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PROMOTING CIRCULARITY IN THE VALUE CHAIN OF PLASTICS IN INDIA

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Executive Summary

The social cost of the plastics industry in India is estimated at **US$62-96 billion** for the year 2023.
(The social cost includes the market price of plastic, emissions cost involved in the production process, and the mismanagement costs of plastic wastes.)

The present value of the social cost of continuing a business-as-usual structure in the plastics industry for the period 2025-2030 is **US$541 billion.**

The present value of the social cost of adopting a 100-percent circular plastic value chain by 2030 is estimated at **US$370 billion.**

The net present value of benefits that will accrue by implementing 100-percent circularity by 2030 is **US$170 billion.**

Present benefit of circularity = Present cost of inaction = **US$170 billion**

The study undertakes a quantitative analysis of the value chain of plastics in India to estimate the social benefits that can be generated from adopting a circular framework.

Circularity Benefit	US$170.47 billion
(i.e. US$170 + billion in social costs can be avoided by adopting circularity)	

The study also conducted an alternate scenario analysis, where the degree of circularity in 2030 is varied to emphasise the need for urgent implementation.

Degree of Circularity in 2030	Net Present Value of Benefit over BAU framework (in US$ billion)
50 percent	28.6
75 percent	31.8
100 percent	33.6

The report also looks at the current structure of the plastics market in India, and especially at the management of plastic waste. It discusses the regulatory frameworks that are in place and makes policy recommendations to facilitate a greater degree of circularity in the sector. The following are some of the key takeaways from this study:

- The use of plastics globally has soared twenty-fold in the past 50 years and is expected to double in the next 20 years due to its benefits like durability and flexibility.
- According to a mean-difference test, advanced nations tend to export more plastics than developing nations and contribute more to global plastic pollution.
- In India, a significant portion of plastic waste is not properly managed. The requirement is a circular economy roadmap that will include recycling solutions.
- The pollution generated by India's plastics industry continues to worsen as India stands among the top five global polluters, producing around 4 million tonnes of plastic waste annually.
- Of the 8,300 million tonnes of polymers, synthetic fibres, and additives produced globally from 1950 to 2015, 55 percent ended up in landfills, 8 percent were incinerated, and only 6 percent were recycled.
- The global trade in plastic waste, often from developed to developing countries, contributes to environmental pollution and poses risks to the health and environment of receiving countries.
- Plastic consumption in India surged from 14 million tonnes in 2016-17 to 20 million tonnes in 2019-20, with Maharashtra, Gujarat, and Tamil Nadu accounting for 38 percent of the total waste in 2019-20.
- Plastic waste generation in India reached 4.1 million tonnes in 2020-21, nearly triple the volume in 2016-17; the primary sources are packaging, automotive, agriculture, and textiles.
- India's urban waste management struggles with the rising volume of plastic waste, achieving only around 85–86 percent collection efficiency in Municipal Solid Waste (MSW).
- Mismanaged plastic waste in India, especially during monsoons, poses risks to water systems, causing blockages and ocean pollution.
- India's 60-percent recycling rate for post-consumer plastic waste is largely due to the informal sector; municipalities, relying on basic recycling methods, contribute less to the recycling effort.

- India's Plastic Waste Management Amendment Rules 2021 targets reducing pollution from single-use plastics by banning items like plastic cutlery and earbuds with plastic sticks.
- If replicated and scaled, proven effective circular practices in the global plastics sector present opportunities for sustainable development.
- Only 50 percent of plastic waste in India is recycled, with the rest contributing to environmental degradation and resulting in a significant social cost. Aiming for 100-percent plastic recycling could yield major economic benefits and align with the Sustainable Development Goals (SDGs).
- A case study is undertaken to highlight the need for aligning corporate responsibility with sustainability needs. Bisleri's Bottles for Change initiative is discussed as a replicable framework for enhancing consumer awareness.[a]
- The report's proposed actions include reducing production of non-recyclable plastics, improving recycling infrastructure, and formalising waste collection systems.
- Amid challenges in policy implementation, such as enforcing bans on single-use plastic and incentivising waste segregation, targeted capacity-building should be provided to small and medium enterprises (SMEs); other imperatives are investment in recycling infrastructure and innovation in end-of-life solutions for plastics.

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[a] This study was funded by Bisleri International.


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I
Introduction

Plastic was once seen as a groundbreaking innovation whose advantages were many, among them its lightweight nature, flexibility, durability, and extended shelf-life. Over the past 50 years, there has been a twenty-fold increase in the usage of plastic, with expectations of doubling over the next two decades due to higher living standards that in turn encourage increased consumerism.[1] Today, however, the widespread and unabated use of plastic has become a massive environmental threat. Indeed, the positive aspects of plastic are offset by the unsustainable production processes and mismanagement of plastic waste, causing issues such as clogged drains, flooding, the breeding of disease-causing vectors, and adverse impacts on land and marine ecosystems.

The COVID-19 pandemic only increased the demand for plastic, as safety and hygiene requirements led to the mass production of commodities like personal protective equipment and packaging. The latter, accounting for 59 percent of Indian plastics consumption,[2] offers a parallel opportunity for a transition to a circular economy. At present, the linear model of plastic production contributes to global oil and gas consumption, and the downstream stage generates substantial volumes of single-use plastics that generate massive waste.[3] In India, despite recycling efforts, a considerable portion of plastic waste ends up mismanaged. This circularity roadmap aims to break the reliance on fossil feedstock, promote recycling, reduce plastic litter, and emphasise the need for recyclable and cost-effective alternatives. This roadmap highlights challenges in biomass availability, market development for recycled plastics, and technological limitations for eco-design. Implementation requires collaboration among governments, industry, academia, and the informal sector, and regular monitoring that will allow for course-correction should ensure optimal effectiveness.

1.1. The Production-Consumption Menace

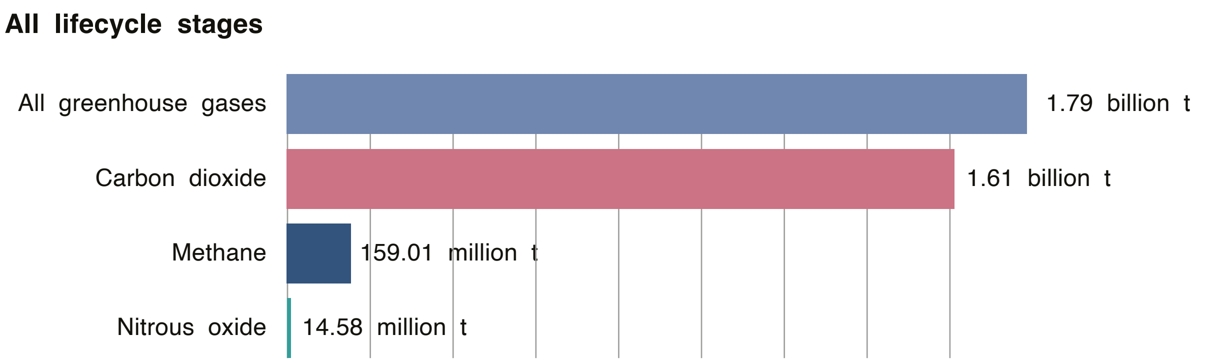
Plastics present a two-pronged problem: greenhouse gas emissions during production and use, and subsequent waste management challenges. The plastic industry's reliance on fossil fuels and the emissions associated with each step of the production process underscore the need for a transition to renewable energy and more sustainable production practices.

The pollution from the production of plastics is significant and multifaceted.[4] The processes involved—from the extraction of raw materials to the manufacture of the final products—contribute to a range of environmental pollutants, including greenhouse gases. During the extraction phase, the procurement of fossil fuels, which are the primary raw materials for plastic production, involves drilling and mining activities. These activities themselves are energy-intensive and release a considerable amount of carbon dioxide (CO_2) and methane (CH_4), both potent greenhouse gases, into the atmosphere.

Another major source of emissions is the refinement of crude oil and natural gas to produce ethylene, propylene, and other plastic precursors. These processes are carried out in petrochemical plants that are powered by burning fossil fuels, leading to the emission of CO_2, sulphur oxides (SOx), nitrogen oxides (NOx), and other pollutants that contribute to air quality degradation and climate change. Furthermore, the polymerisation process, where small molecules are chemically bonded to form polymers, the building blocks of plastics, also requires energy, typically from the burning of fossil fuels.

Plastic production and disposal account for about 3 percent of global emissions, when measured in carbon dioxide equivalents which consider the varying warming impacts of different greenhouse gases. Figure 1 summarises the emissions throughout the life cycle of plastics, from production to disposal. Ninety percent of these emissions come from the production phase.[5]

Figure 1: GHG Emissions from Plastics, 2019 (in tonnes of Carbon Dioxide Equivalent[b])



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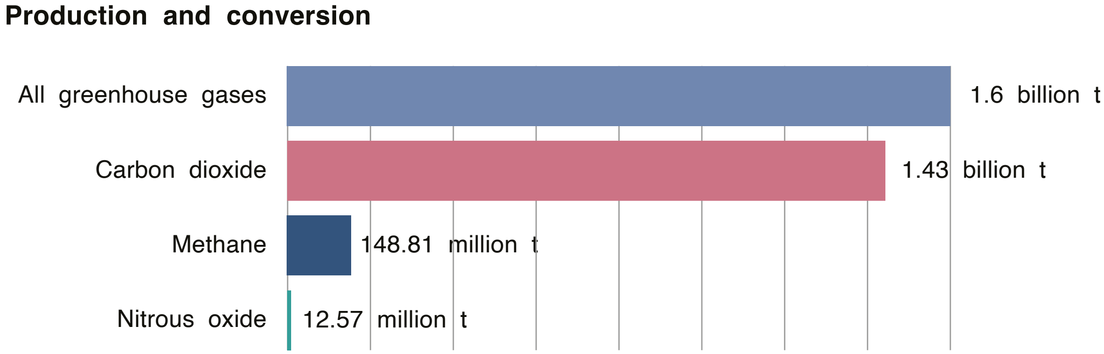
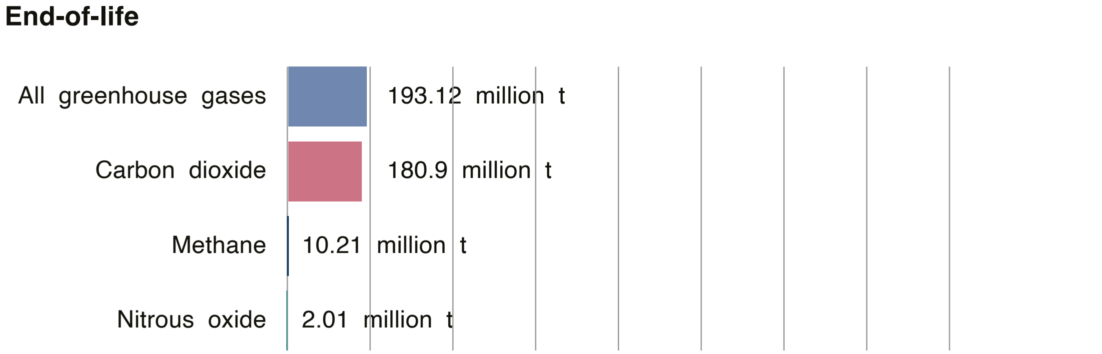
[b] Carbon dioxide is not the sole contributor to global warming, though it accounts for a significant share. To account for all greenhouse gas emissions, researchers quantify them in terms of "carbon dioxide equivalents" (CO_2eq), encompassing the entire spectrum of greenhouse gases. The conversion to CO_2eq involves assigning each greenhouse gas a specific weight based on its global warming potential (GWP). CO_2 for example is assigned a GWP value of one. A gas with a GWP of 10 implies that one kilogram of that gas would generate ten times the warming effect of one kilogram of CO_2. The determination of CO_2 equivalents for each gas involves multiplying its emissions mass by its GWP factor. The extent of warming is calculated over varying timescales: for a 100-year timescale (GWP100), each gas is multiplied by its GWP over 100 years. The cumulative greenhouse gas emissions, expressed in CO_2eq, are then computed by summing the CO_2eq values of each gas.





Source: Our World in Data, data from OECD (2022)[6]

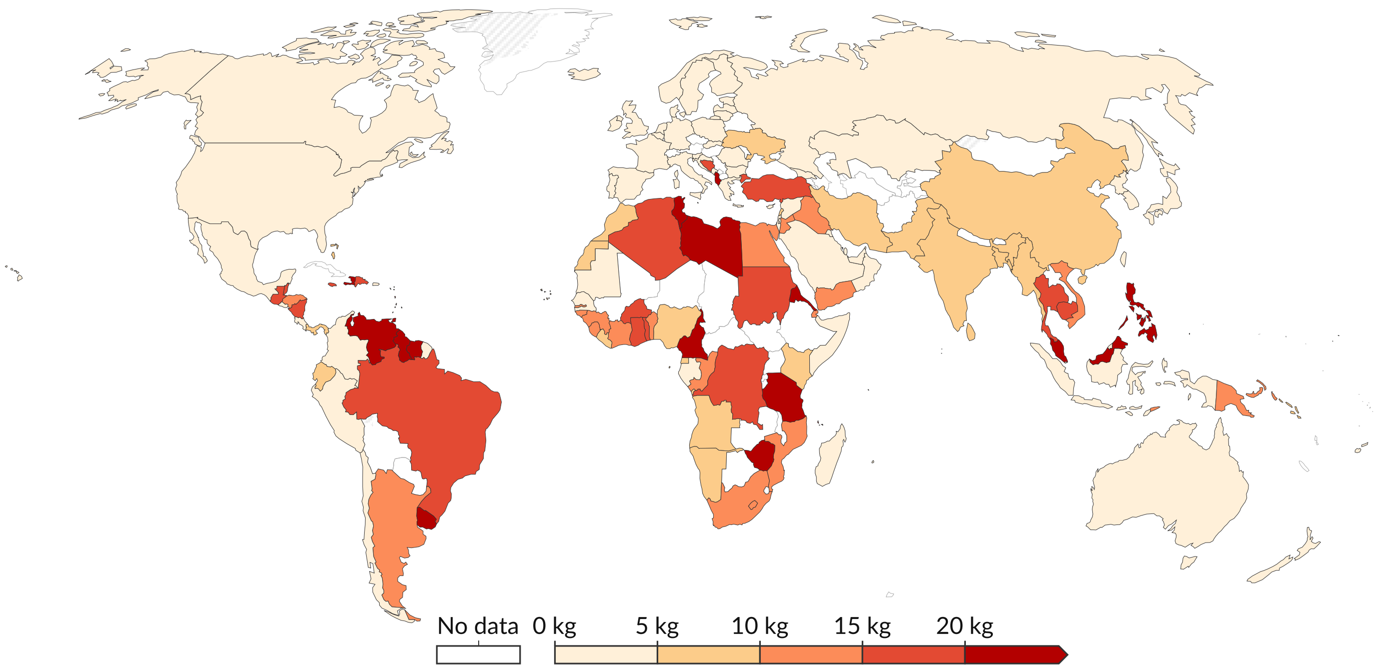
Global plastic production has grown from 2 million tonnes in 1950 to over 450 million tonnes in 2019, highlighting the escalation in potential pollution sources.[7] This increase in production has not only led to more waste but also to a substantial rise in the carbon footprint of the plastics industry. Emissions from plastic could represent up to 13 percent of the remaining carbon budget by 2050, which is critical in the context of the 1.5-degree goal set by the Paris Agreement.[8]

To mitigate the environmental impact of plastic production, it is essential not only to improve waste management but to reduce production overall. At present, only 9 percent of the world's plastic waste is recycled, and half of it goes directly to landfills. Another fifth is mismanaged, either not being recycled or kept in sealed landfills; these then enter and pollute natural environments, including rivers, lakes, and oceans.[9] The remaining fifth is incinerated.

From 1950 to 2015, a total of 8,300 million tonnes of polymers, synthetic fibres, and additives were produced globally, with 55 percent ending up in landfills and 8 percent being incinerated; only 6 percent was recycled. Projections suggest that if current production and waste management trends persist, a staggering 12 thousand million tonnes of plastic waste could be generated by 2050.[10]

Historically, developed countries have produced more plastic waste per capita; however, it is the low- to middle-income countries that often see higher levels of mismanagement as they lack sufficient waste infrastructure. Middle-income countries contribute significant amounts of the total plastic waste that end up in the world's water bodies (see Figure 2).

Figure 2: Mismanaged Plastic Waste Per Capita, 2019 (in kg)[c]



Source: Our World in Data, using data from Meijer et al. (2021)[11]

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c 'Mismanaged plastic waste' refers to plastic materials that are not subjected to proper waste management practices such as recycling, or secure disposal in sealed landfills. This category encompasses plastic items that are either burned in open pits, dumped into oceans or open waters, or disposed of in unsanitary landfills and dumpsites. The mismanagement of plastic waste poses environmental and health risks, as these disposal methods can lead to pollution, habitat destruction, and the release of harmful substances into ecosystems.

A critical factor to consider is the export of plastic wastes which involves the international shipment of discarded plastic materials for recycling or disposal. This practice, which comprises a part of total global trade, is notable for its impact on global inequalities, as developed nations often export their plastic waste to developing countries. The export of plastic waste from affluent to impoverished nations brings about negative consequences, including global environmental pollution, particularly in developing countries, as wealthy nations contribute to widespread ocean plastics. This practice poses substantial health and environmental risks in the recipient nations, negatively impacting communities and ecosystems. Furthermore, allegations of illegal exports[d] reveal a lack of proper regulation and oversight, emphasising the need for more stringent controls.[12] This practice of industrialised nations disposing of substantial volumes of their waste by exporting them to poorer countries is referred to as "waste colonialism".[13]

Table 1: A Global Divergence Snapshot of Plastic Waste Exports

A plastics exports (in kgs per capita) mean difference (between advanced and developing countries) test using the latest available data for 213 countries around the world (see Appendix A) yields statistically significant results at a 1 percent level of significance. The provided t-test compares the means of two independent samples—representing developing nations (Latin America and the Caribbean, East and Southeast Asia, and Sub-Saharan Africa) and advanced nations (Middle East and North Africa, Organisation for Economic Co-Operation and Development, Eastern Europe and Central Asia, and Oceania), assuming unequal variances between the two groups. The negative t-statistic (-3.57) indicates that the mean of developing nations is significantly lower than that of advanced nations. The p-values are extremely low (close to 0), suggesting strong evidence to reject the null hypothesis that the means are equal. Therefore, there is a statistically significant difference between the two groups.

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[d] The Basel convention imposed stringent regulations on the movement of hazardous substances without the consent of the importing countries. Later in 2019, the restriction was extended to include scrapped plastics. However, despite the ban effective since 2021, countries still illegally export plastic wastes to poorer countries, violating the amendment.

The t-statistic lies beyond the critical values for both one-tail and two-tail tests, further supporting the rejection of the null hypothesis. Advanced nations tend to export more plastics, conforming to a variant of the pollution-haven hypothesis, i.e., richer nations shift the cost of pollution to poorer nations. This is attributed to less stringent policies and lower institutional costs with respect to waste management in poorer nations.

Metrics	Developing Nations	Advanced Nations
Mean	1.07	4.64
Variance	6.49	78.01
Observations	131.00	82.00
Hypothesised Mean Difference	0.00	
df	90.00	
t Stat	-3.57	
P(T<=t) one-tail	0.00	
t Critical one-tail	2.37	
P(T<=t) two-tail	0.00	
t Critical two-tail	2.63	

Source: Authors' own, using data from UN Comtrade[14]

The primary reasons for such exports include insufficient domestic recycling capacity, as seen in the case of the UK exporting a substantial portion of its plastic packaging in 2019 due to limited recycling capabilities.[15] European countries are struggling with effectively and sustainably managing increasing volumes of plastic waste. In early 2019, the EU's plastic waste exports amounted to around 150,000 tonnes per month—a significant decrease from the monthly 2015–16 levels of 300,000 tonnes, primarily directed towards China and Hong Kong.[16] This decline could be attributed to import restrictions and a shift in exports to other Asian countries.

With plastic production and consumption on the rise, environmental issues are becoming more acute, and the inefficiency of waste management systems is a growing concern. These issues are prompting regulatory changes and shifting consumer behaviour, particularly regarding the pollution of marine environments. The push towards circular economy models in developing nations like India offers investment opportunities to address plastic pollution and its impacts.

1.2. The Plastics–SDGs Nexus

The sustainable development agenda encompasses 17 Sustainable Development Goals (SDGs), which have motivated member states to commit to adapting their policies to meet specified objectives by 2030. However, the pressing issue of plastic pollution is notably absent from the explicit focus of the SDGs.

The concern about plastic pollution was first crystallised by the Honolulu Commitment of 2011, which primarily addressed plastic debris in the oceans. Only later was plastic pollution recognised to extend beyond the seas to freshwater, land, and air, posing threats to the environment as well as human health. This prompted discussions and actions around SDG 14 (Life Below Water). In July 2017, the United Nations adopted the resolution “Our Ocean, Our Future: A Call for Action”, urging all member countries to intensify efforts to prevent ocean pollution, with an emphasis on reducing single-use plastics (SUP) and single-use plastic packaging.[17]

However, addressing plastic pollution should not be confined to SDG 14 and needs a more holistic approach that integrates SDG 3 (Good Health and Well-Being), SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action), and SDG 15 (Life on Land). The international community must recognise the far-reaching implications of this issue to develop comprehensive, cross-cutting solutions that address the multifaceted nature of plastic pollution across various sectors and dimensions of sustainable development. For instance, additives used to make plastics industry-ready have severe health implications for both humans and animals; the minute nano plastics are poisonous and tend to penetrate organ tissue, leading to varied physiological ailments.

In India, plastic consumption surged from 14 million tonnes in 2016–17 to 20 million tonnes in 2019–20, with a compounded annual growth rate of 10 percent. Maharashtra, Gujarat, and Tamil Nadu contributed significantly, accounting for 38 percent of total plastic waste output.[18]

1.3. Structure of the Study

Despite the size and impact of the plastics industry in India, the benefits of a circular value chain have not been quantified. Existing studies only discuss the regulatory frameworks needed for circularity and the benefits of adopting such frameworks. However, there is little literature that extends beyond the design and estimates the benefits of circularity or the present costs of inaction. This report aims to bridge the gap between theory and practice by estimating the net present benefit of implementing a 100-percent circular framework in the Indian plastics value chain. The report discusses the current structure of the plastics market in India and the existing policy frameworks that guide waste management. Additionally, the role of the informal sector in plastic waste management and the lack of infrastructure are discussed. Existing literature that discusses the state of circularity in India are examined. This report aims to serve as a guide to the contemporary structure of the plastics industry in India and makes key policy recommendations to ease the social burden of plastic waste.

This report analyses the plastics value chain in India. First, the business-as-usual (BAU) scenario is analysed to compute the costs of the plastics industry, which measures the social cost of plastic production per year based on multiple inputs derived from existing estimates. Second, a circularity framework is suggested where the 100-percent-circular plastic value chain goal is aligned with the 2030 Sustainable Development Agenda and recommends aiming for complete circularity by 2030. The net present value of adopting this framework is calculated over the 2025–30 period.[e] The report also presents the methodology and suggested framework as well as presenting the policy recommendations.

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[e] This period was chosen at the authors' discretion.


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II

Plastic Waste in India

In 2020–21, India experienced a surge in plastic waste generation, which reached approximately 4.1 million tonnes—nearly three times that recorded in 2016–17. This escalating demand for plastic is intricately linked with the country's rapid economic growth driven by the packaging, automotive, agriculture, and textile industries, which collectively constitute a US$73-billion sector, as of 2020.[19] However, this symbiotic relationship between economic expansion and heightened plastic consumption is unsustainable and urgently requires restructuring. A circular economy model is a viable approach to uncouple industrial growth from waste generation, allowing for sustained economic development without the associated environmental drawbacks.

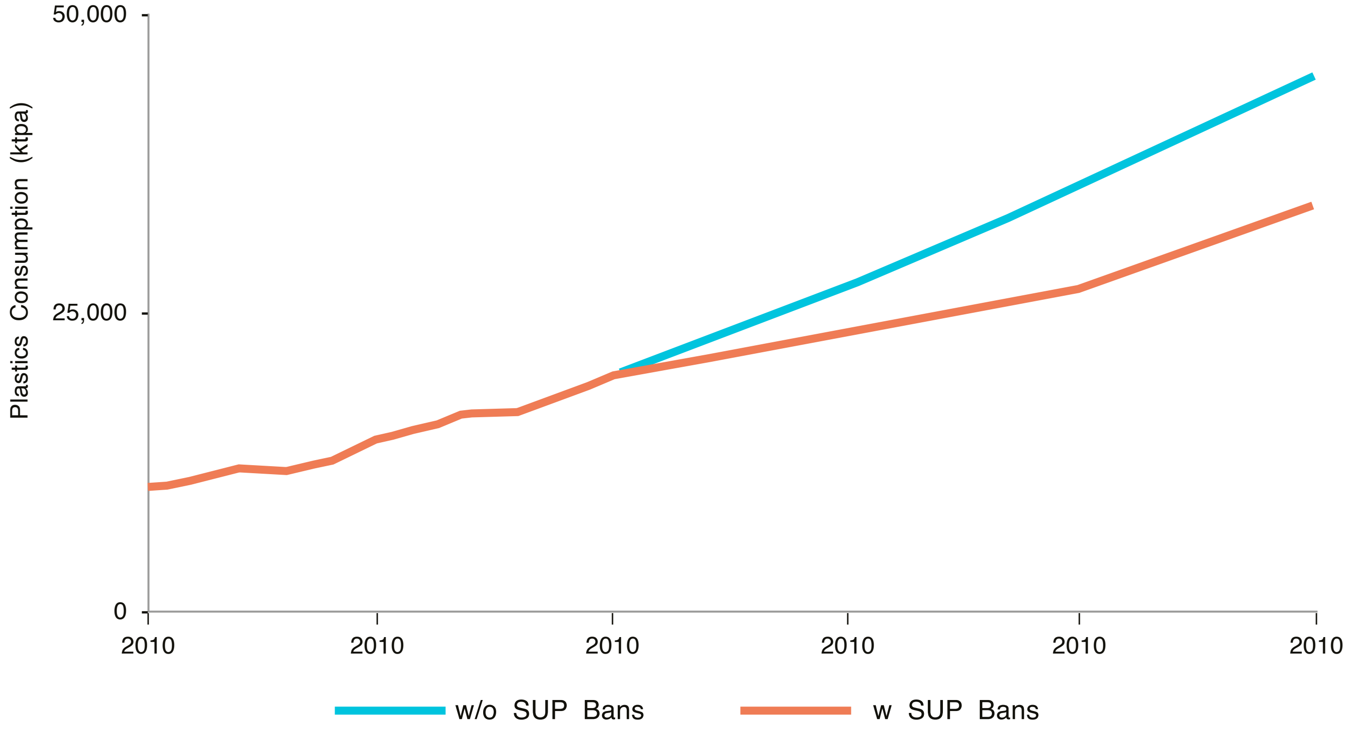
In addressing the plastic predicament in India, it is imperative to consider waste management as well as the environmental toll of plastic production. In

2021-22, of the total plastic production in the country, 42 percent remained in use, with the remaining 58 percent turning to waste. Of this, 60 percent underwent recycling, 8.5 percent was converted to energy, and the rest was mismanaged. The environmental ramifications of plastic production are evident, with 99 percent of feedstock being fossil-based, and 90 percent of polymer-based inputs sourced from virgin feedstock, leaving a mere 10 percent derived from recycled waste.[20] The circular economy approach is instrumental to concurrently tackle production and waste challenges, reduce fossil dependency, mitigate emissions, and curb the volume of plastic waste. A comprehensive understanding of the existing linear plastic value chain is essential before delving into the intricacies of implementing a circular economy framework.

The current waste management practices in India face challenges in effectively handling the increasing volume of urban waste. The collection of post-consumer plastic waste is integrated into municipal solid waste (MSW) systems. Presently, MSW systems have a collection efficiency of approximately 85–86 percent.[21] However, the lack of comprehensive source segregation contaminates potentially recyclable dry waste, including plastics. Recyclable plastics such as single-polymer packaging (both flexible and rigid) risk losing their recyclability if they are not properly segregated, and mixing these plastics with wet or food waste renders them non-recyclable. The mismanagement of contaminated or low-value plastic waste, which goes uncollected, recycled, or repurposed, is a significant challenge for India. This category comprises low-value SUPs, which are widely employed as carry bags or for packaging food and small-sized fast-moving consumer goods (FMCG).

The contamination of difficult-to-recycle plastics pose challenges in collectability and retrievability. Thin plastics, such as carry bags and food wrappers, contribute significantly to litter and marine pollution. The effective recycling of these plastics requires clean, segregated, and mono-material waste, along with an established value chain. Strategies include reducing consumption, legislative measures against hard-to-recycle products, and exploring alternative materials. Enhanced collection, EPR schemes, and public engagement are essential due to the low collectability of these plastics. While a complete phase-out is impractical, policies like the ban on SUPs encourage research on alternatives and recycling.[22] The following figure gives two estimated scenarios of plastic demand/consumption with and without SUP bans in India.

Figure 3: Plastic Consumption Scenarios in India—without (w/o) and with (w) SUP Bans (2010–35)



Source: The Energy and Resources Institute[23]

The lack of economic incentives exacerbates the problem. There is also a lack of mechanisms to capture and prevent the leakage of these low-value, contaminated SUPs into the environment at the end of their brief lifecycle. Post-consumer plastic waste predominantly finds its way into open dumpsites and landfills. Landfills are facing challenges due to population expansion and urbanisation; the availability of land suitable for landfill purposes is diminishing, particularly within the confines of cities, where land has high value. Additionally, landfills contribute to environmental challenges while also giving rise to leachate and the emission of GHGs.[24]

The mismanagement of plastic waste in India poses risks to water systems, especially during the monsoon season, leading to drainage blockages and flooding. Plastics discarded in urban coastal areas often enter the ocean, contributing to the formation of vast garbage patches known as gyres. The prevalence of plastic waste in the environment is exacerbated by improper recycling and disposal methods, as plastics tend to break down into microplastics rather than fully degrade. Furthermore, so-called biodegradable plastics do not rapidly decompose into harmless components, adding to litter and microplastic pollution. Addressing this issue requires a comprehensive waste management strategy that encompasses recycling and disposal as well as the reduction of plastic use; and the development of biodegradable and compostable materials, in conformity with the Food Safety and Bureau of India Standards.

The lack of waste collection mechanisms and improper disposal practices also pose environmental and health threats. Despite bans on plastic bags in some states, enforcement is lax, especially in rural areas, leading to continued use. The demand for small-sized packaged FMCG and food items in rural areas has grown in the last decade due to affordability and convenience. To tackle waste in rural areas, understanding the quantity, quality, and composition of household plastic waste is crucial.[25] Segregation at the household level, along with scientific and technological interventions, is necessary for effective plastic waste management.

2.1. Informal Sector

The Central Pollution Control Board (CPCB) estimates a 60-percent recycling rate for post-consumer plastic waste in India. This rate is predominantly attributed to the informal sector, encompassing waste pickers, aggregators, and informal recycling units, with municipalities (urban local bodies, or ULBs) playing a limited supporting role.[26] Despite the 2016 Municipal Solid Waste Management (MSWM) Rules mandating the integration of the informal sector into formal waste management systems, there is a deficiency in establishing a structured collaboration. Municipalities, the private sector (including multinational companies), and waste management companies encounter challenges in effectively engaging with the informal sector despite evidence showcasing the economic, environmental, and social advantages of fostering mutually beneficial partnerships.

Inefficiencies also stem from the unorganised nature of the informal sector, which further hinders formal recognition. Workers within the informal sector receive low wages, lack proper protective equipment, and endure extended working hours without standardised operating procedures, often operating without health and occupational safety measures. Informal-sector recycling is often initiated with the collection of recyclables from open dumpsites, streets, or households. Subsequently, these recyclables transition through various stages, passing from informal waste pickers to local *kabadiwaalas* (small scrap aggregators), eventually reaching larger aggregators, junkyard owners, intermediate dealers, or other middlemen. This trade occurs within a hierarchical and non-transparent value chain in a market space that is semi-formal or informal and lacks clear price estimates for different plastic products. Following the recycling process, the transformed plastic, now in the form of pellets or granules, is reintroduced into the economy as secondary raw material. Additionally, inadequate technology and equipment in recycling practices contribute to sub-optimal environmental outcomes.

The recycling industry in the country relies heavily on the informal sector, which serves as a pillar for environmental sustainability and the circular economy. Additionally, the sector alleviates the economic burden on urban local bodies. The Bruhat Bengaluru Mahanagara Palike (BBMP) became the first municipality in the nation to formally register waste pickers and systematically document scrap dealers.[27] Assuming an average daily collection of 70 kilograms of waste by an individual waste picker in the city, the annual diverted waste from landfills to waste pickers would amount to 106,671 tonnes (factoring in 60 percent organic waste, 30 percent dry waste, and 10 percent inert waste). Hence, integrating the informal sector into formal waste management systems is crucial to address these challenges and enhance plastic pollution control and worker well-being.

2.2. Inadequate Infrastructure

The absence of advanced technological processes results in the manual or mechanical recycling of plastics through methods such as cutting, shredding, or washing to produce granules, flakes, or pellets of basic quality. These crude materials are subsequently combined with virgin substances to enhance overall quality. Insufficient formal procedures, standardised protocols, and basic recycling techniques contribute to material losses throughout the recycling procedure. Due to these limitations, the recycled flakes, pellets, or granules may lack superior quality and may be tainted with various polymers or materials.

Formal recycling, which primarily encompasses the treatment of uncontaminated, separate pre-manufacturing waste, is concentrated in specific regions across the country. Notably, the western states of Gujarat and Maharashtra exhibit a robust recycling infrastructure, along with efficient transport networks and grid connectivity.[28] These states play a pivotal role in processing both pre- and post-consumer plastic waste, even from distant regions in southern and eastern India. However, the costs associated with transporting plastic waste over extended distances pose a significant challenge, particularly in regions with inadequate infrastructure and road connectivity, such as in North East India.

Despite the presence of recycling facilities in certain locations, the utilisation of their capacity remains sub-optimal, ranging from 50 percent to 60 percent, primarily due to the scarcity of accessible uncontaminated and well-segregated waste.[29] Moreover, the capacity is further underutilised owing to a ban on the importation of plastic waste. Previously, recyclers were able to import uncontaminated polymer waste, which enabled them to operate at full capacity while also treating domestic post-consumer plastic waste. However, with the imposition of the ban, recyclers are grappling with a shortage of clean waste supply, as a significant portion of domestically sourced post-consumer plastic waste is contaminated, rendering it less amenable to recycling processes.

Apart from practices of reusing and recycling, alternatives—such as harnessing energy through co-processing, waste-to-energy facilities, as well as repurposing plastic waste such as by incorporating plastics into road construction or lumber production—represent additional avenues that characterise the final phase of plastic waste management. Nevertheless, the limited segregation of waste, inadequate investments, the absence of viable business models, and constraints related to financial and human resources experienced by Urban Local Bodies (ULBs) have hindered the widespread adoption of these alternatives. Consequently, these initiatives often operate on a smaller scale or as pilot projects, occasionally in collaboration with the private sector.

2.3. Regulatory Frameworks

India has adopted a multifaceted approach to tackle plastic pollution through various regulatory frameworks and initiatives (see Appendix 2 and 3). The Plastic Waste Management Amendment Rules, 2021, form the backbone of India's strategy to combat pollution caused by SUPs. These rules focus on prohibiting certain SUP items that have low utility and high littering potential, such as plastic cutlery, earbuds with plastic sticks, plastic flags, candy sticks, ice cream sticks, and decorative thermocol. The ban on these items took effect on 1 July 2022 as part of India's larger commitment to environmental sustainability—a pledge highlighted during the fourth United Nations Environment Assembly in 2019. In a significant move to reduce plastic waste, the thickness of plastic carry bags was increased from 50 microns to 75 microns as of 30 September 2021 and is set to reach 120 microns by 31 December 2022.[30] This measure aims to curb the littering of lightweight plastic bags and encourage their reuse.

Central to India's regulatory approach is the concept of Extended Producer Responsibility (EPR), which requires producers, importers, and brand owners to take charge of the post-consumer stage of their products' lifecycles. Under the EPR framework, these stakeholders are responsible for collecting and processing waste in an environmentally sustainable manner.[31] The amended rules have delineated specific recycling, use of recycle content and reuse targets that are to be achieved in the forthcoming years, further emphasising the accountability of plastic producers, importers, and brand owners. CPCB has been instrumental in this regulatory regime, tasked with overseeing the registration and compliance of producers, importers, and brand owners through an online portal. The portal facilitates the submission of annual reports on plastic packaging waste management, ensuring transparency and accountability in the process.

The Indian government has also focused on improving the working conditions of informal waste workers and integrating their operations into the formal waste management framework. The Swachh Bharat Mission has been a key initiative in this regard, aimed at strengthening waste management infrastructure across states and union territories.[32] Public awareness campaigns have been another cornerstone of India's strategy, with efforts to educate the populace about the adverse effects of SUPs and the importance of recycling and waste segregation.

Despite these efforts, challenges persist. The plastic ban focuses on a limited range of products and excludes several items produced by FMCG companies that are major contributors to plastic waste. The successful implementation of these regulations and the transition away from SUPs requires a collaborative effort involving the government, corporations, and individuals. With a focus on reducing consumption, improving recycling, and fostering innovation, India is striving to address the immense challenge of plastic pollution.

2.4. Circularity in Plastic Management

In India and globally, numerous effective practices promoting circularity in the plastics sector offer the potential for replication and scaling up. Enhanced innovation, partnerships, and collaboration are essential to unlock mitigation opportunities and derive sustainable development benefits through circular business models. Creating awareness among stakeholders is crucial for the successful replication of best practices, as limited customer knowledge of circular opportunities can hinder scaling up efforts. Awareness generation fosters co-creation with individuals, customers, and suppliers and stimulates the demand for more sustainable plastics and alternatives throughout the value chain.

Circular economy models are designed to maximise the longevity of goods, thereby minimising waste and preventing the leakage of plastics into the natural environment, in alignment with India's commitment to sustainable development. Current practices in plastic production, usage, and disposal often neglect the economic benefits of a circular approach and result in significant environmental harm, with nearly all plastic originating from fossil fuels and emitting greenhouse gases. The circularity roadmap for plastics aims to decouple plastic production from virgin fossil feedstock, promote recycling and reuse, and reduce the impact of plastic litter. The roadmap outlines three key objectives, including adopting sustainable material solutions, increasing the supply of high-quality recycled plastics, and encouraging alternative uses of plastic waste. Implementing a resource-efficient circular economy for plastics involves minimising wasteful use, sourcing plastics from renewable materials, utilising renewable energy, and ensuring that plastics are reused and recycled within the economy without environmental leakage.[33]

Public-private cooperation has become instrumental in achieving circularity goals. Corporations have recognised the need to ensure sustainability, not only to facilitate long-run profitability of businesses but as part of their social responsibility. Commerce cannot flourish in the absence of societal well-being—necessitating the adoption of circularity frameworks by private enterprises. The practices implemented by corporate entities go beyond the integration of circularity methods in their business framework. It also involves practices that raise awareness among consumers about the life-cycle of products and their social costs. Partnership initiatives, such as those between Bisleri International and municipal corporations to educate people about sustainable practices in plastic waste management and enabling responsible disposal and recycling of post-consumer plastic encourage circular economy. Similarly, Aarohana Social collaborates with rural workers to promote recycling and upcycling of plastics into finished goods.

Plastics have substantial demand-side potential, with various applications spanning different categories and end-use sectors (see Appendix D).[34] For example, packaging is divided into rigid and flexible packaging, with flexible packaging dominating the key end uses and projected for significant future growth. The advantages of flexible packaging, such as ease in handling, disposal, and transportation cost advantages, contribute to its prominence in the market. On the supply side, the plastic feedstock process, while essential for production, generates emissions and poses challenges for recycling efforts due to the predominant non-biodegradable nature of resulting plastics. However, advancements include the development of biodegradable fossil fuel-based polymers like polybutyrate adipate terephthalate (PBAT), polybutylene succinate (PBS), polycaprolactone (PCL), and polyvinyl alcohol (PVA), which can be broken down by microorganisms in the presence of light, oxygen, and moisture.[35]

Bio-based plastics offer an alternative by using non-fossil-fuel feedstock, which is typically derived from organic materials like plant fibres (flax, jute, hemp), wood (reclaimed wood fibres and agricultural waste), and starches. Similar to fossil fuel-based plastics, they exhibit various grades and properties, often closely resembling conventional plastic products. Distinguishing between bio-based and conventional plastics may require scientific analysis, especially when the plastics contain both renewable and fossil-fuel-based carbon, making them partially bio-based. The degradation of these polymers varies significantly based on the volume of bio-based constituents and the specific conditions in which they biodegrade.[36]

There are three circularity scenarios for India's plastics sector, which assess the impact of resource efficiency and circular economy (RE&CE) measures, considering both the demand and supply sides (see Appendix E).[37] The business-as-usual scenario foresees standard economic growth with a fixed increase in plastic consumption and waste generation, limited circular innovations, and no explicit upstream circular efforts. The moderate RE&CE scenario envisions a moderate reduction in virgin plastic demand through improved plastic waste management, compliance with legislation, and initiatives such as banning single-use plastics. The high ambition RE&CE scenario anticipates a significant reduction in virgin plastic demand driven by comprehensive circular actions, increased recycling, extended producer responsibility, government initiatives for affordable alternatives, and strengthened legislative enforcement, particularly targeting SUPs and challenging packaging types.

Finally, in order to advance the circular economy for plastics in India, comprehensive policy measures are essential, which encompass fiscal tools, regulatory frameworks, and innovative financing. Proposed fiscal actions include differentiated taxes on virgin and recycled plastics, penalties for difficult-to-recycle products, and corporate tax credits for recycling infrastructure. A regulatory push involves setting recycled content targets and implementing standards. Innovative financing options, such as venture capital funds and green bonds, can catalyse circular supply chains. EPR needs effective implementation, focusing on awareness, infrastructure, and integrating the informal sector. Investments are crucial for recycling infrastructure, technology, and modernising the informal sector. Technology-related advancements like chemical recycling and digital waste management tools are also pivotal. Support mechanisms, including grants and low-interest loans, can empower SMEs, ensuring a holistic approach to promote circularity in India's plastics sector.

2.5. Aligning Corporate Responsibility and Social Needs: A Case Study

As environmental concerns are escalating, the alignment of corporate responsibility with sustainability needs has become not just a moral imperative but a business necessity. The increasing awareness of environmental issues, such as climate change, resource depletion, and waste management, has led to a growing demand from consumers, investors, and governments for companies to adopt sustainable practices. This shift is driving corporations to reevaluate their strategies and operations, ensuring they contribute positively to the planet while still achieving their business goals.

The concept of corporate responsibility in the context of sustainability extends beyond mere compliance with environmental regulations. It involves a proactive approach to minimising environmental impact, fostering community development, and ensuring economic viability for the long term. This approach is rooted in the understanding that businesses are an integral part of society and the environment they operate in, and their long-term success is intertwined with the well-being of these elements.

A key aspect of aligning corporate responsibility with sustainability is the adoption of the circular economy model. This model emphasises the importance of resource efficiency, waste reduction, and the regeneration of natural systems. It challenges the traditional linear model of 'take-make-dispose' and encourages companies to design products and processes that are sustainable by nature. Moreover, this alignment also involves transparent and ethical business practices, stakeholder engagement, and reporting on sustainability performance. It requires companies to be accountable not just for their financial performance but also for their environmental and social impact.

The case of Bisleri's "Bottles for Change" initiative in India serves as a prime example of how a company can successfully integrate its corporate responsibility with sustainability needs.

BOTTLES FOR CHANGE: A CASE STUDY

Bisleri's "Bottles for Change" initiative serves as an exemplary case study in the context of promoting plastic circularity in India.[38,39] This initiative, launched by Bisleri International, aims to address the burgeoning issue of plastic waste by fostering a circular economy model.

The Initiative

Bisleri International launched "Bottles for Change" in 2018 to educate citizens about the importance of plastic recycling and encourage them to participate actively in waste management. The initiative operates on the principle that plastic is not a problem but a resource that can be used efficiently.

Strategies and Implementation

"Bottles for Change" employs a multifaceted approach:

1. **Awareness and Education:** The program conducts educational workshops and awareness campaigns in schools, colleges, corporate offices, and housing societies to inform people about the importance of recycling and proper waste segregation.
2. **Collection and Recycling:** Bisleri has set up collection centres where individuals can deposit used plastic bottles. These bottles are then sent to NGO partners for recycling. The recycled plastic is used to create a range of products, including clothes, bags, and furniture, thus helping promote a circular economy.

3. **Partnerships and Collaboration:** Bisleri collaborates with NGOs, waste picker communities, and local authorities to streamline the collection and recycling process. This collaboration not only aids in effective recycling but also helps uplift the socio-economic status of waste pickers.

Impact and Results

The “Bottles for Change” initiative has achieved a number of milestones:

- **Environmental Impact:** Millions of plastic bottles have been recycled, reducing landfill waste and environmental pollution. The program has demonstrated the feasibility of a circular approach to plastic use.
- **Social Impact:** By involving communities and providing income opportunities to waste pickers, the initiative has had a positive social impact.
- **Educational Impact:** The awareness campaigns have reached thousands of individuals, creating a shift in mindset towards plastic use and recycling.

This program by Bisleri is a stellar example of how corporate responsibility can align with environmental sustainability. The initiative not only addresses the immediate issue of plastic waste but also educates and involves the community in sustainable practices. It sets a precedent for other corporations in India and globally to adopt and promote circularity in plastic use, making a significant contribution to both environmental conservation and societal well-being.

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III

Analysis of Circularity Benefits

3.1. Current Structure of the Plastics Value Chain

While plastic waste management is a critical issue in the Indian context, plastic production also poses a massive environmental cost. This necessitates interventions in both demand and supply sides to minimise the social cost associated with plastic. Of the plastic produced annually in India, 42 percent remains in use, i.e., has a life cycle greater than one year. The remaining 58 percent is converted into waste, of which 60 percent is recycled,[a] 8.5 percent is converted to energy and the remaining 30 percent or so is mismanaged.

The supply side of the problem is equally concerning for the environmental implications of plastic production. Ninety-nine percent of the feedstock used in the production process is fossil-

[a] According to the CPCB report, only around 48 percent of the waste is recycled. This is as a share of the waste processed and not waste generated.

based. Of the polymer-based inputs, 90 percent is virgin feedstock, and only the remaining 10 percent comes from recycled waste. The circular economy approach can mitigate the production and waste problems simultaneously, reducing the fossil requirement and curtailing emissions while also lowering the amount of plastic waste generated.

A simple model of the plastics value chain is shown in Figure 4. While the existing framework is already circular in structure, an excessive proportion of the value is lost in the form of leakages, rendering this system equivalent to a linear framework. As mentioned, only around 0.1 percent of plastic production uses recycled polymer. There is another missing link in Figure 4: recycled plastic in the form of pellets and granules is directly introduced as raw material in businesses instead of as feedstock for plastic production.

It should be noted that the current framework is also circular but the *degree of circularity* is minimal. In order to enjoy the benefits of a circular framework, and to allow the sustained consumption of

Figure 4: Plastics Value Chain in India

Source: Authors' own

plastic, the degree of circularity needs to be exponentially increased. The current structure of the plastics value chain cannot be categorised as a completely linear framework, since recycling takes place and the products are used as feedstock as well as final products. However, the emphasis on circularity stems from the precariously low degree of circularity that prevails in the Indian economy. It should be noted that 'circularity' here means the proportion of inputs which have been recycled. However, this is a very narrow and strict definition of circularity. This report defined plastic circularity thus:

$$\textit{Circularity} = \frac{\textit{Plastic Waste Recycled}}{\textit{Plastic Waste Generated)}}$$

While this is not the only or most ideal definition, it serves as a reasonable measure for the degree of circularity that is attainable in the sector. Some other crude measures can be, $\frac{Plastic\ waste\ recycled}{Plastic\ waste\ processed}$, or, $\frac{Plastic\ waste\ recycled}{Plastic\ waste\ processed}$. However, our definition serves a broader purpose, by accounting for the overall circularity in the system, instead of only focusing on the systemic characteristics.

We develop a simple framework, based on a 2019 World Wide Fund for Nature (WWF) study,[40] where we account for the production, waste management and pollution costs associated along the different streams of the plastic value chain to estimate the cost of the industry. While the WWF study estimated the social cost of the plastic industry on a global scale, this present one analyses the value addition from adopting a circular framework in the Indian context. First, we estimate the Business-as-Usual (BAU) scenario costs for the period 2025-2030. We consider the costs till 2030 to align the circularity goals with the 2030 SDG Agenda. Second, we recommend a gradually incremental policy where circularity is increased from 50 percent to 100 percent over the six years. We then calculate the reduction in costs due to implementation of this policy and establish the social benefit of circularity estimate in 2023 US Dollar value.

3.2. Methodology

3.2.1. BAU Scenario

A key assumption is made in terms of the demand-supply connect. We assume that markets clear and the entire productive capacity ends up in the market. However, that also implies that the unaccounted-for waste can significantly raise our estimate of the social cost. The details of the methodology are discussed in detail below. The step-by-step calculation of the BAU scenario is shown in Table 2.

Table 2: Business-as-Usual Scenario Cost in India

Cost	Bound (or percentage share)	Value	Unit
Plastic production		18.06	Million mt
Market price of plastic per tonne		1207.663839	US$ (Taking US$ 1 = INR 80)
Market Cost of Plastic		21.8	Billion US$
GHG Cost of plastic production per tonne		4.3	CO_2e
Total cost of plastic production		77.68	Million CO_2e
Social cost of carbon per tonne in India		86	US$
Social cost of carbon in India		6.68	Billion US$
Cost of plastic production in India		**28.49**	**Billion US$**

Plastic waste generated in India	0.228431147	4.12	Million mt
Plastic waste processed as a share of waste generated (BAU)	0.268762008	1.10	Million mt
Plastic waste recycled as a share of waste processed (BAU)	0.486347572	0.539	Million mt
Plastic waste mismanaged	0.731237992	3.01	Million mt
Cost of waste management (per tonne)		212	US$
Total cost of waste management		**235**	**Million US$**
Total cost of waste management	in 2023 US$	305	Million US$
Plastics entering marine stream	3.065497746	126,513	mt
Plastic waste in landfills	(Total plastic waste-recycled-waste in marine stream)	3.46	Million mt
End of life cost of plastic in landfills per tonne	0.53 CO_2e		
Total cost of plastic in landfills		157	Million US$
Cost of plastic in marine dumpsites per tonne	Lower Bound	204.27	US$ thousands
	Upper Bound	408.54	US$ thousands

Total cost of plastic in marine dumpsites	Lower Bound	25.84	Billion US$
	Upper Bound	51.68	Billion US$
Total cost of plastic pollution	**Lower Bound**	**33.80**	**Billion US$**
	Upper Bound	**67.39**	**Billion US$**
Recycling cost per tonne	Lower bound	352	US$
	Upper bound	573	US$
BAU Recycling cost in India	**Lower bound**	**246**	**Million US$**
	Upper bound	**401**	**Million US$**
Total cost of plastic production in India	**Lower bound**	**62.85**	**Billion US$**
	Upper bound	**96.60**	**Billion US$**
Per tonne cost	**Lower bound**	**3478.93**	**US$**
	Upper bound	**5347.05**	**US$**

Source: Authors' own

The estimated plastic production is taken from the PlastIndia, 2023 report,[41] used as a measure for the productive capacity of the plastic industry, estimated at 18.06 million metric tonnes. A single average price cannot be assumed for the entire industry due to the different categories of plastics that are produced. These include the following: Polyethylene terephthalate (PET), High density polyethylene (HDPE), Low density polyethylene (LDPE), Polyvinyl chloride (PVC), Polypropylene (PP), and Polystyrene (PS), among other categories. A weighted average price is calculated based on the proportion of the quality produced in India and its average price. Average prices are collected from different sources, including market reports and company tariff rates.[42,43] This average price was estimated at US$1,208 per metric tonne. Thus, the market price of plastic stood at US$21.8 billion.

The market cost does not capture the entire social cost of production; there are multiple externalities involved in the production process. To simplify the analysis, we consider the social cost of the greenhouse gas (GHG) emissions released during the production process. According to the WWF report, the emissions associated with every tonne of production are estimated at 4.3 tonnes of CO_2e (CO_2 equivalent). This resulted in a total emission amount of 77.6 million CO_2e. To convert the CO_2e into monetary terms, the concept of Social Cost of Carbon is applied, which is the estimated cost of emission of an additional tonne of carbon. The current United States administration's estimate is at US$51 per tonne but this is highly contentious. The U.S. Environmental Protection Agency (EPA) has revised this estimate upwards, nearly four times, at US$190 per tonne. However, we consider the social cost of carbon for India, estimated at US$ 86 per tonne of CO_2e.[44] This amounts to a GHG cost of production process of US$6.6 billion. Summing up the market price and the emission externalities, we find the social cost of plastic production to be US$28.4 billion. This is the estimate of the social cost of plastic associated with its production process.

The second segment of costs is associated with the management and disposal of plastic waste. According to the Central Pollution Control Board of India, around 4.10 million tonnes of plastic waste was generated in the country in 2020-21. We assume the same value for the year 2022-23, which translates to a waste generation rate of around 22 percent. This is later rounded off to 25 percent for the circularity framework calculations. Of the total waste generated, only around 1.1 million tonnes were processed, and 0.55 million tonnes were recycled. This implies a 13 percent circularity in the

Business-as-Usual framework. Of the mismanaged waste, it is found that around 3 percent ends up in marine dumpsites,[45] which is an optimistic estimate.

The remaining 3.46 million tonnes of plastic waste is assumed to end up in landfills. However, the processed waste entails a management cost, which is calculated as the sum of the sorting cost and the urban-rural average of the collection cost for low-middle-income (LMI) countries.[46] This summed up to a total plastic waste management cost of US$305 million.

The mismanaged waste that enters landfills and marine dumpsites also imposes a social cost via pollution, health risks, and worsening of living conditions. This does not imply that managed wastes do not impose any social costs. However, we only consider the pollution costs of the mismanaged waste. As discussed, we assume that the mismanaged waste either enters the marine stream or is dumped in landfills. The lifetime cost of plastic released in the ocean was found to be US$204,270 -US$408,541 per tonne.[47] This implies a massive cost of marine pollution at US$25-51 billion. Meanwhile, the cost of plastics dumped in landfills was found to be 0.53 CO_2e per tonne, causing a loss of around US$157 million. Aggregating the land and marine costs, the total cost of pollution due to mismanaged waste stands at US$33-67 billion. This captures the essence of the pollution costs associated with plastics.

Finally, we look at the recycling cost of plastic in India. The recycling process can be either closed-loop or open-loop. Both processes involve operating expenditure, capital expenditure and chemical conversion costs. While the closed loop process costs US$573 per tonne, the open loop process costs only US$352 per tonne. Thus, the total recycling cost can lie in the range of US$246-401 million. This process closes the value chain of plastics. The total social cost of the industry is found to be around US$62 - 96 billion, for a single year. This also means, for India, a per tonne social cost of US$3,478-5,347.

We now assess the present value cost of the plastic industry for the period 2025-30. The detailed estimates are shown in Table 3. The plastics industry is projected to grow at a CAGR of 6.6 percent.[48] We assume the same rate of growth for the plastic production capacity. Using the estimated per tonne cost of plastic, we find the annual range for each of the six years. We discount the cost for each year at a social discount rate (SDR) of 5.2 percent.[49] It is found that the total estimated social cost will be US$426-655 billion. The median cost is around US$541 billion.

Table 3: BAU Projected Cost of Plastics Industry (2025-30)

Year	Projected Size (in million)	Lower Bound (in US$ billion)	Upper Bound (in US$ billion)	Median Cost (in US$ billion)
2025	21.88	68.79	105.73	87.26
2026	23.32	69.71	107.14	88.42
2027	24.86	70.63	108.57	89.60
2028	26.51	71.57	110.01	90.79
2029	28.26	72.53	111.48	92.00
2030	30.12	73.49	112.96	93.23
Lifetime cost till 2030		**426.75**	**655.91**	**541.33**

Source: Authors' own

3.2.2. Circular Framework

To alleviate the massive social cost of plastics, an incrementally circular framework is suggested. A 50-percent circularity is recommended by 2025, with 10-percent increments in each successive year. This will build up to a 100-percent circular plastic value chain by 2030. The following key assumptions are being made:

1. 25 percent of the produced plastic ends up as waste.
2. The required production in any year is given as the excess of the market size over the previous year's recycled stock.
3. Management activities are scaled up to 100 percent, i.e., all waste generated is managed. Circularity implies the percentage of the waste that is recycled.
4. All recycled plastic is introduced in the market, and reduces production.

Circularity will cause the social cost of production to go down but also increase recycling and management costs. However, it will significantly reduce the pollution costs associated with the entire value chain. Our calculations are conservative, as they do not take into consideration the reduction in management and recycling costs with the upscaling of the formal waste management industry. Table 4 shows the projected costs in this circular framework. The total median cost for the period 2025-30 is found to be US$370 billion.

Table 4: Circular Framework Projected Cost

Year	Circularity Median Cost (in US$ billion)	Discounted Cost in 2023 (in US$ billion)	Degree of Circularity (in %)
2025	68.76	62.13	50
2026	72.53	62.30	60
2027	75.88	61.95	70
2028	79.51	61.71	80
2029	83.33	61.48	90
2030	87.38	61.27	100
Present Value of Social Cost	**370.85**		

Source: Authors' own

Thus, the circularity benefit is found to be US$170 billion.

Circularity Benefit	170478496645.22
(i.e., more than US$170 billion in social costs can be avoided)	

3.3. Interpretation

The present value of the median social cost imposed by the Indian plastic industry for the period 2025-30 is found to be around US$541 billion. Meanwhile, the median present value of the recommended circular framework is estimated at US$370 billion. This means that the present benefit of implementing a completely circular framework by 2030 is at US$170 billion. However, this is a highly ambitious target and would require substantial resources and policy intervention. The present benefit can alternately be interpreted as the “Cost of Inaction”. In other words, this implies that the present cost of not adopting a circular framework is US$170 billion.

Further, the optimistic 2030 plan generates a highly conservative estimate of the present cost. Indeed, every year of inaction generates a net social cost from the industry, which is not accounted for. An alternate framework that suggests implementing complete circularity by 2040 will yield a higher present value of social cost. Thus, this estimate should be interpreted as a lower bound of the social cost that will be created by the plastics industry. Moreover, this study only considers the quantifiable aspects associated with the life cycle of plastics. Future revelations of other costs entangled with the plastic value chain will have a multiplier effect on this estimate.

3.4. Alternate Scenario Analysis

The initial framework looks at the net present benefit of implementing a perfectly circular framework by 2030. However, the assumption about uniformly increasing circularity is not entirely practicable. Although it gives a rational measure of adopting circularity, there is also a need to look at the annual benefits of taking a circular approach. A few of these scenarios are outlined in this section.

First, we consider the implementation of a 50-percent circular framework by 2030. This is a more practicable assumption compared to the previous framework. We maintain the same assumptions applied to the initial calculations. However, here we estimate the net present benefit for only the year

2030. It is found that 50-percent circularity will generate a benefit of around US$38 billion by 2030. Adjusted with the social discount rate, this yields a net present value (NPV) of benefit of US$28.6 billion.

Table 5: Benefit of 50-percent Circularity in 2030 (in US$ billion)

Year	50% Circularity Cost	BAU Cost	Net Benefit	NPV
2030	94.17	132.94	38.77	28.60

Source: Authors' own

This benefit is lower than that generated from a completely circular framework suggested in the previous section. It can be seen that the net value of benefits from 100-percent circularity is more than 17 percent higher than that generated from this 50-percent framework.

Table 6: Benefit of 100-percent Circularity in 2030 (in US$ billion)

Year	100% Circularity Cost	BAU Cost	Net Benefit	NPV
2030	87.38	132.94	45.56	33.61

Source: Authors' own

We also consider an intermediate scenario, where 75-percent circularity is implemented by 2030. The benefits generated are about 6 percent lower than the benefits from 100-percent circularity, and 11 percent greater than from 50 percent circularity.

Table 7: Benefit of 75-percent Circularity in 2030 (in US$ billion)

Year	75% Circularity Cost	BAU Cost	Net Benefit	NPV
2035	89.77	132.94	43.17	31.84

Source: Authors' own

This reiterates the fact that a higher degree of circularity and a more ambitious policy, significantly lowers the social costs of plastic wastes. The optimistic outlook towards a completely circular framework is justified and should be urgently facilitated with necessary stimulus.

3.5. Limitations

This estimate looks at the production, waste management, pollution, and recycling aspects of the plastics value chain. While this includes almost the entire value chain, there are multiple features of the system which are not quantifiable. For instance, the impact on human health due to formal disposal of wastes has not been directly captured in this system. It does factor in the social cost of carbon, but no direct quantitative estimates are available for the damage value. The following are the limitations of the estimate:

i. **Incomplete social cost:** The ecosystem services costs of plastic pollution, the emission costs from uncontrolled plastic waste and its health impacts have not been featured in this system. This is due to the paucity of data and lack of methods to appropriately quantify these costs.
ii. **Short implementation period:** The suggested five-year period of implementation is highly optimistic and also unrealistic for an economy. It will require severe policy intervention and massive capital costs to overhaul the current system of plastic management. Moreover, given the structure of the industry, it will also need public-private partnerships to enhance the social responsibility of the stakeholders involved.

iii. **Certain costs ignored:** Increasing management and recycling will also require modern infrastructure and newer technologies. However, these would require substantial investment, which would lower the benefit of circularity. On the other hand, the increase in scale of management and recycling activities will also reduce the overall cost of operation in the long-run. Thus, in a framework with a longer period of implementation, the costs can be completely ignored. In this framework, management capacity has been assumed to remain constant, while only recycling facilities need to scale up to increase circularity.

iv. **Optimistic yet conservative estimate:** This point needs to be reiterated to stress on the stipulated period of policy implementation. While a shorter period makes the recommendation appear outlandish, it also reduces the present value of the social cost. Thus, it should be noted that the optimism is not only in terms of the efficacy of policy implementation but also the size of the threat posed by plastics. Certain implicit assumptions are made which have only eased the present value of the social cost.

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IV

Policy Recommendations

Currently, only a small proportion of plastics waste is properly recycled in India, with the rest making their way into landfills and marine systems. Our analysis highlights that this improper management of plastics comes with a massive social cost of US$62-96 billion annually. This is in addition to the environmental costs that arise as a result of a production process dependent on fossil fuel.

Improving recycling rates in India by creating a circular economy for plastics is therefore crucial to maximise the benefits of plastics while minimising the costs.

The first step will be to set a strong target at the national and state level to achieve 100-percent plastic recycling. Drawing parallels with successful endeavours in sectors like renewables, biofuels, and electric vehicles, setting an ambitious target can invigorate the entire ecosystem and foster confidence in policy predictability. Our analysis has highlighted that achieving 100-percent recycling is associated with massive economic benefits. This can be an effective starting point to catalyse greater investment and policy action towards achieving such a target. Importantly, aligning with this objective not only stands to bolster economic prospects but also contributes to the fulfilment of the SDGs.

This section underlines a number of crucial policy actions that will be needed to achieve a 100-percent recycling rate in India by 2030.

4.1. Reducing Production of Non-Recyclable Plastics

Recycling cannot be a silver bullet for all forms of plastic waste. Reducing the social cost of plastics and enabling a circular economy will depend upon the ability to reduce demand for plastics that are difficult to recycle, particularly the single-use and non-biodegradable.

a. The ban on single use plastics (SUPs) notified through Plastic Waste Management Amendment Rules, 2021 has been adopted by most states, with variations in the specific items covered by the ban. However, the overall implementation of the ban is widely acknowledged to be lacking. Despite the regulatory measures, single-use plastics continue to be readily available in the market, and their production remains unchecked. The enforcement of the ban faces various challenges, with State Pollution Control Boards grappling with insufficient resources for effective implementation. Adding to the complexity is that the definition of ‘banned plastics’ is based on micron measurements or thickness, making it difficult to accurately identify prohibited products. To address these issues, there is a pressing need to establish a dedicated wing within State Pollution Control Boards equipped with adequate resources and expertise to ensure the effective enforcement of the ban.

   Recognising the potential for citizen involvement as a potent tool in enforcing the ban, the Central Pollution Control Board has introduced an app for citizens to report violations. Utilisation is suboptimal, however, due to low awareness of the app and a cumbersome registration process. To enhance the effectiveness of this citizen-centric approach, a comprehensive awareness campaign is essential. This campaign should not only raise awareness of the ban itself but also educate citizens about the available tools that empower them to actively contribute to its enforcement.

b. Beyond the enforcement at the usage stage, the ban on SUP will only be successful if the production of SUPs is replaced by alternatives with similar characteristics and at similar price points. Presently, a significant portion of SUPs is manufactured by Micro, Small, and Medium Enterprises (MSMEs) within the unorganised sector, lacking sufficient motivation to shift to alternative plastics. Addressing this challenge necessitates targeted capacity-building workshops tailored for MSMEs, aimed at identifying viable alternatives within their production capabilities. This identification process must be complemented by the provision of financial and technological support, facilitating a smooth transition towards newer modes of production.

4.2. Improving Segregation and Collection

An impediment to a circular economy is the lack of segregation at the point of use and inefficiencies in the collection process. This is a difficult issue to resolve since it is largely dependent on individual behaviours; the decentralised collection process is also complicated and often informal, with multiple nodes that need to be coordinated.

a. There is a need for monetary incentives for waste generators to segregate waste, which could take either of two forms. First could be a direct fee on waste generation proportionate to the amount of waste generated. This fee could be adjusted based on the amount of waste segregated. This will incentivise greater segregation as well as treatment of waste at source. This might be a more effective mechanism compared to the flat users' fees that are collected by many ULBs for waste management services. However, implementing such a tax will depend to a large extent on the ULBs' capacity. Pilot projects targeted at certain ULBs which have already had some success with waste disposal initiatives could be a useful starting point. The second strategy could be to provide incentives or penalties for landfill operators based on the amount of waste segregation at the landfill, thereby increasing upstream measures to improve collection of only segregated waste.

b. The waste collection ecosystem is largely informal, comprising many unregistered collection units. There is a need to create a program to formalise the complete collection ecosystem by registering all units and creating a database of workers involved in this part of the system. This will be essential to track the implementation of Solid Waste Management Rules notified through different legislations which at present are routinely flouted.

c. The capacity of ULBs for data collection needs to be improved, in particular through the adoption of ICT tools for data reporting. This will be essential to understand the current state of play related to waste segregation and identify areas where targeted interventions may be needed to improve waste segregation and collection.

4.3. Improving Recycling Infrastructure

The recycling infrastructure in India is not only inadequate but also concentrated in urban centres. This remains one of the key impediments to achieving a circular plastics economy. Additionally, majority of the waste is today recycled by the informal sector. This is particularly a big challenge for business who often have to pay high transport costs to send materials to distant areas for recycling. There is an urgent need to improve investment in recycling infrastructure in India:

a. Clear economic incentives should be put in place for industries to develop recycling infrastructure for plastics. This can take the form of graded subsidy for investments in recycling infrastructure and upcycling. The subsidy can be graded based on the level of investment: i.e., a higher subsidy would be provided for higher levels of investment. If a subsidy is not feasible, businesses can be incentivised through tax breaks based on the level of investment in recycling infrastructure.

b. To reduce the transport costs associated with recycling, waste recycling hubs can be created near areas with high levels of waste generation. This will aid in nurturing a hub-and-spoke model to improve the efficiency of waste processing.

c. There is a need to improve investment in innovation in end-of-life solutions for plastics. This will require an ecosystem that promotes entrepreneurship and innovation related to plastic recycling. Central and State Governments can provide grants for research in promising technologies and set up platforms that can help companies take promising technologies to market.

Implementing a comprehensive and multifaceted approach that combines these policy measures can contribute to improving plastic recycling in India. Crucially, implementing these measures will require effective collaboration among the government, private sector, communities, and non-government organisations.


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V
Conclusion

This report examined the environmental impact of plastic use, emphasising the rise in demand due to benefits like durability and flexibility. This, however, is characterised by unsustainable production and waste mismanagement, leading to hazards to the environment and health. The report recommends a shift to a circular economy for plastics, advocating for ambitious recycling goals and multi-sector collaboration. Key recommendations include reducing non-recyclable plastics and enhancing recycling infrastructure.

The report also discussed the integration of plastic pollution concerns into the SDGs. Initially, the focus was on oceanic plastic debris, highlighted by the 2011 Honolulu Commitment. Recognising its broader impact, actions were framed within SDG 14 (Life Below Water), further emphasised by the 2017 UN resolution targeting ocean pollution and single-use plastics. The need for a holistic approach is emphasised, integrating SDGs related to health, responsible consumption, climate action, and life on land, reflecting the massive implications of plastic pollution.

The circular economy model is proposed as a solution to decouple economic growth from waste generation. There is a need for proper segregation to maintain recyclability and address the challenges of low-value, single-use plastics. Comprehensive waste management strategies must be created that will include recycling, reduction in use, and development of biodegradable materials. Addressing rural plastic waste management is also vital, given the absence of effective collection and disposal mechanisms.

The efforts will need to engage the informal sector in India’s plastic waste recycling, which will need to be mustered despite the limited support from municipalities. After all, the informal sector contributes to the recycling process but operates under challenging conditions like low wages and lack of safety measures. The current system sees recyclables moving through various informal channels, often lacking transparency and efficiency. To improve plastic pollution control and workers’ well-being, there is a need for better integration of this sector into formal waste management systems, as exemplified by initiatives like the registration of waste-pickers in Bengaluru.

At present, recycling in India is often manual or mechanical, producing lower-quality materials that are mixed with virgin substances. The lack of advanced technology and standardised procedures leads to material losses. Regions like Gujarat and Maharashtra have robust recycling facilities, but the high transportation costs and insufficient supply of clean, segregated waste hinder efficiency. The ban on plastic waste importation exacerbates these challenges. Alternatives like energy harnessing and repurposing in road construction are constrained by factors such as inadequate waste segregation and lack of investment.

India’s strategy to mitigate plastic pollution incorporates regulatory frameworks and initiatives. The Plastic Waste Management Act Rules, 2021, ban certain single-use plastics and increase the thickness of plastic carry bags to reduce littering. Extended Producer Responsibility (EPR) is central, mandating stakeholders to manage post-consumer waste. Efforts include improving conditions for informal waste workers and public awareness campaigns. However, challenges remain, such as the limited range of banned products and the need for collaborative efforts to effectively transition away from single-use plastics and tackle plastic waste.

The primary value of this present study is in how it quantified the social cost of the plastics value chain in India. The study not only looked at the annual costs, but also used a discount factor to compute the estimated present social cost of inaction for the period 2025-30. The inaction scenario represents the Business-as-Usual methods currently followed in the Indian market. To estimate the present benefit of circularity, an incrementally circular framework is recommended, where 100-percent circularity is attained by 2030. Although optimistic, the derived estimate is a conservative figure as it considers a shorter period of inaction. Increasing the period of implementation will only raise the aggregate net present value of the cost of inaction. Given the period 2025-30, the present benefit of implementing complete circularity (as defined in the report), is found to be around US$170 billion. Circularity will also entail other benefits in terms of employment in the informal sector and better environmental quality.

India’s approach to tackling plastic pollution involves enhancing recycling rates and fostering a circular economy, which is crucial to balancing the benefits and costs of plastics. The country’s strategy should include setting ambitious targets for 100-percent plastic recycling, similar to successful initiatives in renewable energy and electric vehicles. Key policy actions focus on reducing non-recyclable plastics, improving waste segregation and collection, and investing in recycling infrastructure. Implementing these measures, which require collaboration across government, private sector, and communities, aims to address the environmental and social costs associated with plastic waste.


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Appendices

Appendix 1: Exports of Plastic Waste, by Country

Country	Region	Exports of Plastic Waste (kg/capita)	Year
Latin America and the Caribbean (LAC), East and Southeast Asia, Sub-Saharan Africa			
Uruguay	LAC	0.27	2021
Thailand	East & South Asia	2.43	2021
Brazil	LAC	0.02	2021
Argentina	LAC	0.07	2017
Vietnam	East & South Asia	1.27	2021
Bhutan	East & South Asia	1.66	2012
Dominican Republic	LAC	1.25	2021
China	East & South Asia	0.02	2021
Singapore	East & South Asia	5.66	2021
Peru	LAC	0.02	2021
Maldives	East & South Asia	0.57	2021
El Salvador	LAC	1.44	2021
Ecuador	LAC	0.40	2021

Indonesia	East & South Asia	0.33	2021
Malaysia	East & South Asia	1.47	2021
Jamaica	LAC	2.80	2021
Sri Lanka	East & South Asia	0.03	2021
Barbados	LAC	4.15	2021
Bolivia	LAC	0.11	2021
Paraguay	LAC	0.18	2021
Suriname	LAC	1.19	2021
Mauritius	Sub-Saharan Africa	1.29	2021
Guyana	LAC	0.00	2020
Panama	LAC	1.12	2021
Philippines	East & South Asia	0.80	2021
Nepal	East & South Asia	0.02	2020
Bangladesh	East & South Asia	0.23	2015
Brunei Darussalam	East & South Asia	0.60	2021
Cambodia	East & South Asia	0.44	2021
Nicaragua	LAC	1.68	2021
Mongolia	East & South Asia	0.69	2019
Belize	LAC	1.52	2021
Namibia	Sub-Saharan Africa	0.39	2020
South Africa	Sub-Saharan Africa	0.13	2021

India	East & South Asia	0.00	2021
Trinidad and Tobago	LAC	0.73	2021
Lao PDR	East & South Asia	0.27	2021
Honduras	LAC	0.44	2021
Venezuela, RB	LAC	0.20	2013
Botswana	Sub-Saharan Africa	0.18	2021
Sao Tome and Principe	Sub-Saharan Africa	0.00	2018
Cote d'Ivoire	Sub-Saharan Africa	0.03	2020
Senegal	Sub-Saharan Africa	0.19	2021
Ghana	Sub-Saharan Africa	0.01	2019
Kenya	Sub-Saharan Africa	0.12	2021
Bahamas, The	LAC	0.28	2019
Myanmar	East & South Asia	0.25	2021
Rwanda	Sub-Saharan Africa	0.07	2021
Guatemala	LAC	0.58	2021
Pakistan	East & South Asia	0.06	2021
Gambia, The	Sub-Saharan Africa	0.00	2013
Mali	Sub-Saharan Africa	0.10	2019
Eswatini	Sub-Saharan Africa	0.71	2021
Mauritania	Sub-Saharan Africa	0.64	2021
Tanzania	Sub-Saharan Africa	0.24	2021

Malawi	Sub-Saharan Africa	0.01	2020
Togo	Sub-Saharan Africa	0.02	2021
Sierra Leone	Sub-Saharan Africa	0.00	2017
Zimbabwe	Sub-Saharan Africa	0.09	2021
Cameroon	Sub-Saharan Africa	0.02	2018
Benin	Sub-Saharan Africa	0.01	2021
Uganda	Sub-Saharan Africa	0.11	2020
Guinea	Sub-Saharan Africa	0.00	2013
Lesotho	Sub-Saharan Africa	0.01	2021
Ethiopia	Sub-Saharan Africa	0.04	2021
Zambia	Sub-Saharan Africa	0.10	2021
Nigeria	Sub-Saharan Africa	0.12	2021
Burundi	Sub-Saharan Africa	0.01	2021
Mozambique	Sub-Saharan Africa	0.03	2021
Congo, Rep.	Sub-Saharan Africa	0.02	2021
Burkina Faso	Sub-Saharan Africa	0.06	2021
Angola	Sub-Saharan Africa	0.00	2021
Madagascar	Sub-Saharan Africa	0.00	2021
Congo, Dem. Rep.	Sub-Saharan Africa	0.00	2020
Sudan	Sub-Saharan Africa	0.29	2018
Niger	Sub-Saharan Africa	0.00	2021

Central African Republic	Sub-Saharan Africa	0.02	2019
Antigua and Barbuda	LAC	0.30	2018
Grenada	LAC	0.27	2021
St. Lucia	LAC	0.19	2020
St. Vincent and the Grenadines	LAC	1.98	2021
Middle East and North Africa (MENA), Organisation for Economic Co-Operation and Development (OECD), Eastern Europe and Central Asia, Oceania			
Finland	OECD	3.71	2021
Sweden	OECD	9.54	2021
Denmark	OECD	5.89	2021
Germany	OECD	10.02	2021
Austria	OECD	19.70	2021
France	OECD	6.08	2021
Norway	OECD	12.22	2021
Czechia	OECD	7.76	2021
Poland	OECD	3.37	2021
Estonia	OECD	11.67	2021
United Kingdom	OECD	3.92	2021
Croatia	E. Europe & C. Asia	6.66	2021
Slovenia	OECD	63.72	2021
Latvia	OECD	7.64	2021

Switzerland	OECD	2.10	2021
Spain	OECD	2.33	2021
Ireland	OECD	2.02	2021
Portugal	OECD	5.30	2021
Belgium	OECD	28.69	2021
Netherlands	OECD	24.55	2021
Japan	OECD	7.65	2021
Hungary	OECD	0.00	2021
Slovak Republic	OECD	4.45	2021
Italy	OECD	2.12	2021
Moldova	E. Europe & C. Asia	0.10	2021
Canada	OECD	4.30	2021
New Zealand	OECD	5.37	2021
Greece	OECD	5.17	2021
Iceland	OECD	19.28	2021
Chile	OECD	0.58	2021
Korea, Rep.	OECD	1.51	2021
Luxembourg	OECD	18.10	2021
Belarus	E. Europe & C. Asia	1.43	2021
Romania	E. Europe & C. Asia	1.04	2021
Serbia	E. Europe & C. Asia	0.90	2021

Lithuania	OECD	12.09	2021
Ukraine	E. Europe & C. Asia	0.04	2021
United States	OECD	0.37	2021
Australia	OECD	3.10	2021
Malta	E. Europe & C. Asia	5.50	2021
Georgia	E. Europe & C. Asia	0.30	2021
Bulgaria	E. Europe & C. Asia	1.91	2021
Kyrgyz Republic	E. Europe & C. Asia	0.24	2021
Bosnia and Herzegovina	E. Europe & C. Asia	1.81	2021
Israel	OECD	2.10	2021
Russian Federation	E. Europe & C. Asia	0.17	2021
Costa Rica	OECD	2.27	2021
Azerbaijan	E. Europe & C. Asia	0.04	2021
Albania	E. Europe & C. Asia	0.86	2016
Armenia	E. Europe & C. Asia	0.02	2021
Fiji	Oceania	0.85	2021
Tunisia	MENA	2.34	2021
Cyprus	E. Europe & C. Asia	8.14	2021
North Macedonia	E. Europe & C. Asia	2.46	2021
Kazakhstan	E. Europe & C. Asia	0.33	2020
Montenegro	E. Europe & C. Asia	0.80	2021

Uzbekistan	E. Europe & C. Asia	0.00	2021
Morocco	MENA	0.13	2021
Algeria	MENA	0.04	2017
Türkiye	OECD	0.17	2021
Colombia	OECD	0.08	2021
Jordan	MENA	0.08	2021
United Arab Emirates	MENA	1.05	2021
Mexico	OECD	0.00	2021
Egypt, Arab Rep.	MENA	0.01	2021
Tajikistan	E. Europe & C. Asia	0.31	2021
Iran, Islamic Rep.	MENA	0.16	2018
Oman	MENA	0.46	2021
Saudi Arabia	MENA	1.23	2021
Lebanon	MENA	1.32	2021
Qatar	MENA	0.00	2021
Iraq	MENA	0.24	2016
Kuwait	MENA	1.95	2020
Bahrain	MENA	0.65	2020
Papua New Guinea	Oceania	0.00	2012
Afghanistan	E. Europe & C. Asia	0.00	2019
Yemen, Rep.	MENA	0.02	2018

Andorra	E. Europe & C. Asia	15.62	2021
Kiribati	Oceania	0.02	2017
Libya	MENA	0.56	2019
Palau	Oceania	5.87	2018
Solomon Islands	Oceania	0.00	2013
Samoa	Oceania	0.00	2019

Source: Sustainable Development Report 2023, SDSN & Dublin University Press[50]

Appendix 2: Plastics Circularity Implications of Regulatory Frameworks in India

Policy	Year	Government Ministry/ Department	Description
Upstream			
Plastics and recycled plastics manufacture, sale, and usage rules	1999, 2002, 2003	MoEFCC	Rules have laid down provisions for the manufacturing, usage, EoL management, criteria for manufacturing plastic carry bags and containers. Amendments (2002; 2003) provide specifications for virgin and recycled plastic manufacturing, extend definition of vendor, and mandate registration and authorisation for manufacturers, production, sale, or trade for plastic packaging
Policy resolution for promotion of petroleum, chemicals, and petrochemical investment regions (PCPIRs)	2007	MoC&F	Provision for specifically delineated investment regions for the manufacturing facilities for domestic- and export-led production in petroleum, chemicals and petrochemicals, along with associated services and infrastructure
Midstream			
National Design Policy	2007	MoCI	It focuses on 'Design in India' and to enhance the competitiveness of Indian industry

Hazardous and Other Waste (Management, Handling and Transboundary Movement) Rules	2008, 2016	MoEFCC	It has laid down responsibility for handling and storage of hazardous waste. It also deals with the import, export of hazardous waste for recycling, recovery, and reuse. It defines processes generating hazardous waste including plastic production, and where such processes are prohibited. The new (2016) rules banned the import of solid plastic waste, including PET bottles. It also distinguishes hazardous waste from others and recognises waste as a resource for recycling and reuse supplementing industrial processes.
Food Safety and Standards Regulations	2011	MoHFW	It lays down general requirements for packaging and labelling
Notice for withdrawal of producer responsibility organisations	2019	CPCB	Discontinued recognition of PROs with CPCB, and the producers and other stakeholders can plan their EPR implementation as per requirement of PWM Rules, 2018
Downstream			
Guidelines for recycling of plastics	1998	BIS	Describes types of wastes, classification of recycling, and steps involved in the recycling process

Bio-medical waste Rules	1998, 2016	MoEFCC	Earliest policy that addresses the treatment of plastic waste in biomedical area. Focuses on recycling of plastics, sharps and glass to authorised recyclers. Provides colour coding and the type of container for disposal of biomedical wastes containing plastic bags
Municipal Solid Wastes (Management and Handling) Rules, 2000	2000	MoEFCC	Declared responsibilities of authorities on national, state, and municipal levels
	2016	MoEFCC	New rules have mandated source segregation of waste and event organisers, RWAs, market associations, gated communities, institutions, and SEZ have been assigned the responsibility
Plastic Waste Management (Amendment) Rules	2011	MoEFCC	Rules put ban on use of plastic materials in sachets for storing, packing, or selling gutkha, tobacco and pan masala
	2016, 2018	MoEFCC	Requires producers/brand owners who introduce plastic carry bags, multi-layered plastic sachets, pouches, and packaging into the marketplace to submit an EPR plan. The amended (2018) rules state that only those multi-layered plastics (MLPs) will

Guidelines for disposal of thermoset plastic waste including: Sheet Moulding Compound (SMC)/ Fibre Reinforced Plastic (FRP)	2016	CPCB	According to these guidelines, the most preferred option is minimisation of use of SMC/ FRP/ polycarbonate polymer products and promote the use of alternate material which are easily recyclable/reusable/ degradable
Guidelines for the disposal of non-recyclable fraction (multi-layered) plastic waste	2018	CPCB	Guidelines provide the source of non-recyclable plastic waste and management of non-recyclable plastic waste
Guidelines for co-processing of plastic waste in cement kilns	2016	CPCB	Guidelines provide the protocol to be followed by different stakeholders and description of co-processing plastic waste in cement kilns
Environment Protection Act (control of non- biodegradable garbage)	2016	MoEFCC	Prevent throwing or depositing non-biodegradable garbage in public drains, roads, and places open to public view and protect the environment from being polluted by such garbage and for matters connected therewith or incidental there to
Consolidated guidelines for segregation, collection, and disposal of plastic waste	2017	CPCB	Guidelines provide roles and responsibilities of different stakeholders in efficient plastic waste management and technologies for disposal of plastic wastes

Prohibition of import of PET flakes	2019	MoEFCC	GOI prohibits the import of PET bottle waste/ scraps PET flakes made from used PET bottles, etc.
Guideline Document: Uniform Framework for Extended Producers Responsibility (Under Plastic Waste Management Rules, 2016)	2020	MoEFCC	Mandate manufacturers to take responsibilities over materials used in their products beyond the sale-phase

Source: The Energy and Resources Institute

Appendix 3: Examples of Circular Economy Practices in India for Plastics

Best Practice	Location	Plastic Waste Value Chain: Stakeholders	Waste Management Hierarchy	Description
Taj hotels	India	Downstream; Bulk Consumers	Reduce	Zero SUP hotel in the Andamans and have pledged to phase out SUP and eliminate 20 lakh plastic straws in 2019
ITC hotels	India	Downstream; Bulk Consumers	Reduce	Pledge to discontinue SUP in all its hotels since December 2019 including replacing plastic straws with paper or bamboo ones, and replacing plastic drinking bottles with water in glass bottles. Some hotels have also replaced the miniature personal care bottles with permanent dispensers

Hindustan Unilever	India	Downstream; Industry partners, brand manufacturers, recyclers	Reduce/ Recycle	Total waste generated from their factories in 2019 has reduced by 63%. All their factories are also equipped with pre-processing facilities such as waste segregation and waste reduction at source, thus improving recyclability. In 2019, they disposed of more than 39,000MTPA of plastic waste in environment-friendly ways in India
Bizongo	India	Midstream; Brand manufacturers	Reduce and Reuse	Packaging solutions: Elimination of SUP by pushing for alternatives already available, by 2021. They are trying to cut down the cost of alternate material while also promoting by better adaptation and trying to use reusable materials
Zomato	India	Downstream; Bulk Consumer	Reduce	Order without cutlery
Swiggy	India	Midstream; Bulk Consumer	Reduce	Sustainable packaging

Amazon	India	Downstream; Bulk Consumer	Reduce	Packaging material contains less than 7% SUP and aim for elimination of SUP packaging by June 2020
Flipkart	India	Downstream; Bulk Consumer	Reduce	Reduced the 25% of SUP in 2018; has set deadline of 2021 to make all its packaging recyclable
Walmart	India	Downstream; Bulk Consumer	Reduce	Pledged to phase out SUP shrink wrap from our company's stores across India by the first quarter of 2019
Dabbawalla	Mumbai, MH	Downstream; Waste generators, Bombay Tiffin Box Suppliers Association	Reduce	Deliverymen distributing lunch to 200,000 people throughout the city using washable, durable, and reusable containers that are not made of plastic

Cupable Model	Mumbai, MH; Bangalore, KA; Hyderabad, TE; Chennai, TN; Delhi; Pune, MH	Downstream; Waste generators, collectors	Reuse	Cupable has established a reverse supply chain by partnering with restaurants/ event organisers to install drop off bins that allow only their cups to be dropped-off as no other container fits inside. The model focuses on events with large volume of customers so there is potential for scaling and financial flexibility. Waste generators pay directly and are reimbursed part of their deposit back after returning the cup and are also incentivised through discounts on their drinks for using the same cup
Goa Waste Management Model (GWMC)	Goa	Downstream; ULB, waste generators, collectors, recyclers, treatment providers	Recycle/ Co-processing/ WtE	The GWMC set up by the state government has an integrated solid waste management facility that recycles plastics and dry waste at its MRF and sends its non-recyclable plastics for co-processing to Karnataka whereby the ULB bears the heavy cost of collection and transport to co-processing facility. Through its activities over four years - recycling, substituting coal with RDF, and managing its biodegradable waste the plant has reduced about 35,48243,330tCO2-eq. emissions

Bisleri	Pan India 20 Cities	Awareness program, Waste collectors, NGO self-help groups, ULBs, RWAs, Educational Institutes, Corporates, Hotel & Restaurants partnerships	Reduce, Reuse and Recycle	Municipal Corporations of Delhi, Mumbai, Chennai, Bangalore, Hyderabad, Ahmedabad, Chandigarh partnership with Bisleri International for creating public awareness on responsible use of plastic, educating them of the correct disposal methods, and collection used plastic to send directly for recycling. This ensures ZERO plastic waste to landfill. Further, Bisleri & PSG College, Coimbatore created a new Guinness World Record for Collection of most plastic bottles for recycling in 12 hours. They collected 79,738 kgs of used plastic bottles and sent them for recycling. By recycling, this helped in reducing 1.36 lakhs of CO_2 emission, 0.46 gigawatt energy, 70,820 cubic feet of landfill and 2.02 lakh litres of oil.

Reliance Plastic road	Raigad, MH	Downstream; National Highway Authority, State governments, ULBs, Waste collectors	Repurposing	As a pilot, RIL has used about 50 MT of plastic waste at its Nagothane Manufacturing Division for construction of 40 km of road by starting its own its own and also outsourcing garbage collection and segregation which enables the collection of sufficient plastic to be shredded to prepare a mixture at its sites
Plastic Scrap Trading	West Delhi (Tikri-Kalan)	Downstream; ULB, waste generators, plastic traders	Recycle/ Co-processing	Plastic waste trading 1.4 km2 area in Delhi, where around 1875 TPD plastic scraps are flowing, 1818 TPD for recycling and 57 TPD to brick-kilns. This is done mainly on an informal scale including backyard mechanical recycling with no integration of informal sector and little to no health & safety measures. Such plastic trading and recycling clusters need to be upgraded and informal sector needs to be integrated for more efficient, leakage proof trading and recycling

Aarohana Ecosocial	Pune, MH and Dadra and Nagar Haveli	Downstream; Industry Partners	Upcycle	Promotes hand weaving of plastic waste into upcycled bags, fabric, and home decor. They are providing employment opportunities to women in remote villages that lack alternative sources of income. Since its inception, Aarohana has salvaged over 776,500 plastic bags, sold about 10,000 bags, and made sales of INR 14 lakhs in their first year. However, their biggest hurdle is lack of segregation as contaminated post-consumer plastic waste cannot be upcycled

Source: Authors' own, using open sources[52,53]

Appendix 4: Plastics Circularity in Key Sectors

Packaging		
Circularity Aspect	**Existing Practices/Scope (International and Indian context)**	**Opportunities**
Use of recycled plastics	» Commitment by large companies (both Indian and MNCs) will move to 100% recyclable plastic packaging by 2025 » Cargill Oils India, in association with Dow Chemical, reformulated its plastic material, making 90% of its plastic packaging recyclable	» Commitment by large companies (both Indian and MNCs) will move to 100% recyclable plastic packaging by 2025 » Cargill Oils India, in association with Dow Chemical, reformulated its plastic material, making 90% of its plastic packaging recyclable
Re-design of packaging	» Lush, handmade cosmetics have a packaging free line » Cargill's oil business in India has redesigned its packaging by cutting down on the amount of raw plastic used across all products » Cremica Food Industries is reducing lamination in packaging	» Avoid use of extra packaging material or create packaging free line of products » Fewer types of standardised plastics for specific uses in FMCG-reduce plastic waste leakage and improve recycling » Replacing packaging material like shrink wraps with more durable and reusable long lasting alternatives » Stay on tabs for beverages, flip flop caps for FMCG products » Replacing multi-polymer plastic packaging with single polymer plastic packaging » Colour coding and labels for disposing bio-based and/or compostable after use

Re-engineering -packaging design	» Bisleri International has reduced PET and HDPE consumption in packaging	» Blowing machines of latest technology is installed in plants, that can blow PET bottles of lower grammage while having more strength than the high grammage bottles. » Bottle mould design reengineered to give better strength. » Cap moulding machine replaced with modern technology SACMI machine, which helped to reduce cap weight from 1.50 gram to 1.35 gram.
Automotive		
Use of bio-plastics	» Successful pilot experiments have been completed on the use of bio-based plastics for automotive applications » Most important upcoming market within automotive sector is technical applications. Currently, automotive and transport sectors account for 1% of the bio-plastics market segment	» Bio-based polyesters, bio- based PET and PLA-blends in applications such as headliners, sun visors and floor mats, interior fabrics
Use of recycled plastics	» Currently, recycled plastic account for 15% in vehicles » TATA motors engaged in automotive bumper recycling	» Plastic fibres made from used bottles in sound insulation layers in dashboards » Use of plastics recycled from bumpers to create new bumpers, as well as plastics recycled from bottle caps to make new auto parts » Use of recycled plastic content in vehicles is expected to increase to 70%

Use of eco design practices	» BMW uses hemp as well as natural fibres along with acrylic polymers for manufacturing interior door panels » Ford uses bio-polymers from soyabean along with polyurethane to manufacture head rests in their selected models » Nissan Leaf uses natural fibres from corn along with Sorona (polytrimethylene terephthalate) for manufacturing of rugs and mats	» Natural fibres and/or biopolymers draw significant interest from equipment manufacturers due to their biodegradability, low cost, low relative density, high specific strength, and renewable nature » Eco-design approach gets product design environmental oriented
Building and construction		
Use of alternative material	» Bricks and planks made out of plastic waste being used as alternatives to traditional clay and mortar bricks in construction	» Biological nutrients and sustainable, renewable materials can replace materials that are heavily processed and hard to reuse and recycle
standardised approach	» The utilisation of Energy Conservation Building Code and implementation of green rating systems like the Green Rating for Integrated Habitat Assessment (GRIHA) is leading to resource-efficient buildings in India	» Assessing performance of secondary materials in products replaces virgin materials and in the design of construction products » By standardising technology, construction companies can reduce the cost of their production

Use of recycled plastics	» Royal Melbourne Institute of Technology (RMIT) researchers developed a building material made from cigarette butts mixed with plastic waste, bitumen, and paraffin wax » Corepla along with Waste Free Oceans built the first humanitarian shelter prototype by collecting plastic waste along the river » Bengaluru-based non-profit Swachha developed a solution that can convert discarded plastic waste into tiles and irrigation pipes. In association with the Bruhat Bengaluru Mahanagara Palike (BBMP), Swachha developed 'Re-Tile' tiles, which customers can use on pavements	» Recycled plastic blended with virgin plastic lowers the cost » Recycled plastic can save the cost of other materials, such as wood and slate » Recycled plastics can be used to make stronger concrete structures in the form of sidewalks, driveways

Source: Authors' own, using open sources[54]

Appendix 5: Potential Circularity Scenarios for Plastics in India

Circularity Interventions and Scenarios	Substitution between Plastic Polymers » Move to a bio-based as alternative feedstock to fossil feedstock » Shift from multi-polymer material to mono-polymer material	Expansion of Segregated Waste Collection » Improved collection and transportation infrastructure » Awareness generation	Increased Recycling or Reprocessing into a Secondary Material » Increase mechanical recycling capacity and efficiency » Scale up chemical recycling capacity	Design for Recycling » Fewer types of plastics to reduce the complexity in plastic waste management » Design to enable easy disassembly at the EoL	Reduction in Plastic Consumption » Use of alternatives to plastics products and reduction in specific uses (across key end use sectors/ applications) » Re-use of end use products » Design to bring in efficiency in plastic raw material use
Business as usual scenario	Bio-based plastics account for less than 1% of the plastics produced Use of multi-polymer material continues to grow (R&D initiated to identify substitutes)	No change in segregation of waste plastic and collection levels Important to note, collection levels in urban India are currently high but the issue is more linked to unsegregated collection and irresponsible dumping and littering post collection	Limited increase in overall recycling of plastics (at rates witnessed over the last 3–5 years) brought by new localised initiatives and business models. Increased awareness generation brought about by IEC activities	Not happening; R&D process initiated	Very limited substitution brought about in specific applications including those related to SUP

Moderate RE&CE scenario (2035)	Percentage share of bio-based plastics will increase to 10% by 2035 Reason being that the ability of these types of plastics in reducing the accumulation of plastic pollution has been disputed, and their applications are limited	Expansion in infrastructure to support segregated collection and storage (e.g., MRFs and transfer station) has been initiated Improved awareness amongst stakeholders on source segregation	Moderate increase in overall recycling of plastic brought about by improvement in plastic collection, and expansion of recycling capacity in the country by private and public sector; Overall recycling rate increases to 70–75%; the draft National Resource Efficiency policy targets 100% recycling and reuse rate for (PET) plastic by 2025	Pilot experiments around design for recycling	Some substitution brought about in all applications related to SUP; Development of innovative alternative products in a few plastic products, mostly in packaging-related applications; Reducing over packaging; SUP product share decreases to 40% (reduction brought about mainly through reduction in single-use plastic bags and Styrofoam products)
High ambition RE&CE scenario (2035)	Percentage share of bio-based plastics reaches 40% by 2035	Source segregation is enforced in 90% of the cities in India; Infrastructure to support segregated collection and storage (e.g., MRFs and transfer stations) exist; Deposit refund systems/schemes supported by digital technology are in function that enhance collection of uncontaminated waste	High increase in recycling brought about by significant and step changing improvement in PWM (through full implementation of the best available recycling practices) across the country by private and public sector resulting in an overall recycling rate of plastics as 90-94 percent; Deposit refund systems/ schemes supported by digital technology are in function that enhance supply of uncontaminated plastic waste for recycling	Happens and it positively impacts the recycling rates- by reducing the costs linked to plastics separation from the end-of-life products and also improving the recycling per se due to reduced risk of contamination of mixed plastics	High substitution brought about in all applications related to SUP; Reducing over packaging, and development of innovative alternative products to plastic products in all key end use applications; SUP product share decreases to 20% (reduction brought about mainly through reduction in single-use plastic bags and Styrofoam products)

Source: VThe Energy and Resources Institute[55]

Appendix 6: Average Cost of Plastics

Plastic Type	Production Capacity	Share in Industry	Price (INR / metric tonne)	Price
HDPE	2840	0.157195282	98672.31058	15510.82168
LDPE	650	0.035977793	107668.8611	3873.688041
LLDPE	2430	0.134501597	101119.2638	13600.70245
PP	6115	0.33846801	95875.62808	32450.83306
PVC	1560	0.086346704	81630.00223	7048.481653
PET	3455	0.19123581	97600	18664.61501
Others	1016.7	0.056274804	97094.3443	5463.965187
Total	18066.7	1		96613.10709
(in thousand tonnes)				Average price of plastic per tonne
Plastic produced				18066700
Total market price of virgin plastic (in INR)				1745480021835.18
Total market price of virgin plastic (in US$)				21,81,85,00,272.94

Source: Various reports[56,57]

Appendix 7: Waste Management Costs for Lower Middle-Income Countries (in US$)

Management Cost		
Collection Cost		Sorting Cost
Urban	Rural	
81	109	117
Total Cost		212

Source: Pew Charitable Trust[58]

Appendix 8: Recycling Costs for Lower Middle-Income Countries (in US$)

Recycling Cost		
(US$ per ton)	Closed loop	Open loop
Op-Ex	300	200
Cap-Ex	115	75
Chemical Conversion	158	77
Total	573	352

Source: Pew Charitable Trust[59]

Appendix 9: Circularity Scenario Calculations

Year		In metric tonnes		In US$
2025	Projected Size	21885196.34	Production cost	31284540551.95
	Recycled Stock	2053020.295	Management cost	1366436929.50
	Required Production	19832176.05	Pollution cost	34964014296.03
	Waste Generated at 25%	4958044.011	Recycling Cost	1146547677.61
	Plastic recycled at 50% Circularity	2479022.006	Total Cost	68761539455.09
2026	Projected Size	23329619.3	Production cost	32891063242.03
	Recycled Stock	2479022.006	Management cost	1436606153.44
	Required Production	20850597.29	Pollution cost	36759485199.93
	Waste Generated at 25%	5212649.323	Recycling Cost	1446510187.16
	Plastic recycled at 60% Circularity	3127589.594	Total Cost	72533664782.57
2027	Projected Size	24869374.17	Production cost	34296878958.25
	Recycled Stock	3127589.594	Management cost	1498008957.41
	Required Production	21741784.58	Pollution cost	38330643348.09
	Waste Generated at 25%	5435446.144	Recycling Cost	1759725689.27
	Plastic recycled at 70% Circularity	3804812.301	Total Cost	75885256953.02

2028	Projected Size	26510752.87	Production cost	35817800164.20
	Recycled Stock	3804812.301	Management cost	1564439304.99
	Required Production	22705940.57	Pollution cost	40030444906.61
	Waste Generated at 25%	5676485.141	Recycling Cost	2100299502.34
	Plastic recycled at 80% Circularity	4541188.113	Total Cost	79512983878.15
2029	Projected Size	28260462.56	Production cost	37416297711.86
	Recycled Stock	4541188.113	Management cost	1634258009.13
	Required Production	23719274.44	Pollution cost	41816946805.71
	Waste Generated at 25%	5929818.611	Recycling Cost	2468286996.73
	Plastic recycled at 90% Circularity	5336836.75	Total Cost	83335789523.43
2030	Projected Size	30125653.08	Production cost	39103461370.68
	Recycled Stock	5336836.75	Management cost	1707949445.50
	Required Production	24788816.34	Pollution cost	43702543117.70
	Waste Generated at 25%	6197204.084	Recycling Cost	2866206888.76
	Plastic recycled at 100% Circularity	6197204.084	Total Cost	87380160822.64

Source: Authors' own

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