Stockholm Environment Institute

Analysis of the plastic waste value chain in India

A scoping study

SEI report
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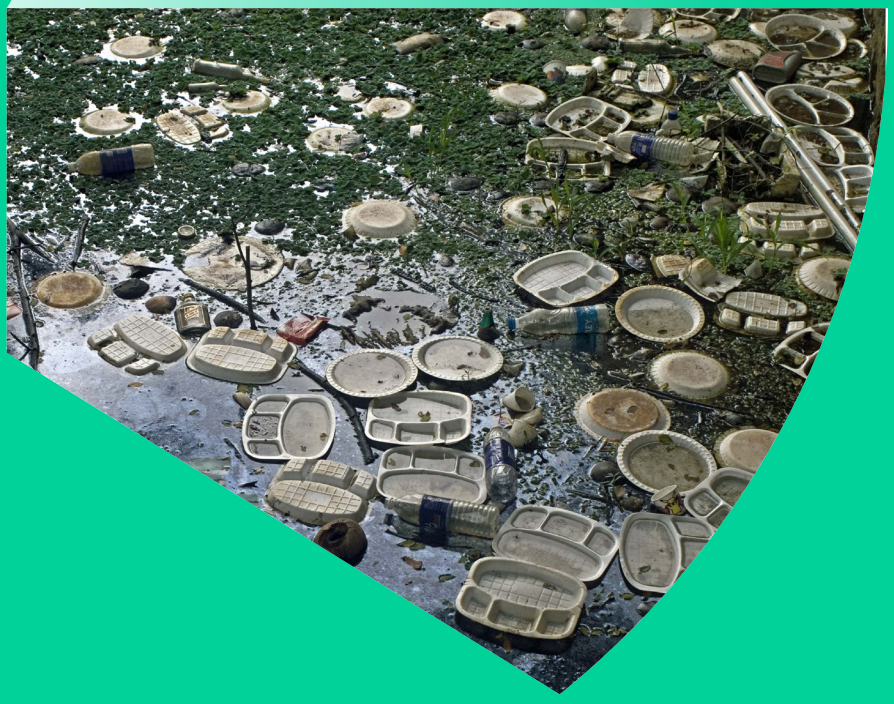

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The **Keep Sweden Tidy** Foundation is a non-profit organization that promotes recycling and combats litter through public awareness campaigns and environmental education..

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Preface

The Waves of Change project is implemented by a consortium led by the non-profit organizations Hand in Hand and Keep Sweden Tidy, with other project partners, in Sweden, India and Kenya. The overall purpose of the project is to reduce plastic leakage to the world's ocean, and thus contribute to a more sustainable environment in Sweden, India and Kenya.

The project consortium aims to achieve this by working towards three concrete sub-goals: 1) reduce plastic waste at sea and on land through preventive measures and improved plastic and waste management processes; 2) create green, profitable, small businesses that increase household income by promoting a circular economy, with a focus on plastic; and 3) identify and share local solutions to the global and borderless plastic challenge through learning and exchanges of experience between authorities, companies, academia, civil society and individuals in Sweden, Kenya and India.

Hand in Hand Sweden commissioned the Stockholm Environment Institute (SEI) to undertake this scoping study, to obtain an overview of the ecosystem of stakeholders and processes involved in the plastic waste management and recycling value chain; the relevant institutional, policy and regulatory frameworks linked to the plastic value chain; and any relevant best practices for use in "cross-learning" experiences. Hand in Hand will use this knowledge to inform the implementation of the Waves of Change project. The baseline knowledge generated from this study also is relevant for policymakers, practitioners and researchers, as well as other stakeholders working towards more sustainable plastic waste management and recycling value chains in other areas, particularly in low- and middle-income countries with similar contexts to Kenya and India.

Key messages

Plastic waste accumulation and inadequate disposal are global issues that are especially problematic for countries with large and growing populations and long coastlines, such as India. This report provides an overview of the complex plastic value chain in India, the key stakeholders involved, and their roles and interactions. Also provided are an overview of some innovative solutions along the plastic value chain and a map of relevant policies and regulations, both nationally and focusing on Tamil Nadu State, as well as the barriers and enablers for their implementation.

The key findings of this report include:

- While plastic pollution is a longstanding problem, plastic regulation is relatively new to India's policy landscape, which means that it is still limited in application and scope. The first national plastic waste policy was implemented in 2011, with ongoing amendments to close loopholes.
- The substantial contribution of the informal sector in plastic waste management leads to higher rates of recycling in India compared to other countries. However, this informality leads to complexity in implementing formal plastic waste management processes at the regional or national level.
- A large portion of unrecyclable plastic waste gets dumped in open landfills or in the ocean; this endpoint forms a significant part of the challenges still to be addressed.
- Some states and union territories have taken active measures to address the plastic waste accumulation issue by implementing innovative solutions, such as repurposing plastic waste to construct roads or using plastic waste to produce fuel.

This report illustrates the plastic value chain in India in a simple format for any practitioner trying to understand the current regulatory framework and relevant stakeholders, along with key recommendations to improve the current plastic value chain.

List of Abbreviations

AECEN	Asian Environmental Compliance and Enforcement Network
ASSOCHAM	Associated Chambers of Commerce & Industry of India
BIS	Bureau of Indian Standards
CII	Confederation of Indian Industry
CPCB	Central Pollution Control Board
DGS	Directorate General of Shipping
EPR	Extended Producer Responsibility
FSSAI	Food Safety and Standards Authority of India
HDPE	High-density polyethylene
IIM	Indian Institute of Management
IIP	Indian Institute of Petroleum
ITC WOW	ITC Well-being Out of Waste
LDPE	Low-density polyethylene
MoEFCC	Ministry of Environment, Forest and Climate Change
PE	Polyethylene
PET	Polyethylene terephthalate
RDF	Refuse-Derived Fuel
SPCB	State Pollution Control Board
UNEP	UN Environment Programme

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Introduction

Plastic has long been an inseparable part of daily life. An important part of most consumer goods, plastic is also used in packaging for transportation of raw materials or in machinery to make production processes more efficient.

Most of the plastic in use is synthetically manufactured from resins derived from raw materials such as natural gas, oil, coal and minerals (American Chemistry Council, 2018). The top seven most popular and commonly used types of plastic are acrylic or poly(methyl methacrylate), known as PMMA; polycarbonate; polyethylene; polypropylene; polyethylene terephthalate, or PET; polyvinyl chloride or PVC; and acrylonitrile-butadiene-styrene copolymer, known as ABS (A&C Plastics Inc, 2022).

Although each type of plastic has unique properties, almost all types have entered every aspect of contemporary life due to the general properties of plastic. These materials are resistant to other chemicals and degradation, good insulators of heat and electricity, and light in mass, and they have a varying degree of tensile strength and are easily mouldable (Science History Institute, 2022).

However, these resilient properties are the main reason that plastic ends up accumulating in the environment. Researchers have estimated that by 2015, more than 8.3 billion metric tons of plastic have been produced since the early 1950s. Only 9% of all plastic waste ever produced has been recycled, 12% incinerated, and the rest (79%) has "accumulated in landfills, dumps or the natural environment" (Geyer et al., 2017). The most common type of plastic waste is cigarette butts, grocery bags, straws, food packaging, bottle caps and stirrers (UNEP, 2022, p. 2022).

Since most plastic waste comes from highly populated areas like cities, and most of the world's biggest cities are situated on coasts or on riverbanks, most of the waste ends up directly dumped in the ocean or dumped in rivers that carry waste from deep inland to the ocean (Micro B Life, 2022). About 8 million tons of plastic waste ends up in the world's ocean annually (Jambeck et al., 2015).

This issue is particularly important for countries with long coastlines like India's. Over 7500 km long, the country's coastline borders the Bay of Bengal in the east, the Arabian Sea in the west, and the Indian Ocean to the south. India's major rivers, the Ganga, Indus, Yamuna, Brahmaputra, Mahanadi, Godavari, Krishna and Kaveri, all merge into one of the three abovementioned water bodies. Additionally, most of the biggest cities in India – such as Mumbai, Calcutta, Chennai and others – are either situated in river basins or on coasts.

With one of the largest populations in the world (1.39 billion in 2021), India generates an especially high amount of plastic waste that ends up in the ocean. As of 2017, about 164 332 tons of plastic waste were carried to the ocean by the Indus River alone, and the Meghna, Brahmaputra and Ganga rivers together carried 72 845 tons of plastic waste (UNEP, 2022).

Coastal states such as Tamil Nadu have higher vulnerability to the accumulation of plastic waste, not only due to the improperly disposed-of plastic waste produced within the state itself. Waste from other states with rivers ends up accumulating on its coastline. According to interviews conducted for this report, awareness regarding the issues of plastic waste management is increasing, among citizens and governments alike.

This report maps out the plastic value chain landscape in India along with the key actors; highlights the policies relevant for plastic waste management in India, both nationally and for Tamil Nadu specifically, along with the barriers and enablers for policy implementation; and presents relevant innovative stories. This report provides an overview of the plastic value chain and relevant regulatory efforts and highlights the gaps in actions for further research.

1. Research methodology

The data for this study have largely been gathered from a desk-based literature review and interviews, along with a walk-through observation of different interview locations, beaches in the areas over the span of a week. The purpose of the literature review was to understand the regulatory landscape of plastic in India broadly and Tamil Nadu specifically, as well as the regulatory barriers and enablers for the implementation of national and regional policies.

We focused on the most problematic types of plastic that are relevant for the plastic pollution challenge. The types of plastic identified as the major constituents of plastic pollution are mostly used in discarded food items, such as PET beverage bottles, polypropylene food wrappers and polyethylene bags, polypropylene and low-density polyethylene caps and lids, and polypropylene straws and stirrers.

1.1 Geographic scope

The focus of this study was India and its policies, using the city of Mamallapuram, Tamil Nadu, as a case study. Interviews were carried out in Mamallapuram and surrounding villages in Tamil Nadu.

1.2 Literature review

Google Scholar was used to identify the peer-reviewed research and scientific papers that examine the relevant regulatory barriers and enablers and that provide an analysis of the plastic supply chain. The general Google search engine was used to identify websites of public authorities that provide information on the relevant policies, as well as to identify grey literature, including newspaper articles, that highlight the current status and development of policies.

The search terms and the relevant search results are detailed in Table 1. Articles were shortlisted based on relevance to the study country and waste type in the title and abstract.

Table 1. Search terms used in searching for literature and the relevant search results

Search terms	Search engine: Google Scholar		Search engine: Google	
	Number of articles identified	Number of relevant articles shortlisted	Number of articles identified	Number of relevant articles shortlisted
India plastic waste regulations	68 700	13	13 500 000	33
India plastic waste policies/standards	81 900	16	11 900 000	10
Barriers to plastic waste policies India/regulatory barriers to plastic waste India	43 300	16	4 900 000	23
Regulatory enablers to plastic waste policies India	4 690	7	6 930 000	6
Plastic waste regulatory success stories India	25 000	11	11 200 000	14
Plastic waste policy/ regulatory suggestions India	25 700	0	25 300 000	9
Tamil Nadu plastic waste policies	10 400	10	623 000	19
Government of India plastic regulations	87 800	4	23 900 000	5
Total		77		119

A total of 196 articles – 77 from Google Scholar and 119 from Google – were shortlisted for further analysis. These shortlisted articles were studied in detail, and relevant data were added to a codebook in the form of an Excel spreadsheet, allowing extracted data to be entered across a systematic list of variables (Nikam et al., 2021). The type of information extracted from the literature into the codebook included bibliographic information, policy information, and more, detailed in Table 2. The dataset with the bibliographic information on the 196 articles is available at www.doi.org/10.5281/zenodo.6326962.

Table 2. Details of the codebook used in the literature review

Section	Description
Bibliographic information	Title, authors, reference, document type, stakeholder sector, research method, subject focus
Policy information	Policy name, date of establishment and amendments where applicable, supply chain section in focus, responsible implementing body, stakeholder relevance
Policy suggestions	Barriers to enforcement, enablers to enforcement, policy level, policy gap addressed, regulatory lessons learned, policy suggestions to address gaps

1.3 Interviews

The interviews focused on understanding the plastic supply chain, the different stakeholders involved, the level of policy implementation, and the challenges and enablers for policy implementation. The interviews were conducted primarily in Mamallapuram, Tamil Nadu, and the surrounding villages in local languages, and the responses were translated to English by a representative of Hand in Hand India and sent to the primary researcher. A total of 15 interviews were carried out for this project. The interviews took approximately 30 to 40 minutes to complete.

In order to get a good overview of the plastic supply chain, we mapped the stakeholders and selected a sample of interviewees with representatives from each of the major sectors of stakeholders. Stakeholder mapping was done by identifying the key sectors and stakeholders in each of the components of the plastic waste value chain, as mapped in Table 3. Hand in Hand India identified and contacted representatives from each of the mapped sectors, to determine if they were willing to participate as an interviewee.

Table 3. List of stakeholders represented among the interviewees

Stakeholder type	Sector type	Number of interviews
Consumers	Citizens and consumer or user groups	3 (Interviewee 5, 6 and 7)
Fishermen Community Leaders	Industry and relevant associations	2 (Interviewee 13 and 14)
Government officials	Regional public authority	2 (Interviewee 2 and 3)
Non-governmental organization (NGO) representatives working on plastic waste issues	NGOs (multinational and local)	1 (Interviewee 4)
Plastic waste recyclers	Private sector (small and medium enterprises, or SMEs)	1 (Interviewee 9)
Plastic waste transporters	Local public authority	1 (Interviewee 15)
Rag Pickers and Sanitary Workers	Local public authority	3 (Interviewee 10, 11 and 12)
Repurposed plastic shop owners	Private sector (SMEs)	1 (Interviewee 1)
Researchers	Research, learning and innovation institutions	1 (Interviewee 8)
Total		**15**

We developed two sets of questions for different types of interviewees, as follows:

- For implementors such as plastic waste aggregators, collectors and processors, the questionnaire focused on the type, source and quantities of waste collected, any pre-processing activities done by the individual, the market situation, regulatory frameworks, challenges faced, and empowerment needs.

- For key informants such as decision makers, coordinators and experts, the questionnaire focused on type, source and quantities of waste collected on the regional or city level, the level of plastic waste management, challenges for current management processes, different stakeholders involved, type of vulnerable population, and relevant laws.

Ethics clearance was completed according to the EU General Data Protection Regulation for the questionnaires and other interview documents such as consent forms, which ensures inclusivity, avoidance of risks and ensuring privacy rights to the interviewee and rules for data storage. After the completion of the ethics clearance, interviews were scheduled with the help of colleagues from Hand in Hand India.

Walk-through observations and interviews were conducted by a representative of Hand in Hand India based in Tamil Nadu, over the span of a week in November 2021, with Covid-19 restrictions and protections in place. First author Jaee Nikam was present via video call throughout the interviews, as well as for the walk-through surveys.

Data were collected in the form of photos and videos of waste recyclers and shops, and interviews using the questionnaires that had been developed by the research team. Photos and videos were used as a confirmation of the interview information provided by the in-the-field interviewer and to record visual cues of how plastic waste is processed.

Each interview began with an introduction of the project and explanation of the consent form and interviewees' rights, provided by Nikam via video call. A consent form with an option for partial or full anonymity was requested to be completed by the respondents. The respondents were provided time to ask questions or express any doubts regarding the project and consent form.

Nikam and the in-the-field researcher, who was fluent in Tamil, were present throughout this process to ensure adequate translation was provided in the local language and the right technical information was provided to the respondent. The interviews were conducted verbally, the questionnaire was completed by colleagues at Hand in Hand India, and the collected data were analysed by the primary researcher.

All the data gathered – including interview questionnaires and walk-through photos and videos – were emailed to the primary researcher, who then added the data to the codebook cited above and were analysed with the literature review. The data collected in the codebook detailed two sets of data according to the type of stakeholder groups:

- For interviews of informants (decision makers, coordinators, experts and knowledge brokers and funders): sources and quantities of plastic waste, types of plastic recovery or recycling activities undertaken, and supporting activities by the current waste management system, along with challenges, vulnerabilities and policies.

- For interviews of implementors (plastic waste collectors, aggregators and processors): sources and quantities of plastic waste, types of processing activities, barriers/enablers to the current system, laws and empowerment needs.

1.4 Research limitations

As a scoping study, the research was carried out in a limited period, which may have led to small response numbers for interviews. Additionally, Covid-19 travel restrictions stopped the primary researcher (Nikam) from traveling to the case study location and carrying out the interviews in person.

While the interviews were carried out in person by a partner organization, following Covid-19 restriction protocols, the number of interviews largely depended on the interviewees' willingness to provide information and meet in person. Not all the interviewees were willing to provide the information, so the number of interviews ended up being limited to 15 total. Also, the interviews were largely carried out in the local language, which later had to be translated to English by the on-the-ground personnel for further analysis by the primary researcher.

Since this research was carried out in English, only online search results in English were considered for further studies. Information in local and national languages could give a better view of the current situation on the ground in the interview locations. Also noteworthy is the potential bias of relying on Google search algorithms, which may have missed related or pertinent publications.

2. Stakeholders and governance structure of the plastic value chain in India

This section provides an overview of the various stakeholders linked to the plastic waste value chain from across the public and private sector, including government agencies, recycling and waste collection companies, civil society organizations and academic institutions.

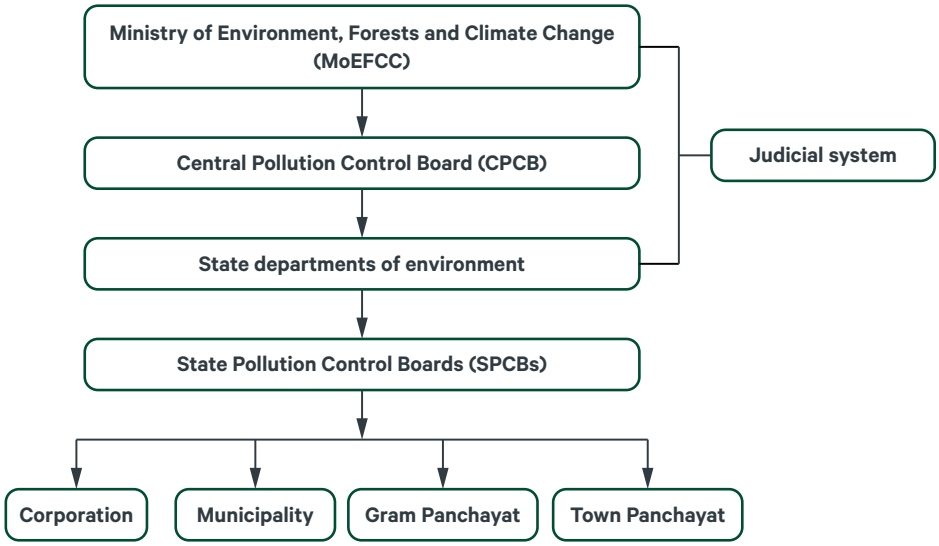
2.1 Public sector stakeholders

India has a broad legal framework with six key environmental laws and over 200 central and state laws that regulate the environment (Agarwal, 2005; Chakravartty, 2015).

In response to the Bhopal disaster in 1984, the Parliament enacted India's Environment Protection Act in 1986, which is the overarching law for all the environment laws enacted in the following years. This Act includes a framework for the protection of environment, specifically air, water, and land, to the central government as well as the state and local authorities. It provides a framework for setting emissions standards, regulating pollution issues and disseminating information related to these issues (AECEN & OECD, 2006).

The primary institutions responsible for the formulation and enforcement of environmental laws are the Ministry of Environment, Forests and Climate Change (MoEFCC), the Central Pollution Control Board (CPCB), state departments of environment, state pollution control boards (SPCBs), and district level authorities such as municipal corporations and village-governing Gram Panchayats (Kini et al., 2020). See Figure 1 for a hierarchical diagram.

Figure 1. Hierarchy of regulatory institutions linked to the plastic value chain



Ministry of Environment, Forests and Climate Change (MoEFCC)

Established in 1985, MoEFCC is the central government agency responsible for the formulation of environmental policies and regulations as well as other environmental activities. The objectives of the MoEFCC that are relevant to the plastic value chain are conservation and survey of plants and wildlife in forests; prevention and control of pollution, and the protection of the environment (AECEN & OECD, 2006; MoEFCC, 2018a).

Central Pollution Control Board (CPCB):

The CPCB is a national board, established in 1977, that functions under the authority of MoEFCC. The CPCB provides oversight over functioning of the SPCBs.

The responsibilities of CPCB that are relevant to the plastic value chain include:

- "Advise the central government on any matter related to prevention and control of water and air pollution and improvement of air quality.
- Plan nationwide programs for the prevention, control and abatement of water and air pollution.
- Provide technical assistance and guidance to the SPCBs, carry out and sponsor investigations and research relating to problems of water and air pollution and for their prevention, control and abatement.
- Prosecute polluting industries pursuant to the Water Act.
- Collect, compile and publish technical data on air and water pollution and measures recommended for their prevention, control and abatement.
- Prepare manuals, codes and guidelines relating to industrial emissions and effluents.
- Disseminate information on water and air pollution and their prevention and control.
- Perform such other functions as prescribed by the central government" (CPCB, 2018).

State departments of environment

Each of the 28 states in India has its own environmental department that functions within the jurisdiction of state-level government. The main responsibility of these departments is to enforce nationally established environmental policies. The specific responsibilities vary among states depending on each state's physical area, population size and economic activities.

This study focused on the Tamil Nadu Department of Environment, which was created in 1995 to serve as the main department dealing with the promotion of environmental protection in the state. The main functions of the Tamil Nadu Department of Environment that are relevant to the plastic value chain include coasts explicitly, as it implements the provisions of the Coastal Regulation Zone Notifications and is responsible for coastal zone management. The department also prepares Environmental Management Plans for towns and creates environmental awareness in schools and colleges in collaboration with non-governmental organizations (NGOs), eco-clubs and the National Green Corps (NGC, a programme of India's Ministry of Environment and Forests; Tamil Nadu Government, 2019).

State pollution control boards (SPCBs)

After state legislatures adopted the Water Act of 1974 and the Air Act of 1981, they established state-level pollution control boards that are responsible for ensuring effective implementation of national environmental laws, monitoring and enforcement. The SPCBs are attached either to the state department of environment or the forest and wildlife department. The specific functions of the SPCBs differ in different states.

In general, SPCBs perform the following functions related to the plastic value chain:

- Environment friendly technology development.
- Control of pollution through inspection of industrial units.
- Regulation of location of industries.
- Disposal of hazardous wastes.
- Collection and dissemination of information on the prevention and control of pollution.
- Advise the state governments on pollution related issues.
- Plan a comprehensive state-level pollution control, prevention or abatement program.
- Implement and enforce national standards, making them more stringent if warranted by local conditions. (AECEN & OECD, 2006; Planning Commission Government of India, 2013).

The Tamil Nadu Pollution Control Board licences small-scale recyclers and reports to the Ministry of Micro, Small and Medium Enterprises annually (Interviewee 9). Its other specific functions related to the plastic value chain are to "advise the State Government on any matter concerning the prevention, control or abatement of water and air pollution" and "collaborate with Central Pollution Control Board in organizing the training of persons engaged or to be engaged in a programme relating to prevention, control or abatement of water and air pollution and to organise mass education programme" and others (Tamil Nadu Pollution Control Board, n.d.).

Judicial system (Supreme Court in India and state high courts)

The Indian judiciary system at national and state levels provides enforcement of environmental laws through citizen-led public interest litigation. In some cases, judicial activism has led to setting new policies and practices, along with providing remedies.

One example is a lawsuit filed by the non-profit organizations Karuna Society for Animals and Nature (KSAN) and Visakha Society for Protection and Care of Animals over inadequate implementation of the plastic waste ban, triggered by plastic waste accumulation that led to cattle and wildlife deaths in 2014. The court that heard the case noted that despite having sufficient laws to deal with the issue of plastic waste, there was poor implementation; the court launched an enquiry by appointing a "three-member panel of lawyers to examine the Rajasthan government's statement that it had banned the manufacture and use of plastic bags in the state since 2010" (Shreeja Sen, 2014).

Additionally, "all environment-related penalties (fines and imprisonment) are provided under criminal law and must be imposed by lower courts" (AECEN & OECD, 2006). Following this, a specialized judicial body, the National Green Tribunal, was established in 2010, to adjudicate environmental cases in the country. The Tribunal is present in five zones: North, Central, East, South and West, with the principal bench in the North Zone, headquartered in Delhi (National Green Tribunal, 2019).

District level authorities (municipal corporations, Gram Panchayat)

The municipal corporations, like town Panchayats and village Panchayats, work on regional and local levels. Tamil Nadu has more than 500 town Panchayats and more than 12 600 village Panchayats (Tamil Nadu Government, n.d.).

The responsibilities of municipal corporations and Gram Panchayats that are relevant to the plastic value chain include implementation of state-level policies and collaborating with state inspectors. They also develop and set up of infrastructure for waste management, including ensuring segregation, collection, storage, transportation, processing and disposal of plastic waste.

These local government organizations also assist citizens and companies to accurately channel the fractions of recyclable plastic waste to recyclers as well as empower and engage with groups working with waste pickers. They collaborate with private actors such as producers to set up a plastic waste management system. They also organize activities that generate citizen level awareness of plastic waste issues and recycling.

At a law and enforcement level, these local governments also create by-laws where required. And in Tamil Nadu, the municipal corporations and Gram Panchayat are responsible for monitoring small-scale local recyclers, a process conducted by local fire departments, and for monthly taxation (Interviewee 15).

2.2 Plastic manufacturers

A wide diversity of manufacturers produces a range of plastic for different uses. As of 2022, India had more than 30 000 plastic manufacturing companies that employed about 4 million people. Among these, 85 to 90% are small- and medium-sized enterprises, and the remainder are large enterprises that are highly fragmented, meaning that they work on a small part of the value chain and work independently of each other, according to recent data from a government-sponsored "knowledge centre", the India Brand Equity Foundation. The list of products made is long and varied, from linoleum and houseware products to cords and fishnets, medical items, packaging, pipes, and raw plastic material. The country's plastic exports are nearly a third plastic raw material; a quarter plastic films, sheets, woven sacks, fabrics, and tarpaulin; and the rest as listed above (India Brand Equity Foundation, 2022).

According to the Centre for Financial Accountability, a project of BIC Trust and the India Institute for Critical Action – Centre in Movement, the few large plastic manufacturers provide the majority of the contribution to the total plastic production in India. For example, Reliance Industries has been estimated to meet about 75-80% of polypropylene demand in India (British Plastics Federation, 2011). Nearly all – 95% – of these businesses "operate as partnerships, proprietorships or private limited companies" (Alliance Experts, n.d.), registered to operate legally.

After the ban on single use plastic in India, announced in 2021 and in force 1 July this year, illegal single use plastic manufacturing units have continued to operate. The government is working on identifying these and shutting them down (Interviewee 2).

Few specific laws apply to legal manufacturing units for single use plastic. These include the Uniform Framework for Extended Producers Responsibility, 2016 (MoEFCC, 2020), which ensures that the plastic produced complies with the laws implemented downstream. One of the requirements in the year 2021–2022 is that the producers must recycle plastic waste equivalent to 25% of their plastic packaging material sold (MoEFCC, 2020).

The laws require all legally operating producers to collect the multilayered plastic waste produced from the products they introduce to the market and properly recycle it, and to be responsible for their emissions for manufacturing processes. Some of these stakeholders are detailed in Table 4.

Table 4. Plastic manufacturers and related stakeholders

Categories	Function
Banks and non-banking financial institutions	Provide financial resources or loans to manufacturers
Converters, processors, plastic producers; importers; brand owners and retailers	Perform midstream processes at state and national levels involving production of plastic components for their use in products
Monomer and polymer producers	Perform upstream processes for production
National industry association	Works in coordination with the local regulatory body, represented by industry members
Product and end-use application industry association	Represents manufacturers that produce a product or products from plastic components
Transporters	Carry out various operations throughout the value chain, such as delivering polymers to product manufacturers and transporting final products to retailers

Source: Kapur Bakshi et al. (2021)

2.3 Plastic waste generators

As is the case globally, in India, plastic waste is produced by almost every household and every section of society. The main types of plastic waste generators in Tamil Nadu are residential, industrial and commercial institutions, such as schools, hospitals and agricultural activities.

Approximately 9.4 million tons per year of plastic waste are generated in India, or an average of 26 000 tons per day (Ministry of Housing and Urban Affairs, 2019; Interviewee 8). With average plastic demand of more than 9 kg per capita, India ranks far below the average per capita consumption in Western countries such as the US, which had high demand of over 81 kg per capita in 2017 (IEA, 2020).

Recycling is embedded in the culture and lifestyle in India, due to a large part of the population living in low- and middle-income households. However, the large absolute quantities of collective waste produced due to a high population density makes India one of the top five plastic waste producing countries in the world (Dobrowolski, 2021).

2.4 Downstream stakeholders

In India, the plastic waste management value chain is a mixture of formal and informal, with the informal sector contributing enormously to the collection and segregation parts of the value chain. For example, the informal sector contributed 70% of PET bottles recycled in India (Shanker et al., 2022). Additionally, the number and type of stakeholders involved vary from location to location and depend largely on the level of urban development and planning.

Generally, in rural areas, informal plastic waste collection and recycling plays a major role in local waste management. However, in larger cities where higher government funding is dedicated to solid waste management, established waste management systems with formal government-appointed employees and collection vehicles are used. Often, more employees and a greater number of vehicles are provided to cities with larger populations.

As reported by Interviewee 3, larger cities have up to 75 municipal employees dedicated for collection, whereas smaller cities have been observed to have about 4 to 6 employees (Interviewee 3). Formal recycling plants are mostly situated in large cities.

Smaller municipalities often are allocated less funding for waste collection (Dobrowolski, 2021). This is particularly an issue for tourist destinations such as Mamallapuram, Tamil Nadu. The local population consists of only about 4500 households, or about 15 000 people as of 2011 (Census2011, 2011), but up to 50 000 to 60 000 visitors travel to the area daily, at peak tourist times, mainly for tourism. These visitors create large amounts of waste, which becomes the responsibility of the local municipality to treat. However, specific funding provided for solid waste management covers only the costs for the 4500 local households (Interviewee 2).

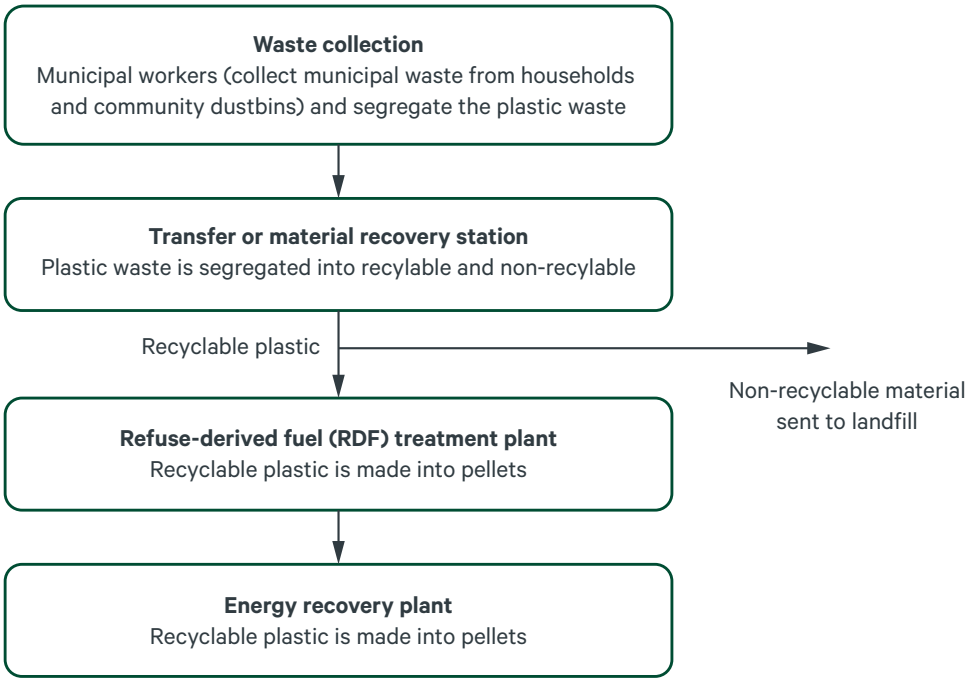
The presence and contribution of the informal sector remains prominent throughout the country. The informal sector includes rag pickers or waste pickers, who mainly play a role in waste collection and manual segregation (Interviewee 8). The informal sector in India consists of about at least 250 000 workers and is largely responsible for India's high recycling rate, estimated over a decade ago to be between 48% and 60% (Mutha et al., 2006). In some areas, formal waste collection works in parallel with the informal waste collection. In some cities, like Pune, organizations such as SWaCH (SWaCH, 2010) have been able to leverage the existing informal system and incorporate it with the formal collection and recycling processes by giving formal employment and employee benefits to informal workers.

Generally, a typical plastic waste management value chain in India includes the stages detailed in Figures 2 and 3. As mentioned above, the informal sector plays a major role in the collection and segregation of waste. In a town or city, where a municipal collection system is in place, collection

is done either by informal waste collectors, sometimes referred to as rag pickers, or via the formal municipal waste collection system.

After waste is collected by municipal workers in the formal municipal waste collection system, it is segregated and recyclable materials are recovered at transfer stations or material recovery stations. In certain cities of historical significance, like Mamallapuram, Tamil Nadu, the plastic waste is collected by the municipality or Archaeological Survey of India in the monument areas, or by NGOs like Saahas (interviewees 3 and 8). The residual plastic is combined with other refuse and sent to a refuse-derived fuel (RDF) treatment plant for forming RDF pellets, which can be used as fuel for running of the RDF treatment plant or in boilers of other power plants and electricity generators used by municipalities (Ganesh et al., 2013). In 2013–2014, CPCB reported 22 operational RDF plants in India (Saha et al., 2017).

Figure 2. Plastic waste collection via formal economy



Source: based on ASSOCHAM (2017)

Rag pickers or waste pickers collect plastic waste in the informal sector. As identified during interviews, the major types of plastic waste collected are polyethylene, polypropylene and PET (interviewees 8, 10, 11 and 12). Waste pickers mainly collect recyclable waste along roadsides, outside shops and restaurants, at dumping sites, from municipal bins and in public and commercial places, as reported by several waste picker interviewees, in exchange for cash or exchangeable items.

The informal sector plays a major role in the collection and aggregation steps, which is very important for the recycling industry. Despite their importance, workers in this sector are exposed to the most hazards, such as harmful chemicals in batteries, tube lights, and aerosol bottles, as most of the waste is mixed and all the rag pickers manually separate plastic from other waste with little or no personal protective equipment (interviewees 8 and 12).

In some cases, plastic waste such as plastic pouches are not separated from human waste drainage, which leads to higher chances of exposure to viruses and bacteria (Interviewee 13). The informal collectors also face gendered vulnerabilities: women get paid much less than men, though numbers are hard to specify (Interviewee 8).

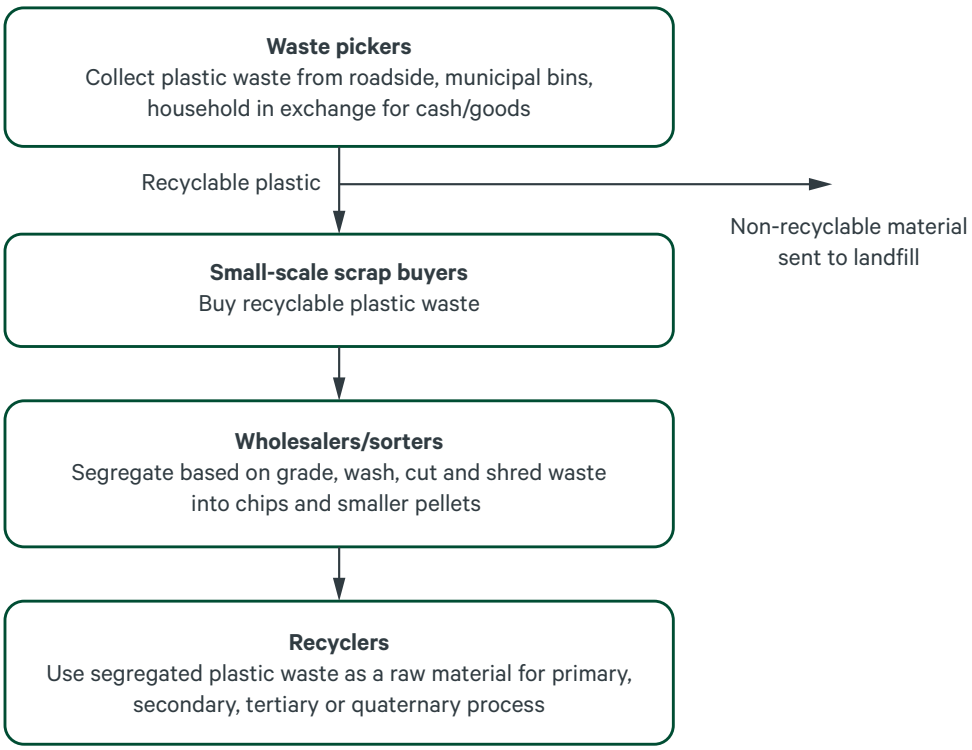
Informal workers collect and sort plastic waste and then sell it to kabadiwalas, or small-scale scrap buyers and recyclers, who select only the recyclable plastic items they need. The kabadiwalas then store these recyclable items and sell them in bulk to wholesalers.

The goods that are unsold are left to decompose or are burned (Interviewee 12). Burning of the unsold or unaccepted plastic waste generally happens in rural areas or small towns, where a municipal waste management plant is not present. This open-air burning is one of the major causes for air pollution in some rural areas.

Wholesalers work with waste sorters who segregate and categorize the waste in various grades and qualities, clean and shred it; then the wholesalers sell the different types of waste, typically to municipally appointed recyclers, independent recyclers, or RDF treatment plants. These buyers are considered to be "recyclers", and they shred the waste and use it as raw materials in one of three ways:

- **Primary:** use plastic waste to make products with characteristics like the original product, for example plastic bottles.
- **Secondary:** use plastic waste to make products with different characteristics to the original product, such as turning plastic bottles into cloth or roads.
- **Tertiary:** use plastic waste to produce basic chemicals and fuels, breaking the plastic down to petrochemicals or creating pellets to burn for electricity.

Figure 3. Plastic waste management via informal economy



Source: Based on ASSOCHAM (2017)

2.5 NGOs and citizen groups

As mentioned in the previous section, informal waste workers play a vital part in the waste management system but are largely ignored by other stakeholders and have minimal to no workers' rights provided by local regulatory bodies. In order to address this issue, tens of NGOs such as the Alliance of Indian Waste-pickers are working to ensure visibility and inclusion of these waste workers in various national level programs (Alliance of Indian Waste-pickers, n.d.). Another NGO, Plastics for Change, connects waste pickers to the market through a mobile app that provides waste workers access to fair market prices (Sharma, 2019).

Some NGOs play an active part in waste collection by organizing volunteer-based activities, including beach clean-up efforts in Tamil Nadu organized by Hand in Hand India (Interviewee 2). Additionally, NGOs play a particularly important part in citizen engagement through awareness-raising activities. Lack of citizen awareness is identified as one of the barriers to effective waste management implementation (see section 3; Kapur Bakshi et al., 2021).

2.6 Social enterprises, academic institutions and think tanks

Many social enterprises and start-ups working on waste management in India primarily focus on the waste collection and recycling section of the value chain. Recently, however, observers have noted that enterprises have shifted their focus to other parts of the value chain, including ways to repurpose and reuse plastic waste.

Typically, researchers or entrepreneurs working in partnership with research institutes start up enterprises to implement a novel method that they have developed. The main challenge for entrepreneurs is that many such social enterprises are relatively new and remain limited in their scope and area of implementation; however, they have a lot of potential to expand their scope nationally.

Research institutions play an important role as a backbone to the implementation of such social enterprises that focus on implementing innovative methods to repurpose plastic waste. One of the interviewees that works at a research institution has a team that established a social enterprise that works on converting plastic to diesel, which is currently used for heating applications. This Chennai based start-up is working on establishing their first commercial unit in Tamil Nadu (Interviewee 6).

Similarly, another Tamil Nadu–based start-up produces solid industrial fuel from plastic waste, funded by StartUp India and a national-level entrepreneur fund (The Hindu, 2020). Examples of other such social enterprises include GEM Enviro Management, a New Delhi–based start-up that collects PET waste from factories, offices, hotels and other sites and repurposes the waste into useful products such as bags and bottles (ASSOCHAM, 2017; Rai, 2017).

Recent trends show an increase in the number of angel investors focused on waste management start-ups in India in recent years. More investment could increase the number of start-ups in waste management. Recent reporting from *The Times of India* projected that "by 2025, India's waste management sector is expected to be worth US$13.62 billion with an annual growth rate of 7.17 percent" (Abraham, 2019).

Research and academia influence all parts of the plastic value chain – production, consumption and end-of-life. Apart from providing innovative technologies to address plastic waste, research and academic institutions also play a very important role in identifying the key gaps in regulatory, value chain and social structures and provide solutions for the same by providing credible data.

Additionally, research institutions and academia play a very important part in raising awareness and on-the-ground action. Examples for this include the Erode district–based Kongu Engineering

College, which received around USD 132 000 in grant money to conduct research on practical and applied waste management technologies (The Times of India, 2021b). The National Environmental Engineering Research Institute (NEERI), in Nagpur, also undertook a detailed survey in collaboration with CPCB to assess the compliance of 59 cities in the country with the Municipal Solid Wastes (Management and Handling) Rules of 2000 (Agarwal et al., 2015).

Academia especially at the school and college level can work on generating awareness among the youth of India. Previous suggestions include introducing sustainability courses, focusing on topics like waste management along with regular courses (Aggarwal et al., 2022).

2.7 Financing institutions

Financing institutions – banking and non-banking financial institutes and international governmental organizations such as the World Bank – are particularly important for developing countries, as they provide financial resources for waste management infrastructure.

For individuals, charitable trusts such as Rang De, in partnership with Hasiru Dala, which is a waste picker organization, help waste workers with loans. Also, as mentioned in the previous sections, Kabadiwalla Connect, in addition to connecting waste workers to the market, also identifies loans for working capital purpose.

Funds can be from non-profit organizations, such as the Circulate Capital Ocean Fund (CCOF) from the Closed Loop Oceans initiative, which encourages the flow of capital investment in waste management in the Indo-Pacific region in order to avoid ocean plastic waste. This fund made its inaugural investments in India in Quarter 1 of 2020 (Ocean Conservancy, 2021).

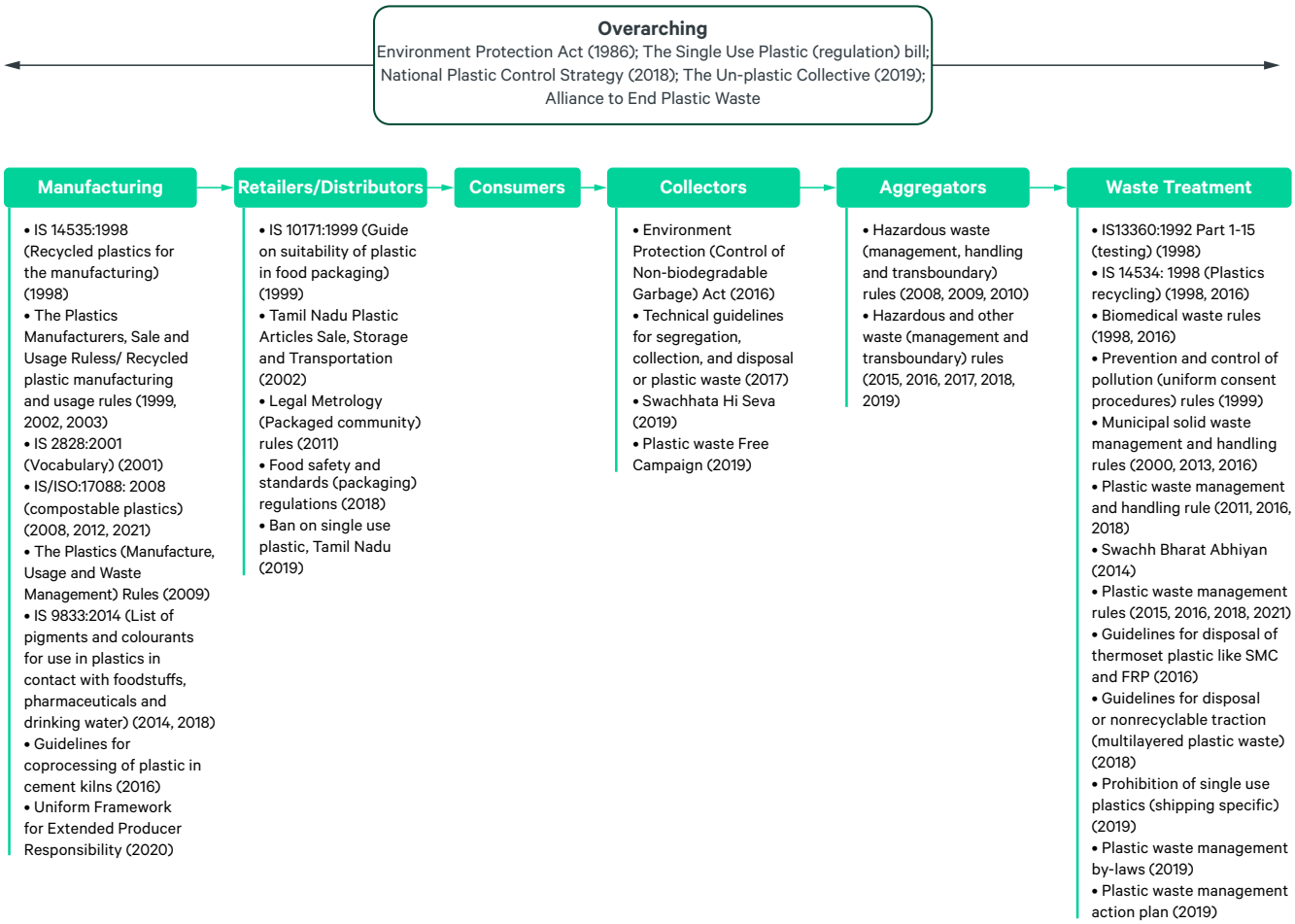
National banks such as the State Bank of India have implemented funds such as the SBI Green Fund, which focuses on activities like tree planting and creating awareness about the impacts of single use plastic (State Bank of India, 2020). The literature search showed that historically, microfinancing has been focused only on the agricultural sector and rural areas; nevertheless, microfinancing for the institutions working in the plastic waste sector has been increasing in India.

For example, Rang De provides 322 loans worth USD 100 000 to waste pickers. While similar microfinance is available to the informal sector, comprehensive data on the loans – including, loan amounts, length, repayment and default rates, and the borrower's gender – are not easily available, making it difficult to track the impact or effectiveness of such financing (Ocean Conservancy, 2021).

3. India's policy and regulatory framework for the plastic value chain

This section highlights the policy and regulatory framework of the plastic value chain in India, as well as the barriers and enablers for policy implementation. Figure 4 shows all the laws and campaigns as they relate to different components in the plastic value chain. The details for these laws are provided in Table 5. Those listed as "overarching" impact all the components of the plastic value chain.

Figure 4. Overview of policies related to the plastic value chain in India (see Table 5 for more details)



The policies in Figure 4, along with their descriptions, are listed in Table 5. They are broadly classified according to sections in the value chain: manufacturing, retail or distributors, downstream processes such as collectors, aggregators, waste management and treatment and industry focused. This classification is not a completely segregated classification, since some policies cover aspects in more than one section of the value chain. For example, the Plastic Waste Management Rules focus on stakeholders involved in the downstream waste management processes but also mentions requirements for plastic waste manufacturers.

As mentioned in the previous section and illustrated in Table 5, almost all the enforceable policies are implemented nationally and are enforceable equally throughout the country. The regional regulatory bodies are mostly responsible for the implementation of the policies in their respective allocated regions. However, some states like Tamil Nadu, are proactive with their actions in handling plastic waste, have implemented regional level policies like plastic waste management

by-laws, enforced by the Tamil Nadu state government. These follow the requirements enforced by Plastic Waste Management Rules 2016 but have stricter restrictions and implementation.

The Environmental Protection Act of 1986 was the first act promulgated by the central (national) government that enforced environment protection to reduce environmental pollution. A multitude of policies have followed that focus on the type of pollution or pollutant controls and limits. Most of the policies that focus on environmental pollution – such as air, water or land pollution – also mention plastic as a type of waste that needs more enforcement.

Plastic waste abatement–specific policies have increased in recent years, starting with the Plastic Waste (Management and Handling) Rules, 2011. Most of these policies and their amendments are focused on waste and ways to minimize it through activities like plastic bans. However, the latest amendment of the Plastic Waste Management Rules, 2021, and the Uniform Framework for Extended Producer Responsibility, 2020, includes clauses for plastic producers' responsibility in management of plastic waste. In the last decade, India has indeed taken strides in implementing plastic waste specific laws and enforcing amendments to address the loopholes observed. This can be seen by the Plastic Waste Management Rules enforced in 2015 followed by its amendments in the years 2016, 2018 and 2021.

The key agency that focuses on managing plastic waste issues is the Ministry of Environment, Forests and Climate Change (MoEFCC). As mentioned above, enforcement is largely a responsibility of the regional regulatory bodies that generally relegate the responsibility to the SPCBs. In addition to plastic waste management, the Bureau of Indian standards (BIS) enforces the labelling and quality control of plastic for different usage purposes. Additionally, there are different industry specific requirements for plastic usages, mostly focusing on plastic packaging implemented by the specific industry regulating body. For example, Food Safety and Standards (Packaging) regulations are implemented by the Food Safety and Standards Authority of India (FSSAI).

The number and breadth of policies are a good indication of the efforts taken by the government to address and control plastic pollution. However, the enforcement and implementation of the national level policies is observed to be lacking in impact on the local and regional level. A study by CPCB assessed plastic waste generation in 60 cities in India: as of 2015–2016, there was little or no processing of either municipal waste or plastic waste in most Indian cities (Prasher, 2018).

This lack was also identified by one of the interviewees for this report, who claimed that the rules are made but not completely implemented (Interviewee 2). Also, these rules are not uniformly enforced, with some states taking greater initiative in addressing the plastic waste issue than others. For example, the Tamil Nadu regional government banned single use plastic a couple of years before the national government took the initiative (Interviewee 8). Following these identified issues, Table 6 lists the barriers and enablers for policy implementation.

One of the key barriers for implementation, as mentioned in Table 6, is the lack of information regarding the actual requirements of the policies, including unclear roles; another is the lack of long-term integration of informal stakeholders, which, as mentioned in previous sections, play an important role in plastic waste management. Additionally, the process of waste collection poses a key barrier: since more of the waste is not segregated or sorted, this leads to high costs of secondary collection and transportation to recycling facilities, especially in rural areas.

Also, most of the policies focus on banning the use and do not provide adequate information on substitute products. This has led to plastic like single use plastic still illegally being used and produced, due to lack of financially viable alternatives. Overcoming these barriers could be possible and practical through focusing on activities like increasing consumer awareness, implementing solution-oriented policies and providing technology support for developing financially viable plastic substitutes, as well as by ensuring accurate segregated collection of plastic.

Table 5. Overview of policy and regulatory landscape linked to the plastic value chain in India

Policy or regulation	Dates; amendments	International (I) National (N) Regional (R) Local (L)	Responsible implementation body	Description (relevant issues)	Reference
Environment Protection Act	1986	N	Central Government	This is an overarching act that provides the Central Government with powers to take all such measures as it deems necessary or expedient for protecting and improving the quality of the environment and preventing controlling and abating environmental pollution.	(Government of India, 1986)
Manufacturing					
IS 14535:1998 (Recycled Plastics for the Manufacturing of Products – Designation)	1998	N	Bureau of Indian Standards (BIS)	Intended to be used for the identification and classification of the recycled plastic material based on its basic properties and applications. It applies to recycled plastic material ready for normal use without any further modifications.	(BIS, 1998b)
Plastics Manufacture, Sales and Usage Rules; Recycled Plastics Manufacture and Usage Rules	1999, 2002, 2003	N	MoEFCC	Intended to restrict the use of polythene bags with thickness 20 microns or less. The rules were amended in 2003 to ban plastic bags less than 40 microns in thickness for carrying and dispensing commodities and mandated registration of plastic manufacturing units with state pollution control authorities. The rules provided specifications for virgin and recycled plastic manufacturing. Rules have laid down provisions for the manufacturing, usage and end-of-life management, as well as criteria for manufacturing plastic carry bags and containers. Amendments provide specifications for virgin and recycled plastic manufacturing, extend definition of vendor, and mandate registration and authorization for manufacturers, production, sale or trade for plastic packaging.	(MoEFCC, 1999c, 1999b; Pani & Pathak, 2021)
IS 2828:2001 (Plastics: Vocabulary)	2001	N	BIS	Provide guidelines for the terms and definitions to be used in plastic industry manufacturing.	(BIS, 2001)
IS/ISO:17088: 2008 (Specifications for Compostable Plastics)	2008, 2012, 2021	N	BIS	Specifies procedures and requirements for the identification and labelling of plastic, and products made from plastic, that are suitable for recovery through aerobic composting.	(BIS, 2008)
Plastics (Manufacture, Usage and Waste Management) Rules	2009	N	MoEFCC	These rules, which have not yet entered into force, are intended to supersede the Recycled Plastics Usage and Manufacture Rules 1999. The rules are designed to regulate the use of plastic in its various purposes including conditions during manufacture, sale, stock, distribution and use and plastic waste management processes.	(Galea, 2010)
Uniform Framework for Extended Producers Responsibility	2020	N	MoEFCC	Establishes the primary responsibility of collecting and recycling plastic packaging waste on producer entities. Established the primary responsibility for collection of used multilayered plastic sachets or pouches or packaging is on the producers, importers and brand owners who introduce the products in the market.	(Kapur Bakshi et al., 2021; MoEFCC, 2020)
Retailers/Distributors					
Tamil Nadu Plastic Articles Sale, Storage, Transportation	2002	R	Ministry of Forests, Tamil Nadu	Established a ban on using non-reusable carry bags, cups, tumblers or plates made of or containing plastic and other such articles.	(P. Mohan, 2002)
Ban on single use plastic, Tamil Nadu	2019	R	Tamil Nadu Environment and Forests (EC2) Department	Established a complete ban on manufacture, sale, use, storage, transportation and distribution of single use plastic.	(EC2, 2019)

Policy or regulation	Dates; amendments	International (I) National (N) Regional (R) Local (L)	Responsible implementation body	Description (relevant issues)	Reference
Collectors					
Environment Protection (Control of Non-biodegradable Garbage) Act	2016	N	Central Government	This Act controls throwing or depositing non-biodegradable garbage in public drains, roads and places open to public view and protects the environment from being polluted by such garbage.	(Government of India, 2016; Kapur Bakshi et al., 2021);
Technical guidelines for segregation, collection and disposal of plastic waste	2017	N	Central Pollution Control Board (CPCB)	Guidelines provide roles and responsibilities of different stakeholders in efficient plastic waste management and technologies for disposal of plastic waste.	(CPCB, 2017; Kapur Bakshi et al., 2021)
Swachata hi sewa	2019	N	Department for Promotion of Industry, and Internal Trade	This initiative is a call to action against plastic waste from industrial estates, parks and other areas by all states and union territories. Focused on industry.	(Akshaya Patra, 2019; Press Information Bureau, 2019)
Plastic waste free campaign	2019	R	MoEFCC	This campaign was carried out by district administrations and focuses on awareness generation activities, alternative products identification in light of the single use plastic ban.	(Tirunelveli District Administration, 2019)
Aggregators					
Hazardous waste (management, handling and transboundary) rules	2008, 2009, 2010	N	CPCB	These rules provide guidelines on the responsibility of the occupier for handling of hazardous wastes, storage of hazardous waste, conditions for sale or transfer of hazardous waste for recycling, and standards for recycling.	(MoEFCC, 2008)
Hazardous and other waste (management and transboundary) rules	2015, 2016, 2017, 2018, 2019	N	MoEFCC	These rules superseded the Hazardous Wastes (Management, Handling and Transboundary Movement) Rules, 2008, except with respect to things done before supersession. These rules impose restrictions and prescribed procedures for management, handling, disposal and transboundary movement of hazardous wastes. In a 2019 amendment, the government banned import of PET flakes.	(Kapur Bakshi et al., 2021; MoEFCC, 2015a; Recykal, 2021)
Waste management and treatment					
IS13360:1992 Part 1-15 (testing)	1992	N	BIS	These provide rules for different methods for testing plastic.	(BIS, n.d.)
IS 14534: 1998 (Guidelines for recycling of plastic)	1998, 2016	N	BIS	This document provides guidelines for selection, segregation, and processing of plastic waste/scrap. It also provides guidelines to manufacturers of plastic products for the right markings to be used on the finished products to facilitate identification of the raw material.	(BIS, 1998a)
Plastic waste (management and handling) rules	2011, 2016, 2018	N	MoEFCC	These rules replace the earlier Recycled Plastics Manufacture and Usage Rules, 1999 (amended in 2003). These rules ban the use of plastic materials in sachets for storing, packing or selling gutkha, tobacco and pan masala, and packaging material less than 40 microns in thickness.	(MoEFCC, 2011)

Policy or regulation	Dates; amendments	International (I) National (N) Regional (R) Local (L)	Responsible implementation body	Description (relevant issues)	Reference
Plastic Waste Management Rules	2015, 2016, 2018, 2021	N	MoEFCC	These rules specify the conditions that must be adhered to by the manufacturers, importers, distributors, sellers and users of plastic bags, sheets and packaging material. Non-compostable plastic bags need to be greater than 50 microns thick. The jurisdiction of the new rules has been extended to cover rural areas also. Increased minimum thickness of plastic carry bags from 40 to 50 microns. Requires producers/brand owners to introduce collect back system of plastic waste as Extended Producer Responsibility. The 2018 Amendment includes phasing out of multilayered plastic, or "non-recyclable, or non-energy recoverable, or with no alternate use" items, and Central Registration system for the registration of the producer/ importer/ brand owner. The 2021 amendment includes banning the manufacture, use, sale, import and handling of some single use plastic. Non-woven plastic bags are not to be less than 60 or 240 microns. So-called thermoset plastic and thermoplastic are to fall within the ambit of these rules. Ban on thickness of plastic carry bags increased from 50 to 75 microns from 30 September 2021 and to 120 microns, coming into effect from 31 December 2022. Guidelines for Extended Producer Responsibility were given legal force.	(Down to Earth, 2021; MoEFCC, 2015b, 2018b, 2021)
Plastic waste management by-laws	2019	R	Tamil Nadu Pollution Control Board	In accordance with the provisions of Rule 6 (4) of the Plastic Waste Management Rules, 2016, the Greater Chennai Corporation framed the by-laws under Section 349 of the Chennai City Municipal Corporation Act of 1919 that focuses on banning the use of plastic sheets and other plastic products.	(Greater Chennai Corporation, 2019)
Plastic waste management action plan	2019	L	Karur Municipality	This action plan focuses on implementing inspection on the municipality level in the effort to eradicate the banned plastic usage.	(Karur Municipality, 2019)
Indirectly related to plastic (policies that are not focused on plastic but cover plastic in one of more sections)					
Prevention and Control of Pollution (uniform consent procedures) rules	1999	N	CPCB, State Pollution Control Boards (SPCBs)	These rules are not directly related to plastic waste but provide guidance for submission of consent forms, sampling and categorization of polythene, plastic and PVC goods through extrusion moulding, rope (cotton and plastic), plastic processed goods.	(MoEFCC, 1999a)
Municipal solid waste (management and handling) rules	2000, 2013, 2016	N	MoEFCC	The rules focus on source segregation of waste to carry out efficient waste management processes. These rules are applicable to municipal areas, urban agglomerations, census towns, notified industrial townships, areas under the control of Indian Railways, airports, airbase, Port and harbour, defence establishments, special economic zones, State and Central government organizations, places of pilgrims, religious & historical importance.	(Mageswari & Vijayalakshmi, 2020; MoEFCC, 2013; Vikaspedia, 2016)
Legal Metrology (Packaged Commodities) Rules	2011	N	CPCB, SPCBs	These rules provide restrictions to the manufacture, stocking, distribution, sale and use of carry bags, plastic sheets or coverings made of plastic sheets and multilayered packaging, in order to explore the possibilities of increasing usage of substitute materials and restricting use of plastic.	(Ministry of Consumer Affairs, Food and Public Distribution, 2011)
Swachh Bharat Abhiyan	2014	N	Ministry of Housing and Urban Affairs	An initiative by the Prime Minister to raise consumer awareness for accurate disposal of waste and use of non-plastic substitutes for carry bags.	(Pani & Pathak, 2021)
Industry specific (policies that only address a specific industry/or process)					
Biomedical Waste (Managing and Handling) Rules	1998; 2016	N	MoEFCC	This is the earliest policy that addresses the treatment of plastic waste in biomedical area. This policy focuses on recycling of plastic, sharps (needles, syringes, scalpels, blades or glass), and glass to authorized recyclers as well as provides colour coding and the type of container for disposal of biomedical wastes containing plastic bags.	(Kapur Bakshi et al., 2021)

Policy or regulation	Dates; amendments	International (I) National (N) Regional (R) Local (L)	Responsible implementation body	Description (relevant issues)	Reference
IS10171:1999 (Guide on suitability of plastic in food packaging)	1999	N	BIS	This regulation focuses on providing guidelines to food packers for selecting of specific thermoplastic material for food packaging.	(BIS, 1999)
IS 9833:2014 (List of pigments and colourants for use in plastic in contact with foodstuffs, pharmaceuticals and drinking water)	2014, 2018	N	BIS	These provide guidance on the list of pigments and colourants accepted for food grade plastic.	(BIS, 2014, p. 201, 2018)
Guidelines for Co-Processing of Plastic in Cement Kilns	2016	N	CPCB	These guidelines provide the protocols for co-processing plastic waste in cement kilns.	(Kapur Bakshi et al., 2021)
Guidelines for disposal of thermoset plastic such as sheet moulding compound and fibre-reinforced plastic	2016	N	CPCB	The guidelines focus on minimization of use of fibreglass reinforced plastic and sheet modelling compound and polycarbonate polymer products, and promote the use of alternate materials that are easily reusable and recyclable.	(Kapur Bakshi et al., 2021)
Guidelines for disposal of non-recyclable fraction (multi layered plastic waste)	2018	N	CPCB	These guidelines provide requirements for non-recyclable plastic waste and non-recyclable plastic waste management.	(Kapur Bakshi et al., 2021)
Food safety and standards (packaging) regulations	2018	N	Food Safety and Standards Authority of India (FSSAI)	Food Safety and Standards Authority of India made the Food Safety and Standards (Packaging and Labelling) Regulations, 2011, but now the Food Authority has decided to divide these regulations into two regulations: (i) the Food Safety and Standards (Packaging) Regulations, 2018; and (ii) the Food Safety and Standards (Labelling and Display) Regulations, 2018. These regulations focus on implementing specific requirements for packaging material used by food business operators.	(FSSAI, 2018)
Prohibition of single use plastic (shipping specific)	2019	N	Directorate General of Shipping	Under this policy all Indian ships under the Merchant Shipping Act, 1958, are prohibited to use single use plastic on board starting January 2020.	(DGS, 2019)
Overarching (policies that cover many or all aspects of value chain)					
Single Use Plastic (Regulation) Bill - national plastic control strategy	2018	N	MoEFCC	To provide for a framework to enable India to achieve its goal of eliminating single use plastic by the year 2022.	(Thakur, 2018)
The Un-Plastic Collective	2019	I	Public-private partnership by Confederation of Indian Industry (CII), the UN Environment Programme, and the World-Wide Fund for Nature (WWF) India	This collective seeks to minimize externalities of plastic on the ecological and social health of our planet by eliminating unnecessary use of plastic, reuse plastic and reduce plastic leakage, circulate plastic within the economy, reducing and replace plastic with sustainable alternative materials in the long term and set time bound, public commitments to reduce plastic externalities.	(UNEP et al., 2019)
Alliance to End Plastic Waste (AEPW)	ND	I	Private sector partnership	AEPW is made up of 30 global companies that is made up of nearly 30 major global companies that have committed over USD 1.0 billion with the goal of investing USD 1.5 billion over the next five years to develop, deploy and bring to scale solutions that will minimize and manage plastic waste and promote post-use solutions. The aim is to develop solutions to mitigate plastic pollution and promote a circular economy by utilising used plastic.	(Alliance to End Plastic Waste, 2021)

Table 6. Overview of the barriers and enablers to policy and regulatory effectiveness in achieving sustainable plastic waste management

Policy or regulation	Barriers	Enablers	References
Uniform Framework of Extended Producers Responsibility, 2020	1. Unclear role and long-term integration of informal stakeholders. 2. Accumulation of mixed type of quality and quantity of plastic waste. 3. The framework leaves the funding of "urban local bodies" for plastic waste management to market forces, thus leaving the organizations dependent on the revenue received from selling plastic waste to independent processors, funding from central agencies, and funding raised by the urban local bodies from market. 4. Less consumption of high value packaging like PET, paper, cardboard, etc., resulting in no cross-subsidization for low- or no-value items. 5. High cost of secondary collection and transportation to recycling facilities (mostly located in urban areas), as many villages generate smaller quantities of plastic waste and are dispersed or remote. 6. Weak Extended Producer Responsibility (EPR) implementation through producer responsibility organizations that help deliver the produced plastic waste back to recycling chain. 7. No regional mandatory EPR targets for producers. 8. Unbranded and fake plastic products in the market adding to the 'free rider' phenomenon and increase in cost. 9. Unclear compliance guidelines. 10. Lack of consistent monitoring, review, and verification mechanism.	1. Existing informal recycling contributing to easier adaptations of EPR. 2. Building on and scaling up current successful initiatives by few urban local bodies, such as door-to-door municipal sanitation and waste collection. 3. Scaling up of EPR conducive infrastructure and operational mechanisms.	(ASSOCHAM, 2017; Manomaivibool, Panate et al., 2007; MoEFCC, 2020; Pandey & Manuja, 2020; Pani & Pathak, 2021)
Plastic Waste Management Rules (2016).	1. Inaccurate accounting of plastic consumed in production of electrical equipment due to lack of accurate inventories. 2. No existing standards related to the optimization of packaging systems and recycling and reuse of packaging materials. 3. Lack of implementable solutions to address the zero plastic waste challenges, irrespective of adequate research solutions available. 4. Absence of cost-effective alternatives for carry bags (<50 microns) 5. Continuation of manufacturing, sale, and stocking of carry bags (<50 microns) in the majority of the states and union territories, post-implementation of the ban.		(Pandey & Manuja, 2020; Rafey & Siddiqui, 2021)

Policy or regulation	Barriers	Enablers	References
Overall plastic waste management implementation	1. High cost of alternative packaging leading to illegal production of plastic below 40 microns. 2. Complex informal waste collection structure. 3. Shortage of raw material for recycling industries. 4. Variable (not uniform) supply of raw material from the informal waste sector for recycling. 5. High taxes (goods and services tax) on recycled plastic pellets and products. 6. Low number of government initiatives to promote biodegradable single use products 7. Most of the current policies focusing on end-of-pipe approach. 8. Low number of policies that promote segregation and reuse at source and conversion of waste into useful materials/energy. 9. Blanket standard funding for solid waste management, provided by the government, 10. Unequal burden on tourist destinations with high visitor turnaround leading to improper waste management and burning of waste. 11. High transportation cost from collection site to recycling plants, leading to inadequate treatment.	1. Increasing consumer awareness using both carrots and sticks via educational institutions, advertisements, and celebrity endorsements. 2. Technology support for development of environmentally friendly and economically viable plastic substitutes. 3. Plastic recycling trade in credits for companies that achieve their recycling targets 4. Ensuring collection of difficult-to-collect low-value and difficult-to-recycle products like multilayered plastic. 5. Innovative ways to repurpose non-recyclable plastic like using plastic to recover energy or to make roads. 6. Strengthening reverse logistics chain and formalizing informal recycling through producer responsibility organizations funded by organizations that provide incentives to the informal sector for collection of low-value plastic. 7. Establishing infrastructure that can help with consistent supply of raw materials to recyclers and establish recycling units closer to the cities. 8. Clarity in the requirements along with timeline for the Guidelines for Single-Use Plastic 9. Financial incentives for manufacturers and retail shop owners to transition to plastic substitutes. 10. Better avenues for transportation of plastic waste from collection site to recycling plants.	(ASSOCHAM, 2017; Caldera et al., 2020; Kaushal et al., 2012, 2012; Lewis & Atherton, 2018; Pandey & Manuja, 2020; Vimal et al., 2020); (Interviewees 2, 3, 8 and 12)

4. Case studies of innovative practices

The Indian policy and regulatory structure around plastic is constantly evolving. Along with existing nationally implemented policies, some states and union territories have gone a step ahead of the requirements, through implementing innovative practices to address the plastic waste issue on a local level. This section highlights these innovative stories and practices that have worked to curb the increasing plastic problem.

4.1 Repurposing techniques

Construction, fuel and cloth are some of the main ways to repurpose plastic waste. The methods can be simple like grinding and mixing of plastic waste to construct roads or plastone blocks for construction or complex including multiple techniques like conversion of plastic to fuel or fibre. Many of these techniques have gained momentum only recently and hence are still limited in their scale of implementation. With governments showing interest and relaying more funds towards repurposing techniques, there is high potential for these to be implemented throughout the country.

Using plastic waste for construction of roads

To address the growing concern over plastic waste accumulation, the Indian government passed an order to integrate plastic waste in road construction. As of 2021, about 703 km of national highways have been constructed using plastic waste (The Times of India, 2021a). The material used for the road constructions contains 6-8% of plastic waste mixed with bitumen. The process is easy and does not need new machinery. Additionally, this mixture reduces the usage of bitumen in road construction.

Using plastic waste in road construction has been shown to increase the quality of flexible pavements and reduce the wear and tear of roads. Also, these roads have better resistance to rainwater and cold weather. These types of roads are now present in 11 of India's states, including 16 000 km in Tamil Nadu as of 2014 (Nanisetti et al., 2021; Prakati, 2021).

Plastic-stone blocks in construction

Construction blocks known as plastone are stone blocks used for construction made by mixing plastic waste and stone (Sivarajah, 2020). They are used in construction as outdoor flooring, liner for water bodies and other purposes. For one manufacturer in Madurai, Tamil Nadu, each plastone block contains the plastic equivalent of 300 plastic bags or 6 PET bottles. Thiagarajar College of Engineering, Madurai, has the patent for plastone blocks and tiles which are made by recycling all types of plastic, including "non-recyclable" packaging material (Sivarajah, 2020).

Plastone blocks withstand more pressure and resist water percolation and are a cheaper substitute for cement blocks, according to manufacturers. Plastone technology is currently procured and used in the state of Maharashtra (Grant Thornton, 2019).

Plastic to fuel

Research units at institutions like the Indian Institute of Petroleum (IIP) and Indian Institute of Management (IIM), Tamil Nadu, have developed a unique process of converting plastic waste to fuel, like gasoline and diesel. The process developed by IIP, has the capacity for converting 1 kg of plastic to 750 ml of automotive grade gasoline that meets Euro III standards, whereas the conversion rate of IIM technology is 60% plastic to fuel (Interviewee 8; Down to Earth, 2014).

Plastic to polyester fibre

Plastic recycling plants around the country have managed to successfully convert plastic to polyester fibre at different scales. These plants use PET bottles and convert them to polyester yarn. The polyester fibre produced in these units is used in automobile industries, packaging material for food products and pharmaceuticals, and other consumer products.

About 35 companies recycle PET bottles and produce 50 000 tons of recycled fibre every month across India (Patel, 2017). Examples of some of these plastic waste recycling units in Dadra and Nagar Haveli have the capacity to process 18 000 tons of plastic a year. Currently, 20 units are installed that convert 300 000 tons of PET bottles to polyester fibre annually (ASSOCHAM, 2017). Polycycle, a company in Tamil Nadu, had a capacity of 100 tons annually several years ago and was looking to expand its production to 200 tons annually (Polycycle, 2019).

4.2 Empowering stakeholders

The power held by stakeholders in the Indian plastic waste value chain varies. Clearly some stakeholders require assistance to improve their work, the reuse and waste management of plastic, and more.

Connecting informal workers to markets

The current system has gaps in collaboration between informal waste collection and urban formal recyclers. This gap was addressed by a technology-based enterprise based in Chennai, Tamil Nadu, named Kabadiwalla Connect, which successfully leveraged technology to connect informal waste collection workers, or kabadiwalas, to urban plastic waste recyclers and hence decrease the waste sent to landfills to 70% (Interviewee 8).

Instead of the traditional door-to-door collection by kabadiwallas, with no guarantee of the quantity of waste, this enterprise provides computer or phone applications that help kabadiwallas plan their day as well as set market standard prices on their material. This enterprise tapped into the siloed system to give informal kabadiwallas a network to help make their work easier (Veolia, 2018).

Integrating the informal sector in municipal solid waste management

Solid Waste Collection and Handling (SWaCH) is one of India's cooperatives of self-employed waste pickers; the cooperative provides door-to-door waste collection, resource recovery, trade and waste processing and other allied waste management services in connection with local municipal cooperation. SWaCH has helped formalize work of 2300 waste pickers and provide them with better health and safety equipment and standard wages.

According to ASSOCHAM (2017), SWaCH collects more than 600 tons of municipal solid waste per day. About 130 tons of waste is composted every day, while 150 tons is "recycled effectively, which amounts to almost 20% of the total waste generated" (ASSOCHAM, 2017).

4.3 Awareness generation

The responsibility of raising awareness lies with the private sector as much as with the government in India. Activities that generate awareness of plastic waste and good management, some of which are described below, have largely been limited in time and in scope. More long-term activities are needed to build awareness.

Private sector

Private companies such as ITC have launched programs focusing on awareness generation among the informal waste collection sector and consumers. ITC's Well-being Out of Waste (WOW) initiative focuses on promoting awareness about the importance of source segregation and recycling and establishes systems to ensure effective practice.

The ITC WOW programme was launched in Bengaluru in 2013 as "Wealth Out of Waste" and currently covers 1100 households. This program partners with local NGOs and works on distributing educational material like flyers on the importance of waste segregation and different

types of plastic waste to households. It also focuses on educating local waste collectors on efficient and safe ways to segregate waste (ITC, 2019; Iyengar et al., 2020).

Incentive schemes and awareness activities

Tamil Nadu government is one of the leading states in India to impose incentives to raise awareness and encourage action to limit plastic waste. One of the ways includes the announcement of a competition for plastic-free villages, self-help groups that play a major role in collection of maximum plastic waste, and the best plastic-free schools. A monetary award of approximately USD 40 000 was awarded to the top three winners who collected the most waste (CPCB, 2019).

5. Conclusions and recommendations

Unmanaged plastic pollution with plastic waste that ends up in the ocean is a major problem in India, mainly owing to its large coastline. Due to its high population density, India is in the top five large plastic waste producers globally. The plastic value chain presents an opportunity to address these issues, despite being itself an urgent problem to solve and improve.

This scoping study reviewed the key stakeholders that directly or indirectly influence the plastic value chain in India. This study also provides an overview of the regulatory infrastructure and the number of policies relevant to plastic in India.

Each of the stakeholders identified for this study have a unique role and potential to enhance the current plastic waste system. Different stakeholders already are making efforts to improve the situation; however, collaborated effort between various stakeholders is needed for efficient plastic waste management. This study identified the barriers and enablers for solid waste management system in India.

5.1 Recommendations

Stakeholders in each sector have different responsibilities and levels of agency. Here we make recommendations for different sectors of stakeholders, including different government agencies, NGOs and others, to improve the plastic value chain in India. Table 7 provides a summary of recommendations for stakeholders according to sector.

Table 7. Summary of recommendations by sector for improving India's plastic value chain

Stakeholder sector type	Recommendation summary
Public sector	Implement more policies on source segregation.
	Decentralize policy, by granting more power to state governments.
	Provide customized budgets, depending on specific local issues, instead of a blanket budget based on the number of households.
	Provide waste transportation budgets.
	Leverage existing informal waste collection structure.
	Give incentives or subsidies directed towards technical implementation for small-scale recyclers.
Plastic manufacturers	Private sector needs to play a larger role in raising awareness.
	Tap into the growing entrepreneurial base and international funding to accelerate waste management process.
Practitioners working with local level NGOs	Increase recycling rates through reduction of gap in the type of collection or availability of the waste and the type of waste being recycled.
	Provide more NGO support for training of informal waste collectors and for on-the-ground activities like beach clean-up drives.
Researchers and academic institutions	Identify and provide financially viable substitutes for single use plastic and plastic thinner than 40 microns.
	Generate awareness among youth.
	Create data inventories for areas such as financing and waste collection and processing.
Financial institutions	Provide microfinancing aimed towards aiding informal workers to carry out better waste management practices.
	Collect better data and maintain data inventories for current financing avenues.

For public sector stakeholders:

- Most of the policies currently implemented focus largely on the waste management part of the plastic value chain, with not many laws focusing on the upstream or source segregation of plastic. Since source segregation is the first key step to carrying out effective waste management practices, it is imperative to **implement more policies on source segregation**.

- Currently, only the national government has the power to introduce new laws and state governments have the enforcement responsibility. However, state and local regulatory bodies are more aware of the local issues and the most urgent problems faced, and they can address the plastic waste problem at the local level better. Hence**, decentralizing policy to grant power to the state governments to introduce new laws or implement state-specific amendments** under the guidance of the national government would help better address the issues at the local level.

- Currently, the budget for waste management is allocated based on the number of households in a community. This poses an unfair barrier for tourist destinations that have a high influx of non-resident visitors, leading to high amounts of waste created on certain days, like public holidays. This leads to pressure on the local regulatory body to manage high amounts of waste on a limited budget. **Provision of customized budget depending on local issues** as opposed to providing a blanket budget based on the number of households is needed.

- The waste budget is provided to towns and municipalities by the state government, largely for the management and collection of waste. The transportation costs from collection sites to recycling sites, which are usually away from the collection location, is not provided. There is a need to **provide specific transportation budget, especially to smaller towns and villages**.

- As identified in the literature and interviews, India has a unique advantage due to its high workforce availability, owing to its large population, and an established informal collection structure has led India to have a higher recycling rate than other wealthy industrial countries. The government needs to **leverage the existing informal collection structure** to better address plastic waste issues. This can be initiated by addressing the current issues that the informal waste collectors are facing, including price fluctuations depending on the season and location limitations in waste collection due to difficulty in transportation.

- Currently, small-scale recyclers carry out sorting and recycling manually, due to recycling and repurposing technology being expensive, thus leading to low quantities and quality of plastic products to be repurposed**. Incentives or subsidies directed towards technical implementation for small-scale recyclers** is needed.

For plastic manufacturers:

- Efforts are currently limited by plastic manufacturers and allied private sector to raise awareness against dangers of plastic waste amongst consumers. The **private sector needs to play a larger role in raising awareness**. This could be in form of labels or warning signs on products or contributing to campaigns.

- Municipal solid waste is currently a promising sector for entrepreneurs. There is high potential for innovation. There is also growing interest from international funding agencies for funding plastic waste management. **Tapping into the growing entrepreneurial base and international funding** may help accelerate the waste management processes on a national level.

For practitioners working with local level NGOs:

- As identified in interviews, the recyclers and small-scale scrap buyers only accept recyclable waste, and the rest of the waste is either burned or left at the disposal site. This leads to almost 80% of the plastic waste going untreated. Additionally, the major type of plastic waste preferred by the small-scale recycling shops is PET followed by PE and PVC, largely due to the recyclable component. However, the major types of waste collected by the informal waste collectors are polyethylene and polypropylene, followed by PET. This shows that there is a **gap in the type of collection or availability of the waste, further leading to lower rates of recycling as well as less income earned by informal collectors and deficiency in the availability of raw material for recyclers**.

- The informal collectors are not formally trained to identify the right type of plastic. Most of them work through experience, leading to low quality of plastic waste collected. Some NGOs work to provide training and personal protective equipment in some states; however, their impact is still limited. Thus, **greater NGO support for training as well as other activities like beach clean-up drives is needed**.

For researchers and academic institutions:

- Our literature review as well as interviewees have identified that despite the ban on manufacturing of plastic less than 40 microns, these types of plastic are still illegally being manufactured or used largely due to lack of financially comparable substitutes and mostly by the lowest economic strata of society. Hence, there is an urgent need to **identify and provide substitutes for single use plastic and plastic thinner than 40 microns, which are inexpensive to make and buy.**

- Academia – especially at the school and college level – can work on **generating awareness** among the youth of the country by introducing sustainability courses, focusing on topics like waste management along with regular courses.

- One of the major barriers for efficient waste management systems is lack of data in different sections of the plastic waste value chain. **Academia can aid in creating data inventories for areas such as financing and waste collection and processing** for better understanding of the current plastic waste management systems and easier identification of areas to improve.

For financial institutions:

- Our literature search identified that historically, microfinancing has focused on the agricultural sector. Since the majority of the contribution in waste management is done by the informal sector, **microfinancing aimed towards aiding informal workers to carry out better waste management practices** is needed.

- **Better data and data inventories for current financing avenues** would aid increased effectiveness throughout all components of the plastic waste value chain.

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