Models of Capitalization & Promotion of Innovative Technology in Solid Waste Management

Underscoring the Role of Public Sector

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Circular Waste Solutions India NAMA

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Ministry of Environment, Forest & Climate Change

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LIST OF ABBREVIATIONS

AB-PM-JAY	Ayushman Bharat-Pradhan Mantri Jan Arogya Yojana
ADD	Acute Diarrheal Disease
AGR	Anaerobic Gas lift Reactor
AI	Artificial Intelligence
ALM	Advanced Locality Management
AMRUT	Atal Mission for Rejuvenation and Urban Transformation
BBMP	Bruhat Bengaluru Mahanagar Palike
BEMP	Best Environmental Management Practices
BSFL	Black Soldier Fly Larvae
BSWML	Bengaluru Solid Waste Management Ltd.
BWG	Bulk Waste Generators
CBSE	Central Board of Secondary Education
CCP	Corporation of the City of Panaji
DST	Department of Science & Technology
DSR	Deposit Refund Scheme
EPR	Extended Producer Responsibility
GFC	Garbage Free City
GOBARdhan	Galvanizing Organic Bio-Agro Resources Dhan
GPS	Global Positioning Systems
GWMC	Goa Waste Management Corporation
IEC	Information, Education, and Communication
IMC	Inter-Municipal Cooperation
IoT	Internet of Things
KKPKP	Kagad Kach Patra Kashtakari Panchayat
LFG	Landfill gas
MHRD	Ministry of Human Resource Development
MRFs	Material recovery facilities
MoHUA	Ministry of Housing and Urban Development
MSW	Municipal Solid Waste
NBP	National Bioenergy Programme
NDUW	National Database of Unorganised Workers
NF	Nanofiltration
NSSI	National School Sanitation Initiative
NULM	National Urban Livelihood Mission
NUSP	National Urban Sanitation Policy
ODF	Open Defecation Free
OECD	Organisation for Economic Co-operation and Development
PAYT	Pay-as-you-throw
PET	Polyethylene terephthalate
PM-JDY	Pradhan Mantri Jan Dhan Yojana

PM-JJBY	Pradhan Mantri Jeevan Jyoti Bima Yojana
PM-SYM	Pradhan Mantri Shram Yogi Maan-dhan
PM-SBY	Pradhan Mantri Suraksha Bima Yojana
PMC	Pune Municipal Corporation
RCPMP	Resource Circulation Performance Management Program
RFD	Refuse-derived fuel
R&D	Research and Development
RFID	Radio frequency identification
SAIL	Steel Authority of India
SBM (G)	Swachh Bharat Mission (Grameen)
SBM (U)	Swachh Bharat Mission (Urban)
SDGs	Sustainable Development Goals
SHGs	Self-help groups
SME	Small and medium-sized enterprises
SWM	Solid Waste Management
SWM Rules, 2016	Solid Waste Management Rules, 2016
TMC	Thiruvananthapuram Municipal Corporation
ULBs	Urban Local Bodies
UNDP	United Nations Development Programme
UN	United Nations
VBWF	Volume Based Waste Fee System
WtE	Waste-to-Energy
WtW	Waste-to-Wealth
WHO	World Health Organisation

EXECUTIVE SUMMARY

Solid Waste Management ("SWM") stands as a critical global concern, given its profound implications for the environment, public health, pollution levels, and climate change. Taking into account its far-reaching impact, nations across the globe are prioritizing development of robust waste management strategies. In response, the waste management sector is undergoing rapid expansion, marked by the swift evolution of technologies and guiding principles. This evolution is driven by a dual imperative: mitigating the adverse effects of improper waste disposal and capitlaizing on the potential of waste as a valuable resource.

As India strives to address the waste management challenges exacerbated by the growing population, rapid urbanisation, escalating consumerism, industrialisation and the consequent surge in waste production, the quest for innovative, sustainable and scalable solutions have gained importance. In this context, our comprehensive study explores the role of the public sector in managing Municipal Solid Waste ("MSW") and examines various models utilized for the monetization of waste. It delves into the approaches employed by Germany aand South Korea to understand the waste management framework employed in their respective country to materialise revenue from waste. It highlights the Pay-as-you-throw ("PAYT") system and deposit refund schemes implemented by the South Korea and Germany, as notable examples for generating revenue and enhancing the effectiveness of SWM.

The report also analyses the SWM ecosystem in Germany, and South Korea to understand the various innovative technologies adopted by them for SWM. Further, it highlights the enabling role played by the public sector through legal instruments, public procurement strategies, and research and development ("R&D") to support innovations for enhancing waste management systems. The report also takes into account the different schemes and missions undertaken by the Government of India, such as the Swachh Bharat Mission, and their impact. Additionally, it sheds light on the vital roles played by women and the informal sector in India's waste management landscape.

By extracting valuable insights from the best practices of South Korea and Germany, the report suggests a set of strategic recommendations to fortify the waste management framework in India. Some of the recommendations suggested in this report are as follows:

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- **Enhancing Waste Segregation through Stringent Regulations and Technologies:** To ensure proper segregation and sorting of waste, it is recommended that laws should be made more stringent at the state and municipality levels, mandating waste sorting. Further, modern technologies, such as smart bins should be established to facilitate proper waste disposal. Lastly, Urban local bodies ("ULBs") must be held accountable for inefficient sorting processes.
- **Advanced technologies for tracking and monitoring of waste:** India faces the challenge of managing, collecting, transporting, and monitoring of vast amounts of waste generated on a daily basis. Hence, it is recommended that the governments should take measures for adoption of radio frequency identification ("RFID") or other advanced tracking technologies mandatory to effectively utilise waste generated in the country.
- **Public procurement of recycled and green technologies to enhance innovations:** India should strategically leverage public procurement to drive sustainable innovation in SWM by favouring recycled and green technologies. Clear guidelines promoting eco-friendly technologies should be established at the central level to incentivize the development of innovations that contribute to a circular economy.
- **Waste Recycling as a tool for enhancing capitalization and innovation:** India should adopt a model of legally mandated waste recycling targets and each state should formulate annual recycling targets to drive demand and boost capitalization and innovation in the sector. Further, a reward system for states exceeding the recycling targets may be established to foster healthy competition and improve waste recycling capacity of the country.
- **Government-Authorized Colour-Coded Bags for Waste Collection:** It is suggested that India should introduce colour-coded garbage bags for distinct waste types. The implementation of specific prices for these bags shall help boost municipal revenue and further, raise public awareness on the need for separation of waste. Further a 'waste calendar' may be developed with scheduled waste collection days for different wastes to streamline the collection process and enhancing efficiency.

INTRODUCTION

"Waste" was once defined by the World Health Organisation ("WHO") as something which the owner no longer wants at a given time and space, and which has no current or perceived market value.[1] However, this perception and approach towards waste has changed dramatically over the years. As of 2022, the global waste management industry was valued at USD 1043.9 million and it is expected to grow to USD 1685.5 billion by 2030.[2] Over time, the global perspective has shifted, now considering waste not as a burden but as a valuable resource. This transformation has been facilitated through the advent of concepts like Waste-to-Energy ("WtE") and circular economy that extract value out of material deemed to be of no use. Technological processes like repurposing waste into new materials, carbon capture and utilization, and conversion of MSW into ethanol and jet fuel variants, etc., have played a vital role in shifting the perception of countries and businesses towards waste.[3] This effect is compounded by the increasing scarcity of resources around the world, the dearth of which can be fulfilled by extracting requisite resources from waste. Waste has thus evolved into a potential resource that can be harnessed for economic, environmental, and social benefits.[4]

Waste management as a process involves addressing diverse types of waste, including industrial waste, municipal waste, e-waste, plastic waste, hazardous and other forms of waste. Among these, the management of solid waste is of paramount concern for countries worldwide. The importance of SWM is highlighted by its specific reference in Sustainable Development Goals ("SDGs") Indicator 11.6.1 of the United Nations ("UN").[5] Further, SWM is intricately tied to 12 of the 17 UN-SDGs, addressing critical areas such as public health, environmental concerns, and resource value, and serving as a fundamental utility system lacking for over 2 billion people.[6] SWM has far-reaching impact on personal, public, and environmental well-being, influencing aspects such as health, safety, community aesthetics, and ecological sustainability.

The need for a robust SWM framework is exacerbated by the growing population, rapid urbanization, escalating consumerism, and industrialization, leading to a surge in waste production with no clear system for its proper disposal. According to World Bank's Report on *What a Waste 2.0: A Global*

[1] Ozoemene et al, 'Evaluation of Domestic Solid Waste Disposal in Two Selected Housing Estates in Awka, Anambra State (Case Study of Udoka and Real Estates)', Vol 4(16), Journal of Environment and Earth Science (2014), available at https://www.iiste.org/Journals/index.php/JEES/article/view/15155 (last accessed on December 27, 2023)
[2] Waste Management Market Size, Share & Trends Analysis Report by Service Type (Collection, Transportation, Disposal), by Waste Type (Industrial Waste, E-waste), by Region, and Segment Forecasts, 2022-2030, Research and markets, available at rb.gy/0p6rqu (last accessed on December 30, 2023)
[3] Henrik Hvid Jensen, 'Why the circular economy is a business imperative', World Economic Forum, (October 2, 2023), available at https://www.weforum.org/agenda/2023/10/why-the-circular-economy-is-a-business-imperative/ (last accessed on December 30, 2023)
[4] Eva Amsen, The end of waste as we know it? 4 ways to turn waste into treasure, (May 10, 2021), The World Economic Forum available at https://www.weforum.org/agenda/2021/05/the-end-of-waste-as-we-know-it-5-ways-to-turn-waste-into-treasure/ (last accessed on December 01, 2023)
[5] SDG 11- Make cities and human settlements inclusive, safe, resilient and sustainable, Department of Economic and Social Affairs, United Nations, available at https://sdgs.un.org/goals/goal11#targets_and_indicators (last accessed on December 30, 2023)
[6] Hari Bhakta Sharma, Kumar Raja Vanapalli, Biswajit Samal, V.R. Sankar Cheela, Brajesh K. Dubey, Jayanta Bhattacharya, Circular economy approach in solid waste management system to achieve UN-SDGs: Solutions for post-COVID recovery, Science of The Total Environment, Volume 800, (2021), available at https://doi.org/10.1016/j.scitotenv.2021.149605. (last accessed on December 27, 2023)

Snapshot of Solid Waste Management to 2050,[7] around 2.01 tonnes of solid waste was generated in 2016 alone and the volume of the solid waste is estimated to increase to 3.40 billion tonnes by 2050. The increasing waste is a pervasive issue affecting all citizens and organizations. Although the actors involved in SWM vary across countries, ranging from public and private sectors to even informal segments, the responsibility for SWM primarily rests with the public sector. While private sector participation is being encouraged to optimize the SWM structure, the public sector still remains at the core of SWM.

The government of the country, at the national or local level, often holds the primary responsibility for handling solid waste as the responsible entity/agency concerned with maintaining civic health, cleanliness, public wellness, and the environment. The public sector is entrusted to ensure effectiveness right from the systemic and policy level to the very grassroots. Optimized and dedicated participation from the public sector in this essential service is significant for improving the well-being of citizens, fostering a healthy living environment, and contributing to sustainable development. As a country generating around 155,537.10 tonnes per day,[8] amounting to 56.7 million tonnes of waste in a year, the effective management of SWM is still a challenge for India. Even with the Solid Waste Management Rules, 2016 ("SWM Rules, 2016") stating that all municipal authorities or ULBs are answerable for generation, collection, transportation, processing and treatment of MSW in an ecologically congruous way with due thought to the standards of economy, energy and aesthetics, the total percentage of waste processed in the country only amounts to 68%. Further, international agencies have reported that around 20% to 50% of municipal budgets have to dedicated to SWM services to have an effective waste management framework.[9] This financial burden poses challenges, especially in developing countries such as India, where issues of funding are prevalent within the waste management system.[10] In such settings, capitalization of waste emerges as an option for reducing fiscal expenditure of municipal bodies.

In this regard, the project is being undertaken to align the need for effective SWM in India with the extraction of resources to create a sustainable and viable model that optimizes resource utilization, reduces waste-related costs, and fosters economic growth through sustainable practices. The report aims to conduct a comparative analysis of the public sector's role in waste capitalization and management with that in Germany and South Korea, and understand the various types of technologies and innovations used within the SWM framework to enhance its efficacy. The selection of Germany and South Korea as study regions is rooted in their exceptional performance across multiple parameters in the 2022 Environmental Performance Index,[11] which considers SWM and

[7] Silpa Kaza, Lisa Yao, Perinaz Bhada-Tata, and Frank Van Woerden. 'What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050', (2018), World Bank Group, available at http://hdl.handle.net/10986/30317 (last accessed on December 30, 2023)
[8] Status of Dumpsites, Mission Progress, Swachh Bharat Mission Urban 2.0, MoHUA, available at https://sbmurban.org/swachh-bharat-mission-progess (last accessed on December 30, 2023)
[9] Solid Waste Management, The World Bank, (February 11, 2023), available at https://www.worldbank.org/en/topic/urbandevelopment/brief/solid-waste-management (last accessed on December 30, 2023)
[10] Waste Management in India- Shifting Gears, Assocham India in association with PWC, available at https://smartnet.niua.org/sites/default/files/resources/waste-management-in-india-shifting-gears.pdf (last accessed on December 03, 2023)
[11] The Environmental Protection Index Results (2022), available at https://epi.yale.edu/epi-results/2022/component/epi (last accessed on December 30, 2023)

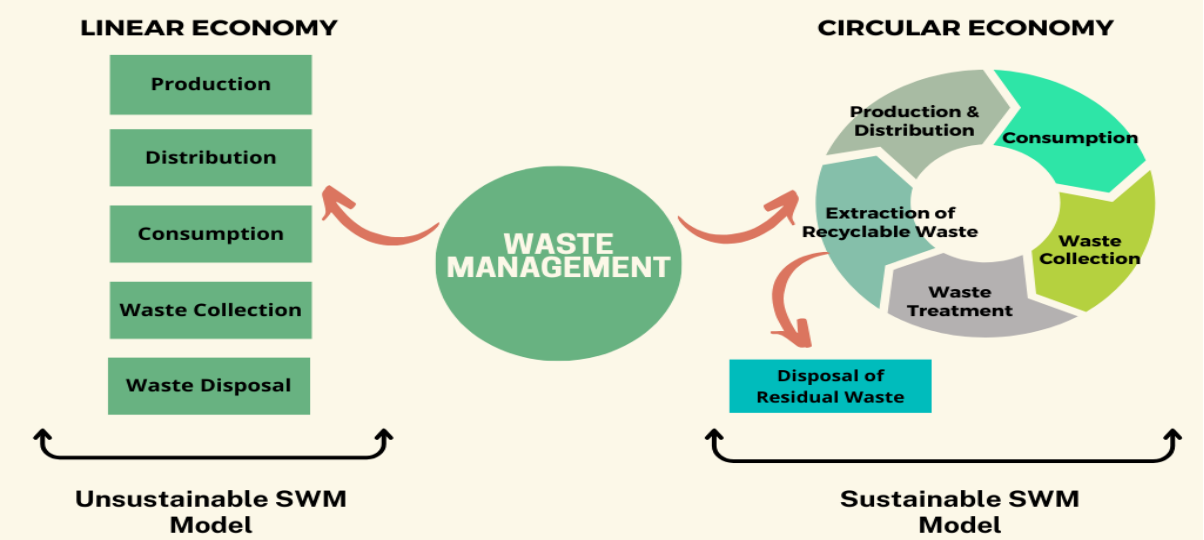
recycling standards followed in a country. In the EPI index, South Korea emerged as a leader in waste recycling securing the top position and achieving an overall rank of 6 for waste management and solid waste. Similarly, Germany secured an overall rank of 11 in waste management, with 8th and 9th rank for SWM and recycling, respectively. The report also aims to analyse the impact of various government-funded schemes and programs initiated at the national level for enhancing SWM governance and framework in India. Based on the findings, the report aims to propose changes that can be implemented to ensure greater efficacy and impact of the public sector in SWM.

2. PUBLIC CAPITALIZATION MODELS FOR SUSTAINABLE WASTE SOLUTIONS

2.1 Understanding Waste Capitalization

2.1.1. Waste Capitalization: Concept and Significance

At its core, waste capitalization is a strategic approach that converts challenges associated with waste disposal into opportunities for revenue generation. Capitalization of waste represents a paradigm shift in waste management, transforming what was once considered a burden into a valuable economic asset. Through this approach, the conventional linear model of waste management, involving collection, treatment, and disposal incurring substantial public expenditure is reimagined through a circular economy lens. Resources derived from discarded materials are processed and repurposed for revenue until the completion of a product's life cycle. The approach introduces diverse methods, including direct revenue generation from recycled products, composting, and incineration for energy, effectively alleviating the financial burden associated with waste management.[12]



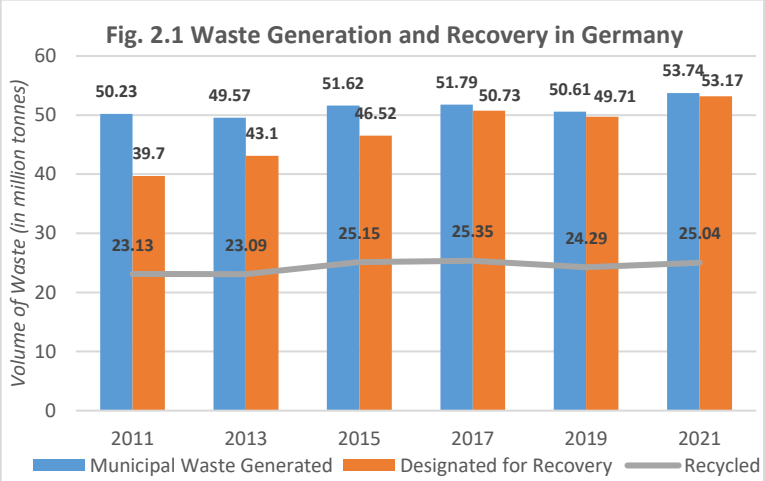
From a governance standpoint, the strategic initiative of waste capitalization offers a multitude of benefits. It holds the potential to substantially reduce manufacturing costs and increase selling prices.[13] Through the reprocessing of recyclable materials to substitute raw materials, governments can strategically decrease production costs, fostering a more competitive industrial landscape. Further, by extracting revenue from waste and transforming it into a profitable sector, the government can establish a robust financial foundation reducing the dependency on the national or state exchequer for managing SWM services. Apart from fulfilling the financial needs of waste

[12] Global Waste Management Outlook, United Nations Environment Programme (UNEP), (March 2015), Pages 204-205, available at https://www.unep.org/resources/report/global-waste-management-outlook (last accessed on December 03, 2023)
[13] Madhur Rathi, Recycling waste can generate crores in revenue in India, The Times of India, (June 9, 2022), available at https://timesofindia.indiatimes.com/blogs/voices/recycling-waste-can-generate-crores-in-revenue-in-india/ (last accessed on December 03, 2023)

management, the process also actively contributes to achieving the SDGs of the country. The capitalization of waste operates within the principles of the circular economy, following a strategy where natural resources are utilized sustainably to protect the environment during economic growth. The overarching aim is to progressively realize a high-efficiency, low-cost economy, characterized by reduced pollutant emissions and a high rate of recycling.[14]

2.1.2. Waste Management Industry and Revenue Potential

The global waste management industry has witnessed exponential growth in recent years, reflecting an increasing awareness of the value of waste and its impact on environmental sustainability. Governments and businesses across the globe have acknowledged the significance of waste capitalization and are actively seeking optimal technologies to harness the potential of waste. Developed nations have adopted integrated waste management systems strategically aiming to maximize revenues from waste in the form of energy, fuels, recyclables and value-added products. Among the nations actively engaging in effective waste management practices, Germany and South Korea has emerged as notable examples oftentimes lauded for their sustainable practices and innovative solutions.

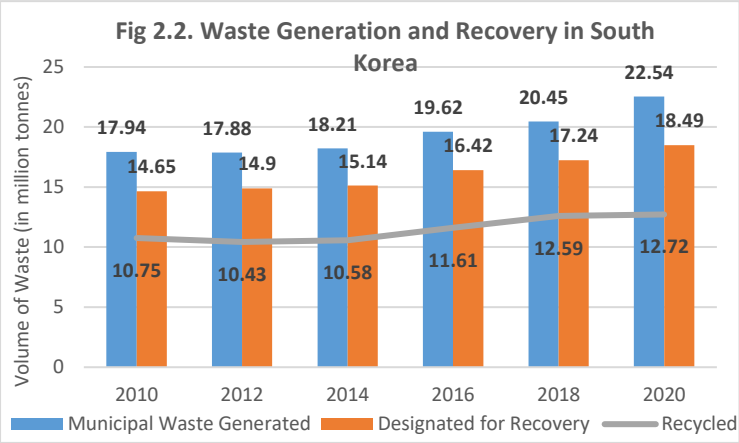


Germany, known for its rigorous segregation and recycling practices, has made significant strides in enhancing its recovery and recycling processes. In 2021, Germany produced approximately 53.7 million tons of waste from households and communities. Despite an overall increase in waste generation over the past decade, from 50.23 million to 53.74 million, the recovery of waste has seen remarkable growth, escalating from 39.7 million in 2011 to 53.17 million in 2021. (*Figure 2.1).* [15] The stringent enforcement of circular economy principles through law and recycling targets has led to a near-complete recovery of waste generated in the country. Recovery includes recycling, re-use and composting, indicating that the waste was successfully diverted from disposal. Reportedly, the waste management and recycling market of Germany reached EUR 62 billion in 2022 and is projected to

[14] Oana Lupu, Marius Ardelean, Ana Socalici, Erika Ardelean, 'Research regarding the Capitalization of the Waste Resulted from the Steel Industry, U.P.B. Sci. Bull., Series B, Vol. 83, Iss. 1, 2021 ISSN 1454-2331, available at https://www.scientificbulletin.upb.ro/rev_docs_arhiva/fullcf4_298507.pdf (last accessed on December 03, 2023)
[15] Germany, Municipal waste, Generation and Treatment, OECD Stats, available at https://stats.oecd.org/index.aspx?DataSetCode=MUNW# (last accessed on November 21, 2023)

reach EUR 70 billion in 2024.[16] Germany has effectively capitalized on waste, as evidenced by the fact that, as of 2016, 14% of the country's resource demand is sourced from waste.[17]

Similarly, South Korea has advanced in waste management by improving the amount of waste designated for recovery. Over the years, the waste designated for recovery has improved from 14.65 million tons in 2010 to 18.49 million tons in 2020, along with an increase in the recycling rate. *(Figure 2.2)* Studies have estimated that the waste management industry of South Korea is projected to reach around KRW 3.3 trillion (USD 25.74 billion) in 2025.[18]



The narratives surrounding Germany and South Korea effectively highlight the transformative potential of waste capitalization in reshaping waste management framework. India is poised to confront a projected increase in waste amounting to 150 million tons by 2030.[19] The amount of waste generated in India is unsurprisingly higher in comparison to the other two nations owing to its larger population and increasing urbanisation. Rather than viewing the mounting waste as a predicament, India has the unique opportunity to redefine its waste management landscape. India, with its large population, holds immense potential to capitalize on waste. If fully realized, the Indian waste management industry could emerge as a substantial revenue source. According to the 2022 report by the Ministry of Housing and Urban Development ("MoHUA"), the estimated revenue potential from MSW is approximately INR 15,000 crore and INR 10,000 crore from liquid waste.[20] Furthermore, material recovery facilities ("MRFs") are projected to increase their cost recovery from INR 5,187 crore in 2021 to INR 11,836 crore in 2025. These facilities are anticipated to play a crucial role in job creation, contributing significantly to employment in construction and operations.[21]

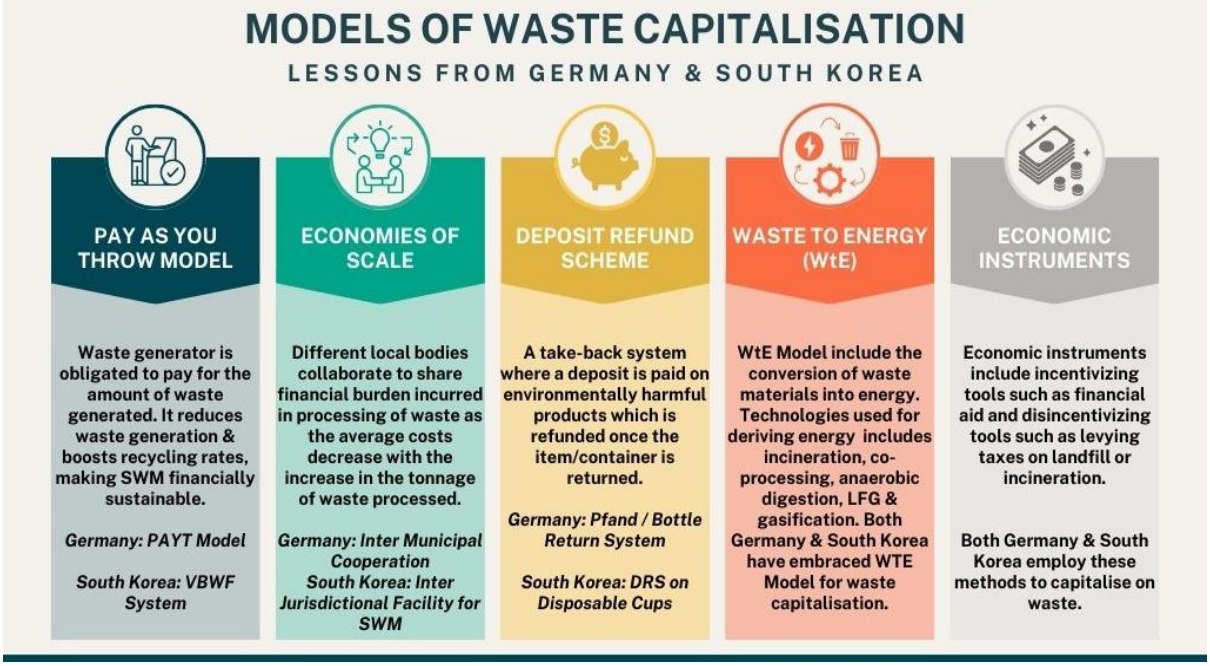
[16] Germany's Circular Economy: Recycling and Waste Management, Germany Trade & Invest (GTAI), 2023, available at https://www.gtai.de/en/invest/industries/environmental-technologies/recycling-waste-management-68380 (last accessed on December 03, 2023)
[17] Modern Waste- Goals and Paths, Germany's expertise for an advanced circular economy, available at https://www.giz.de/en/downloads/giz2016-en-vdma_Modern_Waste_Management.pdf (last accessed on December 03, 2023)
[18] Korea Waste Management Market Insights & Forecast Report 2021-2025: Accelerating Generation of e-Waste and Expanding Urbanisation Driving Growth, PR Newswire, (December 24, 2021), available at https://www.prnewswire.com/news-releases/korea-waste-management-market--insights--forecast-report-2021-2025-accelerating-generation-of-e-waste-and-expanding-urbanization-driving-growth-301450684.html (last accessed on December 03, 2023)
[19] Sustainable Processing of Municipal Solid Waste: Waste to Wealth, Press Information Bureau, (October 23, 2020), available at https://pib.gov.in/PressReleseDetailm.aspx?PRID=1667099 (last accessed on December 03, 2023)
[20] Circular Economy in Municipal Solid and Liquid Waste, Ministry of Housing and Urban Affairs, available at, https://mohua.gov.in/pdf/627b8318adf18Circular-Economy-in-waste-management-FINAL.pdf (last accessed on December 03, 2023)
[21] Dipak K Dash, Recyclable city waste may help generate 30k crore a year: Govt report, The Times of India, (May 18, 2022), available at https://timesofindia.indiatimes.com/india/recyclable-city-waste-may-help-generate-30k-crore-a-year-govt-report/articleshow/91608114.cms (last accessed on December 03, 2023)

These abovementioned data is of noteworthy for a developing country like India where municipalities are frequently grappling with the challenge of insufficient funds. Studies have shown that municipalities are highly dependent on financial aid from the state and centre owing to insufficient allocation of funds and low revenue generation of municipal corporations.[22] This fiscal constraint hampers their ability to manage solid waste efficiently. In this context, recognizing the potential of waste to contribute to income generation becomes particularly crucial. By adopting methods to generate revenue from solid waste, municipalities can establish a sustainable business model wherein municipalities can be self-sufficient and reduce financial dependence on state or centre-allocated aid. Waste capitalization presents a golden opportunity to not only address environmental concerns but also to establish a resilient and economically robust waste management industry in India.

2.2 Modes of Capitalization of Solid Waste: Germany and South Korea

Waste capitalization is achieved in countries through different models and schemes. Each country has its own method based on the outcome it intends to achieve through the capitalization process. The intended outcome of such efforts encompasses a range of goals such as environmental sustainability, economic growth, resource conservation, or a combination of these factors. The various models employed by South Korea and Germany to enhance the capitalization process highlight the versatility of approaches. These models may be implemented by either the public sector or the private sector or may result from a joint collaborative effort between the public and private sectors.

[22] Report on Municipal Finances, Reserve Bank of India, November 10, 2022, available at https://rbidocs.rbi.org.in/rdocs/Publications/PDFs/RMF101120223A34C4F7023A4A9E99CB7F7FEF6881D0.PDF (last accessed on December 6, 2023); Chapter 21, Economic and Financial Considerations, Ministry of Housing and Urban Development, available at https://mohua.gov.in/upload/uploadfiles/files/chap21(1).pdf (last accessed on December 6, 2023); Municipal corporations are gasping for funds, depend on the State, Centre for grants, The Hindu, (January 11, 2023), available at https://www.thehindu.com/data/data-municipal-corporations-in-india-are-gasping-for-funds/article66360699.ece (last accessed on December 6, 2023)



2.2.1. Pay-as-you-throw Model

One of the main instruments employed by the public sector that is being uniformly applied in some form or the other in both the nations is the imposition of waste disposal fees on the residents. PAYT is a measure based on the polluter-pays principle wherein the waste generator is obligated to pay for the amount of waste generated. The disposal fee acts as a disincentive for citizens, fostering waste reduction, encouraging waste separation, and promoting efficient material use.

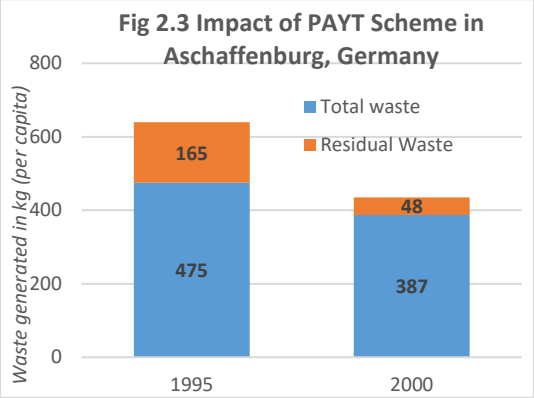
For instance, in South Korea, the *Volume Based Waste Fee System* ("VBWF") established in 1995 has significantly transformed the SWM ecosystem of the country.[23] Under the VBWF system, households and small businesses are mandated by law to purchase standardized plastic bags sold by governments for waste disposal, with different bags incurring fees based on size and volume. There are five types of bags designated for different types of waste, including domestic waste, food waste, business waste, public-purpose waste, and construction debris. The system facilitates the free collection of recyclable waste, encouraging the general public to actively participate in waste recycling.[24] Therefore, recyclable materials, such as plastic, paper, and cans, are collected from containers or bins outside households or small businesses without incurring any charges.[25]

Notably, by 1996, two years after the implementation of the model, the amount of waste disposed decreased by 11%, equivalent to about 1,712 tons per day. Additionally, the system also improved the financial independence rate of local governments dealing with waste management systems. The

[23] Two Decades in Effect: Volume-Based Waste Fee System in South Korea, Korea Environmental Policy Bulletin, Ministry of Environment, Volume 14 Issue 2, 2016, available at https://rb.gy/d8ucg6 (last accessed on December 27, 2023)
[24] Volume-Based Waste Fee System, Korea Environmental Policy Bulletin, Ministry of Environment, Volume 1 Issue 1, 2003, available at https://rb.gy/fa4vk3 (last accessed on December 6, 2023)
[25] Dong-Young Kim, How the Volume-based Waste Fee Policy Increased Household Recycling Rates in the Republic of Korea (1995-2009), Global Delivery Initiative, March 2019, available at https://rb.gy/va15z1 (last accessed on December 6, 2023)

payments generated through waste generators rose from KRW 119.9 billion in 1993 to KRW 153.6 billion in 1995, indicating a growth rate of 28%. The Korean government assessed the decade-long effectiveness of the PAYT system in 2005 and it revealed that a reduction of 1 ton of waste yielded a benefit of KRW 144,071, whereas recycling 1 ton of waste generated a benefit of KRW 18,901.[26] The VBWF system aided in promoting recycling practices among the residents and also helped generate funds for the government to enhance waste management efficiency. The successful implementation of the VBWF system involved extensive stakeholder consultation,[27] public awareness campaigns, and monitoring to ensure compliance.[28] This model has been instrumental in reducing waste generation and boosting recycling rates, making waste management financially sustainable.

Similarly, in Germany, certain cities have employed the *PAYT Scheme* with the aim of improving source segregation and recycling rates. A prime example of the success of the PAYT model in Germany is the county of Aschaffenburg in Germany. Prior to 1990, Aschaffenburg depended on the landfills of neighbouring counties for the purpose of waste disposal. However, over time, priorities shifted towards waste prevention and recycling. The PAYT model was rolled out in the county in 1997 through door-to-door collection and it has resulted in a significant reduction in residual waste generation and an increase in recyclable waste collection. Recyclable waste includes paper, cardboard boxes, glass, wood, metal scrap, etc. whereas residual waste includes bulky waste and certain household wastes including commercial waste.[29] Before introducing the scheme, the county's total waste per person in 1995 was 475 kg, with residual waste accounting for 165 kg. After implementation, both the total waste generated and residual waste decreased significantly to 387 kg and 48 kg per person, respectively.[30] The success of the PAYT scheme has influenced other German municipalities,[31] and even European nations like Italy and Belgium to adopt



[26] Volume Based Waste Fee(VBWF) System for Municipal Solid Waste, Seoul Solution, available at https://seoulsolution.kr/en/content/6326 (last accessed on December 6, 2023)
[27] Dong-Young Kim, How the Volume-based Waste Fee Policy Increased Household Recycling Rates in the Republic of Korea (1995–2009), Global Delivery Initiative, (March 2019), available at https://archives.kdischool.ac.kr/bitstream/11125/41357/1/How%20the%20Volume-based%20Waste%20Fee%20Policy%20Increased%20Household%20Recycling%20Rates%20in%20the%20Republic%20of%20Korea%20%281995-2009%29.pdf (last accessed on December 30, 2023)
[28] Tessa Kwek Wei Ling, Lim Wei Da, 'A Softer Approach To Managing Domestic Waste: The Importance of Stakeholder Engagement in Seoul's Waste Management Strategy', Centre for Liveable Cities, available at https://www.clc.gov.sg/docs/default-source/commentaries/a-softer-approach-to-managing-waste.pdf (last accessed on December 30, 2023)
[29] City of Aschaffenburg, Waste figures by local authorities, Working group for waste advice in Lower Franconia, available at https://www.abfallberatung-unterfranken.de/abfallzahlen/abfallzahlen_stadt_aschaffenburg.html (last accessed on 23 November 2023)
[30] J. Morlok et al., 'The impact of Pay-As-You-Throw Schemes on Municipal Solid Waste Management: The exemplar case of the county of Aschaffenburg, Germany', MDPI, (February 8, 2017) available at https://www.mdpi.com/2079-9276/6/1/8 (last accessed on November 20, 2023)
[31] Early warning assessment related to the 2025 targets for municipal waste and packaging waste: Germany, European Environment Agency, June 2022, Page 11, available at https://www.eea.europa.eu/publications/many-eu-member-states/germany (last accessed on December 4, 2023)

similar waste disposal fee models.[32] These waste disposal fees, implemented under the PAYT model, have been recognized as Best Environmental Management Practices ("BEMP") due to their transformative impact on residents' behaviour and the waste management sector.[33] The model incentivizes the reduction of residual waste, contributing to the overall success of waste capitalization efforts.

2.2.2. Economies of Scale through Shared Responsibilities

Another critical avenue for waste capitalization involves collaborative efforts among two or more public bodies to lower costs and achieve economies of scale in waste management. The fundamental idea is that by pooling resources and working together, municipalities or public bodies can enhance the efficiency of waste management practices while reducing overall costs.

For instance, in Germany, Inter-Municipal Cooperation ("IMC") is practised as an economically viable method where different municipalities join forces to enhance governance and lighten the financial burden incurred by individual municipalities. Research has shown that these models have the capability to improve the quality of public services while simultaneously delivering financial advantages to the authorities.[34] The crux of IMC lies in achieving economies of scale, where the higher the volume of waste transported by one vehicle, the lower the cost incurred per ton.[35] The reduction in expenditure is attributed to the collaborative efforts undertaken in providing joint public services.

Since German municipalities have the right to self-govern at their jurisdictional level, they engage in public agreements or cooperative practices, particularly with neighbouring counties.[36] An example of successful IMC which resulted in economic benefit is the case of the neighbouring towns of Dreieich and Neu-Isenburg in Germany. Their collaborative efforts in waste collection resulted in a 10 per cent reduction in waste disposal fees in 2015.[37] This significant reduction was attributed to economies of scale achieved through IMC, wherein individual municipal expenditures on material resources decreased.

Likewise, in South Korea, an instance of shared responsibility among public sector bodies is the Sudokwon Landfill site, established as an *Inter-Jurisdictional Waste Management Facility* in 2000. The government procured land for the site in 1988 and subsequently transformed it into waste treatment

[32] M. Dri et al., Best Environmental Management Practice for the Waste Management Sector, JRC Science for Policy Report, May 2018, available at https://susproc.jrc.ec.europa.eu/product-bureau/sites/default/files/inline-files/WasteManagementBEMP.pdf (last accessed on November 20, 2023)
[33] Ibid.
[34] Mario Villalba Ferreira, Geske Dijkstra, Peter Scholten, Dolores Sucozhañay, 'The effectiveness of inter-municipal cooperation for integrated sustainable waste management: A case study in Ecuador', Waste Management, Volume 150, 2022, Pages 208-217, available at https://doi.org/10.1016/j.wasman.2022.07.008. (last accessed on December 27, 2023)
[35] M. Dri et al., Best Environmental Management Practice for the Waste Management Sector, JRC Science for Policy Report, May 2018, Page 342, available at https://susproc.jrc.ec.europa.eu/product-bureau/sites/default/files/inline-files/WasteManagementBEMP.pdf (last accessed on November 20, 2023)
[36] Silvia Bolgherini, 'Local government and inter-municipal cooperation in Italy and Germany', PIFO Occasional Papers No.12/2011, Department of Political Science, Justus Liebig University, (January 2011), Page 13-14, available at http://dx.doi.org/10.22029/jlupub-2005 (last accessed on December 27, 2023)
[37] Cora Werwitzke, Citizens will save garbage fees from 2014, Offenbach Post OP-Online, available at http://www.op-online.de/lokales/nachrichten/dreieich/muellgebuehr-dreieich-sinktdank-interkommunaler-zusammenarbeit-3181820.html (last access on November 24, 2023);

facility utilized by three local governments - Seoul, Incheon and Gyeonggi Provinces.[38] The facility, established as a federal venture to promote sustainable waste management practices has become the world's largest sanitary landfill sprawling across an area of 20 million square meters.[39] The Sudokwan landfill site project is a program supported by the national as well as municipal governments. It stands as a successful business model, capable of generating revenue independently. Its capitalizing activities include gas power plants fuelled by landfill gas ("LFG"). Furthermore, in 2013, a portion of the land was turned into an eco-friendly golf course generating revenue used for the maintenance of LFG facilities and creating job opportunities in the community.

2.2.3 Deposit Refund Scheme

Deposit Refund Scheme ("DRS") is another system of waste capitalization that utilizes a take-back mechanism with an additional fee on products having a potential environmental impact. In this system, buyers pay a deposit when purchasing containers and upon returning the products, they receive a refund, incentivizing pollution prevention and enhancing recycling rates, especially for items like beverage containers. DRS is widely recognized as a highly effective approach for boosting recycling rates and the system is also acknowledged as a BEMP.[40] In Germany, the DRS system, also known as the bottle return system, operates on a "return-to-retail" model where an additional deposit (pfand) is paid by the buyer when purchasing a beverage container which is subsequently refunded on return of the bottle. The retailers and manufacturers in Germany have been mandated by law to adopt these schemes under the packaging law.[41] On the other hand, municipalities have the option to mandate the scheme or administer their own deposit refund systems.[42] For instance, the city of Schwäbisch Gmünd in Germany mandated a minimum deposit of 2 EUR for glasses used at a city festival[43] and the city of Nuremberg mandated the use of reusable containers which shall be supported by a deposit for all events taking place in public institutions and on any land belonging to the city.[44]

Similarly, South Korea implemented the *Producer Deposit Refund System* in 1992, requiring manufacturers to pay the Ministry of Environment a fee equal to the cost of recycling their

[38] Eiko Wataya et al., Extracting Value from Municipal Solid Waste for Greener Cities: The Case of the Republic of Korea, Green Growth in Action, World Bank Group, 2014, Page 10, available at https://www.wbgkggtf.org/sites/kggtf/files/publications/KGGTF_Knowledge_Note_04.pdf (last accessed on December 7, 2023)
[39] Seoul Metropolitan Government, Smart Waste Management – Sanitary Landfill, Case Study Database, Urban Sustainable Development Goal Knowledge Platform, September 17, 2015, available at http://www.urbansdgplatform.org/profile/profile_caseView_detail.msc?no_case=97 (last accessed on December 27, 2023)
[40] Best Environmental Management Practice for the Waste Management Sector, JRC Science for policy report, European Union, available at https://susproc.jrc.ec.europa.eu/product-bureau/sites/default/files/inline-files/WasteManagementBEMP.pdf (last accessed on December 27, 2023)
[41] Act on the Placing on the Market, the Take-Back and the High-Quality Recycling of Packaging (Packaging Act - VerpackG), available at https://www.gesetze-im-internet.de/verpackg/BJNR223410017.html (last accessed on December 27, 2023)
[42] M. Dri et al., Best Environmental Management Practice for the Waste Management Sector, JRC Science for Policy Report, May 2018, available at https://susproc.jrc.ec.europa.eu/product-bureau/sites/default/files/inline-files/WasteManagementBEMP.pdf (last accessed on November 20, 2023)
[43] Ibid.
[44] Section 7(3), Statute on Prevention, Recycling and Disposal of Waste 2009, City of Nuremberg, Germany, available at https://www.muelheim-ruhr.de/cms/satzung_ueber_die_abfallentsorgung1.html (last accessed on December 27, 2023)

manufactured products and packaging.[45] Under this, manufacturers had the opportunity to recover a portion or the entirety of the deposited fee based on the quantity of products they recycle. Further, in 2022, the Ministry of Environment announced a compulsory DRS for disposable cups, requiring buyers to pay a deposit of 300 won (US 21 cents) on single-use cups.[46] The scheme has also been implemented with the intent to reduce waste and improve recycling in the region.

As part of this initiative, a government-issued barcode sticker will be affixed to the cups for deposit reimbursement. Buyers can return these cups to any chain café or restaurant franchise to receive a refund, including establishments such as McDonald's, Starbucks, Burger King, and Baskin Robbins. To ensure the proper recycling of the recovered cups, the Ministry of Environment intends to designate three to five waste collection firms and one or two recycling companies for each region. This mandatory DRS system has been operational in the Sejong and Jeju regions in South Korea since December 2022 and is scheduled for nationwide implementation by 2025.[47] Studies indicate that the implementation of DRS schemes in South Korea has the potential to substantially reduce production costs. The refund amount is typically 40% of the cost of manufacturing new containers.[48] Therefore, when manufacturers receive the beverage containers back, they can be reused for resale, significantly reducing the production costs.

2.2.4 Waste-to-Energy

WtE is another crucial model in waste capitalization, focusing on the conversion of waste materials into energy. This approach is particularly relevant for addressing the dual challenges of waste management and energy generation. The technologies employed for WtE processes at the municipal level differ based on factors such as the type of waste and considerations related to operations, legality, environment, and finances. The various technologies used for deriving energy from municipal waste include incineration, co-processing, anaerobic digestion, LFG and pyrolysis/ gasification.[49] Notably, both Germany and South Korea has embraced WtE as a method of capitalizing waste.

Germany stands as one of the world's largest WtE markets with a significant percentage of the waste generated in Germany being utilized for recovery of energy.[50] Further, projections have indicated that the WtE market in Germany is poised for growth, expected to increase from USD 3.90 billion in 2023

[45] Expanding Producer Responsibility for Waste Management in Korea: From the Deposit Refund System to Extended Producer Responsibility, Global Delivery Initiative, September 2019, available at https://rb.gy/9l22ea (last accessed on December 7, 2023)
[46] Press Release, Government to charge KRW 300 deposit per disposable cup starting from June 10 of this year, Ministry of Environment, Republic of Korea, (January 26, 2022), available at https://rb.gy/keeqi2 (last accessed on December 7, 2023)
[47] Disposable cup deposit-refund scheme to go into effect in December in Jeju, Sejong, The Korea Times, September 23, 2022, available at https://www.koreatimes.co.kr/www/nation/2023/12/113_336596.html (last accessed on December 7, 2023)
[48] Case study for OECD project on extended producer responsibility: Republic of Korea, Organisation for Economic Co-operation and Development, (May 22, 2017), Page 7, available at https://www.oecd.org/environment/waste/OECD_EPR_case_study_Korea_revised_140522.pdf (last accessed on December 7, 2023)
[49] Waste-to-Energy Options in Municipal Solid Waste Management, GIZ, available at https://www.giz.de/en/downloads/GIZ_WasteToEnergy_Guidelines_2017.pdf (last accessed on December 7, 2023)
[50] Market value of Waste to Energy Technology in Germany, Global Data, available at https://www.globaldata.com/data-insights/environment-waste-management/market-value-of-waste-to-energy-technology-in-germany-2080506/#:~:text=Germany%20is%20one%20of%20the,tonnes%20of%20waste%20into%20energy. (last accessed on December 7, 2023)

to USD 4.90 billion by 2028.[51] Studies conducted in 2015 reported that waste contributed 3.7% to Germany's total energy consumption, underscoring the significant role of WtE in the country's energy landscape.[52] In fact, certain regions like the City of Hamburg in Germany are adopting WtE as a strategy to reduce or eliminate the use of coal.[53] Likewise, South Korea actively promotes WtE as a practical approach to harness resources from waste. It has been reported that, as of 2021, South Korea produced approximately 1.2 million tonnes of oil equivalent through WtE processes.[54] These technologies contribute to providing 8% of the thermal energy supplied to residential and commercial areas in South Korea by transmitting steam or hot water through a network of insulated pipes.[55] The utilization of WtE in Germany and South Korea serves as a noteworthy example of how waste can be transformed into a valuable resource, aligning with global efforts towards a more circular and sustainable economy.

2.2.5 Economic Instruments

Lastly, one of the most crucial strategies employed by the public sector involves the use of *economic instruments* to promote and support sustainable waste management practices while simultaneously creating economic opportunities. These economic instruments include a variety of incentivizing tools such as financial aid and disincentivizing tools such as levying taxes and imposing bans on single-use items. The public sector uses economic instruments in one form or another in both countries to achieve the objective of capitalization. For instance, in Germany, under the Circular Economy Act of 2012, states are required to prepare their own waste prevention program wherein they shall undertake economic measures to incentivize responsible waste management practices through financial aid and funding assistance, and specifically assist research projects aimed at waste prevention and recycling.[56] This acts as an incentive for private companies to adhere to the waste hierarchy and be eligible for said financial assistance. Likewise, each regional state in Germany establishes its own waste management regulations wherein it may provide for additional monetary measures to incentivize environmentally sound SWM practices. At the regional level, states like Bavaria empower public authorities to allocate financial assistance for waste management projects[57] and research on innovative waste-related technologies.[58] Further, to ensure compliance with the

[51] Waste to Energy Germany Market Size & Share Analysis - Growth Trends & Forecasts, Mordor Intelligence, available at https://www.mordorintelligence.com/industry-reports/germany-waste-to-energy-market-industry (last accessed on December 7, 2023)
[52] Kathrin Weber, Peter Quicker, Jörg Hanewinkel and Sabine Flamme, 'Status of waste-to-energy in Germany, Part I – Waste treatment facilities', available at https://publications.rwth-aachen.de/record/782180/files/782180.pdf (last accessed on December 7, 2023)
[53] Hamburg's plan to recover heat from waste, Germany energy solution limited, Federal Ministry for Economic Affairs and Climate action, (January 12, 2022) available at https://www.german-energy-solutions.de/GES/Redaktion/EN/News/2022/20220112-heat-from-waste-hamburg.html (last accessed on December 7, 2023)
[54] Volume of renewable energy produced using waste-to-energy in South Korea from 2010 to 2021, available at https://www.statista.com/statistics/1153961/south-korea-volume-of-waste-to-energy-produced/#:~:text=In%20South%20Korea%2C%20there%20were,significant%20impact%20on%20the%20figures. (last accessed on December 7, 2023)
[55] A.C. Bourtsalas et al., The status of waste management and waste to energy for district heating in South Korea, Waste Management, Vol. 85, February 15, 2019, Pages 304-316, available at https://doi.org/10.1016/j.wasman.2019.01.001 (last accessed on December 7, 2023)
[56] Section 33, Circular Economy Act, 2012, available at https://www.bmuv.de/fileadmin/Daten_BMU/Download_PDF/Abfallwirtschaft/kreislaufwirtschaftsgesetz_en_bf.pdf (last accessed on December 7, 2023)
[57] Article 23, Bavarian Waste Management Act, 1996, available at https://www.gesetze-bayern.de/Content/Document/BayAbfAlG (last accessed on November 24, 2023)
[58] Article 24, Bavarian Waste Management Act, 1996, available at https://www.gesetze-bayern.de/Content/Document/BayAbfAlG (last accessed November 24, 2023)

responsible practices of SWM, certain disincentives such as polluter-related fee and taxes or fees for waste disposal through landfills and incineration are in place.[59]

Similarly, South Korea has enacted comprehensive penalty provisions under the Wastes Control Act of 1986. It states that penalties, including surcharges and fines, may be imposed upon those engaging in incinerating industrial waste or those who may treat industrial waste in a manner which is in violation of the Act. Further, residents failing to properly dispose of their waste and not utilising the officially issued standard bags may also be fined up to USD 900 for non-compliance.[60]

The governments of both countries have also implemented the EPR Scheme which is based on the principle of polluter pays and is aimed at promoting circular economy and responsible SWM practices. Notably, recycled products and items have been able to generate KRW 3,055 billion over a period of 10 years since the launch of the scheme in South Korea.[61] In Germany, EPR operates within a fee-modulation system wherein different types of packaging and items incur different amounts of charges under the Packaging Act.[62] These essentially creates a favourable environment for recycling.

Basically, the abovementioned policies not only aligns with sustainability goals but also transforms waste challenges into opportunities for revenue generation and resource utilization.

2.3 Waste as a Source of Revenue: Indian Scenario

In India, the onus of SWM primarily rests on local municipalities, each empowered to frame rules and regulations for waste management within their jurisdictions. The municipalities, acting as autonomous entities, wield the authority to set waste disposal fees, user charges, and devise inventive waste handling and capitalization models.[63] Recognizing the potential of waste capitalization, several states and cities in India have pioneered unique schemes, setting exemplary standards for responsible SWM practices. One such model of capitalization was initiated in Varanasi, Uttar Pradesh, with a distinctive endeavour to liberate the city from plastic pollution. A *plastic waste bank* was established in collaboration with the private sector which allows individuals to bring in plastic bottles or other waste materials and exchange them for monetary compensation. The collected plastic waste undergoes recycling, contributing to both environmental preservation and

[59] Annex 5, Circular Economy Act, 2012, https://www.bmuv.de/fileadmin/Daten_BMU/Download_PDF/Abfallwirtschaft/kreislaufwirtschaftsgesetz_en_bf.pdf (last accessed on December 7, 2023)
[60] Pay as you throw Case Study: Republic of Korea's volume-based waste charging scheme, Low Carbon Green Growth Roadmap for Asia and the Pacific, United Nations Economic and Social Commission for Asia and Pacific (UNESCAP), available at https://www.unescap.org/sites/default/files/39.%20CS-Republic-of-Korea-Volumn-based-Waste-Charging-Scheme.pdf (last accessed on December 7, 2023)
[61] Case study for OECD project on extended producer responsibility: Republic of Korea, Organisation for Economic Co-operation and Development, May 22, 2017, available at https://www.oecd.org/environment/waste/OECD_EPR_case_study_Korea_revised_140522.pdf (last accessed on December 7, 2023)
[62] Early warning assessment related to the 2025 targets for municipal waste and packaging waste: Germany, European Environment Agency, (June 2022), Page 15, available at https://www.eea.europa.eu/publications/many-eu-member-states/germany (last accessed on December 7, 2023)
[63] Municipal Solid Waste Management Manual - Part II: The Manual, Swachh Bharat Mission, Ministry of Urban Development, Government of India, 2016, Page 70, available at https://mohua.gov.in/upload/uploadfiles/files/Part2.pdf (last accessed on December 7, 2023)

economic gains.[64] Similarly, the Uttarakhand Government in collaboration with a tech startup introduced a *digital deposit refund system* in 2022. Like the system introduced in Germany and South Korea, the initiative established deposit refund centres where people can submit waste material, earn money, and contribute to recycling efforts.[65] The scheme, initially rolled out on a smaller scale, has been mandated for statewide implementation by the Uttarakhand High Court.[66]

Similar to the South Korean Sudokwan landfill site, Goa Waste Management Corporation ("GWMC") has transformed an old dumping ground in Saligao, Goa, into a scientific integrated SWM facility in collaboration with Hindustan Waste Treatment Pvt. Ltd. This facility focuses on resource recovery, recycling dry waste, and converting organic fractions into biogas and electricity through a WtE program.[67] As of May 2022, the facility has successfully treated up to 2.84 million tons of solid waste and generates over 25,000 units of electricity per day.[68] The economic benefits derived from the facility include the sale of segregated dry waste to recyclers, conversion of wet waste to biogas and the production of refuse-derived fuel ("RDF") for construction purposes.

The Thiruvananthapuram Municipal Corporation ("TMC") has also set an example for other local bodies by building an economically sustainable model of SWM. TMC's waste management plan is a perfect blend of the ULBs robust framework and public participation wherein TMC has employed a *decentralized waste management system*.[69] The municipal body has introduced segregated collection with formalized system for source-level composting of wet waste. Non-recyclables are collected by the TMC at designated centres and subsequently sent to authorized recyclers. The wet waste is converted into fertilizers and sold along with the segregated recyclables and non-biodegradable items. This approach allows TMC to focus its expenditure on disposal, saving significant costs related to waste collection and transportation. The collection and transportation processes are managed by external agencies through a PPP model. The municipal body also receives fees[70] from waste management agencies which further contributes to the revenue generation. Additionally, TMC has established the Clean Kerala Company, a state-owned enterprise engaged in processing e-waste and

[64] Bring plastic to this bank, take money, The Times of India, (April 6, 2021), available at https://timesofindia.indiatimes.com/city/varanasi/bring-plastic-to-this-bank-take-money/articleshow/81919872.cms (last accessed November 22, 2023)
[65] Vishwa Mohan, Govt streamlines collection and recycling of plastic packaging waste, producers to pay penalty for mishandling (February 18, 2022), available at https://timesofindia.indiatimes.com/india/govt-streamlines-collection-and-recycling-of-plastic-packaging-waste-producers-to-pay-penalty-for-mishandling/articleshow/89671340.cms (last accessed on November 22, 2023)
[66] Neeraj Santoshi, Start refund system for plastic water bottles across state: Uttarakhand HC (May 19, 2023) available at https://www.hindustantimes.com/cities/dehradun-news/uttarakhand-high-court-orders-digital-deposit-refund-system-for-plastic-water-bottles-across-the-state-101684504243888.html (last accessed on November 22, 2023)
[67] Mehar Kaur and Shabana Kazi, Goa's model on scientific waste management, The Goan, available at https://www.thegoan.net/sunday-mag/goa%E2%80%99s-model-on-scientific-waste-management/58724.html (last accessed December 7, 2023)
[68] 250 TPD Integrated Solid Waste Management Facility, Saligao: About Facility, Goa Waste Management Corporation, Government of Goa, available at https://gwmc.goa.gov.in/swmf-saligao/ (last accessed December 7, 2023)
[69] Thiruvananthapuram, Kerala: A Sustainable Waste Management Success Story with Revenue Generation, Champions of Change, NITI Aayog, available at https://abp.championsofchange.gov.in/content/830a-sustainable-waste-management-success-story-with-revenue-generation/ (last accessed December 7, 2023)
[70] Ibid.

low-value plastics for road construction. All these factors collectively contribute to revenue generation.[71]

Although the EPR policy, mandated by law,[72] initially faced limited adoption by civic bodies, the municipal body of Bengaluru, Bruhat Bengaluru Mahanagar Palike ("BBMP"), has taken a step to alter this scenario. In an effort to change the status quo, the Bengaluru Solid Waste Management Ltd. ("BSWML"), a government-owned entity mandated to oversee SWM operations on behalf of BBMP, has taken charge of executing the scheme. BSWML is set to impose a fee on manufacturers and producers involved in processing e-waste and plastic. Although it aims to promote recycling practices while discouraging the use of environmentally harmful products, the scheme is anticipated to yield substantial annual revenue, exceeding INR 100 crores.[73] The combination of EPR charges and user fees is expected to enhance the financial autonomy of the company and reduce the municipal body's dependency on state funding to perform SWM operations.

Another model implemented in India is Panaji's *16-way Segregation Model* under the United Nations Development Programme ("UNDP") Dry Waste Management Project. The 16-way source segregation involves sorting waste into 16 different categories including paper, cardboard, clothes, soft plastic, hard plastic, ceramics, glass, metal, e-waste, sanitary and biomedical waste, non-recyclables, etc. Bulk waste generators ("BWG"), including housing societies and commercial complexes, participate in this system by maintaining 16 bins for segregated waste collection. The sale of segregated waste generates revenue for both BWG and informal workers, fostering economic and environmental benefits.[74] Under this model, wet waste is utilized for composting, while dry recyclable waste is sent to recyclers. Mixed dry waste undergoes further reprocessing, and non-biodegradable waste is sold to construction industries for utilization in the form of RDF. Although this model is not public sector-

[71] Sonia Henam and Swati Sambyal, Ten zero-waste cities: How Thiruvananthapuram cleaned up its act, Down to Earth, (December 24, 2019) available at https://www.downtoearth.org.in/news/waste/ten-zero-waste-cities-how-thiruvananthapuram-cleaned-up-its-act-68539 (last accessed December 7, 2023)
[72] Draft Notification on Extended Producer Responsibility, (2021), Ministry of Environment, Forest and Climate Change, Government of India, available at https://cpcb.nic.in/uploads/plasticwaste/Draft-Notification-EPR-6-10-2021.pdf (last accessed December 7, 2023)
[73] Shreyas H.S., BBMP to implement EPR policy, aims to earn 100 crore annually, The Hindu, (August 26, 2023), available at https://www.thehindu.com/news/cities/bangalore/bbmp-to-implement-epr-policy-aims-to-earn-100-crore-annually/article67234935.ece (last accessed December 7, 2023)
[74] 16 ways of segregating waste: Panaji's innovative model of solid waste management, UNDP India, (January 18, 2023), available at https://www.undp.org/india/stories/16-ways-segregating-waste-panajis-innovative-model-solid-waste-management (last accessed December 7, 2023)

led, it has received support from the Corporation of the City of Panaji ("CCP"). In 2020, the municipal body mandated all BWGs to implement a 16-way segregation of waste at their premises, promoting the buy-back system for dry waste.[75] The model significantly contributes to the economic and environmental well-being of society by minimizing manual labour and enhancing recycling rates through the proper segregation of waste.

In addition to the above, the Government of India has also launched various initiatives such as the Waste to Wealth ("WtW") Mission,[76] and the National Bioenergy Programme ("NBP"), under which the WtE initiative falls. The WtE programme aims to support the setting up of plants for the generation of Biogas, BioCNG and power,[77] which can convert waste into valuable resources. While the government has made strides in harnessing the potential of waste generated in the country, there remains significant scope for further improvement, particularly in the conversion of waste into energy. Technically, there are around 20 WtE (12 operational and 8 non-operational) facilities in India.[78] However, due to improper segregation of waste, India remains at a lower calorific value of solid waste and thereby the WtE plants are not able to fully utilise the value of waste generated.[79] Hence, there is a need to create a stronger mechanism for the segregation of waste.

It is also crucial to recognize that various regions in India generate distinct types and volumes of waste. For instance, Telangana produced the highest amount of plastic waste in 2020-21,[80] while Maharashtra generated the highest amount of solid waste.[81] As each state grapples with unique waste management issues, there is a need to formulate policies tailored to the specific waste management challenges in different geographical areas of India. Moreover, the incorporation of best practices from countries like South Korea and Germany requires consideration of various factors. For instance, both Germany and South Korea have robust frameworks for the DRS, with established rules, guidelines, and monitoring frameworks for assessing schemes' effectiveness. Similarly, India has also initiated the Plastic Bank scheme and system of user charges in different regions. However,

[75] Newton Sequeira, Wealth and waste: CCP offers cash for trash in Panaji, The Times of India, (January 26, 2023), available at https://timesofindia.indiatimes.com/city/goa/wealth-and-waste-ccp-offers-cash-for-trash-in-panaji/articleshow/97339480.cms (last accessed December 7, 2023) ;
Soon, segregate waste into 16 categories in Panaji, The Times of India, October 17, 2020, available at https://timesofindia.indiatimes.com/city/goa/soon-segregate-waste-into-16-categories-in-state-capital/articleshow/78711336.cms (last accessed December 7, 2023)
[76] About Us, Waste to Wealth Mission, Government of India, available at https://www.wastetowealth.gov.in/about-us (last accessed December 7, 2023)
[77] Government initiates various steps under National Bioenergy Programme to promote and encourage establishment of new waste to energy plants, PIB, (February 3, 2023) available at https://pib.gov.in/PressReleasePage.aspx?PRID=1896067#:~:text=MNRE%20is%20implementing%20Waste%20to,umbrella%20of%20National%20Bioenergy%20Programme. (last accessed December 7, 2023)
[78] Bidisha Banerjee, How India can rejuvenate its Waste-to-Energy sector (August 24, 2023) available at https://energy.economictimes.indiatimes.com/news/renewable/opinion-how-india-can-rejuvenate-its-waste-to-energy-sector/103030931 (last accessed December 22, 2023)
[79] Pushkara S.V., Explained- Why do so many waste-to-energy plants fail?, The Hindu, (March 16, 2023), available at https://www.thehindu.com/sci-tech/energy-and-environment/explained-why-do-so-many-waste-to-energy-plants-fail/article66610994.ece (last accessed December 7, 2023)
[80] Generation of plastic waste, PIB, (July 27, 2023), available at https://pib.gov.in/PressReleasePage.aspx?PRID=1943210 (last accessed December 7, 2023)
[81] Annual Report 2020-21 on Implementation of Solid Waste Management Rules, 2016, CPCB, available at https://cpcb.nic.in/uploads/MSW/MSW_AnnualReport_2020-21.pdf (last accessed December 7, 2023)

there is limited to no information available on its effectiveness, making it challenging to identify and address potential challenges. A thorough evaluation of schemes implemented across different regions is necessary to fully comprehend the challenges in solid waste capitalization.

In conclusion, it is evident that Indian cities have come up with several self-sustainable and responsible models for waste capitalization and set an example for other cities to follow suit. These models can also be replicated by other cities and states in order to generate revenue and reduce the financial dependency of the municipal bodies. Apart from learning from other Indian states, India as a whole, can also replicate the capitalization models currently being followed in Germany and South Korea. Nonetheless, it is important to fine-tune the current framework through strategic adjustments to enhance the utility of waste generated in the country.

3. MODERNISING WASTE MANAGEMENT THROUGH TECHNOLOGICAL SOLUTIONS

3.1 Significance of Technology in SWM

Sustainable solutions which promotes circular economy form the cornerstone of every effective waste management strategy. Reduce, recycle and reuse are cardinal components that play an integral role in achieving circular waste solutions.[82] Globally, nations have implemented various measures and policies to import the 3Rs into their waste management frameworks. The relentless advancement of technology, which has exerted a transformative influence across all sectors, has also ushered in significant positive developments in the waste management sector by fostering innovative solutions oriented towards resource recovery. These solutions have become imperative to realising the overarching objective of the circular economy.

The promotion of innovative solutions and technologies in the waste management sector has not only helped countries address environmental and economic challenges but has also facilitated adherence to the principles of the waste hierarchy. For instance, Apeel Sciences and Hazel Technologies are innovations introduced in the United States that have helped to reduce food wastage. Apeel developed an invisible, indelible, natural and tasteless coating to protect the produce from transpiration and oxidation[83] while Hazel Technologies created sachets releasing 1-MCP to control ethylene production, thereby extending the shelf life of produce.[84] These types of innovations effectively tackle avoidance of waste which is the first and foremost principle of waste management. Similar scientific inventions promoting recycling and reuse of waste have also been developed in the world.

Additionally, from the initial stages of waste collection to its transportation and subsequent processing at facilities, technology plays a crucial role at every step of the waste management process. The different types of technologies used at each stage of waste management and their importance in reshaping the SWM framework are detailed below.

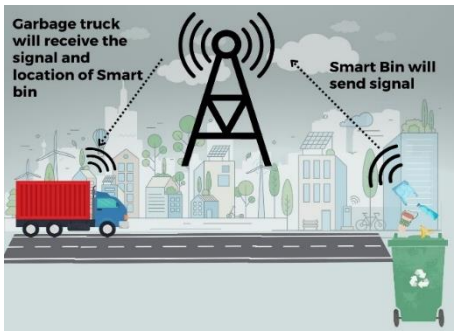
3.1.1 Smart Solutions in Waste Collection

Waste management commences with the collection stage, arguably the most critical aspect of the SWM process.[85] This aspect poses significant challenge for developing countries such as India, grappling with increased urbanisation and population growth. Nevertheless, recent technological

[82] Parthiban Manickam, Gopalakrishnan Duraisamy, '4 - 3Rs and circular economy', In The Textile Institute Book Series, Circular Economy in Textiles and Apparel, Woodhead Publishing, (2019), Pages 77-93, ISBN 9780081026304, available at https://doi.org/10.1016/B978-0-08-102630-4.00004-2 (last accessed December 7, 2023)
[83] How Apeel works, Apeel, available at https://www.apeel.com/how-apeel-works (last accessed on December 15, 2023)
[84] How it works- Hazel Technologies, available at https://www.hazeltechnologies.com/how-it-works (last accessed on December 15, 2023)
[85] Collection of Municipal Solid Waste in Developing Countries, UN Habitat, (2010) available at https://unhabitat.org/sites/default/files/2021/02/2010_collection-msw-developing-countries_un-habitat.pdf (last accessed on December 15, 2023)

advancements have led to the integration of cutting-edge technologies within the SWM system, ensuring efficiency and optimisation in the waste collection process.

A noteworthy example in this regard is a product named 'bin-e' introduced by a Poland-based company.[86] Bin-e are artificial intelligence ("AI")–powered products adept at recognising and sorting different types of waste, promoting waste management efficiency at the collection level. Beyond sorting, this technology also compresses waste, monitors fill levels and processes data to optimise waste collection. A technology of a similar nature has also been invented in South Korea which utilises Internet of Things ("IoT") smart sensors and solar power to monitor the levels of rubbish in each bin placed in a public area.[87] These smart bins have been successfully implemented in different countries including the Dublin Airport. Notably, the adoption of smart bins developed by a Korea-based company has reportedly reduced the frequency of bin changes in the Dublin airport from a staggering 1,200 bins per day to just 93 changes per day, showcasing the tangible impact of technology on optimising waste management operations.[88]



Automated sorting systems, equipped with advanced sensors and AI, are also streamlining the sorting process, resulting in substantial time and cost savings in the waste management process.[89] Robotic systems guided by AI are helping in carrying out intelligent physical tasks such as sorting, picking, and placing materials, revolutionising waste management processes and paving the way for increased efficiency, accuracy, and sustainability in the handling of diverse waste streams.[90] These technological interventions not only enhance operational efficiency but also significantly reduce the risk of workers being exposed to hazardous materials, ensuring a safer and healthier working environment.

3.1.2 Innovations in Solid Waste Transportation

The transformative impact of technology reverberates through every facet of waste management, revolutionising each stage of the process. Advancements in waste transportation are exemplified by the integration of GPS tracking systems in waste management fleets, ensuring efficient and

[86] Bin-e World, available at https://www.bine.world/ (last accessed on December 15, 2023).
[87] Smart Waste Management Solutions, Ecubelabs available at https://www.ecubelabs.com/ (last accessed on December 27, 2023); Elaine Ramizer, 'Internet of Bins: Smart, solar powered trashcans in Colombian cities', The Guardian, (June 14, 2016) available at https://www.theguardian.com/sustainable-business/2016/jun/14/internet-of-bins-smart-solar-powered-trashcans-in-colombian-cities (last accessed on December 27, 2023).
[88] Airport Smart Bins Improve Recycling Rates, Dublin Airport, (July 18, 2017) available at https://www.dublinairport.com/latest-news/2019/05/31/airport-smart-bins-improve-recycling-rates (last accessed on December 15, 2023)
[89] Thien-An Tran Luu, Hong-Minh Le, Minh-Quyen Vu, Bich-Van Nguyen (Văn Lang Private University, Vietnam) 'AI application for solid waste sorting in Global South') available at https://sdgs.un.org/sites/default/files/2023-05/A41%20-%20Thien-An%20Tran%20Luu%20-%20AI%20Application%20for%20Solid%20Waste%20in%20the%20global%20south.pdf (last accessed on December 15, 2023).
[90] AMP Robotics, available at https://www.amprobotics.com/robotic-system (last accessed on December 15, 2023); About 2B0, available at https://2b0.io/ (last accessed on December 15, 2023)

streamlined transportation from collection points to processing facilities. Songdo City in South Korea stands out as a remarkable example, having completely transformed waste transportation with a revolutionary truck-free waste disposal system.[91] Remarkably, Songdo City employs a 'pneumatic waste disposal system' which eliminates the need for street garbage bins and traditional garbage trucks.[92] When individuals dispose of garbage in designated bins throughout the city, the waste is automatically transported through an underground network of pressurised pneumatic tubes to the central waste processing facility.[93] In the waste processing facility, waste undergoes sorting and is then directed either to the recycling facility or the incineration plant. The heat generated during the incineration process is then distributed to the buildings in Songdo. Similar technological innovation is also used in the Al Raha Beach, Abu Dhabi.[94] The technology relies on a network of underground pneumatic waste pipes, functioning as an advanced system for the collection and transportation of waste. The use of such automated waste collection technology not only streamlines waste transportation but also significantly reduces the environmental impact associated with traditional waste management practices.

While the immediate elimination of garbage trucks may not be universally feasible, there is a concerted effort to enhance their efficiency through innovative technology. The garbage truck weighing mechanism is one such mode by which this is done. The mechanism is used to measure and store the weight of waste containers, and this stored data is later used to predict fill levels accurately.[95] The predictive technology allows waste collection companies to discern when a truck is nearing capacity, enabling strategic planning for timely waste collection trips and ultimately reducing annual collection costs.

3.1.3 Advancements in Recycling and Disposal Techniques

Recycling and resource recovery at the disposal stage enable production and consumption of goods while minimising the depletion of natural resources and energy. It further diminishes the adverse impact on the environmental system. The concept of waste valorisation has emerged at this stage as a transformative process, encompassing the reuse, recycling, or composting of waste materials to generate more valuable products including materials, chemicals, fuels, or alternative energy sources.[96] Compared to other stages of waste management, this stage of the waste management

[91] Olesya Benedikt (2016), Changing Worlds Idelogies, Utopias and Ambitions in Science & Technology, https://gjss.org/sites/default/files/issues/full/GJSS%20Vol%2012-2.pdf#page=17 (last accessed on December 15, 2023)
[92] Baek, Insoo, 'A study on the sustainable infrastructure of the Songdo City Project : from the viewpoint of the metabolic flow perspective', available at https://scholar.sun.ac.za/handle/10019.1/96906 (last accessed on December 15, 2023)
[93] Lucy Williamson (2013),'Tomorrow's Cities: Just how smart is Songdo?', BBC News, 2 September, available at https://www.bbc.com/news/technology-23757738 (last accessed on December 15, 2023)
[94] Al Raha Beach Case Study, available at https://www.scribd.com/document/346148709/Al-Raha-Beach-Case-Study-Rev1-151111-0 (last accessed on December 15, 2023)
[95] Foued Melakessou et al., Heterogeneous Sensing Data Analysis for Commercial Waste Collection, Sensors (Basel), Vol. 20(4), February 2020, available at https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7071114/ ; Janki Govani et al., Chapter 4 - New generation technologies for solid waste management, Current Developments in Biotechnology and Bioengineering, Elsevier, (2021), Pages 77-106, ISBN 9780128210093, available at https://doi.org/10.1016/B978-0-12-821009-3.00015-4 (last accessed on December 15, 2023)
[96] Xiang Wang, Chong Li, Chun Ho Lam, Karpagam Subramanian, Zi-Hao Qin, Jin-Hua Mou, Mushan Jin, Shauhrat Singh Chopra, Vijay Singh, Yong Sik Ok, Jianbin Yan, Hong-Ye Li, Carol Sze Ki Lin,
Emerging waste valorisation techniques to moderate the hazardous impacts, and their path towards sustainability, Journal of Hazardous Materials, Volume 423, Part A, 2022, 127023, ISSN 0304-3894, available at

process has received substantial interest in terms of research and innovations owing to the range of benefits derivable from what is discarded as waste. The imposition of the EPR and Polluter Pays principle has also impacted the level of participation of the private sector in this stage.[97] The range of technologies developed at the recycling/disposal stage ranges from repurposing end-of-life products for alternative use to implementing advanced waste valorisation techniques such as plasma gasification,[98] pyrolysis,[99] incineration, etc.[100] In some countries like Sweden, the system of deriving energy from waste accounts for a percentage of the country's overall supply of energy.[101]

In addition to advancements across various phases of waste management, the technology has progressed to a point where it can assist in gathering real-time data on the processes involved. An exemplary illustration of such technological advancement is the 'Allbaro' system of South Korea.[102] Allbaro is an online waste disposal verification system which actively monitors all activities related to waste transportation and disposal. It meticulously records the quantity of waste collected and transported, and further analyses truck routes, documents licenses and authorisations, and aggregates statistics with the help of Global Positioning Systems ("GPS") to facilitate evidence-based policy formulation.[103] The data collected by Allbaro serves as a foundation for generating annual statistical reports on waste management and conducting in-depth statistical analysis on the efficacy of the waste management process. Hence, from collection to transportation, sorting, and ultimate disposal or recycling, technology has emerged as a transformative force, streamlining processes and optimising resource utilisation. The examples from diverse showcase the vast potential of technological advancements in addressing the complex challenges of waste management.

3.2 Innovative Technologies and Public Sector in Indian SWM

Building upon the significance of technology in MSW management, India has also embarked on a transformative journey of imbibing technologies in the SWM framework. Kabbadiwalla Connect[104]

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https://www.sciencedirect.com/science/article/pii/S0304389421019919 (last accessed on December 15, 2023).

[97] European Union, Ministry of the Environment (2014) Global Forum on Environment: Promoting Sustainable Materials Management through Extended Producer Responsibility (EPR) (Online), available at https://www.oecd.org/environment/waste/Global%20Forum%20Tokyo%20Issues%20Paper%2030-5-2014.pdf (last accessed on December 15, 2023).

[98] Eric Sanjaya, Ali Abbas, Plasma gasification as an alternative energy-from-waste (EFW) technology for the circular economy: An environmental review, Resources, Conservation and Recycling, Volume 189, (2023), available at https://doi.org/10.1016/j.resconrec.2022.106730 (last accessed on December 15, 2023).

[99] K. Radhakrishnan, P. Senthil, Kumar, Gayathri Rangasamy, L. Praveen Perumal, S. Sanaulla, S. Nilavendhan, V. Manivasagan, K. Saranya, A critical review on pyrolysis method as sustainable conversion of waste plastics into fuels, Volume 337, (1 April 2023), available at https://www.sciencedirect.com/science/article/abs/pii/S0016236122037140 (last accessed on December 15, 2023).

[100] Anirban Goutam Mukherjee, Uddesh Ramesh Wanjari, Rituraj Chakraborty, 'A review on modern and smart technologies for efficient waste disposal and management', Journal of Environmental Management, Volume 297, (2021), ISSN 0301-4797, available at https://doi.org/10.1016/j.jenvman.2021.113347 (last accessed on December 15, 2023).

[101] How Sweden is Successfully Turning Waste to Energy, available at https://earth.org/sweden-waste-to-energy/ (last accessed on December 15, 2023).

[102] Republic of Korea, Ministry of Environment (2008). Korea Environmental Policy Bulletin – Allbaro, https://wedocs.unep.org/20.500.11822/9044 (last accessed on December 15, 2023).

[103] Namil Um, Yoon Soo Park, Tae-Wan Jeon, 'An improved strategy for effectively managing the transboundary movement of waste based on the Basel convention: A case study in South Korea', Heliyon, Volume 9, Issue 6, (2023), e16496, ISSN 2405-8440, available at https://doi.org/10.1016/j.heliyon.2023.e16496 (last accessed on December 15, 2023).

[104] Indian firm's digital solution for urban waste pickers, (July 30, 2021) available at https://aiforgood.itu.int/indian-firms-digital-solution-for-urban-waste-pickers/ (last accessed on December 15, 2023).

which utilises AI-powered solutions for connecting informal waste collectors with recycling facilities, and Phool,[105] a company that repurposes floral waste discarded by temples are some among many examples of innovation growing in the Indian landscape. Moreover, technologies such as vermi-composting, decentralised composting, pit composting, and anaerobic digestion have been implemented by various municipalities in India for waste treatment.[106] The utilisation of these technologies reflects a multi-faceted approach to address the diverse challenges posed by different types of waste.

In addition to these grassroots innovations, the public sector has played a pivotal role in steering the trajectory of technological advancements in SWM. Research grants by public sector institutions have been instrumental in fostering innovation and technological advancements. For instance, the government funded research focusing on the novel Black Soldier Fly Larvae ("BSFL") Technology,[107] was able to demonstrate the capability of the technology to successfully segregate and treat the biodegradable component within commingled MSW. Another notable outcome of the public sector support is the development of a new high-rate biomethanation technology for the integrated treatment of sewage and organic solid waste. This technology, supported by the 'Waste Management Technology' program of the Department of Science & Technology ("DST"), incorporates an Anaerobic Gas lift Reactor ("AGR") and Nanofiltration ("NF") for the treatment of sewage and organic solid waste. The decentralised treatment system benefits areas generating 2 to 4 million litres per day of sewage and 5 to 10 metric tons per day of organic solid waste by producing quality water with a small footprint and lower costs. [108]

At the policy level, the establishment of the Standing Committee on Technology for Waste Management in 2021 showcases the public sector's commitment to promoting financially viable and sustainable innovations in waste management technologies.[109] This proactive stance led to the development of the Protocol for Evaluation of Technology for Waste Management, setting the standards for evaluating technologies suitable for managing various types of waste in the country.[110] Further, schemes like the Swachatta Startup Challenge launched as part of the Swachh Bharat Mission (Urban) ("SBM (U)") in 2022, which provides startups with a platform to present novel

[105] Phool – A Story of Change, (July 20, 2021), available at https://www.unesco.org/en/articles/phool-story-change (last accessed on December 15, 2023).
[106] Satpal Singh, Chapter 12: Decentralized Solid Waste Management In India: A Perspective On Technological Options, Cities: 21st Century India, Bookwell Publications, available at https://smartnet.niua.org/sites/default/files/webform/Decentralized%20SWM%20in%20India.pdf (last accessed on December 15, 2023).
[107] Debasree Purkayastha, Sudipta Sarkar, Black soldier fly larvae for treatment and segregation of commingled municipal solid waste at different environmental conditions, Journal of Environmental Management, Volume 302, Part A, (2022), ISSN 0301-4797, available at https://doi.org/10.1016/j.jenvman.2021.114060 (last accessed on December 15, 2023).
[108] New High Rate Bio-methanation Technology for Integrated Treatment of Sewage & Organic Solid Waste Useful for Decentralized Applications, PIB, (September 3, 2021), available at https://pib.gov.in/PressReleasePage.aspx?PRID=1751723#:~:text=An%20integrated%20model%20plant%20comprising,bio%20manure%2C%20and%20reusable%20water (last accessed on December 15, 2023).
[109] Protocol for Evaluation of Technology for Waste Management, Central Pollution Control Board Delhi (June 2021), available at https://cpcb.nic.in/uploads/Technology_WM_1.pdf (last accessed on December 15, 2023)
[110] Ibid.

solutions in the field of SWM demonstrates the active role public sector plays in promoting entrepreneurial spirit and innovation culture in the country.[111]

WtW mission also indirectly benefits the innovation landscape by incentivising the development and implementation of sustainable technologies and practices in waste management. The introduction of the Plastic Bank in Varanasi, which provides monetary compensation for bringing in plastic waste, and the Polythene Banks in Dehradun, where citizens can deposit plastic for compensation are some notable examples in this regard.[112] Such sustainable solutions embraced by the municipalities in the area not only optimise waste collection processes but also revolutionise consumer involvement in waste disposal mechanisms.[113] The Decentralised Waste Management Technology Park set up in Delhi recently, in collaboration with the WtW Mission, also deploys new and innovative technologies such as 'Xaper' for semi-automated waste segregation, 'Plasma Pyrolysis Unit' for thermal disintegration, 'Enviro-RISE R-A1100' for solid waste removal, 'Gasifier' for waste gasification, and 'Johkasou STP' for decentralised sewage treatment and water recycling.[114]

Moreover, the government has expressed its inclination toward innovative technologies in waste management through their adoption and utilisation. One noteworthy example is the initiative by the public sector undertaking, Steel Authority of India ("SAIL"), which introduced IoT-enabled waste bins across the Delhi Municipal Corporation area. These smart bins, deployed in 2019, automatically transmit signals to waste collection vehicles when they reach full capacity, optimising waste collection processes.[115] Similarly, the Indore Municipal Corporation has also set up an automated facility capable of segregating dry waste into 35 categories.[116]

However, the development and adoption of innovations in the waste management sector in India have not kept pace with the increasing growth of waste in the country. Although the government has introduced noticeable and instrumental changes in the waste management system in the last decade, particularly to promote innovation in the sector, the overall implementation and scale-up of innovative technologies face challenges. These challenges include limited financial resources,

[111] Startup Gateway for Garbage Free Cities, PIB Delhi, (December 5, 2023), available at https://pib.gov.in/PressReleasePage.aspx?PRID=1982743 (last accessed on December 15, 2023)
[112] Bring plastic to this bank, take money, The Times of India, (April 6, 2021), available at https://timesofindia.indiatimes.com/city/varanasi/bring-plastic-to-this-bank-take-money/articleshow/81919872.cms (last accessed on November 22, 2023); 'Polythene bank' to tackle the plastic menace in Dehradun, Times of India, (September 30, 2023) https://timesofindia.indiatimes.com/city/dehradun/polythene-bank-to-tackle-plastic-menace-in-dehradun/articleshow/104055991.cms (last accessed on December 15, 2023)
[113] Sixth Plastic Bank set up in Doon, Times of India (December 18, 2019), available at https://timesofindia.indiatimes.com/city/dehradun/sixth-plastic-bank-set-up-in-doon/articleshow/72858908.cms (last accessed on December 15, 2023)
[114] Inauguration of Decentralised Waste Management Technology Park at New Jaffrabad, East Delhi, PIB Delhi, (March 28, 2022), available at https://www.pib.gov.in/PressReleasePage.aspx?PRID=1810412 (last accessed on December 15, 2023)
[115] Smart Garbage Station utilizing SAIL's Stainless Steel Bins will help to give a smart, clean and beautiful look to the cities, Steel Authority of India Limited (March 18, 2019) available at https://sail.co.in/en/sail-news/sails-stainless-steel-garbage-bin-will-be-used-develop-smart-garbage-stations-national (last accessed on December 15, 2023)
[116] Ashok Kumar, 'Swachh upgrade: Indore Municipal Corporation to segregate your dry waste into 35 categories', Times of India, (November 26, 2021) http://timesofindia.indiatimes.com/articleshow/87924769.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst (last accessed on December 15, 2023)

fragmented waste management infrastructure, and the need for increased awareness and education at both the institutional and community levels. While there have been successful pilot projects and localised initiatives, scaling up these innovations to a national level remains a complex task. The diverse nature of waste streams and variations in waste generation patterns across regions require customised solutions. Additionally, the integration of innovative technologies into existing waste management practices demands strategic planning, policy support, and collaborative efforts.

To address these challenges and further catalyse innovation in waste management, there is a need for comprehensive policy frameworks, increased investment in R&D, and strategic partnerships between the public and private sectors. Moreover, raising awareness and promoting community engagement in waste management practices are essential components of a sustainable and innovative waste management ecosystem. In conclusion, while India has made significant strides in embracing innovative technologies for waste management, there is a need for concerted efforts to achieve widespread adoption of innovative technologies in SWM.

3.3 Role of Public Sector in Promotion of Innovations in Waste Management: Best Practices from South Korea and Germany

In the pursuit of sustainable waste management practices, the role of the public sector emerges as a key driver in fostering innovation. Both Germany and South Korea stand as compelling examples, having emerged as technologically advanced countries in the sphere of MSW management owing to multiple factors, including prominent support by the government. The South Korean government has made substantial investments in R&D, bolstering its technological industries with financial backing, and tax incentives. The Ministry of Environment, which is the primary arm of the Korean government for municipal waste management in the country, has adopted an ear-to-the-ground approach concerning MSW treatment by not restricting itself merely to setting up recycling targets[117] and fixing goals for both local and businesses relating to MSW treatment. It also ensures that there are inventions of technologies in the SWM sector. Similarly, Germany stands out as a global leader in waste management technology, contributing a remarkable 25% to the world market in this sector.[118] The various factors that have facilitated the growth of innovative technologies for SWM in Korea and Germany are as follows:

3.3.1 Legal Instruments as a catalyst for innovation

One of the most integral roles the public authorities play in promoting innovation in any sector is creating a conducive environment for innovation. This commitment is evident in the legislative efforts of both Germany and South Korea. Notably, In Korea, in addition to the enactment which provides the basic framework for waste management, the government has enacted a specific legal

[117] Republic of Korea, Ministry of Environment, 'Land & Waste ' Available at https://eng.me.go.kr/eng/web/index.do?menuId=466#:~:text=By%202030%2C%20Korea%20aims%20to%20reduce%20plastic%20wastes,from%20production%2C%20consumption%2C%20disposal%2C%20collection%2F%20separation%20to%20recycling. (last accessed on December 15, 2023)

[118] Germany, Federal Ministry for the Environment, Modern Waste Management Goals And Path, available at https://www.giz.de/en/downloads/giz2016-en-vdma_Modern_Waste_Management.pdf (last accessed on December 15, 2023).

framework for recycling waste namely, the Act for Promotion of Saving and Recycling of Resources, with the objective to facilitate the use of recycled resources through waste minimisation and upcycling.

Moreover, the 2016 implementation of the Framework Act on Resource Circulation in South Korea underscores the commitment to establishing a society that actively circulates resources. This law encourages innovative approaches and technologies by prioritising reuse and recycling of waste materials over traditional disposal methods like incineration or landfilling. It emphasises the significance of innovation in waste management by placing responsibility on business entities to develop technologies that effectively reduce the volume of disposed of waste.[119] Further, the introduction of the Resource Circulation Performance Management Program ("RCPMP") in the legislation mandates provincial governments and businesses to establish goals related to final waste disposal and resource circulation. These predefined targets serve as a strategic roadmap for businesses, aligning their initiatives with broader waste reduction and resource circulation objectives. Businesses and companies that successfully meet the targets outlined in the RCPMP are entitled to receive comprehensive support from the government, spanning administrative, financial, and technological domains.[120] These mandatory provisions act as catalysts, enabling the growth of innovations in the waste management industry.

Similarly, the German government has cultivated a regulatory framework that actively promotes innovation in waste management. Beyond the foundational legal structures governing waste, Germany has implemented targeted legal frameworks to stimulate advancements in resource utilisation and recycling. One notable aspect is the Packaging Ordinance, which places responsibility on manufacturers for the recycling and proper disposal of their packaging materials. This regulation fostered a culture of EPR, motivating businesses to innovate in product design and packaging to enhance recyclability. A report published by Organisation for Economic Co-operation and Development ("OECD") on Global Plastics Outlook noted that the impact of the Packaging Ordinance on innovation was such that within five years of law's introduction, the market of recycling innovation spurted by 190%.[121] The Circular Economy Act, which is the primary legislation governing MSW in Germany, also suggests creating economic instruments to promote research and innovation within the waste prevention programme to promote technological innovation in the field.[122]

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[119] Intorduction of the Framework Act on Resource Circulation towards Establishing a Resource-Circulating Society in Korea, Korea Environmental Policy Bulletin, Vol. XIV Isssue2, (2016), available at https://www.greenpolicyplatform.org/sites/default/files/downloads/policy-database/Introduction%20of%20the%20Framework%20Act%20on%20Resource%20Circulation%20toward%20Establishing%20a%20Resource-Circulating%20Society%20in%20Korea.pdf (last accessed on December 15, 2023).

[120] Ibid.

[121] Global Plastics Outlook Economic Drivers, Environmental Impacts and Policy Options, (April 2022), Page. 109, available at https://read.oecd-ilibrary.org/environment/global-plastics-outlook_de747aef-en#page109 (last accessed on December 15, 2023).

[122] Reorganising the Law on Closed Cycle Management and Waste Act, (2012), Annex 5, available at https://www.bmuv.de/fileadmin/Daten_BMU/Download_PDF/Abfallwirtschaft/kreislaufwirtschaftsgesetz_en_bf.pdf (last accessed on December 15, 2023).

3.3.2 Investing in Innovation through Public Procurement

Public procurement of technologies is a critical element that can drive demand for innovations in SWM in a country.[123] Public authorities in Korea are required to purchase products that have received environmental certifications such as Eco Label or Good Recycling Mark, thereby encouraging the growth of innovations in the waste management sector.[124] The Act on Promotion of Purchase of Green Products in South Korea specifies the responsibilities, processes and procedures to be followed by public institutions when procuring products.[125] The government procurement and use of novel and green products in the waste management system is very common in South Korea.

Case Study :Ecube Labs and Seoul

Seoul is one of the most populated cities in the world and was earlier facing the issue of frequent waste collection and overflow.[126] The Seoul Metropolitan Government collaborated with a local company, Ecube Labs, which found the solution. The company provided the government with a smart bin that utilised solar-powered technology and wireless connectivity to redefine the capabilities of trash compactors. The technology controlled by IoT helped reduce waste collection costs by 83% and frequency of collection by 66 %.[127] The successful collaboration between the public and private sectors illustrates how advancements in smart waste management solutions can be achieved through innovative partnerships. Today, the local company has transformed into an international company consisting of various innovative solutions with a presence in multiple countries like Colombia, America, etc.[128]

Like Korea, Germany has also implemented an environment-friendly procurement framework for public authorities.[129] All public contracts with a specified threshold are mandated to consider the social and environmental nature in addition to the principles of economic efficiency. Procurement is a critical channel through which government promotes innovation. The existing legislation and

[123] Bastian Krieger, Vera Zipperer, Does green public procurement trigger environmental innovations?, Research Policy, Volume 51, Issue 6, (2022), ISSN 0048-7333, available at https://doi.org/10.1016/j.respol.2022.104516 (last accessed on December 15, 2023).

[124] Policy instruments for waste and materials management, Waste Management and the Circular Economy in Selected OECD Countries: Evidence from Environmental Performance Reviews, available at https://www.oecd-ilibrary.org/sites/9789264309395-en/1/2/4/index.html?itemId=/content/publication/9789264309395-en&_csp_=eb1a6df214d830e8947687c08b10a07b&itemIGO=oecd&itemContentType=book#section-d1e5535 (last accessed on December 15, 2023).

[125] Act On Promotion Of Purchase Of Green Products, available at https://faolex.fao.org/docs/pdf/kor136730.pdf (last accessed on December 15, 2023).

[126] Ecube Labs, 'Case Study: City of Seoul', available at https://www.ecubelabs.com/references/city-of-seoul/ (last accessed on December 15, 2023).

[127] Tcyrempilova Serzhena, The Circular Economy In South Korea. The Case Of Samsung, (2019), available at http://real.mtak.hu/109043/1/HAE36-75-80.pdf (last accessed on December 15, 2023).

[128] Smart Waste Management Solutions, Ecubelabs available at https://www.ecubelabs.com/ (last accessed on December 27, 2023);
Elaine Ramizer, 'Internet of Bins: Smart, solar powered trashcans in Colombian cities', The Guardian, (June 14, 2016) available at https://www.theguardian.com/sustainable-business/2016/jun/14/internet-of-bins-smart-solar-powered-trashcans-in-colombian-cities (last accessed on December 27, 2023).

[129] Section 46- Obligation to provide advice on waste
(1) The public disposal providers within the meaning of section 20 shall be obliged, within the framework of the tasks conferred on them, and through self-administration, to provide information and advice concerning possibilities for preventing, recovering and disposing of waste. The chambers of commerce and industry, chambers of trade and chambers of agriculture, shall also be obliged to provide advice, The Circular Economy Act, available at https://www.bmuv.de/fileadmin/Daten_BMU/Download_PDF/Abfallwirtschaft/kreislaufwirtschaftsgesetz_en_bf.pdf (last accessed on December 15, 2023).

practices in both countries indicate that green purchasing is employed to encourage innovation in the waste management industry.

3.3.3 Research and Development of Innovative Solutions

Both South Korea and Germany recognise the significance of investing in R&D to drive transformative solutions in waste management. In Germany, the government has facilitated the growth of innovation in waste technologies through multiple funding channels. The AI Lighthouse Projects for the Environment program initiated by the Federal Ministry for the Environment in Germany has allocated around EUR 46 million to support 35 projects employing AI for advancing the objective of environmental sustainability. [130] Among these projects, innovations related to SWM include WERTIS-KI which employs AI to enhance waste segregation awareness among users through a mobile app, and RecycleBot which optimises plastic recycling using AI-driven collaborative robots.[131] Additionally, Germany's Environmental Technologies Export Initiative led by the Federal Ministry for the Environment provides additional funding to promote the global application of environmental technologies developed in the Germany. The funding programme supports German GreenTech small and medium-sized enterprises ("SMEs") in waste management solutions to advance their international presence and competitiveness in environmental technologies.[132] Further, the Environment Innovation Programme established by the German Environment Ministry also fund industry-scale pilot projects in the waste sector provided the technology can reduce or prevent environmental harm.[133] In addition, an array of financing options is available to waste management corporations in Germany, facilitating the development of scientific innovations within the sector.[134]

South Korea, on the other hand, fosters an innovation-friendly environment, promoting R&D in waste management technologies. This is evident in the fact that South Korea is a global leader in waste management technologies, holding the fourth position globally in total patents related to climate change mitigation technologies in waste management. The substantial increase in patents, rising from 22 to 946 between 1990 and 2016 in South Korea,[135] highlights the international competitiveness of South Korean research in innovative waste technologies and the favourable environment provided by the public sector to tech innovators, and private entities. Also, the government's investment of KRW 26.7 billion in 2008 in clearer production technology and more

[130] BMUV funding initiative- AI lighthouse projects for the environment, climate, nature and resources, available at https://www.bmuv.de/en/topics/digitalisation/overview-digitalisation/bmuv-funding-initiative-ai-lighthouse-projects-for-the-environment-climate-nature-and-resources (last accessed on December 13, 2023)

[131] Zukunft Umwelt Gesellschaft, 'Verbund- AI Recyclables information systems with artificial intelligence', https://www.z-u-g.org/foerderung/ki-leuchttuerme-fuer-umwelt-klima-natur-und-ressourcen/projekt/wertis-ki/ (last accessed on December 13, 2023)

[132] German RETech Partnership, BMUV, available at https://www.bmuv.de/en/topics/water-management/circular-economy-overview/international-policy/german-retech-partnership#:~:text=RETech%20serves%20as%20a%20contact,and%20consultants%20considering%20international%20activities. (last accessed on December 13, 2023)

[133] Funding programs of the BMU, German RETech Partnership, available at https://www.retech-germany.net/en/themes/support-programs/funding-programs-of-the-bmu (last accessed on December 13, 2023)

[134] Other funding programs of are, ERP Start-Up Loan Startgeld, ERP Start-Up Loan Universal, the International climate initiative (IKI), Federal Environment Ministry's Advisory Assistance Programme and AI Lighthouse Projects for the Environment, Climate, Nature, and Resources, available at https://www.bmwk.de/Redaktion/EN/Dossier/financing-for-start-ups-company-growth-and-innovations.html#:~:text=The%20ERP%20Start%2Dup%20Loans%20programme%20consists%20of%20two%20parts,out%20more%20(in%20German), (last accessed on December 15, 2023).

[135] Mele, M., Magazzino, C., Schneider, N. *et al.* Innovation, income, and waste disposal operations in Korea: evidence from a spectral granger causality analysis and artificial neural networks experiments. *Econ Polit* 39, 427–459 (2022). https://doi.org/10.1007/s40888-022-00261-z (last accessed on December 15, 2023)

than 140 sponsored environmental and technology development projects has yielded tangible results. It has led to continuous improvements, reducing commercial waste and enhancing ecological and economic efficiency in the country. [136]

3.3.4 Large–scale adoption of technologies in SWM practices

In addition to legal instruments, public procurement strategies, and R&D initiatives, both Germany and South Korea exhibit a strong commitment to the large-scale adoption of technologies in MSW practices. The introduction of the RFID-based weighing system for waste collection in South Korea is a notable example. Since 2012,[137] the technology has been used across various regions of South Korea to calculate the weight of waste generated in the country.[138] Aluminium bins are strategically placed in common recycling areas for residents to deposit food waste. Each resident possesses an electronic identification tag with encoded information. When an individual touches the card to the RFID machine, the system recognises them and calculates the waste weight. The residents are charged a monthly fee accordingly. As of 2017, around 137 local governments and approximately 3,550,000 households had adopted the technology.[139] This initiative by the government aids in accurately recording data on the quantity of waste generated and the corresponding waste fees to be imposed on individuals or businesses.[140] The data is also utilised by the Allbaro system to prevent illegal disposal of waste in the country.[141]

Germany's waste management framework is characterised by strict enforcement of the waste hierarchy, placing a strong emphasis on both industrial and household waste management. This commitment positions Germany as an ideal market for the adoption of high-tech innovations in the sector. The European Union's target recycling rates further incentivise businesses and individuals to embrace new innovations. Notable innovations such as Stadler, [142] providing automated sorting systems contribute to the sector's advancements. Further, the mandatory pre-treatment requirements, in place since 2005, encourage the development and adoption of innovative technologies and processes aimed at optimising the treatment of waste before its final disposal.

The examples mentioned above highlight that the public sector plays a major role in effective SWM. The successful tech-innovations of private players in driving innovation in waste management sector are closely intertwined with the proactive role played by the government. The approaches adopted

[136] The report of 18th-19th Session of the Commission on Sustainable Development (CSD) National Report, available at, https://sustainabledevelopment.un.org/content/documents/dsd/dsd_aofw_ni/ni_pdfs/NationalReports/korea/full_report.pdf (last accessed on December 13, 2023)
[137] Leon Kaye (2012), 'Swiss card Technology introduced for food waste bis', The Guardian, 26 January, available at https://www.theguardian.com/sustainable-business/south-korea-swipe-card-food-waste (last accessed on December 13, 2023)
[138] Kwangho Jung, Sabinne Lee, 'A systematic review of RFID applications and diffusion: key areas and public policy issues', J. open innov. 1, 9 (2015). https://doi.org/10.1186/s40852-015-0010-z (last accessed on December 13, 2023)
[139] Kwangho Jung, Sabinne Lee, 'The Role of Community-led Governance in Innovation Diffusion: The Case of RFID Waste Pricing System in the Republic of Korea Sustainability', 2018; 10(9):3125. https://doi.org/10.3390/su10093125 (last accessed on December 13, 2023)
[140] OECD Environmental Performance Reviews: Korea 2017, OECD Environmental Performance Reviews, OECD Publishing, (2017), https://doi.org/10.1787/9789264268265-en (last accessed on December 13, 2023)
[141] Republic of Korea, Ministry of Environment (2008). Korea Environmental Policy Bulletin - Allbaro (Online Waste Disposal Verification System) available at https://wedocs.unep.org/20.500.11822/9044 (last accessed on December 13, 2023)
[142] Stadler- Sorting Plants, available at https://w-stadler.de/en/sorting-plants (last accessed on December 13, 2023)

by both South Korea and Germany have proven effective in managing solid waste. India can draw inspiration from the success stories of advanced waste sorting systems, the digitalisation initiatives in waste reporting, and the incorporation of advanced technologies in waste management infrastructure. By learning from these global examples, India can adapt its waste management strategies to address its unique challenges, aiming for more sustainable and efficient systems in the future.

4. ROLE AND IMPACT OF INDIA'S ONGOING WASTE MANAGEMENT INITIATIVES

Waste management stands as a pivotal challenge in the contemporary context, demanding strategic interventions and innovative approaches to alleviate the environmental burden while fostering economic sustainability. National Missions, integral to the government's commitment to citizens well-being, address diverse objectives such as rural development,[143] healthcare,[144] and education.[145] Amidst these, waste management emerges as a critical focus due to escalating waste generation.[146]

In the last decade, more importantly, since 2014, the management of solid waste is an aspect that has received considerable attention from governments at all levels. The public sector has played an active role in bringing about significant change in waste management practices, recognizing its multifaceted impact on environmental health and economic prosperity. The SBM, for instance, has been instrumental in driving sanitation coverage and waste management practices across the nation. Between 2014 and 2019, the SBM led to the construction of over 10 crore individual household toilets, resulting in 100% sanitation coverage.[147] Moreover, 50% of villages achieved Open Defecation Free ("ODF") status.[148]

India's continued efforts to enhance efficiency in the SWM framework is demonstrated by the significant progress made in waste processing capacity. In 2014, ULBs in India had a meagre 18 per cent waste processing capacity.[149] However, by 2022, these ULBs have showcased a remarkable improvement by successfully processing 73 per cent of the waste generated.[150] The key initiatives undertaken by the government for the improvement of SWM in the country are as follows:

[143] Ministry of Rural Development, https://rural.nic.in/en/swachhgram (last accessed on December 24, 2023)
[144] Ministry of Health and Family Welfare, 'National Health Mission', Annual Report 2015-16, 11- 23, https://main.mohfw.gov.in/sites/default/files/569875321456325665 78.pdf (last accessed on December 24, 2023)
[145] Ministry of Education, https://www.education.gov.in/technology-enabled-learning-0 (last accessed on December 24, 2023)
[146] Sunil Kumar, Stephen R. Smith, Geoff Fowler, Costas Velis, S. Jyoti Kumar, Shashi Arya, Rena, Rakesh Kumar and Christopher Cheeseman, 'Challenges and opportunities associated with waste management in India',
(22 March 2017), available at https://doi.org/10.1098/rsos.160764 (last accessed on December 24, 2023)
[147] About Swachh Bharat Mission, available at https://swachhbharatmission.gov.in/sbmcms/index.htm (last accessed on December 24, 2023)
[148] India Achieves Another Major Sanitation Milestone - 50% Villages Are Now ODF Plus Under Swachh Bharat Mission Grameen Phase II, PIB Delhi, (May 10, 2023) available at https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1923036 (last accessed on December 24, 2023)
[149] Waste-Wise Cities- Best practices in municipal solid waste management, Niti Aayog and Centre for Science and Environment (2021), available at https://www.niti.gov.in/sites/default/files/2021-12/Waste-Wise-Cities.pdf (last accessed on November 22, 2023)
[150] Ibid.

National Urban Sanitation Policy	•This policy aims to sanitize urban cities in India through community-driven initiatives. It focuses on establishing proper systems of segregation, collection, transportation, processing and treatment of waste.
Jawaharlal Nehru National Urban Renewal Mission (JNNURM)	•The sub-mission, Urban Infrastructure and Governance, under JNNURM focus on creating stronger infrastructure projects relating to water supply and sanitation, sewerage, and solid waste management in the country.
National Bioenergy Programme	•NBP supports setting up of Bioenergy projects in the country under the components: Waste to Energy Programme, Biomass Programme, Biogas programme. This programme promotes the utilization of surplus biomass and also provide an additional source of income for rural households.
The National Action Plan for Municipal Solid Waste Management by CPCB	•This action plan was developed with the aim to reduce the quantity of waste and lay down time-targeted plan for management of MSW for each city and town.
Swachh Bharat Mission (Grameen)	•SWM (G) was implemented in 2014 to eliminate open defecation in India and further promoting cleanliness and hygiene in rural areas. In 2021 Phase II i.e ODF-Plus was launched with the objective to provide interventions for safe management of solid and liquid waste in villages.
Swachh Bharat Mission (Urban)	•The SWM (U) was devised with the aim to devise a proper, door to door, waste collection and disposal system, both in villages as well as urban areas. One of main intent of the mission was to modernise MSW management through scientific methods and bring behavioural change regarding healthy sanitation practices in India.
Waste to Wealth Mission	•This mission focus on generating wealth from waste. It aims to strengthen the present waste management system by introducing technological innovations to solve the issue of waste in the nation.
Swachhata Startup Challenge Initiative	•The programme was initiated to create an enabling environment for startups and entrepreneurs to develop and innovate in the waste management sector.

Each of the aforementioned initiatives has multifaceted impacts on waste management practices, contributing significantly to various key areas.

4.1. Public Awareness

Waste is inherently produced as a result of human activities. Therefore, public awareness and participation stand as essential components in any waste management program. Awareness generation, through a country-wide Information, Education, and Communication ("IEC") strategy, was a key goal of the National Urban Sanitation Policy ("NUSP") of 2008.[151] NUSP implemented this goal by designating schools and students as pivotal agents for change. Further, the National School Sanitation Initiative ("NSSI") was established at the Central Board of Secondary Education ("CBSE") in collaboration with the Ministry of Human Resource Development ("MHRD") and GIZ to enhance awareness of sanitation and hygiene.[152] Further, competitions and awards, like the National Award Scheme for Sanitation for Indian Cities, encouraged cities and states to improve their performance,[153] serving as effective channels for promoting awareness among the larger public.[154] Since then, the government has rolled out multiple programmes and initiatives under SBM to generate awareness among the public. Around 15% of the total funding in SBM is devoted to public awareness.[155] Garbage Free City ("GFC") Star rating protocol is one such initiative where ULBs are encouraged to adopt best practices in waste management. It promotes healthy competition among cities through rankings based on parameters like 100% source segregation, door-to-door collection, and scientific waste management.[156] These initiatives have aided in addressing some of the immediate challenges regarding waste management and further laid foundation for behavioural change regarding waste.

4.2. Behavioural Change

Waste management initiatives under national missions have played a pivotal role in instigating transformative behavioural changes among citizens.[157] SBM stands out as a prime example, triggering a profound shift in people's attitude towards garbage.[158] Media campaigns, featuring songs and social media posts acted as potent tools for reshaping public mindsets.[159] The shift in behaviour

[151] National Urban Sanitation Policy, Ministry of Urban Development, Government of India, available at https://mohua.gov.in/upload/uploadfiles/files/NUSP_0.pdf (last accessed on December 24, 2023)
[152] Support to the National Urban Sanitation Policy (NUSP), GIZ, (June 2012)available at https://sswm.info/sites/default/files/reference_attachments/WALTHER%202012%20SNUSP.pdf (last accessed December 27,2023)
[153] Supporting a Community-Driven Sanitation Policy in India, (2019), https://www.citiesalliance.org/resources/publications/project-case-studies/supporting-community-driven-sanitation-policy-india (last accessed on December 24, 2023)
[154] National Urban Sanitation Policy, Ministry of Urban Development, Government of India, available at https://mohua.gov.in/upload/uploadfiles/files/NUSP_0.pdf (last accessed on December 24, 2023)
[155] Sadhan Kumar Ghosh, Swachhaa Bharat Mission (SBM) – A Paradigm Shift in Waste Management and Cleanliness in India, Procedia Environmental Sciences, Volume 35, 2016, Pages 15-27, ISSN 1878-0296, available at https://doi.org/10.1016/j.proenv.2016.07.002 (last accessed on December 27, 2023)
[156] President of India Announces Results of Swachh Survekshan 2022, PIB Delhi, (October 01, 2022) available at https://pib.gov.in/PressReleasePage.aspx?PRID=1864209#:~:text=Indore%20further%20cemented%20its%20position,5%2Dstar%20Garbage%20Free%20certifications. (last accessed on December 24, 2023)
[157] Swachh Bharat Abhiyan, available at https://www.pmindia.gov.in/en/major_initiatives/swachh-bharat-abhiyan/ (last accessed on December 24, 2023)
[158] Policy Guidelines- Promoting Behaviour Change for Strengthening Waste Segregation at Source, NITI Aayog, (November 2021), available at https://www.niti.gov.in/sites/default/files/2021-12/PromotingBehaviourChange-forStrengtheningWasteSegregation-at-Source-PolicyGuidelines.pdf (last accessed on December 24, 2023);
Mohapatra, 'Projected Behavioural Change in Swachh Bharat Mission: A Public Policy Perspective', Indian Journal of Public Administration, 65(2), 451-474, available at https://doi.org/10.1177/0019556119863856 (last accessed on December 24, 2023)
[159] Progress Report on Multimedia Campaigns under Swachh Bharat Mission-Gramin, https://archive.pib.gov.in/4yearsofnda/Comprehensive-Materials/DWS.pdf (last accessed on December 24, 2023)

is evident in concrete outcomes, including the attainment of ODF status by over 50% of villages in India. SBM has also invested in trained staff capable of effective interpersonal communication with villagers and local communities to facilitate affirmative changes in the behaviour of individuals, both in rural and urban areas.[160]

The Swachhta Saarthi Fellowships, launched as part of the WtW initiative in 2021, aims to recognize and appreciate the contributions of individuals such as students, community workers/self-help groups ("SHGs"), and municipal/sanitary workers actively involved in addressing the challenges of waste management in a scientific and sustainable manner.[161] These fellowships, coupled with titles like 'Swachhata Doot' (messengers of cleanliness), 'Ganga Praharis'[162] or 'Swachhagrahis,'[163] have acted as powerful tools for recognizing and incentivizing the dedicated individuals contributing to waste management, thereby fostering a positive behavioural change and creating a sense of pride and responsibility within communities.[164]

4.3. Economic Impacts

While exact figures on the economic impact of national-level waste management missions remain vague, the initiatives and schemes introduced by the government for SWM have undoubtedly developed vehicles for revenue generation. The primary objective of the WtW initiative launched under SBM aimed to discover, formulate, and implement technologies for the effective treatment of waste, leading to energy generation, material recycling, and the extraction of valuable resources. The initiative has led to the development of a Decentralised Waste Technology Park in Delhi and a Decentralized Waste Incinerator in Bihar.[165] The objective of the project was to complement the Swachh Bharat and Smart Cities initiatives to foster financially viable circular economic models for waste management in the country.[166] Further, the process of converting household waste into cement kilns for road construction, utilizing plastic waste, has resulted in significant cost savings amounting to approximately INR 35,000–40,000 per kilometre.[167] This cost-effective technology implemented under the SBM addresses the issue of waste management and also, highlights the

[160] Dandabathula G, Bhardwaj P, Burra M, Rao PVVP, Rao SS. Impact assessment of India's Swachh Bharat Mission - Clean India Campaign on acute diarrheal disease outbreaks: Yes, there is a positive change. J Family Med Prim Care, (March 2019), available at doi: 10.4103/jfmpc.jfmpc_144_19 (last accessed on November 22, 2023)
[161] Swachhta Saarthi Fellowship, Office of the Principal Scientific Adviser to the Government of India, available at https://www.wastetowealth.gov.in/fellowship-home (last accessed on November 22, 2023)
[162] Ganga Prahari, available at https://nmcg.nic.in/wii/prgbggp.aspx (last accessed on December 24, 2023)
[163] Neha Pawar, 'Swacchagrahis: The frontline workers of India's largest sanitation program' India Waterpool, (April 13, 2021), available at https://www.indiawaterportal.org/articles/swacchagrahis-frontline-workers-indias-largest-sanitation-program (last accessed on December 24, 2023)
[164] Indian Sanitation Coalition, Swachhta Doots, available at https://www.indiasanitationcoalition.org/our-initiatives/swachhta-doots.html (last accessed on December 24, 2023)
[165] Current Project, Office of the Principal Scientific Adviser to GOI, available at https://www.wastetowealth.gov.in/current-intervention-listing (last accessed on December 27, 2023)
[166] Waste to Wealth, Office of the Principal Scientific Advisor to GOI, available at https://www.wastetowealth.gov.in/about-us. (last accessed on December 24, 2023)
[167] Plastic Waste Management- Issues, solutions & case studies, Ministry of Housing & Urban Affairs Government of India (March 2019), available at http://swachhbharaturban.gov.in/writereaddata/SBM%20Plastic%20Waste%20Book.pdf (last accessed on December 27, 2023)

economic advantages of adopting environmentally friendly practices in infrastructure development.[168]

Further, it is estimated that processing 50% of wet waste through bio-methanation in urban India could contribute a net profit of INR 2,460 crores annually by 2025.[169] Similarly, incorporating circular economy principles into the dry waste industry has the potential to generate a net benefit of INR 11,836 crores per annum.[170] The potential economic impacts of national initiatives can extend to employment opportunities, with an estimated creation of about 1 crore man-days during the implementation of these schemes, including manual labour in the construction of bio-methanation plants and MRFs.[171] Moreover, the proactive allocation of financial investment amounting to INR 10,000 crores for the development of 500 new WtW plants under the Galvanizing Organic Bio-Agro Resources Dhan ("GOBARdhan") initiative by the government further enhances the economic impact of waste management efforts.[172] These plants are slated to contribute to WtE through compressed biogas (CBG) plants and community or cluster-based plants. In Delhi, three WtE plants are already scientifically processing 5,900 tonnes of solid waste per day out of the total 11,000 tonnes collected, showcasing tangible progress in the WtE initiative. [173]

The abovementioned underline the diverse economic benefits of national-level waste management missions, resulting in not only revenue generation but also advancements in sustainable technology, cost savings through innovative practices, and potential job creation.

4.4. Socio – Environment Impact

The national initiatives have brought about significant positive impacts on the environment. According to data from the SBM dashboard, ongoing schemes and missions at the national level have resulted in the remediation of 879 lakh tonnes of waste, amounting to 35% of the total legacy waste.[174] Reportedly, the government aims to address approximately 1,000 legacy landfill sites, totalling around 16 crore metric tonnes of waste.[175] This involves the establishment of bio-methanation plants and WtE plants under the NBP 2022.[176]

[168] Ibid.
[169] Ministry of Housing a Urban Affairs (2021), 'Circular Economy in Municipal Solid and Liquid Waste', https://mohua.gov.in/pdf/627b8318adf18Circular-Economy-in-waste-management-FINAL.pdf (last accessed on December 24, 2023)
[170] Ibid.
[171] Ibid.
[172] Summary of the Union Budget 2023-24, PIB Delhi, (February 1, 2023), available at https://pib.gov.in/Pressreleaseshare.aspx?PRID=1895320 (last accessed on December 24, 2023)
[173] MoHUA holds high-level meeting for time-bound remediation of dumpsites in Delhi, PIB, (April 11, 2022) available at https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1815657 (last accessed on December 27, 2023)
[174] Mission Progress- Swachh Bharat Mission Urban 2.0, available at https://sbmurban.org/swachh-bharat-mission-progess (last accessed on December 27, 2023)
[175] All legacy dumpsites containing 16 crore metric tonnes of waste, and taking up 15,000 acres of prime land, will be remediated, PIB Delhi, (September 29, 2022), available at https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1863445#:~:text=I%20am%20proud%20to%20note,contributing%20almost%203%2C000%20crore%20rupees (last accessed on December 27, 2023)
[176] Government initiates various steps under National Bioenergy Programme to promote and encourage establishment of new waste to energy plants PIB Delhi, (February 3, 2023) available at https://pib.gov.in/PressReleasePage.aspx?PRID=1896067 (last accessed on December 27, 2023)

The SBM mission has successfully led to the adoption of a zero-landfill model of waste management in cities such as Ambikapur in Chhattisgarh, Chandrapur in Maharashtra, and Taliparamba in Kerala.[177] The model has eliminated reliance on new landfills, promoted resource recovery, and is aligned with the principles of a circular economy. The government recognizes the environmental hazards posed by landfills, including the release of methane gas, which is detrimental to the environment. Uncontrolled dumping of waste exacerbates water pollution and land degradation, imposing significant environmental and public health costs on residents with marginalized social groups being the most affected. [178] Hence, through these national schemes, the government aims to remediate all legacy dumpsites by converting them into green zones.[179] For this purpose, the government has earmarked INR 8,000 crore for the remediation of dumping sites across India. [180]

From a health perspective, waste management initiatives have contributed to disease prevention and public well-being. Taking the SBM as an example, there has been a significant reduction in cases of acute diarrheal disease (ADD). Before the launch of SBM, during the peak months of May to August, 55%–60% of ADD cases were reported annually nationwide. However, by 2018, the total outbreaks has reduced to 46%, significantly lower than the regular range of outbreaks in the peak season. [181] In 2014, there were 199 million deaths due to diarrhoea,[182] and SBM aimed to reduce this number to 33 million by 2018,[183] successfully contributing to public health improvement.

It is evident from the highlighted national missions that they play a crucial role in achieving the vision and priorities of the country regarding waste management. By aligning resources and efforts towards specific goals, these missions serve as instrumental drivers in steering the trajectory of nation-building.

[177] Waste-Wise Cities- Best practices in municipal solid waste management, Niti Aayog and Centre for Science and Environment (2021), available at https://www.niti.gov.in/sites/default/files/2021-12/Waste-Wise-Cities.pdf (last accessed on November 22, 2023)
[178] Abubakar, Ismaila Rimi, 'Environmental Sustainability Impacts of Solid Waste Management Practices in the Global South', International Journal of environmental research and Public Health vol. 19,19 12717. (October 5, 2022), available at doi:10.3390/ijerph191912717 (last accessed on November 22, 2023)
[179] Planning and implementation of Swachh Bharat Mission Urban 2.0, PIB (July 31, 2023), available at https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1944255 (last accessed on November 22, 2023)
[180] Rs 8,000 cr approved to remediate 1,000-plus dumping sites: Hardeep Puri, The Print, (September 29, 2022), availhttps://theprint.in/india/rs-8000-cr-approved-to-remediate-1000-plus-dumping-sites-hardeep-puri/1148530/ (last accessed on November 22, 2023)
[181] Dandabathula G, Bhardwaj P, Burra M, Rao PVVP, Rao SS. Impact assessment of India's Swachh Bharat Mission - Clean India Campaign on acute diarrheal disease outbreaks: Yes, there is a positive change. J Family Med Prim Care, (March 2019), available at doi: 10.4103/jfmpc.jfmpc_144_19. (last accessed on November 22, 2023)
[182] Health gains from the Swachh Bharat initiative, (July 27, 2018) available at https://www.who.int/india/news/detail/27-07-2018-health-gains-from-the-swachh-bharat-initiative#:~:text=Water%20and%20Sanitation.-,Key%20findings,of%20the%20SBM%20in%202014. (last accessed on November 22, 2023)
[183] Swachh Bharat Mission – Preliminary estimations of potential health impacts from increased sanitation coverage, Ministry of Jal Shakti, Department of Drinking water and Sanitations, available at https://jalshakti-ddws.gov.in/sites/default/files/WHO_study_on_lives_saved.pdf (last accessed on November 22, 2023)

5. INFLUENCE OF WOMEN & INFORMAL SECTOR IN SWM

SWM is a critical aspect of urban development and environmental sustainability, and its success relies not only on formal structures but also on the active involvement of diverse stakeholders. Among these stakeholders, women and the informal sector play pivotal roles in shaping the landscape of waste management practice.

Women, often at the forefront of household and community activities, exert a significant influence on waste generation patterns in India.[184] In a typical household in India, women are actively involved in waste collection and sorting activities, ensuring systematic waste management and identification of recyclable materials.[185] In affluent households, women may ascribe waste management responsibilities to domestic workers, who are also predominantly women. Women's involvement in waste management extends beyond the household level, influencing community initiatives and fostering sustainable waste management practices. They act as key influencers in promoting awareness and behavioural change within their communities.[186]

Further, the informal sector, comprised of waste pickers, recyclers, itinerant waste buyers and small-scale entrepreneurs, forms a dynamic workforce that actively participates in waste collection, recycling, and resource recovery. [187] Informal sector workers play a crucial role in source segregation of waste, separating recyclables from non-recyclables and establishing the foundation for effective waste management.[188] Globally, approximately 15 million informal waste workers are engaged in sorting, collecting, transporting and trading waste.[189] In India, where there is no formal separate collection system for recyclable materials, over 4 million waste pickers operate,[190] handling potentially hazardous waste without adequate protective gear. Notably, women constitute a significant portion of this sector. The sector's impact is substantial, diverting over 20% of the cities waste from landfills[191] and contributing to 70% of polyethylene terephthalate ("PET") recycling in India.[192]

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[184] Irtifa Mukhter & Richa Chowdhary, 'What rural women say about their role in household waste management in Kashmir?' A case-series approach, Local Environment, (2023), available at DOI: 10.1080/13549839.2023.2284937 (last accessed on December 18, 2023).
[185] Gender and Waste Management, United Nations Environment Programme, available at: https://www.unep.org/ietc/what-we-do/gender-and-waste-management#:~:text=As%20the%20primary%20users%20of,sustainable%20and%20fair%20waste%20management. (last accessed on December 18, 2023).
[186] The Role of Gender in Waste Management, Gender Perspectives on Waste in India, Indonesia, the Philippines and Vietnam, Commissioned by Ocean Conservancy (June 2019), available at, https://oceanconservancy.org/wp-content/uploads/2019/06/The-Role-of-Gender-in-Waste-Management.pdf (last accessed on December 21, 2023).
[187] Richa Singh, Solid waste management: Why integrating informal sector is a must, available at: https://www.downtoearth.org.in/news/waste/solid-waste-management-why-integrating-informal-sector-is-a-must-83841 (last accessed on November 16, 2023).
[188] Hong Yang, Mingguo Ma, Julian R. Thompson, Roger J. Flower, 'Waste management, informal recycling, environmental pollution and public health', available at https://core.ac.uk/download/pdf/195312457.pdf (last accessed on December 21, 2023)
[189] Ibid.
[190] Shubhangi Priya, Sonam Gupta , 'The State of Informal Waste Workers In India', Social & Political Research Foundation, (August 19, 2020), available at https://sprf.in/wp-content/uploads/2021/02/19.8.2020_The-State-of-Informal-Waste-Workers-In-India.pdf (last accessed on December 28, 2023)
[191] Swachh Bharat Mission An Inclusive Swachh Bharat through the Integration of the Informal Recycling Sector: A Step by Step Guide, (2016), available at https://smartnet.niua.org/sites/default/files/resources/towards_an_inclusive_swachh_bharat-integrating_informal_sector_recyclers.pdf (last accessed on December 28, 2023).
[192] Aryan Y, Yadav P, Samadder SR (2019) Life cycle assessment of the existing and proposed PW management options in India: a case study. J Clean Prod 211:1268–1283. https://doi.org/10.1016/j.jclepro.2018.11.236 (last accessed on December 18, 2023).

A study conducted in Delhi highlighted that waste pickers save over 900,000 CO_2 tonnes per annum, [193] contributing significantly to climate change mitigation. As of 2018, the waste sector contributed about 4% of India's total GHG emissions, emphasizing the informal sector's crucial role in mitigating this environmental impact. The manual door-to-door collection and use of handcarts for waste transportation from one place to another further reduce the costs of waste management by avoiding alternative processing and disposal expenses.[194] A study conducted in 2011 by Hasiru Dala showed that approximately 15,000 waste pickers in Bengaluru saved BBMP a significant sum of INR 84 crore annually in collection and transportation costs.[195] Consequently, the work undertaken by women and informal sector workers in waste management is considered green jobs, significantly contributing to environmental preservation. Further, the inclusion of women in the waste management brings a fresh perspective to the waste management sector and promotes economic empowerment and gender equality.[196] In regions where women traditionally face limited employment opportunities, their participation in the waste management sector creates jobs and contributes to breaking gender stereotypes.

Despite their indispensable contributions, the work of the sector often goes unquantified, with the lack of comprehensive research on the total number of women and informal sector workers in the MSW management sector. The segregated nature of their work poses challenges in terms of registration and regulation. In recent years, governments and international organizations have implemented various measures to highlight the crucial role played by the informal sector and women in waste management in India. The social impact of including women and the informal sector in the waste management workforce is universally acknowledged as undeniably beneficial, contributing positively to various facets of society. Recognition and formalization of their contributions to the economy are key to providing better working conditions, fair wages, and improved social well-being for these workers.

5.1 Role of Government in Promoting Women & Informal Sector

Acknowledging the pivotal role women and the informal sector play in SWM, the central and state governments in India, in collaboration with local bodies and non-government organisations have donned a facilitative role to enhance their involvement in the waste management process and improve their overall standard of living.

A significant stride in this direction was taken in 2016 when the Government of India introduced key regulations, namely the SWM Rules, 2016, and the Plastic Waste Management Rules, 2016. These regulations marked a crucial step toward the recognition and acknowledgement of the services

[193] Swachh Bharat Mission An Inclusive Swachh Bharat through the Integration of the Informal Recycling Sector: A Step by Step Guide, (2016), available at https://smartnet.niua.org/sites/default/files/resources/towards_an_inclusive_swachh_bharat-integrating_informal_sector_recyclers.pdf (last accessed on December 28, 2023)
[194] Wastepickers: Delhi's Forgotten Environmentalists?, Chintan, (2018), available at https://www.chintan-india.org/themes/nexus/assets/images/waste-101/Chintan%20Supreme%20Court%20Report_01.pdf (last accessed on December 28, 2023)
[195] Pinky Chandran, Nalini Shekar, Marwan Abubaker and Akshay Yadav, 'Informal Waste Workers Contribution in Bangalore', (2014), available at https://hasirudala.in/wp-content/uploads/2020/12/Informal-Waste-Workers-Contribution-in-Bangalore.pdf (last accessed on December 28, 2023)
[196] Gender and waste management, International Environmental Technology Centre, available at https://www.ctc-n.org/files/resources/gender_and_waste_management.pdf (last accessed on December 28, 2023)

provided by women and the informal sector in the waste management industry. The SWM Rules of 2016 play a vital role by providing specific definitions for terms such as "informal waste collector" and "waste picker". Furthermore, the SWM Rules have directed states and union territories to formulate comprehensive policies and strategies that explicitly recognize the indispensable role played by the informal sector, including guidelines for their integration into the formal waste management system. The rules also outlined the responsibilities of local authorities and panchayats such as the establishment of a system that officially recognizes organizations of waste pickers and informal waste collectors. Similarly, the Plastic Waste Management Rules of 2016 have tasked ULBs with responsibilities for establishing and coordinating the operationalization of the waste management system, with a specific focus on engaging civil societies and groups working with waste pickers. This strategic move by the government aims to institutionalize the role of the informal sector in waste management, ensuring their inclusion in the overall waste management framework.

In addition to amendments in the legal framework, the government at the national level has implemented several policies and schemes to empower the informal sector and women in the waste management industry. The e-Shram National Portal, launched in 2021, represents a pivotal step in the creation of a National Database of Unorganised Workers ("NDUW").[197] A unique eShram card is issued by the government as an identity document for workers belonging to the unorganised sector enabling seamless identification for effective delivery of social security benefits and implementation of welfare schemes. As of December 2023, the e-Shram National Portal has successfully enrolled over 29.20 crore unorganised workers, providing them with a platform to avail themselves of social security benefits and actively participate in welfare initiatives.[198]

The central government has also introduced a pension scheme namely, Pradhan Mantri Shram Yogi Maan-dhan ("PM-SYM") for unorganised workers, including ragpickers and sanitation workers. Informal sector workers aged 18 to 40 can voluntarily join this contributory pension scheme by contributing between INR 55 to INR 100 per month, and upon reaching 60 years, pensioners or their families are assured a minimum monthly amount of INR 3,000.[199] Notably, the government has allocated a total of INR 1,950 crores under this pension scheme for the unorganised sector over the past five years.[200]

Apart from the abovementioned, the vulnerable workforce in urban areas such as women and those employed in occupations such as rag picking are also being supported through financial aid under

[197] About the e-Shram Portal, Mi
istry of Labour & Employment, Government of India, available at: https://eshram.gov.in/e-shram-portal (last accessed on December 27, 2023)
[198] Press Release, e-Shram card issued to 29.20 crore unorganised workers registered on e-Shram portal, Press Information Bureau, Government of India, (December 11, 2023), available at: https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1985030 (last accessed on December 27, 2023)
[199] Pradhan Mantri Shram Yogi Maan-dhan (PM-SYM) Scheme, Ministry of Labour & Employment, Government of India, available at: https://labour.gov.in/pm-sym (last accessed on December 27, 2023)
[200] Press Release, Pradhan Mantri Shram Yogi Maan-Dhan (PM-SYM) scheme to provide old age pension to unorganized sector workers, Press Information Bureau, Government of India, available at: https://pib.gov.in/Pressreleaseshare.aspx?PRID=1909995 (last accessed on December 27, 2023)

MOHUA's National Urban Livelihood Mission ("NULM").[201] Beyond assisting individual informal workers, the government has initiated programs to support their families. Notably, the Pre-Matric Scholarships Scheme was introduced to assist the education of their children, particularly targeting those whose parents are engaged in high-risk cleaning occupations such as waste picking.[202] The central government has already released around INR 141.01 crore under this scheme to over 6.25 lakh beneficiaries for FY2023-24.[203] This initiative is vital in ensuring continuous education for such children.

Apart from the abovementioned targeted schemes, there are various general policies issued by the government which can also be availed by the disadvantaged strata such as Ayushman Bharat-Pradhan Mantri Jan Arogya Yojana ("AB-PM-JAY") under which eligible families may receive up to INR 5,00,000 health coverage; Pradhan Mantri Jeevan Jyoti Bima Yojana ("PM-JJBY") which provides life insurance coverage for death caused due to any reason; Pradhan Mantri Suraksha Bima Yojana ("PM-SBY") which provides accident insurance coverage for death or disability caused by accident; and Pradhan Mantri Jan Dhan Yojana ("PM-JDY"), aimed at enhancing financial inclusion by enabling zero-balance account opening and accident insurance coverage.[204] These social protection programs and welfare schemes are part of the government's efforts to make it easier for informal workers in the waste management sector to access and benefit from supportive measures.[205]

Likewise, at the local level, various government bodies and municipalities in states and cities have implemented similar or comparable measures. For instance, to empower women in the waste management sector, ULBs in cities such as Patna, Bengaluru, Varanasi, and Goa have launched the Pink MRF program in collaboration with GIZ and MoHUA.[206] In Patna, the municipal corporation, in conjunction with GIZ's Pink MRF initiative, has established specialized centres for SWM. These centres are exclusively operated by women in the informal sector and allow citizens to return disposable or recyclable items and, in exchange, receive cash.[207] This enabling role played by the Patna Municipal Corporation not only aids in effective waste management but also provides valuable employment opportunities for women.

Further, the Paradeep Municipal Corporation has devised an innovative waste management approach, engaging women's groups, third-gender groups, and ragpickers' associations in its 'Swachh

[201] Social Mobilisation and Institution Development - Revised Operational Guidelines, Deendayal Antyodaya Yojana - National Urban Livelihoods Mission (DAY-NULM), Ministry of Housing and Urban Development, Government of India, available at: https://nulm.gov.in/PDF/NULM_Mission/NULM-SMID_Guidelines.pdf (last accessed on December 27, 2023)
[202] Pre-Matric Scholarships Scheme for Scheduled Castes & Others, Department of Social Justice & Empowerment, Ministry of Social Justice & Empowerment, Government of India, available at: https://socialjustice.gov.in/schemes/23 (last accessed on December 27, 2023)
[203] Press Release, Pre-Matric Scholarships Scheme for SCs & Others and Post-Matric Scholarships Scheme for SC students (PMS-SC), Press Information Bureau, Government of India, September 25, 2023, available at: https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1960387 (last accessed on December 27, 2023)
[204] Scheme Details, Pradhan Mantri Jan Dhan Yojana, Government of India, available at: https://pmjdy.gov.in/scheme (last accessed on December 27, 2023)
[205] Rising Beyond: Transformative Impact on the Lives of Safai Saathis, United Nations Development Programme, December 2023, available at: https://www.undp.org/sites/g/files/zskgke326/files/2023-12/utthan_book_wc_low_compressed.pdf (last accessed on December 27, 2023)
[206] Empowering Women in the Waste Management Sector, GIZ India, December 6, 2023, available at: https://www.youtube.com/watch?v=WCA0DxKaRks (last accessed on December 18, 2023)
[207] Dallu Slathi, Now residents of Patna will earn money by selling dry garbage, Pink MRF centre opened here, News18 India, September 1, 2023, available at https://hindi.news18.com/news/bihar/patna-pink-mrf-center-opened-in-patna-city-residents-will-sell-dry-household-waste-know-details-7418557.html (last accessed on December 18, 2023)

Karmi' initiative.[208] This inclusive model involves the door-to-door waste collection, composting at small centres, and generating revenue through fees and selling recycled items. They have small centres where waste is turned into compost, and they make money from people paying a small fee for waste collection, fines, selling recycled items, and compost. Notably, Paradeep spent INR 20.5 lakh on waste management from February to July 2021, making a profit of INR 2.8 lakh. The WtW projects in Paradeep further empower women by assigning them leadership roles in waste management, resulting in successful revenue generation through organic manure sales.[209]

In Bengaluru, judicial intervention, specifically the Lok Adalat, prompted the BBMP to register waste pickers and issue occupational identity cards.[210] BBMP's commendable effort led to the distribution of over 5,000 ID cards by 2013, recognizing the pivotal role played by informal workers. [211] The Pune Municipal Corporation ("PMC") has also taken significant steps for the protection of the informal sector workforce. In 1995-96, it became the first municipality to provide waste pickers with identity cards and provide medical insurance cover to all registered waste pickers in the city. Further, in collaboration with the Kagad Kach Patra Kashtakari Panchayat ("KKPKP") which is the first membership-based trade union for waste pickers and itinerant waste buyers and PMC, a training program was initiated to educate the waste pickers in the city on systematic door-to-door waste collection.[212] These proactive public sector initiatives have helped in strengthening the informal sector network.

The level of government assistance provided to women and informal sector workers in SWM varies based on the involvement of NGOs, the active participation of women and informal sector workers in waste management initiatives, and the collaborative efforts between civic bodies and local communities. In areas where NGOs play a proactive role in waste management, government support is often more robust.

[208] The cleanest cities of India: The transgender community and women keep Paradeep clean, Down To Earth, January 27, 2022, available at: https://www.downtoearth.org.in/video/the-cleanest-cities-of-india-the-transgender-community-and-women-keep-paradeep-clean-81298 (last accessed on December 18, 2023)
[209] Decentralised Solid Waste Management through MCC & MRF: Wase to Wealth, available at https://urban.odisha.gov.in/sites/default/files/2023-09/Decentralisedsolidwastemanagement.pdf (last accessed on December 18, 2023).
[210] Hasiru Dala- Our Story, available at https://hasirudala.in/about/our-story/#:~:text=Following%20the%20Lok%20Adalat's%20direction,pickers%20and%20enumerate%20scrap%20dealers. (last accessed on December 18, 2023)
[211] Integration Of Informal Sector in Solid Waste Management Strategies and Approaches: Centre for Science and Environment, available at https://www.cseindia.org/content/downloadreports/10886 (last accessed on December 18, 2023)
[212] Ibid.

INTEGRATING WOMEN AND INFORMAL SECTOR THROUGH COMMUNITY DRIVEN INITIATIVES

The Advanced Locality Management (ALM) scheme initiated in 1997 by the Municipal Corporation of Greater Mumbai (MCGM), exemplifies the collaborative approach between the civic body and NGOs. The Stree Mukti Sanghatana (SMS), a local NGO, played a pivotal role in raising awareness and providing training to waste pickers, of which approximately 85% were women. Through interactive sessions, SMS addressed key aspects like waste segregation, handling, composting, and operationalizing bio-gas plants, fostering a symbiotic relationship between the government and civil society that uplifts the social and economic status of women working in SWM.

Ambikapur in Chhattisgarh stands out as a noteworthy example of transformative SWM, particularly in its efforts to empower women and informal sector workers. The city successfully converted its former dumpsite into a waste recycling centre, leveraging the active involvement of women's self-help groups (SHGs) for the collection, sorting, and processing of waste. In this unique model, a federation of SHGs predominantly comprising women workers, known as didis, operates under the patronage of the Ambikapur Municipal Corporation. Out of the total workforce numbering 700–800 employees within the federation, an impressive 470 actively engage in solid waste management tasks. Each employee is compensated with a monthly salary of Rs 5,000, supplemented by incentives of up to Rs 3,000. The financial sustainability of these salaries is achieved through fixed user charges levied on households and commercial establishments, in addition to the revenue generated from the sale of recyclables.

Source: *The Advance Locality Management scheme, Mumbai[213]; Dumpsite into a waste recycling centre, Ambikapur, Chhattisgarh[214]; The financial sustainability of SHGs employees[215]*

Similar initiatives have been undertaken by various municipal bodies, including the Indore Municipal Corporation, Kumbakonam Municipality, Vijayawada Municipal Corporation, and others, showcasing a growing trend in community-driven waste management endeavours.[216] These cities have

[213] Municipal Solid Waste Manual, 2016, page 302, available at: http://swachhbharaturban.gov.in/writereaddata/Manual.pdf (last accessed on November 24, 2023).
[214] Ministry of Housing and Urban Affairs, The Critical Role of Community-Based Organizations in Urban Sanitation and Waste Management, A Compendium of Case Studies February 2019, Page 40, available at: https://nulm.gov.in/PDF/ResourceMaterial/COMPENDIUMONBESTPRACTICE.pdf (last accessed on December 18, 2023).
[215] Waste-Wise Cities- Best practices in municipal solid waste management, Niti Aayog and Centre for Science and Environment (2021), page 167, available at https://www.niti.gov.in/sites/default/files/2021-12/Waste-Wise-Cities.pdf (last accessed on November 22, 2023).
[216] Richa Singh, Domestic Hazardous Waste: An Approach Towards Scientific Collection, Treatment and Disposal in India, June 21, 2022, Centre for Science and Environment, available at: https://www.cseindia.org/content/downloadreports/11320 (last accessed on November 24, 2023); Waste-Wise Cities- Best practices in municipal solid waste management, Niti Aayog and Centre for Science and Environment (2021), page 130, available at https://www.niti.gov.in/sites/default/files/2021-12/Waste-Wise-Cities.pdf (last accessed on November 22, 2023)

proactively engaged women and informal sector workers in the sustainable handling of solid waste, contributing to both environmental conservation and socio-economic empowerment.

The municipal corporation's inclusion of women in the informal sector in SWM serves multiple government objectives, including waste capitalization and reducing the gender gap. Collaborative efforts between civic bodies and local communities are crucial in determining the success of waste management programs. When municipal corporations actively involve community members, especially women and informal sector workers, in the planning and execution of waste management strategies, it leads to more inclusive and effective solutions.

6. RECOMMENDATIONS

Waste management stands as an important concern for nations worldwide, and the public sector emerges as a key player in the creating effective solid waste management strategies. This research report sheds light on the role of the public sector in shaping waste management practices in South Korea, Germany, and India. In South Korea, a groundbreaking initiative was introduced through the pay-as-you-throw model, where individual citizens bear direct responsibility for the waste they generate. This innovative approach not only created a sense of accountability but also aligns with environmental conservation goals, contributing significantly to the overall waste management framework. Similarly, in Germany, the public sector implemented the Pfand system, through which the public needs to mandatorily pay a waste deposit fee which is refunded once you return certain products.

In India, the government has proactively addressed waste management challenges through initiatives like Swachh Bharat. The mission has created positive outcomes by influencing public behaviour and developing a culture of cleanliness. The concerted efforts of the government, coupled with public awareness campaigns, have contributed to transforming waste management practices at the grassroots level. The models implemented in India , Germany and South Korea, highlight the crucial role of the public sector in creating innovative and impactful waste management strategies. Whether through individual responsibility models, mandatory deposit systems, or nationwide cleanliness missions, the public sector continues to be a driving force in shaping sustainable waste management practices on a global scale. Based on a comprehensive study of role of the public sector in MSW management, the following recommendations have been suggested to fortify the waste management framework In India by capitalizing on waste and fostering innovations in the sector. The recommendations have been categorised as short-term (6 months to 1 year), mid-term (between 1 to 2 year) and long-term goal (more than two years).

6.1 SHORT TERM

1. Public procurement of recycled and green technologies to enhance innovations

India needs to promote an innovation-friendly environment to enhance technological advancements in SWM. The Government, as a pivotal player, can actively contribute to this transformation by leveraging its procurement practices. Drawing inspiration from the successful model in South Korea, where eco-friendly product acquisition stimulated innovation, India can strategically adopt and adapt similar principles. Incorporating a clear and transparent preference for technologies that blend efficiency in waste management along with environmental sustainability in SWM sector can incentivize the development of innovations that contribute to a circular economy. By transparently aligning procurement procedures with eco-friendly goals, the government can help propel demand for innovative technologies in waste management. This strategic approach shall not only enhance operational efficiency in SWM but also help cultivate a culture of sustainability and innovation within the waste management sector. To implement this model effectively in India, explicit procurement guidelines should be established which promotes technologies that resonate with environmental sustainability objectives. It shall also incentivise private companies to invest more in research and development of innovative technologies.

2. Yearly Impact Assessment of Schemes

Impact assessment is very important to evaluate the implementation and identifying potential shortcomings of any mission or scheme. The current research has highlighted a notable gap in the availability of comprehensive studies assessing the impact of various government-initiated waste management schemes across states. In light of this observation, a key recommendation is for the government to institute research grants specifically aimed at conducting impact studies of the schemes and missions for each state. These studies would delve into the on-ground implementation of different schemes and missions, providing valuable insights into their success, challenges, and areas for improvement. Researchers and institutions receiving these grants should be encouraged to collaborate with local bodies, NGOs, and communities to ensure a holistic understanding of the ground reality. These proposed research grants would serve multiple purposes. Firstly, they would enable the collection of empirical data on the performance of waste management initiatives, shedding light on their real-world impact. Secondly, these studies could uncover region-specific factors influencing the success or failure of different schemes, allowing for issues-specific interventions. Thirdly, by fostering a culture of research and evaluation, the government can ensure a continuous feedback loop that informs policy adjustments based on empirical evidence.

6.2 MID-TERM

1. Implementing RFID and GPS technologies for monitoring and tracking waste

India grapples with the formidable task of managing large amounts of waste volumes on a daily basis. This necessitates a comprehensive approach by ULBs to address collection, transportation, and monitoring of waste. In the pursuit of sustainable waste management, meticulous tracking and monitoring of waste is critical for efficient processing, recycling, and disposal of waste. To effectively capitalize waste generated, it is recommended that governments mandate municipalities to incorporate advanced technologies like RFID or real-time GPS tracking systems in their garbage bins/vehicles to enhance waste tracking capabilities. By equipping waste bins with RFID tags, authorities can monitor the entire waste management lifecycle, from generation to disposal. Further, GPS tracking can provide precise data on the movements and activities of waste collection vehicles, delivering invaluable insights into their operations. It shall help ULBs gain access to detailed information, including the duration of stops at individual homes, specific routes taken, and any deviations from estimated timeframes. A robust tracking system not only enhances operational efficiency but also enables ULBs to respond promptly to any issues, ensuring timely waste collection. Moreover, implementation of such system shall bring transparency in the waste collection process, enhancing accountability and liability among stakeholders responsible for waste disposal and recycling.

3. Government authorised colour coded bags for waste collection

As discussed earlier, the practice of waste segregation remains crucial in India, and implementing color-coded bags can significantly enhance the sorting process. Taking inspiration from South Korea's successful waste management system which is characterized by the use of distinct garbage bags for various types of waste, India can adopt a similar approach to promote citizen awareness and conscientious waste disposal. The introduction of special prices for these designated bags can contribute to revenue generation for ULBs and help offset the costs associated with waste

management. Further, introducing color-coded garbage bags, in addition to the existing use of color-coded bins, would help streamline waste collection. Hence, it is recommended to design distinct color-coded garbage bags for different types of waste, including paper, glass, plastic, metals, and food waste. This shall simplify identification for waste collectors and raise public awareness regarding the diverse classifications of waste and the need for segregation. To complement the introduction of color-coded garbage bags, ULBs can also develop a 'waste calendar' designating specific days for the collection of different types of waste. For example, daily pickups for food waste and bimonthly collections for glass waste can be scheduled. This systematic approach ensures efficient waste management and aligns with international best practices.

4. Spreading awareness for the entire value chain

The Swachh Bharat Mission and other national missions implemented by the government has made significant changes in terms of how waste is perceived within the Indian community. However, there is insufficient understanding on the intricacies of the entire waste management value chain. To address this gap, it is recommended to expand and intensify ongoing efforts, such as the Swachh Bharat Mission by providing comprehensive information and awareness about the complete waste management process. The campaigns should focus on essential aspects, including responsible waste handling, roles of individuals in the waste management process, importance of segregation, and the transformative potential of waste as a valuable resource. Public awareness regarding the intricacies of the waste management process, spanning from segregation at the source to recycling and final disposal should be heightened. Additionally, emphasis should be placed on communicating the environmental and economic benefits of adopting conscientious waste management practices.

Apart from the existing modalities for promoting awareness, it is suggested that social media platforms may be used for disseminating information and creating awareness on the subject. Social media influencers from popular social media platforms such as *Instagram, YouTube,* and *Facebook* may be appointed as brand ambassadors to reach a diverse set of demographics. Further, a *'Youth Ambassador Fellowship Program in Solid Waste Management'* may be initiated by the government to provide young individuals, including students and recent graduates, with an opportunity to actively contribute to waste management initiatives. Through this fellowship program, applicants shall work closely with professionals including bureaucrats from MoHUA, engaged in waste management activities. This collaborative approach shall enable participants to gain practical insights into the challenges and successes of waste management schemes. Furthermore, it shall provide them with a platform to actively participate in shaping the future of waste management.

6.3 LONG-TERM

1. Enhancing Waste Segregation through Stringent Regulations and Technologies

Promoting innovative technologies for effective SWM and capitalization of waste is closely linked to waste segregation and separation during the collection process. Experience from various countries indicates that maintaining separate waste fractions at the source and collecting them individually plays a pivotal role in the recovery of secondary resources that can be capitalized. Countries like Germany have set a precedent by mandating the pretreatment of MSW through sorting or Mechanical Biological Treatment before landfilling, diverting a significant portion of waste toward

recycling and contributing to the circular economy. Similarly, Korea enforces waste sorting by residents, imposing separate charges for different types of waste. Moreover, both Germany and Korea have implemented strict penalties for individuals who fail to segregate waste correctly.

In India, waste segregation at the source is emphasized by the Solid Waste Management Rules, 2016. However, the efficiency of the process faces challenges, hindering the full utilization of the country's waste management potential. To address these issues, it is recommended to:

- Make laws more stringent at the state and municipality level to enforce mandatory waste sorting.
- Devise mechanism where ULBs are held accountable for inefficient sorting processes.
- Implement innovative technologies such as smart bins in public spaces to ensure waste is disposed off correctly.

2. Waste Recycling as a tool for enhancing capitalization and innovation

Setting explicit waste recycling targets can serve as a strategic tool to boost capitalization and foster innovation in waste management. To enhance capitalization and innovation in India's waste management sector, adopting a model of legally mandated waste recycling targets similar to Germany's successful approach is recommended. Germany has established clear responsibilities and targets for various authorities and stakeholders in MSW management, fostering commitment and accountability. Like India, MSW management is devolved among states and municipalities in Germany. However, by virtue of EU and German law, the country has specific recycling targets for MSW, and all authorities responsible for undertaking MSW activities are mandated to develop a waste management plan in accordance with the national agenda.

It is recommended that each state government should formulate an annual target plan, declaring specific recycling targets in advance. This approach allows for a transparent and goal-oriented waste management strategy. The central government should play a crucial role in periodically reviewing and assessing the achievement of these recycling targets of each state government. In the event that a state government falls short of its recycling targets, a compensation mechanism may be instituted. A fund may be created at the central level where the the state falling short of targets may be required to contribute compensation. The funds collected through these compensations can be earmarked for nationwide waste recycling initiatives, creating a sustainable financing model for the sector.

Furthermore, it is also recommended to introduce a reward system or a ranking mechanism that serves as an incentive for states to excel in waste recycling efforts. States consistently meeting or exceeding their recycling targets could be acknowledged and rewarded. Such recognition shall not only motivate healthy competition among states but also foster a culture of excellence in waste management practices. By implementing a recycling target plan with clearly defined responsibilities, periodic evaluations and financial incentives, India can significantly enhance its waste recycling capabilities, thereby promoting capitalization and innovation.