6 Climate change and SWM

This chapter captures the impacts of climate change such as effect of flooding, increase in temperature, increased precipitation and rise in sea levels on SWM activities in Kochi. An estimate of greenhouse gas (GHG) emissions released through composting as well as through disposal of waste in landfill is also carried out.

6.1 Impact of climate change on SWM activities

Effect of flooding in Kochi: The city of Kochi has started to witness global warming induced climatic changes such as the consecutive floods in the years 2018 and 2019, of which the one in 2018 was the worst in a century killing scores of people and destroying crores worth of infrastructure. As Kochi is adjacent to the coast it is subject to floods during monsoons and heavy rains thus affecting normal life. Additionally water logging is a major problem in Kochi wherein the dumping of large amounts of waste in canals and drains leads to their blockage thus contributing to urban flooding. Some of the effects of flooding on SWM activities are described below:

- Solid waste accumulation: Both solid waste accumulation and flooding are interdependent on each other. While solid waste accumulation in drainage canals increases the risk of urban flooding in Kochi, urban flooding, in turn accumulates solid waste blocking drainage canals, resulting in inundation and public health concerns. Thus waste accumulation is a major problem when floods occur, thereby making it difficult for solid waste collectors to collect such huge quantities of waste and transport the same for processing or disposal at the landfill site, which itself maybe flooded.

- Effect of flooding on landfill sites*:* Impacts of flooding on landfills are inundation, waste solution migration to neighboring areas and physical erosion. Erosion is particularly significant at landfills constructed in a way that the waste is above ground level. Flooding of landfill may cause increased leachate production by adding water to the volume of wastes in the landfill and causing varying degrees of saturation.

- Effect of flooding on waste treatment areas: Excessive flooding may affect the land treatment areas wherein waste could dissolve or be suspended in the nearby soil, increased leachate production and migration are also possible.

- Effect of flooding on the waste pile: Waste piles employing biological decomposition in the treatment of waste are affected by increased rainfall and flooding wherein waste suspension could occur and waste pile may remain saturated after floodwaters have receded leading to an increase in moisture content and a decrease in calorific value. Additionally saturation of the pile could lead to structural weakening and result in collapse of the pile.

- Effect of flooding on storage facilities: Waste storage tanks and containers would overflow, containers would float or spill if not properly secured, thus leading to the spread of vector borne diseases due to spillage of waste.

Effect of increase in temperature: Another effect of global warming is the increase in temperature in Indian cities. As per ICLEI ACCCRN[9], the projected mean temperature in Kochi may show a net increase of 0.53 degree Celsius in 2015-44 with respect to the mean temperature of 1969-2000. Increase in temperature over the years, may alter the waste decomposition rate and leachate production rate thus leading to the spread of infectious diseases and posing problems for solid waste collection and disposal.

[9]The *ICLEI ACCCRN Process (IAP) enables local governments to assess their climate risks in the context of urbanisation, poverty and vulnerability and formulate corresponding resilience strategies*

Effect of rainfall: The rainfall, which hit Kochi on October 21st 2019, caused many low-lying parts under KMC to be waterlogged for three days as storm water drains had not been cleaned on time. On October 23, the district administration launched 'operation breakthrough' with the support of local volunteers and cleaned main water drainages in Kochi. Thus, lack of cleaning of drains and increased precipitation can lead to an extreme risk of improper waste management related problems, especially clogging of storm water drains and other outlets, thus leading to urban flooding and the spread of water/vector borne diseases.

Effect of rise in sea levels: A study has found that sea level in Kochi coastal line is rising by 1.8 mm every year. This affects the quality of water resources such as ground water. Further, a study of the tide gauge from 1971 to 2007 and satellite visuals between 2002-2012 revealed that an area about 30 km on Kochi coast, which is about 80% of the total coastal area of the Kochi district, has been affected with soil erosion. Salinity was found in water samples collected from the coastal areas. The impacts of sea level rise on SWM activities are explained below.

- Effect of sea level rise on landfill sites*:* The impacts of sea level rise on landfills are inundation, waste solution migration, physical erosion, and saltwater intrusion. Waves can cause extensive erosion of any loose cover material on a landfill site. Erosion is particularly significant at landfills constructed in a way that the waste is above ground level. Salt intrusion from sea level rise may affect landfills with clay caps and/or liners, leading to significant clay-salt interaction. Increased salt concentrations may cause a decrease in the shear strength of clay, thus weakening its structural stability. Sodium chloride may cause clay to dehydrate, resulting in a decrease in permeability but an increase in porosity. Inundation of a landfill can result if flood waters are high enough. A ponding effect will cause increased leachate production by adding water to the volume of wastes in the landfill and causing varying degrees of saturation.

- Effect of sea level rise on land treatment areas*:* A rise in sea level could have two effects on land treatment areas - (a) waste could dissolve or be suspended in the nearby soil, increased leachate production and migration are also possible and (b) physical erosion caused by coastal wave action might result in a total washout or removal of the soil layer and the incorporated wastes

- Effect of sea level rise on waste piles*:* A sea level rise could have three primary effects on waste piles, which employ biological decomposition in the treatment of waste - (a) waste solution or suspension could occur, (b) waste pile may remain saturated after floodwaters have receded, allowing waste to continue leaching out, and the calorific value would decrease, moisture content and saline content of waste piles would increase, and (c) saturation of the pile could cause structural weakening and result in a collapse of the pile.

- Effect of sea level rise on waste storage facilities: Tanks could overflow, containers could float or spill if not properly secured, structural damage to above-ground or partially above-ground tanks could be caused by floating debris or by increased hydrostatic pressure, and saltwater could corrode tanks and containers

6.2 Impact of SWM activities on climate change

The waste management policies currently followed by KMC could lead to several environmental concerns which are highlighted below.

Pollution by solid and liquid waste: Unscientific management of collection centers, landfill site and transportation trucks could result in solid waste pollution along routes and neighborhood, wherein scavengers and animals/birds could scatter the waste leading to pollution. Additionally light waste can become airborne quickly and can spread to areas outside the landfill leading to pollution.

Air pollution: City wise waste collection services do not reach slum dwellers and urban poor residential areas in Kochi thus forcing them to either burn their waste or bury it in an unscientific manner thus leading to air and soil pollution. Some households and other waste generators also burn their waste such as dry leaves, paper and plastic in order to avoid paying the waste collection fee to the collection workers. Such unscientific and illegal burning/burying of waste pollutes the air and soil thus leading to unhygienic conditions in the city. Additionally windrow composting of organic waste at Brahmapuram facility releases greenhouse gases whereas direct disposal of solid waste in disposal sites/landfills also emit methane and other GHGs, thus polluting the environment.

Fire hazards*:* As highlighted above, the unscientific dumping of waste leads to increment in biological activity and can trigger chemical reaction which may lead to fire. The dumpsite at Brahmapuram has witnessed such fires on several occasions. These uncontrolled fires could lead to significant loss of vegetation and could lead to air pollution.

High odor levels: The odor emanating from the waste dump at the Brahmapuram facility can impact the population up to 2 km away, is a nuisance for nearby residents and its proximity to the new Smart City is already having a very negative impact on that development. The waste to energy project however will prevent such uncontrolled waste dumps in the city and will support collection and removal of existing waste dumps to generate power.

Land and soil pollution: There have been occurrences of waste, including plastic lying in paddy fields in the Kochi district. Such waste if not removed will lead to soil pollution, which will make the paddy growing in such fields unfit for human consumption. Additionally, as per the environmental impact assessment (EIA) / environmental management plan (EMP) assessment report, over 136 unauthorized locations, (apart from the Brahmapuram facility), in Kochi city and adjoining areas are used for illegal dumping of waste, huge tracks of land are thus rendered unusable due to dumping of waste piles.

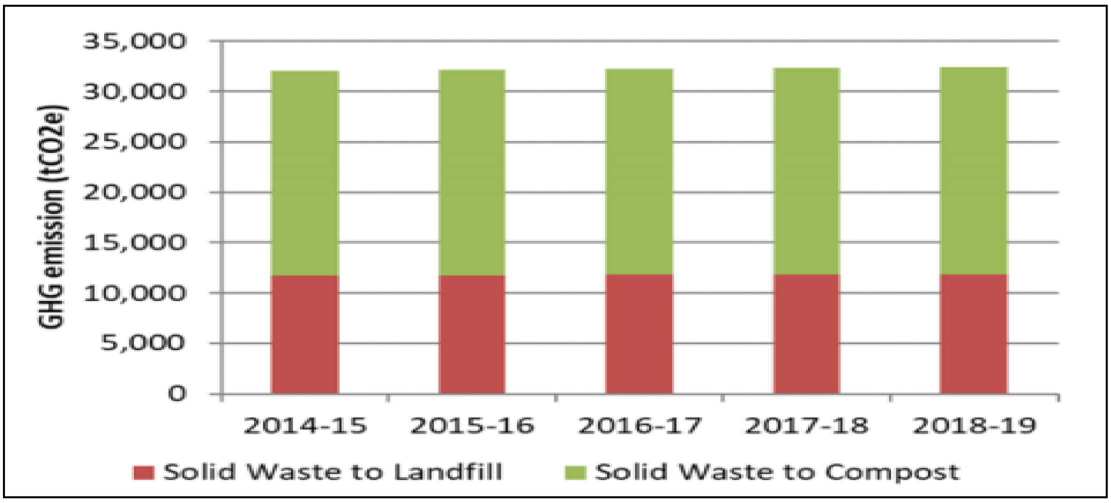
Water pollution: Canals are considered as the lifeline of Kochi. However, these canals are highly polluted and in a bad shape because of dumping of large amounts of the uncollected waste in Kochi. The waste dumping leads to blockage in canals which leads to reduced capacity of canal systems to support transportation, and it also becomes an issue in case of rising sea levels in the future. The combination of water stagnation, waste accumulation, and warm temperatures provide an excellent breeding ground for disease causing organisms and the disease vectors (mosquitoes, flies and rodents) which can transmit the diseases to humans. Additionally, the unscientific open dumping of waste at Brahmapuram is a major pollution contributor, there are no controls of processing systems in place and contaminates and leachate are able to flow freely off the site into surrounding rivers, ponds, streams and it also leads to organic and microbial pollution of ground water table. The impact from the effects of leachate and waste water is high and leads to long term irreversible effects beyond the boundaries of the landfill site.

Noise pollution*:* Movement of trucks near secondary collection centers, creates noise pollution for the citizens living in the nearby residential areas. Movement of vehicles and the usage of heavy machinery at landfill site both during operations increases the levels of noise and vibration in the local environment near the landfill site. The effect will cause health problems such as respiratory diseases for the inhabitants near the landfill site.

6.3 Greenhouse emission estimates

Municipal solid waste consists of biodegradable organic matter, partially degradable matter and non-degradable materials. Windrow composting of organic waste present in MSW releases greenhouse gases whereas direct disposal of solid waste in disposal sites/landfills also emit methane (CH4) and other GHGs, thus polluting the environment. The generation and composition of waste (carbon content in particular) as well as the methods and technologies used for waste handling, processing and disposal determine the final amount of greenhouse gas emissions associated with solid waste treatment/disposal.

Figure 5: GHG emissions from solid waste management at community level in Kochi



Source: GIZ Kochi Climate Action Plan

6.4 Solutions for minimizing the impact of SWM on climate change

Source reduction and recycling: Management of municipal solid waste presents many opportunities for GHG emission reductions. Source reduction, in general, represents an opportunity to reduce GHG emissions in a significant way. Source reduction and recycling can reduce GHG emissions at the manufacturing stage, increase forest carbon sequestration, and avoid landfill CH4 emissions. Landfill CH4 emissions can be reduced by using gas recovery systems and by diverting organic materials from landfills. Landfill CH4 can be flared or utilized for its energy potential. When used for its energy potential, landfill CH4 displaces fossil fuels, as with MSW combustion. Using compost as landfill cover on closed landfills provides an excellent environment for the bacteria that oxidize CH4. Under optimal conditions, compost covers can practically eliminate CH4 emissions. Furthermore, the covers offer the possibility of controlling these emissions in a cost-effective manner. This is particularly promising for small landfills, where landfill gas collection is not required and the economics of landfill gas-to-energy projects are not attractive. Use of Bioreactors can accelerate the decomposition process of landfill waste through controlled additions of liquid and leachate recirculation, which enhances the growth of the microbes responsible for solid waste decomposition. The result is to shorten the time frame for landfill gas generation, thereby rendering projections of landfill gas generation rates and yields that are much more reliable for landfill gas recovery.

Adopt solid waste sustainability goals: Kochi Municipal Corporation should update general plans to reflect solid waste sustainability issues such as green house gas (GHG) reduction goals, landfill gas recovery and programs based on specific targets. The landfill site should be designed taking into consideration of tapping landfill gas. The monitoring and update of records should be done on a regular basis to check performance of reduction strategies. According to the Clean Development Mechanism (CDM) and Joint Implementation (JI) of the Kyoto protocol, there is a great potential for addressing methane emissions by reducing the amount of waste that ends up in a landfill. Globally nearly 70% of our solid waste is landfilled, a meagre 19% is recovered through composting or recycling, the remaining 11% is converted to energy through incineration or other waste-to-energy technologies.

Adoption of technology: There are multiple technological options to reduce GHG emissions from post-consumer waste. Composting can eliminate greenhouse gas emissions from landfill, and reduce overall GHGs from solid waste. It is the organic material in landfill that produces methane. Contrary to the decomposition that happens in a landfill which emits methane, composting is aerobic, which emits carbon dioxide which has comparatively lesser greenhouse gas potential per atom of carbon emitted. Offsetting this, the use of compost in agriculture increases carbon sequestration, decreases the need for irrigation by as much as 70%, and also reduces the need for chemical fertilizers. Waste-to-energy via combustion is another option with potential for climate change mitigation. There are over 800 of these plants worldwide, producing electricity and district heating for the community by incinerating waste. Some of the countries have passed legislation to prohibit future landfilling of combustible waste.

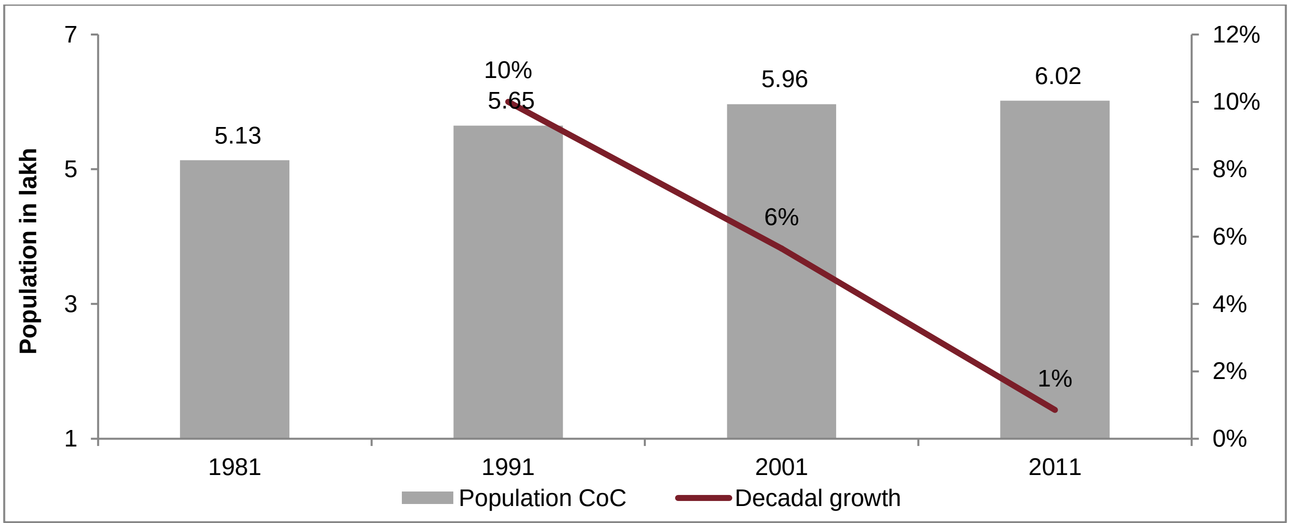
7 Future trends

This chapter presents demographic and macroeconomic trends in Kochi and solid waste generation estimates looking at a 20 year horizon.

7.1 Demographic trends

Kochi city's population as per the 2011 census is 602,046 with a decadal growth of 1% during 2001- 2011. The city's growth in population is low as compared to the country's decadal growth of 17.64%.

Figure 6: Population growth of Kochi city



Source: Kochi CSP

The Kochi city sanitation plan was consulted for the population projections for the city. The CSP projects that the population growth in the city is expected to remain moderately low considering the high rentals in the city as well as the growth of the adjoining regions. The population projection for the Kochi city have been provided below:

Table 6: Population projections for Kochi city

Year	Arithmetic	Geometrical	Incremental	Updated Average	Average population as per CSP
1971	439,066	439,066	439,066	439,066	439,066
1981	513,249	513,249	513,249	513,249	513,249
1991	564,589	564,589	564,589	564,589	564,589
2001	596,473	596,473	596,473	596,473	596,473
2011	601,574	601,574	601,574	601,574	636,000*
2021	642,201	623,484	619,174	628,286	680,000
2031	682,828	646,191	613,746	647,588	728,000
2041	723,455	669,726	585,291	659,491	782,000

*Source: Kochi CSP, *Projected in CSP*

Being a major economic and tourist hub in the district, Kochi witnesses a large floating population, as per estimates provided in city sanitation plan, the city has a daily floating population of 250,000.

7.2 Macroeconomic trends

Kochi has been one of India's main port since 14th century when it was a spice trading center of the world and it is one of the major economic and trading hub in the country. The major economic sectors in Kochi include - Information technology (IT), health services, shipbuilding, international trade and tourism. Today, the city mainly has a service-focused economy with companies including retailing gold and textiles, exports of seafood and spices, IT, tourism, health services, banking, shipbuilding, and fishing. A multi-product Special Economic Zone (SEZ) has recently been established in Kochi, where businesses have been set up by a number of information technology firms.

Eloor is the largest industrial belt in Kerala, 17 kms north of the city centre, with over 250 factories producing a range of products including chemical and petrochemical products, pesticides, rare earth elements, rubber chemicals, fertilizers, zinc and chromium compounds, and leather products. Kochi Refineries of Ambalamugal (BPCL) is one of the largest oil refining companies in South India.

7.3 Solid waste generation estimates

To estimate the solid waste that will be generated in Kochi in the upcoming years, we referred to the calculations provided in the City Sanitation Plan (CSP) updation status report prepared by ICRA Management Consulting Services Limited (iMaCS). The waste generation projections in the city are expected to remain in line with the resident population projections as depicted in the demographic trends (decadal growth in population). The estimated solid waste to be generated in the upcoming years has been calculated using the projected resident population and assuming per capita solid waste generated to be constant that is 600 gm per capita over the years (as per the calculation in the CSP). Additionally we have also calculated waste generated using the waste generated per capita figure of 507 gm/capita as provided by C-HED and assuming the waste generated per capita to be constant over the years.

Table 7: Solid waste generation estimates of Kochi city

	2016	2021	2026	2031	2036	2041
Population	614,930	628,286	637,864	647,588	653,513	659,491
Waste generated (tons) as per CSP	369	377	383	389	392	396
Waste generated (tons) as per C-HED data	312	319	323	328	329	334

Note: The values for all years including 2016 are estimated values

Source: CSP Updation status report - IMaCS Analysis, C-HED data, CRIS analysis.

For more accurate analysis and results, a deeper analysis is required which would require historical data on the number of households, number of commercial establishments, institutions, hospitals, industries and other waste generators in the city of Kochi. The detailed analysis may be undertaken during the feasibility study for SWM in Kochi.

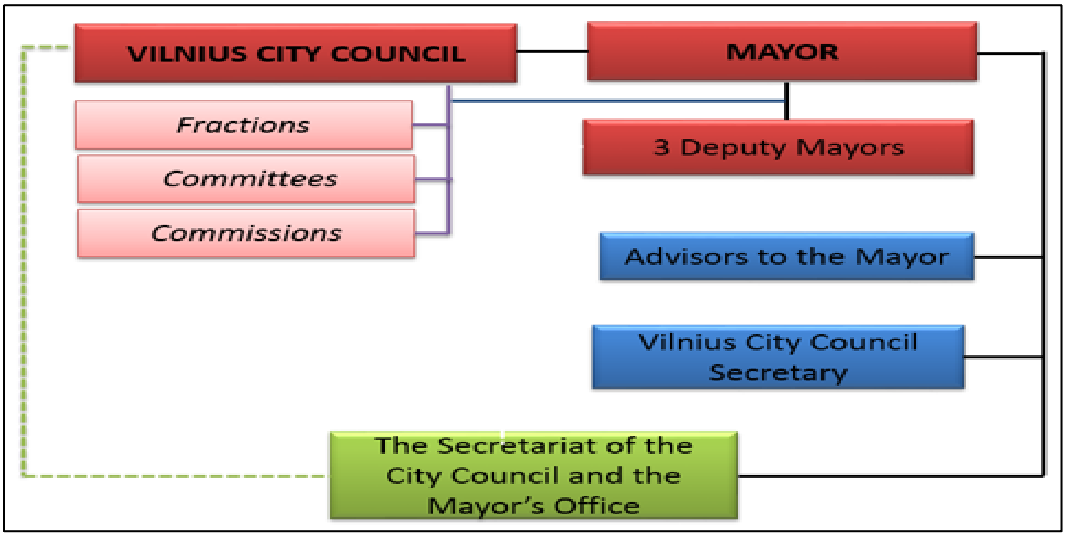
8 International & national best practices

The following chapter analyses three cases studies, one each from Vilnius (Lithuania), Leeds (UK), Stockholm (Sweden) and three case studies from India, in order to assess the best practices and processes in solid waste management. The chapter also seeks to explain how the key learnings from national and international best practices and case studies can help shape an efficient solid waste management in Kochi city.

8.1 Experience from Vilnius, Lithuania

Vilnius – city profile: Vilnius, the capital of Lithuania, is situated in south east of the country. It is the 2nd largest city in the Baltic states having an area of 401 km^2. The city has multilingual residents wherein 50% speak two foreign languages, dominant foreign languages being English, Russian, German and Polish. Vilnius is the second youngest capital in North Europe after Copenhagen[10], and Vilnius has the largest population of young people in the Baltic Sea region capitals. The population of Vilnius is 580,020 as of January 1, 2020. The city of Vilnius holds shareholding in 25 stock and closed stock companies, 71 public companies and 313 budgetary institutions. The Vilnius municipality is one of the 60 municipalities in the country, has 51 members, provides administrative services, organizes the provision of public services and adopts political decisions. The council committees perform activities related to environment and energy, economy and finance, culture, education and sports, urban planning and development, services and city maintenance, social affairs, health and local government development. Additionally the municipality has 1.6 administrative employees per 1,000 inhabitants under the municipality. The political structure of Vilnius municipality is illustrated in the figure given below.

Figure 7: Political structure of the Vilnius municipality



Source: Presentation on Vilnius city and Vilnius municipality

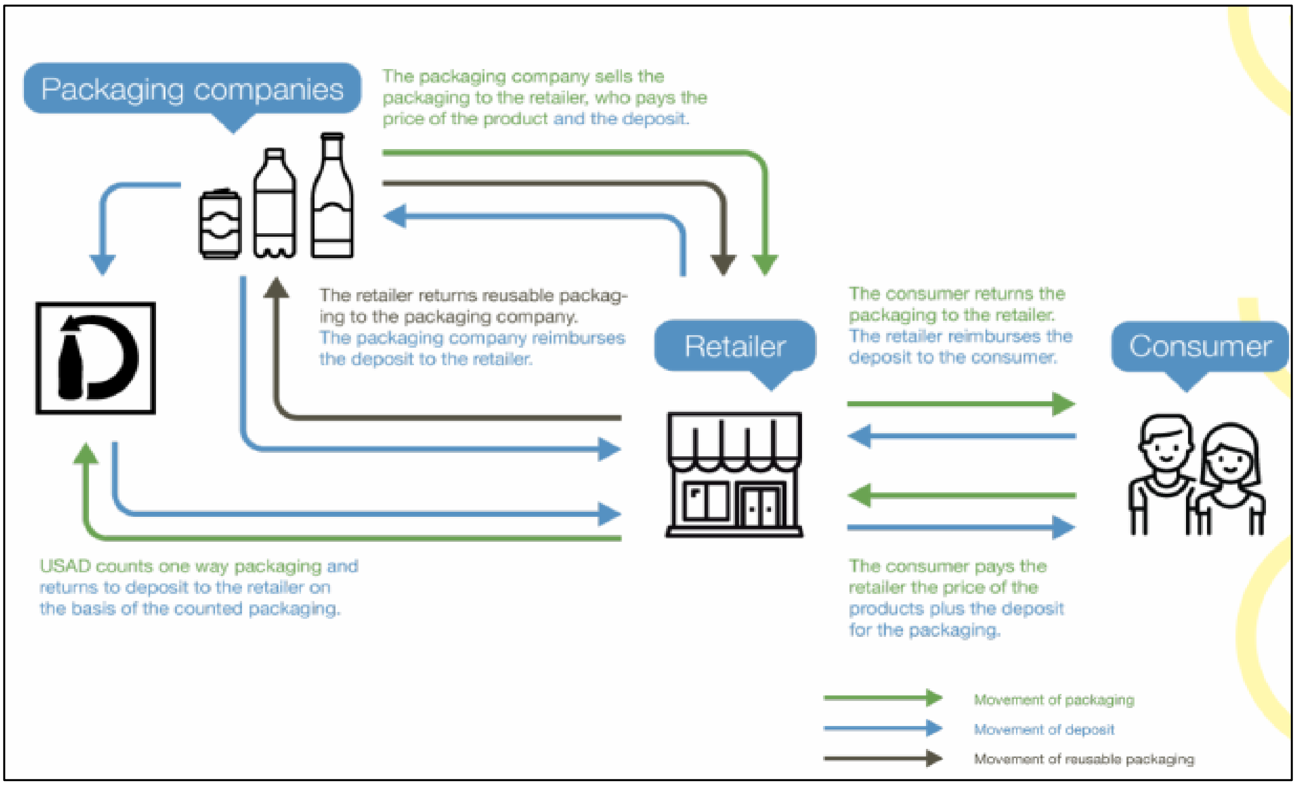
Solid waste collection in Vilnius: The Vilnius municipality is responsible for organizing collection and disposal of waste, and collection of recyclables such as paper, glass, plastic etc. Service providers for collection of waste and recyclables are selected by the municipality through tendering procedure. For private (individual) households, municipality appointed waste collectors, provide door-to-door collection services for the collection of paper, glass, cardboard, mixed cans, plastics etc. Owners of such individual houses have signed contracts for the use of containers for segregated waste collection. An underground waste container system has also been developed in Vilnius, which is described below. Apart from individual houses, residents

[10] *Nordea Analysis from EU National Statistics, 2015*

of apartments must deliver the recyclable waste to 'collection points' located within a distance of 50-500 meters from homes) and bio-waste to 'Civic Amenity sites' (one civic amenity site per 50,000 inhabitants), operated by municipality appointed contractors. Additionally, a deposit and return system is in place for all kinds of packaging products primarily drink containers. While waste collection, transportation to civic amenity sites and waste disposal are financed through municipal tax levied on homeowners, door-to-door collection of recyclables is financed by manufacturers and importers. The underground waste container system and deposit recycling facility used in solid waste collection are described below.

- Underground waste container system: An underground waste container system has been developed in Vilnius as per which all the residents in the capital city have installed dozens of underground and semi-underground containers, which will be separate for household wastes, paper, plastics and glass. These containers are economical, reliable, and suited for both urban and rural communities, especially for areas undergoing redevelopment. Areas having large amounts of waste such as shopping centers, residential areas etc., have high utility for such containers. These containers have 75% of their depth underground and hence are aesthetically more pleasing than scattered collection bins.
- Deposit recycling initiative: Under this initiative, the recyclable and reusable material is returned for recycling, back to shops or to reverse vending machines. While returning the material and packaging (such as PET, metal, glass, plastic, beverage packaging etc.) with printed deposit marks, a small refund (incentive) is provided. To combat litter and increase waste collection and recycling rates, consumers pay a deposit amount, while purchasing say drink containers, and the amount is refunded, when the empty container is returned for recycling. To get the refund, the returned packaging must be empty, with its original shape maintained, its labels undamaged and barcode clearly visible. This is a supplementary waste collection system organized by manufacturers and importers association and financed by manufacturers and importers. Collection points are in comfortable locations. The facility has brought about considerable reduction of packaged waste with 91.9% of all beverage containers being returned for recycling by the end of 2017. The prices of the deposit system are provided in Table 9 below:

Figure 8: Packaging and deposit flow for deposit recycling system at Vilnius



Source: USAD presentation 2018 – Lithuania deposit system

Table 8: Prices of the deposit system

Deposit system	Price (EUR/tonne)
PET	2,000
Aluminium	1,000
Iron	1,500
Glass	83

Source: Vilnius data

Solid waste disposal and treatment in Vilnius: In addition to waste collection and transportation, Vilnius municipality is also responsible for organizing disposal of waste generated in the city. Vilnius County Waste Management Center (VAATC), founded in 2003, by the municipality is responsible for creating a waste management system for Vilnius city and for effectively implementing waste management tasks. It is a large solid waste management plant with state-of-the art facilities. The plant manages the mechanical biological treatment (MBT) plant, operates the Vilnius county regional landfill, operates 17 bulky waste disposal sites and six green waste composting sites. The waste management center sets an example by paying attention to reducing environmental impact, evaluating practical examples, and applying best available techniques.

- Vilnius county regional landfill: In 2017, an year after the mechanical biological treatment plant started operations, ~175,000 tonnes of waste was disposed at the landfill site, whereas ~225,000 tonnes of waste was treated at the MBT plant. The waste is received at the waste reception area of the landfill site, registered, and then disposed of at the landfill site. The landfill gas, wastewater and leachate are collected and treated wherein the landfill gas is collected and treated by a contractor. Continuous monitoring of operations and maintenance and environmental monitoring is conducted at the landfill site.
- Mechanical biological treatment (MBT), Vilnius: Vilnius city has a mechanical biological treatment plant, which is a type of waste processing facility that uses source separated waste, combines re-sorting of mixed utility waste from the Vilnius region with a form of biological treatment of waste such as anaerobic digestion or composting. Biological processing produces solid recovered fuel (SRF). The MBT was built on a design, build, operate (20 years) model and started operations in 2016 and was partially financed by EU funds. The MBT is managed by Vilnius County Waste Management Center (VAATC) and is operated by UAB Energesman. The plant serves eight municipalities including Vilnius city and Vilnius district. Some advantages of the MBT plant in Vilnius are: a) Reduces landfilled waste especially biodegradable waste and hence reduces greenhouse gas emissions, b) Sorts secondary material for recycling, c) Prepares RDF for waste to energy plant, d) Prepares high calorific value SRF for cement industry, e) It is cost efficient through economies of scale, f) 11,000 tonnes per year from the Vilnius region treated, and g) Accurately weighs municipal waste and commercial and industrial waste is no more accounted as municipal. The main parameters of the MBT plant are provided in table 10 below:

Figure 9: MBT plant at Vilnius

Source: http://www.versina.lt/portfolio/vilnius-mechanical-biological-waste-treatment-plant/

Table 9: MBT plant parameters

Design capacity	250,000 tonnes/year
Number of workers	120-150
Working days/week	Five
Shifts	Two
Land plot	40,000 m^2
Area of buildings	21,000 m^2

Source: Vilnius data

- Vilnius waste system administrator – Sivasa (VASA): Apart from VAATC, as described above, the Vilnius waste system administrator is a company established in 2015 by the Vilnius municipality pursuant to the provisions of the law on waste management of Lithuania. The aim of the company is to carry out efficient administration of waste management, control and supervise the provision of municipal waste management services, and to create a provision to transfer information to municipal waste holders and authorities of the Vilnius municipality. The company is responsible for monitoring the efficacy and efficiency of the waste management system in Vilnius. The company does so by maintaining and constantly updating the database of municipal waste holders, developing and determining the accounting system and quantum of user charge for waste management related activities, undertaking detailed studies regarding the quantum of waste collected, the amount of waste collection containers required and waste transport route monitoring and formulation. The entity is also responsible for waste related information collection, management and dissemination.
- Waste to energy (WtE) cogeneration plant: A WtE cogeneration power plant is being constructed in Vilinius, which will convert waste into useful heat and electricity. It is expected that the plant will treat 160,000 tonnes/year of non-recyclable, non-usable waste (after sorting) at the MBT facility, following which the waste will be incinerated for production of electricity and recovery of heat simultaneously, known as cogeneration. The plant funded by the European Union (EU) and led by Vilinius kogeneracinė jėgainė, is expected to have a capacity of 70 MW, of which electricity would account for 16-20 MW and the rest would be heat (51-55 MW). It is expected that the plant will supply electricity to 90,000 households (~20%) in Vilinius and will result in EUR 10 million savings each year on spends in waste diposal services by Vilinius inhabitants. The project would result in 95% reduction in landfill space and would result in reduction of 10% of greenhouse gas emissions from the waste sector or reduction in ~130,000 tonnes of CO_2 annually.

The WtE project, expected to be completed by 2020 is important for Vilnius as it will help to build a sustainable and integrated municipal SWM system.[11]

Other best practices followed by Vilnius: The city of Vilnius follows some best practices in other areas apart from SWM, such as different companies for handling the city's different functionalities, a separate maintenance company providing all utility services as well as the usage of drones for city surveillance. Such best practices are described below.

- Different companies for handling city's functionalities: The Vilnius city municipality has formed companies, each handling a separate functionality for the city. These companies have their own independent CEOs, supported by a team of experts and dedicated individuals focused on the roles assigned to them. For Indian cities this is a new concept and a novel idea.
- Utility services in the city*:* Vilnius city municipality has a maintenance company called Grinda UAB which provides all utility services to the city such as repair and maintenance of streets and courtyards, removing graffiti from monuments, bridges and viaducts, organizing work on the beaches of Vilnius, providing special care and quarantine for homeless animals, providing specialized sanitary services, providing internal network emergency services etc. Grinda's formation has revolutionized the utility sector in Vilnius. It has brought many innovative and smart applications for better service delivery such as electronic task management system that helps to manage tasks, Open Vilnius that shows the routes of special vehicles online, WAZE that helps users to register obstacles and potholes on mobile application etc.
- Usage of drones: Grinda, the maintenance company uses drones for city surveillance, assessing emergency situations, identifying illegal buildings and/or landfill sites, for maintenance of urban infrastructure networks and supervision for road cleaning.

Conclusion*:* The city of Vilnius has exhibited a well-rounded approach to solid waste management across the entire lifecycle from collection to disposal. The city has introduced several novel concepts such as underground waste collection bins, deposit recycling facilities, and setup of cogeneration plants to meet the cities power and heat requirements. Kochi could adapt a similar integrated waste management adopting the best practices employed by Vilnius. Kochi can also look at setting up of a dedicated company which will be wholly owned by the Kochi municipal corporation and shall be responsible for the entire municipal waste management lifecycle. The setup of an independent organization will reduce the burden of waste management from KMC and also enable the organization to employ waste management experts who are well equipped at tackling the specific waste management challenges faced by Kochi.

8.2 Experience from Leeds, UK

Leeds - City Profile: Leeds is the third largest and one of the fastest growing cities in the United Kingdom. Leeds had a population of 789,194 in 2018**.** The city has a thriving economy with industries in financial services, legal, manufacturing, health and retail. The city boasts of leading educational institutions and highly skilled workforce. Leeds is well connected with road, rail and air networks.

Leeds recycling and energy recovery facility (RERF): Veolia, a French transnational company signed a 25 year Private Finance Initiative (PFI) with Leeds City Council in 2012 for the purpose of municipal waste treatment and energy recovery. The Leeds recycling and energy recovery facility (RERF), developed by Veolia, (officially opened in 2016) uses state-of-the art technology to recover 90% of waste from the city's black bin waste (which contains Leed's inhabitants general household waste excluding hazardous waste) to produce ~11 MW of electricity. Leeds currently produces, 165,000 tonnes of black bin waste per year of which 10% of the waste is taken for recycling and the remaining 90% is provided to the RERF for producing electricity. RERF is not just an incinerator but employs a special combustion process wherein the remaining 90% of black bin

[11] https://ec.europa.eu/regional_policy/en/projects/lithuania/cogeneration-in-vilnius-converting-waste-into-electricity-and-useful-heat

garbage is burnt thereby producing heat to convert water into steam, which in turn drives a turbine to create electricity, which is then transferred to the national grid.

Figure 10: Recycling and energy recovery facility, Leeds

Source: https://www.veolia.co.uk/leeds/

Benefits of the RERF: The waste to energy plant prevents all black bin waste from landfill each year, thus saving EUR 7 million a year as compared to the previous cost of landfill. This will save ~EUR 200 million over the next 25 years compared to landfill. This innovative method of electricity generation supplies electricity to approximately 20,000 households in the UK. Moving away from landfill sites has also reduced the amount of greenhouse gases being released into the atmosphere, the amount of which is equivalent to taking off ~29,000 cars off the road each year. The facility will result in EUR 250 million saving in landfill tax over 25 years by Leeds inhabitants. The plant created 200 jobs during construction and post commissioning 58 new jobs have been created. This facility helps reduce Leed's carbon footprint, increase recovery of recyclables and energy from waste, decreases landfill and increases re-use. The plants helps Leeds to achieve the aim of being a zero waste city and is committed to bring about sustainability and the ability to make the best use of available resources.[12]

Conclusion: Leeds has exhibited an exceptional approach to energy generation from waste. The city has been able to process almost 90% of its black bin waste to generate heat as well as energy. The efficiency in energy generation enable the city to utilize land for other productive activities as well as generate significant savings.

8.3 Experience from Stockholm, Sweden

Stockholm - City Profile: Stockholm is the capital and most populous urban area Sweden. Stockholm had a population of 975,904 as of December, 2019**.** The city is the cultural, political and economic centre of the country, accounting for over one thirds of Sweden's GDP. It has an extensive network of roads, rails and airways connecting the City of Stockholm with the surrounding urban and metropolitan municipalities (together forming the Stockholm County).

[12] *https://www.veolia.co.uk/leeds/our-facility/leeds-recycling-energy-recovery-facility-rerf-works*

https://www.veolia.co.uk/leeds/

https://www.leeds.gov.uk/residents/bins-and-recycling/your-bins/future-of-leeds-waste

Solid waste generation in Stockholm: The total waste generated in Stockholm has been decreasing over the recent years. The volume of waste processed in 2018 was 614,110 tonnes compared to 688,330 tonnes processed in 2017. Household waste accounted for 441,530 tonnes (~72%) of the total waste generated in 2018. The recent trend of decreasing waste generation is primarily because of the emphasis of congestion taxes, waste management plans and policies related to waste generation. Further, data suggests that the volume of household waste per resident is projected to decrease to 452 kg in 2020 and 424 kg in 2026 (as compared to 477 kg waste per resident in 2015). [13]

The Swedish Recycling Revolution: One of the special focus of the country has been to achieve a zero waste society – transitioning from dumping waste in landfills to recycling and reusing. Sweden has had a can and bottle deposit system for a long time. This system gives people money back on recycling and has been in place since 1984 for aluminum cans, and since 1994 for plastic bottles. Each year Sweden recycle 1.8 billion bottles and cans. In 2017, the government also reformed its tax regime so that people prefer used items/reusing. In 2018 the Swedish government even established a special advisory group to help it make circular economy a key part of its policy, the so-called cradle-to-cradle approach. Due to its position in the Swedish economy and populace, Stockholm has had a lot of influence from these policies. It has been one of the main centres of driving the recycling revolution for the Swedish government. [14]

Figure 11: Waste to energy power plant, Sweden

Source: https://www.nytimes.com/2018/09/21/climate/sweden-garbage-used-for-fuel.html

[13] https://www.stockholmvattenochavfall.se/globalassets/pdf1/riktlinjer/avfall/avfallsplan/sva072-avfallsplan_en.pdf

https://www.avfallsverige.se/fileadmin/user_upload/Publikationer/SAH_2019_EN.pdf

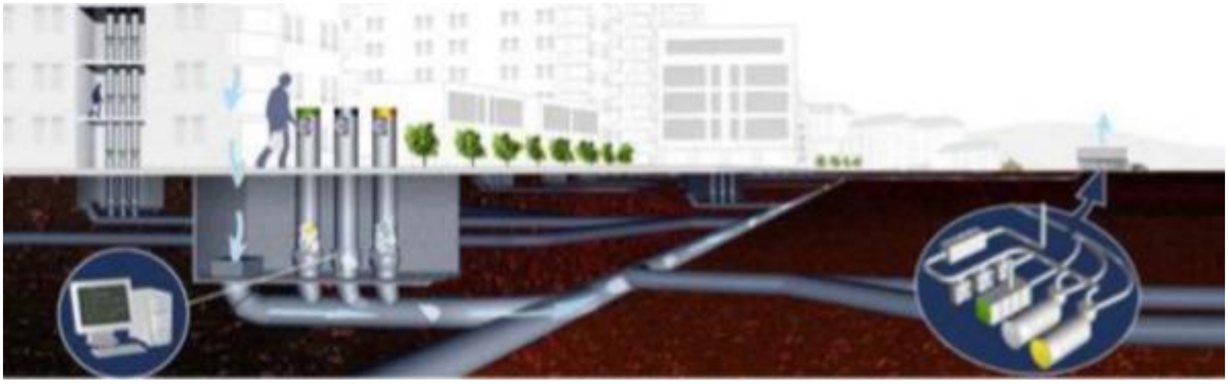
https://www.avfallsverige.se/fileadmin/user_upload/Publikationer/Avfallshantering_2018_EN.pdf

[14] https://sweden.se/nature/the-swedish-recycling-revolution/

Stockholm Waste Management Plan 2017-2020: The purpose of the Stockholm waste management plan is to have a strategy to manage, recycle and reuse through planning new areas, reviewing building permits and supervising environmentally hazardous activities, besides specifying how residents, businesses and other organisations manage their waste. The plan has four major objectives: (a) waste from household/businesses to decrease and waste produce to be utilised in resource-efficient manner, (b) harmful waste to be prevented and managed early, (c) waste management to be adapted to people and (d) waste management to be a natural part of cities physical planning.

Benefits of the Stockholm Waste Management Plan: Due to the waste management plan in effect, the City of Stockholm was able to process 614,110 tonnes of waste in 2018, generating an energy of 1,641,360 MW. The plan has helped keep the residual waste generation relatively constant at 230,000 tonnes per year despite the population growth. It targets to collect 70% of the available food waste by 2020, corresponding to just over 66,000 tonnes. It has developed 30 different classifications to separate and collect bulky wastes and plans to add 5 more categories of waste fractions by end of 2020. Everyday waste is processed in waste to energy plants to generate energy for home and the city. Stockholm has also launched a biochar pilot plant in 2017 to manufacture biochar through pyrolysis of resident's garden waste. There are also plans to build a new sorting, pre-treatment and anaerobic digestion facility. The city is also creating a network for stationary underground vacuum waste collection system across buildings with three refuse chutes. At a later stage, this will be incorporated with a built-in recording and weighing system so that waste can be utilised optimally. All this has been possible through the utilization of Green IT – IT infrastructure to support waste management and environment.[15]

Figure 12: Mechanical underground waste collection, Stockholm



Source: http://sajms.com/wp-content/uploads/2015/01/Sustainable-Solid-Waste-Management-Best-Global-Practices1.pdf

Conclusion: Stockholm has an exceptional approach to cover the entire value chain to manage solid and other types of waste. This spans from the point to waste generation to the point of waste use. It has put in place tax regimes and incentive structures to curb waste generation and promote reuse of materials. The city has prepared plans for an underground waste collection and sorting system. The collected waste is then segregated into 30 categories before it is used for energy generation through one of the two means- anaerobic digestion or waste to energy through incineration– to achieve flexibility and resource efficiency. Through an integrated waste management plan the city recycles almost 99% of the household waste generated.

[15] https://www.stockholmvattenochavfall.se/globalassets/pdf1/riktlinjer/avfall/avfallsplan/sva072-avfallsplan_en.pdf

https://www.avfallsverige.se/fileadmin/user_upload/Publikationer/SAH_2019_EN.pdf

https://www.avfallsverige.se/fileadmin/user_upload/Publikationer/Avfallshantering_2018_EN.pdf

http://sajms.com/wp-content/uploads/2015/01/Sustainable-Solid-Waste-Management-Best-Global-Practices1.pdf

8.4 Experience from Indore, India

Indore - City Profile: Indore the commercial capital of Madhya Pradesh is located 200 kms west of Bhopal, the state capital of Madhya Pradesh. Indore city has a population of 1,964,086 as per the 2011 census. Textile industry is an important industry in the city as there are a number of textile mills around the city. The city has also seen the rise of companies in the IT domain in the recent past. The city is well connected by rail, road and air and has several religious as well as tourist spots.

Introduction: Indore has been adjudged as the cleanest city in India consecutively for four years by the Ministry of urban development. To accomplish this feat Indore Municipal Corporation (IMC) has ensured that efficient long-term plans, and not quick fixes were adopted to address the city's SWM problems. The IMC, which governs 85 wards and a population of ~27 lakh people, implemented a series of carrot-and-stick measures that has led to the position the city finds itself in now. Since 2016, IMC has eliminated garbage dumps in the city, ensured 100% waste segregation, strived for zero landfill and converted waste to usable products such as compost and fuel. It partnered with NGOs, to run awareness campaigns, contracted private companies to run some SWM operations, used technology and improved municipal capacity to ensure implementation of its waste management plan. Some features of the SWM value chain and the best practices followed by IMC in the SWM domain are stipulated below. [16]

Sweeping and cleaning work: Every night, 800 km of main and wider roads are swept by machines, footpaths and road dividers are washed with water mist, using 400 liters of water every night, most of it being recycled water from the three sewage plants set up by IMC. Internal roads that make up for the rest of the 2,200 km are swept by 8,500 sweepers, deployed by IMC and waste is collected in gunny bags, and transported by vans to the waste processing facility. Sweeping in residential areas is done once a day whereas sweeping in commercial areas is one thrice a day. The sweepers are managed by sanitary inspectors and health officers, whereas monitoring and coordination is done by the control room team, online. In the first six months of road cleaning between 20,000 and 30,000 metric tonnes of dust was cleared.

Solid waste segregation: In 2016, when IMC started by collecting waste every day from households, it asked residents to provide segregated waste. At that time almost 80% of households did not used to segregate their waste, for which the sanitation and SWM supervisors were notified and such households were fined. Households just wanted the municipality to solve their problems, but did not want to do their bit by providing segregated waste. The IMC at this time started a helpline, for problems of residents (related to SWM) to be resolved within 48 hours thus building a trust between the IMC and the residents. By now, 95-100% households provide segregated waste such as kitchen waste (wet), dry waste and hazardous waste.

Solid waste collection: Indore city consists of 85 wards that have been grouped into 20 zones. Waste collection is done door-to-door by IMC from all commercial areas, households and localities including slum areas and illegal colonies at the cost of INR 60-150 (EUR 0.7 -1.8) per month for residential users and INR 100-180 (EUR 1.2 – 2.2) per month for commercial units (as of 2018). 470 specifically designed vehicles (in addition to other vehicles already present) have been procured to collect waste from all the 85 wards (100% wards coverage) and transport the same to 10 transfer stations. Each vehicle driver is assigned a collection area and a route map. Each household divides the waste in three parts, viz. kitchen waste (wet waste), dry waste and hazardous waste, and all the three types of wastes are deposited into separate compartments in the vehicle as well. The vehicle helper ensures that house owners drop the waste in right compartments. While hazardous waste is mechanically picked up in a capsule and is transported to the incinerator for burning, dry and wet waste are also picked up in separate capsules and are transported to waste handling plants and

[16] https://scroll.in/article/939210/how-indore-became-indias-cleanest-city-and-how-others-can-follow

https://www.indiaspend.com/how-indore-became-indias-cleanest-city-and-how-others-can-follow/

https://www.financialexpress.com/infrastructure/how-indore-became-the-cleanest-city-of-india-2/1876831/

composting plants respectively, outside the city limits. In 2017-18 IMC collected INR 27 crore (EUR3.3 million) as user fees for solid waste collection. Some other best practices followed by IMC in managing solid waste are stipulated below.

- Removal of dustbins: 1,400 dustbins around the city have been removed, as residents used to put their garbage in plastic bags and used to throw it in and around public dustbins, often not taking the effort of getting out of their cars and just chucking the garbage in the direction of the bin from the car window, It created more mess at prime locations resulting in filthy smell around the city. Removal of these bins is proof that efficient door-to-door collection is happening. These bins have been replaced by smaller litter bins for pedestrian use.

- Decentralized solid waste management: An organic waste collection center lies inside a triangle at the end of Chappan Dukaan, a street famous for its small eateries and food market. All food outlets at this street separate food waste and carry it to a small garden inside a triangle at the end of the street. At night an NGO team called Swaha, managing the composting, weighs the trash and prepares it for initial composting inside a mobile van, after which the compressed waste is sent for further processing at another center.

- Tracking garbage vans: IMC has set up a command center that tracks the routes of garbage vans around the city using GPS based vehicle tracking and monitoring system (VTMS), tracks the stops these vans make and also provides assistance in times of breakdown. The web based VTMS system uses data feed for real time route adherence of garbage vans.[17]

- Rewards and punishments: The IMC has ensured that its own employees and officials adopt the programme for SWM suspending officials who were not working adequately in supervising solid waste segregation and collection, while rewarding those who worked well.

- Behavior of residents: For the waste collection exercise to be successful, IMC tried to understand the behavioral traits of its residents. For example, residents of one locality do not wake up before 10 am or 11 am and so the collection vans go to such localities only in the afternoon for waste collection.

- Information campaigns: IMC has conducted information campaigns, roping in religious leaders for giving sermons on the importance of cleanliness as mentioned in religious texts, though schools and cleanliness competitions and oath taking ceremonies for children pledging a zero waste city.

- Zero dumping of solid waste in vacant plots: The sanitary workers of IMC ensure no dumping of solid waste in vacant plots, other convenient corners and other open garbage spots in residential areas, rich colonies, upmarket areas and alongside roads. About 850 such open spots have been removed.

- Residents are sensitized about SWM: Sarafa, a popular hangout place and a street food heaven in Indore, which used to be littered with trash and infested with flies earlier is now very clean and street food hawkers point you to the bin even before they collect payment. Failure to keep their surroundings clean would result in losing their spots and livelihood as well.

[17] https://india.smartcitiescouncil.com/article/indore-deploys-vtms-tracks-waste-real-time

Figure 13: One of the 10 transfer stations in Indore

Source: https://scroll.in/article/939210/how-indore-became-indias-cleanest-city-and-how-others-can-follow

Solid waste treatment and processing: The collected waste is taken to 10 transfer stations across the city, where IMC staff ensures the waste is weighed, properly segregated. From these transfer stations, the waste is then transported to the waste processing facility. At the central waste processing facility (which was previously a landfill site), 645 tonnes of recyclable waste is sifted through, daily, and separated by 300 workers. Two NGOs Sarthak and Basix, (collaborated with by IMC) have further integrated the informal sector to sort the waste. The recyclable waste thus segregated is sold to either the recycling industry or to companies that use recycled material.

- Conversion of landfill site to garden: Indore's landfill site was its biggest dumping ground. Indore has converted its landfill site into a garden (planted with trees) and a central waste processing facility. Indore strives to become a zero landfill and garbage free city for which the landfill site has been converted into a central waste processing facility. At this facility dry waste is segregated and sent to different industries for various uses and wet waste is treated to generate revenue generating products using eco-friendly technologies. These processing facilities have cleared the legacy waste at this landfill site, thus converting it into a garden.
- Solid waste handling plants (Dry waste): There are two dry waste handling plants in the city capable of handling 300 TPD of solid waste. The first plant is fully automatic, is installed and maintained by an outsourced agency, and segregates waste into 12 categories, coverts them into bales which are sent to different industries for various uses .For example the non-recyclable waste is sent to a cement plant at Neemuch and to M. P. Rural Road Development Corporation to be used in road construction. The second waste handling plant is operated by IMC on similar lines, except that segregation is done manually.
- Composting plant: As much as 550 tonnes of organic waste is produced daily. The composting plant converts wet and organic waste into manure which is purchased by landscapers and neighboring farmers at INR 2/kg. Sometimes it is given off free of charge to farmers as farmers agree to transport the compost at their own cost.
- Construction waste processing facility: Construction waste is sent to a separate privately-operated facility, where it is ground to different sizes, and then used as raw material for making bricks, paved tiles and material to edge footpaths, procured by the government for its NREGA and other public works programmes
- Mobile composting vans: As discussed above the food waste generated in the Chappan Dukaan area of Indore is collected by food outlet owners in a small garden in a triangle located at the end of the street and

the waste is then composted daily in mobile vans, by Swaha (NGO) workers thus processing the waste near the source of waste collection.

Figure 14: Mobile composting van at Indore

Source: https://www.indiaspend.com/how-indore-became-indias-cleanest-city-and-how-others-can-follow/

- Biomethanation plant: IMC has also installed a biomethanation plant opposite the vegetable, fruit and flower market. This plant of 20 tonnes capacity converts organic waste to methane is operated by Mahindra Waste to Energy Solutions limited for a 15 year contract period. About 20 tonnes of waste is collected daily and is converted into 750-800 kg of bio compressed natural gas (bio-CNG) which is used to run city buses and sold as cooking fuel for hotels and IIM Indore at subsidized rates.

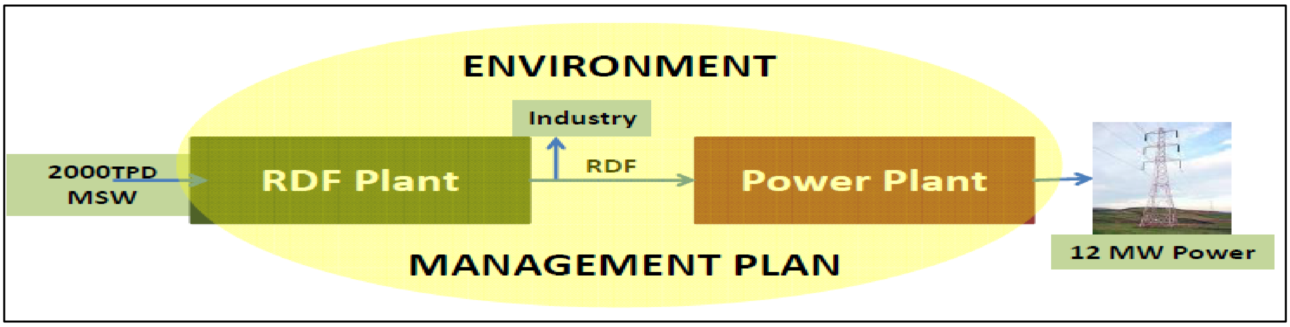
Conclusion: Indore has been adjusted as the cleanest city in India for four consecutive years. The city has attained this feat through a collaborative and innovative approach. The municipal corporation has been instrumental in bringing together the various stakeholders in the city, conducting awareness programs and adopting an integrated approach to solving the city's waste management puzzle. The city has showcased that user charges can be collected from citizens if efficient waste management systems are put in place by the ULBs.

8.5 Experience from New Delhi, India

New Delhi – City Profile: New Delhi is the national capital of India. New Delhi Municipal Council (NDMC) is one of the three statutory urban regions within Delhi and is spread over an area of 42.74 km^2. The population of the New Delhi municipal area is 133,713 as per the census of 2011. New Delhi is a major commercial hub and houses the Parliament, Supreme Court and Diplomatic missions of all major countries. The airport in New Delhi is one of the busiest airports in the country, the city has India's largest bus transport system which are operated using compressed natural gas. Delhi was the country's first city to introduce the metro rail – a modern public transport system.

12 MW Waste to Energy (WtE) facility: The 12 MW WtE plant at Ghazipur is a public private partnership (PPP) project of the Delhi government for scientific management of solid waste. The plant was commissioned by the East Delhi Municipal Corporation (EDMC) and setup by IL&FS Environmental Infrastructure & Services Limited (IEISL), a wholly owned subsidiary of IL&FS, which has made all the investment for the execution of the project. The plant at Ghazipur processes 2,000 tons of waste on a daily basis and generates 127 tons of Refuse derived fuel (RDF - RDF plant) and 12 MW of power at the power plant, as depicted in the figure below.[18]

Figure 15: WtE plant at Ghazipur, producing RDF and power



Source: *https://www.globalmethane.org/attachments/Ghazipur%20WTE%20Project.pdf*

- RDF plant: The MSW received at the RDF plant is highly heterogeneous in composition and size, has high moisture content and is mixed with soil, dust and road sweepings. The RDF plant at Ghazipur uses a Department of Science & Technology – Technology, information, forecasting & assessment council (DST-TIFAC) recommended pre-processing technology for pre-processing of mixed MSW in order to produce superior quality RDF and to achieve reduced pollution due to plant operations. The pre-processing technology incorporates manual sorting, mechanical sieving, shredding, drying and air classification and provides a sustained and efficient combustion, higher boiler reliability, lesser volume of ashes, reduced quantity of dioxins, good shelf life of RDF, less cost of leachate treatment, and RDF produced is free from dust and smell. The RDF produced is a low density material with moderate moisture content, high quantity of volatile matter and low carbon content. As part of abatement measures for odor control, following three steps are carried out which are a) waste is sprayed with an organic culture solution, b) waste storage area is maintained at negative pressure and c) Odor containing air is injected into the boiler.

Figure 16: RDF and power plants of the Ghazipur waste to energy plant


Dryer section of RDF plant

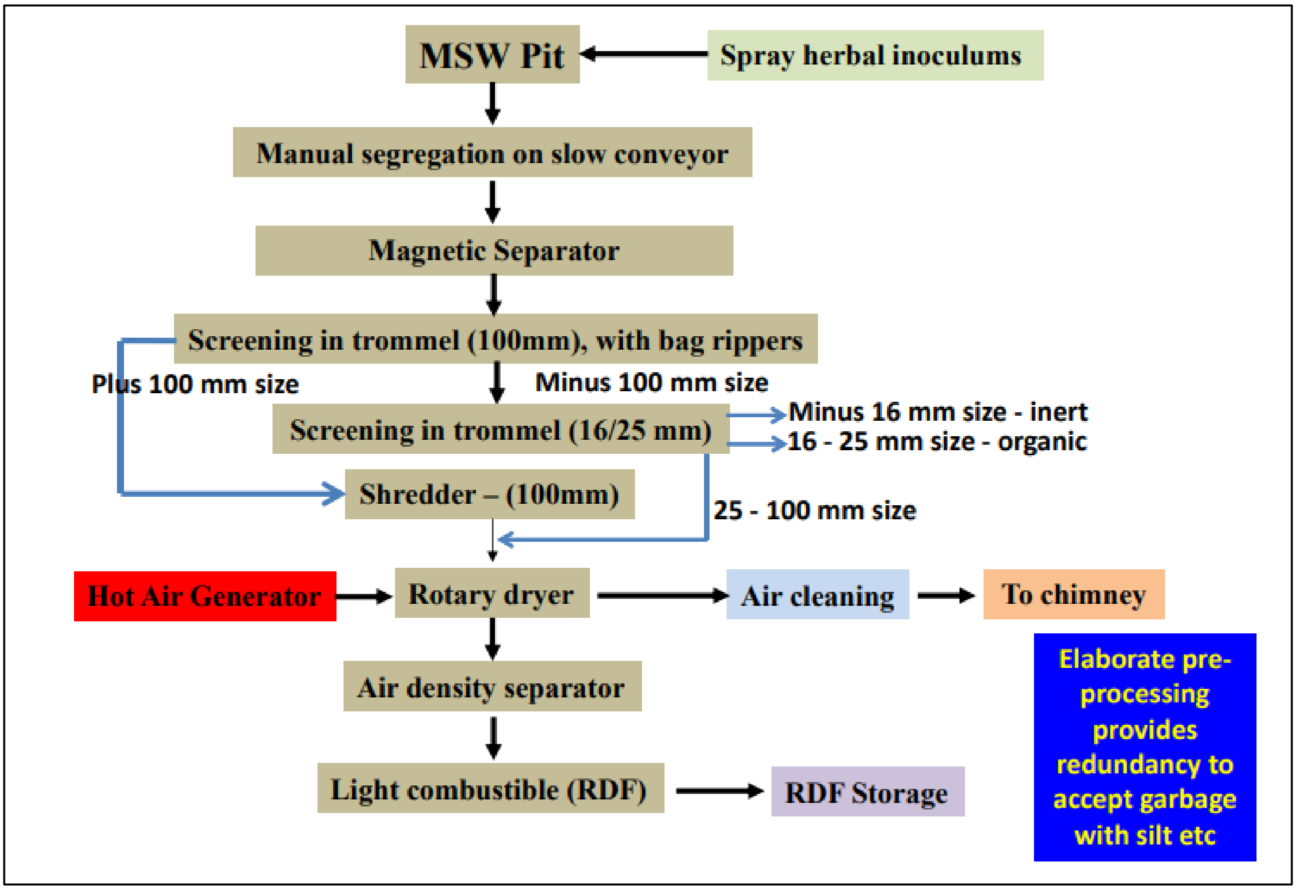

Pre-processing section of RDF plant


Power plant section

Source: https://www.globalmethane.org/attachments/Ghazipur%20WTE%20Project.pdf

[18] *https://www.globalmethane.org/attachments/Ghazipur%20WTE%20Project.pdf*
https://www.waste.ccacoalition.org/sites/default/files/files/trip_report_-_ccac_city_exchange_johannesburg_delhi_final_0.pdf
http://www.derc.gov.in/ordersPetitions/orders/Misc/2018/Petition%20no.%2027.2018%20-%2002.11.2018.pdf

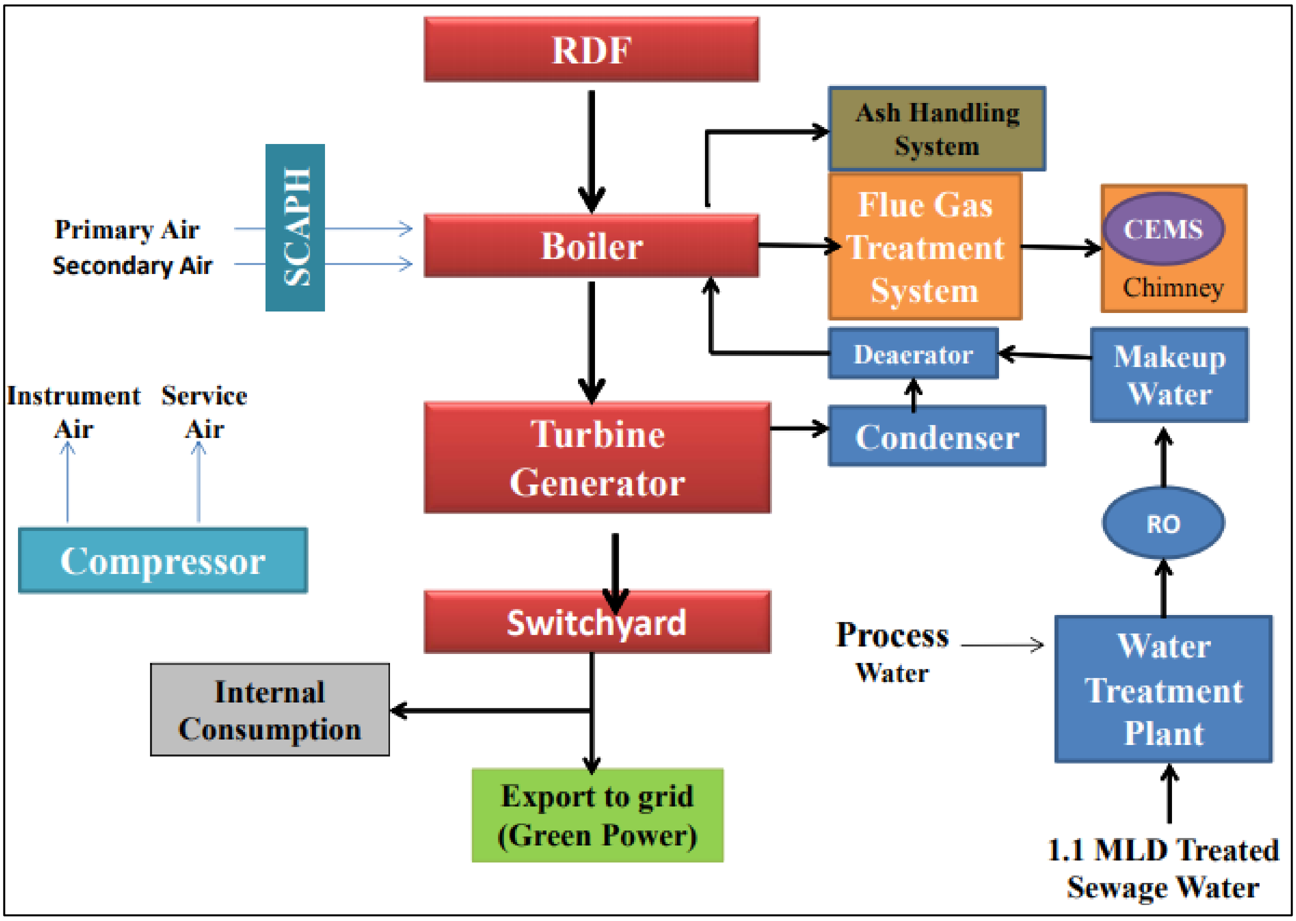
Figure 17: RDF plant process flow at Ghazipur, New Delhi



Source: https://www.globalmethane.org/attachments/Ghazipur%20WTE%20Project.pdf

- Power plant: The power plant has adopted some global technologies such as a) Basic engineering and boiler technology from Kepper Seghers, Belgium which is World leader in WtE plants with more than 100 operational plants worldwide, b) Tailor made, reciprocating, moving and tumbling Grate designed for higher combustion efficiency of RDF and low pollution emission, c) The plant uses triple pass boiler for complete combustion and progressive removal of SPM to reduce toxic emissions, d) There is a design provision in the boiler to have more than a 2 second retention of flue gases at 850 degree Celsius plus temperature to disintegrate dioxins and furans and e) The plant uses a flue gas treatment system, (to treat SPM, NOx, SOx, heavy metals, toxic gases, dioxins and furans) compliant with Euro Norms by Keppel Seghers, Belgium.

Figure 18: Power plant process flow at Ghazipur, New Delhi



Source: https://www.globalmethane.org/attachments/Ghazipur%20WTE%20Project.pdf

- Benefits of the WtE Plant: The government has signed a power purchase agreement with BSES Yamuna Power Limited (BYPL) to purchase 49% of exportable power. The electricity generated in this unit is supplied to East Delhi area. The remaining 51% of the power is free to be captively consumed/ sold/ traded using open access, by the East Delhi Waste Processing Company (EDMC). Since its operation, the plant has generated 13.6 million kWh of power and processed 244,000 tons of waste, up till 2017. Over a period of 25 years, the plant is estimated to mitigate the production of ~8.2 million tons of GHG emissions, which is the equivalent of removing all cars from the roads of Delhi for 100 days. The plant is India's first WtE plant, compliant with Euro norms, for emission along with highest standards of pollution control measures and will help in saving 260 acres of urban land by preventing landfill.

Challenges in operations of the WtE plant: The WtE plant at Ghazipur is taking more waste than stipulated every month for processing. However, of the waste that goes to the plant, 20% is said to be rejected. Additionally the waste dumped at the neighboring Ghazipur landfill site has risen into a 100 feet mountain of trash resulting in a putrid smell and nuisance for neighboring residents. Excess waste is not being treated at the WtE plant which has resulted into a massive garbage dump at the Ghazipur landfill site, signifying challenges in operations of the WtE plant. Additionally a major fire broke out at the Ghazipur landfill in 2017.[19]

Conclusion: New Delhi has adopted the PPP approach to setup a waste to energy facility in the city. The city has been facing an uphill task in waste management and the WtE plant is the step in the right direction. The plant utilizes state of the art global technologies from European companies. The plant however is facing challenges pertaining to capacity which requires augmentation at the earliest.

[19] *https://www.thehindu.com/news/cities/Delhi/probe-irregularities-at-ghazipur-wte-plant/article24525035.ece*

8.6 Experience from Hyderabad, India

Hyderabad – City Profile: Hyderabad is the capital city of the state of Telangana, the city has a population of 6,731,790 as per the 2011 census. The city is the fourth most populous city in the country. Hyderabad is dominated by the service industry being a hub for IT and financial services companies. The city is also known as the City of Pearls due to its role in trading of pearls. Hyderabad is home to 13 universities and several other educational institutions making it a hub for skilled workforce.

Integrated SWM at Hyderabad: The Greater Hyderabad Municipal Corporation (GHMC) green flagged an integrated municipal SWM project under the JNNURM through a PPP model. Ramko Enviro Engineers Ltd (REEL) were shortlisted to execute the project, and an agreement was signed between REEL and GHMC in February 2009. A special purpose vehicle named Hyderabad Integrated MSW Ltd (HIMSW) was setup for the implementation and operations of the project.[20]

Responsibilities of private player: The project entails the following activities to be undertaken by the private player: a) Infrastructure development or upgradation, operation, maintenance, and management of the plant as per the operational requirement, b) Primary and secondary collection of MSW and transportation of this waste to transfer stations and subsequently to the integrated waste management facility, c) Processing the solid waste as per the stipulated waste disposal rules and disposal of residual matter post processing at the landfill site. Recycling and reuse of the waste also needs to be done, d) Reclamation and alternative use of existing dump sites at Jawaharnagar, Fathullaguda, Shamshiguda, and Gandhamguda, e) Information, Education and Communication activities for public as well as other stakeholders to develop good MSW practices, f) Interface with existing organized and unorganized waste collection and management systems to ensure smooth functioning of the system. HIMSW Ltd is currently involved in two broad activities – a) Collection and transfer and b) Processing and disposal.

Collection & transportation of waste: The collection and transfer activities involve door-to-door collection of waste via tricycles and mechanized mini hoppers. The waste is then transferred to the closest transfer bin. It is ensured that the waste from commercial units is transferred through separate vehicles and to separate bins. All the collection and transfer activities adhere to a pre decided schedule to ensure maximum efficiency and coverage. Secondary waste is collected through a network of mechanised, rear loading haulers based on the size of the roads, maneuverability at the location and the amount of waste generated. These vehicles are earmarked for specific areas / regions and follow the specified route charts. The waste collection for critical areas is scheduled at the night to avoid traffic congestions and public inconvenience. Further, the operator ensures deployment of additional vehicles and manpower during festival days. The waste collectors are trained to collect the waste at sites and to ensure disinfection of the site post collection. The waste collected from the primary and secondary activities is then transferred to the treatment facility using hydraulic compacted bins. In case of non-availability of the bins, tippers with appropriate covering are deployed for waste transportation.

Waste treatment facility: The treatment and processing facility has several components such as a) Waste reception area, b) Tipping floor / pre-sorting facility, c) Windrow platform, d) Monsoon shed, e) Curing shed, f) Storing and packing facility, g) Recycling shed, h) Leachate management system, i) Leachate treatment plant, and j) Landfill. The company has projects such as RDF facility, WtE plant, and a training school for providing MSW training. The waste material received at the treatment facility is initially weighed at the waste reception area, the vehicle number, driver name and the payload is recorded in the MIS portal of the plant. The waste is then transferred to the tipping floor where it sorted as per the size of the waste. The smaller waste particles are transferred to the windrow platform while the larger ones are sent to the RDF bunker. At the windrow platform, the waste is composted for a period of one month with the help of effective microorganism culture. The waste here undergoes continuous turning with the help of cranes and is segregated as per different maturation levels. The waste is further refined by passing it through smaller screens for further separation. At

[20] www.himsw.in

the end of this, the smaller particles are transferred to the curing shed while the larger particles are either sent to the landfill or the RDF bunker. The processed material is then spread out to cure at the curing shed. The waste undergoes further screening at the curing shed and the composted material which is now of a finer texture is packaged as bio fertilizer at the storing and packing facility.

Treatment of plastic waste: The waste segregation at the plant also yields plastic waste which is treated through the plastic granulation process at the recycling shed of the plant. The integrated waste management at the plan has led to a considerable improvement in the leachate management system. The leachate treatment facility at the plant treats the leachate into a usable form of water. The effective waste management at the plant has also led to considerable reduction in the waste being transferred to the landfill site at Jawaharnagar.

Conclusion: The city of Hyderabad is implementing an integrated SWM approach through the PPP model. The SPV for the project is responsible for collection of waste, transportation of waste and treatment of the waste. The city follows innovative practices such as waste collection in congested areas at night, deployment of additional manpower during festivals, active waste monitoring system etc. The SWM project in the future also aims at training manpower to be employed in the SWM domain.

8.7 Key learnings

The key learnings from the analysis of case studies are as follows.

Key comparative points for the case studies evaluated: The six case studies showcased in the section above highlight two major categories – Integrated waste management and Waste to Energy conversion. The cities analysed have implemented innovative approaches to tackle the solid waste management issue. The following table presents a comparative analysis of the four case studies presented in the previous section:

Table 10: Comparison of case studies

City	Approach	Innovative practices
Vilnius	Integrated waste management	Dedicated company to handle SWM lifecycle Underground waste bins Deposit recycling facility Co-generation plant
Leeds	Waste to Energy	Highly efficient combustion process
Stockholm	Integrated waste management	Underground vacuum collection systems Green IT 99% of household waste is recycled
New Delhi	Waste to Energy	RDF plant utilizing state of art European technology
Hyderabad	Integrated waste management	Active waste tracking system Treatment of plastic waste End to end waste treatment facility
Indore	Integrated waste management	Waste segregation User charge collection

City	Approach	Innovative practices
		100% waste collection Decentralized waste management etc.

Formation of dedicated companies: Separate companies, each handling a separate functionality in the city, can be formed. These companies could have their own independent CEOs, supported by a team of experts and dedicated individuals focused on the roles assigned to them. For example, Kochi can look at setting up of a dedicated company which will be wholly owned by the Kochi municipal corporation and shall be responsible for the entire municipal waste management lifecycle. The setup of an independent organization will reduce the burden of waste management from KMC and also enable the organization to employ waste management experts who are well equipped at tackling the specific waste management challenges faced by Kochi.

Sensitization of stakeholders: Information, Education and Communication (IEC) activities such as training schools for providing MSW training, for the public as well as other stakeholders are important to develop good MSW practices and to sensitize them to mitigate harmful effects of SWM activities on environment and climate. Additionally information campaigns could be conducted, roping in religious leaders for giving sermons on the importance of cleanliness, through schools and cleanliness competitions and oath taking ceremonies for children pledging a clean city.

Solid waste segregation: Solid waste should be segregated at source itself and households should be asked to provide segregated waste in different categories such as dry waste, wet waste and hazardous waste. The households not following segregation of waste need to be reported to SWM supervisors and inspectors and such households need to be fined accordingly. Strict measures need to be adopted to ensure 100% waste segregation.

Solid waste collection and transportation: Some key learnings, best practices and efficient processes in solid waste collection and transportation, as derived from national and international experiences are highlighted below.

- Tendering procedure: A formal mechanism could be setup wherein a private player could be given an annual contract (through tendering procedure) for waste collection, transportation and disposal (integrated SWM) and a user fee is levied on waste generators for such collection.

- Behavioral trait of residents: For the waste collection exercise to be successful, municipalities need to understand the behavioral traits of its residents. For example, in localities whose residents wake up late in the morning, the waste collection vehicles can go to such localities late in the afternoon, for waste collection.

- Rewards and benefits: Municipalities to ensure that their own employees and officials adopt efficient SWM practices suspending officials who do not work adequately in supervising solid waste segregation and collection, while rewarding those who work well. Similarly strict fines should be levied on residents not practicing waste segregation and not cooperating in waste collection.

- Efficiency in waste collection and transfer: All collection and transfer activities could adhere to a pre-decided schedule to ensure maximum efficiency and coverage. Waste collection for critical areas could be scheduled at night to avoid traffic congestion and public inconvenience. Waste could be collected through vehicles, such as rear loading haulers, keeping in mind size of the roads, maneuverability needed at the location, and amount of waste generated.

- Deposit recycling system: A deposit recycling system as implemented in Vilnius, is very effective in combating litter rates and increasing waste collection and recycling rates, wherein recyclable/reusable material and packaging is returned back to the point of sale or reverse vending machines, in exchange for a refund (incentive) that is deposited by the consumer while purchasing the material.

- Efficient monitoring: A system should be set up to track the route of waste collection vehicles around the city using GPS based vehicle tracking and monitoring system, to track the stops these vans make and to provide assistance in times of breakdown. Advanced forms of technology could be utilized, such as drones, for assessing waste collection activities, for monitoring the landfill sites and also for maintenance of urban drainage networks and supervision for road cleaning. Additionally top officials such as municipal commissioners, should monitor the waste management activities regularly.

Solid waste disposal, treatment and processing: Some key learnings, best practices and efficient processes in solid waste disposal, treatment and processing, from national and international experiences are highlighted below.

- Decentralized processing: Maximum waste should be treated through decentralized processing, with the bio-degradable fraction of waste treated at source level, i.e., households, institutional and community level, through composting and bio methanation, in order to minimize transportation cost, landfill, and environmental costs.

- Zero landfill: Cities should strive to achieve zero landfill with complete conversion of waste into usable products. While dry waste should be segregated and sent to different industries for various uses, wet waste could be treated to produce revenue generating products such as compost and fuel. The landfill site could then be planted with trees and converted into a garden.

- Odor control measures: As part of odor control measures, a) waste could be sprayed with an organic culture solution, b) waste storage area could be maintained at negative pressure, and c) odor containing air could be injected into the boiler in case of a WtE plant.

- Mechanical biological treatment plant: A mechanical biological treatment plant is effective for re-sorting of mixed waste and for biological treatment of waste, and prepares RDF for a WtE plant and high calorific value SRF for the cement industry. It is cost effective, reduces landfill and GHG emissions, and could be implemented for waste treatment.

- Waste to energy plant: A WtE plant produces heat and electricity which could be supplied to a number of households in the city, results in substantial reduction of landfill, reduced GHG emissions from traditional waste treatment facilities, and substantial reduction in emission of carbon dioxide from landfill sites.

- Biomethanation plant: A biomethanation plant could be installed near vegetable, fruit and flower markets to convert waste into bio compressed natural gas (bio-CNG) which can be then used to run city buses and sold as cooking fuel for hotels at subsidized rates.

9 Key challenges and solutions

This chapter provides potential challenges detrimental to the solid waste value chain in Kochi, including the processes of solid waste collection, transportation, disposal and processing/treatment. The chapter also provides possible solutions to such challenges.

9.1 Key challenges

Waste composition: The MSW generated in Kochi possesses several technical and practical challenges when converting it to fuel (RDF) to produce an effective energy generation source. The waste has high moisture content of 60%, which goes up to 75% during monsoons. The waste has seasonal variations in waste profile and has very high volume of biodegradable food waste whereas plastics and other high calorific value waste are in relatively low quantities. This makes the handling and processing of this kind of waste very difficult, wherein the production of RDF is challenging.

Low waste collection rate: Of the 305 TPD of MSW generated in 21 circles in Kochi (comprising of one to five wards each), 230 TPD of waste is collected for processing and disposal at the landfill site resulting in a current waste collection rate of just 75%. Of the 230 TPD of MSW collected, 130 TPD is processed while 100 TPD is disposed of at the landfill site.

Pollution of drains and canals: The canals, considered as the lifeline of Kochi, are currently highly polluted and in a bad shape due to dumping of large amounts of the uncollected waste in Kochi. The waste dumping leads to accumulation of solid waste and blockage in drains and canals, which in turn, leads to the problem of urban flooding.

No revenue from SWM activities: KMC does not charge any user fee for waste collection but KMC and Kudumbashree workers responsible for waste collection charge INR 50-100 (EUR 0.6 - 1.2) from each household for the same. This fee is paid directly by the households to the waste collectors and does not provide any source of revenue for KMC. Although KMC does not generate any revenue from SWM activities but expenses, such as salaries, program expenditures etc, pertaining to SWM related activities are borne by the organization.

Unscientific management of landfill site: The disposal site at Brahmapuram is not a scientific landfill. The waste dump at the site is a major pollution contributor as there are no controls or processing systems in place so that contaminates and leachates are able to flow freely off the site into surrounding water bodies such that the ground water table is polluted and impacts quality of land and people, in and around the existing waste dump. Odors emanating from the site is another nuisance for development of the Smart City project and other infrastructure development. The Brahmapuram landfill has not been functioning scientifically due to improper management. Additionally, as per the EIA/EMP assessment report, over 136 unauthorized locations in Kochi and adjoining areas are used for illegal dumping of waste which is another nuisance in the city.

Menace at the plastic dumping yard: The plastic dumping yard at Brahmapuram receives ~100 tonnes of plastic waste each day. Around 1% of this plastic waste is suitable for recycling, and is recovered from the waste, the remaining 99% of waste is dumped as a heap at the landfill. The plastic dump is a menace for the municipal corporation, and has seen several fires over the past few years. The accumulated waste has reached the volume of 180,000 m^3, weighs ~68,400 tonnes and is spread over 16 acres of land.

Low capacity and poor state of the windrow composting plant: The existing windrow composting plant is not able to process all the waste received and the site has become a dump site. The waste dump is a major pollution contributor and odors emanating from the site are a big nuisance for the development of the Smart City project and other infrastructure development. Additionally, the plant operated optimally till the first year of its operation but by the nature of being constructed on a wet land, the plants platform sunk and a few columns collapsed. All the windrow sheds are in a dilapidated condition and the drains provided are blocked with hard slurry flowing from the compost plant. The reconstruction of the plant has not yet been commissioned due to the high proposed cost.

Quality of compost produced at windrow composting plant: As per tests conducted by the State Pollution Control Board, the compost produced at the Brahmapuram facility in Kochi has the presence of heavy metals in excessive concentration. The board found that the quantity of manure produced out of the biodegradable waste dumped at the site was far less compared with the daily waste collected at the facility. The manure, when tested for its fertilizer value, did not meet standards stipulated under the Solid Waste Management Rules, 2016.

GHG emissions: MSW comprises of biodegradable organic matter, partially degradable matter and non-degradable materials. Windrow composting of organic waste present in MSW releases greenhouse gases whereas direct disposal of solid waste in disposal sites/landfills also emit methane (CH_4) and other GHGs, thus polluting the environment.

Increased precipitation and flooding in Kochi*:* High rainfall in Kochi coupled with clogged drains and canals due to inadequate SWM and lack of cleaning leads to flooding in the city which results in accumulation of tons of waste, making it difficult for solid waste collectors to collect such huge quantities of waste. The impact of rainfall and flooding on landfills are inundation, waste solution migration to neighboring areas, and physical erosion. Excessive precipitation and flooding have harmful effects for land treatment areas, waste pile, and waste storage containers as well.

9.2 Possible solutions

Pre-heating and pre-processing waste in WtE plants: MSW generated in Kochi should be handled and processed carefully in the WtE plants. Waste must be carefully pre-heated and pre-processed, else unprocessed MSW would have low combustion efficiency – due to high inert and organic content, larger flue gas volume – due to high moisture content, larger volume of ash, large volume of dust in boilers, and frequent breakdowns due to corrosive nature. It would also require extra amounts of supplementary fuel due to low calorific value of MSW. A pre-heating and pre-processing technology would produce superior quality RDF, which in turn is used for producing power, and to achieve reduced pollution due to plant operations.

Increase in waste collection rate: The waste collection rates to be increased from the current 75% to 95-100% in phases i.e. 95% in the first few years and then increasing it gradually to 100% in further years. For this KMC could increase the coverage for waste collection and could also implement a policy, levying appropriate fines on waste generators illegally burning/burying their waste in unscientific manner or disposing it off in drains and canals leading to the problem of clogging and urban flooding. Strict policies should be implemented to prevent waste generators and collectors from dumping waste at 136 illegal dump sites in Kochi.

Cleaning of drains and canals: Drains and canals should be cleaned regularly so as to prevent their clogging and to prevent the problem of urban flooding in Kochi. The solid waste dumped in such canals and drains leads to blockage and accumulations of tons of waste making it difficult for waste collectors to collect waste. Thus this type of solid waste should be removed from drains and canals on a regular basis.

Revenue from SWM activities: As per the Kerala State Waste Management Policy 2018 waste generators must pay a user fee for SWM as specified in the by-laws of the local bodies. Therefore KMC could formalize the user charges for waste to be collected from waste generators such as households, commercial units, industries, institutes, hospitals etc., and include the same in the bye-laws.

Scientific management of landfill site: The landfill site at Brahmapuram should be upgraded so that it is able to function in a scientific manner with complete control over methane gas developed in the landfill (preventing air pollution) and limited access of vectors and flies to the waste. Adequate controls and processing systems should be in place so that leachates and contaminates are not able to flow freely into surrounding water bodies, polluting water bodies and rendering large tracts of land unusable. Additionally to combat the problem of odor, odor control measures such as waste being sprayed with an organic culture solution and waste storage area being maintained at negative pressure must be carried out.

Reconstruction of windrow composting plant: The windrow composting plant at Brahmapuram is in a dilapidated state and needs immediate refurbishment. The plant should be redeveloped to have sufficient capacity for treating the waste collected in the city. Additionally, the RDF facility at the facility should also be made operational. The refurbishment and operationalization of these facilities will help in reduction of the waste accumulation at Brahmapuram.

Setup of dedicated entity catering to SWM activities in Kochi: One key and unique learning from Vilnius is the establishment of special purpose vehicles (SPV's) for specific urban functions. Among the SPV's, the Vilnius county waste management center (VAATC) and the Vilnius waste system administrator (VASA), which were established for solid waste management activities in Vilnius are noteworthy and great examples. On similar lines Kochi can look at setting up a dedicated company (SPV) which will be wholly owned by the KMC and shall be responsible for the entire solid waste management lifecycle. The setup of an independent organization will reduce the burden of waste management from KMC and also enable the organization to employ waste management experts who are well equipped at tackling the specific waste management challenges faced by Kochi. As per the KMC's budget documents of fiscal 2020, the KMC has earmarked an amount of INR 200 lakh (EUR 0.24 million) to start an SPV in the waste management sector, on similar lines of VASA. The amount will be utilized for the incorporation of the SPV and other activities.

10 Conclusion

This chapters summarizes the need for an efficient SWM in Kochi and lists out important points as a way forward for relevant stakeholders.

Need for an efficient SWM system: Currently only 75% of waste generated is being collected for treatment and disposal at Brahmapuram, the remaining being dumped in canals and drains. While KMC does not generate any revenue from SWM activities but expenses pertaining to SWM activities are borne by the organization. Additionally the Brahmapuram facility is not functioning scientifically (including the windrow composting plant, RDF facility, and the dumping yard) due to improper management. Thus, there is an imminent need for upgrading and streamlining the SWM value chain in Kochi as stipulated below

- Increase in waste collection rates: The waste collection rate in Kochi needs to be increased from the current 75% to 95-100% in phases, by preventing waste generators from illegally burning/burying their waste or dumping it in drains and canals and increasing coverage of waste collection.

- Revenue from SWM activities: As KMC does not earn any revenue from SWM activities, it needs to formalize and levy user charges on waste generators, thus earning revenue through solid waste collection.

- Cleaning of drains and canals: Drains and canals should be cleaned regularly and accumulated solid waste be removed to prevent their clogging and to prevent the problem of urban flooding in Kochi.

- Efficient transportation: The waste transportation vehicles in the city need to adhere to specified transportation route charts, and need to adhere to a pre-decided transportation schedule. Additionally care should be taken to ensure that transportation vehicles do not create congestion and traffic problems in the city. Also a system should be set up to track the route of transportation vehicles around the city using GPS based vehicle tracking and monitoring system, to track the stops these vehicles make and to provide assistance in times of breakdown.

- Scientific management of landfill site: The landfill site at Bharmapuram needs to be upgraded so that it is able to function scientifically with complete control over methane gas developed in the landfill (to prevent air pollution) and limited access of vectors and flies to the waste. Adequate controls and system should be in place so that leachates and contaminates are not able to flow freely thus polluting water bodies, ground water table, and land. Odor control measures should also be followed.

- Reconstruction of the windrow composting plant: The windrow composting plant at Brahmapuram should be reconstructed so as to have adequate capacity and to improve its dilapidated condition thus significantly reducing the waste dump at the landfill site. Additionally the RDF facility at Brahmapuram should also be made operational.

- Operation of a WtE plant: Large quantities of waste currently being dumped at the landfill site would be converted into electricity, by a WtE plant, thus significantly reducing landfill, pollution, GHG and CO_2 emissions. A WtE plant with a minimum capacity of processing 300 TPD of waste is proposed to be built at Brahmapuram, as per a tender floated by the KSIDC in June 2020.

- Setup of dedicated entity catering to SWM activities in Kochi: Kochi can also look at setting up of a dedicated company which will be wholly owned by the Kochi municipal corporation and shall be responsible for the entire municipal waste management lifecycle. The setup of an independent organization will reduce the burden of waste management from KMC and also enable the organization to employ waste management experts who are well equipped at tackling the specific waste management challenges faced by Kochi. KMC has earmarked a budget of INR 2 crore (EUR 0.24 million) for the incorporation and other related activities of such a company.

Next steps/way forward: Having established the need for an efficient SWM value chain in Kochi and the need to adapt and implement best practices from India and abroad, KMC should undertake a detailed feasibility study in this regard. The baseline study prepared as a part of this assignment should feed into the feasibility study. The study should cover in detail the following:

- Technical feasibility: This part of the feasibility report should cover all the technical aspects, including upgrading and streamlining the SWM value chain in Kochi. Additionally, the technical feasibility should comprise of identification and assessment of best practices and processes used for solid waste collection (for example, deposit recycling facility), transportation, disposal, and processing/treatment, along with an estimation of feasibility and costs related with each new process or best practice thus added to the value chain. For the SWM value chain, the input and output specifications, performance standards, social and environmental assessment, and risk assessment would also need to be conducted.

- Financial feasibility: The feasibility study should cover in detail the user charges that could be formalized and levied on different waste generators such as households, institutions, industries, commercial units and hospitals, thus earning revenue for KMC. It should also undertake a detailed financial assessment of streamlining the SWM value chain, covering a detailed estimation of capital expenditure, operational expenditure and revenue, sensitivity analysis, and value for money analysis.

- Project structure: The study should cover the feasibility of appointing a private player for integrated waste management, for upgrading and streamlining the entire SWM value chain in Kochi. This would include roles and responsibilities of various stakeholders, particularly that of the private developer and the implementing agencies, mode of contracting such as PPP or EPC, mode of payment, and contract duration.

- Bid-process management: The feasibility study should also provide details regarding the next steps in project preparation and execution, i.e., bid process management. This part should explain in detail the number of stages that will be employed for the procurement process, bidding parameters including technical and financial parameters, appointment of transaction advisors, formation of data rooms, and customization of bidding documents.

- Workshop by Vilnius: Selected experts from Vilnius would deliver a workshop cum training to the SWM department of KMC. The workshop is planned to happen in the later part of the year and will focus on transfer of best practices from Vilnius to Kochi.

11 References

The chapter lists the documents provided by C-HED, and links to various news articles, publications, policy documents, research papers, company reports, and case studies that were referred to during the preparation of this study.

Table 11: Table of references

Date	Title	Author	Link
Case Studies			
-	Hyderabad Integrated Municipal solid waste management	-	www.himsw.in
October 2, 2019	How Indore Became India's Cleanest City (And How Others Can Follow)	Shreya Khaitan	https://www.indiaspend.com/how-indore-became-indias-cleanest-city-and-how-others-can-follow/
February 24, 2020	How Indore became the cleanest city of India	-	https://www.financialexpress.com/infrastructure/how-indore-became-the-cleanest-city-of-india-2/1876831/
July 25, 2017	Indore deploys VTMS; tracks waste real time	-	https://india.smartcitiescouncil.com/article/indore-deploys-vtms-tracks-waste-real-time
-	12 MW Waste to Energy Project (Ghazipur, Delhi)	IL&FS Environment	https://www.globalmethane.org/attachments/Ghazipur%20WTE%20Project.pdf
-	Climate and Clean Air Coalition (CCAC) MSW Initiative, Trip report	Aditi Ramola and Amrita Sinha	https://www.waste.ccacoalition.org/sites/default/files/files/trip_report_-_ccac_city_exchange_johannesburg_delhi_final_0.pdf
October 25, 2018	Petition filing	-	http://www.derc.gov.in/ordersPetitions/orders/Misc/2018/Petition%20no.%2027.2018%20-%2002.11.2018.pdf
July 27, 2018	Probe irregularities at Ghazipur WTE plant	-	https://www.thehindu.com/news/cities/Delhi/probe-irregularities-at-ghazipur-wte-plant/article24525035.ece
-	Leeds Recycling & Energy Recovery Facility (RERF) works	Veolia	https://www.veolia.co.uk/leeds/our-facility/leeds-recycling-energy-recovery-facility-rerf-works
-	Working together in partnership	Veolia	https://www.veolia.co.uk/leeds/
-	Future of Leeds' waste	-	https://www.leeds.gov.uk/residents/bins-and-recycling/your-bins/future-of-leeds-waste
-	Sustainable Solid Waste Management (Best Practices–Global Benchmarks)	Shailesh Kumar Jha	http://sajms.com/wp-content/uploads/2015/01/Sustainable-Solid-Waste-Management-Best-Global-Practices1.pdf
June 12, 2020	The Swedish recycling revolution	Dominic Hinde	https://sweden.se/nature/the-swedish-recycling-revolution/
-	Waste Management Plan for Stockholm 2017-22	-	https://www.stockholmvattenochavfall.se/globalassets/pdf1/riktlinjer/avfall/avfallsplan/sva072-avfallsplan_en.pdf

Date	Title	Author	Link
-	Swedish Waste Management 2018	-	https://www.avfallsverige.se/fileadmin/user_upload/Publikationer/SAH_2019_EN.pdf
-	Swedish Waste Management 2018	-	https://www.avfallsverige.se/fileadmin/user_upload/Publikationer/Avfallshantering_2018_EN.pdf
-	Cogeneration in Vilnius: converting waste into electricity and useful heat	-	https://ec.europa.eu/regional_policy/en/projects/lithuania/cogeneration-in-vilnius-converting-waste-into-electricity-and-useful-heat
-	Field visit report, Kochi municipal corporation to Vilnius	IUC India	-
-	Vilnius MBT plant company presentation	UAB Energesman	-
-	Grinda – Municipal enterprise presentation	Grinda	-
-	Lithuania Deposit System - *Public institution "Užstato Sistemos Administratorius"*	Viešoji įstaiga Užstato sistemos administratorius	www.grazintiverta.lt
-	Vilnius county waste management center presentation	UAB VAATC	-
-	City of Vilnius presentation	Municipal corporation, Vilnius	-
Documents provided by IUC India and C-HED Kochi			
-	Waste to Energy project presentation	GJ Eco Power Pvt Ltd	-
-	Solid Waste management system overview - Kochi	C-HED	-
-	Data pertaining to Kochi SWM	C-HED	-
Existing reports and studies			
-	Kochi city development plan	-	https://cochinmunicipalcorporation.kerala.gov.in/web/guest/development-plan
March 2014	City Sanitation Plan Updation – Status Report	ICRA Management Consulting Services Limited	-
June 2010	Kochi city sanitation plan	ICRA Management Consulting Services Limited	https://sswm.info/sites/default/files/reference_attachments/ImaCS%202010%20Status%20Report%20Kochi.pdf
July 2019	EIA/EMP Report for Kochi waste to energy project	L&T Infra Engineering	http://environmentclearance.nic.in/writereaddata/FormB/EC/EIA_EMP/05072019Y9DLPB2WConsolidatedFinalEIAKochiWtE.pdf
-	Climate Action Plan for Kochi City	GIZ	-
September 2018	Kerala State Policy on Solid Waste Management	Government of Kerala	http://sanitation.kerala.gov.in/wp-content/uploads/2018/09/go-65.2018-13.09.18-_-State-policy-on-SWM.pdf
April 8, 2016	SWM Rules, 2016	Ministry of Environment, Forest and Climate Change	http://bbmp.gov.in/documents/10180/1920333/SWM-Rules-2016.pdf/27c6b5e4-5265-4aee-bff6-451f28202cc8

Date	Title	Author	Link
2016	Municipal solid waste management manual	Ministry of Urban Development	http://mohua.gov.in/upload/uploadfiles/files/Part2.pdf
News articles and other relevant publications			
October 25, 2019	Why global warming has left Kerala vulnerable	Jeemon Jacob	https://www.indiatoday.in/india-today-insight/story/why-global-warming-has-left-kerala-vulnerable-1612792-2019-10-25
August 14, 2019	Is Climate Change Making Floods an Annual Affair in Kerala?	K.A. Shaji	https://thewire.in/environment/floods-in-kerala-experts-point-to-climate-change
-	Study on municipal waste in Kochi	-	https://www.slideshare.net/cppr123/study-on-muncipal-solid-waste-management-in-kochi
-	Implications of Sea Level Rise for Hazardous Waste Sites in Coastal Floodplains	Timothy J. Flynn, Stuart G. Walesh, James G. Titus, and Michael C. Barth	http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.391.7715&rep=rep1&type=pdf
-	Greenhouse gas emissions from windrow composting of organic wastes: Patterns and emissions factors	Sintana E Vergara and Whendee L Silver	https://iopscience.iop.org/article/10.1088/1748-9326/ab5262/pdf
March 12, 2020	Faulty windrow composting led to Brahmapuram crisis: PCB	G. Krishnakumar	https://www.thehindu.com/news/cities/Kochi/faulty-windrow-composting-led-to-brahmapuram-crisis-pcb/article31044626.ece
October 26, 2019	Brahmapuram in a state of disrepair	G. Krishnakumar	https://www.thehindu.com/news/cities/Kochi/brahmapuram-in-a-state-of-disrepair/article29803010.ece
Official websites of stakeholders and other government agencies			
https://cochinmunicipalcorporation.kerala.gov.in/			
https://www.c-hed.org/			
http://www.sanitation.kerala.gov.in			