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Creating Circular Economic Potential as a way for Achieving Smart and Sustainable Cities

(Background Paper for Mayor Session 2 of the Programme)

Final Draft

This background paper has been prepared Dr. Prasad Modak, for the Eighth Regional 3R Forum in Asia and the Pacific. The views expressed herein are those of the author only and do not necessarily reflect the views of the United Nations.

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Dr. Prasad Modak

Abbreviations

ADB: Asian Development Bank

ALM: Advanced Locality Management

C&D: Construction and Demolition

CE: Circular Economy

CPCB: Central Pollution Control Board

EPR: Extended Producer Responsibility

EU: European Union

GHGs: Green House Gases

GoI: Government of India

ICLEI: International Council for Local Environmental Initiatives

IDA: Infocomm Development Authority of Singapore

ITU: International Telecommunication Union

JnNURM: Jawaharlal Nehru National Urban Renewal Mission

MoEFCC: Ministry of Environment, Forests and Climate Change

MSW: Municipal Solid Waste

MSWM: Municipal Solid Waste Management

RECP: Resource Efficiency and Cleaner Production

SCM: Smart Cities Mission

SDGs: Sustainable Development Goals

SPCB: State Pollution Control Board

SWM: Solid Waste Management

ULBs: Urban Local Bodies

UNECE: United Nations Economic Commission for Europe

UNEP: United Nations Environment Programme

UNCRD: United Nations Centre for Regional Development

UTs: Union Territories

WHO: World Health Organization

Executive Summary

Circular Economy (CE) is widely discussed in the development circles today. It is a concept that attempts to provide an alternative discourse on growth, stepping away from the traditional 'take-make-dispose' models towards circularity of material, energy and economic flows. CE has been discussed in the context of smart product design, renewable energy integration and material recovery amongst several. An important area where circular economy has immense need and potential is bringing sustainability to our urban environment. This paper closely looks at the circular economic potential of cities and comes up with recommendations to pursue a sustainable growth trajectory.

The paper investigates and presents the circular economic potential for smart and sustainable cities with a focus on India. The case of Solid Waste Management has been considered to analyse the circular economy potential. The introductory chapter sheds light on the global and Indian scenario of urbanisation. The section further delves into urban solid waste generation, an overview of other waste streams and the waste governance in India. The second chapter sheds light on the waste management infrastructure and integration of 3Rs in waste management. The third chapter delves into more details about circular economy and aligns it with waste to resource management. A value-chain analyses has been conducted for two waste streams as an illustration. The fourth chapter focuses on Smart and circular cities and discusses how to leverage smartness while embedding or mainstreaming sustainability.

Chapter 5 assesses the science-policy-business interaction particularly in the context of India. This chapter looks at the existing gaps in the system which are currently not addressing the circular economy practices. Taking cues from these analyses, Chapter 6 discusses about smart waste management in circular cities. The Smart Cities Mission by the Government of India is closely analysed in the section to recognise its circular economic potential. Expansion of the scope to consider liquid waste management, regional and decentralised waste management solutions is discussed. Sustainable Public Procurement and Green Entrepreneurship as stepping stones towards circular economy is subsequently discussed. Chapter 7 concludes that Indian cities have significant potential for embracing circular economy, provided that right policies, stakeholder interactions, innovations and capacity building are put in place.

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Chapter 1

Urbanization and Waste Management Trends

Cities are the hubs of growth, innovation, collaboration and knowledge. Globally, cities are growing in population leading to more resource consumption and waste generation. Factors responsible for this rapid growth include better employment opportunities and access to better infrastructure and services.

There has been a considerable rise in urbanisation, compared to the previous decades. In 1995 there were 22 large cities, and 14 megacities globally, however by 2015, both categories of cities had doubled[1]. Around 79 per cent of the megacities are located now in Latin America, Asia and Africa. The proportion of global urban population is projected to rise to 60% by 2030, and Asia and Africa will be the major contributors to this increase. In 2016, 54.5 % of the world's population was estimated to be residing in urban areas.

Cities are the centres of production and consumption thus directing the economic growth of countries. Across the world, 750 cities are expected to contribute to about 61% of global GDP in 2030[2] (see Figures 1 and 2). About 91 percent of growth in consumption in 2015-2030 period is attributed to large cities[3]. Furthermore, cities consume about 2/3rd of the world's energy and contribute to 70% of all global Greenhouse Gas (GHG) emissions[4]. Additionally, cities contribute to 70% of all wastes generated on the planet[5]. Cities are thus becoming the epicentres of growth, innovation, consumption and resource use which in turn lead to environmental concerns.

World Cities Projections for 2030

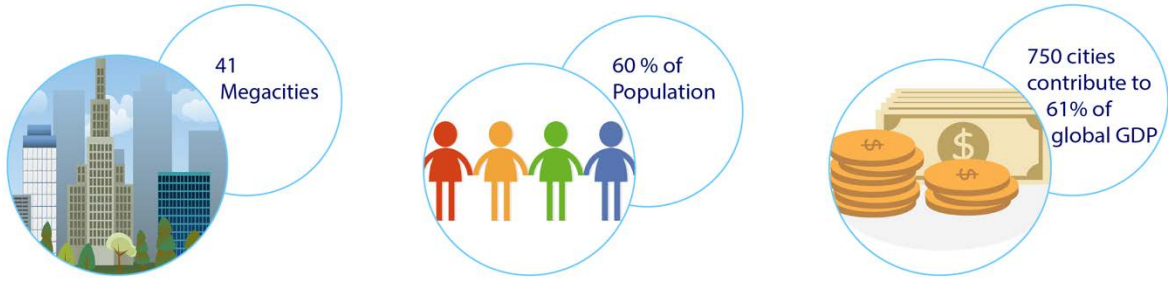

Figure 1: Population Projections for Cities across the Globe- 2030, Source: Oxford Economics, (2014)

[1] United Nations, Department of Economic and Social Affairs, Population Division (2016). The World's Cities in 2016 – Data Booklet (ST/ESA/ SER.A/392).
[2] Oxford Economics (2014). Future trends and market opportunities in the world's largest 750 cities. Retrieved from: https://www.oxfordeconomics.com/Media/Default/landing-pages/cities/OE-cities-summary.pdf
[3] McKinsey Global Institute (2016). Urban World: The global consumers to watch. Retrieved from https://www.mckinsey.com/global-themes/urbanization/urban-world-the-global-consumers-to-watch
[4] The World Bank (2017). Urban Development. Retrieved from: http://www.worldbank.org/en/topic/urbandevelopment/overview
[5] The Conversation (2016), Our cities need to go on a diet. Retrieved from: http://theconversation.com/our-cities-need-to-go-on-a-resource-diet-68984

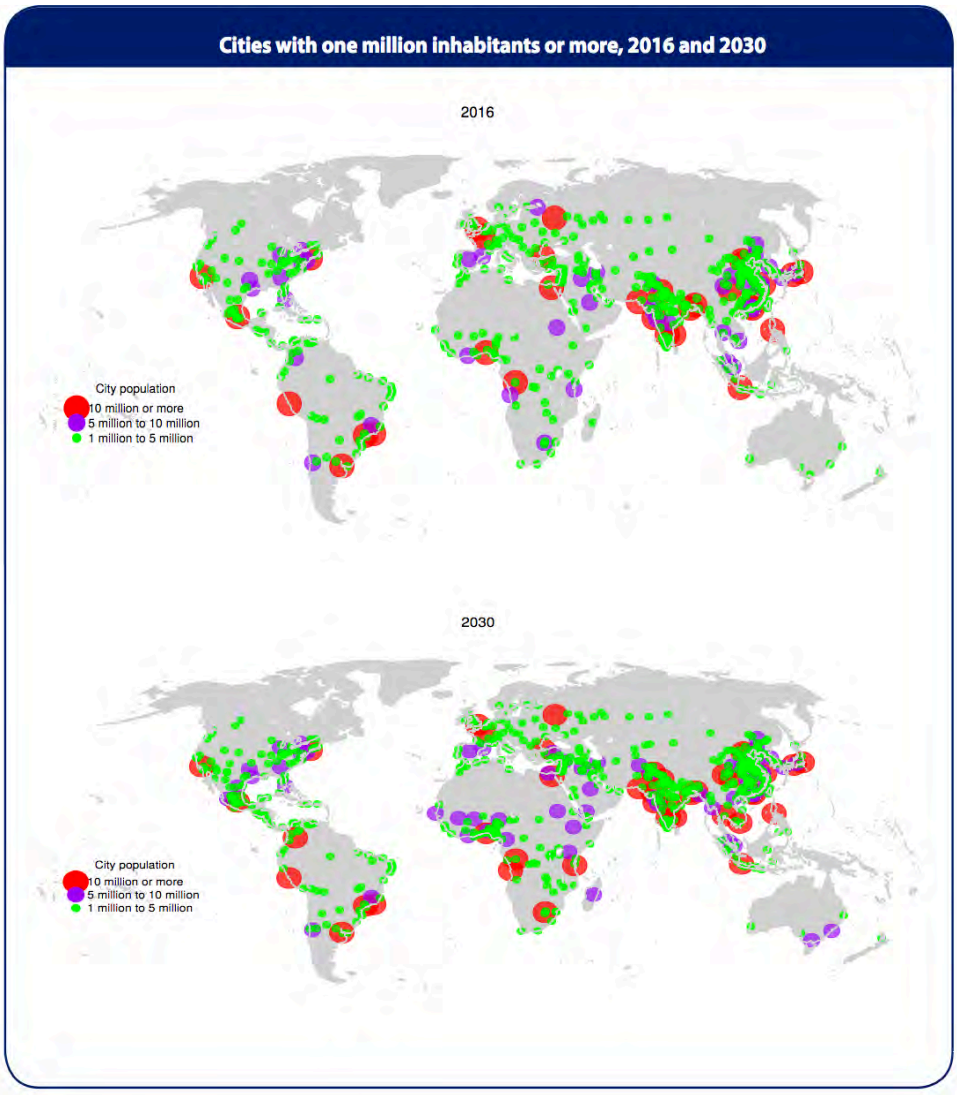

Figure 2. Urbanization across different regions of the world, Source: UNDESA (2016)

1.1 Urbanisation in India

India is the seventh largest country in the world, divided into 29 States and 7 Union Territories (UTs). India is urbanizing rapidly with an annual urbanization rate of 2.28 %[6]. About 31.14% of Indians live in urban areas as per the 2011 census which is projected to increase to 40 % by 2031

[6] Considering the 2015-2020 period; CIA World Factbook (2017). Retrieved from: https://www.cia.gov/library/publications/the-world-factbook/fields/2212.html

and to 50% by 2051[7]. Between 2016 and 2050, India is expected to add 400 million urban dwellers and the country will account for one third of all global urban dwellers[8].

There are currently five mega cities - Greater Mumbai, Delhi, Chennai, Bengaluru and Kolkata with population of more than 10 million[9]. India will have seven mega cities by 2030 with each city surpassing 10 million population. The most urbanized regions with more than 50% urbanization, in India are Delhi, Chandigarh, Lakshadweep, Daman & Diu, Puducherry, Goa and Mizoram. Among major States, Tamil Nadu, Maharashtra and Kerala are the most urbanized. Ernest & Young report (2017), projects 8 metros and 42 new-wave markets by 2020 which will account for 70% of the total GDP of the country.

1.2 Urban Solid Waste Generation

Urban areas of India which houses about 377 million people, generate 62 million tons of (Municipal Solid Waste) MSW per annum[10]. It is projected that by 2031 these urban centres will generate 165 million tons of MSW annually and by 2050 it could reach a whopping 436 million tons (CPCB, 2013)[11].

MSW contributes to nearly 80% to the urban waste generation but the contribution of Construction and Demolition (C&D) Waste is rapidly increasing. The State-wise generation of MSW is depicted in Figure 3 (see Annex 1 for more details). State of Maharashtra tops the list with 0.022 million tonnes of MSW generation per day, followed by Uttar Pradesh[12]. See Figures 4 and 5. According to Kumar et al. (2017), the waste generation rate (kg per capita per day) ranges between 0.17 to 0.62 for 48 cities analysed across India. Cities with population greater than 2 million had the highest waste generation in the range of 0.22-0.62 kg per capita per day[13].

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[7] Ministry of Urban Development, Government of India (2016). Handbook of urban statistics. Retrieved from: http://moud.gov.in/pdf/5853c4c9864675832b25ba492dhandbook%20of%20urban%20statistics.pdf

[8] United Nations, Department of Economic and Social Affairs, Population Division (2016). The World's Cities in 2016 – Data Booklet (ST/ESA/ SER.A/392).

[9]Kumar, A & Randhawa, A. (2017). Exploring sustainability of smart development initiatives in India. International Journal of Sustainable Built Environment. https://doi.org/10.1016/j.ijsbe.2017.08.002

[10] Planning Commission Report. (2014). Report of the Task Force on Waste to Energy (Volume I)

[11] As per 2011 census, 31.16 % population (i.e. 377 mn people) of India live in 4,041 municipal authorities. It is estimated that by 2050, 50% of the population will be living in urban areas, and the volume of waste will grow by 5% per year. Accordingly, the expected waste quantity for the year 2021, 2031, and 2050 are 101 mn metric tonnes per year, 164 mn metric tonnes, and 436 mn metric tonnes per year respectively

[12] CPCB. (2013). Status report on municipal solid waste management. Retrieved from http://www.cpcb.nic.in/divisionsofheadoffice/pcp/MSW_Report.pdf

[13] Kumar et al. (2017). Challenges and opportunities associated with waste management in India. Retrieved from http://rsos.royalsocietypublishing.org/content/4/3/160764#xref-ref-13-1

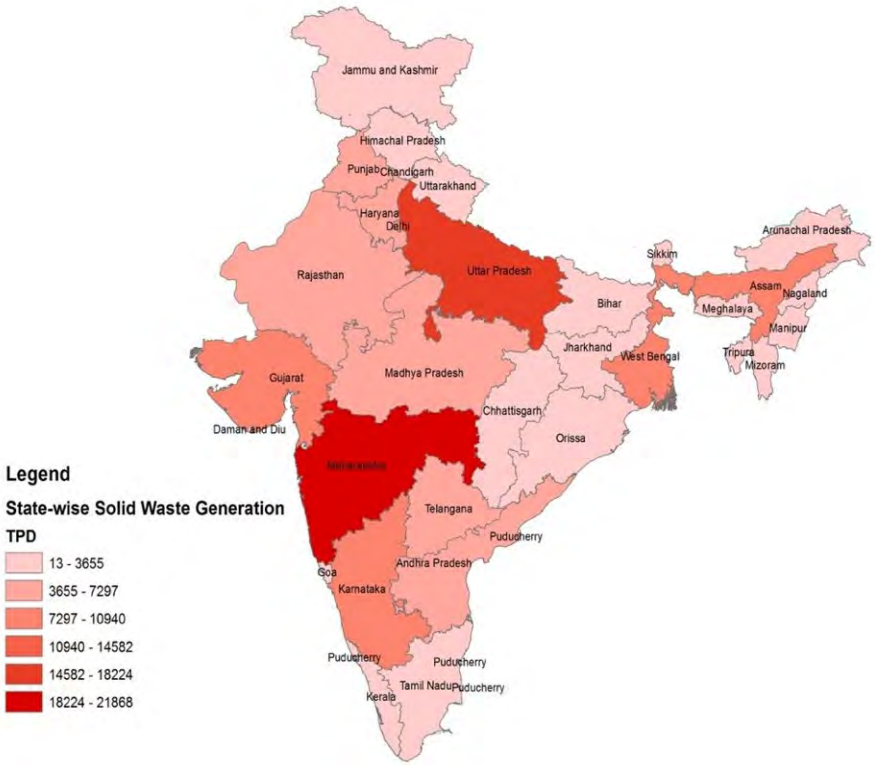
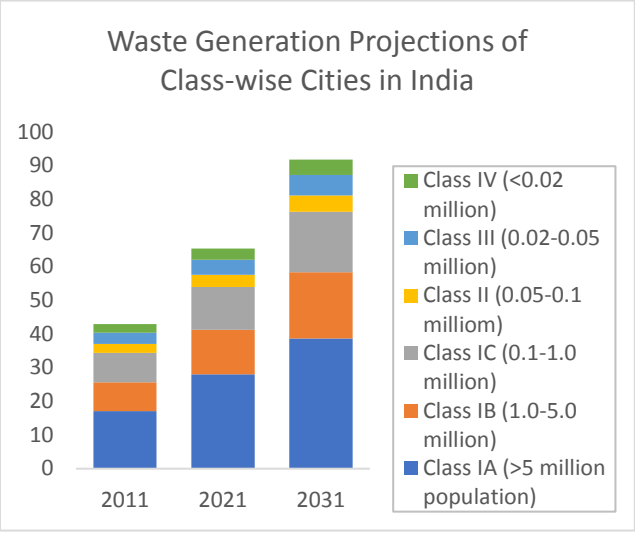


Figure 3: Total Solid Waste Generation (2013-16), Source: CPCB. (2013)



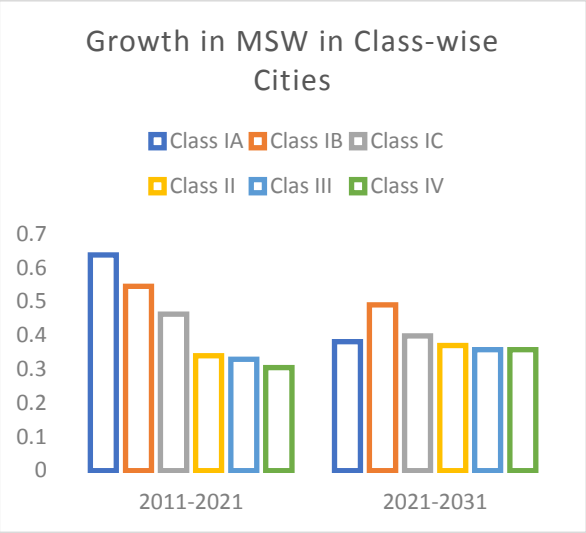


Figure 4: Waste Generation Projections; Figure 5: City-wise growth in MSW, Source: Jindal[14] (2016) and PWC

[14] Jindal, S. (2016). Revised Legal Framework for Solid Waste Management. Waste to Energy Research and Technology Council – India (WTERT–India), 30.

The projections point out a greater rise in waste generation in class IA and IB cities in the 2011-2021 period. Then the growth shifts to IB and IC cities in the following decade. (See Annex 2 for more details). It is important therefore to focus on class IA and IB cities for a proactive integrated waste management.

1.3 Other Important Waste Streams

With growth and transition in cities, their consumption patterns change. As consumption patterns change, waste composition in the cities is also changing. In addition, new waste streams arise, and new materials get added to the existing waste streams. In the last two decades, in addition to MSW, four major waste streams have emerged. These waste streams include E-waste, Construction & Demolition (C&D) Waste, Plastic Waste and Health Care waste. See Figure 6 that shows rise in the plastic and metallic content of the Municipal Solid Waste.

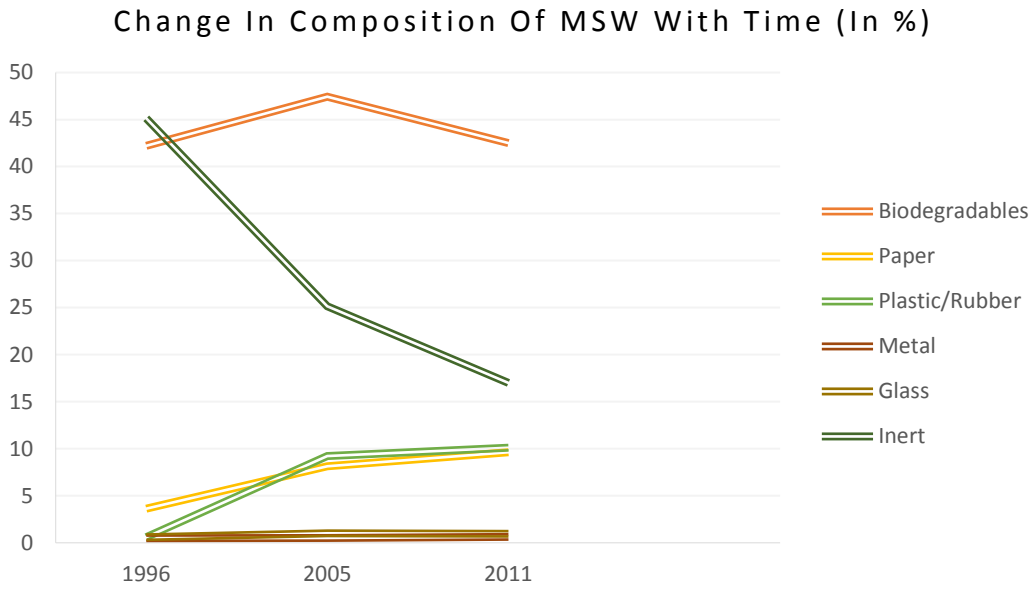


Figure 6: Change in Composition of MSW (National Average), Source: Joshi & Ahmed[15] (2016)

In 2016, India was the fifth largest e-waste generator in the world. Indian cities were the major contributors, with Mumbai producing 1,20,000 tonnes of e-waste annually followed by Delhi and Bengaluru with 98000 and 92000 tonnes respectively[16]. In addition to e-waste, C&D waste, plastic waste and healthcare waste count for significant proportion of urban waste. India currently recycles about 60% of its plastic wastes which is higher than the global average of 14%[17]. Based

[15] Joshi & Ahmed (2016). Cogent Environmental Science. 2: 1139434. Retrieved from: http://dx.doi.org/10.1080/23311843.2016.1139434

[16] ASSOCHAM-KPMG (2016). Electronic Waste Management in India

[17] CPCB 2013 estimates

on CPCB statistics for 2011-12[18], about 15,342 tonnes of plastic waste was generated in India per day, out of which, 9,205 tonnes were reported to be recycled and the remaining 6,137 tonnes were left uncollected and littered. C&D waste is generated from the construction, maintenance and disposal phases of a building. As per TIFAC and CSE estimates, India produced C&D waste of 50,000 million tonnes in 2013 from new constructions. Considering demolition as well, approximately an additional 288 MT is estimated to be generated[19]. Healthcare waste mostly constitutes of hospital waste like syringes, bandages, human tissues, used culture media etc. In India, this is approximated to be around 0.33 million tonnes per year[20]. Despite regulations in place, handling of hospital waste is still rudimentary in the country owing to financial constraints, improper segregation and lack of institutional arrangements. About 15 percent of healthcare waste falls under high risk category and their improper management can lead to epidemic breakouts and infections[21].

Table 1 provides key characteristics of the above waste streams. Detailed depiction is given after the table. Inventorying these four waste streams is a challenge and hence all the estimates reported in the literature must be treated with great caution. Figures 7 and 8 provide insights into the characteristics of the urban waste streams based on different factors chosen.

Table 1 Key Characteristics of Urban Waste Streams on a Relative basis

SN	Waste Stream	Generation in terms of volumes	Potent Environmental and Health Impacts/Risks	Technology Availability & Maturity	Economic potential for Recovery	Policy and Regulatory Experience
1	**Municipal Solid Waste**	High	Medium	High	Medium	High
2	**Electronic waste**	Medium	High	High	High	Low
3	**Plastic waste**	Medium	Medium	High	High	Low
4	**Construction & Demolition waste**	High	Low	Medium	Medium	Medium
5	**Healthcare waste**	Low	High	Low	Low	Medium

[18] CPCB (2013). Overview of Plastic Waste Management. Retrieved from: http://www.cpcb.nic.in/divisionsofheadoffice/pcp/management_plasticwaste.pdf

[19] CSE (2014). Construction and Demolition Waste. Retrieved from: http://www.cseindia.org/userfiles/Construction-and%20-demolition-waste.pdf

[20] Muduli, K & Barve, A. (2012). Challenges to waste management practices in Indian healthcare sector. International Conference on Environment Science and Engineering IPCBEE (32). Retrieved from: http://www.ipcbee.com/vol32/011-ICESE2012-D035.pdf

[21] WHO (2015). Healthcare Waste. Retrieved from: http://www.who.int/mediacentre/factsheets/fs253/en/

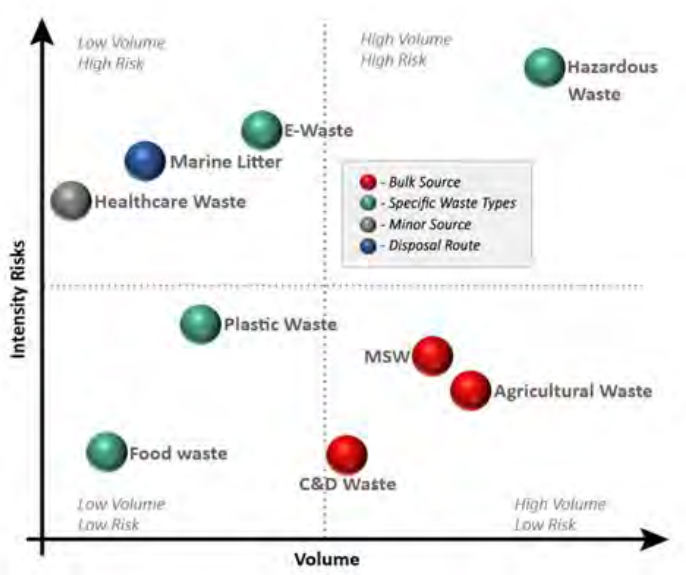


Figure 7: Key Characteristics of urban waste streams on a relative basis- volume vs intensity risks

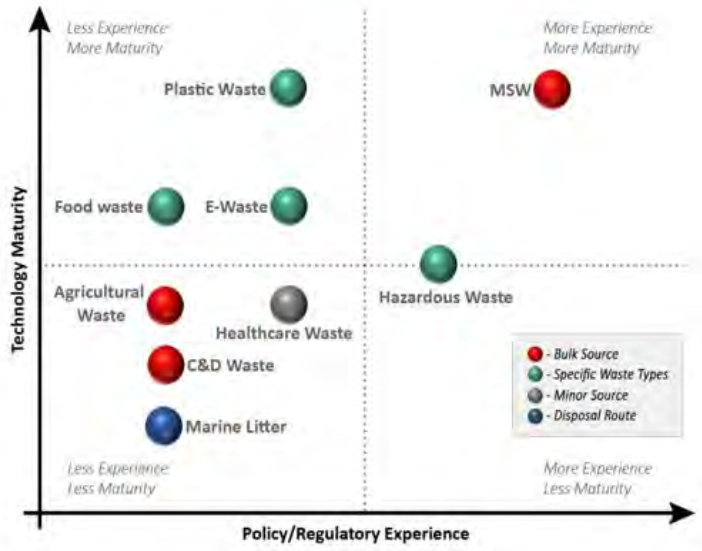


Figure 8: Key characteristics of urban waste streams on a relative basis-policy vs technology maturity

1.4. Impacts of Uncontrolled Waste Management

Rising consumption of resources and increasing waste generation result in adverse impacts on our limited natural resources and quality of life. The resources come under threat due to overexploitation and degradation caused by uncontrolled release of wastes and emissions. Contaminated resources lead to risks to human health and the ecosystems. Many studies have

documented the negative impacts on the people living near waste disposal sites or waste pickers. Waste when mismanaged impairs the aesthetics of the city and affects economic sectors such as tourism, fishing, and lowers values of the infrastructure assets such as housing.

For example, the cost in terms of Disability Adjusted Life Years (DALY) of diarrhoea for children from poor sanitation is estimated as $86 million. A similar study by the Water and Sanitation Programme of the World Bank using data for 2006 shows that the per capita economic cost of inadequate sanitation, including mortality impact in India, is $38.[22]

Pollution and environmental degradation were attributed for a GDP loss of $ 80 billion a year, by the World Bank Diagnostic Report of 2013. Lack of access to sanitation reduced India's GDP by $ 106.7 billion in 2015[23]. Thus, waste when mismanaged can lead to significant economic impacts.

E-waste has been found to have detrimental effects on environment and public health. The dangerous chemicals and metals in the e-waste products can seep into the environment and contaminate groundwater and atmosphere. Additionally, researchers have linked e-waste to inflammation and oxidative stress, which can cause cancer, cardiovascular diseases and DNA damage[24]. As e-waste consists of about 92% recoverable and reusable materials[25], improper management is undermining the economic potential of it. Improper management of healthcare waste can lead to infections and outbreak of contagious diseases. The waste workers who handle this waste without proper protection are prone to infections and injuries. C&D waste generally ends up in landfills without significant treatment or resource recovery. C&D waste uses up the limited landfill resources available. The cost of mitigating the impact of their disposal is also very high[26].

1.5. Waste Governance

Waste Governance in India aims at developing and executing a system for waste management rooted in sustainable development. 'Precautionary' and the 'Polluter Pays 'principle are at the centre of Indian waste management regulations[27]. The 3Rs Principle which revolves around 'Reduce, Reuse and Recycle' is embedded into the waste management rules and industries as well as civilians are encouraged to adhere to the 3R principles while dealing with waste. However, the thrust is still on Recycle and Reuse among the 3Rs and the Reduce is the least applied and encouraged mechanism.

[22] TERI (2014). The costs of Developmental inactions. Retrieved from: http://www.teriin.org/files/POLL-2014.pdf
[23] India Environmental Portal. (2016). The true cost of poor sanitation. Retrieved from: http://www.indiaenvironmentportal.org.in/content/435393/the-true-cost-of-poor-sanitation/
[24] Yang, F., Jin, S., Xu, Y & Lu, Y. Comparisons of IL-8, ROS and p53 responses in human lung epithelial cells exposed to two extracts of PM 2.5 collected from an e-waste recycling area, China. Retrieved from: http://iopscience.iop.org/article/10.1088/1748-9326/6/2/024013/meta
[25] ECORECO. Importance of recycling e-waste. Retrieved from: http://ecoreco.com/Uploads/Downloads/importance-of-recycling-of-e-waste.pdf
[26] Marzouk, M & Azab, S. (2014). Best practice measures assessment for construction and demolition waste management in building construction. Resources, Conservation and Recycling, 75. 52-62. Retrieved from: https://doi.org/10.1016/j.resconrec.2013.03.009
[27] Down To Earth. (2017). India's challenges in waste management. Retrieved from: http://www.downtoearth.org.in/blog/india-s-challenges-in-waste-management-56753

The rules and regulations are formulated by the Ministry or Environment, Forests and Climate Change (MoEFCC). The responsibility to carry out waste management is on municipal authorities or Urban Local Bodies (ULB). The recent SWM rules of 2016 brought in several new guidelines and directives such as

- The source segregation of waste has been mandated to channelize the waste to wealth by recovery, reuse and recycle.
- Special Economic Zone; industrial estate; industrial park have to earmark at least 5% of the total area of the plot or minimum 5 plots/ sheds for recovery and recycling facility
- Generator will have to pay 'User Fee' to waste collector and 'Spot Fine' for Littering and Non-segregation

Similarly, Waste Management Rules were revised for E-Waste, Plastic waste and C&D waste in 2016. The E-waste Management Rules (2016) specifically mentions the responsibilities for the manufacturer, producer, collection centres, dealers, refurbishers, consumers, dismantlers and recyclers pertaining to each stage in the life of an electronic product. There are also responsibilities entrusted on State Governments for environmentally sound management of e-waste.

The Plastic Waste Management Rules (2016), is a revision over the Plastic Waste (Management and Handling) Rules, 2011. The new rules emphasise on plastic waste minimization, source segregation and involvement of waste pickers amongst other features. Major responsibilities of plastic waste management are entrusted on local bodies (ULBs and Panchayats). Use of plastic waste for road construction and energy recovery options are encouraged by the new guidelines and segregation of waste is the responsibility of the generator for household waste.

The Biomedical Waste Management Rules (2016) is an amendment of Bio-Medical Waste (Management and Handling) Rules, 1998. The rules define specific duties to the Occupier, Operator of a common bio-medical waste treatment and disposal facility as well as Authorities. The new rules stress on occupational safety of all workers handling the waste, pre-treatment of laboratory waste and separation of treated healthcare waste from MSW amongst other guidelines. The authorities are mandated to check that the occupiers set up 'requisite biomedical waste treatment equipment like incinerator, autoclave or microwave in cases where service of the common bio-medical waste treatment facility is not available'.

Construction and Demolition Waste Management Rules, 2016 apply to waste emerging from construction, construction and demolition, de-construction and demolition of civil structures. The rules specify the duties of the waste generator, service providers and contractors as well as local authorities. There are additional mandates regarding the construction and maintenance of recycling or processing sites for C&D.

Table 2 depicts an overview and comparison of the regulations for different waste streams.

Table 2 Overview of Waste Governance in India

SN	Waste Stream	Major Rule & year	Major Amendments	Elements it Captured (In context to 3R's)				Key institutions
				Environmental Benefits	Social Responsibility	Economic Instruments	Corporate Responsibility	
1	**Municipal Solid Waste**	Municipal Solid Waste Rules - 2000-2011	Solid Waste Management (SWM) Rules-2016	Emphasis on source segregation	Informal sector is recognized	User fees for waste collection	Waste segregation mandates	MoEFCC, ULBs, CPCB, SPCB
2	**Electronic waste**	Electronic Waste Rules-2011	E Waste Management Rules-2016	Pre-treatment for immobilising Mercury, safe storage and transportation of e-waste	Skill development for workers	Deposit refund system	Extended Producer Responsibility, Producer Responsibility Organisation	MoEFCC, ULBs, CPCB, SPCB
3	**Plastic waste**	Plastic Waste Rules-2011	Plastic Waste Management Rules-2016	Ensuring segregation, no open burning	Awareness creation among stakeholders	User fee	Extended Producer Responsibility	MoEFCC, ULBs, CPCB, SPCB
4	**Construction & Demolition waste**	Construction & Demolition Waste Management Rules-2016		Waste segregation and safe storage/processing	Health and safety concerns are looked at	Processing and disposal fees for higher waste generation	Bulk C&D Waste Generators addressed	MoEFCC ULBs CPCB, SPCB

5	**Healthcare waste**	Bio-medical waste (management and handling) rules, 1998	Bio-medical Waste Management Rules, 2016	Safe handling to avoid any environmental degradation, Operational standards	Occupational Safety		Annual Reporting	MoEFCC ULBs Ministries of Health CPCB, SPCB

Chapter 2

Status of Waste Management Infrastructure

2.4. Waste Cycle

Waste generation starts with the extraction of resources, followed by transportation to the point of consumption or the processing facility. Wastes are generated during processing while making products. Waste is also generated when the products (e.g. food and treated water) are used and when discarded (e.g. paper, plastic bottles, batteries). The MSW is collected by local bodies or private parties and are sent to transfer stations or storage centres. If not segregated at the source, the sorting centres are required to sort and separate the waste. Here household e-wastes and plastic waste get separated. The segregated waste is further treated at the waste treatment centres or at valorisation plants on decentralized or centralized basis. Figure 9 provides an overview of different stages of the waste cycle. The C&D waste is managed separately from the construction sites.

Figure 9: Waste Management Cycle, Source: Waste Life Cycle. (2017). Retrieved from: http://www.epur.fr/en/environmental-services/)

To realise a smart waste management system, maximize resource recovery and reduce risks to humans and ecosystems, an efficient method for waste segregation is required. It is the most important step in the transition to a circular waste management paradigm. Some cities like Panaji and Mysuru have been doing it well and this needs to be replicated in other cities. Certain corporations like Pune, Mumbai and Bengaluru have resorted to fines and penalties for failing to

segregate waste at source. If segregation at source is not achieved as intended, efficient sorting centres come to the rescue. Pune in Maharashtra and Mysuru in Karnataka are leading examples in waste segregation. In Mysuru, an effective waste segregation program is taking place in the city with community participation (see Box 1). Pune in Maharashtra also has a commendable system in place for the sorting of wastes. In Pune, sorting of the waste collected from households is carried out at the sorting centre. Sorting centres are used to sort the waste into different categories like plastic, metal, glass, paper etc. based on resource recovery potential and the secondary market. In Pune, each corporator was asked to give a small area for each rag picker in that locality. They would collect the mixed waste from the houses and take it to the sorting centre (see Box 2).

Box 1 Mysuru: The Indian leader in Waste Management

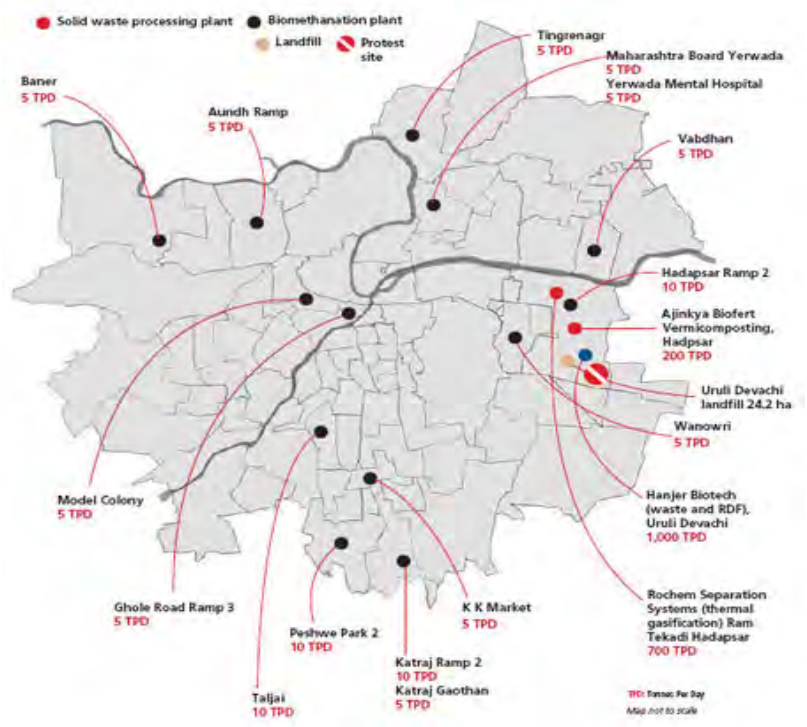
Mysuru, the second largest city in Karnataka sets forth many good practices when it comes to waste collection and management. The city of 0.89 million people generates about 0.45 kg of garbage per person. A distinguishing factor of the waste management system in Mysuru is the citizen participation via 'Let's do it Mysore', a non-government initiative. Citizens are constantly given instructions on effective waste segregation and the city has 100 percent door-to-door waste collection. Mysuru emphasises on source segregation and has nine waste-segregation plants that focus on producing quality manure. All the vehicles used for waste collection are monitored through GPS system. More high-tech measures like use of chip-readers at home for waste collection are under trial. A 'zero waste' plan for the city is under progress and currently the Municipal Corporation gains revenue from the sale of manure and dry waste like plastic from the collected waste.

Source: Swachh Bharat Urban Twitter

Source: ET. (2016). Swachh Bharat@2: What separates garbage city Bengaluru from the clean Mysuru? Retrieved from: https://economictimes.indiatimes.com/news/politics-and-nation/swachhbharat2-what-separates-garbage-city-bengaluru-from-the-clean-mysuru/articleshow/54502204.cms

Box 2 Sorting Centres and Decentralized Waste Processing in Pune

Pune is a pioneer among Indian cities in decentralized municipal waste management system. Sustainable Waste Management is an integral part of the Advance Locality Management (ALM) in the city. Participatory Budgeting done as a part of ALM brought many issues in MSW into limelight. This further led to the construction of 30 waste sorting centres and 16 decentralised waste processing facilities. The programme also successfully integrated waste pickers in the city into the MSW management system. The city was the first in India to register waste pickers in 1995. They were offered trainings for safe waste handling as well as the city built a system in place for them to work with dignity. SWaCH is the cooperative of waste pickers in Pune and it has 2700 members as of 2017 December. It covers 550000 households daily and handles 50000 metric tons of recycled waste.



SWaCH Impact. (2017). Retrieved from: https://swachcoop.com/

Pallavi. (2014). Lessons from two cities. Down To Earth. Retrieved from: http://www.downtoearth.org.in/coverage/lessons-from-two-cities-43741

i. Transfer stations: A waste transfer station is a facility where the MSW is temporarily stored before transferring it to waste processing facilities or landfills. Sometimes, decentralized waste processing facilities are collocated with the transfer stations.

ii. Transportation network and vehicles: Transportation network is important in a waste management system. It involves transport of waste from the sources to sorting centres,

from sorting centres to transfer stations and then further to waste processing plants or landfills.

Typically costs of waste collection, storage and transportation consume 60 to 70% of the operating budget. Use of “smart” technologies that reduce the costs of operations become important. RID enabled bins, GPS enabled fleet of vehicles with optimum vehicle routing help in reducing the transportation cost, increase collection coverage, reduce fossil fuel consumption, reduce emissions as well as GHGs and save the non-renewable resources. Smarter options are also possible where the organic fraction of the waste is processed in bio-methanation plants to generate bio-gas. The collection vehicles are then operated using the bio-gas, eliminating consumption of fossil fuels and avoiding the GHG emissions (due to processing of waste).

iii. Decentralized plants: These plants process the wastes generated in the neighbourhood and recover useful resources such as biogas or compost. Segregation at the source or sorting centres are very important for their success.

Figure 10: Statistics on Solid Waste Processing Plants in India, Source: CPCB

iv. Centralized facilities: These facilities include a centralized management for waste for the entire urban area. They may include waste-to-energy plants and waste-to-compost plants that require economies of scale, availability of large areas or are not preferred to be in the densely populated areas within cities. Facilities for processing special waste streams such as health care wastes, plastic and C&D wastes are typically operated on a centralized basis.

v. Landfill: These are facilities for safe disposal of wastes that do not have any economic value and are hazardous. Till the submission of Annual Report for 2010-11, there was record of 59 landfills constructed in the country, 376 landfills under plan and 1305 landfill

sites were identified for future use[28]. See Figure 11 for the depiction of the details on landfills.

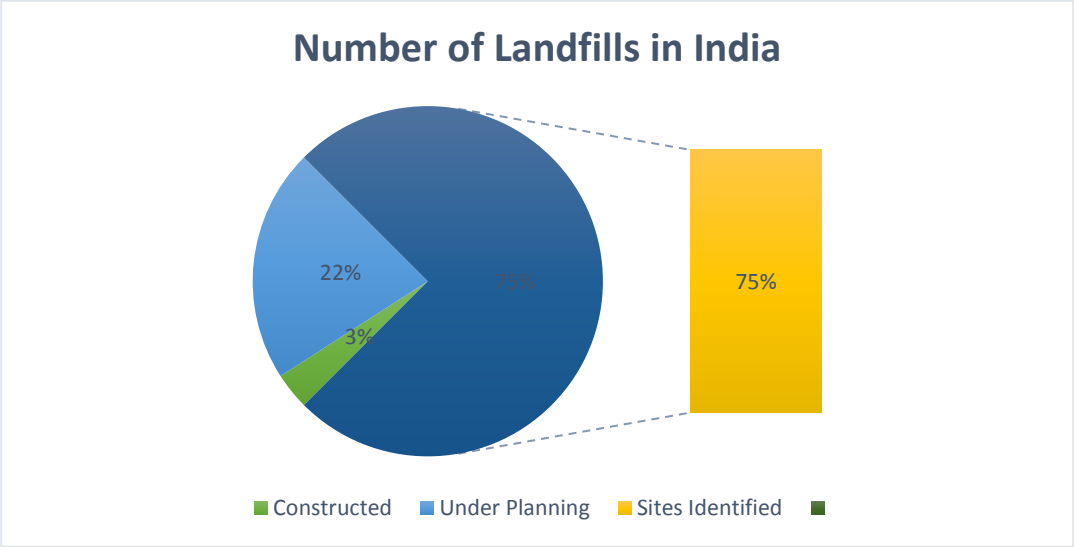


Figure 11: Landfills in India

Adequate waste management infrastructure is needed at all the above stages of the waste cycle. Effective waste management is expensive, and it often comprises of 20-50% of total municipal budgets[29]. Satisfactory operation of the assets or the waste management infrastructure requires additional operational budget. Private sector and the communities have therefore a greater role to play.

There are a few private sector entities in the waste management sector in India providing services ranging from waste collection to waste processing and waste disposal. Already there are contracting options existing in the waste sector. Private Sector Participation can bring in more finances, modernisation, better service delivery and increase productivity of labour and machinery[30]. There are also certain start-ups in the sector offering innovative business models for urban waste management. See Box 3 for waste management initiative by private companies in Indian cities.

[28] CPCB. (2013). Status report on municipal solid waste management. Retrieved from http://www.cpcb.nic.in/divisionsofheadoffice/pcp/MSW_Report.pdf

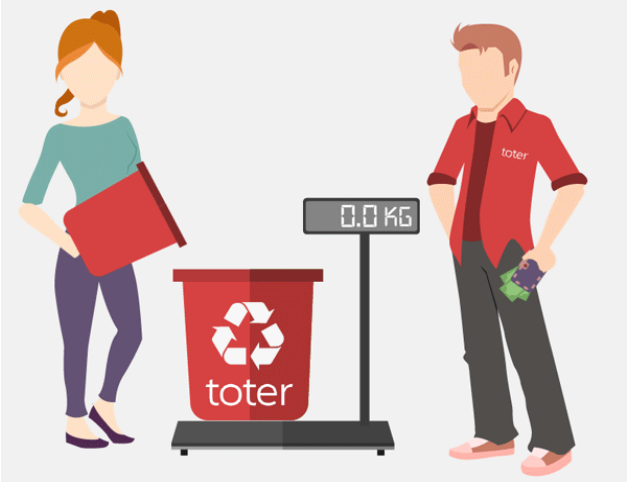
[29] World Bank. (2017). Solid Waste Management. Retrieved from: http://www.worldbank.org/en/topic/urbandevelopment/brief/solid-waste-management

[30] http://siteresources.worldbank.org/ENRLP/Resources/460956-1163449042857/Private_Sector_Participation.pdf

Box 3 Private Sector Waste Initiatives in India

Waste management sector in India has been recently witnessing the entry of private players with innovative business models.

Waste Ventures India



Waste Ventures India offers professional waste collection and processing services to households, corporate clients and waste pickers. Since 2013, the company has reverted over 3,000 tons of waste from Indian landfills. Waste ventures India boasts to offer Hyderabad's first digital doorstep recyclable pickup service. The customers can earn money for their trash and the digital weighing, transparent pricing, and on-the-spot payment in the process makes it convenient and credible.

Priti International

Priti International is an ecommerce start-up that recycles industrial and consumer waste into useable products. The firm has a turnover of $10million and designs and manufactures handmade products out of waste materials, like handbags from old gunny bags, cast off military tents and denim pants. The company also produces furniture from waste tins, drums, old military jeeps, tractor parts, waste machine parts and lamps from old scooter and bike lights.

Banyan Nation

Banyan Nation specialises in recycling plastic. The firm collects plastic wastes from industries and recycles it for further use in the industry. The firm is focusing on engineering initiatives and now also looks at adding performance enhancers to the recycled plastic. The goal is to ensure greater lifecycle for recycled plastic ensure. Banyan Nation has its recycling unit at Patancheru in Hyderabad. The company recycles more than 300 tons of plastic every month.

Source: Waste Ventures India. (2017) Retrieved from: https://wasteventures.com/

Source: Officechai. (2016). 14 Indian start-ups and projects that are helping the country go green. https://officechai.com/stories/green-startups-sustainable-development-india/#sthash.pQsHKrUC.vMFKvzaD.dpbs

2.2. 3Rs in Waste Management Infrastructure

The 3Rs have been in the waste management realm highlighting the importance of resource recovery and economic gains from waste. Reduce, Reuse and Recycle form the *mantra* for an efficient system for waste management rooted in sustainability. When the 3Rs are integrated into the waste management infrastructure, it can ensure resource security in the long run. The 3Rs can be integrated to the waste management system to realise resource recovery and resource recirculation. This can further lead to resource efficiency and economic gains (see Figure 12).

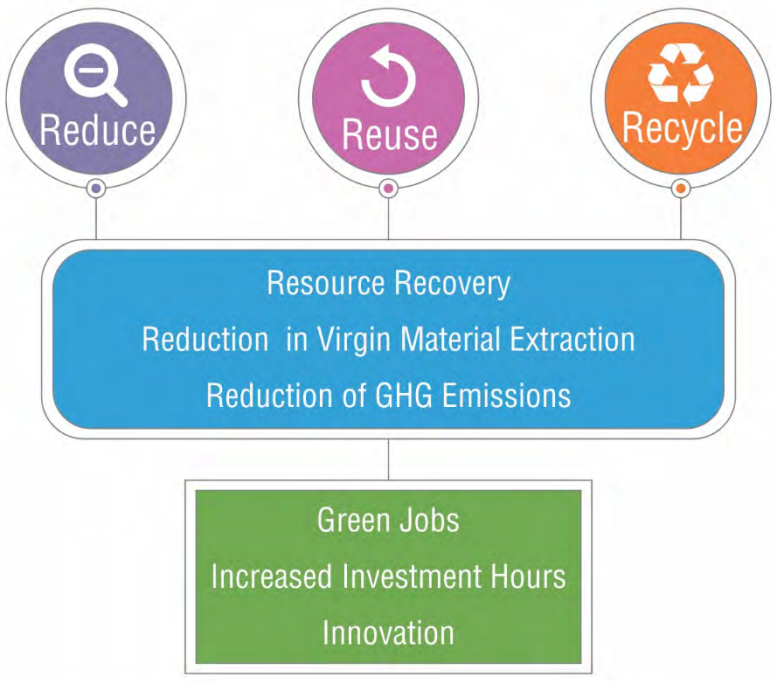


Figure 12: 3Rs to Economic Gains

An example in this case is the use of waste plastic as an additive in road construction. The use of plastic for road pavement has been found to increase the life of roads. While using this technique, the payment is only approximately $ 420 more, against an expenditure of $18,000/- for upgradation in 2-3 years, thus leading to savings of approximately $17,500 per km[31]. So far, several cities have integrated the 3Rs to their waste management practices in successful ways. Few cases and the achievements are listed in Table 2. Box 4 explains the use of biogas in Indian cities as a way for managing urban waste.

[31] https://www.mygov.in/sites/default/files/user_submission/16c4c059fb4718d59dc3af4266c66741.pdf
Price approximations based on 2013 dollar-rupee exchange rates, unaccounted expenditure which may arise has also been accounted

Table 3 Success stories from Cities – 3Rs in Waste Management[32]

MSW Success Cases	City	State	Achievements
High collection efficiency, payment scheme for resident societies	Surat	Gujarat	Ninety-seven per cent collection efficiency. 92 per cent door-to-door collection, exploring plastic-to-fuel possibility
Decentralised waste management systems	Alappuzha	Kerala	Community waste participation, 12 total sanitation wards with 80% households with recycling/composting units, City clean drives
100 % door-to-door collection of waste	Bobbili	Andhra Pradesh	100 per cent door-to-door collection of waste, municipality earns about $11,000 annually by selling recyclables like plastic bottles, paper glass bottles, and bio-compost.
High rate of segregation at source, resource recovery	Mysuru	Karnataka	95 per cent door-to-door waste collection and 30 per cent segregation at source
Involving waste pickers for door-to-door collection, SWaCH initiative	Pune	Maharashtra	85% of waste recovered/processed, 13 bio-methanation plants Annual Savings of $2.3 million
Community led initiatives in waste management	Vrindavan	Uttar Pradesh	Livelihood to 50 waste pickers, 80% of households make regular waste collection payment
Involving waste pickers in community level waste recycling and processing	Mumbai	Maharashtra	200-300MT of waste per day diverted away from landfill, employment for 3000 females waste pickers
Waste-to-Energy from vegetable market waste	Chennai	Tamil Nadu	500 units of electricity produced per day, GHG emission reduction of 8308 tons of CO_2 equivalents per annum
Moving towards scientific waste disposal mechanisms	Srinagar	Jammu & Kashmir	Closure of 240 open dumping sites and replacing those with smart bins, set up 3 leachate ponds of 0.12 million litres capacity
Awareness creation on SW management	Gangtok	Sikkim	IEC measures, cleanliness drives in schools
Creative Campaigns for MSW management	Warangal	Telengana	First ULB in the country to undertake 100% door-to-door

[32] PEARL. (2015). Urban Solid Waste Management in Indian cities. Retrieved from: https://pearl.niua.org/sites/default/files/books/GP-IN3_SWM.pdf

			collection and 70% source segregation, Awareness programs
Using PPP for sustainable waste management in small towns	Pammal	Tamil Nadu	Collected and segregated a total of 11, 934 MT of waste in the year April 2012 to March 2013 from the 16 wards, plastic upcycling and biogas generation
Sustainable model for fully privatised waste management system	Patna	Bihar	Program covers 63000 households, Reduction of nearly 43 MTs of landfill waste, composting and plastic recycling
Color-coded five category waste segregation system	Panaji	Goa	Excellent waste segregation system, 70 composting units, bin-free city with only door-to-door collection
Sanitation points and efficient garbage management system	Aizawl	Mizoram	Efficient waste collection system, journey towards scientific waste disposal

Box 4 The Biogas Revolution in Indian Cities

Several major Indian cities are adopting biofuels for running the public transportation system. Mysuru in Karnataka has been following this system for a while. However, what is new to this green journey is the biogas bus which has been started in Kolkata. It runs on biogas from cow dung and offers a green transport solution. Many other small cities are promoting bio-gas for households and small establishments, though mostly for meeting household fuel needs. Alappuzha in Kerala is pursuing the household bio-gas model and found it successful. Pune in Maharashtra on the other hand follows a decentralised system for housing societies/collectives on biogas generation and the pilots have been found to be feasible.

Biogas Plant in Pune

Bio-gas bus and travel route in Kolkata

Source: Guru mavin. (2016). Biogas plants in every ward. New plan of BBMP. Retrieved from: https://gurumavin.com/biogas-plants-every-ward-new-plan-bbmp/

2.3. 3Rs in Policy Frameworks

3Rs are embedded into the waste management practices in India. Though source reduction is still limited and not much information is readily available, Recycling and Reusing are important parts of the Solid Waste Management Regulations as well as practices. Moreover, informal sector and the formal sector share the responsibilities in the 3R framework of India. The recently amended Solid Waste Management Rules (2016) integrates the 3Rs to the waste management policy.

Designed at the national level, Swachh Bharat Mission encompasses a multi-pronged approach to build a clean India. It is a pan-India initiative by the Government of India and has a subsection, Swachh Bharat Urban which focuses on urban areas, operated by Ministry of Housing and Urban Affairs. Solid Waste Management in urban areas is an integral component of the program. The 3 Rs – Reduce, Reuse and Recycle are incorporated in the policies of the Programme. The Mission aims for 100% waste collection/recycling/treatment in urban areas. Figure 13 gives the Swachh Bharat Mission Objectives.

Figure 13. Swachh Bharat Mission Objectives, Source: Swachh Bharat Abhiyan Twitter feeds

The 3Rs are integrated into Scientific MSW management objective of Swachh Bharat Mission. Recycling of waste, reducing the generation of waste and resource recovery are emphasised under the mission along the lines of SWM rules of 2016. With two components for specific focus on urban and rural issues, the program envisages area-wise solutions and considers the region-specific economic and environmental aspects.

Several State Governments have additional waste management policies incorporating 3Rs. Himachal Pradesh upholds their sold waste management based on MSWM Rules of 2015. The rules closely align with 3Rs and the major principles of the policy include source segregation, community participation, zero landfill status, maximising recycling, polluters pay and waste to value. Tamil Nadu launched its E-Waste Policy in 2010 which was the need of the hour when

Chennai became an IT hub. The policy emphasised on the 'creation of efficient and uniform infrastructure for collection, utilization and disposal of E-Waste' as well as the 'Promotion of recycling and reuse of E-Waste which has high resource potential'. Gujarat unveiled its Waste to Energy Policy in 2016 and the plan intends to facilitate and promote generation of electricity from MSW. Solid wastes from 8 corporations and 162 municipalities of Gujarat offers the potential to generate power up to 100 MW. Goa is another State that is on the path of developing a comprehensive waste management plan. The Goa Waste Management Corporation (GWMC) in on a mission to development a solid waste management plan based on scientific waste management practices with a long-term perspective. Similarly, the States of Rajasthan and Karnataka have State policies on Solid Waste Management whereas, Gujarat, West Bengal, Kerala etc. have high power state missions in place to facilitate prompt implementation of MSW rules[33].

Similar to solid wastes, States have developed own policies in waste water management complementing the national policies. The State of Madhya Pradesh released the State Level Policy (2017) for Waste Water Recycle & Faecal Sludge Management (FSM) for improving the health status of urban population. This policy adds to the national policies and brings in aspects specific to the state in sewerage, septage and service provision for urban dwellers. Jharkhand launched its new Waste Water Policy in 2017 which aims 'to ensure increased use of recycled water for purposes other than drinking through appropriate technologies for water recycling and protection of environment'.

2.4. Circularity in Waste Management

Circular Economy has the potential to unleash a new industrial revolution. It could evolve to be an integral element of the fourth industrial revolution connecting technology, information, people and sustainability. Circular Economy is defined as a system that is "restorative and regenerative by design, and aims to keep products, components, and materials at their highest utility and value at all times". The thrust in circular economic models is on ensuring the value of the resources constantly and closing the production and consumption loops. Most circular economy frameworks distinguish between biological and technical nutrient cycles and specifically explicate the different ways for ensuring prudent resource use in both the cycles. This new economic model will involve rethinking and redesigning many existing production and consumption systems.

[33] World Bank. Private Sector Participation in Solid Waste Management in India. http://siteresources.worldbank.org/ENRLP/Resources/460956-1163449042857/Private_Sector_Participation.pdf

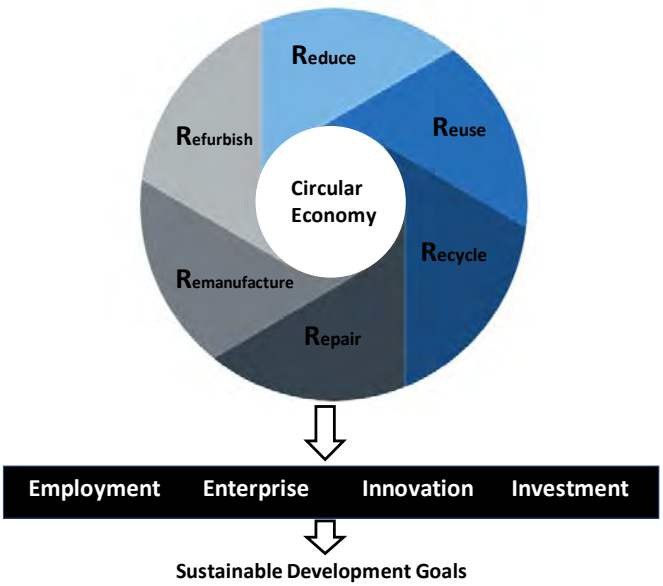


Figure 14. 6 Rs in Circular Economy

The 3Rs which have been used traditionally in resource efficiency discussions are important in circular economy. The 3Rs namely Reduce, Reuse and Recycle have been illustrated as the factors integral to sustainable manufacturing. Circular Economy is embedded on the concept of sustainable manufacturing and hence the 3Rs are considered in CE models. However, circular economy goes further on continuous value creation and adds other factors to the 3Rs. In the place of traditional 3Rs, most circular economy models add **3 additional Rs namely- Repair, Refurbish and Remanufacture** (Figure 14).

These 6Rs form the pivots of circular economy and the interaction of these factors lead to employment, enterprise, innovation and investment in societies leading them to be sustainable and circular societies. The 6Rs are used to realise smart and environmentally friendly design of products rather than mitigating once the environmental impact has been made. The Repair, Refurbish and Remanufacture stand for the circularity in the system where these three factors ensure a closed loop.

Repair: This involves restoring the products after end of life and using them for the same purposes

Refurbish: This involves revamping products after their lifetime without losing value.

Remanufacture: This involves re-processing already used products for making new products without loss of value.

Figure 15. Examples of 6Rs in Practice

As shown in Figure 15, different industries can inculcate the 6Rs in their manufacturing processes so as to achieve sustainable manufacturing. It can not only save resources and provide environmental benefits, but also realise cost savings in water, energy and raw materials. The same 6Rs can be practised at household level as well.

Box 5 illustrates the example of Repair Café. Such repair Cafes have been set up in Bangalore in India.

Box 5: Repair Café[34]

Initiated by Martine Postma on October 18, 2009 in Amsterdam. It was a great success and since 2011, this non-profit organization has provided professional support to local groups in the Netherlands and other countries wishing to start their own Repair Café.

Repair Café are free meeting places where they repair things together. Tools and materials are provided to help make any repairs on clothes, furniture, electrical appliances, bicycles, crockery, appliances, toys, etc. Expert volunteers, with repair skills in all kinds of fields are available.The Repair Café Foundation has been appointed by the Dutch tax authorities as a "Public Benefit Organization" (Dutch: "Algemeen Nut Beogende Instelling", ANBI). This ANBI status makes it fiscally attractive for donors to support the foundation. Today, there are more than 1,400 such cafés in 33 countries, from the US to Japan. Repairing has prevented about 250,000kg of waste from heading to landfills in 2016.

[34] RepairCafe. (2016). About the Repair Cafe. Retrieved from Wordpress by Van Ons web: https://repaircafe.org/over/

Chapter 3

Circular Economy and Waste Management

3.1. The Circular Economy Concept

The dwindling resource base, rising costs of raw materials, price volatility and uncertainties due to climate concerns emphasise on the need of a transition to circular economy models. The pursuit of economic growth at the cost of environment, has led to environmental challenges in many parts of the world. It is high time that the shift towards a circular 'resource-product-waste-recovery-regenerated resource' based system is in place.

The idea of circular economy draws from several other programs and strategies that discuss environment as an integral part of economic development. In the context of sustainable manufacturing, circular economy succeeds eco-efficiency, 3Rs and (Resource Efficiency & Cleaner Production) RECP based models. Figure 16 shows the evolution of the circular economy concept.

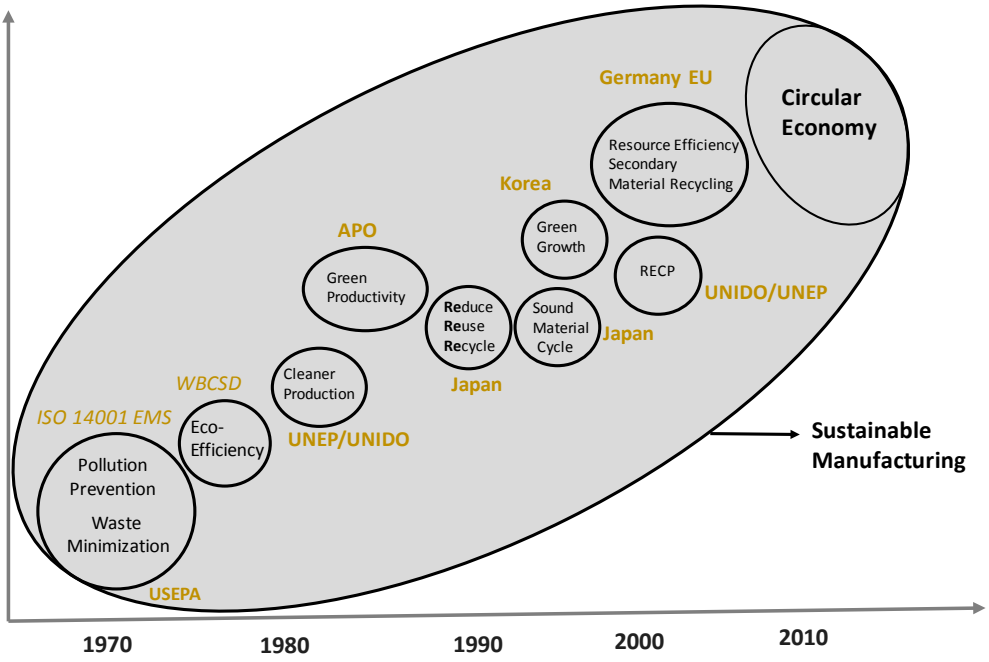


Figure 16. Evolution of Circular Economy

Circular Economy that closes the production and consumption loops is a solution to many sustainability related conundrums of today. Circular economy is rooted in resource reduction recycling and smarter resource use across the life cycle[35]. It can be used to design smarter production and consumption systems while enabling more stakeholder involvement and

[35] Ellen MacArthur Foundation, 2012

participation. European Union (EU) and countries like Japan, Korea and China have been undertaking several circular economy initiatives with regional as well as national goals (see Boxes 6 and 7).

Box 6: Circular Economy in European Union

European Union is a pioneer in Circular Economy. EU has been working closely with its industries, governments, academia and entrepreneurs to propagate and realise the idea of CE. EU adopted an ambitious Circular Economy package to stimulate Europe's transition to a closed loop circular economy. This in turn brings forth competitiveness, job creation and sustainability in Europe. EU Action Plan for Circular Economy is an important part of the package and it provides a systematic plan for the circular transition in production and consumption.

The major circular goals for waste (2018) are:

-A common EU target for recycling 65% of municipal waste by 2030;

-A common EU target for recycling 75% of packaging waste by 2030;

-A binding landfill target to reduce landfill to maximum of 10% of municipal waste by 2030;

-A ban on landfilling of separately collected waste;

-Promotion of economic instruments to discourage landfilling;

-Simplified and improved definitions and harmonised calculation methods for recycling rates throughout the EU;

-Concrete measures to promote re-use and stimulate industrial symbiosis - turning one industry's by-product into another industry's raw material;

-Economic incentives for producers to put greener products on the market and support recovery and recycling schemes (e.g.: for packaging, batteries, electric and electronic equipment, vehicles).

Source: European Commission. (2017). Circular Economy. Retrieved from: http://ec.europa.eu/environment/circular-economy/index_en.htm

The following box depicts the circular initiatives of China.

Box 7 - Circular Economy in Chinese cities

A decade ago, Chinese economy was grappling with resource scarcity and massive waste challenges. In 2014 China produced 3.2 billion tonnes of industrial waste and projections show that the country will contribute to one quarter of all global waste in 2025. In view of such an impending resource crisis, China adopted its ambitious waste recirculation plan along the lines of 'circular economy'. The initial stages of circular economy in China focused on industrial parks while the further stages stepped into eco-cities. An interesting case is of the Suzhou New District which is a 52-square-kilometre industrial zone near Shanghai with 4000 manufacturing firms. The

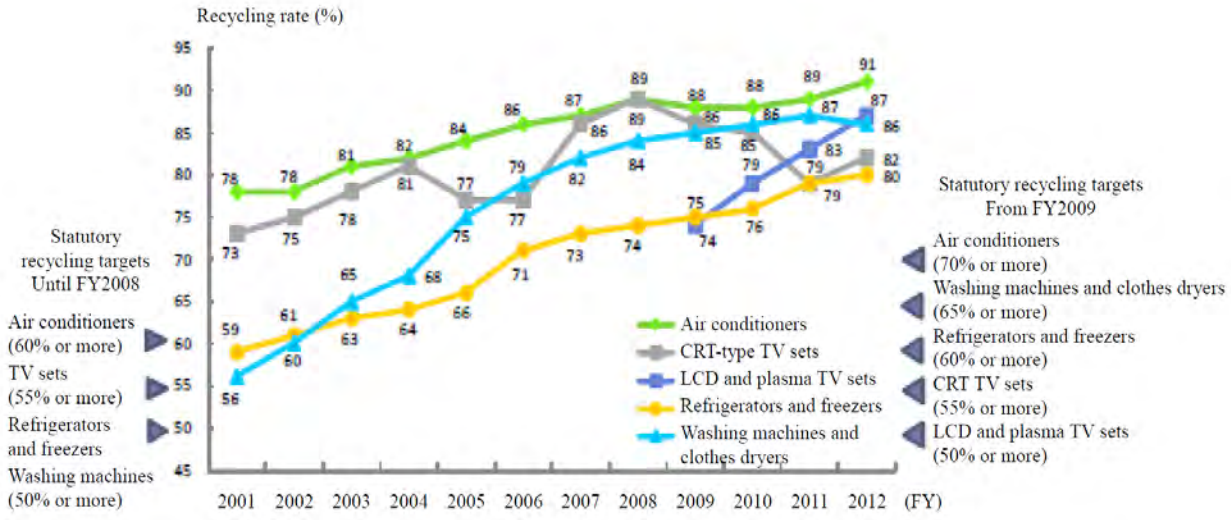
manufacturers of printed circuit boards in the zone use copper that is recovered from waste produced by other firms in the park, thus avoiding virgin copper[36].

China adopted a circular economy promotion law in 2008 and circular economy was upgraded to a national development strategy in the 12th Five Year Plan of 2011-15. In addition to industrial parks, the circular economy plan was extended to 100 demonstration cities. The circular initiatives are found to help in the sustainable transition of China- resource intensity and waste intensity improved by 34.7 and 46.5 percent respectively in the 2005-2013 period[37].

The following case is about increased e-waste recycling in Japan owing to Extended Producer Responsibility.

Box 8 Extended Producer Responsibility for e-waste management in Japan

Japan is a front-runner in environmental regulations and specifically in e-waste management. The Fundamental Environmental Law has been launched in 1993 and since then the country has taken several measures for sound waste management, resource recovery and material recirculation. For effective e-waste management, the home appliances recycling law was floated in 2001. Under the EPR system customers are responsible for proper transfer and payment for discarded appliances whereas the retailers collect and transfer the appliances. Manufacturers oversee the management of the recycling system. The EPR system has been successful in achieving high recycling rates for electronics.



Source: Morita, Y. (2018). Institute for Global Environmental Strategies

[36] Wen, Z. G. & Meng, X. Y. (2015). Quantitative assessment of industrial symbiosis for the promotion of circular economy: a case study of the printed circuit boards industry in China's Suzhou new district. Journal of Cleaner Production. 90, 211–219. https://doi.org/10.1016/j.jclepro.2014.03.041

[37] Mathews, J.A.& Tan, H. (2016). Circular Economy: Lessons from China. Nature, 531(7595). Retrieved from: http://www.nature.com/news/circular-economy-lessons-from-china-1.19593

3.2. The Economics of Waste

Waste generation and sustainable waste management are important topics in national policy debates. Waste management entails significant investments from local governments and could lead to environmental and health impacts in case of improper practices. However, the economic value of waste is often not fully exploited which could in turn convert the waste to wealth and no more a liability. A 3R -centric approach to waste has been found to add social, economic and environmental benefits to India[38]. According to the Planning Commission, MSW that is not utilised has the potential to produce 439 MW of power from 32,890 tons per day of combustible waste. This includes refuse-derived fuel, 1.3 million cubic metres of biogas per day and 5.4 million metric tonnes of compost (all annual) that can be utilised for agricultural purposes.

Economic potential for each waste stream is analysed in this section illustrating the different components of the waste and possible resource recovery options. For municipal solid waste 50% of organic waste proportion has been chosen. In the case of MSW, composting, biogas and electricity generation are considered. For the other valuable constituents of MSW and e-waste, the value of the recovered resources is calculated. Not all components of the wastes are included owing to the fact that their amounts are not fully recorded, and recovery values are not available. See Figures 17 and 18 for a depiction of the value chain of waste streams[39]. Details about prices considered are given in Annex 3. This is however work in progress and the Author proposes to continue this work further by accessing more data.

[38] Narayana, T. (2009). Municipal Solid Waste Management in India: From waste disposal to recovery of resources? Waste Management, 29, 1163-1166. Retrieved from: http://sgpwe.izt.uam.mx/files/users/uami/citla/Lecturas_temas_selectos/municipal_solid_waste_in_india.pdf

[39] Scrapregister. (2017). India scrap metal prices. Retrieved from: http://www.scrapregister.com/scrap-prices/india/13

India Mart. (2017). Waste Paper prices. Retrieved from: https://dir.indiamart.com/impcat/waste-paper.html

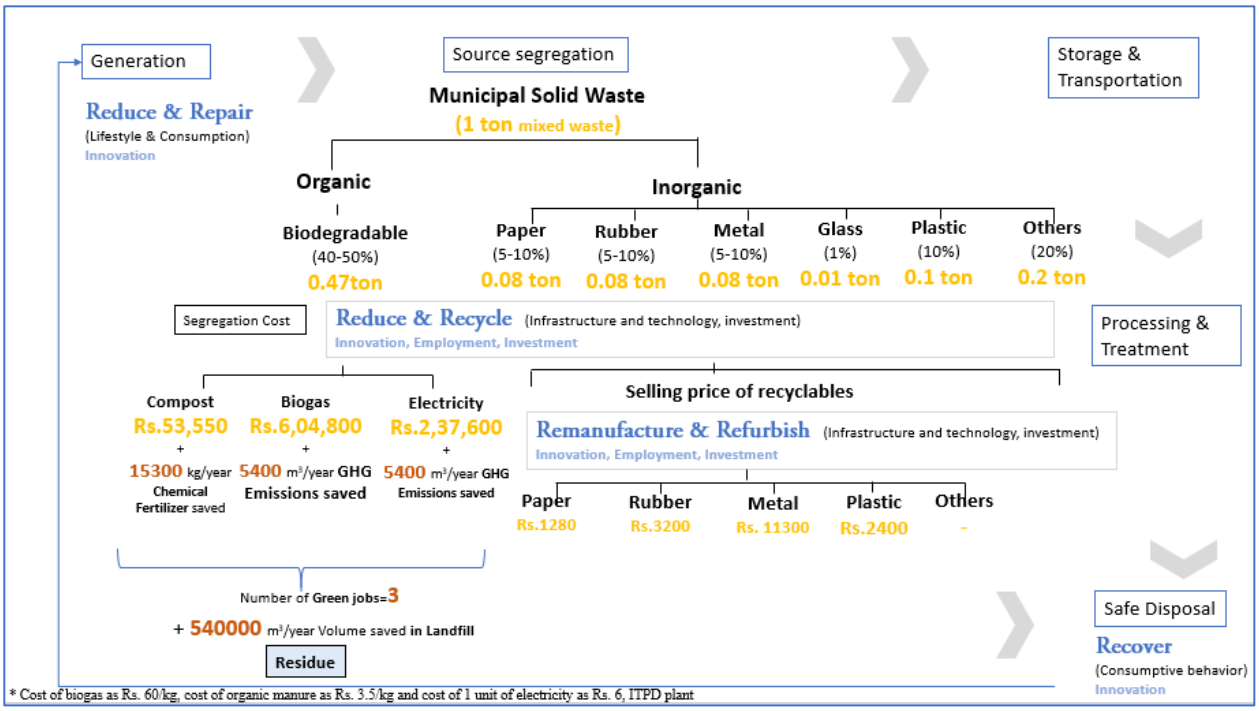


Figure 17. Value Chain for Solid Waste (1$= ₹65, 2018 exchange rates)

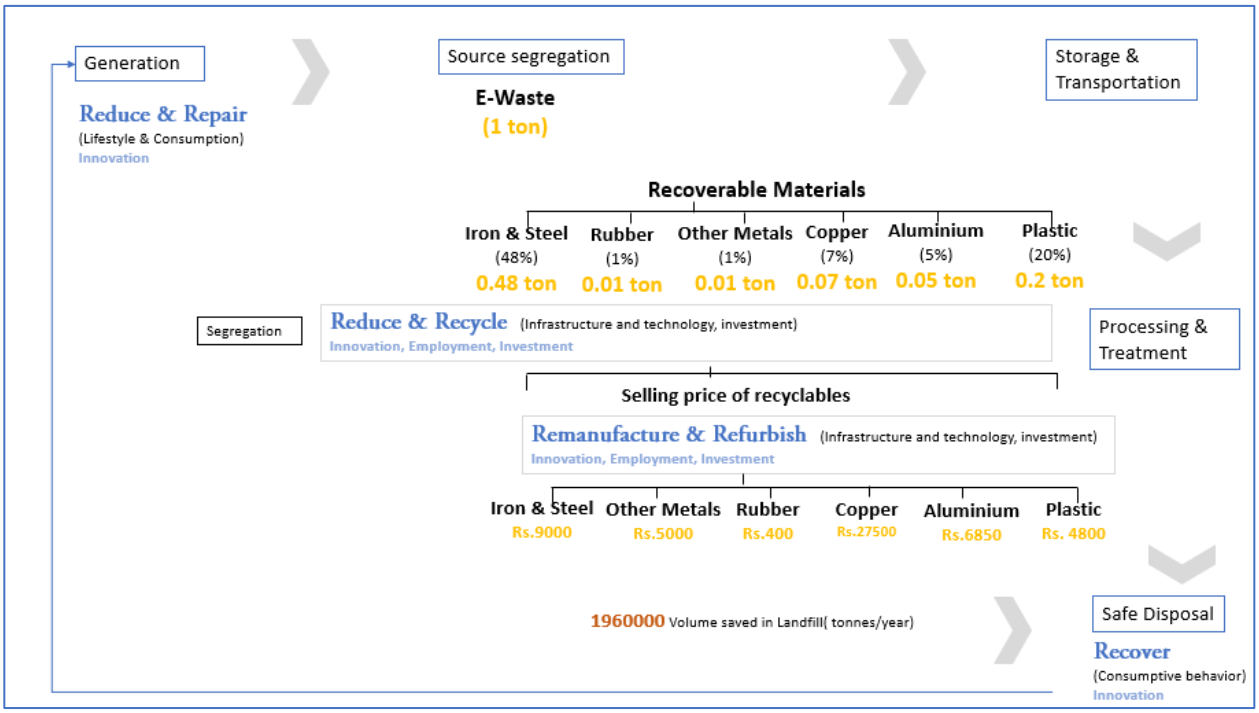


Figure 18. Value Chain for E-Waste (1$= ₹65, 2018 exchange rates)

3.3. Circularity in Waste Management in Cities

The innovative waste management practices by following CE ensures sustainable waste management in cities that are already burdened with resource constraints. There are several circular waste management practices emerging in different countries like Sweden, the Netherlands (see Box 9) and People's Republic of China. These models are based on the 'closed loop' or 'circular' systems where waste from a process is recovered or converted as a raw material for another process. Industrial parks in People's Republic of China have adopted this mode of resource recirculation taking inspiration from Eco-Towns of Japan.

Box 9: Circular Economy and Waste Management in Amsterdam

Amsterdam is on a journey moving from a linear to a circular economy aiming at minimising the waste and pollution in the city by reducing, recycling and reusing. The City of Amsterdam aims to redesign twenty products- or material chains. According to the city, 'the implementation of material reuse strategies has the potential to create a value of €85 million per year within the construction sector and €150 million per year with more efficient organic residual streams'. Amsterdam has set up an innovation program on the circular economy for supporting the circular transition.

There are many interesting projects that are taking place as part of the circular city program of Amsterdam. *Hemelswater* is a project that turns rainwater into beer. It aims at the twin goals of rain proofing the city and harvesting rainwater. *Bundles* is another project that offers home appliances on a subscription model of 'pay per use'. Bundles provides high quality sustainable appliances in the place of disposable appliances with short lifetimes. These appliances come with lower environmental impact as the applied materials and production efforts are utilized more efficiently. Build2Map is another company with one of the projects as part of the Circular City Amsterdam. The firm focuses on 100 percent material reuse, material value and zero-waste in the construction industry.

It is possible for the Indian Waste Management sector to traverse a circular economy journey. There are already existing factors that make this transition possible as shown in Box 10.

Box 10 Factors supporting the CE transition in Indian waste management sector[40]

- Rising environmental concerns in cities

-Informal sector in Waste Recycling

-Existing Repair, Refurbish and Remanufacturing and Reuse Culture

-Policy frameworks like Swachh Bharat Mission and State Policies on Recycling of Waste and Wastewater

-Digital knowledge, social networking and innovative business models (B2B, B2C and C2C)

- Shift to service industry where leasing/renting are becoming preferred choices than ownership

Box 11 provides a case study of Integrated Waste Exchange in Cape Town.

Box 11 Integrated Waste Exchange in Cape Town[41]

IWEX (or Integrated Waste Exchange) is a free online system that enables waste generators and users to exchange waste materials.

Operating on the principle that 'one person's garbage is another person's gold, IWEX facilitates the re-use of waste, thereby conserving energy, minimizing resource use and reducing the pressure on Cape Town's landfill space. The service is freely available to anyone who generates or uses waste, including companies, individuals, institutions, schools, NGOs, and community groups.

Circular Waste Management projects have immense potential for Indian cities. Considering the growth in waste generation, population growth in cities and resource constraints, achieving circularity in waste management could be the way ahead for smart and sustainable cities. Moreover, the recycling sector in India employs several thousands of informal waste pickers. Achieving circularity in Indian waste management sector can not only tackle the impending resource crunch but also integrate several informal sector waste workers to a formal waste

[40] Picture source: http://www.freeworldmaps.net/asia/india/location.html

[41] Integrated Waste Exchange. (n.d.). CCT_IWEX_advertorial_New_CI_April_2014.indd. Retrieved from Cape Town - IWEX: http://resource.capetown.gov.za/documentcentre/Documents/Graphics%20and%20educational%20material/IWEX%20Flyer.pdf

management system. The revised Waste Management Rules which were launched for solid waste and e-waste amongst other waste streams, have special attention for the inclusion of informal sector through training and capacity building.

Chapter 4
Smart and Circular Cities

4.1. Smart cities: An Introduction

Smart cities are gaining more attention in the international development context. The idea of smart cities aligns closely with the holistic approaches to managing people, knowledge and resources. There are many definitions for smart city and one that encompasses many of its features states that "Smart city is a high-tech intensive and advanced city that connects people, information and city elements using new technologies, in order to create a sustainable, greener city, competitive and innovative commerce and an increased life quality"[42].

A smart city will entail 'smart management' of solid wastes as well. With the advanced technologies, available, smart cities can realise efficient waste management in centralized and decentralized modes. See Boxes 12,13 and 14 for the definitions, differences and common elements in smart and sustainable cities.

Box 12 Cities getting Smart in Waste Management[43]

Toronto is a front runner is MSW management and they adopted the 30-to-50-year integrated waste management strategy combining circular economy and zero waste factors in 2016. The programme goes beyond managing the traditional MSW, and has additional focus on reducing food waste and textile waste. The project emphasises on improving waste management in multi-family homes, nevertheless it also integrates other components of smart cities like shifting to CNGs and use of autonomous vehicles for waste management.

Arlington, Va, is a county that acts a city and has adopted a solid waste management plan. Arlington developed a zero-waste goal in 2016 to achieve 90 percent diversion rate by 2038. Aligned with the goals, the country has weekly collections for single stream recyclables, yard trimmings and garbage. There are RFID tags on all waste collection carts and the data from these will be utilized in future. The county intends to incorporate food waste collection by 2019 to reach diversion rates of 70 percent.

[42] Bakici, T., Almirrall, E., & Wareham, J. (2012). A Smart City Initiative: The Case of Barcelona. Journal of the Knowledge Economy,2(1),1-14.
[43] Szczepanski, M. (2017). How smart cities are managing solid waste? Retrieved from: http://www.waste360.com/generators/how-smart-cities-are-managing-solid-waste

Box 13 Definition of Smart city

"In India, there is no one way of defining a Smart City. It means different things to different people. The conceptualization of Smart City, therefore, varies from city to city and country to country, depending on the level of development, willingness to change and reform, resources and aspirations of the city residents".

-MOUD, 2015

"Smart City refers to a city-a district, city, region or small country- which takes a holistic approach to employing information technologies with real-time analysis that encourages sustainable economic development".

-IDA, 2012[44]

"A smart sustainable city is an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social and environmental aspects as well as cultural."

-UNECE and ITU, 2014[45]

Box 14 Sustainable cities

Cities are to become focal points of sustainability owing to the huge production and consumption taking place in urban areas. The concept of sustainable cities has been in the discussions since the early 1990s. According to International Council for Local Environmental Initiatives (ICLEI), "Sustainable cities work towards an environmentally, socially and economically healthy and resilient habitat for existing generations, without compromising the ability of future generations to experience the same". Achieving sustainability is cities is now conceived as consisting of four pillars – social development, economic development, environmental management and urban governance.

Sweden is a frontrunner in transforming its cities into sustainable cities and in assisting sustainable city programmes worldwide. From Stockholm to Malmo, Swedish cities are embracing sustainable practices. Växjö touted as the greenest city of Europe lies in South of Sweden. It was first city in the world to declare its intent to go fossil free in 1991. The city with a population of 66,000 adopted its Environmental Programme in 2006, promoting sustainable living, fossil free transport and conservation of nature. The city has been successful in upholding to its green goals. Sweden now carries forward the sustainable city mission through collaborative efforts with other countries. Swedish architectural firms are supporting the construction of two Eco cities in China – the Caofedian and Wuxi Eco-cities.

[44] IDA Singapore. (2012). iN2015 Masterplan. Retrieved from: http://www.ida.gov.sg/~/media/Files/Infocomm%20Landscape/iN2015/Reports/realisingthevisionin2015.pdf.

[45] Smart sustainable cities: An analysis of definitions, ITU-T Focus Group on Smart Sustainable Cities, 2014

The idea of smart and sustainable cities has been evolving since the early 1990s in the global development arena. The major thrust to the idea of sustainable development occurred post the Brundtland Commission Report and embedding the theme to cities came about in a few years after that. The UN Sustainable Cities Programme which emerged in 1992 made sustainability an important feature of cities. With time, smart cities, resilient cities, low-carbon cities and circular cities joined the bandwagon. Though there are multiple terms and characteristics specific to each, a balance of economic, social, cultural and environmental facets of development is inevitable for all these cities. Refer to Figure 19 that attempts to show a rough time line of the evolution from sustainable cities to circular societies.

Figure 19. Sustainable journey of cities

4.2. Leveraging on Smartness to Propel Circular Economy

Circular Economy in Smart Cities

Cities can be the focal points of circular transition in economies. Digital technologies and smart practices can strengthen this transition towards regenerative and restorative systems. According to Ellen MacArthur Foundation, *"Circular cities aim to eliminate the concept of waste, keep assets at their highest utility at all times, and are enabled by digital technology. A circular city aims to generate prosperity and economic resilience for the city and its citizens, while decoupling this value creation from the consumption of finite resources*[46]". Circular cities with strong digital infrastructure, can be smart, resilient and sustainable. Such cities will have closed loop systems with components like smart mobility, renewable energy and materials tracking. Figure 20 gives an overview of the potential elements of a smart and circular city.

[46] Ellen Macarthur Foundation. (2017). Cities in the Circular Economy: The role of digital technology.

Internet of Things: Ensures a well-connected digital infrastructure for the city

Smart Mobility: Ensures efficient and time saving transport solutions

Sustainable Water Use: Enables prudent use of limited water resources, water recycling and reuse

Products as Services: Enables new business model for resource recirculation, supporting 6Rs

Renewable Energy: Integrates clean energy to all activities

Materials Tracking: Supports productivity and ways to conserve resources

Waste=Resource: Ensures smart waste management, resource recovery and 6Rs to achieve zero-waste goals

Figure 20. Elements of Smart and Circular Cities

Are smart and sustainable cities the same? Though the terms pervade the urban development agenda and are used interchangeably to refer to the cities of the future, there are differences between the two concepts and their goals. The gist of the smart city concept revolves around the technological empowerment of urban spaces. The smart cities focus on widespread, inclusive and available technology which can lead to improved quality of life in cities[47]. Sustainable planning is an integral part of smart cities. However, sustainable cities go beyond technology driven urban development and encourages public and private sector participation and transparent governance. Further, more factors contributing to environmental sustainability and social acceptance are considered in the designs of sustainable cities[48]. A smart city focuses on integrating digital infrastructure into cities whereas a sustainable city encompasses culture, diversity, eco-friendly designs, heritage, resilience, sustainable technologies and so on.

Municipal Solid Waste Management has immense potential to adopt smart technologies. This could improve the efficiency in waste collection as well as treatment. Many solutions for smart treatment of MSW is arising in different parts of the world. Certain important components of these

[47] Fistola, R & La Rocca, R.A (2014). The sustainable city and the smart city: measuring urban entropy first. WIT Transactions on Ecology and Environment. 191, 537-548.

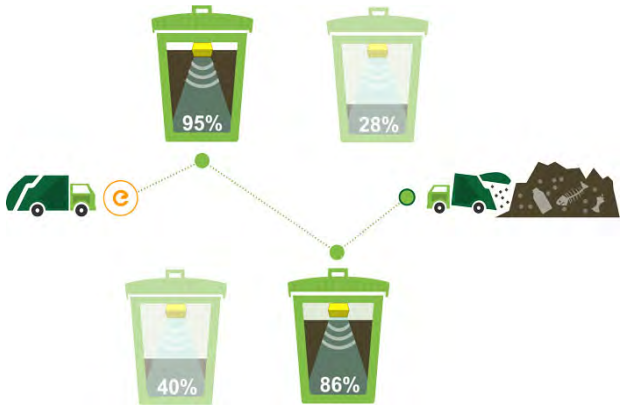
[48] Ahvenniemi, H., Huovila, A., Pinto-Sepp¨a, I. & Airaksinen, M. (2017). What are the differences between sustainable and smart cities? Cities 60, 234–245.

smart waste management practices are GPS based collection systems, Smart bins, RFID tagged bins, Internet of Things (IoT), SCADA systems, real time information processing and advanced systems for resource recovery. See Box 15 for smart waste management in Seoul. Integration of cleaner fuels and CNG driven vehicles are important for smart and sustainable waste management in urban centres. Automation of decentralized plants and real-time availability of information can reduce the labour demand in the sector and improve the efficiency considerably.

Smart Waste collection and treatment offers significant possibilities for the urban areas of India. It could pave the way towards integrating sustainable practices to our smart cities. Globally it was found that the smart waste collection technology market is expected to grow from $57.6 million in 2016 to over $223.6 million in 2025[49]. India could reap the benefits of this by investing in smart waste management and making it an integral component of its urban renewal missions. Improving the waste collection efficiency can reduce the net waste management cost considerably. World Bank report (2012) points out that collection takes up about 80% of total MSW budget in low income countries whereas it accounts for less than 10% of MSW budget in developed countries[50].

Box 15 Smart Waste Management in Seoul

The city of Seoul in the Republic of Korea has adopted Smart practices in MSW and has been able to reduce the collection frequency by 66%. Littering due to overflowing of dust bins and insufficient number of public dust bins were two major problems faced by the city. The city installed solar powered trash compactor bins and adopted real-time monitoring with Clean City Networks. These measures reduced waste collection costs by 83% and increased recycling diversion rates to 46%[51]. Seoul does not face the problem of waste overflow anymore!



Graphic Source: Enevo, retrieved from https://enevo.com/

A smart and circular city should be able to leverage smartness for achieving circularity in its practices. This includes adopting smart solutions which could lead to closing of resource loops (see Figure 21). There are different smart solutions that can realise circularity in cities. Integrating Energy Management, Waste Management, E-Governance, Smart Mobility, Water Management

[49] Navigant research. (2016). Retrieved from: https://www.navigantresearch.com/research/smart-waste-collection
[50] World Bank. (2012). What a Waste? A Global Review of Solid Waste Management. Retrieved from: (http://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1334852610766/What_a_Waste2012_Final.pdf
[51] ECube Labs. (2017). Case Study: City of Seoul. Retrieved from: http://ecubelabs.com/case-studies/city-of-seoul/

etc. can realise a smart city that is sustainable. Indian cities have been integrating these smart practices to their smart city objectives. Indore in Madhya Pradesh and Nagpur have been successful in achieving several smart solutions.

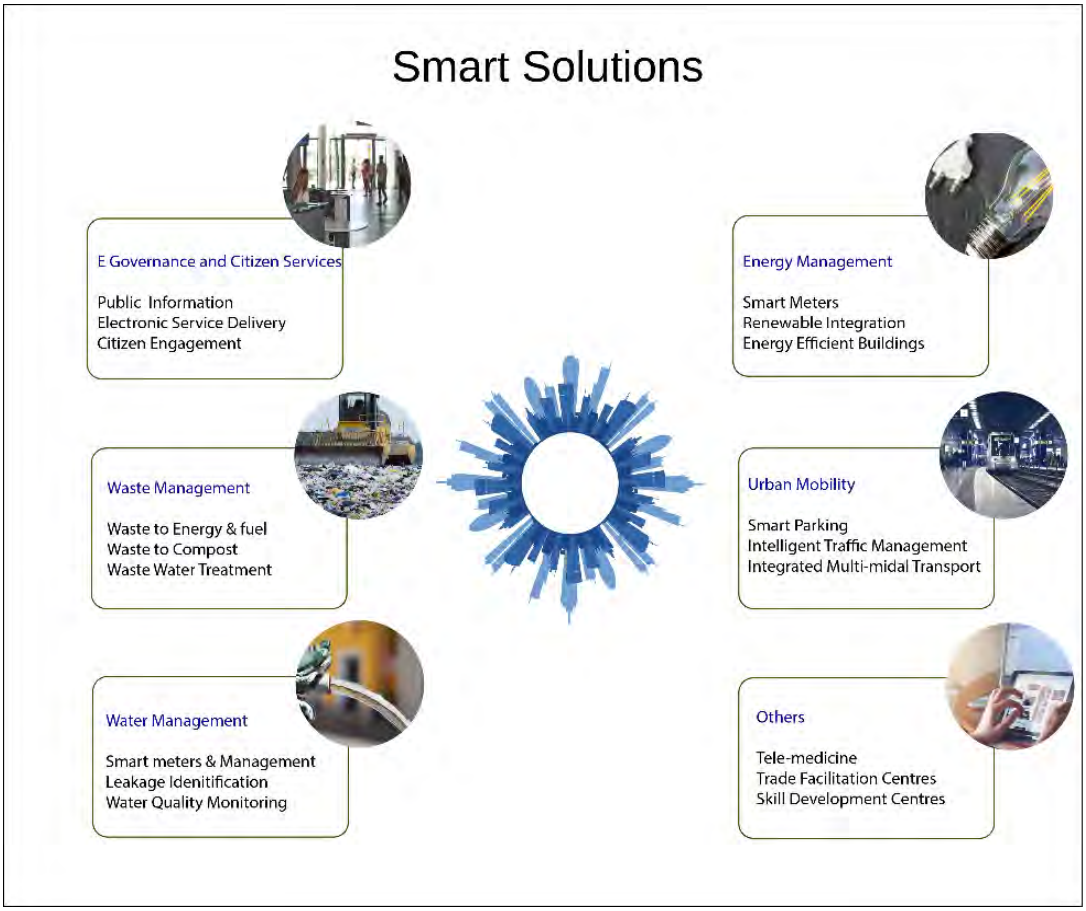


Figure 21: Smart Solutions for Cities

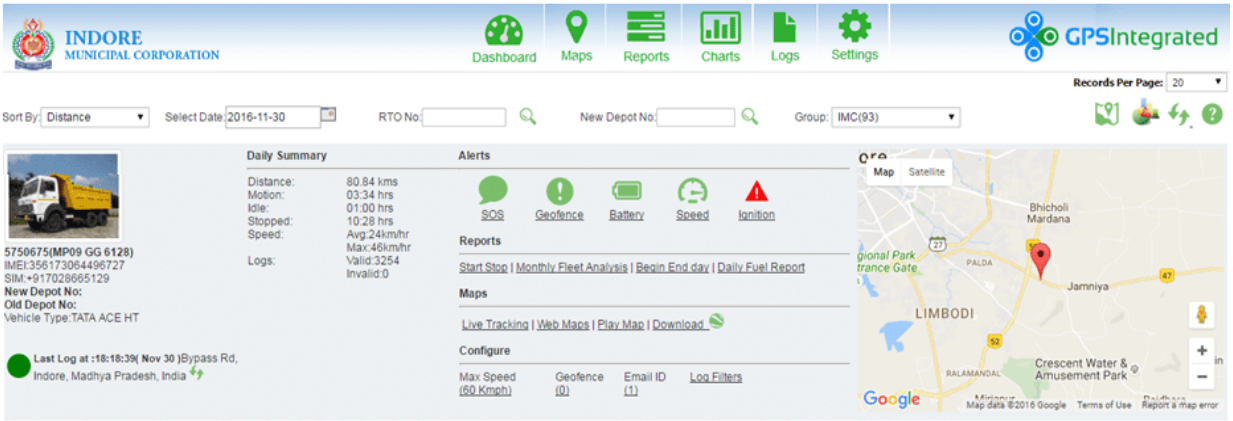
Smart Cities Mission has been under progress in India since 2015. It envisages a smart transition of Indian cities and embrace of smart practices in different sectors like transport, waste management, energy management and so on. Several cities have significant progress in smart waste management. Jabalpur and Indore in Madhya Pradesh (see Box 16) along with Nagpur in Maharashtra offers good examples on how to integrate 'smartness' to waste management. Jabalpur is adopting several measures for smart waste management as part of its Smart City initiative. The city has already implemented waste to energy targets and has a door-to-door waste collection system in place[52]. RFID tagging of household bins are in progress and Vehicle Tracking and Monitoring System is under progress.

There are counterparts of Jabalpur who present remarkable progress on the waste management front. A big city that has several initiatives on waste management and sanitation is Coimbatore in Tamil Nadu. The city has a population of over 1 million. The city has an ambitious plan of *Project Shunya* for city-wide decentralised composting and for constructing waste to energy plants. Those

[52] https://smartnet.niua.org/sites/default/files/resources/8.pdf

are in progress while several initial measures have been adopted in SWM. RFID tracking of vehicles, bio-methanation and decentralized waste processing are being implemented and getting wider reach in the city. There are several other cities in the smart city mission like Kakinada, Bhopal, Surat and so on which have integrated smart waste management practices to their smart city missions.

Box 16 GPS based Vehicle Tracking and monitoring system, Indore – Smart City



Indore is the commercial capital of the state of Madhya Pradesh. It has a population of over 4 million (estimates for 2017) and has been ranked as the cleanest city in India by Swachh Sarvekshan Survey. What makes the city stands out from other smart cities, is the GPS based Vehicle Tracking and Monitoring System (VTMS) for SWM which has rendered a successful model. The VTMS Project includes web-based application for real-time route adherence, training for stakeholders and Integrated Weighbridge Vehicle Monitoring System. The programme was launched in March 2017 and as of May 2017, 90% of the garbage vehicles are included in the system. The Programme has improved the waste handling and operational efficiency in the city. The city on its path to achieve 'Zero Waste' status and VTMS is a major step in this regard.

Challenges and potential in including CE principles for smart and sustainable city

Integration of CE principles and developing smart and sustainable cities are not devoid of challenges. From the design till the implementation phase, these urban projects had to face various hurdles. Circular Economy calls for an overhaul in terms of product designs, supply chain management and resource management. This requires drastic changes in the conventional ways of dealing with products and services. There will be new requirements and meeting them would be challenging in the initial stages of CE.

- Policy level reforms
- Institutional capacity building

- Uplifting Infrastructure /technology[53]
- Financing Mechanisms
- New Business Models

There will be considerable investment needs along with new business models to sustain the CE efforts. SWM in smart cities call for an investment of 112 million USD (see Figure 22) while integrating CE components requires additional investments.

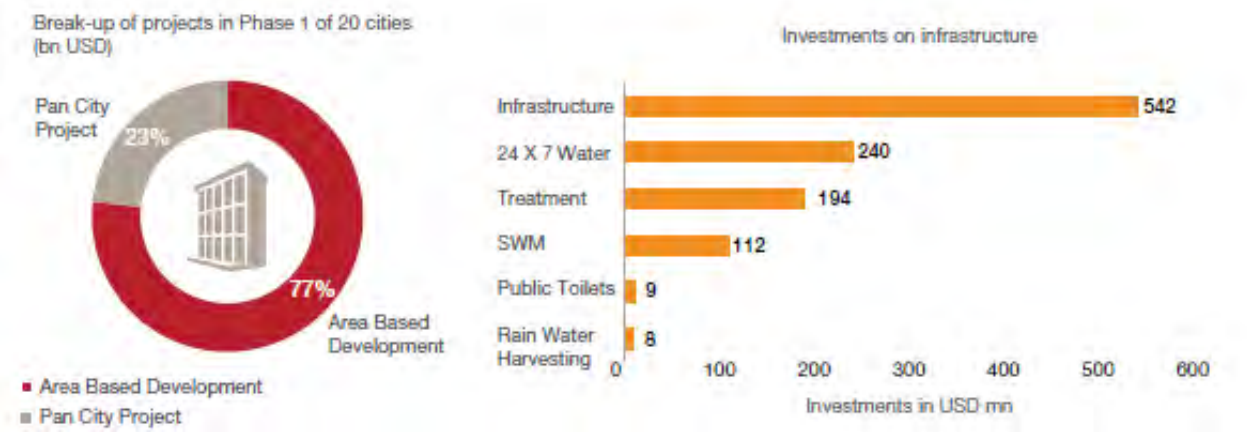


Figure 22: Investments in Indian Smart Cities[54], Source: ASSOCHAM (2016)

4.3. Enabling Framework

Urban development came to the forefront of India's development agenda since the beginning of the 21st century. Be it the small urban renewal missions or grant urban development programmes, Indian cities have been taken on a mission towards advancement. The various governments that came into power since the last decade, placed urban development programmes at the centre of their policy agendas. As we trace and analyse these developments, JNNURM, AMRUT and SCM are three programmes which calls for special attention.

Jawaharlal Nehru National Urban Renewal Mission (JNNURM) is the first massive nation-wide urban development programme that facilitated the support of central government to urban bodies. It was launched in 2005. The programme facilitated large-scale institutional reforms and financial investments in urban areas. The programme saw improvement in several urban areas and in

[53] ASSOCHAM. (2017). Waste management in India-shifting gears. Retrieved from: https://smartnet.niua.org/sites/default/files/resources/waste-management-in-india-shifting-gears.pdf

[54] ASSOCHAM. (2017). Waste management in India-shifting gears. Retrieved from: https://smartnet.niua.org/sites/default/files/resources/waste-management-in-india-shifting-gears.pdf

investment and infrastructure development in cities. Several urban projects were sanctioned under JNNURM during 2005–2014, and central assistance of approximately 48,000 crore INR was committed during this period through the mission[55]. JNNURM was replaced in 2014-2015 by another series of urban development programmes. These schemes are (1) the Atal Mission for Rejuvenation and Urban Transformation (AMRUT), focussing on capacity building in sewerage networks and water supply; (2) Smart Cities Mission (SCM), aimed at developing smart solutions for selected cities to decent quality of life, inclusive and sustainable development; (3) Swachh Bharat Mission (SBM), focusing on cleanliness, waste management and sanitation; and (4) Heritage City Development and Augmentation Yojana (HRIDAY), for promoting the development of heritage cities.

The Smart Cities Mission of India aims to create 100 smart cities by 2020. The mission revolves around the creation of cities equipped with smart digital infrastructure and other solutions. The Smart Cities Mission of India emphasises on sustainable development in cities, hence waste management using 'smart solutions' in an integral part of it. 'Sanitation including solid waste management' is a key aim among the SCM targets. This provides a platform to integrate waste management into the emerging smart cites. The thrust on waste management in the policies makes it impossible for the Urban Local Bodies to overlook it in their development practices. The smart cities as planned and in progress can enable the integration of circular economy goals and SDG targets.

Sustainable development has been emphasised in SCM highlighting the role of comprehensive urban development. The mission objective of the Smart Cities Mission is "to promote cities that provide core infrastructure and give a decent quality of life to its citizens, a clean and sustainable environment and application of 'Smart' Solutions"[56]. Along with emphasis on digital solutions, the mission also stresses upon 'quality of life'. According to the mission statement, "Area-based development will transform existing areas (retrofit and redevelop), including slums, into better planned ones, thereby improving liveability of the whole City".

[55] PWC. (2016). Urban development in India. A special focus. Retrieved from: https://www.pwc.in/assets/pdfs/pf/archives/public-finance-quarterly-issue-xi.pdf
[56] https://smartnet.niua.org/smart-cities-network

Chapter 5

Assessing the Potential of Circularity in Cities

5.1. Science-Policy-Business Interaction

Development of a smart and sustainable city calls for collaboration from science, policy and businesses. As resilient and future-proof cities require multi-faceted approaches to growth, the development plans cannot be formulated without collaborations among different sectors. It requires the technical and scientific expertise, financial support and new business models as well as robust policies to facilitate the sustainability targets. A healthy science-policy-business interaction coupled with active citizen participation is important for the success of smart and sustainable cities (see Figure 23). It can support the co-design, co-production and co-implementation of knowledge.

Figure 23. Stakeholders in Urban Development

As cities are epicentres of growth, talent and ideas, integrating different voices and interests are important. Businesses in isolation cannot realise smart or sustainable cities. The same applies for policy sector. A smart and circular city should be built on the knowledge, entrepreneurship,

capital and dialogues. Smart and circular cities cannot overlook diverse voices and perspectives of the public. The cities have to integrate different factors viz. economic, environmental and social amicably for a balanced development trajectory.

5.2. Gap Analysis and Findings

Stakeholder participation is an inevitable component of development programmes. Lack of sufficient understanding of the science-policy-business interaction will hamper the effective stakeholder participation in urban development projects be it for realising smart transitions or sustainability targets. Hence a gap analysis of Science-Policy-Business interaction in the context of Indian cities has been conducted and is elicited below. This gap analysis sheds light on certain gaps existing in the city development context through selected indicators. The major gaps which were found in the science-policy-business interaction in Indian cities are depicted in Table 4.

Table 4 Gaps in the Science-Policy-Business Interaction in India

	Gap	Missing Links
1	Absence of policy-business-science interaction in sustainability sector	The foundational links among the three interested parties; absence of suitable platforms of interaction and exchange
2	Limited knowledge on CE and mainly focusing only on Recycling and Reusing	Resistance to change; Knowledge from R&D not reaching industries and business on redesign of products and services, Lack of Life Cycle Thinking
3	Lack of new business models in CE in an Indian context	Missing business –industry interaction, less outreach to potential investors, no focused schemes for promotion
4	CE yet to find a space in policy regulations/development agendas	Limited understanding of the benefits of CE to Policy makers and Planners
5	Limited academic-business collaboration in CE practices	Research-Business links are weak or missing, CE not introduced in the academic curricula, No continuing education programs for the practitioners on CE
6	Absence of organizational and social innovations pertaining to CE deployment in India	Weak or missing links among all parties, mining of innovations on CE by the informal sector particularly missing, no targeted micro-finance schema on CE

A symbiotic relationship among different stakeholders are important to achieve the goals of circular economy. The three different entities need to act together for bringing in circularity at all levels. This nexus is missing in urban India and abridging this gap is vital for successful deployment of CE. Gaps highlighted in Table 4 need to be addressed. A programmatic approach followed after piloting will be helpful to bridge the gaps.

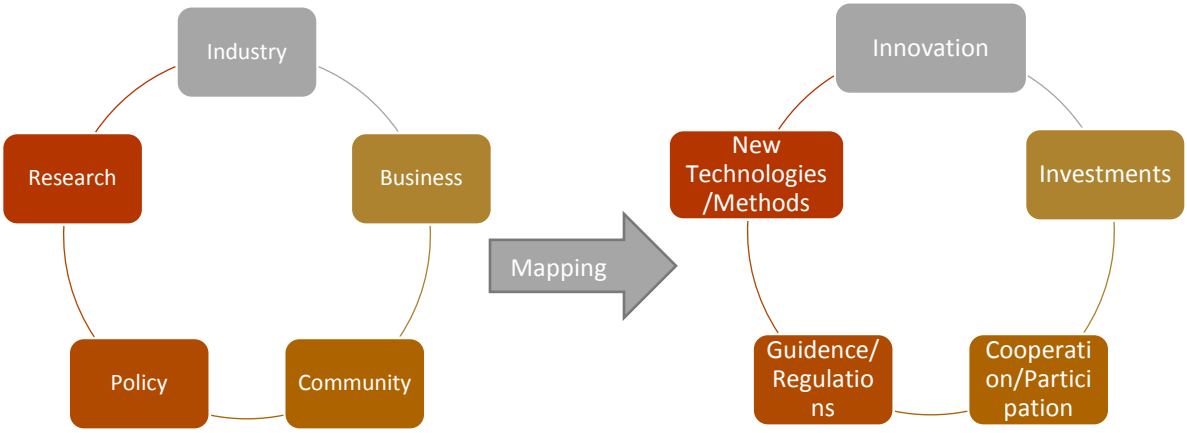


Figure 24. Mapping within Science-Policy-Business Interaction

For realising a circular pathway and to exploit the circular potential of a city, the science-policy-business network has to escape the fetters of regulations, funding inadequacy and technology constraints. Circular Economy rests on cooperation and collaboration. Collaboration and sharing can result in the dissemination and wider adoption of CE goals (see Figure 24). Circular transitions rest on several factors which call for strong and active collaboration among stakeholders. Whilst such transformation can be realised only through "technical, social, and organisational innovations throughout the value chain, while bridging production and consumption activities", bringing all stakeholders to a common platform is essential. To draw the case of Circularity and Science-Policy-Business interaction clearer, an example with plastic packaging is illustrated here (see Figure 25).

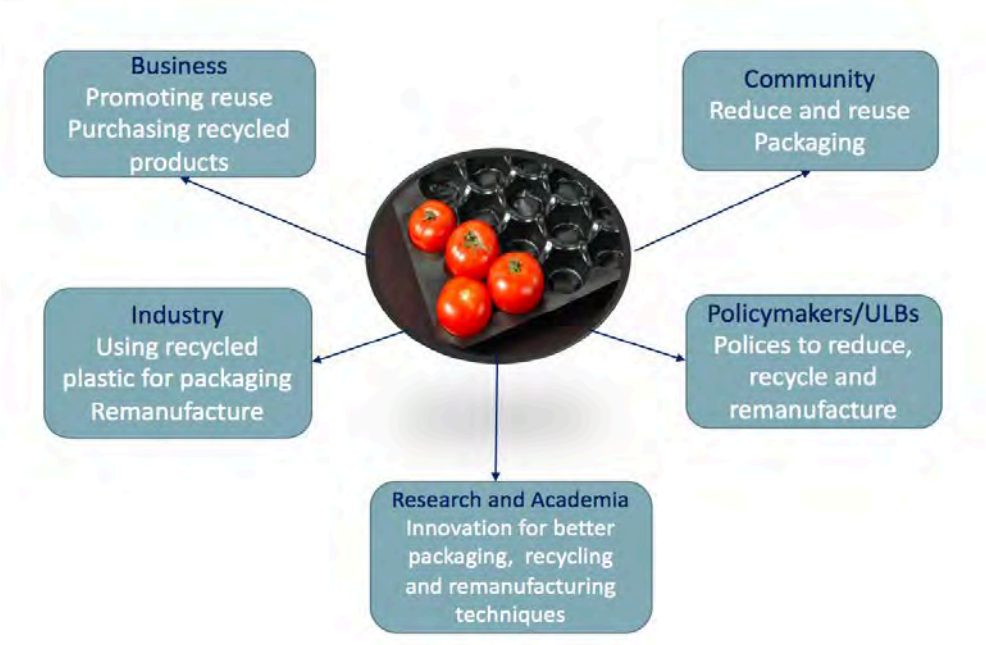


Figure 25. Applying 6Rs of Circular Economy with stakeholder interaction in Plastic Packaging

Box 17 shows case study of Banyan Nation on Plastic recycling.

Box 17 Plastic Recycling by Banyan Nation in India[57]

Banyan is one of India's first vertically integrated plastic recycling companies that helps global brands use more recycled plastic instead of virgin plastic. Banyan's proprietary plastic cleaning technology converts collected post-consumer and post-industrial plastic waste into high quality recycled granules – Better Plastic – comparable in quality and performance to virgin plastic. Its plastic cleaning technology removes inks, coatings, and other contaminants using environment friendly detergents and solvents to supply near virgin quality recycled granules to brands, a first in India highly informal, low tech industry.

Banyan specializes in recycled resins for consumer packaging, auto components, consumer durables such as furniture, and consumer electronics. It works with bulk waste generators and aggregators and accept post- consumer and post-industrial scrap plastic.

Banyan is one of the first companies in the country to use mobile, cloud and IoT to integrate thousands of informal sector last mile collectors into its supply chain to recover postconsumer as well as post-industrial plastic waste. The platform has now been extended to help cash-strapped municipalities understand waste flows through their cities and use a data-centric approach to make waste management more efficient, effective, and economical. The platform integrates thousands of informal recyclers into our supply chain and also helps cities manage their waste more effectively.

Banyan pioneered closed loop recycling initiatives with India's leading automotive company TATA Motors (making new bumpers from discarded ones) and a global cosmetics company LOREAL(making new bottles from discarded ones), establishing circular economy leadership in the automotive and beauty sector respectively, that can be extended to other industries.

[57] Banyan Nation- Hyderabad. (2017). Our Work. Retrieved from Banyan Nation- Our Work: http://banyannation.com/#ourwork

Chapter 6

Smart Waste Management in Circular Cities

The adoption of policies, strategies and mainstreaming smart waste management into urban agendas are important for realising smart and circular practices in Indian cities. The success of programmes is contingent on the strategies chosen for different categories of cities.

According to the Report by Ellen MacArthur Foundation[58], circular economy offers immense potential for India. A circular scenario can reduce GHG Emissions and consumption of virgin non-renewable materials considerably in comparison with the current development scenario (see Figure 26).

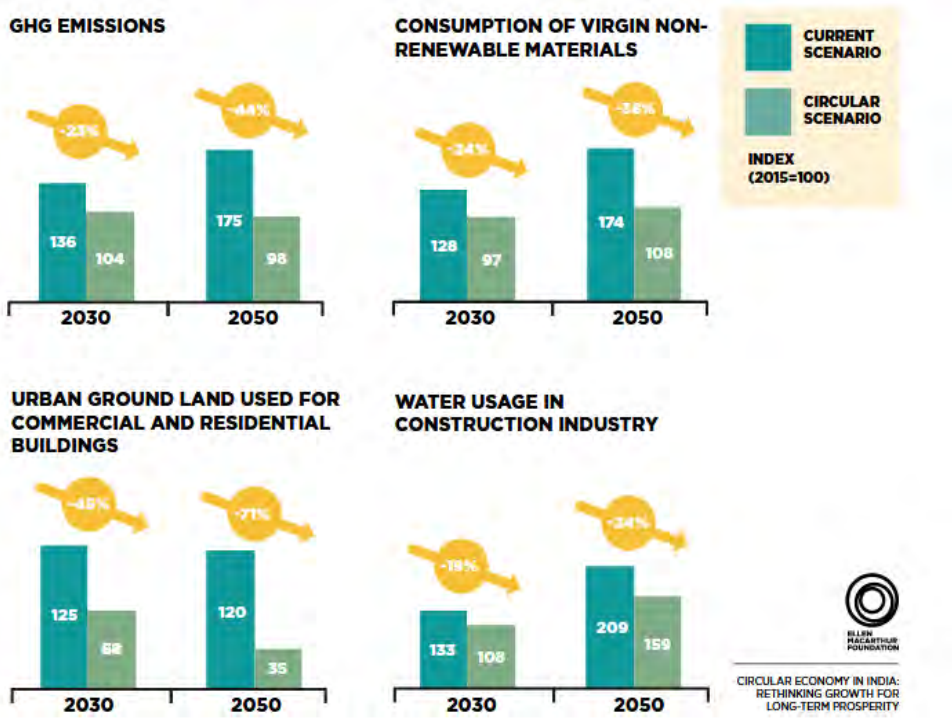


Figure 26. Potential circular economy development paths for India, Source: Ellen MacArthur Foundation

Considering above and as the population growth and consumption in 1B and 1C cities are going to rise tremendously in the coming decade, developing a smart and circular agenda for waste management can offer immense possibilities for resource recovery in those cities.

[58] Ellen MacArthur Foundation. (2016). Circular Economy in India: Rethinking Growth for Long-Term Prosperity

6.1. Holistic strategy of Integration of Solid with Liquid Wastes

India suffers from twin problems of water scarcity ("upstream") and improper management of sewage ("downstream"). Urban centres comprising Class I cities and Class II towns generates about 38,254 million litres per day (mld) of wastewater[59]. According to the TERI report[60], there exists huge capacity gap in terms of waste water treatment in Indian cities (see Figure 27). Moreover, about 93.3 % of waste water in urban areas are discharged without any treatment.

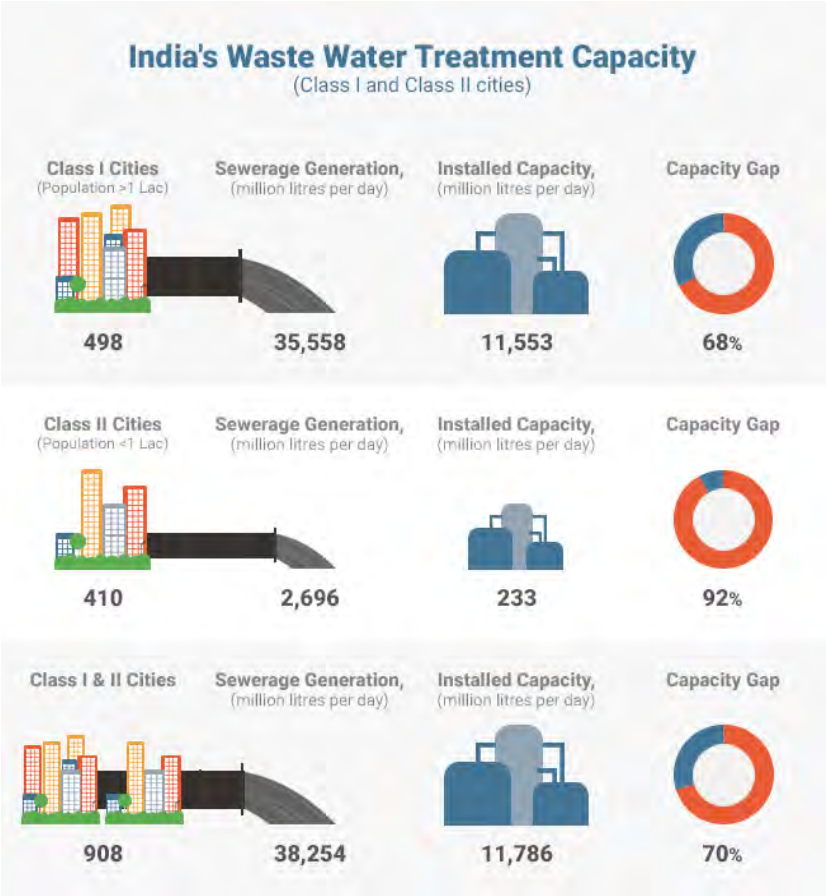


Figure 27. India Waste Water Treatment Capacity, Source: TERI

It is important to achieve sustainable solid waste management and liquid waste management in cities for realising sustainability and environmental quality. Cities currently follow a centralised approach to sewage management and it has been found inadequate considering the spurt in urban population. An ideal approach for waste water management in India would be a

[59] Kamyotra, J.S. & Bhardwaj, R.M. (2011). Municipal waste water management in Indian. India Infrastructure Report 2011. Retrieved from: https://www.idfc.com/pdf/report/2011/Chp-20-Municipal-Wastewater-Management-In-India.pdf

[60] Bharat, G.K. (2017). Is Decentralized Waste-Water Treatment and Reuse System? The Way Forward for India's Tail-End Sanitation Challenge? Retrieved from: http://www.teriin.org/index.php?option=com_featurearticle&task=details&sid=1068&Itemid=157

combination of centralised and decentralised measures. Such a programme with customised approaches with different cities and residential zones can ensure recycling of water, safe treatment and sanitation thereby abating water pollution and associated health hazards.

With higher population projections, water pollution and rising water scarcity in cities, planners need to have strategies to best utilise water resources, including untreated, partially-treated, and fully-treated wastewater, for various productive purposes (Amerasinghe, et al., 2013). A circular approach to urban waste water management is the need of the hour. It could reduce the capacity gaps while ensuring water security. The current system of transporting water to cities over several hundreds of kilometres is neither sustainable nor smart. Indian cities could benefit greatly if waste water recovery, reuse and nutrient recovery can be achieved[61]. A viable approach would be integrating private sector as well into waste water management in cities. They could bring in the finance as well as advanced technology while Government can facilitate smart waste treatment through stringent and effective policy regulations. Cities will thus need to integrate both wastewater and solid waste management to ensure sustainability.

Solid and Liquid Waste Management (SLWM) is one of the key components of Swachh Bharat Mission (SBM) (G), launched with the objective of bringing improvement in cleanliness, hygiene and the general quality of life in rural areas. A recent Technical Note prepared by the Swachh Bharat Abhiyan lists several case studies of success[62]. Taking this cue, the smart cities program could adapt this experience on a decentralized scale especially in class I-A and I-B cities.

6.2. Decentralised Solutions and Associated Capacity Building

Centralised solutions currently dominate the waste management sector in India. Many cities pursue centralised waste sorting, treatment and disposal methods. However not many of these centralised systems have been found to be successful or efficient. In the light of inadequacies of the centralised waste management systems, decentralised systems have been emerging in different parts of the country. Many cities are in the phase of transition towards adopting decentralised modes and some of these portray efficient and effective solutions.

An important feature of decentralised waste management solutions is the community participation and ownership. The success of decentralized solutions has been widely seen in Pune, Mysuru and several other cities (see Box 18). When stakeholders including communities are included in waste management decision making from an early stage, it offers opportunities to discuss alternatives, potential sites and community benefits[63]. India can take this further in by

[61] 2030 Water Resources Group. (2016). Circular Economy Pathways for Municipal Waste Water Management in India: A Practitioners Guide. Retrieved from: https://www.2030wrg.org/wp-content/uploads/2017/01/Circular-Economy-Report-04Apr17.pdf

[62] Solid and Liquid Waste Management in Rural Areas – A Technical Note Online source http://swachhbharatmission.gov.in/sbmcms/writereaddata/images/pdf/technical-notes-manuals/SLWM-in-Rural-Areas-Technical-Note.pdf

[63] Cotton, M. (2013). NIMBY or not? Integrating social factors into shale gas community engagements. Natural Gas and Electricity, 29 (9), 8-12.

incorporating micro-finance in the low-income communities. Community groups and informal sector workers can gain the required financing for recycling or remanufacturing through micro-financing enterprises.

Box 18 Decentralised Waste Management in Alappuzha

Alappuzha, a city of nearly 2 million people in Kerala has recently won accolades from UNEP for its decentralised waste management system. The city has adopted a ward based decentralised system in solid waste management. Biodegradable waste was segregated at the ward level, and treated in small composting plants. The biogas produced from the waste, provides many of its 1,74,000 residents with biogas for cooking.

The waste management plan has cleaned up this coastal city which is also a prominent tourist destination in the region. The stink has given way to cleanliness and green energy for households.

Aerobic composting unit set up as part of the waste management park at Vazhicherry in Alappuzha

Source: The New Indian Express (2017). Paradise Regained. How Alappuzha in Kerala is setting an example to the world. http://www.newindianexpress.com/states/kerala/2017/dec/10/paradise-regained-how-alappuzha-in-kerala-is-setting-an-example-to-the-world-1723251.html

Capacity Building in waste management can be achieved successfully only if all stakeholders are included in the planning and implementation. This could further lead to building leadership in the communities who can facilitate efficient and sustainable waste management practices that can be scaled up gradually. Swachh Bharat Mission has been emphasising on capacity building in waste management and so far, 68 cities are part of the program. Capacity Building is an important component of SBM and includes policy aspects and DPR preparation and implementation.

6.3. 3R and Circular Economy in 100 Smart Cities Program

The Smart Cities Mission offers opportunities for integrating 3R principles and circular economy. As the Program envisions digitally enabled cities with sustainable development as a central focus, circular economy can be embedded into it from the planning phases. The 3Rs can be integrating to different aspects of the smart cities like water management, waste management, urban agriculture, urban energy consumption and so on. Reduce, Reuse and Recycle can be the gamechangers in the circular transition towards 'regenerative and restorative' urban spaces. The program is taking place in such a big scale (see Figure 28) such that it can pave way for technology, knowledge and innovation revolution in cities.

Figure 28. India Smart Cities Mission statistics, Source: Smart Cities Mission website

The principles of circular economy can be integrated to smart cities owing to the technological and innovative aspects that are integral to smart cities. It is important for ensuring sustainability and inclusivity in the cities. Indian cities fare poorly when it comes to air quality and standard of living. One of the major sources of urban air pollution is open burning of waste. Mumbai was the highest ranked city in the Mercer 2017 Quality of Living Index[64] with a rank of 141. As per WHO's

[64] Mercer. (2017). Quality of Living Ranking. Retrieved from: https://mobilityexchange.mercer.com/Portals/0/Content/Rankings/rankings/qol2017e784512/index.html

2016 air quality database, half of world's 20 most polluted cities are in India[65]. Smart Cities Mission can bring in the necessary change to transform Indian cities. When coupled with circular economy principles, the cities can improve the living standards (see Figure 29). This Figure illustrates major components that act simultaneously in a circular and smart city. The digital infrastructure of smart city is strengthened by the circular economy factors in the model.

Figure 29. Towards smart and circular cities in India

6.4. Sustainable Public Procurement for Smart and Circular cities

Sustainable Public Procurement (SPP) or Green Public Procurement (GPP) offers immense possibilities for ULBs to follow a gradual transition to circular economy. Purchase of environmentally friendly goods and services can be initial steps for local bodies and municipalities to adopt circular measures. SPP entails the integration of economic, social and environmental risks into public procurement processes and decisions via laws, policies and practices[66]. Public Procurement in India is around 20-30 percent of the national GDP[67]. This is a substantial amount and if it can be greened gradually, the possibilities for circular economy are remarkable.

[65] WHO. (2016). WHO Global Urban Ambient Air Pollution Database. Retrieved from: http://www.who.int/phe/health_topics/outdoorair/databases/cities/en/

[66] Turley, L. & Perera, O. (2014). Implementing Sustainable Public Procurement in South Africa. Where to start? International Institute of Sustainable Development.

[67] UNODC (2013). India Probity in Public Procurement. United Nations Office against Drugs and Crime

Many countries are adopting green procurement practices for improving sustainability and improving sustainable practices in local bodies and Government offices. EU policies have recognised GPP as a vehicle for green growth and many European cities like Vienna, Ghent, Barcelona and Copenhagen have shown that it is possible with strong political commitment. GPP is not about environment or eco-friendly actions. It incorporates the case for better pricing and better performance with long term objectives. For a country like India with huge population and impending environmental degradation, public procurement provides a good starting point for the circular transition. The Box 16 elicits the case of GPP in South Africa and it provides a good model for emerging economies. Another major factor that could bring in more innovation into the cities via green initiative is green entrepreneurship. Sustainable or green entrepreneurship emphasises on a new holistic sustainable system based on three dimensions – economy, environment, and society. In additional to environmental and economic sustainability, green entrepreneurship incorporates social factors to develop business models. India has been witnessing successful strides in green entrepreneurship in the recent years. A few cases are elicited in box 19.

Box 19 Sustainable Public Procurement in South Africa

South Africa has been trying to adopt SPP on the lines of its previous missions to adopt several secondary objectives like empowerment of disadvantaged communities via government procurement. SPP has not only improved environmental performance, but also has improved employment opportunities and economic performance of communities.

Several provinces have come up innovative and feasible solutions. The Western Cape Provincial Government had the 110% Green Initiative. The Give Green Initiative is a flagship project under the umbrella of 110% Green and encourages the procurement of environmentally friendly, sustainable and locally produced gifts. “When procuring materials for events/conferences or corporate gifts, procurers can use a simplified “give green” contract that reduces the administrative burden of procuring in an environmentally friendly manner”. Another province that with a green strategy is the province of ‘Gauteng’. The province had the goal that by 2015, government only procure “products and services satisfactorily rated as green according to clear standards”. Though many ambitious targets could not be met in the South African SPP, the successful and ongoing projects shed light on the possibility to achieve SPP with political will and cooperation. There were real applications like procurement of eco-friendly furniture in classrooms and purchase of electric cars by Department of Environmental Affairs.

IISD. (2008). Sustainable Public Procurement in South Africa.

6.5. Green Entrepreneurship

Green entrepreneurship is expected to play a crucial role in the putting circular economy in practice. State Governments, ULBs, Business Associations and Investors need to promote Green entrepreneurship through coaching/mentoring, providing incentives as well as finance. Green entrepreneurs could get involved in making of green products, offer repair and refurbishing services and get into remanufacturing. Natural resource conservation, waste recycling, renewable

energy and waste to resources are other examples. Box 20 depicts case studies on green entrepreneurship in India.

Box 20 Green Entrepreneurship in India

D&D Eco Tech

The start -up helps households and organisations to adopt rainwater harvesting. D&D Ecotech also designs its own rainwater harvesting recharge structures based on clients' needs and specifications. Based on the needs of the client, the projects can be of storage or recharge focus. The company provides solutions to tackle the erratic rainfall and water scarcity in India.

Green Ventures

Green Ventures is a firm that creates green technologies and innovative business models for sustainable energy solutions. The solutions are large-scale renewable energy generation projects, energy efficiency schemes, and rural social energy initiatives.

The Living Greens

The company focuses on rooftop farming and kitchen gardens. The Jaipur-based firm aims to grow organic vegetables on every roof and to convert every building into a living green building. This could generate the largest number of urban carbon credits in the world.

Source: Officechai. (2016). 14 Indian start-ups and projects that are helping the country go green. https://officechai.com/stories/green-startups-sustainable-development-india/#sthash.pQsHKrUC.vMFKvzaD.dpbs

www.thelivinggreens.com

www.dndecotech.com

Chapter 7
Conclusions and Recommendations

Circular Economy offers a promising platform for realising smart and sustainable cities. The circular economic potential that is offered by such cities is remarkable and offers many possibilities for meeting the Sustainable Development Goals. The urban missions that India has, like the Smart Cities Mission and the Swachh Bharat Mission can integrate circular economy principles to it in a pronounced way so as to pave way towards a circular transition.

Solid Waste Management requires immediate attention in India considering the massive growth in waste generation. The current waste management practices lack focus on Reduce principle among the 3Rs. As circular economic potential of cities is to be harnessed, it requires going beyond the traditional 3Rs. The Circular Economy concept introduces other equally important 3Rs such as repair, refurnishing and remanufacturing. Redesigning the production systems, establishment of reverse logistics and integration of 'green concepts' to growth becomes imminent.

An important factor that supports circular economy in emerging countries like India is the already existing repair and refurbish culture. As the countries have strong local traditions integrating the 6Rs, it would be feasible to pursue a circular transition. This circular transition can eliminate several deleterious effects of the linear economic system that plagues the society now like environmental degradation, resource loss, economic disparity and so on. Circular Economy is thus not only about environmental performance but also systems that integrates economic, social and cultural aspects for a holistic and inclusive growth. Policies such as Green Public Procurement and promotion of green entrepreneurship will play an important role. Creation of platforms that connect science, policy and business at the city level will help in innovation, knowledge exchange and partnerships.

Key recommendations to be considered in this regard are:

1.Creating awareness among different stakeholders regarding smart and circular cities to understand the economic, environmental and social benefits

2. Creating a comprehensive waste to resource database

3. Ensuring compliance to waste-related regulations at national, State and city level

4. Formulating new business models, testing them followed by nurturing

5. Practicing Green Public Procurement and promoting green entrepreneurship

6. Introducing and supporting Innovative financial mechanisms for supporting circular ventures, such as Green Bonds

7. Introduce circular economy in the higher education system especially in the subjects such as science, humanities, engineering and management.

8. Build capacities at city and regional levels; with public sector and private sector participation

The challenge is how to build leadership in circular economy. This challenge must be recognized and addressed. Leadership programs need to be offered to city managers, administrators of industrial estates, executives at the pollution control boards, heads at the financing institutions and chief sustainability officers at the Corporates. It is only through creation of such a leadership that India can achieve its mission towards smart, circular and sustainable cities.

Chapter 8

The Way Forward

A path towards sustainable and smart cities following the principles of circular economy promises a lot of opportunities and new developments for Asian cities and especially for cities in India. While significant opportunities and benefits are possible by smart management of solid wastes, embracing a circular pathway can achieve clean water, clean land and clean air thus building sustainable societies and communities. Hence for the future course, an integrated approach to address circularity across solid as well liquid steams is necessary. The experience on Solid and Liquid Waste Management (SLWM) in the rural areas of India has been promising and this experience will be useful to come up with SLWM at decentralized level in urban areas. Use of waste as source of energy to avoid open burning of wastes will help in reducing air emissions and improve the air quality. Indeed, the cities will achieve in this process better climate resilience.

As cities move towards circularity deploying smart technology, more green jobs are expected to be created with more green entrepreneurs stepping in stimulating innovation as well as investment flows. Projects identified on this basis will qualify for financing instruments such as Green Bonds.

The key questions that we need to address are

a. How do we introduce the concept of circularity in the smart cities mission? How do we develop urban environmental and social management frameworks that guide projects, programs and investments ensuring circularity?
b. How do we establish collaborative platforms between government, business and communities that can help in building partnerships, raise finance, exchange knowledge and spur innovations?
c. How do we build leadership that steers cities towards smart, circular and sustainable governance?

Moving cities towards circularity is going to be transformational. This process of transformation and adaptation will lead to integration of policies, institutional partnerships and technological innovations. This will help the cities to realise the Sustainable Development Goals as well as the Habitat III New Urban Agenda (NUA). Cities will become smart and sustainable with strong stakeholder interaction, policy and operational reforms and achieve transparent urban governance. The cities of tomorrow will thus become liveable, safe and resource efficient providing sound and smart infrastructure and services.

Annexures

Annex 1: State wise waste generation statistics- Source CPCB

STATE-WISE GENERATION, COLLECTION AND TREATMENT
[Based on Annual Reports: 2013-14, 2014-15 & 2015-16 (till Dec)*]

Sl.No.	States	Solid waste generation status(TPD)			
		Solid waste generation	Collected	Treated	Land filled
1	Andaman Nicobar*	70	70	5	
2	Andhra Pradesh	6440	6331	500	143
3	Arunachal Pradesh	13	11	Nil	Nil
4	Assam	7920	6336	200	nil
5	Bihar	1670	0	0	no
6	Chandigarh	370	360	Nil	230
7	Chhattisgarh	2245.25	2036.97	828.18	1294.97
8	Daman Diu*	85	85	0	
9	Delhi	9620	8300	3240	5060
10	Goa	450	400	182	
11	Gujarat	10480	10480	2565	7730
12	Haryana	4837.35	3102.51	188	2163.18
13	Himachal Pradesh*	276	207	125	150
14	Jharkhand	3570	3570	65	3505
15	Jammu & Kashmir	1634.5	1388.7	3.45	425
16	Karnataka	8842	7716	3584	3946
17	Kerala*	1339	655	390	
18	Nagaland*	344	193	-	
19	Lakshadweep*	21	-	-	
20	Madhya Pradesh	6678	nil	nil	nil
21	Maharashtra	21867.27	21867.27	6993.2	14993.07
22	Manipur*	176	125	-	
23	Mizoram*	552	276	0	
24	Meghalaya	187	156	36	122
25	Orissa	2574.7	2283.9	30	-
26	Punjab	4456.2	4435	3.72	3214
27	Puducherry	513	513	10	503
28	Rajasthan*	5037	2491	490	
29	Sikkim*	49	49	0.3	
30	Tamil Nadu	230	210		207
31	Telengana	6628	6625	3175	3050
32	Tripura	414	368.2	250.4	164.4
33	Uttarakhand	917	917	No MSW treatment facility existing the state	No Sanitary landfill site
34	Uttar Pradesh	15192	11394	1857	
35	West Bengal*	9500	8075	851	515
	Total	**135198.27**	**111027.55**	**25572.25**	**47415.62**

Annex 2: Waste Generation Projection in Indian cities

Table 4: Waste generation projections of class-wise cities in India

Class of city	Waste generation (in TPD and million tonnes per year)						
	2011			2021		2031	
	Nos	(in TPD)	(in million tonnes/Year)	(in TPD)	(in million tonnes/year)	(in TPD)	(in million tonnes/year)
Class IA (>5 million population)	8	46,854	17.10	76,727	28.01	106,013	38.69
Class IB (1.0–5.0 million)	45	23,416	8.55	36,190	13.21	53,934	19.69
Class IC (0.1–1.0 million)	415	23,958	8.74	35,053	12.79	49,012	17.89
Class II (0.05–0.1 million)	7467	7,341	2.68	9,837	3.59	13,486	4.92
Class III 0.02–0.05 million		9,140	3.34	12,168	4.44	16,517	6.03
Class IV (< 0.02 million)		7,084	2.59	9,271	3.38	12,585	4.59
Total		117,793	43.00	179,247	65.00	251,547	92.00
High							Low

Source: PwC analysis

Source: PWC & ASSOCHAM. (2017). Waste Management in India, Shifting Gears.

Annex 3: Prices used for the Value Chain Calculation

Waste Components	**Price per Tonne (INR average for Indian cities)**
Paper	16000
Rubber	40000
Plastic	24000
Iron	15000
Steel	21000
Aluminium	137000
Copper	392000
Glass	1000