India – Australia Industry and Research Collaboration for Reducing Plastic Waste

National Circular Economy Roadmap for Reducing Plastic Waste in India

Acknowledgments

The National Circular Economy Roadmap for Reducing Plastic Waste in India has been developed with input from industry, government and community participants who we thank for sharing their information and thinking on how to progress India's endeavour for a circular economy for plastics. We thank the Australian Federal Department of Industry, Science and Resources for the financial support. We thank the Indian Government for their interest in our research and their engagement in the effort to facilitate greater circularity of plastics. The comprehensive partnership between Australia and India created the means for this Roadmap and allowed for a collaboration of Indian and Australian research partners led by the CSIRO and including The Energy and Resources Institute in New Delhi, the National Environmental Engineering Research Institute of CSIR in Nagpur, Development Alternatives in New Delhi, the University of New South Wales and the University of Technology Sydney. We are grateful for the support of the leadership of the six research institutes and special thanks to the over 50 researchers from India and Australia who collaborated on this research. We also thank Josh Dowse for advising the storyline of the summary, Karin Hosking and Jacqui Meyers for editorial services.

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The India – Australia Industry and Research Collaboration for Reducing Plastic Waste is a three-year collaboration with partners in both India – the Council of Scientific and Industrial Research (CSIR), Development Alternatives and The Energy and Resources Institute (TERI) – and Australia – the University of New South Wales (UNSW), the University of Technology Sydney (UTS) and CSIRO. Through key activities, this collaboration works closely with industry, government and community stakeholders to evaluate the economic and policy implications of transitioning to a circular economy for plastics.

Abbreviations

ABS	Acrylonitrile butadiene styrene
ASSOCHAM	Associated Chambers of Commerce and Industry of India
BAU	Business as usual
BIS	Bureau of Indian Standards
CBM	Circular Business Model
CII	Confederation of Indian Industry
CPCB	Central Pollution Control Board
CPMA	Chemicals and Petrochemicals Manufacturers' Association
CSIR-NEERI	Council of Scientific & Industrial Research – National Environmental Engineering Research Institute
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSR	Corporate Social Responsibility
EFP	Environmentally friendly packaging
EPR	Extended Producer Responsibility
EPS	Expanded polystyrene
FICCI	Federation of Indian Chambers of Commerce & Industry
HDPE	High-Density Polyethylene
IoT	Internet of Things
IPWM	Improved plastic waste management
ISO	International Organization for Standardisation
LCA	Life cycle analysis/assessment
LDPE	Low-Density Polyethylene
MFA	Material flow account/analysis
MoCI	Ministry of Commerce and Industry
MoE	Ministry of Education
MoEFCC	Ministry of Environment, Forest and Climate Change
MoF	Ministry of Finance
MoHUA	Ministry of Housing and Urban Affairs
MoMSME	Ministry of Micro, Small and Medium Enterprises
MoSDE	Ministry of Skill Development and Entrepreneurship
MoSPI	Ministry of Statistics and Programme Implementation
MoST	Ministry of Science & Technology
MRF	Material Recycling Facility
Mt	Million tonnes
NASSCOM	National Association of Software and Service Companies
NGO	Non-Government Organisation
NIF	National Indicator Framework
NITI Aayog	National Institution for Transforming India (NITI) Aayog, Government of India
NSW	New South Wales
OECD	Organisation for Economic Co-operation and Development
OPTOCE	Ocean Plastic Turned into an Opportunity in Circular Economy
PE	Polyethylene
PET	Polyethylene terephthalate
PIBO	Producers, Importers and Brand Owners
PP	Polypropylene
PRO	Producer Responsibility Organisation
PS	Polystyrene
PVC	Polyvinyl Chloride
PWM	Plastic Waste Management
PWP	Plastic Waste Processor
QCI	Quality Council of India
SDG	Sustainable Development Goals
SPCB	State Pollution Control Board
SUP	Single-Use Plastic
TERI	The Energy and Resources Institute
ULB	Urban Local Body
UNEP	United Nations Environment Programme
UT	Union Territory
WtE	Waste-to-Energy
WtO	Waste to oil

Preface

Dr Deborah Lau, CSIRO Ending Plastic Waste Mission Lead

The problem of plastic pollution has become an urgent global issue, with an estimated 8 million metric tons of plastic entering our oceans annually. This massive scale of plastic waste is increasing every day and has devastating consequences for marine ecosystems and the environment at large and international collaboration is vital to address this crisis effectively.

India and Australia are actively participating in the negotiations towards a UN Global Plastics Treaty which aims to encourage a circular economy for plastics. It will promote a systemic shift in the way plastics are designed, produced, consumed, and managed at the end of use. This treaty provides a framework for participating countries to coordinate their actions, share best practices, to drive global change and reduce plastic pollution. Through this instrument, both countries aim to leverage their respective strengths in waste management, recycling policies, and environmental initiatives to foster a circular economy that prioritizes resource efficiency and environmental protection.

CSIRO, Australia's National science agency, has launched the Ending Plastic Waste (EPW) Mission to address the plastics issue. The mission has a goal of reducing plastic waste in the Australian environment by 80% and adopts a holistic approach, fostering collaboration among industry, government, and community stakeholders to tackle plastic pollution at its source. Through such partnerships, CSIRO aims to generate actionable insights, develop innovative technologies, and promote behavioural change among consumers and businesses alike.

The **National Circular Economy Roadmap for Reducing Plastic Waste in India** will be instrumental in helping India reduce plastic waste by providing a strategic framework and a clear course of action to tackle the issue. Through specific goals, milestones, and timelines, it serves as a reference point for all stakeholders involved. This enables organisations to align their efforts, monitor progress, and adapt their strategies as needed. It has established clear targets for plastic waste reduction, recycling rates, and sustainable materials usage, allowing India to track its progress and evaluate the effectiveness of its strategies. It will also provide guidance for developing and strengthening policy frameworks ensuring a more coordinated and comprehensive approach to addressing plastic waste issues.

Furthermore, The National Circular Economy Roadmap for Reducing Plastic Waste in India identifies priority areas for research and innovation, facilitate stakeholder collaboration, encourage public awareness and engagement, and identify funding and investment opportunities. The collaborative approach fostered by the Roadmap can help India leverage the expertise, resources, and capabilities of different sectors, including the government, industry, academia, and civil society, to tackle plastic waste more effectively.

It is clear that international collaboration is crucial to solving the plastics issue, as it enables nations to share expertise, resources, and innovative solutions. The Global Plastics Treaty, the collaboration between India and Australia, and the partners, CSIRO, CSIR-NEERI, Development Alternatives, TERI, SMaRT Centre UNSW and UTS-ISF, who have joined to develop the Roadmap all exemplify the power of collective action. This comprehensive Roadmap can further guide these efforts, ensuring that we move closer to a world free of plastic pollution.

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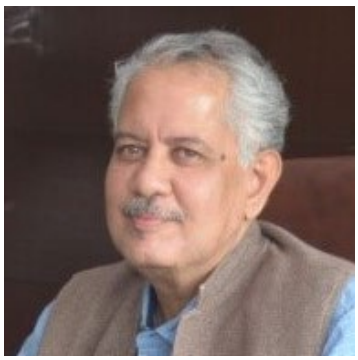

Dr Atul N. Vaidya, Director CSIR-NEERI

India, in the last five years, has witnessed a two-fold increase in per capita plastic waste generation, owing to increased population and rapid urbanization. Detrimental impacts of waste plastic on environment are ever increasing and evident, seeking significant media and public attention. The obvious imbalance or mismatch between exponential rise in plastic consumption and recycling and disposal calls for all-inclusive efforts from the community to global level are required to address this global issue, necessitating urgent establishment and proliferation of circular economy for plastics.

Government of India has launched several policies and funding schemes for plastic waste management, such as Swachh Bharat Mission, Swachh Survekshan, Extended Producer Responsibility (EPR), plastic waste (handling and management) rules 2016, and ban on the use of single use packaging plastics. Despite these regulatory mechanisms, the transition from linear to circular economy for plastics, warrant immense efforts from all stakeholders across the entire plastic value chain.

The industry and research collaboration between India and Australia predominantly aims to foster this transition to circular economy for plastics keeping with the clarion call made by Governments of Australia and India to reduce the plastic waste. Honourable Prime Ministers of both the countries, in a joint statement, specifically mentioned and welcomed the initiative for the Roadmap leading to cooperation in plastic waste reduction and circular economy. The *National Circular Economy Roadmap for Reducing Plastic Waste in India* will be a very effective tool and shall serve as a blueprint for implementation of a circular economy in India by virtue of rich overview and in-depth analysis of the barriers and enablers of circular economy as it has been developed based on the inputs from stakeholder engagements, illustrations drawn from a range of interviews, field survey, high level round table meetings and brainstorming sessions with representatives of the plastic value chain.

The interesting insights provided in the Roadmap can serve as a logical framework for green innovations, enhancing recycling rates and strengthening policies. The timelines and milestones provided in the Roadmap shall facilitate establishing a clear target for all the stakeholders to strengthen the efforts towards the circular economy transition. The recommendations delineated in the study - incentives, increased financial support, green public procurement and quality standards to name a few - will enable overcome the challenges for circular economy barriers.

This comprehensive Roadmap can further serve as a formidable response to the needs of Global Plastic Treaty, that will motivate more inclusive circular economy for plastics, attainment of sustainable development goals and net-zero targets. The research Collaboration between India and Australia partnering CSIR-NEERI, Development Alternatives, and TERI, from India and CSIRO, SMaRT Centre UNSW and UTS-ISF from Australia, is viewed as an exemplary collaborative research of two countries developing sustainable solutions to a shared problem of the world.

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Why a circular economy roadmap for plastics is needed for India

The **Government of India's commitment** to address plastic waste challenges and consequential human health and ecological impact concerns has been a key motivation for the development of a Roadmap to help drive the transformation of the plastic waste economy in India into a circular economy. Management of plastics has historically been dealt with by governments at State and Municipal levels, through regulatory strategies of bans and fines, and by education and awareness campaigns led by civil society actors. These interventions have mainly been from a waste management perspective, directed predominantly at individual behaviour shifts and with some success.

In 2016, India acknowledged the scale and complexity of the plastic waste problem and its interconnectedness with global ocean plastic pollution and global warning concerns. A raft of measures directed at municipal, industry, residential and commercial actors have since been introduced. These measures, led by the Plastic Waste Management (PWM) Rules, have ranged from bans, fines, municipal and social enterprise models for collection, segregation and recycling, education and awareness campaigns across a range of stakeholders, to rules for Extended Producer Responsibility (EPR), and tracking and monitoring the problem at the municipal level. Most operational interventions are directed at end-of-use of plastic and some gaps exist between policy intent and policy design, which are compounded by multiple barriers at implementation level. These include gaps in data flow and data transparency posing a barrier for tracking and design of effective strategies, technological limitations in recycling, remanufacture and green manufacture, inadequate infrastructure for collection of products at the end-of-life, market and price barriers for secondary plastic-based products and alternatives to single-use plastics, knowledge capacities across stakeholders, and business models that do not include the potential of the large informal recycling sector. The roadmap, therefore, is motivated by **the need for a comprehensive view of the entire value chain of the plastics economy and to provide systemic recommendations for addressing the challenge**.

The other side of any challenge is opportunity. The Roadmap is designed with **a motivation to unlock opportunities in the transition to greener more inclusive and circular economy as a strategy to achieve Sustainable Development Goals (SDG) and net zero targets**. For India, as in other emerging economies this is an opportunity to leap over the trade-offs between development and the environment, and between losers and winners in the transition. These opportunities range from enhancing resource security through recovery of materials, accelerating industry and market shifts to low embodied carbon products through innovations, to creating new economic opportunities and green jobs through inclusive business models. This promotes good health and sustainable living in line with strategic action for the **LiFE – Lifestyles for Environment** intervention of the Government of India as introduced in COP26 on 1 November, 2021.

This Roadmap recognises that the problem is dynamic and while some responses are required urgently other solutions and strategies will evolve and emerge over time and through engagement of stakeholders from across the ecosystem of the plastics economy. The motivation for a Roadmap is therefore to create **a living framework document supported by robust research and recommendations for policy and industry strategies**, technology interventions, and community and social action. The document acknowledges the active unfolding of the plastics economy in India and provides guidance for systematically navigating it, with an objective of multiple wins across climate, resources, pollution and livelihood challenges at global, national and local levels.

Finally, the Roadmap can support the Government of India and industry associations in responding to the requirements of the **Global Plastics Treaty** that is expected to be in force by 2024. The Roadmap identifies systematic actions that need to be taken by different stakeholders in the short, medium and long terms so that environmental and human health concerns in the plastics economy can be addressed comprehensively. Technical, business and industry wide solutions successful in India have huge potential for informing and replicating in emerging economies of the Asia Pacific, Africa and Latin America, thus the Roadmap can stimulate and lead **transformative change at global scale**.

The Roadmap audience

The Roadmap has been co-developed with researchers, industry, government and community in India. Several key stakeholders have been identified to take ownership of the Roadmap as India drives to transform its plastic waste economy into a circular economy for plastics.

NITI Aayog, as the public policy think tank of the Government of India, has the responsibility to coordinate with various ministries to streamline policy development and implementation and could be a key champion of the roadmap.

The Roadmap is directed at the **policy design community**, to enable transition management and track monitoring and evaluation of the implementation of current and new policies.

The **Ministry of Environment, Forest and Climate Change (MoEFCC) & Central Pollution Control Board (CPCB)** are the implementing agencies for formulation and preparation of guideline manuals and codes related to practices in solid waste management. They are also responsible for dissemination of relevant information.

The ministries directly responsible for the initiation of policies like Atmanirbhar Bharat (Self-Reliant India), Smart cities and Swachh Bharat Abhiyan (Clean India), such as **Ministry of Housing and Urban Affairs (MoHUA)**, would benefit from supporting implementation of the Roadmap as it represents principles and practical information for the management of end-of-life plastics in India.

The Roadmap can be a device for **plastic manufacturers and plastic product manufacturers**, who connect with the waste management agencies at industry levels. Environmental Social Governance compliance is challenging and voluntary contribution as delineated in the Roadmap is one way of fulfilling moral and ethical leadership.

The **Ministry of Commerce and Industry** has a flagship initiative for the start-up ecosystem in India and can identify innovations in technology and circular business models (CBMs) in this ecosystem that can address the gaps and barriers identified in the roadmap.

Finally, the findings and recommendations of the Roadmap are directed to anyone interested in promoting or addressing the plastic waste problem in India, and globally to initiate a change process by which waste is avoided from the get-go, valuable materials are kept in circulation and primary resources are conserved.

Summary: A circular economy for India's plastics

The need to solve India's plastics problem

Plastic, one of the great inventions of the 20th century, is now seemingly indispensable. However, its lifestyle and economic benefits come at a steep cost, making it one of the greatest challenges of the 21st century.

Despite several initiatives, India continues to confront the enormous challenge of an essentially linear 'take-make-waste' industry. India generates nearly 26,000 tonnes of plastic waste each day (CPCB, 2020), 3.46 million tonnes (Mt) per year, more than any economy except the USA and European Union.[1] Three-quarters of this waste consists of three polymers, polypropylene (PP), polyethylene (PE), and polyvinyl chloride (PVC), the rest stems from the other members of the polymer family listed in Table S.1. Packaging dominates consumption, with a share of 59%, followed by building and construction (13%) and agriculture (9%).

Before this report, India was thought to recycle around half of its plastic, but this research radically reduces that estimate. A significant share of household waste is plastic, with 50% to 80% of that plastic being collected, and only 40% of that segregated for resource recovery. The rest is either incinerated or dumped and can find its way into water bodies and become part of the food chain for humans, marine and terrestrial life (Issac and Kandasubramanian, 2021).

While good government, corporate and community initiatives can be found, the overall sector is plagued with problems. It is challenged by mixed streams of plastic waste, waste contamination, poor segregation and lack of technology investment. Regulations and organisational norms guide larger businesses, but they are a relatively small part of the picture. Most of India's waste is handled either by small businesses or workers in the informal sector, with their material flows being fragmented and difficult to track. As a result, the sector is dominated by low skilled labour, manual segregation, uncertain pay and lack of social security, weak medical and human health support, and weak environmental protections against leaching into soil, air and water.

Likewise, while producers, importers and brand owners (PIBOs) have extended producer responsibilities (EPRs), many of them are yet to register for compliance. A lack of publicly available data hinders both innovation and tracking of policy implementation. As well, the July 2022 government ban on single-use plastics only covers about 10% to 15% of plastics used.

The alternative is to strive for a circular economy of plastics, one that retains the value of materials or products within the economy as long as possible (Geissdoerfer et al., 2018). A circular economy would use as little virgin plastic as possible and maximise the use of recycled material. It would substitute its use with alternative materials, extend the use of plastic materials, collect waste and end-of-life plastic and recycle it for its next use.

Table S.1 Different types of plastic, and of waste

NAME	TYPE	USE EXAMPLES
Polypropylene (PP)	Soft or hard	Straws, food containers, tape and diapers
Polyethylene (PE)	Soft	Bags, films, geomembranes
Polyvinyl Chloride (PVC)	Hard	Pipes, toys, credit cards and medical equipment
Polystyrene (PS)	Soft	Cups, takeaway food, packaging, insulation
High-Density Polyethylene (HDPE)	Hard	Toys and pipes
Low-Density Polyethylene (LDPE)	Soft	Bags, wraps, cartons, tubing
Polyethylene Terephthalate (PET)	Hard	Drink bottles and food jars

1 However, according to the estimates provided by CPCB in the Annual Report on Implementation of PWM Rules, 2016, India ranks 5th in the total quantum of plastic waste.

Transitioning to a circular economy for plastics is critical for India. The opportunities and benefits are social, environmental, economic and international. A circular economy can:

- Divert dry waste from landfill, leading to a cleaner environment, 20% to 50% less greenhouse emissions (d'Ambrières, 2019; Lai et al., 2022), improved air quality, and reduced microplastics in the food chain.
- Integrate the informal sector into the formal economy by recognising their role, enabling their access to government services and benefits and supporting them in developing their own business ventures in the sector.
- Support a cultural shift, away from 'use and throw', to one that leads future generations to value resources and care for the environment even as they develop their economy.
- Create new secondary markets for used plastics in construction and manufacturing, and new primary markets for alternative, eco-friendly products.
- Accelerate India's progress on the SDGs and its commitments under the Global Plastics Treaty (2024).
- Offer an example for emerging economies of the Asia Pacific, Africa and Latin America, to support transformative change at global scale.

Securing the benefits of a circular economy are within India's reach if all parties in the plastics value chain, with support from government, share a clear, new framework for action. The shift from traditional linear business models is a significant change for businesses and consumers. A circular framework is likely to need support as institutions and systems adapt over time.

Relaunching efforts for a circular economy in plastics

Plastic pollution has been a concern to Indian governments and citizens for over three decades, with multiple local campaigns directed mainly at individual behaviour shifts. A stronger response followed with the Plastics (Manufacture, Usage and Waste Management) Rules in 2009, with broader responses from municipal, industry, residential and commercial actors accelerating from 2016.

Now, this major research effort has been launched as a collaboration between six premier research organisations, three in India and three in Australia, as part of the Australia-India Comprehensive Strategic Partnership. It has engaged directly with stakeholders along the plastics value chain; evaluated recycling technologies; reviewed all available data, reports and working papers; identified gaps, challenges, opportunities and barriers for action; and made well supported recommendations for policy makers, regulatory authorities and industrialists.

Its ambition is to guide all participants who want to or need to be part of India's circular economy of plastics, progressively reducing the amount of virgin materials made from natural resource extraction, and the pollution we give back.

This Roadmap traces the current successes and urgent needs for India's plastics industry and sets out a path for it to become a leading sector in India's circular economy, addressing fundamental environmental issues and fostering a positive economic evolution.

It offers:

- A comprehensive review of the entire plastics value chain.
- A living framework for policy and industry strategies, technology interventions and community and social action, supported by robust research.
- Clear recommendations to build a circular flow of plastic materials through production, consumption and recycling, supported by action to build financial sustainability, awareness and readiness, essential infrastructure and consistent compliance.
- A Roadmap of actions in the short, medium and long term to comprehensively address environmental and human health concerns in line with the Global Plastics Treaty.
- Clear roles for participants in the plastics circular economy, spanning the public, household, private and non-profit sectors.
- Practical guidance for leaders at municipal and community levels, in both the formal and informal economy.

The India-Australia Industry and Research Collaboration for Reducing Plastic Waste present this Roadmap as an essential step on India's path to a sustainable plastic waste management strategy.

The current and potential future of India's plastic value chain

India often reports recycling rates for plastics of 60% to 70% (CPCB, 2020; CSE, 2020; Kapur-Bakshi et al., 2021; Mohanty, 2017; Sikka, 2007), which may be true of some valuable plastics. However, the comprehensive material flow account (MFA) of plastics undertaken for this study determined a total circularity rate of 8% in 2019 – that is, only 2.0 Mt of the 24.1 Mt of plastic consumed is returned to another use (Figure S.1).

We have considered two scenarios: one without any significant policy ambition beyond what is already in place (a "business as usual" or BAU scenario), and another where there are significant policies and targets (an "improved plastic waste management" or IPWM scenario).

Business as usual (BAU)

If historical trends continue, Indian use of plastics will grow to around 39 Mt by 2025 and 70.5 Mt by 2035 (OECD, 2019). The resulting waste, already unsustainable at 15.2 Mt, would rise to 45.7 Mt. As India's per capita plastic use is still relatively low by international standards, further growth can be expected beyond 2035, leading to further environmental damage.

Improved plastic waste management (IPWM)

In the IPWM scenario, we explored the potential implications of several measures on the material flow of plastics in India. The first measure considered was a potential ban on single-use plastic to reduce the demand for virgin plastic. The government of India is pushing towards developing affordable substitutes/alternatives to single use of plastics (CPCB, 2020; Kapur-Bakshi et al., 2021; Schandl et al., 2020). Other measures would be to support businesses that are seeking to comply with existing plastic waste management legislation, including the implementation of Extended Producer Responsibilities (EPR) and collection and resource recovery targets (CSE, 2020).

The potential changes in the main streams under the IPWM scenario are provided below:

- single-use plastics could be reduced by 20% by 2025, then 50% by 2030, and be phased out completely by 2035;
- recycling rates would increase from 13% in 2025 to 67% in 2035;
- landfill could be reduced by 10% in 2025, then 30% by 2035; and
- mismanaged or untracked waste streams could be reduced by 30% in 2025 and up to 80% by 2035, with coherent collection systems and large-scale behaviour change in businesses and households.

Taken together, overall plastics use would be limited to 53 Mt in 2035, or 17 Mt less than the BAU scenario. Two thirds of all plastic end-of-life materials would be captured by the recycling system, reducing landfill and incineration to only 6% combined.

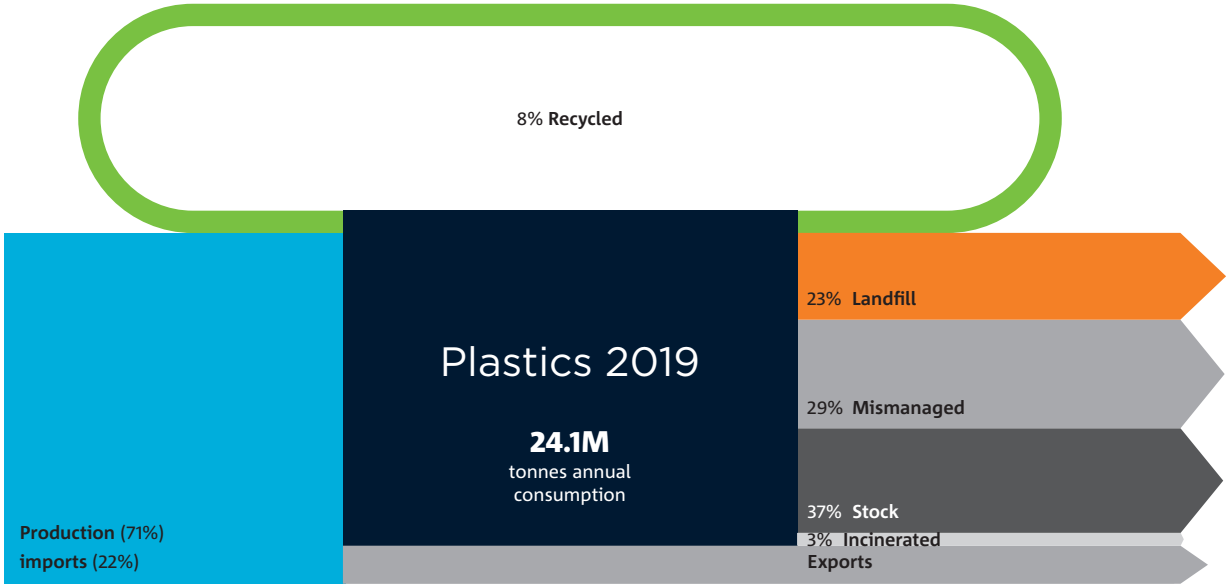
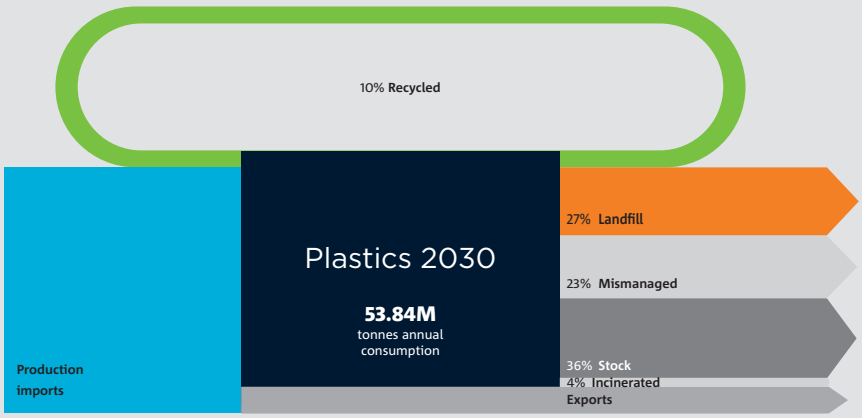


Figure S.1 The MFA of plastics in India, 2019

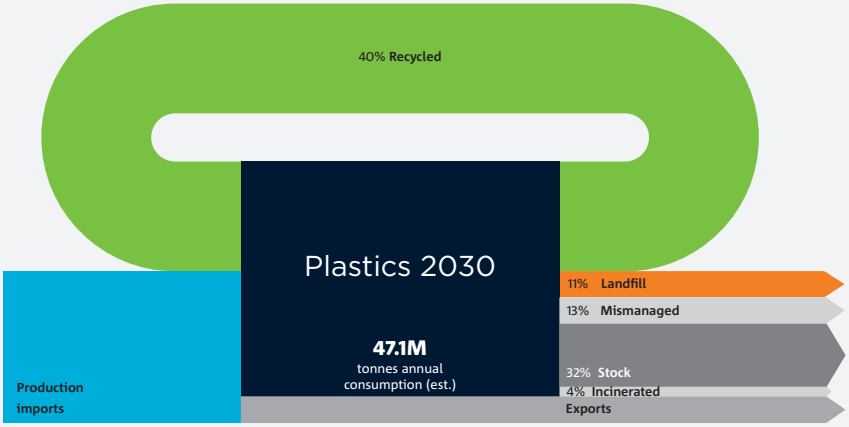
Figure S.2 The MFA of plastics in India under BAU and IPWM scenarios until 2035

2030

BAU **b**

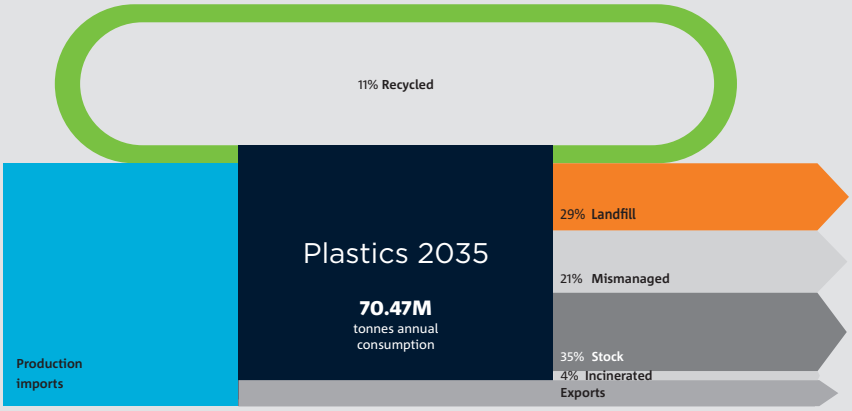


IPWM **e**

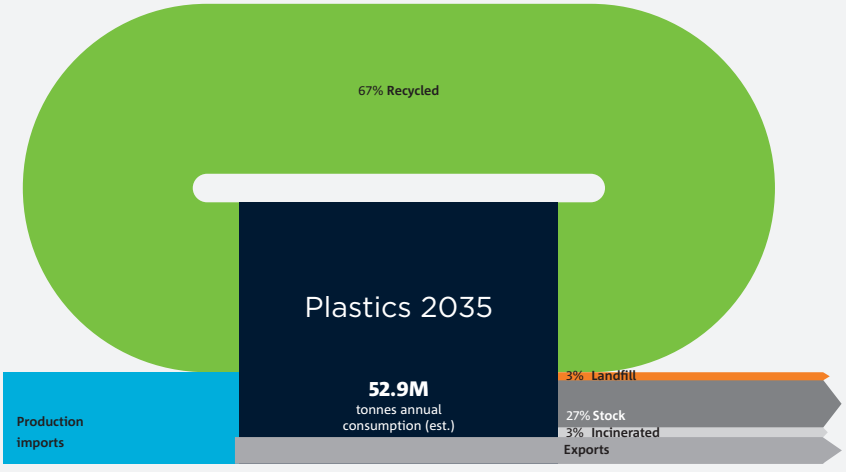


2035

BAU **c**



IPWM **f**



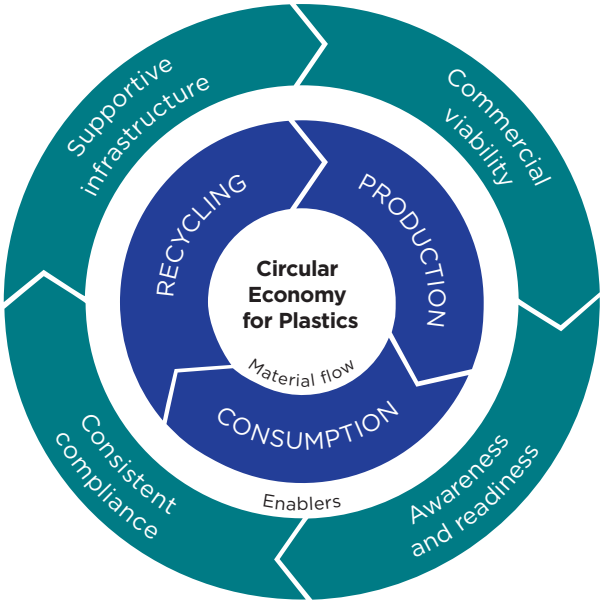


Figure S.3 The seven elements of India's circular economy for plastics

The seven elements of the circular economy for plastics in India

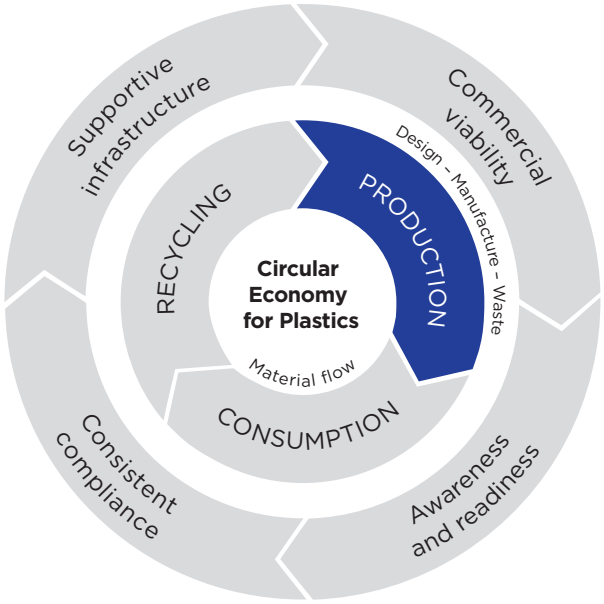
Any steps towards a circular economy will improve plastic waste management in India. Planning these steps must take into account a clear framework for the plastics circular economy in India. In our framework, there is a clear flow of materials through three broad stages, supported by four primary enablers. Each of these elements are depicted in Figure S.3 and described in full below. In a circular economy, all these elements would be developing at once, each supporting the others as a true system. We can only attempt to describe it in a linear fashion. It is a simplified system, but it needs to be if we are to understand how the many dimensions of this problem fit together.

The inner material flow elements represent what happens to the plastic itself. Products that use plastic would be designed to be recycled. Their manufacture would incorporate recycled 'secondary source' stock rather than virgin material. Any waste from that manufacture would be continually collected and reprocessed, ready for a later manufacturing run.

Given a choice, homes and businesses that consume plastic products would choose those from the circular economy over any linear economy alternative. In their use and re-use of the product and its ultimate disposal, they would be conscious of the need to extend the life of its raw material. At end of life, the item becomes part of the recycling stream, being collected, sorted and processed, ready to become part of its next manufacturing.

None of this physical flow can happen, however, without the four sets of enablers, and it is here that the Roadmap for India's circular economy of plastics would focus. Any business or physical asset needed for production and recycling must be commercially viable, able to attract capital and government incentives to operate in a sustainable market.

Those businesses must operate with the support of digital, research and planning infrastructure that enables to them to become part of a circular system, without having to invent one. Any business owner or plastics user must be engaged on the issues, with the information and, where appropriate, the training available to them. And so that their efforts have the impact they seek, the plastic materials and its treatments must be subject to consistent compliance, with appropriate standards, monitoring and enforcement.



Collaborative production

Consider all aspects of the value chain. Substitute virgin plastics with recycled and alternative materials. Design to minimise material, avoid low-value and hard-to-abate plastics, and aid end-of-life decomposition. Design for recyclability by reducing multi-material composites, where possible. Avoid unnecessary plastic packaging. Manufacture efficiently, capturing all waste streams for reuse or recycling.

Priorities

Aim: To design products that can be easily and efficiently recycled, with minimal contamination, to reduce waste and promote a circular economy – by using materials that are widely accepted for recycling, minimising the use of additives, designing products for disassembly, and providing clear instructions for recycling.

Action focus:

Design: Currently, new and compound materials enter the Indian market with little consideration of their end-of-life. Despite SUP bans across India, single-use polyethylene bags are rampant. Alternatives are either expensive or inconvenient, and more collaboration is needed between academia, finance and industry to commercialise technical solutions for reducing plastic use.

Investment is needed for products that incorporate plastic materials to be designed for end-of-life disassembly and recyclability, with low-quality single-use plastics phased out entirely.

Manufacturing: Currently, the use of re-processed plastics as a feedstock for a next cycle of manufacturing is limited by the lack of enabling infrastructure. This includes uniform standards for re-processed plastics, as well as quality management to achieve those standards and facilities to test stock against those standards. As a result, recycled plastic stock has limited commercial viability as an alternative to virgin material. Investment is needed to remove those barriers, as well as reduce the use of non-recyclable composites and manufacturing practices such as over-moulded silicone.

Waste collection: Currently, India has more than 10,000 collection units, most operated by unregulated bodies. To accelerate waste collection and reuse, the 2020 MoEFCC framework set three models for PIBOs based on fees, producer responsibility organisations and plastic credits. The PWM Rules set targets for PIBOs to take back 100% of their plastics by 2023–24, but the targets assume that collection systems are already in place, and there is little guidance on how PIBOs can achieve these targets. Investment is needed in:

- better regulation for waste collection and sorting to secure a consistent supply of waste plastic, and
- technology to collect that plastic waste from micro-systems and convert them into plastic 'nuggets' that may be either reused or combusted for energy.

Staged priorities

2025:

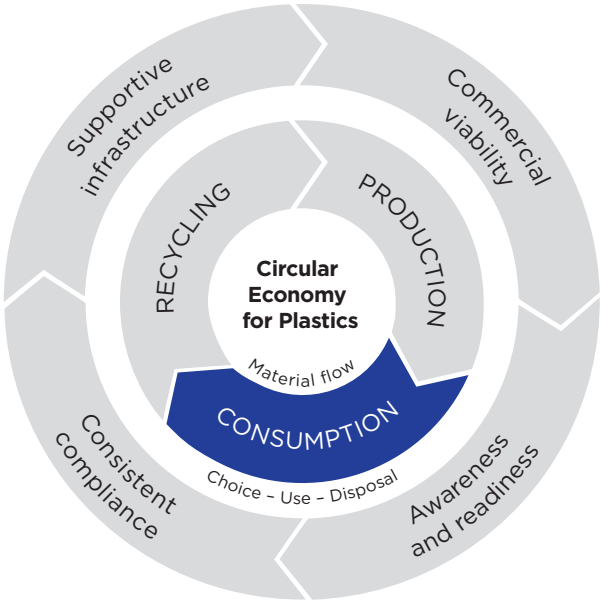
- Establish a plastics innovation Hub to drive technology development for designing out waste and use of secondary materials in the manufacturing and construction sectors.
- Pilot level implementation of automated sorting techniques based on colour, gravity, and polymertype that are less labour intensive and more accurate when compared to manual sorting.
- Setting targets for replacement of certain polymers with sustainable alternatives.
- Standards for plastic recycling to be laid out and any directives to use recycled plastic should be considered in the context of food and health safety.

2030:

- Significant scaled up production of alternatives to plastics and used across selected sectors; faster adoption due to competitive prices and better availability.
- Review the operation of the innovation Hub based on successful inventions delivered by start-ups, SMEs and larger enterprises.
- Implement green public procurement and circular procurement strategies at the national, state and local levels.

2035:

- Every state should have a plastics innovation centre or hub co-funded by industry and government to support material and technology R&D, provide education and knowledge resources for better waste management, skills training and business support to transition to a circular economy.



Sustainable consumption

Choose products with minimal plastics and reject unnecessary plastic packaging. Reuse wherever possible; materials that are kept in circulation are valuable twice over as they reduce the need for virgin materials and reduce waste going to landfill. Reduce plastic consumption and introduce policy, programs, and initiatives that support and enable avoidance of single-use and low-value plastics. Choose products that are recyclable and made with recycled content. Reject SUP packaging and switch to reusable materials. Reuse wherever possible and provide financial and technology support for business models that encourage sharing and second-hand markets. Dispose responsibly. Segregate into different types of waste streams after use and expand collection systems of all kinds. Work with the informal sector for the efficient collection of waste materials.

Priorities

Aim: For consumers to avoid single-use plastics, choose products with extended lifetimes, reuse plastics, choose products made with recycled plastic, and segregate plastic at end-of-life to facilitate recycling.

Action focus: Extend knowledge and awareness of circular economy practices to all education and income groups, promote a culture of resource value and match local campaigns with necessary infrastructure. Potential solutions to foster sustainable consumption practices span informed and responsible choices for consumption through social processes, a 'rebranding' for enhanced value of resources in use, and accessible infrastructure for recycling.

Informed Choice: Household behaviour follows the 4 Rs of purchasing, use and disposal of products. The extent of adoption of the 4 R behaviours by consumers is not commensurate with the many programs to raise awareness. Increasing availability of and access to affordable alternatives to SUPs must support interventions on social and cultural attitudes to hygiene and 'purity' to foster behaviour shifts. Education and awareness must be extended to include households with lower access to information and supported with leveraging appropriate messaging and demonstrated action by social leaders and influencers in campaigns.

Use with care: Despite frugal consumption being part of Indian culture, rising income levels and consumption patterns, bolstered by e-commerce, are fostering a 'use and throw' culture. Campaigns to shift consumer perceptions about the quality of recycled plastics and eco-friendly packaging, likening them to the quality and cleanliness of valuable cutlery and crockery, and disassociating them from 'unclean', unhygienic or lower-status images are needed.

Responsible disposal behaviours: Upon purchase or use, most people do not consider the impacts of plastic pollution on the environment and human health. Education and awareness programs need to be supported by infrastructure for waste segregation and disposal to enhance and extend to rural areas and in local languages. Targets for recycling at domestic levels supported with recognition, awards, incentives and disincentives will reinforce desired behaviours.

Staged priorities

2025:

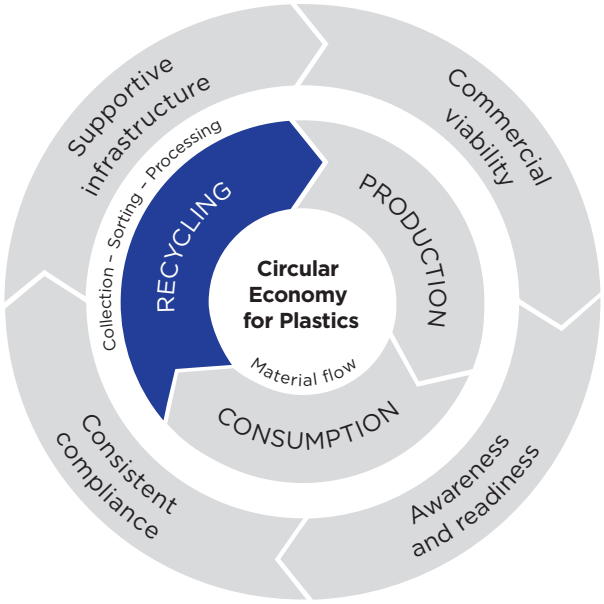
- Information, knowledge and training portals for citizens, businesses and students are operational and running with clear targets of outreach and engagement.
- Consumers engage with novel waste collection systems established in urban centres and collection rates have expanded to 40%.

2030:

- Every household, institutional and commercial establishment has access to segrated waste disposal facility and is using it.
- Products with initially 30% and up to 50% recyled content conforming to heath and quality standards are available and affordable with competive market positioning.

2035:

- Single-use plastics including low-value packaging have been phased out, supported by EPR, community and consumer behaviour change.
- Affordable alternatives ranging from no packaging to alternative biodegradable options are available widely and are the consumer option of choice.



Effective recycling

Radically improve India's recycling capability, with government-finance-research-industry collaboration. Build sorting facilities with artificial intelligence (AI) capabilities, and advanced mechanical and chemical processing infrastructure in proximity to source for efficient recycling. Push for reverse logistics and state-of-the-art recycling technology to sit alongside industry and commerce in a distributed model, with smaller-scale community-based solutions.

Priorities

Aim: To promote closed-loop recycling and chemical upcycling technologies, to retain plastic in the material loop for longer, and so reduce dependency on virgin resources and the environmental impact of plastic waste.

Action focus: to stimulate the awareness, collaboration and technologies needed for a closed-loop system where plastic waste is collected, sorted and processed, ready to be transformed into new products.

Collection: Collection of waste plastics is mostly handled by the informal sector, as most plastics have very low economic value. The inadequate collection of flexible and rigid packaging waste and SUPs in particular leads to low recycling rates for these types of plastic.

Further inclusion of marginalised communities as formal waste collectors in a businesslike manner is needed. Infrastructure can be delivered by the Smart City and Swachh Bharat (Clean India) Missions for liveable and sustainable cities. Further investment is also needed in EPR, including enhancing EPR categories, targets and value chain adoption and monitoring impacts of EPR on designing products for recyclability and investments by producers in recycling infrastructure.

Sorting: Sorting of plastic waste is often performed manually. Established technologies for sorting include zigzag or air-classifier separation, air tabling, ballistic separation, density separation, magnetic separation, dry and wet gravity separation (or sink-float tank), froth flotation, and electrostatic separation (or triboelectric separation). Newer sensor- and AI-based technologies include plastic colour sorting, X-ray spectroscopic and near-infrared (NIR) sorting (MoHUA, 2019), but these are rare due to their high cost.

Further investment is needed to incentivise waste segregation at source, including extended producer responsibility programs, and to scale up advanced sorting methods to reduce their cost.

Processing: Waste plastic is easier to process if it is consistent, clean, undegraded, has no or minimal additives, and is properly sorted. Presently PET, HDPE and LDPE are widely recycled plastic types, with further research needed for sustainable recycling of PVC, Acrylonitrile butadiene styrene (ABS), nylon and polycarbonate. Chemical recycling technologies are at the nascent stage, with the few players concentrating on using plastic waste as fuel.

Further investment is needed to track international innovation in waste processing, to exhibit available technologies on an accessible and updated platform, to create standards for recycling plastic waste, to digitally monitor the flow chain of polymer, and to certify recyclates and their use in ecolabels or codes for recycled content in plastic products.

Staged priorities

2025:

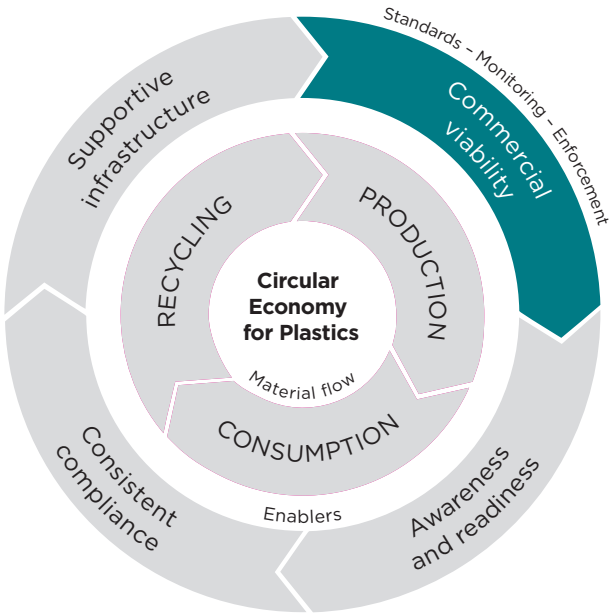
- Investment by government and private sector players through Corporate Social Responsibility (CSR) for recycling and sorting infrastructure in vicinity of source.
- Exhibition/ expo/ workshop of technologies promoting Make in India Campaign.

2030:

- Recycling capacity has substantially grown to manage 18.8 Mt of end-of-life plastics that are retuned for another use.
- Compendium of technologies and interactive consumer forum is avalaible.
- There is a regular and adequate resource allocation/ funding for recycling/upcycling technologies .
- A healthy pipeline of innovations in machineries for optimal resource utilisation is set-up.
- Digitalization of flow chain of polymers are mandatory and applied.

2035:

- 35.2 Mt of materials now recycled through a regional network of up-to-date recycling facilities.
- Secondary plastics with ascribed value and mechanisms for industrial applications are available.
- Product certification and secure traceability across production consumption and recycling is set-up.



Commercial viability

Draw on government and CSR funds both for start-ups and for those at next-stage commercialisation who find it hard to attract capital on manageable terms. Use incentives to preference circular economy businesses. Develop markets for high quality secondary material, with government agencies and sustainable corporations seizing the opportunity to 'buy recycled'.

Priorities

Aim: For small businesses and industries who want a part in the circular economy, who need a financially viable path to get there, with finance available, markets to sell to, and preferential incentives to build their businesses.

Action focus: Create more coordinated, dedicated finance and incentive streams, with deep understanding of the plastics industry, to open and access new markets for CBMs.

Finance: Circular economy businesses need advance capital to establish their systems, but to access finance, they need evidence of returns: 'it's always egg or hen first'. Recycling businesses often need major capital investment before they sign long-term contracts with municipalities. Innovative businesses fostering circular products and practices often find it difficult to access finance. The informal sector does not have the product sales data or proof of contracts to gain finance. Pilot schemes often do not have funding to transition to commercial applications. Actions to open finance for the circular economy for plastics include:

- Pooling of government and CSR funding to open finance as well as provide legitimacy and recognition.
- Pooling funds to create incubators and accelerators that can offer finance, connect people, trigger mentoring and training, and engage with community-level initiatives.
- Exploring social investment platforms (peer-to-peer lending) for financial inclusion and empowerment of workers in the informal waste management sector.
- Developing credit products that prioritise the circular economy and informal sector workers.
- Setting up funds that are geared to assess the potential of circular economy businesses and technology, including a Viability Gap Fund (Kapur-Bakshi et al., 2021) to cover high start-up expenses and shorten long payback periods, and a Revolving Fund to invest in next-stage circular business with an expectation of commercial returns.

Markets: Material and energy recovery in the informal sector is one of the most established CBMs in India. Local markets for second-hand goods in metropolitan cities are central to it, and e-commerce platforms are stimulating trade. There are now around 91 start-ups working to formalise roles beyond the second-hand trade.[2] However, the markets for materials and processes in the recycled plastics supply chains are extremely fragmented, with little data and uncertain volumes. As one business explained, 'it's a lot of figuring out what is the right application, industry, feedstock and who will buy the next product that comes out'. Bioplastic or renewable fibre substitutes for single-use and packaging plastics are also emerging; however, many may actually increase emissions according to the United Nations Environment Programme (UNEP) Life Cycle Analysis (LCA).

Actions that will accelerate markets for the plastics circular economy include:

- Incorporating plastic waste as a secondary source material for applications such as bitumen binding, coke substitute in steel manufacturing, pet coke substitute in cement manufacturing and in other construction products like sand brick, recycled plastic lumber and tiles.
- Enhancing EPR regulations to incorporate the informal sector, building on initiatives of online marketplaces to connect actors in the waste and recycling value chain or social enterprises that act as Producer Responsibility Organisations (PROs) on behalf of corporate businesses, technology parks and resident welfare associations.
- Develop standards, certification and verification mechanisms based on the scientific analysis of lifecycle costs of products including as a basis for product and service taxation and public procurement to enable development of markets for recycled and other secondary products from plastic waste.
- Promote and strengthen waste exchange platforms and marketplaces that reduce recovery and transportation costs for companies generating and collecting waste.

Incentives: Policies to add incentives for the plastics circular economy include:

- An environmental tax on producers to encourage better product design, reduce planned obsolescence, and enforce the traceability of end-of-life waste.
- Lower taxation on recycled products and materials in comparison to virgin polymers, overcoming taxation for informal businesses to formalise.
- Incentives for municipal corporations such as green credits in Swachh Bharat Mission (Clean India) to offset high local sorting and recycling costs for plastic waste.
- Incentives for capital investment in efficient, modern collection, sorting and processing technologies to encourage entrepreneurship in the circular economy and phase out inefficient high-waste facilities.
- Listing of waste management initiatives by the private sector to be eligible for claiming tradeable green credits, under newly announced schemes.

Staged priorities

2025:

- Develop a compendium of commercially proven technological solutions of varying investment range (from low to high) and automation (from manual to fully automatic) for management of plastic waste.
- Promote and strengthen waste exchange platforms and marketplaces that reduce recovery and transportation costs for companies generating and collecting waste while also making it more affordable for users to seek for what they need.
- Encourage public-private-community partnerships for innovation in business model and financing strategy for investment in waste management infrastructure.

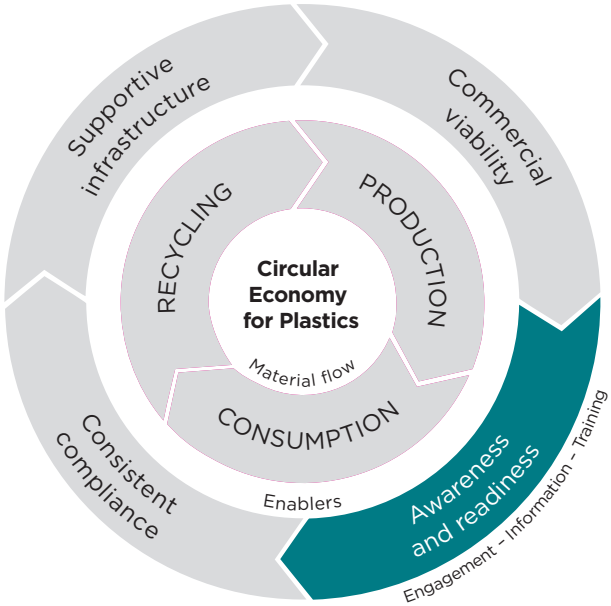
2030:

- Agree on new financial support and credit facilities for implementing circular business models and novel approaches to design, recycling and manufacturing of secondary materials to reduce end-of-life plastics.
- Introduce fiscal and tax incentives for development and promotion of plastic waste-based products and uptake of such businesses; amend public procurement policy to preference circular businesses.
- Develop standards, certification and verification mechanisms to enable development of markets for recycled and other secondary products from plastic waste.
- Explore social investment platforms (peer-to-peer lending) for financial inclusion and empowerment of workers in the informal waste management sector.
- Develop credit products that prioritise circular economy and meet entrepreneurial aspirations of informal sector workers.

2035:

- Create an effective waste collection and management system assisted by technology-based processes for tracking the quality and quantity of material and products across the plastic waste value chain.

2 https://www.recyclingstartups.org/country/India/



Awareness and readiness

For a true 'zero waste' culture, practices must change in industry, in offices, and at home. The channel of schools, universities and other educational institutions should be used to raise awareness and build readiness and selective curricula on waste management that can be included as a part of study curriculum. Similarly, waste management policies in industry, administrative and commercial establishments could drive practices at work and industry premises. That readiness includes the desire to change practices, and ultimately support for the infrastructure and materials needed. Broad national principles should be interpreted into India's multiplicity of communities and languages, with a focus on simple tools that are available on phones and devices, digital information portals, and multi-layered training.

Priorities

Aim: For communities and industry to play their roles in the plastics circular economy, we need systematic engagement strategies to raise awareness, open-access platforms to share information, and opportunities for skills and innovation training.

Action focus: Align engagement, information and training efforts – separately in industry and the community - so that people are ready to shift to circular economy practices.

Engagement: The Swachh Bharat Mission and Swachh Survekshan carry India's main efforts to drive citizen engagement and awareness. Standout efforts have been led in Alappuzha (Kerala), Panjim (Goa) and Indore (Madhya Pradesh). However, more extensive efforts are needed to:

- Educate the public on the environmental and health impacts of plastic waste, what they can do to reduce it, how to read packaging labels to make better choices when they buy, how to dispose end-of-life plastics responsibility and the policies and regulations that apply every day.
- Communicate in all languages and through effective channels, especially with informal workers (ragpickers, waste collectors and shopkeepers) as the primary source of information for households, as well as school programs and colleges, and improved digital options for locating local recycling partners.
- Establish institutional mechanisms / solutions exchange platforms to link local governments with community-based local initiatives to enable support as well as learn from local innovations and community actions.
- Establish and support networks and solutions platforms for circular business models and links with support services for start-ups, SMEs and cooperatives /collectives of informal workers.

Information: *Where does one go currently for industry information?* Initiatives to improve the information available to industry should include:

- An online compendium of recycling technologies, of low-to-high costs and low-to-high automation for management of plastic waste, with recent innovations, contact details for technology providers, forums to share experiences and best practices, and 'problem solvers' to help communities.
- Comprehensive data on the volume of polymers produced, traded, consumed and disposed of, and on impacts due to plastic pollution available online and in popular media for public in different languages from time to time.
- Expand Swachh Survekshan with a systematic monitoring, evaluation and learning mechanism of circular management of plastics through the value chain with recommendations for policy, planning and practice actions.

Training: The Ministry of Education's online portal, Swayam, provides PWM education for university students and professionals. The Swachh Bharat Mission offers administrative and technical training to Urban Local Body (ULB) staff, also leveraged by NGOs and community service organisations for the informal sector, with states such as Goa having comparable training. These initiatives should be enhanced with:

- On the ground training on data collection for municipalities and connected stakeholders, leading to better evidence-based solutions, and training to communities and other stakeholders in circular economy and waste, co-funded by industry and government.
- Targeted and progressive training for the informal sector, both to raise awareness of the health hazards of plastic waste, and to prepare them to communicate with households.
- A knowledge platform for shared learning highlighting success stories and innovative work by local community groups, start-ups, municipalities and private partnership-based projects that address plastic waste, market recycled plastic products and uses, include the informal sector and marginalised communities, and promote CBMs.

Staged priorities

2025:

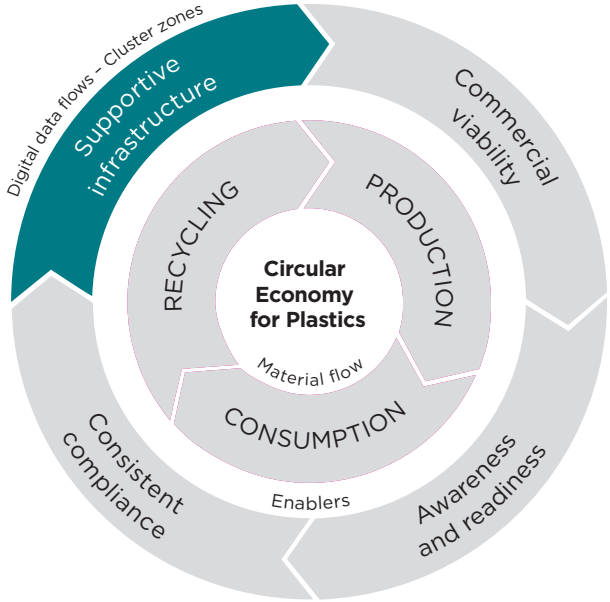
- Online platforms for education and training including a compendium of recycling technologies, communication platforms to promote CBMs, and real-time data on plastics material supply chains are set up.

2030:

- Evidence-based monitoring, evaluation and learning mechanisms at municipal and state levels linking government initiatives with community and industry processes to foster and manage plastics circular economy transition dialogues are established and running.

2035:

- Evidence of desired culture shift in business and community achieved through transition management are documented and analysed for planning for the next decade.



Supportive infrastructure

The circular economy would ideally be built on a digital, research and physical backbone. Digital data flows would link material flow from virgin plastics manufacture through to reuse, secondary processing, or disposal. The physical hubs for this data should be local industrial ecologies where manufacturing, materials collection and reprocessing feed each other.

Priorities

Aim: To invest in recycling and digital infrastructure needed to collect, sort, track, and assess the quality and value of end-of-life plastics, including horizontal integration of recyclers and industries that take up secondary materials.

Action focus: Local councils, SMEs and MSMEs to establish the necessary infrastructure under a national recycling modernisation plan. A **Recycling Modernisation Fund** would expand India's capacity to sort, process and remanufacture plastic.

Digital infrastructure is becoming an enabler for integrating the informal sector into new 'cycling' businesses. Digital platforms provide an end-to-end waste management platform that connects and facilitates transactions across the waste management and recycling value chain. Once established, they require minimum additional infrastructure to scale. More investment is needed in digital waste management tools such as GPS-enabled tracking for vehicles, image recognition tools, leveraging the Internet of things (IoT) and AI. Stronger data analytics of the circular waste value chain is also needed, using a unified digital platform to capture data, identify gaps, help improve collection and recycling rates, and guide policy making. Finally, waste exchange platforms and marketplaces would reduce recovery and transportation costs for companies generating and collecting waste while also making it more affordable for users to seek what they need.

Research and development ecosystem: While funding for commercialising innovation is scarce, funding for early-stage R&D is even more difficult to secure. India might consider strengthening its research ecosystem, with business support and incubation labs for SMEs similar to North America's Small Business Innovative Research (SBIR) Model, which brings industry, academic research and SMEs together with co-funding. Other initiatives may include relaxing the patents arrangement between industry and academia, and setting up a common information platform on emerging technologies on plastics segregation, processing and recycling.

Industrial clusters. The most successful business models occur in industrial zones where recycling facilities are clustered along with downstream producers who use the recyclates. This industrial symbiosis drives collaboration and innovation, and saves transport and transaction costs. It exists at few places in India, including Chennai and Nagpur for post-consumer plastic wastes.

Further investment is needed to expand these models across India, so that recycling is part of a true circular economy for plastics rather than an isolated function. Capital investment for infrastructure with modern facilities can be procured through ULBs and corporates via CSR activities. Similar investment in infrastructure is required in Material Recycling Facilities (MRFs) for identification of plastic types.

Staged priorities

2025:

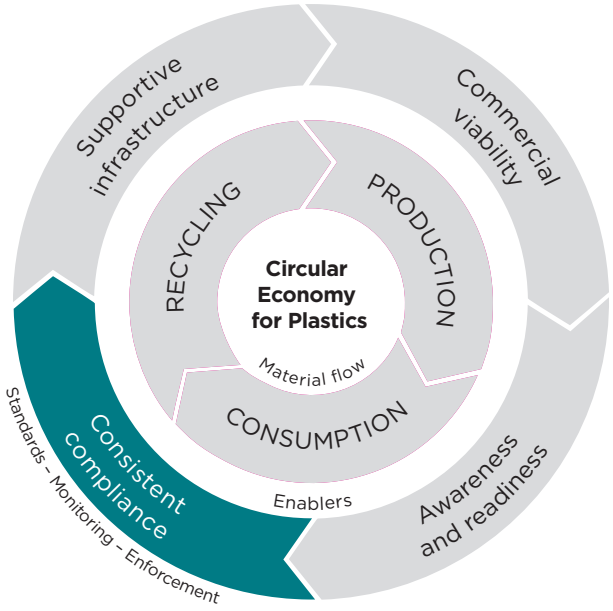
- Establish a national recycling modernisation fund enabling public-private partnerships to assist in growing and updating recycling infrastructure co-funded by government and the private sector.

2030:

- Digital platforms for data collection and transparency ,waste exchange platforms and marketplaces.
- Substantial growth in the available recycling technologies including mechanical, chemical and advanced recycling options suited to different end-of-life plastic materials.

2035:

- Industrial clusters driving collaboration and innovation in product design enabling commercial viability and true circular economy for plastics.



Consistent compliance

With a shared national framework and standards, state governments must set targets and monitor progress on plastics reduction, reuse and recycling. After enough time to licence and educate participants in the circular economy, incentive-based enforcement can be pursued to ensure targets are met, and that sustainable companies are not placed at an unfair disadvantage.

Priorities

Aim: To establish easily understandable rules for the plastic value chain including shared definitions and agreed standards to guide product design, production processes, consumption and appropriate treatment and management of end-of-life of plastics.

Action focus: Nationally agreed definitions, standards and rules to guide the handling and treatment of plastics across the value chain, supported by compliance awareness in municipalities, industry, informal sector, SMEs and citizens.

Standards: Quality concerns prevent the use of plastic waste as secondary source material, with standards not yet in place for recycled polymer. Although 'Eco-Mark' labelling has been used since 1990, there is no set indicator to achieve SDG 12, and no current standards for recycled polymers. Investments by the government and industry are needed for:

- digital codes for primary and recycled chemical composition, on a standardised platform, for open-loop polymer recycling
- testing standards for physical properties such as mechanical strength, tensile strength, Young's modulus etc. for recyclates, and qualities for food contact applications
- Develop standards, certification and verification mechanisms based on the scientific analysis of lifecycle costs of plastic-based products for enhancing markets of recycled products and limiting the number of recycling cycles based on health and quality parameters

Monitoring: The potential for data collection, triangulation for ensuring accuracy and collation for use by policy makers, start-ups, and other market players is immense. India has not fully explored its technological capabilities for tracking, monitoring with feedbacks into planning and policymaking. Action has commenced with Digital India, the EPR and GST portals, the annual Swachh Survekshan across urban areas and the central command and control system linked to emerging MRFs in all smart cities. Ministry of Statistics and Programme Implementation (MoSPI) updated the National Indicator Framework (NIF) in 2021 and developed an India SDG Dashboard with the United Nations Resident Coordinator Office. The 'NITI Aayog SDG Index', also developed with the UN, measures national and subnational progress towards 17 SDG goals and targets. Further investment is needed to:

- Integrate approaches for EPR, incentives, standards, finance and tax mechanisms to ensure there is standardised information, target setting, monitoring and reporting, to enable timely and effective evaluation of progress.
- Streamline data systems across municipalities and state levels and by industry to accurately report on the quantities of waste produced, collected, processed and reused; the number of dumping sites, uncontrolled landfills, open burning, source segregation, and littering; the extent to which awareness and behaviours are changing over time; and on the environmental, economic, and social consequences of waste.
- Incentivise SMEs to register with state and local initiatives to track and trace waste flows (and address the disincentive of being exposed to possible penalties for non-compliance).
- Monitor fund management by governments and ULBs, and regular reporting to the public on the achievements of investments on circular economy and plastics management.
- Establish a national database (or knowledge base) of effective plastic circularity intervention programs enabling the tracking, evaluation, and learning throughout the system to examine the effectiveness of plastic circularity programs to promote learning from others.

Enforcement: Enforcement of compliance and mandates is weak. For example, though the central government may issue a ban, implementation lies with the respective state governments and their state pollution control boards, where implementation strategies need strengthening. PIBOs and plastic waste processors are allowed to carry on business via registration on the CPCB's EPR portal however, there is no tracking PIBOs who have not registered.

- Set-up and enforce targets for compliance of segregation of wastes at source for domestic, commercial and industrial establishments with supportive infrastructure, education, awards and incentives coupled with stringent penalties for non-compliance.

- Integrate national and state policy with implementation and regulatory approaches at municipal levels including small towns and tier II and tier III cities and rural areas to provide clear direction and better alignment in order to encourage higher policy uptake and implementation.
- Ensure action at a state level to integrate and register different stakeholders involved in bulk generation and management of waste plastics including collection, segregation, processing and recycling.

Staged priorities

2025:

- A Circular Economy transition body or mechanism has been set up to connect industry government and municipalities.
- Targets for reduction of virgin plastic use, segregtaion at source and recycling for bulk generators, municipalities, PIBOs and industry have been agreed and established.
- Data tracking mechanisms across producers, recyclers municpalities have been set up and streamlined.

2030:

- Incentives and regulations for reducing virgin plastic use and incorporating secondary plastics in products have been operationalised.
- EPR has been extended to all complex material streams such as textiles, agricultural products, automobiles, tyres targeting all stages of the lifecycle including design and production.

2035:

- National standards for end-of-life plastic definitions and quality expectations to ensure the required characteristics for secondary use are available, including digital capability and testing standards for physical properties, including monitoring mechanisms.
- Mandatory regulatory measures and fiscal measures for product design and production processes, procurement, consumption and disposal have been set up for industry to citizens all, based on LCA logic.
- Ecological and human health externalities integrated in product, production process and consumption pricing and risk assessments for financing.
- Enforcement of non-compliance with the protocols of recycling quality standards, is supported with penal provisions.

• Overall strategy

India needs a holistic strategy and actionable agenda to push towards a circular economy:

1. **Set a single, clear framework and implementation plan:** a practical policy framework for circular economy, in which all initiatives and information have a place, and a plan to put it into action.
2. **Develop a circular economy transition body** to connect industry and government.
3. **Include all plastic types:** municipal solid waste, industrial waste, hazardous waste, e-waste, medical waste, and so on.
4. **Recognise and engage all stakeholders,** especially the informal sector of waste pickers and recyclers. They are the backbone of the Indian waste management system through their door-to-door collection yet are excluded from formal policy support and recognition. Collaboration must encompass the strengths and opportunities of the entire ecosystem: across the petrochemical industry, ULBs, informal cooperatives, PIBOs and regulators.
5. **Streamline effective regulations:** make regulations and guidelines for recycling, materials reuse and energy, clear enough to be effective for developing CBMs and fostering circular consumption behaviours.
6. **Create systems to support state governments to design and implement action-plans for circular economy for plastics** that encourage decentralised governance and implementation at municipal and panchayat levels, leveraging local skills, networks and enabling local contextual responses.
7. **Integrate learning along the supply chain.** Enable continuous bottom-up learning, feedback and knowledge to all stakeholders across the plastic value chain.
8. **Phase out plastics:** set dates beyond which the manufacture of certain plastics is banned, and support manufacturers of these materials to transition to alternative products and businesses.
9. **Support the circular economy** with public procurement policies and fiscal and tax incentives that prefer secondary plastic waste-based products and businesses.


MOONG DAL

Call to action from all parties

All participants in the circular economy have a shared responsibility to make it efficient and effective, and to help scale up or replicate initiatives across the nation.

Government

Central agencies like MoEFCC, CPCB, MoHUA, Department of Chemicals, as well as state public actors and local bodies, etc. can accelerate a plastics circular economy by:

- setting the leadership agenda with comprehensive policy strategies foused on the circularity agenda, data streams to support tracking and monitoring, disaggregated targets for sectors, industry and cities, benchmarking based on LCA, setting standards for secondary plasctic use in products and regulation production and consumption regulations for industry, businesses, cities and citizens;
- ensuring there is adequate resourcing to monitor and enforce those regulations, particularly at state and municpal levels;
- funding priority areas with grants, subsidies, taxation incentives and grant or loan schemes;
- sponsoring roadshow showcases and supporting waste stream opportunities through enabling finance, information flows and technical services;
- endorsing local initiatives and multi-stakeholder partnerships for scaling up and replication of good practice, incuding learning from practice to improve policy design and implementation
- leading community education initiatives; and
- setting standards in its own procurement and incentivising secondary resource based product procurement in private sector to support promote the circular economy.

Industry

Industry includes the specialist plastic waste and manufacturing sectors, as well as the infrastructure, product, service and investment companies who either use or can sponsor waste recovery and recycling through their Environmental-Social-Governance (ESG) initiatives. Large corporates and industry organisations can support the plastics circular economy by:

- coordinating input into policy, research and supply chain priorities;
- investing in symbiotic industrial zones for waste recovery and reuse;
- investing in research and development for technologies and innovative materials to reduce use of virgin plastics, especially low-value mutli-layered plastics;
- initiating or broking collaborative pilots and research initiatives;
- scaling up those initiatives where they span multiple geographical areas; and
- liasing with government on local, state or national policies and initiatives.

Informal economy

Waste pickers and sorters play a critical role in resource recovery, and must be included as stakeholders in circular economy planning. They can as well:

- use phones to adopt digital data and payment apps;
- inform and lead households on the need and behaviours for plastic recovery and recycling;
- establish unions to access training, tools and better conditions for waste collection and sorting; and
- convert their informal operations into collective-based businesses for secondary resource collection,

aggregation and recycling, and raise their value proposition in the plastics value chain.

Civil society and community organisations

Civil society and community organisations are partners and facilitators for all those who are or would be a direct part of India's circular economy for plastics. They can:

- lead community education initiatives;
- advocate for equitable and efficient regulation; and
- support households and small businesses in adopting the recycling behaviours on which the circular economy depends.

Households and small businesses

Households and small businesses generate most of India's recyclable plastic waste. They can:

- look to buy products of recyclable material and packaging and increase efficiencies to remove waste from their day to day operations;
- ensure segregation at source to enable value maximisation of all recyclables and compostables and improve working conditions when working with the informal sectors to sort and collect recyclable paper, plastics and glass; and
- support and participate in initatives led by their local communities and businesses.

Research

Agencies such as universities, think tanks and NITI Aayog have both research and facilitation roles, undertaken either independently or at the request of any other participants, to:

- identify barriers through the value chain;
- identify possible solutions, inlcuding block chain data and e-governance mechanisms, whether or not original or in India or overseas;
- test those solutions with industry participants;
- engage with and inform government policy; and
- track progress against targets.

Building the Roadmap is just the start

The next steps needed to advance this vision may be to:

- Mainstream the Roadmap into policy and industry strategies through extensive dialogues, communication and outreach – making the Roadmap tangible at policy, industry, business and community levels.
- Bring key actors to collaborate to design and make the circular economy in Plastics Fund.
- Call for Collaborations and partnerships across industry and Research Institutions to roll out Circular Economy Innovation Hubs in all states.
- Enable resources to develop and nurture support systems for MSMEs for enabling small businesses and communities to play their part in the operationalizing this road map, specifically, the Knowledge Portal for circular economy in plastics, the Technology Compendium for Plastics Management and the CBM Support Hub.
- A political and legislative commitment to design and operationalise the MEL framework for tracking circular economy in plastics at municipal, state and central levels.
- Demonstrate pilots across municipalities and SMEs for EPR, data management, circular economy businesses and behaviour shifts.

Overview

The research behind this Roadmap was undertaken by an ambitious international research collaboration between six premier research organisations, three in India – Council of Scientific & Industrial Research – National Environmental Engineering Research Institute (CSIR-NEERI), Development Alternatives, and The Energy and Resources Institute (TERI), and three in Australia – Commonwealth Scientific and Industrial Research Organisation (CSIRO), University of New South Wales – Sustainable Materials Research and Technology Centre (SMaRT@UNSW), and University of Technology Sydney – Institute for Sustainable Futures (UTS-ISF).

The research commenced in July 2020 as part of the India-Australia Comprehensive Strategic Partnership announced by the Indian and Australian Prime Ministers in June 2020. A collaborative team of more than 30 researchers with a broad range of skills and expertise was established.

In addition to the research capability described above, the Roadmap was co-developed with industry, government and community stakeholders through semi-structured interviews and site visits, a survey of households in India, and a series of roundtable discussions. A more detailed outline of how the research was conducted can be found in Appendix A – Methods. This collaboration between researchers, industry, government and community stakeholders has resulted in a Roadmap that is based on up-to-date scientific evidence.

The research program design covered three main areas relating to plastics and plastic waste in India: Metrics and Data, Innovation and Technology, and Policy and Behaviour.

Metrics and Data – develop an understanding of the main supply chains for different polymers in India, the magnitude of plastic waste, how quickly waste flows are growing, waste flow destinations and leakages to waterways and oceans.

Innovation and Technology – investigate the existing situation regarding waste systems and infrastructure, recycling technologies, manufacturing options for plastic production and future opportunities for innovations in recycling and manufacturing utilising plastic waste, creation of new materials, products, processes and business models that will enable a circular economy for plastics in India.

Policy and Behaviour – examine current public policy and institutions, business models, community and industry initiatives and behaviour change programs that address the growing plastic waste issue in India and are either successfully driving change or creating barriers to change.

Furthermore, in each of these three main areas research was undertaken to identify the gaps that exist in knowledge or practice and the opportunities that can aid India in transitioning to a circular economy for plastics.

Each of the following seven chapters in this document delved deeper into a specific aspect associated with one of the three areas outlined above.

Chapter 1: Data transparency focuses on the importance of quality data across the plastic supply chain, the need for data transparency, metrics, indicators and targets to meet, the barriers to meeting these needs, such as technology and awareness, and finally recommendations going forward to overcome the barriers faced.

Chapter 2: Policy frameworks for a circular economy for plastics in India examines the policy frameworks relevant to plastic management in India, specifically the effectiveness of current policy, successful policy implementation, gaps in current policy, global opportunities leading to furthering the circular economy, and potential policy applications for India.

Chapter 3: Circular business models assesses current CBMs for plastics operating in India utilising an adapted framework as part of the assessment. Further, successes, current trends, barriers to mainstreaming and actions to help overcome the barriers and drive greater uptake of CBMs for plastics in India have been identified.

Chapter 4: Plastic recycling technologies explores both mechanical and chemical recycling technologies that are currently used in India, the various gaps in plastic waste recycling, and opportunities to develop plastic waste recycling technologies in India such as advance recycling, along with potential enablers associated with plastic recycling that can support and accelerate the transition to a circular economy for plastics.

Chapter 5: Uptake of secondary materials in manufacturing and infrastructure reviews the use of plastic waste in manufacturing and infrastructure in India and globally. It identifies the barriers that exist preventing or reducing uptake in India and opportunities that can lead to an increase in use of plastic as a secondary material in manufacturing and infrastructure to assist with the management of India's plastic waste stream.

Chapter 6: Community- and industry-led local initiatives focuses on circular economy initiatives at the local community and industry level, addressing plastic-related issues in India and the role they play in plastic management. The scope and focus (the beginning, middle or end stage of the life cycle of plastics) of the initiatives, the type of activity involved, along with the barriers and enablers to their implementation are investigated.

Chapter 7: Behaviour change assesses circular household behaviour in relation to plastic purchase, use and disposal in India and aims to understand the factors that hinder or support households in taking up circular practices towards plastics, including system-wide changes needed to facilitate a cultural shift.

Each chapter concludes with specific recommendations that arose from the research that can aid with India's transition to a circular economy for plastics.

Policies and regulations are only effective if backed by transparent tracking and accountability

A lack of accurate and reliable data is a known key barrier to plastics policy success; therefore, in order to support economic and environmental policy decisions, it is essential to:

- Develop unified data collection methods at a national level.
- Allow tracking of the success of policy interventions, as well as an avenue to accountability.
- Document the registration of informal sector to support more transparent tracking of their contributions. Use advanced sorting techniques that can facilitate data transparency.

In such a way, decision makers will be able to identify effective measures and solutions for the sustainable plastics industry, to redirect currently wasted resources into more circular economic models.

1 Data transparency

1.1 Introduction

The SDGs are designed to tackle and overcome the global challenges of poverty, inequality, consumption, climate change, and more. They are a global compass for synchronising three core components for the future: social inclusion, economic growth and environmental protection. In its voluntary national review in 2020, NITI Aayog stated that achieving sustainable development is, among other factors, contingent on efficient utilisation of resources (NITI Aayog, 2020).

A data-driven approach is often regarded as one of the most efficient means for ensuring progress towards any set target. This is largely because it facilitates periodic monitoring and evaluation of various policies and programs, and necessary amendments to them, so that the desired goals can be achieved in a timely manner. The United Nations SDGs have a global indicator framework that guides countries in selecting relevant indicators for their National Indicator Framework (NIF), which can be used to track progress towards set targets. A data-driven approach is also essential to track progress around the plastic economy.

1.2 What is working well so far?

A number of SDGs concomitantly deal with the issue of plastics[3], particularly SDG 12, (Responsible Consumption and Production), which calls for environmentally sound management of all wastes including plastic throughout their life cycle. Plastic is a persistent material. Once in the environment, it does not go away, and it takes centuries to degrade. Over the past 50 years, global production and consumption of plastics have increased more than 20-fold, and plastic production has reached 320 Mt a year.

The Ministry of Statistics and Programme Implementation (MoSPI) of the Government of India developed a NIF that was last updated in 2021. Based on the NIF, MoSPI has also developed an India SDG Dashboard in collaboration with the United Nations Resident Coordinator Office. This dashboard is a unified data repository on SDG indicators. In addition, NITI Aayog developed an index, namely the 'NITI Aayog SDG Index' which is a comprehensive reporting index, developed in collaboration with the United Nations in India. This index provides an aggregate assessment of the performance of all Indian states and union territories (UTs) on a set of national indicators derived from the NIF, measuring progress of interventions and schemes in the country's journey towards meeting the global goals.

India, as per the recent NITI Aayog SDG Index Report 2020–21 (NITI Aayog, 2021) showed positive progress overall towards SDG goals, identified as a Front Runner (with an Index score of 74). When looking at plastic waste generation specifically, an average of 2.5 tonnes of plastic per annum was generated per 1,000 population in India (2018-19) with the SDG target being 1.27 tonnes/annum, indicating further room for improvement. When looking at the states and UTs individually, there are significant differences in the quantity of plastic waste generated. Based on 2018-19 data (the latest used by the NITI Aayog SDG Index) the state of Goa was the highest plastic waste generator in the country (21 tonnes of plastic per annum per 1,000 population), while Sikkim, Mizoram and Tripura generated the least (0.01 tonnes each). Among the UTs, Delhi generated the highest amount of 11.49 tonnes of plastic per annum per 1,000 population, and Dadra and Nagar Haveli produced the least (2.12 tonnes). In the 2020-21 report, 28 states/UTs (over three quarters) were identified in the category of Front Runner, eight states/UTs in the bracket of Performers and only one state featuring in the Aspirant categories[4].

3 SDGs dealing with the issues of plastics include no poverty (SDG 1), zero hunger (SDG 2), promotion of good health and well-being (SDG 3), clean water and sanitation (SDG 6), affordable and clean energy (SDG 7), industry, innovation, and infrastructure (SDG 9), reduced inequality (SDG 10), sustainable cities and communities (SDG 11), responsible consumption and production (SDG 12), climate action (SDG 13), and life on land (SDG 15).

4 Classification of states/UTs is based on their performance on the SDG India index (a score out of 100), they are classified into four categories - Aspirant: 0–49; Performer: 50–64; Front-Runner: 65–99, Achiever: 100.

1.3 Data across the polymer value chain

The polymer supply chain is extremely complex due to its multiple forms, numerous applications across sectors and products, and vast time range within which they can reach their end-of-life. The useful life of a plastic item can be as short as a few hours (e.g., simple packaging materials) to as long as a decade (e.g., plastic components in televisions or automobiles). Also, the groups of stakeholders who are involved in the entire value chain are numerous. Stakeholders range from large refineries and polymer manufacturers to intermediate businesses where polymers are used for manufacturing thousands of products and sub-assemblies, followed by commercial entities that assemble them in products to be sold in the form of final goods. Retailers and end consumers also are very diverse. Finally, when polymers reach their end-of-life, these are managed and recycled by entities operating in both the formal and informal sectors. Hence capturing data across the production consumption value chain for plastics becomes extremely challenging not only for India, but for other countries as well.

Data availability and quality is strong when it comes to polymer production, including imports and exports, and is published annually by the responsible ministries (Department of Chemicals and Fertilizers and Ministry of Commerce). Data on polymer use across various sectors is largely reported by selected industry associations based on primary surveys and inputs received from member companies. However, the real challenge lies in having accurate data on plastic waste generation, collection and disposal.

Data across the plastic value chain is provided by various national and international organisations including the Plastindia Foundation, OECD.Stat data, CPCB, etc., however, several of these data points are conflicting in nature. We have developed data pedigree tables represented in Tables 1.1 to 1.4 based on Hoekman and Blottnitz (2016) and Weidema and Wesnæs (1996), to determine the most suitable data for analysis of individual stages across the plastic value chain. The tables assess the existing data based on scores for reliability, completeness, temporal and geographical correlation, access, additional steps, frequency, and whether informality and illegality are considered.

Data on imports, domestic production and exports of polymer resins was obtained from country reports published by Chemicals and Petrochemicals Manufacturers' Association (CPMA) in the Asia Petrochemical Industry Conference (APIC) series of conferences (CPMA, 2020).

Table 1.1 Pedigree table of data sources for the Upstream Stage of the plastic value chain

UPSTREAM								
	RELIABILITY	COMPLETENESS	TEMPORAL CORRELATION	GEOGRAPHICAL CORRELATION	ACCESS	ADDITIONAL STEPS	FREQUENCY	INFORMALITY &ILLEGALITY
Plastindia Foundation (2019)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
CPMA (2020)	Qualified estimate (e.g., by industrial expert)	Representative data but from a smaller number of sites and shorter periods or incomplete data from an adequate number of sites and periods	Time period is equal to the period of study	Data from area under study	Publicly and readily available data	No additional steps involved	New data collected on annual basis	Suggest that inclusion of informal flows may be increasing the veracity
OECD (2022)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
CPCB (2020)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 1.2 Pedigree table of data sources for the Production Stage of the plastic value chain

PRODUCTION								
	RELIABILITY	COMPLETENESS	TEMPORAL CORRELATION	GEOGRAPHICAL CORRELATION	ACCESS	ADDITIONAL STEPS	FREQUENCY	INFORMALITY &ILLEGALITY
Plastindia Foundation (2019)	Qualified estimate (e.g., by industrial expert)	Representative data but from a smaller number of sites and shorter periods or incomplete data from an adequate number of sites and periods	Time period is equal to the period of study	Data from area under study	Publicly and readily available data	Simple calculations or conversion required (easy to repeat)	New data collected on annual basis	Suggest that inclusion of informal flows may be increasing the veracity
CPMA (2020)	Qualified estimate (e.g., by industrial expert)	Representative data but from a smaller number of sites and shorter periods or incomplete data from an adequate number of sites and periods	Time period is equal to the period of study	Data from area under study	Publicly and readily available data	No additional steps involved	New data collected on annual basis	Suggest that inclusion of informal flows may be increasing the veracity
OECD (2022)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
CPCB (2020)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Data analysis of life cycle stages for limited polymers

Due to the unavailability and inconsistencies in various data sources studied, different sources have been consulted to develop the entire plastic material flow.

The shares of polymers in different sectors such as packaging (flexible and rigid), household, building and construction, agriculture, electrical and electronic, automotive are derived from the Plastic Industry Status Report (Plastindia Foundation, 2019). The report acknowledges 60 plastic industry stakeholders and major polymer establishments, including research and development institutes, private organisations and other small and large plastic industries, for providing data that helped them in formulating the report. Certain calculations based on assumptions and verification from other sources like Statista and Federation of Indian Chambers of Commerce & Industry (FICCI) were made accordingly to sum up the estimated result. According to the data gathered using the aforementioned sources, the total polymer consumption for India for the year 2018–19 was estimated to be 18.45 Mt. The data for the polymer level consumption disaggregation within end-use sectors came from different sources (Mittal, 2021; Khemka, 2019; Plastindia Foundation, 2019). Primary information obtained from an India-based PRO, dealing with waste management including polymers, validated the PET recycling and consumption rate as mentioned in the data. The chosen datasets turned out to be more suitable, in terms of total scores, in the respective categories of the pedigree tables above.

When it comes to plastic waste streams (plastic waste/end-of-life) data, the Organisation for Economic Co-operation and Development (OECD) Stat reports are more suitable and also scored better on the pedigree table developed. According to the OECD database, the plastic waste generated in India for the year 2019 was 18.51 Mt, which is segregated into various sectors. The waste generated is further broken down by waste treatment, that is, recycled (collected for recycling), incinerated, landfilled, mismanaged and littered waste, taking into account differences across regions. OECD links plastic use/consumption to sectoral and regional economic projections, which are used to establish the evolution of plastics use over time. These volumes of plastics are then used to calculate generated waste, based on product lifespans of different applications. The OECD employed economic modelling to generate the database. More specifically, projections of the economic flows, plastics, plastic waste and environmental impacts rely on OECD in-house modelling tools and involve different steps. The data for the 2019 base year has been estimated by building on output from the OECD – Computable General Equilibrium (CGE) GTAP model (ENV-Linkages).

The pedigree tables for plastic consumption and end-of-life and waste are represented in Tables 1.3 and 1.4.

Table 1.3 Pedigree table of data sources for the Use Stage of the plastic value chain

USE								
	RELIABILITY	COMPLETENESS	TEMPORAL CORRELATION	GEOGRAPHICAL CORRELATION	ACCESS	ADDITIONAL STEPS	FREQUENCY	INFORMALITY &ILLEGALITY
Plastindia Foundation (2019)	Qualified estimate (e.g., by industrial expert)	Representative data but from a smaller number of sites and shorter periods or incomplete data from an adequate number of sites and periods	Time period is equal to the period of study	Data from area under study	Publicly and readily available data	Simple calculations or conversion required (easy to repeat)	New data collected on annual basis	Suggest that inclusion of informal flows may be increasing the veracity
CPMA (2020)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
OECD (2022)	Verified data based on measurements	Representative data from a sufficient sample of sites over an adequate period to even out normal fluctuations	Time period is equal to the period of study	Data from area under study	Publicly and readily available data	No additional steps involved	New data collected on annual basis	Suggest that inclusion of informal flows may be increasing the veracity
CPCB (2020)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 1.4 Pedigree table of data sources for the End-of-life and Waste stage of the plastic value chain

END-OF-LIFE AND WASTE								
	RELIABILITY	COMPLETENESS	TEMPORAL CORRELATION	GEOGRAPHICAL CORRELATION	ACCESS	ADDITIONAL STEPS	FREQUENCY	INFORMALITY &ILLEGALITY
Plastindia Foundation (2019)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
CPMA (2020)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
OECD (2022)	Verified data based on measurements	Representative data from a sufficient sample of sites over an adequate period to even out normal fluctuations	Time period is equal to the period of study	Data from area under study	Publicly and readily available data	No additional steps involved	New data collected on annual basis	Suggest that inclusion of informal flows may be increasing the veracity
CPCB (2020)	Verified data based on measurements	Representative data but from a smaller number of sites and shorter periods or incomplete data from an adequate number of sites and periods	Time period is equal to the period of study	Data from area with similar production conditions	Publicly and readily available data	Simple calculations or conversion required (easy to repeat)	New data collected every 2-3 years	Suggest that inclusion of informal flows may be increasing the veracity

1.4 Challenges and needs for data transparency, metrics and indicators, and targets (current gaps, global best practice)

Countrywide data gathering and analysis is challenging, as there is no clear standardisation for SDG 12 and other sustainable consumption and production (SCP) related targets since many SCP-relevant activities are carried out by the informal sector. In the context of SDG 12, the MoSPI is the responsible ministry for compilation of data related to sustainable management and efficient use of natural resources. However, as per the latest report published in 2022, the ministry is yet to finalise the indicators.

Information that countries may need to report on includes plastic waste generation, import and export of plastic scrap, collection and sorting, recycling of plastic, disposal and mismanaged waste. The Global Plastics Treaty process will provide unprecedented opportunity to accelerate and scale existing national efforts to document data, followed by ensuring transparency of the process, so that there is evidence of good and standard measurement practices. These pioneering efforts by a handful of countries will serve as a key resource for establishing much of the treaty's substance to be negotiated in the months to come.

Many developing and least developed countries have already started quantifying waste flows. For example, Indonesia, Vietnam and Ghana have recently commenced measuring plastic waste flows – a thorough process engaging government, industry, civil society and academia alike with the support of the Global Plastic Action Partnership. This is an open-source national analytics tool developed together with SYSTEMIQ that has allowed the three countries to understand their plastic pollution situation and what concrete steps are needed to transition to a circular economy for plastics.

Kenya, Mozambique, South Africa, Mexico and Thailand are other examples of countries that have stepped up efforts in measuring plastic pollution with support from UNEP and the International Union for Conservation of Nature's (IUCNs) wide-ranging hotspot assessments. These assessments will also include deploying modelling functionalities, allowing countries to run projections into the future, test different strategy scenarios and understand their environmental, economic and social impacts.

Countries such as Canada, Germany and France are equally active in tracking plastic waste flows and are taking an increasingly proactive approach in sharing insights and advocating for alignment at regional and global levels.

Organisations currently supporting in-country plastic waste and pollution data collection and evaluation are UNEP-IUCN via their National Guidance for Plastic Pollution Hot spotting and Shaping Action programme and their global data platform PLASTEAX. The Global Plastic Action Partnership is doing the same with SYSTEMIQ via their National Assessment and Modelling (NAM) tool. Others include the World Bank, the Alliance to End Plastic Waste with their data platform PRISM, the University of Georgia's Circularity Assessment Protocol (CAP), UN Habitat via their Waste Wise Cities initiative, and WWF via ReSource.

With the aforementioned platforms already in place, India must connect with them to bring more international credibility to the data being generated and for a more standardised data collection methodology.

India already has some policies in place that have provided data documentation frameworks, such as the PWM Rules, 2016, and the EPR guidelines. The PWM Rules require minimising the generation of plastic waste, avoiding littering, ensuring segregated storage of waste at source, and handing it over. However, there is no framework or platform to document and provide the data associated with activities that are mandated under the rules.

The rules impose EPR on PIBOs. EPR is applicable to both pre-consumer and post-consumer plastic packaging waste. Under the guidelines, there is provision for a centralised website where producers of plastics will have to declare their annual plastic production to the government. However, this centralised platform is still in a very nascent phase, which disrupts reporting compliance by producers. EPR is inversely proportional to the size of the informal sector of the country. The success of EPR depends on the documentation of targets fulfilled, which becomes tedious considering the integral role that the informal sector plays in the Indian plastic waste value chain.

The major challenge in the data ecosystem remains to be collection methodology. Even with established systems, most organisations and countries (and sometimes provinces or cities) apply different measurement methods, often based on national or regional-specific policies or priorities. While some countries predominantly trace packaging waste or single-use plastics, others may include extra categories like industrial plastics and microplastics. Definitions of different types of plastic are another aspect where a harmonised approach is still lacking. This makes comparison across two methods or two countries difficult, thereby sometimes making analyses incomplete.

This is where a global treaty on plastics could largely alleviate these challenges by supporting countries and other documenting organisations with one consistent measurement and reporting system that builds on the insights of the world's current best-in-class methodologies. Learning current approaches undertaken by individual countries will be imperative in developing one consistent framework. Reliable plastic data could be the magic ingredient we need to ensure the transparent and accountable application of a treaty.

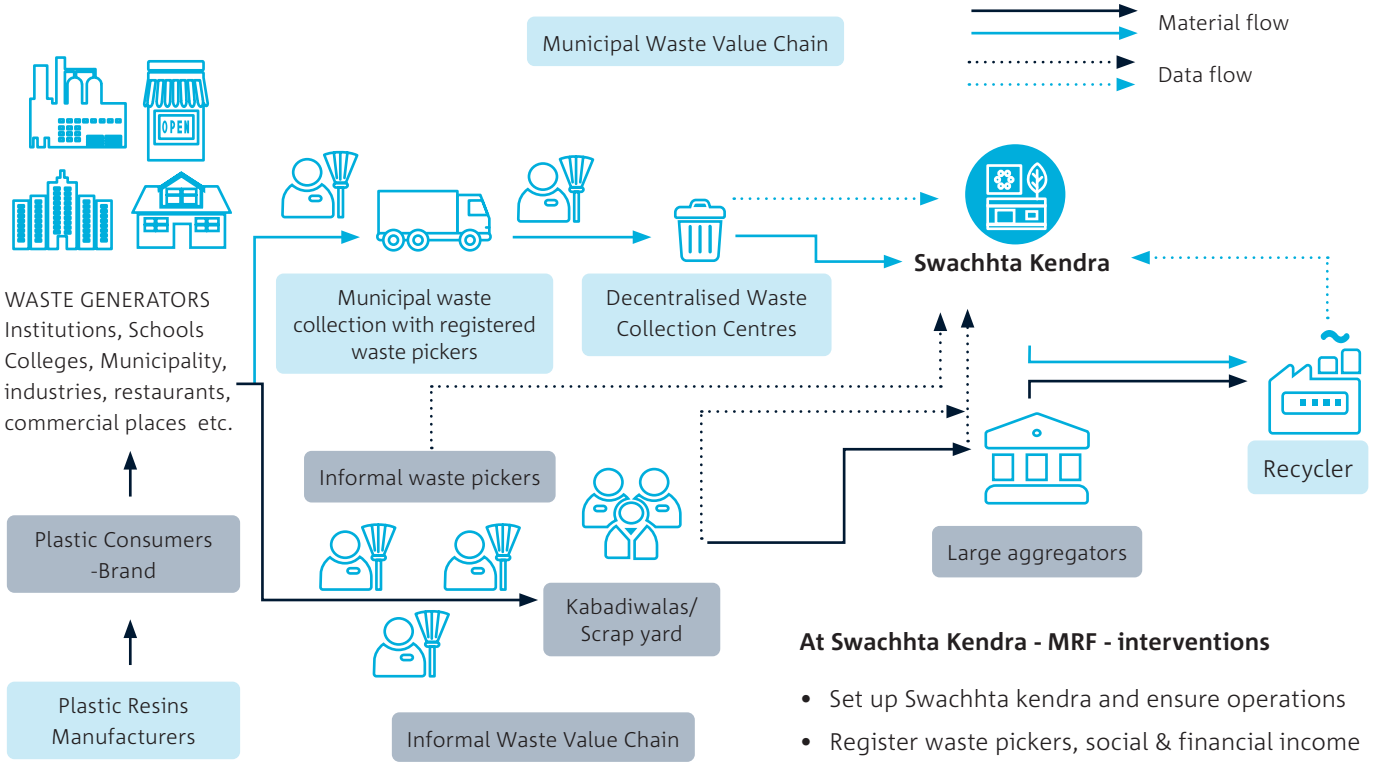
A global standardised methodology seems to be a farfetched option in the current scenario. What we need in the Indian context is a standard collection and reporting framework accepted by all national, state and city level agencies.

1.5 Barriers to implementation in India

Informal sector

For the initial implementation of any guidelines or rules and its subsequent effectiveness, relevant and organised data related to the sector is paramount. Considering the plastic waste value chain in India and the undeniable presence of an unorganised informal sector, data availability poses a major barrier to orderly implementation of guidelines, thus reflecting on overall transparency.

Materials flow – waste value chain: Swachhta Kendra (MRF)



At Swachhta Kendra - MRF - interventions

- Set up Swachhta kendra and ensure operations
- Register waste pickers, social & financial income
- Ensure operations
- Data management and financial inclusion of kabadiwalas /scrap yard and aggregators
- Data management ,reporting and traceability

Figure 1.1 Formal and informal ideal waste value chain in India

Figure 1.1 inspired by Figure 6 in NITI Aayog – UNDP Handbook on sustainable urban plastic waste management (2021)

The informal sector, dominated by unregistered waste pickers and rag pickers, contributes significantly to the plastic waste value chain. They are present and constitute a large percentage at each stage of the chain. While there is scope for tracking data along formal movement, a huge amount of data gets lost along the informal movement of plastic.

In Figure 1.1, the informal waste value chain presented is actually the ideal case scenario. However, in reality, such a chain of events is not observed. Instead, waste picked up by rag pickers often ends up as street litter, which eventually becomes a Garbage Vulnerable Point. There is no tracking mechanism for incoming and outgoing flows associated with the informal waste value chain, hence such massive numbers are either unreported or are assumption-based, which never gives a clear picture. Also, efforts to bring informal players into the formal system to-date have not been completely successful. The prime responsibility for bringing such a change is largely on local authorities, well supported by state and central governments along with local civil society organisations. This is important for an efficient top to bottom flow of information, that is, from local authorities to state level and further to the central level.

Technology

Plastic recycling technologies for various types of polymers are still a grey area for the plastic recycling scenario in India. For instance, the PET recycling rate in India is comparatively high, compared to other countries, due to a higher collection rate of PET by all categories of waste pickers (registered and unregistered). This is because of the high monetary value associated with PET. This high rate of recycling and value associated with PET translates to the technology available for its recycling and results in significant demand from recyclers. Hence, to upscale the recycling scenario to other polymers, substantial technology upgradation is required, which at the same time is accessible and affordable to on-ground recyclers.

Information and awareness

Another crucial barrier is awareness among waste generators about the magnitude of the issue. Lack of knowledge and incentive among households about the importance of segregation and outcomes of waste collected are issues that potentially leave these primary waste generators entirely out of the system. Once they are on board, household-based data could solve the first step of data lacunae, which could then help fill gaps further into the process.

Compliance mechanisms for existing policies

At the industry level, there are rules in place empowering pollution control boards to undertake periodic audits and inspections to check compliance of PIBOs and waste processors, however, there is no inventory of their total number. Thus, questions remain about what fraction of total plastic waste the EPR targets represent. It is only now, through disclosures on the portal, that authorities are hoping to gauge the quantity of plastic packaging material introduced in the market by PIBOs.

The pollution control board is also expected to carry out a compositional survey of collected mixed municipal waste to determine the share of plastic waste, as well as of different categories of plastic packaging material on a half-yearly basis, as per the EPR guidelines.

1.6 Possibilities in the Indian context

There is a lot of focus on technology for waste treatment, as technology is an important cornerstone in all stages of the waste value chain, covering traceability, accountability and digital governance. Mobile phone apps can be developed for this purpose and can be used by various stakeholders such as waste pickers, recyclers, ULBs and citizens in order to integrate everyone into one digital cloud. This would enable access to real-time data from the field to track the integrated plastic waste supply chain right from the point of collection to the end recycler. It would also help address PWM compliance mandated by the CPCB and State Pollution Control Boards (SPCBs).

Dedicated agencies like municipal corporations must go beyond their expected responsibilities of waste collection, segregation and treatment. They must work towards bridging knowledge gaps among waste generators so that households can be included as the first stakeholder in the data ecosystem. India, as a society, is very community-driven and thus incentives like words of appreciation, decreased collection fees in localities, and formalisation of informal players for elimination of Garbage Vulnerable Points can help to sustain positive behaviour in the long run. This will ensure that household-level waste moves only through established flows, thereby eliminating data mismatch.

Once an efficient plastic value chain is developed, a unified digital platform should be considered as an option. This would work as an extensive database to track, monitor and organise waste collection and processing efforts.

India is a member of the United Nations Environment Assembly (UNEA). With a total of 124 countries as signatories to UNEA, India is part of a resolution to draft an agreement that will make it legally binding for signatories to address the entire lifecycle of plastics, from production to disposal. To ensure that such an effort is successful when implemented, India must immediately work to develop its data infrastructure, focusing specifically on standardised methodology and data tracking systems at each stage of the plastic value chain. Existing data and policy infrastructure must be utilised fully to achieve such an outcome. The MoEFCC has already notified guidelines on EPR for Plastic Packaging early in 2022. Plastic Waste Processors (PWPs) have been given specific mandates under the guidelines and they are to register themselves on a centralised EPR portal developed by the CPCB. PWPs already registered with the SPCBs and Pollution Control Committees are also required to register on the EPR portal. It is important to note that only PWPs that are registered on the portal will be able to issue certificates for plastic waste processing. This will be considered as fulfilment of EPR obligations by PIBOs, which are also required to be registered on the same portal. As per the CPCB's Annual Report of 2019-20 (CPCB 2020), there are 4,953 registered units engaged with plastic in 30 states/UTs in India. This includes 3,715 plastics manufacturers or producers, 896 recyclers, 47 manufacturers of compostable plastic and 295 manufacturing multilayer plastic. Streamlining data coming out of these entities and developing a solid database should be the starting point of India's unified plastic data portal.

1.7 The way forward

Technology-related investments in digital waste management tools such as GPS-enabled tracking for vehicles or image recognition tools are required. These tools can leverage the IoT and AI technology for enhanced performance during uncertain situations. Data analytics is another opportunity where investment can play an important role in moving towards digital maturity and helping to improve plastic collection and recycling rates.

Simultaneously, data transparency is required to build a circular plastic waste value chain. This could be achieved via a unified digital platform where information linked to the data, and the justification related to it, is provided along with the completeness of the data associated with the sector. Instead of just providing the numbers, transparency could be improved by stating the methods of data collection and its completeness, which would translate to how veritable the quoted numbers are and where gaps are required to be filled through assumptions and calculations. Data transparency will lead to the implementation and formalisation of substantial policy making, guidelines and rules and will also simplify the process of identifying defaulters in the value chain, eventually helping the transformation to circularity of the sector.

In addition to basic data collection, the quality of data collected needs to be reliable. Taking into consideration the various types of polymers produced and their categories, the current data available is not up to the mark of categorical distribution, leading to the incorrect estimation of mismanaged waste.

Considering the complexities of the plastic waste value chain, data integration continues to be a major challenge. There are unified platforms/portals in progress or proposed to facilitate data integration across the plastic waste value chain. This calls for future investments on data integration and reporting infrastructure for driving data sustainable business practices along the production and consumption value chain.

Short-term priorities (to 2025)

- Under the Swachh Bharat Mission, municipalities are periodically collecting and collating data on the volume of waste generated and collected. However, there are limited efforts in undertaking assessments of waste composition and characterization. Accelerate the adoption of such practices by all states in a time bound manner.
- Plastic waste processing capacities and actual processing of collected waste across different states to be mandatorily reported on an annual basis. This will help in tracking capacity distribution and capacity increase across states in tandem with plastic waste generation.
- As identified above, the key challenge in the data ecosystem had been the harmonization/standardisation of the data collection and compilation. The CPCB must issue data collection and reporting guidelines, particularly on the plastic waste share of the total waste generation, frequency/periodicity of assessment, plastics classification by types etc.
- Polymer and/or plastics manufacturing process rejects may often be recycled, however, the type of rejects, volume and extent of recycling are unknown. The EPR portal can and should provide data related to percentage of process rejects recycled as furnished by PIBOs, as well as recyclers.

Medium-term priorities (to 2030)

- Mobile phone apps need to be developed and used by stakeholders, including manufacturers of polymers, plastic waste pickers, recyclers, ULBs and citizens, to integrate stakeholders into one data platform.
- More granular tracking is needed, which will enable better sorting throughout the value chain, reducing contamination.
- Government to support and facilitate channelling investments into the smart waste ecosystem, leading to digitization of the plastic waste sector.
- Incorporating periodic third-party audits as a part of a compliance mechanism.
- Using a data-led approach to increase consumer awareness.

Long-term priorities (beyond 2030)

- Integration of all production, consumption and end-of-life management data of various polymers into the NITI Aayog SDG Index and Dashboard.

An Innovation Hub could be a mechanism to support India's transition to a circular economy for plastics

Transitioning to a circular economy will be aided by innovation – all along the plastic supply chain. An Innovation Hub is a platform that supports transforming promising ideas into impactful, real-world solutions and can be a key mechanism in India's shift to a circular economy for plastics.

An Innovation Hub in India would involve:

- Collaboration between researchers, NGOs, SMEs, start-ups, Government, industry and investors.
- Leveraging existing funding and attracting new investment.
- Rethinking the way plastic is created, used and managed, as well as the management of plastic waste.
- The housing and development of a compendium of plastic recycling technologies, providing information, current innovations and recent technological developments in the sector.
- Both technology innovations and social innovations.

Benefits of an Innovation Hub in India:

- Could house best practice examples from across India.
- A boost in capability in the plastic innovation ecosystem.
- Enhanced stakeholder collaboration.

2 Policy frameworks for a circular economy for plastics in India

2.1 Introduction

This chapter examines the dynamically evolving policy framework relevant to plastics management in India, with the intention of supporting the transition to a circular economy for plastics. The analysis is based on stakeholder perspectives of the effectiveness and gaps in policy design and implementation for a circular economy for plastics in India. A framework adapted from Dovers and Hussey (2013, Table 2.1) was used to categorise the research findings. This research builds on a previous review of the policy frameworks for a circular economy for plastics in India, which was published by the project team in December 2021 (Talwar et al., 2021).

Previous research from this project revealed that most policies and institutions in India addressed the consumption, waste generation and resource recovery phases of the plastics value chain, with inadequate policy guidance for upstream efforts to support sustainable production and reduction, or the expansion of alternatives to single-use plastics. The vast majority of policy instruments focused on end-of-life management, including recycling and reprocessing activities. Some subnational policy instruments such as the Goa Resource Efficiency Strategy (2020) reflect recent advances in formalising a circular economy plan for a state, demonstrating diverse stakeholder consultation.

Table 2.1 Adapted framework based on Dovers and Hussey (2013)

INSTRUMENT CLASS	MAIN INSTRUMENT AND APPROACHES
Monitoring and evaluation	Measurement of EPR effectiveness, data transparency, environmental or social impact assessment, risk assessment, lifecycle assessment, and statutory monitoring requirements
Market mechanisms	GST, other taxes/charges, subsidies, rebates, penalties, supporting expansion of CBMs, technology incentives and support, efficiency in production/recycling, financial incentives to expand the use of alternative materials or reduce the use of virgin polymers, and intellectual property support and processes to enable research commercialisation
Standards	E.g., Bureau of Indian Standards (BIS), labelling, international treaties and standards (e.g., Basel Convention, Stockholm Convention on Persistent Organic Pollutants treaty)
Consultation	Mediation, negotiation, dispute resolution, inclusive institutions and processes, inclusiveness for informal sector actors and institutions, and consultative policy design
Research and development	Increase knowledge generally (basic research) or specifically (applied research), with the aim of informing the setting of a goal or standard; developing technologies or practices; establishing socioeconomic implications; and monitoring environmental conditions, human development, or policy impact
Information and communication	Research findings leading to policy as well as policy imperatives leading to research aiding information flow to firms, agencies, and individuals. Mechanisms include sustainability indicators, state of the environment reporting, natural resource accounting, community-based monitoring, environmental auditing, and mechanisms for consultation or policy debate
Community involvement	Participation in policy formulation; freedom of information laws; rights to comment on development proposals; community-based monitoring; community implementation of programs; cooperative management; community ownership and management, citizen engagement, education and awareness

Figure 2.1 maps a typical flow of activities for municipal waste management in the country. Using the example of the PWM Rules, state governments and UTs are required to establish a state-level advisory committee, whereby the Secretariat responsible for Urban Development enforces the PWM rules (in rural areas, this responsibility lies with the Gram Panchayat). As per the PWM Rules, entities involved in plastic manufacturing and recycling can conduct operations only after registering with the respective SPCB or the CPCB, depending on their geographic scope.

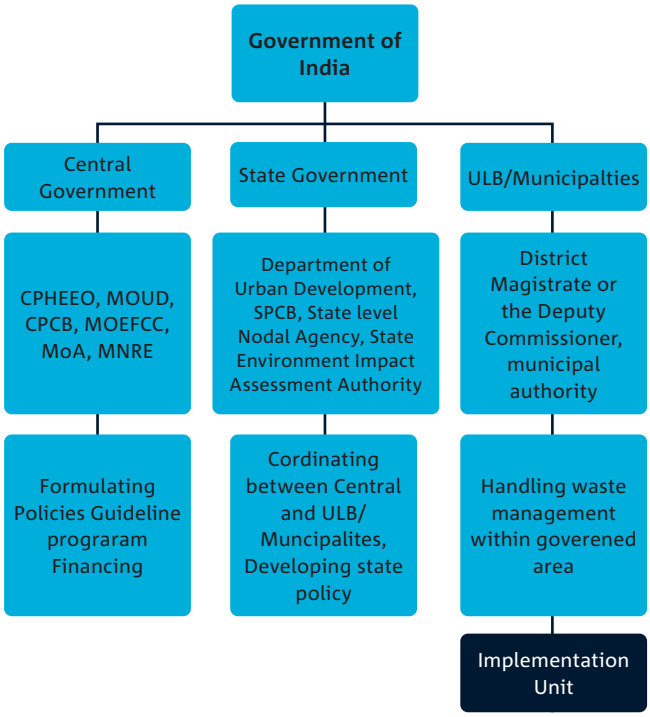


Figure 2.1 Municipal Waste Management in India

Source: Priti and Mandal (2022)

Table 2.2 Stakeholder roles for EPR in India

Source: Pani and Pathak (2021)

KEY PWM STAKEHOLDERS AND THEIR RESPONSIBILITIES		
NO.	**PWM STAKEHOLDERS**	**KEY RESPONSIBILITIES**
1	Pollution control boards (CPCB and SPCBs)	• Overall EPR implementation • Stakeholders' registration and certification • Create and manage technology platform • Set targets and impose penalties
2	Producers, importers, brand owners	• Overall PWM responsibility • Plastic credit mechanism • Compliance reporting to CPCB/SPCBs • Co-ordinating and funding of PROs
3	PROs	• EPR planning • Capacity building of waste value chain • Material flow through value chain • Waste processing
4	Independent processors	• Waste processing including collection from ULBs, segregation, and recycling
5	Local bodies (ULBs or Gram Panchayats)	• Demarcate locations/area, set up infrastructure and access funds from various sources for PWM • Ensure source segregation and collection • Create citizen communities and allocate human resources • Co-ordinate with PROs/independent processors and review progress
6	Retailers and street vendors	• Consumer awareness • Provide dustbins for waste disposal • Ensure that plastic waste enters appropriately into PWM value chain
7	End users (institutional or individual waste generators)	• Minimize waste generation by reduced consumption, following sustainable disposal methods, and putting public pressure on producers • Ensure that waste produced is directed correctly into the PWM value chain • Segregation at point-of-disposal

Local governments are directly responsible for implementing waste management policies, whereas a ULB is responsible for waste management within their jurisdiction. India follows a bottom-up implementation structure; thus, successful policy implementation requires good infrastructure, budget, skill and staff motivation within a ULB, coupled with active community engagement. Some interesting examples of local action to address plastics pollution are in the state of Himachal Pradesh, where a buy-back scheme (Vasudeva, 2022) and technology solutions to identify single-use plastic dumping sites near water sources were introduced (The Times of India, 2022). Another state, Tamil Nadu, banned 14 types of single-use plastics on 1 January 2021, and the district of Nilgiris within the state has successfully eliminated single-use plastics since 2000. Table 2.2 outlines the stakeholder roles for EPR regulations within the country.

2.2 Methodology

From January to August 2022, the research team conducted in-depth interviews with stakeholders in India comprising think tanks, local, state and federal government actors, policy makers, academics, industry peak bodies and community organisations (Table 2.3). The aim of these interviews was to assess perspectives about the effectiveness of current policy, challenges and gaps needing to be addressed, as well as strategies to improve implementation and effectiveness, in order to drive a circular economy for plastics in India. Previous research by this group had identified gaps in policy design, taking a plastics value chain perspective, noting the need to assess barriers and enablers for effective implementation of policy alongside the institutional and technical levers to support a just transition.

Table 2.3 Stakeholders interviewed in this research

STAKEHOLDER GROUP	NO. OF INTERVIEWS
Think tanks	4
Industry bodies	3
Academia	3
Central ministry	2
State-level entity	2
International multilateral organisations	2
Urban Local Body	1
Total No. of interviews	**17**

2.3 Current policy landscape

The PWM Rules 2022 set targets for PIBOs of plastics, who were expected to take back 25% of their material by 2021–22, followed by 70% by 2022–23, and 100% by 2023–24 (PWM Rules, 2022; Shah, 2022). The targets rely on the presumption that collection systems will be in place, or that producers who have failed to meet their obligations under the PWM Rules 2016 will now comply. However, no formal guidance is available for actors to be able to achieve these targets (Shah, 2022). A gap exists in the integration of informal sector recycling activities into formal systems (Talwar et al., 2021).

The draft E-waste (Management) Rules Amendment 2022 assigns the CPCB the responsibility to implement EPR. A wide range of electronic goods are to be covered under the legislation, including laptops, landline and mobile phones, cameras, recorders, music systems, microwaves, refrigerators and medical equipment. The E-waste Rules also stipulate e-waste recycling targets of 60% by 2022–2023, 70% by 2023–2024, and 80% by 2024–2025, with importers of used electrical and electronic equipment requiring 100% EPR for imported materials at the end-of-life if the materials are not re-exported.

The EPR certificate offsets and environmental compensation scheme will be administered by the CPCB. The environmental compensation scheme will be applied when PIBOs have not met their EPR obligations. PIBOs will be required to submit annual reports about their performance against targets, using an online portal via the CPCB. However, the lack of third-party auditing or independent verification of the reporting, as well as the fact that producers and brand owners will be able to seek refunds or compensation, which is intended to be a penalty, has raised doubts about the operational practicalities and effectiveness of this approach (Shah, 2022). Another gap is that the certification schemes only apply to registered recyclers and processors, which represent formal recycling institutions, and thus preclude India's vast informal sector activities.

One of the most controversial elements of the amendments is the shift away from using PROs. The PROs were previously designed to be a key actor in the E-waste (Management) Rules 2016, as intermediaries between manufacturers of electronic goods and formal recyclers. The Draft E-waste Rules 2022, instead, vest all recycling responsibility with authorised recyclers, which has generated criticism about the vast network already established by PROs, as well as the associated job losses and their role in driving business and community education programs. Such a move also reflects the general inconsistency in policy directives, which adversely impacts business and consumer confidence, a recurring theme that also came up in the interviews.

What is working well

National policies such as the Swachh Bharat Mission, PWM Rules, single-use plastic bans in different states, draft National Resource Efficiency Policy, Smart Cities Initiative, and BIS and International Organisation for Standardization (ISO) standards provide guidelines for plastic use and packaging in India. Multi-dimensional policy instruments, such as the Swachh Bharat Mission and the Swachh Survekshan, are notable in driving citizen engagement and awareness generation for issues related to solid and PWM. The stakeholder analysis revealed that current policy was effective in achieving certain economic, social and human health outcomes, evidenced by the following themes:

- Successful grassroots policy implementation;
- Uniform framework for EPR;
- Training and capacity development for awareness and education;
- Investment in research and development; and
- Advances in standards and certification for effective market creation.

Successful grassroots policy implementation

India's approach to managing plastic pollution is evident through the PWM Rules and multi-faceted citizens' programs such as the Swachh Bharat Mission, Swachh Survekshan (which provides an annual ranking of cities' performance against Swachh Bharat Mission targets), and a proliferation of localised tracking and aggregation platforms such as Recykal, to integrate activities of the formal and informal sectors in waste collection and management.

The main focus of the Swachh Bharat Mission, launched in 2014, has been to eradicate open defecation in the country, build toilets and sanitation facilities, increase women's hygiene, and improve solid waste management awareness and practices. Under Swachh Survekshan, an annual survey of urban and rural sanitation and cleanliness is undertaken, which is now considered a useful tool in implementing plastics regulations involving ULBs, municipalities, citizens and community organisations. Swachh Survekshan has been successful in increasing participation by cities. 4,355 cities participated in 2022 compared with just 73 in 2016 (MoHUA, 2022). According to the 2022 results, Indore is the only city in India to have achieved 7-star certification, with Surat, Bhopal, Mysuru, Navi Mumbai, Visakhapatnam, and Tirupati ranking 5-stars (MoHUA, 2022a). [5]

Case study: Practice to policy design

Hasiru Dala, a grassroots organisation, has demonstrated the concepts of decentralised waste management, EPR, dry waste collection centres and MRFs in Bangalore city since 2011. They were pursuing decentralised waste management even before the model was formally recognised in the PWM Rules in 2016. Hasiru Dala's successful implementation of dry waste collection at ward level, endorsed support from the city to provide adequate infrastructure. Today, Bangalore city has a successful model of working with waste-picker collectives to manage the dry waste collection centres. In 2019, the state government of Karnataka expanded this model state-wide.

Case study: Effective implementation of plastic rules in Goa

The state of Goa and its ULBs have demonstrated excellent progress in implementing plastic waste regulations through the creation of good infrastructure, capacity building programs and training for waste management officials, supported by awareness campaigns for citizens. The state is also progressing EPR implementation through the creation of a nodal agency, Goa Waste Management Corporation (GWMC). GWMC's primary function is to secure and assist the establishment of facilities for the scientific management of various types of waste in Goa. Along with training local bodies on all waste-related matters, GWMC also assists in policy formulation through active stakeholder consultation. A segregation rate of 85% was reported in the state.

Beginning with two-way segregation of dry and wet waste, the capital city of Goa, Panjim, now segregates waste into 16 different types. The city initiated a Shop With Your Waste campaign in 2020, where the citizens are able to purchase daily commodities in exchange for dry waste in predetermined shops. The campaign mimics a barter system for recyclables and the shop owner receives a handling fee to provide clean recyclables to recyclers. The city has also banned various single-use plastics with ample availability of alternatives. Under the Smart Cities Mission, Goa has deployed several waste management tools, such as Radio Frequency Identification (RFID) tags at waste generators, to help with real-time tracking.

5 See more at https://sbmurban.org.

Uniform framework for Extended Producer Responsibility

The MoEFCC initiated a uniform framework for EPR in June 2020 under the PWM Rules, 2016. The framework was further amended in 2022, to provide EPR, recycling, end-of-life disposal, and use of recycled content targets for PIBOs. Under the uniform framework, waste management policies have become more producer-centric, compared to ULB-led waste management previously. Given the socioeconomic and environmental diversity of India, the framework recognises that a single EPR model is not feasible. Instead, three different models have been set forth for PIBOs: i) Fee-based model, ii) PRO-based model, iii) Plastic credit-based model.

Fee-based model: The primary responsibility for managing plastic waste rests with the ULB. PIBOs are required to pay a fee to the central EPR corpus fund. This account will be managed by a Special Purpose Vehicle (SPV), a legal entity created to carry out the specified activity. The fee is determined based on the normative cost to ULBs for managing the waste.

Producer Responsibility Organisation (PRO)-based model: On behalf of the PIBOs, a certified producer responsibility organisation is recruited to manage end-of-life products. The framework suggests a fee per kilogram for different plastic types. The model also allows ULBs to act as PROs if they have the infrastructure to process plastic waste.

Plastic credit-based model: Although manufacturers are not required to collect plastic waste, they are required to recover and recycle comparable quantities of waste. This model allows producers and recyclers to pre-set terms based on which plastic credits may be applicable.

Although PIBOs are able to decide on a suitable EPR model, there is a requirement to submit volumes of waste processed using accredited processors (MoEFCC, 2020). The framework proposes a phased approach to achieve targets and PIBOs are able to update progress using the MoEFCC portal.

Training and capacity development for awareness and education

With relevance to consumers and the larger community

Since the 2016 amendment of the plastic waste regulations, there have been many initiatives to create consumer education and awareness. While most Indian cities have implemented dry and wet waste segregation, NITI Aayog (2021) identified some cities such as Alappuzha (Kerala), Panjim (Goa), and Indore (Madhya Pradesh) where active community awareness and engagement have helped achieve better segregation outcomes (Sirur and Bikhchandani, 2021). Initiatives led by civil society organisations targeting schools and the youth have been well received. An online portal, Swayam, through the Ministry of Education, provides PWM education for university students and professionals.

With relevance to ULBs and waste management personnel

Under the Swachh Bharat Mission, the Government of India offers administrative and technical training to ULB staff. States such as Goa undertake regular training for waste-related matters. NGOs and community service organisations are aligned with ULBs to facilitate capacity building, hotspot mapping and leakage assessment, as well as the development of management plans for ULBs.

With relevance to other stakeholders

Initiatives are underway to educate actors within the plastic industry and users in the tourism and hospitality sectors where demand for plastic products is high, in order to better manage disposal, and reduce plastic pollution and marine litter. Informal sector actors are an integral part of India's waste management landscape and receive training in scientific waste management from ULBs and NGOs, with multiple initiatives under way to connect the disparate activities with formal recyclers, to create equitable economic, social, and human health outcomes for the informal sector.

Investment in research and development

There are efforts by the government and other stakeholders to adopt and develop indigenous technologies to improve policy implementation. Academic institutions and multilateral organisations such as UNEP are investing in scientific research to assist in developing evidence-based policy initiatives. UNEP is also collaborating with the MoEFCC to develop and commercialise SUP alternatives. The Department of Science and Technology also offers research funding for plastic alternatives. Other localised initiatives are being promoted, such as the conversion of secondary materials into paper blocks, tiles, roads and construction materials.

Case study: Technological innovation for better waste management

In 2020, Bruhat Bengaluru Mahanagara Palike (BBMP) adopted multiple ICT solutions to monitor waste management in the city and improve coordination among different waste stakeholders. The city has introduced a Radio Frequency Identification (RFID) based attendance system and geo-tagging of collection routes. Hot spots are monitored, and violators penalised using a mobile application called Ezetap. The BBMP has been able to successfully eliminate waste hotspots and achieve 100% door-to-door waste collection through effective adoption of ICT-based technologies (NITI Aayog, 2021).

Advances in standards and certifications for effective market creation

The Government of India introduced the first eco-labelling standards, 'Eco-Mark', in 1990 for product categories including plastic products for easy identification of environment-friendly products. The PWM rules also refer to BIS standards for compostable plastic products, including guidelines for recycling plastic products and labelling.[6] In 2021, the PWM (Third Amendment) rules and Food Safety and Standards (Labelling and Display) approved the use of recycled plastic in food contact packaging which, despite worries about unscientific recycling practices by the informal sector, was considered to be a big win to help expand the markets for recycled content in packaging.

2.4 Gaps in current policy

India has numerous statutes for handling waste, with distinct rules for different waste streams. Despite regular amendments to PWM regulations and EPR, there is weak integration of circular economy principles. The CPCB, SPCBs and municipalities are concerned with public health issues of waste and pollution rather than resource value. While there is an attempt in current EPR models to create demand for recycled polymers, they mainly support efficient recycling and cost viability, rather than promoting models for reuse.

A general gap exists in the inconsistency of definitions and messaging across different policies and initiatives, causing apprehension among the business community and consumers. The research showed that implementation of the PWM Rules and EPR was poor in many parts of the country due to weak source segregation, inadequate infrastructure, and unavailability of reliable alternatives to plastic. Despite the informal sector's major role in India's waste management, no formal mechanisms to recognise their activities or to build capacities or provide adequate security and compensation exist. There are ample social and human health risks that merit urgent attention but have not been adequately addressed by recent policy amendments. In terms of training and awareness programs, waste-related messaging is adapted to local languages, given India's diversity, yet neither the messaging nor the medium is tailored to suit the needs of the informal sector (Niazi et al., 2021).

Lastly, this research found that policies need to address the expansion of CBMs for sustainable consumption, for example, container refills and reuse businesses, and that the vast and informal local repair economy is absent from policy initiatives. Stakeholder analysis reveals the following gaps in current policy:

- Lack of integration between formal and informal sector activities.
- Need for capacity building to improve implementation and monitoring.
- Need for incentives to expand markets for plastics alternatives.
- Lack of effective monitoring and data transparency.
- Need for standards and certifications for better product design.
- Need for multi-stakeholder consultation and cross-sector collaboration.
- Ineffective policy design, e.g., EPR regulations that do not address design and production.

6 Indian Standards – Guidelines for recycling of plastic

Lack of integration between formal and informal sector activities

In India, the informal sector comprises not just waste pickers but also a large number of recyclers who operate informally. They are often not included in formal compliance systems and lack legal status. The reality is that informal waste collectors in India provide an invaluable door-to-door collection network, yet this sector's activities are excluded from formal policy support and recognition.

There are also self-perception issues and a weak understanding of the forms of integration that would be most meaningful to the sector. Moreover, mechanisms to improve the informal sector's health, hygiene and social status are largely absent in current policy frameworks, with calls for a just transition.

Often in national level plastic pollution deliberation forums, the informal sector is represented by a high-level representative who might not be able to effectively communicate the on-ground challenges.

'The central authorities are silent on the elephant in the room – the informal sector.'

'The informal sector consider themselves to be part of an illegal activity.'

'Any discussion impacting their activities must occur in active consultation with the informal sector actors directly to ensure there is a just transition.'

Case study: Pune Municipal Corporation (PMC) – SWaCH Cooperative Model

The PMC signed a Memorandum of Understanding with SWaCH, an informal waste-picker cooperative, in 2008. The primary function of SWaCH is to provide door-to-door waste collection and other waste management services. Apart from covering SWaCH's administrative costs, PMC also provides access to waste and equipment that are necessary to fulfil its responsibilities. The waste pickers are paid a service fee and are accountable to both the PMC and its residents. The waste pickers sort and sell the recyclable materials they have collected from houses, which provides an alternative revenue stream for them. Non-recyclable waste is disposed of at designated points in the secondary waste collection system. The cooperative has designated coordinators to ensure the receipt of service fees, redress grievances, and provide value-added services like composting and e-waste collection. SWaCH is the best example of effective implementation of waste regulations, inclusivity of the informal sector, and just transition (ESCAP, 2019).

Need for capacity building to improve implementation and monitoring

Waste management is a responsibility of ULBs, mandated through the 74th Constitution Amendment Act, 1992. However, Prasad and Pardhasaradhi (2020) indicate that states are reluctant to extend the financial and functional autonomy of ULBs, thereby restricting enforcement powers of ULBs. Additionally, many states and ULBs lack the technical skill and physical capacity to manage waste issues. Based on the results of the Swachh Survekshan, it is observed that often big cities are rewarded but smaller or slow-performing cities are left wanting feedback and support to improve capacity. There are calls for cities to be offered equal opportunities and cross-learning opportunities.

Compliance monitoring in a massive country like India, with many PIBOs, and consumers, is a big challenge as the country lacks solid monitoring mechanisms and appropriate application of technological systems. Although there is a central reporting portal for reporting plastic data, there is weak reliability of the accuracy of data. Inadequate staffing in government offices makes effective monitoring a glaring challenge. There is a need to assign responsibility to all stakeholders, including ULBs, and need for a system to enable penalties for violators. A shared vision and a shared understanding of resource circularity across all stakeholders would go a long way in the design of data collection and management systems to support innovations in waste reduction, resource recovery and recycling.

Need for incentives to expand markets for plastics alternatives

Despite the SUP bans across most states in India, single-use polyethylene bags are rampant owing to weak economically and environmentally sustainable alternatives. Plastic alternatives are found to be either expensive or inconvenient, which discourages wide-scale adoption. The research identified a need for greater collaboration between academia and industry to commercialise technical solutions for reducing plastic use. More financial and technological backing is needed to expand the footprint of indigenous technologies and businesses, to make them globally competitive.

Another challenge with plastic alternatives was the lack of cost parity between plastic bags and paper bags as a barrier to adoption, especially for small/informal businesses like local/street-side vegetable vendors. There is a role for 'standards' and 'regulations' in setting the baseline, and further enablers in terms of market mechanisms and infrastructure are needed to support industry to adopt alternative materials.

Rather than uni-directional bans, the government must actively consult with industry to design policies that support a just transition. Formalised programs and incentives are required to upskill and educate industry actors, along with encouraging market demand for alternative and secondary materials. For example, India was able to catalyse local renewable energy generation and demand to make the industry cost competitive compared to coal-fired power generation.

Lack of effective monitoring and data transparency

India has several reporting systems, but none give clear-cut information on environmental, economic, and social consequences. Baseline estimates for pre-regulation status are absent, making it difficult to measure post-regulation environmental, social, and economic benefits. Quantitative assessment and auditing exercises to estimate the quantity of waste produced, collected, post-collection status, and the quantity of products made of recycled materials is absent in current systems. Hence, self-disclosure reports provided by states, ULBs, and private parties are not fully reliable. Benchmarks to assess performance, including target setting through policy and annual reporting, are needed to measure progress. With the central reporting platform under way for EPR reporting, maintaining the robustness of data while ensuring effective implementation could be a significant challenge in the absence of adequate monitoring and benchmarking systems.

The need for standards and certifications for better product design

Recently, the PWM (Third Amendment) Rules, 2021, and Food Safety and Standards (Packaging) Regulations, addressed the use of recycled plastic in food contact packaging.[7] However, there are concerns in the scientific community as most recycling is carried out by the unregulated informal sector using unscientific processes, often resulting in contaminated recycled materials flowing into packaging. The PWM Rules Amendment, 2021 received criticism from scientific experts and environmentalists, who argued that standards for plastic recycling needed to be laid out and any directives to use recycled plastic should be considered in the context of food and health safety[8] from plastic food packaging, also requiring involvement of the food sector (Ujaley, 2022). Currently, there is no standardisation of recycled plastic products or recycled plastic polymers, mainly because these are handled by the informal sector.

The need for multi-stakeholder consultation and cross-sector collaboration

The current regulations do not adequately reflect crossovers between different sectors in the plastics value chain. Most policies focus on plastic waste, resulting in an absence of dialogue with the petrochemical industry to influence reduction strategies. To achieve systemic change driven by a circular economy for plastics, various ministries such as finance, environment, industry and commerce, and skill development, need to engage with industry, small-scale recyclers and the informal sector. Industry expects clear frameworks, timeframes and guidelines to drive implementation. Further, Indian industry is not always proactively involved in policy design, hence extra effort is needed to ensure ongoing consultation and multi-stakeholder dialogue.

Ineffective policy design, e.g., EPR regulations lack aspects of designing for the environment and minimising production

EPR in India currently targets mostly small-scale plastic processors and manufacturers whose activities are highly fragmented and informal, whereas polymer manufacturers are few in number and mostly large firms. Targeting policy incentives to include polymer manufacturers will have much more impact downstream, rather than starting with the downstream, which is a symptom, not the cause of the prevalence of plastic in the economy.

The scope of EPR needs to expand beyond direct producers, for example, to bulk consumers such as IT companies who are large users of electrical and electronic products. Further, EPR regulations need to acknowledge informal

7 Plastic Waste Management (Third Amendment) Rules, 2021

8 Reports from the Food Packaging Forum found high levels of contaminants, such as pesticides, rare earth elements, flame retardants, and other substances, to be able to transfer from plastics into food (Singh, 2021; Parkinson, 2021).

waste actors, as waste management is one of the most prominent sectors for the informal economy (e.g., in Bangalore city, 3,500 tonnes of plastic are traded daily, with the informal sector at the core of operations).

2.5 What could be done to further the circular economy?

Countries across the world are investing in innovative solutions to tackle the plastics challenge. Interventions range from EPR, plastic taxes, bans on plastic bags and microbeads in cosmetic products, to using plastic waste in constructing roads and co-processing in cement factories. A Global Plastics Treaty to eradicate plastic pollution by 2025 was agreed in Kenya in March 2022, by 175 UN member countries, including India. The pact is expected to include provisions for the entire lifecycle of plastics, spanning manufacturing, product design, use and end-of-life management (Prakash, 2022).

In March 2022, the European Commission proposed Ecodesign for Sustainable Products Regulation (ESPR) as a part of the Sustainable Products Initiative (SPI) under the European Green Deal (Anthesis, 2022). The proposal establishes a framework for the design of specific product groups to make them more circular, sustainable, and environmentally responsible by enabling them to be more durable, reusable, recyclable, and upgradable. It introduces the idea of a 'Digital Product Passport' that makes it possible to access information about a product's environmental sustainability. It facilitates repairs and recycling, and provides increased transparency about a product's life cycle impact on the environment, helping consumers and businesses make informed purchase decisions (European Commission, 2022). Such an Ecodesign approach will be valuable in India.

Taxation and finance are important instruments to facilitate market creation for alternatives, while reducing dependence on SUPs. For example, Ireland enacted the 'PlasTax' – a levy on plastic bags at retail points in 2002. Aiming to prompt consumer behaviour change, the tax was set six times higher than the projected willingness to pay. Ireland saw a more than 90% decrease in plastic bag use within a year of the tax's implementation. The proportion of plastic bag waste in national waste reduced from 5 percent in 2002 to less than 1 percent in 2004 (Convery et al., 2007). The Irish levy on plastic bags exemplifies the importance of broad public support for the successful implementation of policy tools. Other examples of combating plastic pollution through taxation include France's regulation on increased VAT on non-recyclable bottles, increased tax on sending waste to landfills, and subsidised tax on recycling operations (Rush, 2018; Stieger, 2018).

India's pursuit of EPR implementation will benefit from the expansion of collective voluntary schemes and take-back schemes co-funded by industry and government. The stakeholder research suggested an urgent need for multiple collective schemes, co-funded by industry, to increase collection, centralised dismantling and processing, by extending training and employment opportunities to the informal sector.

The product take-back scheme is a widely adopted instrument to address plastic waste. McCarthy (2020) reports that 40 countries have successfully integrated container take-back systems into their waste management systems. Countries such as Germany and Norway have shown great results in plastic bottles returned for recycling. Germany has diverted 120 billion containers from waste since the implementation of the deposit return scheme in 2003, where buyers pay 25 cents per bottle at the time of purchase, and 99% of plastic bottles are now returned for recycling. In Norway, since the scheme was introduced in 2014, 97% of the country's plastic bottles have been returned for recycling (Campbell, 2021). Similar successes are evident in Australia, with the Return and Earn Scheme in New South Wales (NSW) driving exceptional consumer awareness and engagement, as a national model for rolling out container-deposit legislation.

Another intervention that is gaining traction globally to promote sustainable production and consumption is the 'right to repair'. Countries and regions such as the USA, the UK, and the EU have formalised action. India proposed introducing the 'right to repair' in July 2022, which would require manufacturers to provide customers with information about their products so that the products can be easily repaired by themselves or by a third party, rather than just by the original equipment manufacturers. The framework aims to facilitate trade between the original equipment manufacturers and third-party buyers and sellers, which will also lead to the creation of new jobs (The Times of India, 2022) and the expansion of second-hand markets.

2.6 What would work in India?

Efficient source segregation and enforcement of regulations will contribute significantly to a circular economy for plastics in India. There is a need to demonstrate the business case for a circular economy where the government can play the role of enabler as well as in the expansion of secondary markets. International examples to share best practice and the need for more private investment were identified as current gaps. There is a need to incentivise greater collaboration between waste management bodies and waste generators, such as through state government to ULBs based on performance.

Financial mechanisms that would enable a circular economy for plastics in India include introducing an environmental tax. Imposing a cost on producers (e.g., through a tax) to incentivise them to make more environmentally responsible products can be a means to encourage better product design, reducing demand (planned obsolescence)

and addressing the issue of traceability of waste (if relying on end-of-life management). There is a need to provide fiscal incentives to recyclers to promote the use of recycled feedstock; for example, lowering GST on recycled products and materials in comparison to virgin polymers. Given that the waste and recycling sector in India is highly unorganised and has a large informal economy, GST is a disincentive to businesses formalising their operations. Instead, incentives to attract businesses to formalise their operations are needed to achieve holistic social and environmental benefits. Such incentives will encourage big organisations to invest in recycling infrastructure, spurring higher competition in the sector.

The Indian Government can play a more proactive role in supporting industry transition away from plastics to enable the strengthening of markets for alternatives. Newly emerging alternatives to plastics, such as leaf and agri waste-based packaging, algae and mushroom-based, and bamboo and paper-based materials need research, marketing and fiscal support and incentives. The government should provide support and incentives to invest more time in alternative material production, material innovation, and to enable the shift for plastic manufacturers/traditional entrepreneurs who have technical knowledge to be able to invest in the manufacture of alternative materials. Similar incentives have been provided in the past to nascent but important industries such as renewable energy – a comparable approach is needed to enable a systemic transition away from SUP in India.

The informal sector is the backbone of the Indian waste management system. Policies need to be inclusive and equitable to ensure communities are not unfairly disadvantaged, and that the interests of the majority are reflected in policy. Policy design should better reflect local needs and behaviours and offer flexibility and adaptability to suit the needs of different stakeholders and cultural diversity in India. Policy frameworks need to create space to capitalise on existing skills and networks of the informal waste sector to ensure there is a just transition. Consumption patterns and local, informal, cash economies need to be integrated to measure progress.

There are several challenges in adopting international policy and industry standards without adapting to the Indian socio-economic-political context. Regulations such as SUP bans do not acknowledge India's unique circumstances in terms of informal sector activities and the grey economy. The informal sector's physical network should be considered in urban planning, to consider avenues to integrate informal waste collection activities into industrial and urban development plans. Policies should create mechanisms for informal waste actors to be able to secure formal funding to invest in recycling. There need to be incentives for the informal sector to operate in special recycling zones, and tax-free operations for defined periods.

2.7 Recommendations

1. Set a single policy framework and implementation plan for circular plastics, in which all initiatives and information have a place, and a plan to put it into action
   - Streamline regulations and guidelines for recycling, materials reuse and energy.
   - Develop a circular economy transition body to connect industry and government.
   - Support the circular economy with public procurement policies and fiscal and tax incentives that prefer secondary plastic waste-based products and businesses.
   - Enhance EPR regulations to incorporate the informal sector, building on initiatives of online marketplaces to connect actors in the waste and recycling value chain or social enterprises that act as PROs.
   - Develop standards, certification and verification mechanisms based on the scientific analysis of lifecycle costs of products to enable development of markets for recycled and other secondary products from plastic waste.
   - Promote and strengthen waste exchange platforms and marketplaces that reduce recovery and transportation costs for companies generating and collecting waste.
   - Integrate approaches for EPR, incentives, standards, finance and tax mechanisms to ensure there is standardised information, targets, monitoring and reporting, to enable timely and effective evaluation of progress.
2. Recognise and engage all stakeholders
   - Recognise and engage all stakeholders, especially the informal sector of waste pickers and recyclers.
   - Integrate all the actors – ULBs, PIBOs, regulators, informal sector – and encourage collaboration among the 'entire ecosystem'.
   - Consider strengths of all stakeholders and how they can better serve the system of resource recovery.
   - Formalise the informal sector by supporting informal cooperatives as social business.
   - Ensure there is feedback and learning to reflect on the ground realities, and further amend the policy based on these learnings.
   - Policies should enable knowledge transfer and learning for all stakeholders across the plastic value chain.

3. Facilitate decentralised, locally relevant and equitable implementation of policies
   - Ensure action at the state level to integrate and register different stakeholders.
   - Understand and tap into local systems, so that responses from government and industry are contextually relevant. Local governments can also implement by-laws.
   - Ensure equitable implementation of policy in different contexts in India, beyond the large cities.
   - Include small producers and the informal sector (small and medium producers enable alternatives to plastic and need to invest in these).
4. Drive stronger enforcement and implementation of existing policies.
   - Integrating policy and regulatory approach to provide clear direction and better alignment in order to encourage higher uptake and implementation.
   - Encouraging state-level data collection, monitoring, and evaluation as well as higher transparency in public reporting to enable better measurement.
   - Set benchmarks to assess performance, including annual target setting and reporting.
   - Enforce targets for recycling for households, neighbourhoods, cities and municipalities with recognition and awards program for clean neighbourhoods, towns, and cities.

Short-term priorities (to 2025)

- Develop a circular economy transition body to connect industry and government.
- Support plastics collection, sorting and source segregation, through investment in infrastructure, community education and incentives to consumers to foster source segregation and R behaviours.
- Develop financial and tax incentives to encourage business innovation and investment in R&D, as well as the expansion of circular business models including increasing demand for alternative materials.
- Provide funding to support ULBs for better waste management, community education, staff training, infrastructure development and initiatives to support the integration of the informal sector.
- Implement policies that enable training and capacity building with a variety of stakeholders including the informal waste sector to enable monitoring and safe handling of plastic waste and to fill knowledge gaps regarding the circular economy.
- Develop peer networks on a hub and spoke model among cities to share best practices and resources.

Medium-term priorities (to 2030)

- Enhance EPR targets and scope to include other complex material streams such as textiles, agricultural products, automobiles, and tyres. EPR should target all stages of the lifecycle including design and production and engage a range of stakeholders.
- Invest in setting up eco-industrial parks (EIPs) to create industrial symbiosis opportunities and explore possibilities of the upcoming plastic processing hubs and special economic zones to have EIP and circular economy features.
- Develop a circular plastics strategy to integrate management of various plastic types at all stages of the lifecycle including design, production, consumption and end-of-life. The strategy should engage a wide range of stakeholders and consider the use of national standards, phase outs of some plastics and streamlining the regulatory framework.
- Invest in R&D, recycling technology and infrastructure, including for advanced sorting and waste processing. Establish a recycling modernisation fund to assist in growing and updating recycling capabilities and technologies, co-funded by government and the private sector.
- Provide incentives for stronger collaboration between research and industry (e.g., the Small Business Innovative Research Model in Canada, patents co-ownership between industry and academia). Facilitate market commercialisation of technologies and innovations, such as alternative materials to reduce use of virgin plastics, recycling technologies, innovative products, and data management solutions.

Long-term priorities (beyond 2030)

- Implement green public procurement and circular procurement strategies at the national, state and local levels.
- Every state should have a plastics innovation centre or hub co-funded by industry and government to support material and technology R&D, provide education and knowledge resources for better waste management, skills training and business support to transition to a circular economy.

Programs to foster innovation and financing will unlock opportunities for circular businesses

To create an enabling environment for circular business model success, start-ups and transitioning businesses will require supportive programs to facilitate supply chain networking and collaboration, as well as access to finance.

Access to finance is a key issue for businesses starting up, even when product and service innovation is developed. Part of the challenge is that new business models require evidence of returns or social and environmental benefits, this can be difficult for small businesses to collect. In addition, payback periods for circular business models may be longer.

To overcome these challenges with **financing**, a number of innovative mechanisms can be applied, such as:

- A Viability Gap Fund* dedicated to circular business model initiatives to cover high start-up expenses and shorten long payback periods.
- A revolving fund set up to specifically finance circular business models.
- Public-private-community partnerships to help finance waste management infrastructure.
- Microfinancing to facilitate entrepreneurship for the informal sector.
- Considering peer to peer lending platforms for financial inclusion of the informal sector.

Programs to **foster innovation** and provide the supportive ecosystems for CBMs could include:

- Further development of circular business incubators and accelerators through public-private partnership models that can offer funding, mentoring, capacity building, and networking (academia, industry and civil society).
- Publishing success stories and innovative work by start-ups, municipalities and private partnership-based projects that address plastic waste to promote circularity and knowledge sharing.
- Setting up networks enabling different industries and different parts of supply chains to interact and share information.

* Kapur-Bakshi, S., Kaur, M., and Gautam, S., 2021. Circular Economy for Plastics in India: A Roadmap. New Delhi: The Energy and Resources Institute. Available at https://www.teriin.org/sites/default/files/2021-12/Circular-Economy-Plastics-India-Roadmap.pdf

3 Circular business models

3.1 Introduction

Since the second industrial revolution, India has been following the take-make-waste linear economy approach. On one hand this has enabled economic benefits and brought prosperity but on the other hand, it has led to the overuse and depletion of resources, increased environmental degradation, and inflated prices of raw materials (NITI Aayog-UNDP, 2021).

The shift towards CBMs is often discussed as a key mechanism for change to drive a circular economy (Henry et al., 2020). The basis of a circular economy business model is to avoid waste and retain the value of materials or products within the economy as long as possible (Geissdoerfer et al., 2018). CBMs can be defined as:

> Business models that are cycling, extending, intensifying, and/or dematerialising material and energy loops to reduce the resource inputs into and the waste and emission leakage out of an organisational system. This comprises recycling measures (cycling), use phase extensions (extending), a more intense use phase (intensifying), and the substitution of products by service and software solutions (dematerialising) (Geissdoerfer et al., 2020, p. 7).

The shift away from traditional linear business models towards a circular business model represents a significant change for businesses and consumers. As such, circular businesses are likely to meet with resistance and may need support as society and its institutions and systems adapt over time. In this chapter, we explore the types of CBMs already operating in India and investigate the barriers and opportunities for driving greater uptake of CBMs for plastics.

Table 3.1 Circular business model framework

Adapted from Geissdoerfer et al. (2020) and Bocken et al. (2014, 2016).

TYPOLOGY	PLASTIC RELEVANT EXAMPLES
Substituting	Replacing plastic packaging with non-plastic alternatives
Extending	Long warranty electrical and electronics, upgradable mobile phones, repair of e-products, second-hand sales, reusable packaging
Intensifying	Car rental/sharing, internet cafes, computer and phone leasing, toy, tool and equipment libraries, agricultural equipment cooperatives, ride-pooling, taxis (instead of owning a car)
Cycling	Upcycling plastic products, take-back schemes, recycling plastics, industrial parks using waste plastics as inputs

To investigate CBMs, we compared frameworks from the literature and adapted a framework from several sources – see Table 3.1 above. The framework identifies four major categories of CBMs. Using this framework, we undertook a literature and practice review (see Retamal et al., 2021) to identify businesses currently operating in India that fit with this CBM framework for plastics. We subsequently conducted semi-structured interviews with 16 businesses, with the aim of sampling for diversity across the four categories. Finally, we undertook a qualitative analysis of interviews using a mix of inductive and deductive approaches using Dedoose software[9].

9 Dedoose Version 9.0.90, cloud application for managing, analyzing, and presenting qualitative and mixed method research data (2023). Los Angeles, CA: SocioCultural Research Consultants, LLC www.dedoose.com.

3.2 What is working well?

Circular business models and innovations offer alternatives to the established norms but face some challenges in their operation and scalability. Through the stakeholder interviews with businesses adopting CBMs in India, we have identified barriers to mainstreaming CBMs and gathered ideas on actions that can help to enable CBMs and overcome the barriers. In this section, we draw on the interviews and literature to highlight aspects of the CBM ecosystem that are currently working well, as well as factors that are currently contributing to CBM success and creating an enabling business ecosystem for CBMs.

With growing awareness of plastics issues and the establishment of plastics-focused policies, there has been a recent increase in the number CBMs set up in relation to plastics. This study identified the existence of both older 'established' and newer 'emerging' circular business model types for plastics in India.

'Established' CBMs in India relate to:

- Recovery of materials for recycling and energy recovery.
- Services that avoid packaging (e.g., Dabbawallas).
- Repair, reuse, resale (formal or informal businesses) (e.g., for electrical and electronic goods).

Newer examples of CBMs described as 'emerging' include:

- Renewable materials for packaging, as a substitute for plastic (SUPs).
- Technology platforms for aggregation of recyclables enabling EPR.

These examples highlight which business types already fit within established business ecosystems, and which may be in the process of establishing and may encounter resistance. The CBM framework specifies four categories of business models, namely: substituting, intensifying, extending and cycling. In the practice review, it became evident that CBMs relating to substituting and cycling were fairly common in relation to single-use and packaging plastics. Businesses 'extending' product lifetimes through repair and reuse are also common in relation to electrical and electronic goods and automobiles. Businesses 'intensifying' plastic use were the least common in India.

Key CBM trends

1. 'Cycling' / recycling businesses are established and new CBMs are emerging

The recovery of materials for recycling and energy recovery is one of the most established CBMs in India. This is achieved primarily through the informal sector. Many start-ups and companies are now innovating to streamline it in a more formal or organised manner. There are around 91 start-ups working in the field of collection and recycling of various types of waste.[10]

2. Second-hand goods market continues to flourish in India

There are some very well organised second-hand markets in India, such as Chor Bazaar in Mumbai, which has been operating for over 150 years. With the advent of smartphones and the increasing rate of internet penetration, this sector has become more formalised and is growing. E-commerce platforms such as olx, quickr, secondhandbazaar, and kiabza help to trade pre-used products more easily. Among the second-hand goods category, the trading of electronics is dominant. The second-hand smartphone market in India is expected to double in three years to USD 4.6 billion by 2025, according to a joint report by the mobile devices industry body India Cellular and Electronics Association (ICEA) and research firm IDC.[11] Other categories of second-hand goods broadly include automobiles, furniture, home appliances, electronics, toys, sports, and branded clothes. This type of business model not only extends the life of a product but also significantly reduces waste generation.

3. Many alternative packaging materials are emerging with lots of innovation occurring

Many industries have started using innovative ideas to substitute for single-use and packaging plastics. There are two common replacement options for plastics: (i) bioplastics or bio-based polymers, and (ii) renewable fibre-based alternatives. Bioplastics are made from non-fossil sources, such as agricultural byproducts, but are manufactured into plastics. Bioplastics may have similar properties to regular plastics, or they may be biodegradable or compostable, so there is significant variability in their environmental impacts.

Many businesses in India are working on fully compostable natural alternatives for manufacturing disposable cutlery/plates/bowls with materials such as sugarcane bagasse/waste (Ecoware, 2021, Dinearth, 2022, Pappco Greenware, 2021), areca-nut leaves (Ecotopia, 2021), or bamboo (Bamboo India, 2021). There have also been attempts to make edible cutlery (bowls and spoons) using cereals (Edible Pro, 2021). Paper bags and paper straws have become the preferred choice of many consumers. However, as per the Life Cycle Assessment (LCA) done by UNEP (2020), both paper and bio-derived plastics could

10 https://www.recyclingstartups.org/country/India/

11 https://www.business-standard.com/article/economy-policy/second-hand-smartphone-market-in-india-to-reach-4-6-bn-in-2025-report-122012801920_1.html

be major greenhouse gas emitters. Reuse of all types of bags/products needs to be promoted, as this extends the lifetime of products and reduces impacts from the production of new products as well as waste management.

4. EPR requirements are encouraging innovation and new business models

EPR is 'an environmental policy approach in which a producer's responsibility for a product is extended to the post-consumer stage of a product's life cycle' (OECD, 2016), especially for the take-back, recycling, and final disposal of the product. In India, EPR regulations were first introduced in India in 2012 to focus on e-waste and was extended to plastic waste in 2016. Other products such as batteries, tyres and rubber, and solar photovoltaics are under consideration.

One of the main challenges in effectively implementing EPR has been the dispersed waste collection networks in India, which are highly localised and dominated by the informal sector. As discussed in the policy frameworks chapter (see Chapter 2), the informal sector's role has been largely ignored in formal policy, especially policies related to plastics and EPR. Thus, we found an increasing number of examples of technology platforms which fill the gap of connecting the informal sector to formal EPR collection, thereby assisting in improved EPR implementation.

One example is Recykal, which is an end-to-end waste management platform connecting actors within the waste management and recycling value chain. The business hosts an online marketplace to congregate waste actors and to facilitate transparency and traceability of waste material flows. Recykal also partners with producers and brand owners to implement plastic take-back and customer engagement programs. Another social enterprise is Saahas Zero Waste, which offers waste management services connecting consumers and recyclers. The business also performs the role of being a PRO on behalf of corporate businesses, technology parks and resident welfare associations.

5. Digital technologies and integration of informal workers into business models

Digital technologies have been an enabler for integrating the informal sector into new 'cycling' businesses. Kabadiwalla Connect uses ICT and IoT-based platforms to set up a network of 'kabadiwallas' (waste aggregators) to improve the efficiency of the informal recycling system. It facilitates people segregating and selling recyclable waste materials (such as plastic, paper, metal scrap, glass) to local kabadiwallas, who in turn sell it to be upcycled, or recycled for a profit, to larger waste aggregators and processors (Kabadiwalla Connect, 2021). Similarly, Banyan Nation, one of India's first vertically integrated plastic recycling companies, uses a proprietary data intelligence platform that integrates thousands of informal recyclers into its supply chain. The platform has also been extended to municipalities to better understand city waste flows and use a data-centric approach to manage their waste more efficiently, effectively and economically. Recykal also provides an end-to-end waste management platform that connects and facilitates transactions across all stakeholders in the waste management and recycling value chain. Its digital solutions help organise the fragmented waste management sector and facilitate transparent and traceable material flows with real-time visibility.

The enabling environment

Interviewees in this study referred to a number of existing and potential factors that can contribute to mainstreaming CBMs in India. These are:

Indian Government policy focus on plastics

Interviewees explained that the broad policy landscape focused on solid waste and plastics has contributed to awareness and demand for alternatives. The Swachh Bharat Abhiyan (Clean India Mission) has brought waste issues to mainstream awareness, and single-use plastic bans and extended producer responsibility have a direct impact on businesses. The UN Global Plastics Treaty (UNEP, 2022) is also an important global driver of action on plastics. Businesses explained that policies inspired new products, spread awareness faster and generated demand. Grant and accelerator schemes have also helped to support the growing number of waste-related start-ups. There is, however, a need for stronger implementation of existing policies, not just at national and state level, but also at the panchayat (village) level, as they have the potential to make decisions about waste and sanitation.

Growing awareness, advocacy and collaboration

The international focus on plastics has helped drive awareness and has also enabled collaborations and funding from overseas. This external pressure helps to support CBMs in India. There is also demand from tourism for eco-businesses. Organisations noted that they wanted to see more two-way exchanges between South-South countries.

Several businesses that were interviewed play an education and advocacy role in relation to plastics issues and the alternatives. Their activities range from doing talks and workshops, to running online courses, to engaging with different stakeholders. Overall, interest and acceptance of plastic alternatives is growing but still has a long way to go. Interviewees explained that greater environmental awareness is needed to generate demand.

Partnerships with government have also been particularly helpful for enabling legitimacy of waste organisations. As one suggested, *'building partnerships with different government entities in all our programs has made our programs a lot more credible and much more engaging with the community'*.

3.3 Current challenges and opportunities

Circular business models are diverse. As described in Section 3.1, they include businesses offering i) alternative materials to replace plastic products (substituting), ii) plastic products that have been designed to last longer and be reused (extending), iii) plastic products that can be used more intensively among multiple users (intensifying), and iv) plastics that can be collected and recycled into new products (cycling). As each of these business model types have different offerings, they encounter some distinctive challenges. Some common challenges include costs and supply chain issues as well as difficulty accessing finance.

3.3.1 Costs and supply chain issues

Businesses **substituting** plastics noted that plastic is very cheap and it is difficult for alternatives to compete on price, so customers pay a premium. Businesses offering services for more **intensive** use of products highlighted that maintenance and operational costs are higher for renting equipment and conducting deliveries. Some 'intensifying' businesses also require reverse logistics, which necessitates cooperation within the supply chain. Some waste management businesses enabling **recycling** spoke of fragile profit margins, fragmented supply chains and difficulty accessing finance.

Renewable fibre-based alternatives to plastic are less cost competitive and are more vulnerable to farming/sourcing issues as well as decomposition depending on climate. One manufacturer explained that a fibre-based plate sent to Pune was still intact after two years, while the same plate sent to Goa needed to be packed very carefully due to the humidity. Renewable fibre-based substitutes are less economical than plastic and cost more to transport as they are heavier and larger. The shorter shelf life of fibre-based products especially became a problem during pandemic shutdown periods as they spoiled while in storage.

Fragmented supply chains and the need for cooperation can pose challenges for new markets. The informal sector plays a very important role in the collection and recycling of plastics, so cooperation must be developed within this highly fragmented supply chain, where there is often a lack of data. This becomes a larger problem when recycling businesses are successful; as one recycling aggregator explained, 'as we scale it becomes more challenging to work with a fragmented supply chain', due to uncertainty about volumes.

Beyond the collection and processing, recycling businesses also need to find a buyer and end market for the recycled plastic content. As one business explained, 'it's a lot of figuring out what is the right application, industry, feedstock and who will buy the next product that comes out'.

In a slightly different example, reuse schemes require cooperation and arrangements for reverse logistics. For example, a cafe needs to promote the use of reusable cups and take them back on behalf of the reusable cup provider.

3.3.2 Policy issues

In terms of policy-related barriers for businesses, there was a general awareness of the difficulty for businesses to transition to a circular business model and the need for policy to drive change. However, some stakeholders highlighted the need for 'baby steps' or phased changes to make it easier for industry and consumers.

Plastics recycling businesses said that progress is difficult where there is a **lack of policies and targets or a lack of policy implementation.** For example, recycling businesses explained that in jurisdictions without baseline data, monitoring or KPIs for recycling, it is much harder to increase recycling. Stakeholders also emphasised that the plastic bans do not include all single-use plastic items. For example, disposable coffee cups have a plastic lining, and while they are not banned, there is a lack of incentives to use alternative cups.

Policy awareness may be limited and this affects implementation. While some stakeholders felt that Swachh Bharat Abhiyan brought 'the whole conversation on waste' to mainstream awareness, others described a lack of public awareness about specific laws in relation to plastic. As one organisation explained, 'the problem everyone has is that there is law but no one knows that the law exists'. This highlights a lack of awareness and enforcement of plastic bans limits their impact and influence in the market.

Only one regulatory barrier was identified, where recycled material cannot be used for food grade packaging in India. However, one interviewee noted that there are some examples overseas (e.g., New Zealand) where post-industrial recycled material can be used, rather than post-consumer recycled content. This type of concession could expand the market for recycled plastics.

3.3.3 Informality

Recycling businesses highlighted a number of challenges they encountered due to informality in supply chains, particularly in relation to the lack of data, difficulty accessing finance, and ambiguity in the policy regime.

There is a lack of data on the quantity and value of waste collected by the informal sector, which makes it hard to quantify opportunities. Consequently, it is also hard to obtain finance when the informal sector is key to the supply chain.

> 'The recognition of each and every aggregator is still lacking by the system. People know the waste collector, but they do not know the stakeholders in the next aggregator who is more like a waste bank. We do not yet understand the power they have in the value chain.'
>
> Recycling aggregator

Recyclers explained that smaller aggregators and scrap shops need to be recognised for their role in the supply chain, and that there is **policy ambiguity** around their role, which creates confusion for supply chain partners.

One organisation highlighted the need for **capacity building for informal sector workers** to increase the value of the waste they collect and to improve hygiene and sanitation.

3.3.4 Lack of finance

Access to finance was a common problem for businesses. Gaining support for an innovative new alternative to plastic is a challenge as businesses need to provide evidence of returns but need initial investment to produce the evidence – 'it's always egg or hen first'. In some cases, recycling businesses require advance payments to establish their systems, but municipalities can be unwilling to provide this. Businesses often need major capital investment in order to sign long-term contracts with municipalities.

Accessing finance is also linked to a lack of data, as funders are looking for metrics of success. Small businesses can find it difficult to quantify or do not align with traditional metrics, such as product sales. To gain long-term contracts, businesses need data and proof of contracts, and this information is not available when working with the informal sector.

Data is also needed to verify sustainability claims and to avoid greenwashing, and some businesses would like to see the use of standards to demonstrate green credentials.

3.3.5 Lack of technology and waste infrastructure

Recycling businesses were particularly affected by the systems and environments in which they operate. As one explained, 'the problem that we are facing right now is the infrastructural gap' where a **lack of waste infrastructure**, including for collection, baling and processing plastic, severely reduces opportunities for recycling. Some businesses also cited a lack of technology or physical storage space as limiting factors.

3.3.6 Lack of awareness

A few businesses mentioned a **lack of consumer and industry awareness** as a barrier. For example, a lack of awareness of the environmental impacts of plastics and a lack of awareness of alternative offerings. As one start-up business explained, 'there was a lack of trust and low demand for the services we provided', which slowly changed, and now 'the ecosystem is developing, the market is heating up and more companies are doing this in the next few years. All of this gives us more confidence to work further'.

3.3.7 Opportunities

Based on this study, there are several initiatives that could address the barriers identified by businesses. These include:

- Integrating the informal sector in legal frameworks to clarify their role, improve working conditions and reliability, and facilitate data collection and access to finance.
- Increase awareness and implementation of existing policies, as well as awareness of the impact of plastics to drive the transition.
- Work with the financial sector and provide funding arrangements specifically for CBMs.
- Invest in technology to improve the performance characteristics of renewable fibre-based packaging alternatives.
- Invest in waste management infrastructure to provide infrastructure for improved recycling.
- Create a conducive ecosystem for development of markets for recycled and other secondary products including required standards, certification and verification mechanisms.
- Establish network-based knowledge and support platforms to exchange solutions, good practices, and learnings specifically for CBMs. Connections and networks foster innovation and promotion. As one business explained, *'We need to build a landscape where the circular economy is not just about technology, but is also process and people driven'.*
- Enable South-South exchanges to share knowledge around CBMs.

In addition, successful business models operating overseas can be adapted for the Indian context. The following are examples of reuse businesses operating in Australia, which would fit in the 'intensifying' category.

Green Caffeen[12] is an Australian reusable coffee cup system that allows cafes to sign-up for free, and provides cafes and consumers with an alternative to disposable coffee cups. More than 700 cafes and 35,000 customers currently use this service, which allows customers to use the cups for coffee at a participating cafe, then return the used cup to any other participating cafe at a later date, where it will be cleaned and made available for reuse.

Cercle[13] offers a reusable coffee cup service in Australian offices. The business model follows a simple take-back system whereby takeaway metal cups (often without lids) are made available to customers at a cafe, or coffee cart. The cups can later be returned to Cercle Drop Pods located in workplaces. These cups are then washed and made available for reuse by cafes. Since April 2021, the business has successfully diverted 104,555 coffee cups from landfill. The business currently services four commercial buildings in Sydney and has been able to bring down the cost of using the service to around 70 cents (~ INR 40) per cup, closing the gap with single-use cups which cost around 10–15 cents (~ INR 6–8) per cup.

12 Read more at https://greencaffeen.com.au

13 See how Cercle cups work https://www.youtube.com/watch?v=yjwlvrQcCNc. Read more about the business at http://www.cercle.com.au

3.4 Which possibilities should be implemented in India?

Based on the barriers and enablers identified through this study, and further ideas from the literature, we can make a number of recommendations for action to drive the uptake of CBMs. The circular economy offers a comprehensive strategy for managing plastics, and to reach their full potential, business models that are circular must generate value for society and the environment in addition to profit. In this section, we outline our recommendations in terms of policy, technology, business and market support, financing and developing the business ecosystem.

Enabling policy

- Develop practical, implementable and unambiguous policy frameworks and schemes.
- Implement existing government policies and enforce regulations that could enable development of CBMs for plastics.
- Introduce fiscal and tax incentives for development and promotion of plastic waste-based products and uptake of such businesses.
- Amend public procurement policy to preference circular businesses.

Business and market development support programme

- Support further development of circular business incubators and accelerators through public-private partnership models that can offer funding, mentoring, capacity building, and networking (academia, industry and civil society).
- Develop standards, certification and verification mechanisms to enable development of markets for recycled and other secondary products from plastic waste.

Highlight success stories and innovative work by start-ups, municipalities and private partnership-based projects that address plastic waste and promote circularity.

Leverage technology including digital

- Develop a compendium of commercially proven technological solutions of varying investment range (from low to high) and automation (from manual to fully automatic) for management of plastic waste.
- Build strong communication platforms for promoting CBMs that market plastic products as services and promote sharing and leasing.
- Use information platforms and digital technologies to help drive inclusion of the informal sector and marginalised communities while making access more equitable.
- Promote and strengthen waste exchange platforms and marketplaces that reduce recovery and transportation costs for companies generating and collecting waste while also making it more affordable for users to find what they need.
- Create an effective waste collection and management system assisted by technology-based processes for tracking the quality and quantity of material and products across the plastic waste value chain.

Innovative finance

- Encourage Public-Private-Community partnerships for innovation in business models and financing strategies for investment in waste management infrastructure.
- Explore social investment platforms (peer-to-peer lending) for financial inclusion and empowerment of workers in the informal waste management sector.
- Develop innovative credit products to meet entrepreneurial aspirations of informal sector workers.
- Set up a Viability Gap Fund (Kapur-Bakshi et al., 2021) dedicated to circular business model initiatives to cover high start-up expenses, shorten long payback periods, and boost technological advancement.
- Set up a Revolving Fund that can be used expressly to encourage the circularity of business models by enabling those that are thought to be at risk to acquire finance for their business models or particular resource efficiency strategies.

A robust plastic waste management ecosystem

- Establish a circular business network to provide support and exchange knowledge on solutions, good practices, and learnings specifically for CBMs.
- Rethink the waste management business model in municipalities, with shared investment and profit, creating a win-win situation for all stakeholders, including the informal sector.
- Establish a network of business support service providers (e.g., special purpose vehicles) to sustain CBMs over the longer term.

3.5 Recommendations and timeframe

Based on the barriers and enablers identified through this study, and further ideas from the literature, we can make a number of recommendations for action to drive the uptake of CBMs. The circular economy offers a comprehensive strategy for managing plastics, and to reach their full potential, business models that are circular must generate value for society and the environment in addition to profit. In this section, we outline our recommendations in terms of policy, technology, business and market support, financing and developing the business ecosystem.

Short-term priorities (to 2025)

- Build robust communication platforms to promote CBMs and highlight success stories and innovative work by start-ups, municipalities and private partnership-based projects that address plastic waste and promote circular business activities.
- Support further development of circular business incubators and accelerators through public-private partnership models that can offer funding, mentoring, capacity building, and networking with academia, industry and civil society.
- Develop a compendium of commercially proven technological solutions of varying investment range (from low to high) and automation (from manual to fully automatic) for management of plastic waste.
- Promote and strengthen waste exchange platforms and marketplaces that reduce recovery and transportation costs for companies generating and collecting waste while also making it more affordable for users to find what they need.
- Encourage Public-Private-Community partnerships for innovation in business models and financing strategies for investment in waste management infrastructure.
- Establish a circular business network to exchange knowledge on solutions, good practices, and learnings specifically for CBMs, and provide support services (e.g., special purpose vehicles) to sustain CBMs over the longer term.

The key actors and stakeholders for carrying out the above collaborative actions include relevant ministries, departments and institutions of the Government of India such as NITI Aayog, MoSDE, MoST, MoMSME, MoE; commerce and industry associations such as CII, FICCI, NASSCOM, ASSOCHAM; start-ups, businesses, incubators and accelerators such as Indian STEP & Business Incubator Association, Entrepreneurs Association of India; finance institutions; municipalities and ULBs; workers in the informal waste management sector and their associations; corporate, brand owners and organisations under the ambit of EPR guidelines and rules; and civil societies, NGOs, and other community institutions.

Medium-term priorities (to 2030)

- Introduce fiscal and tax incentives to encourage the development and promotion of plastic waste-based products and uptake of such businesses; amend public procurement policies to preference circular businesses.
- Develop standards, certification and verification mechanisms to enable the development of markets for recycled and other secondary products from plastic waste.
- Explore social investment platforms (peer-to-peer lending) for financial inclusion and empowerment of workers in the informal waste management sector.
- Develop credit products that prioritise circular economy and meet entrepreneurial aspirations of informal sector workers.
- Set up funds that are geared to assess the potential of circular economy businesses and technology, including a Viability Gap Fund (Kapur-Bakshi et al., 2021) to cover high start-up expenses and shorten long payback periods, and a Revolving Fund to invest in next-stage circular business with an expectation of commercial returns.

The key actors and stakeholders for carrying out the above collaborative actions include relevant government departments, institutions and ministries such as MoEFCC, CPCB, SPCBs, MoF, MoCI, MoMSME; standards, accreditation and certification bodies such as BIS, QCI; financial institutions, social and environmental investors; corporate, brand owners and organisations under the ambit of EPR guidelines and rules; and relevant commerce and industry associations; supported by other actors in the business ecosystem such as start-ups, businesses, incubators and accelerators; waste management agencies, workers in the informal waste management sector and their associations; technology, machinery and equipment suppliers; civil societies and grassroots organisations.

Long-term priorities (beyond 2030)

- Create an effective waste collection and management system assisted by technology-based processes for tracking the quality and quantity of material and products across the plastic waste value chain.

The key actors and stakeholders for carrying out the above collaborative action over the long term include municipalities and local bodies in rural and urban areas, waste management agencies, consumers, polymer producers, manufacturers, brand owners, and organisations under the ambit of EPR guidelines, CPCB, SPCBs, start-ups and businesses offering circular solutions, workers in the informal waste management sector, waste aggregators and recyclers. This requires leadership and ongoing support from relevant ministries and government departments, which can be provided through the institutionalisation of an autonomous special purpose vehicle (e.g. Indian Plastics Circular Economy Forum), financial institutions, technology providers, commerce and industry associations, and civil societies and NGOs.

Pertinent application of mechanical and advanced recycling (chemical) technologies could be a viable and safe solution for keeping plastic waste streams in circularity

- Mechanical and advanced recycling (chemical) technologies can complement one another.
- Enforcement of full phase robotics, software solutions and artificial intelligence in the sorting and recycling processes will provide a clean homogeneous stream of plastic feedstock. Mechanical recycling should be reserved for higher value, cleaner waste streams.
- Advanced recycling can tolerate higher levels of lower value, mixed, or contaminated waste streams.
- Deployment of Advanced Recycling units will require careful LCA to ensure that the process is safe, effective and sustainable for the given circumstances.

4 Plastic recycling technologies

4.1 Introduction

The transition from a linear to a circular economy for plastics is critical to the Indian economy given the challenges associated with recycling plastic waste, its potential value as a resource across the value chain, and consequent impact on greenhouse gas emissions. LCA studies have indicated that substituting virgin plastics with recycled plastics can reduce emissions by 20–50% (d'Ambrières, 2019, Lai et al., 2022). A modern and viable plastics recycling industry is essential for a sustainable circular economy for plastics and important for India's progress on the SDGs and its participation in the forthcoming Global Plastics Treaty (2024).

Recycling of plastic waste in India encompasses 73% of all plastic waste, but effective technologies for recycling are needed to create a true circular economy for plastics, as reported in our findings. Currently, 61% of generated plastic waste is recycled, 12% is reutilised and 27% is being mismanaged (Baynes et al., 2021). Mechanical recycling recovers plastic material from plastic waste in a number of steps including sorting, segregation, cleaning, shredding and thermo-mechanical extrusion to form granulates without significant changes to their chemical composition. These granulates are used for making different recycled products or mixed with virgin plastics for manufacturing of products. Chemical recycling converts plastic waste into monomers, fuels and value-added chemicals. Mechanical recycling has a 94% share of the Indian market, supported by chemical recycling and alternative uses. These recycling technologies delay the end-of-life of plastic and limit resource consumption. However, some of these technologies downcycle the plastic and result in open-loop recycling, limiting their potential secondary uses after two or three life cycles. In a circular economy for plastics, there is a need for sustainable recycling technologies, with a major emphasis on keeping material in the loop through subsequent recycling and reuse.

We assessed what is needed for India to pursue a circular economy for plastics by developing a framework and baseline study in five stages. The first stage was stakeholder engagement which included onsite investigations with plastic waste recyclers to gain a deep understanding of current plastic waste recycling practices in India. The next stage was to **prepare an inventory of recycling technologies** and analyse primary data to determine optimal recycling technologies using Multi-Criteria Decision Analysis. Simultaneously, data on PWM and the circular economy for plastics were collected from literature, statistical documents, discussions, working papers, government reports and policy documents. The third stage identified **gaps and challenges** in the current recycling system. The fourth stage identified regulatory and voluntary **opportunities** for the development of recycling infrastructure and industrial zones. The **implementation barriers** to these opportunities were then identified. The final stage involved the development of **recommendations** and enforcement mechanisms **for policy makers, regulatory authorities and industrialists.**

Hence, this chapter sets out India's potential to develop plastic waste recycling technologies that will support and accelerate India's transition to a circular economy for plastics, through the uptake of advanced recycling technologies and actions required to address the associated challenges in the short, medium and long term.

The chapter confirms that significant steps need to be taken over the next decade for rapid transition towards a circular economy for plastics, with a 'full-system approach' to advance plastic waste recycling technologies while considering sustainability, resource efficiency, circularity and standards.

4.2 Overview of recycling technology in India

Mechanical recycling is the leading technology across the sector, which is also dominated by small-to-medium sized local facilities servicing industrial precincts. However, several factors including variations in quality of feedstock, lack of connectivity and awareness among stakeholders, poor investment in recycling infrastructure and lack of standards for plastic waste recycling, are among the issues making it difficult to establish large-scale facilities on an economic basis. Data on post-industrial plastic waste generation and recycling is not available. Similarly, data on textile waste which utilises mechanically recycled PET is not available.

Registered and unregistered recycling units

While there are 5,776 recycling units in India, most rely on a large informal workforce with little capital investment. Plastic waste recycling in India is mainly due to the large number of people in the informal workforce whose livelihoods depend on collecting, sorting, and recovering valuable plastic from mixed waste (Neo et al., 2021). Unlike other countries, India does not export plastic waste and instead manages it domestically through regulatory bodies and organisations such as ULBs.

According to CPCB, post-consumer plastic waste generated by various states/UTs is used in recycling, road construction, waste-to-energy (WtE) plants, waste to oil (WtO) plants and co-processing in cement plants. However, exact quantities used is not provided by most states/UTs. Currently, there are 4,953 (3,715 plastic manufacturers/ producers, 896 recyclers, 47 compostable manufacturing, 295 multi layered plastic) registered units in 30 states/ UTs. There are 823 unregistered plastic manufacturing/ recycling units operating in nine states/UTs (CPCB, 2020).

Stakeholder engagement: Major findings

Mechanical recycling the dominant technology

Mechanical recycling is the dominant technology in the recycling market with a 94% share, followed by energy recovery and alternate use (5%), and chemical recycling or pyrolysis (1%), (Shanker et al., 2022).

Mechanical recycling of post-industrial and post-consumer polyethylene plastic waste to produce regranulates and recycled products such as pipes, films and bags was observed. Recycling of expanded polystyrene (EPS), also known as thermocol, is carried out by hot melt extrusion and alternatively through crushing and grinding. There are approximately ten chemical recycling plants that use either pyrolysis or catalytic pyrolysis for production of fuel, whereas one industry is involved in depolymerisation of PET to obtain the parent monomer for closed-loop recycling of PET. Some plants, in their pilot stage, are investigating the extraction of carbon nanomaterials from plastic waste for use in semiconductor and electronics applications. A few start-ups are utilising post-consumer plastic waste for end-of-life options such as tiles, furniture and home wares; however, the cost of recycled products is prohibitively expensive and needs incentivisation to reduce it.

Discussions with stakeholders during our study showed that mechanical recycling is an effective and widely-used tool for achieving a circular economy for plastics. In most cases, mechanical recyclers use fabricated and completely indigenous plastic recycling machinery. Prominent recycling technologies that are widely practised across India include single screw extrusion and pelletisation, blown film extrusion, post-consumer PET to washed PET flakes, PS and EPS recycling. Some recycling units produce semi-virgin grade recyclate to produce LDPE films and straps for high strength applications. The recycling rate of PET in India is significantly higher (around 90%) when compared to other polymers due to considerable market demand for PET recyclates; however, quality data on closed-loop and open-loop recycling is not available.

Single screw extrusion is most prevalent in the mechanical recycling units due to its associated benefits of low-cost, simple design, ruggedness and reliability. Single screw extrusion is reliable for extrusion of less complex ingredients with low melting points, such as HDPE, LDPE, PP and ABS. However, the use of twin screw can enhance the output and productivity of plastics with highly viscous melt, such as EPS and other polymer blends, by providing homogeneous mixing. Other automation required for segregation, cleaning and shredding of plastic waste feedstock also needs technical advancement to result in less resource consumption.

Post-industrial plastic waste recycling with *'in-house'* material recycling facilities for recycling the scrap generated in virgin units is the best example of industrial symbiosis. Such examples are observed at Nagpur for LDPE manufacturing, Pune for recycling of EPS waste, and Chennai for recycling of industrial plastic waste. A chemical recycling plant in Pune has installed smaller capacity plants near the city to recycle plastic waste from nearby areas instead of larger capacity plants outside the city. This, in turn, reduces costs of transportation and overall processing.

Many chemical recyclers have ties with municipal corporations for providing plastic waste. Some have tie-ups with NGOs that raise awareness about source segregation and collect plastic waste from nearby areas. It was observed that many recyclers have good networks for supplying feedstock or recyclate to one another, both inter- and intra-city and state-wide.

Inclusive systems at local levels

Irrespective of proper and designated PWM systems at local levels, recycling of plastic waste is successfully implemented in India because of the inclusive systems. An ecosystem where the informal sector is involved, along with indigenous machinery and local government support, performs well in comprehensive plastic waste recycling and management. Government initiation plays a very important role in successfully establishing recycling facilities and introducing PWM rules effectively in the system.

The most economically successful business models appear where recycling facilities are clustered in industrial zones, where post-industrial waste is easily available, saving costs on transportation and cleaning. The recyclates produced are reused by such industries as their primary feedstock, establishing industrial symbiosis and helping in maintaining circularity. Similar findings are made in our study for a cluster of industries in Chennai, India for post-consumer plastic waste flows. The techno-economic-environmental analysis showed better economic feasibility due to readily available plastic waste and reduced transportation costs. This provides an example of gate-to-gate recycling where the plastic waste before entering the gate (consumer) gets recycled and again used as a feedstock, whereas post-consumer plastic waste recycling depicts a cradle to gate system boundary.

A recycling unit visited in Haldwani, Uttarakhand, is involved in the production of recycled PE pipes using recycled pellets made from plastic waste. This post-consumer unit has formalised the marginalised community involved in sorting of plastic waste from municipal solid waste dumps situated 0.5 km from the recycling unit and is a typical example of inclusive growth. The transportation costs for raw materials are hence almost nil. The municipal corporation has provided the infrastructure and land, thus reducing the capital investment cost to the recycler.

Lack of recycling for Polyvinyl Chloride (PVC) and other category (type seven) plastics

PVC with resin identification code 3 is a widely used polymer in India. A major challenge in the recycling of PVC is the presence of high chlorine content and the high quantity of additives, mainly plasticisers, which are added during the manufacturing of various PVC plastic products. Flexible PVC is plasticised to increase its flexibility, whereas hard PVC is un-plasticised. PVC used in footwear has a different PVC content. Few examples of mechanical recycling of PVC exist; however, in order to produce high quality recyclate, PVC plastic waste with uniform material composition is required. PVC is an excluded polymer in WtE and WtO plants.

Similarly, large quantities of other category plastics come from the automobile and electrical and electronics industries. Limited recycling was observed for type seven (other category) plastic. Few stakeholders are recycling ABS, nylon and polycarbonate into regranulates; further research is required for the development of sustainable recycling technologies for these types of plastics. The associated challenges of the 'other' category are low waste flows, and variable chemical properties of polymer blends including the melting point. Innovations in recycling processes are required in order to address the challenges.

4.3 Overview of gaps in current recycling

Field visits and stakeholder interviews revealed the following gaps and challenges for existing recycling technologies, which summarised in Figure 4.1.

While there are significant challenges to the growth of plastic waste recycling industries in India, the widespread practice and facilities for recycling are a sound platform on which opportunities for development can be pursued.

Gaps in PW recycling in India

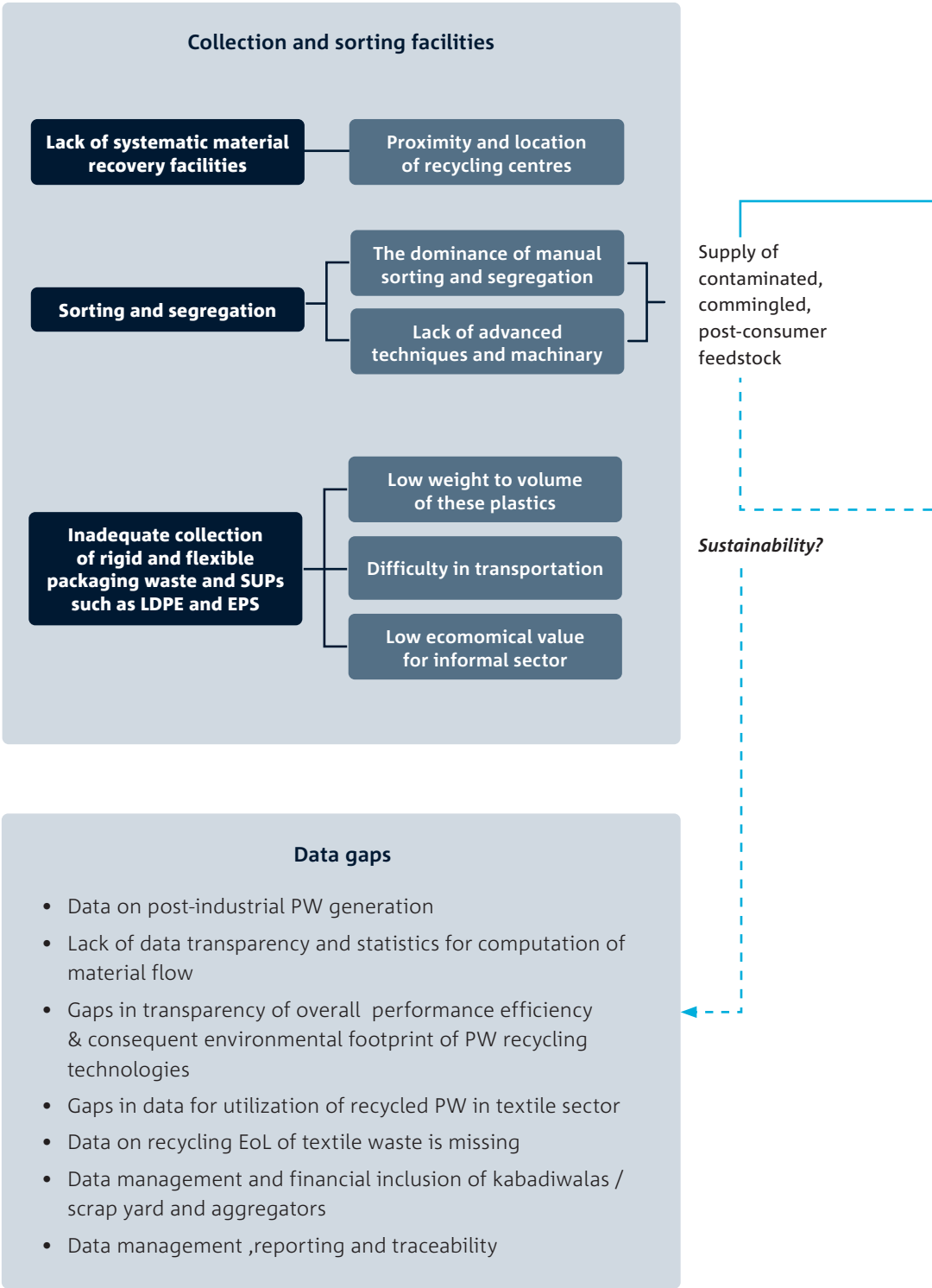
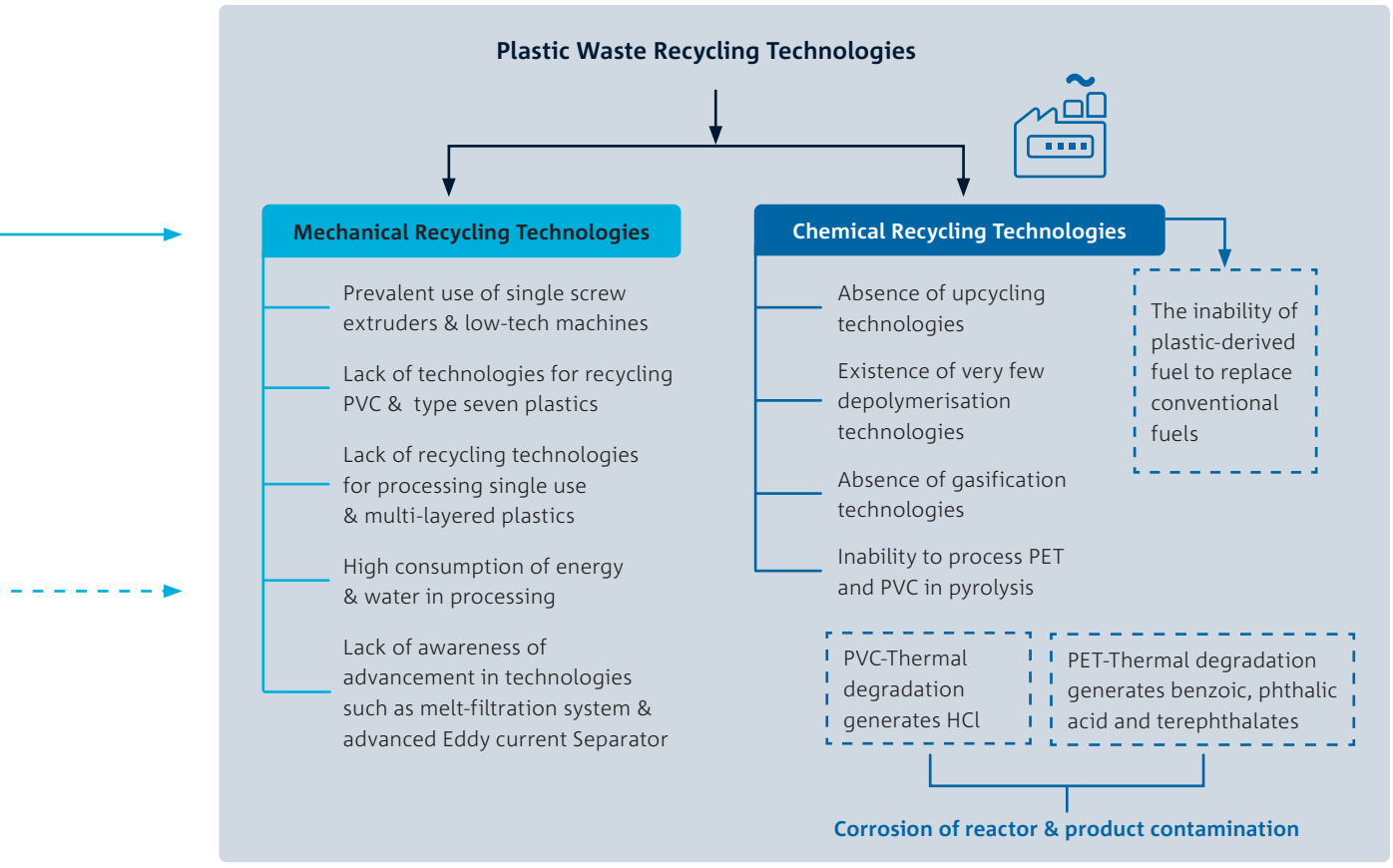
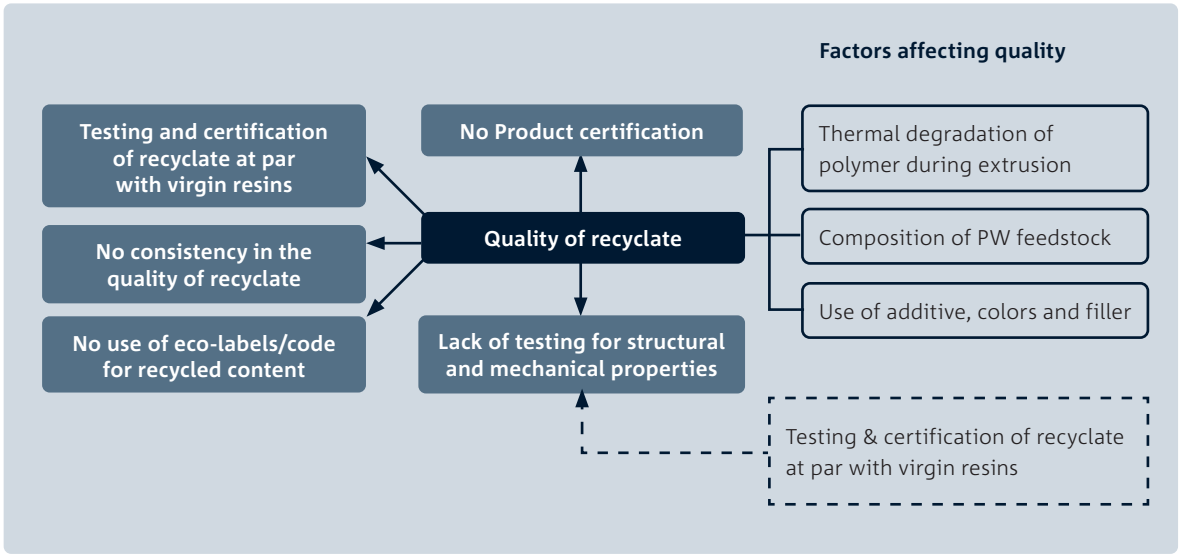


Figure 4.1 Gaps in current plastic waste recycling technologies in India


Plastic Waste Recycling Technologies
Mechanical Recycling Technologies
Prevalent use of single screw extruders & low-tech machines
Lack of technologies for recycling PVC & type seven plastics
Lack of recycling technologies for processing single use & multi-layered plastics
High consumption of energy & water in processing
Lack of awareness of advancement in technologies such as melt-filtration system & advanced Eddy current Separator
Chemical Recycling Technologies
Absence of upcycling technologies
Existence of very few depolymerisation technologies
Absence of gasification technologies
Inability to process PET and PVC in pyrolysis
The inability of plastic-derived fuel to replace conventional fuels
PVC-Thermal degradation generates HCl
PET-Thermal degradation generates benzoic, phthalic acid and terephthalates
Corrosion of reactor & product contamination


Factors affecting quality
Testing and certification of recyclate at par with virgin resins
No consistency in the quality of recyclate
No use of eco-labels/code for recycled content
No Product certification
Quality of recyclate
Lack of testing for structural and mechanical properties
Thermal degradation of polymer during extrusion
Composition of PW feedstock
Use of additive, colors and filler
Testing & certification of recyclate at par with virgin resins

4.4 Opportunities to drive greater plastic recycling

Addressing issues such as the poor quality of feedstock will require changes in both the technologies used and the behaviours of participants from consumers to manufacturers. From a technical point of view, progress can be driven by technological innovation, higher recycling targets, scalability and cost efficiency, strict environmental norms, promotion of circular design applications, development of circular design guidelines, and specification of minimum recycled plastic content for certain products. Opportunities occur all along the development path to a true circular economy for plastics, as discussed in the following section.

Common forum for technology options

The creation of an online platform portal for a **compendium of plastic recycling technologies** would facilitate access to existing information, innovations and recent technological developments. The information could be substantiated by providing open access to stakeholders and technologists along with the contact details of the technology provider. It would disseminate free knowledge and a mechanism for a forum where interested stakeholders could share experiences, best practices and on-field problems which would serve the purpose of its creation. The link to the compendium should be included in PWM rules and governed by a board of experts for verification and inclusion.

Our interactive experience in India shows that the technological scenario is indigenous, with machinery fabricated locally. There is no information sharing platform for continuous updating of technologies, improvement in machinery and emerging product design. Improvements in machinery would include advancements in energy and water consumption reduction, as well as pollution control devices such as scrubbers for emission control. End-of-life recycling options for non-recyclable plastic waste with catalytic cracking, higher quality and increased quantity of output, that is, fuel and better utilisation of plastic waste, should be included in the compendium.

Information on investment costs, machinery production capacities, resource efficiency and technology costs could be included, in addition to alternative greener cleaning materials as alternatives to chemicals. Innovations in cleaning and separation of dust and metals would comprise an important section of the compendium.

Funding infrastructure for sustainable plastic waste recycling

Lack of infrastructure for plastic waste collection and recycling remains a major problem, thus, its development for efficient plastic waste recycling is important. Many stakeholders have raised the issue of purchasing plastic waste at high costs which should be predominantly available at scheduled costs. The hierarchy in the waste collection system, from marginalised communities to formal waste collectors, can be harmonised as seen with Hasiru Dala Innovations, Bengaluru, where the informal sector in waste collection was professionalised by providing an identification card from the municipality.

Investment in waste management infrastructure can be devised through smart city missions and the Swachh Bharat Mission (Clean India) (MoHUA, 2019), which aims to develop liveable and sustainable cities. Waste management can also contribute to meeting India's aim for net zero emissions and provide a way forward for signing the Global Plastics Treaty planned for 2024.

Advanced sorting methods for supply of clean feedstock

Automated sorting techniques based on colour, gravity, and polymer type are less labour intensive and more accurate when compared to manual sorting. Some popular dry sorting techniques are spectrum-based, x-ray-based, air sorting, specific gravity-based, and electrostatic – based on electrostatic charges. Apart from dry sorting, there are wet sorting and chemical sorting techniques available with more sensitivity and delivering high transparency. Such kinds of transitions in innovations and advancement should be brought into the recycling ecosystem as these are lacking in the present market.

Innovations in coding, quality and subsequent scope of reuse

Plastic waste recycling is being made easier by special codes at the point of manufacture, and similar innovations in coding could also be provided to recycled plastic products, so they can be easily identified by consumers and recyclers. Recycled product codes will aid in understanding recycling potential, its frequency and also identification of the polymer composition. The quality of the recycled product can be optimised by categorising codes and thus help prevent mismanagement and leachate breakdown. Similarly, the polymer composition of product containers/ bottles should be revealed by manufacturers via providing separate coding to channelise better and logical recycling likelihood and establishing a standardised platform.

Certification and data tracking of plastic recycled products

There are currently no criteria or material testing standards that exist for recyclates to test physical properties such as mechanical strength, tensile strength, Young's modulus, etc. Moreover, standards for chemical properties, which establish composition in terms of adulterants and additives, can broaden the potential application of recycled materials, including food packaging.

It is necessary to standardise and implement protocols for the quality of recycled pellets and other recycled products. Recycling units should be able to ascertain the recycled content in a product for open-loop polymer to polymer recycling. QR codes, bar code systems, mobile apps and AI are some of the ways to identify virgin and recycled content. Defined standards are useful for further remanufacturing sectors or green product design of recyclate in all applications, particularly those that require material strength or will be used in food contact applications.

Testing and certification of recycled plastics should be mandatory as it allows for the substitution of virgin polymer for end-use applications. This requires an elementary evaluation of the recycled polymer/product, including the batch frequency, in order to gain a better understanding of the consistency in the recycled polymer stream. This will further encourage consumers and manufacturers to use recycled polymers as a product or feedstock. To ensure the quality of the recycled products, the source of the plastic waste needs to be traceable.

Furthermore, recyclers should have a provision for registering themselves in the quality management system as per ISO 9001 or equivalent, and an audit program could review the records for compliance with respect to all the test methods used to check quality. The PWM rules specify the conditions under which plastic bags should be white in colour, or colours should use pigments and colourants as per Indian Standards listed under IS 9833:1981. Also, recycled plastic bags should meet Indian Standard IS 14534:1998 (Guidelines for recycling of plastics) with a dedicated label as recycled. Compostable plastics should have a label saying 'compostable' and should meet Indian Standard IS/ISO 17088:2088.

Certification should be accompanied by data transparency throughout the recycling process. Annual surveys for upstream production and importation, identification of polymer types, material flow and product applications should be conducted. This activity could be well supported by blockchain technology and an online tracking system.

Adequately funded R&D for plastic waste recycling technologies

Committed and adequately funded R&D is required for the development of advanced plastic recycling infrastructure. Several technologies such as transitions in machinery for improved efficiency, better material recovery facilities with sensors/AI for sorting, advance pressure washing systems, crushers and grinders and screw extruders, and suitable fluidised bed reactors are important in recycling. Reactors capable of scaling up large quantities of plastic waste need extensive research on reactor design.

Approaches in research funding for PWM towards upcycling technologies, gasification, catalytic pathways, hydrocracking, and product redesign and remanufacturing are required. This aligns with efforts under the flagship 'Make in India' program to encourage development of indigenously developed advanced recycling systems.

Financial incentives for participants in plastic waste recycling

Transformation of plastic waste as a cashable commodity can be realised by incentivising recovery and higher recycling rates and participation of various stakeholders involved in plastic waste recycling. This can be achieved within the policy guidelines for various stakeholders including municipal corporations, plastic recyclers, waste collectors, and consumers. Incentive schemes should aim to be inclusive, formalised and must address the financial challenges faced by plastic recyclers.

Financial incentives for recyclers can be designed to promote capital investment for required modern infrastructure and encourage voluntary contributions by plastic manufacturers. Voluntary contributions by industries towards investing in transformative technologies will encourage entrepreneurs and players in recycling businesses. Polymer to polymer technologies can be developed profitably and increase the use of plastic waste.

Mechanical recyclers are using low-cost fabricated machinery which exhibits low throughput and consumes more resources. Subsidies for machinery may help recyclers to procure advanced recycling systems. Moreover, a green tax on the recycling system could encourage recyclers to use sustainable recycling systems that consume less energy and water.

Incentivisation and subsidies for municipal corporations, as well as green credits in the Swachh Bharat (Clean India) mission for plastic waste recycling to municipalities, will yield positive results in domestic recycling volumes of post-consumer plastic waste. Presently, higher recycling costs prevent municipalities from recycling plastic waste and implementing local recycling programs. Development of a policy with financial incentives for municipalities may help to improve commingled post-consumer plastic waste chemical recycling at more local levels.

Landfill taxes to discourage plastic waste from reaching landfill

Disposal of plastic waste in landfill must be the least preferred option. Landfill taxes can be imposed on plastic waste reaching landfill. Transition management for this option may encounter hurdles and implementation could be an indirect option. This would serve to generate funds for environmental mitigation as well as inhibiting disposal of plastic waste in landfill by raising the cost.

Creating a true circular economy for plastics with industrial symbiosis

Most of all, plastic recycling needs to be seen as part of a true circular economy for plastics rather than as an isolated function. This applies both to securing the feedstock, and the ultimate uses of high-value upcycled plastic.

Industrial symbiosis, with close association between industries, is required for effective industrial waste recycling and is good for creating economic value from plastic waste. This reduces resource consumption, transportation costs, and environmental impact by reducing greenhouse gas emissions from transportation, leading to cost-effective recycling. It may result in increased data transparency with increased responsibility with respect to post-industrial waste flows.

Alternative uses of plastic waste in the construction industry, e.g., roads, tiles, compressed boards and other recycled products, offer sustainable end-of-life PWM options and true circularity can be attained if further reuse in recycling of plastic waste materials is not possible. There is a need to promote closed-loop recycling to achieve true circularity. Similarly, tertiary or chemical recycling producing WtE, oil and gas from plastic waste should be performed with end-of-life plastic waste that cannot be recycled further, thus retaining the value of mechanically recyclable plastic waste.

Global case studies provide ample evidence and inspiration for these opportunities. These voluntary stages need to be pursued as opportunities before recycling and reuse are made mandatory, with enforcement mechanisms and technologies to ensure standards are met.

Global case studies

Case study I – France and the United Kingdom have introduced a good initiative to limit waste to landfill by imposing landfill taxes (d'Ambrières, 2019). Landfill taxes, or outright bans on allowing landfill disposal of certain types of waste, are the most effective way to reduce the amount of waste plastic sent to landfill. The European Union has set a goal of only 10% of plastic waste to landfill by 2030, down from around 30% currently. Incineration taxes are also being used to limit this type of waste process.

Case study II – ACO recycling (Turkey) provides an economically feasible segregation process and increased material flows in the supply chain by utilising IoT sensors based on AI algorithms. Smart bins are used for collection because they automatically assess the level of garbage in the bins and provide information to waste collectors. This will be useful in optimising collection timing, routes, and frequencies. Robots (AI-powered) are used in recycling centres to perform waste segregation at high speed, saving time and labour costs as well as fuel costs in waste management (Watine, 2021).

Case study III – Upcycling/Depolymerisation technology and modifications (gate to cradle)

- British Petroleum (United Kingdom), in collaboration with Clean Planet Energy (UK), has initiated conversion of hard-to-recycle plastic waste into naptha and diesel with ultra-low sulphur content at very low temperature (BP and Clean Planet Energy, 2022).
- PyroCore (United Kingdom) transforms plastic waste by pyrolysis under high temperature and inert atmosphere into solid and syngas. This process aids in the reduction of carbon emissions as well as energy costs[14].
- Poly (methyl methacrylate) (PMMA) is a widely used polymer, particularly in bio-medical applications. Lab studies have established depolymerisation of PMMA at less than 300° C, into monomers in a fluidised bed reactor (Kang et al., 2008).
- Ioniqa Technologies (Netherlands) is able to reduce a variety of plastic waste including PET waste at a low temperature (Artigas, 2014) by an ionic catalyst complex.
- IBM's glycolysis process uses an active and volatile organocatalyst which selectively degrades clean and contaminated plastics, producing a good quality BHET (Bis-(2-Hydroxyethyl) Terephtalate) with lower production of waste[15].
- JEPLAN's BRING Technology™ consists of glycolysis of PET combined with specific purification steps in order to remove all inorganic and organic compounds existing in waste PET. They started a 'textile-to-textile' recycling demonstration plant in 2018[16].
- Gr3n (Switzerland) employed hydrolysis at a pilot scale to form PET to terephalic acid and claim to produce virgin grade monomers using microwave-assisted catalysis via an alkaline hydrolysis. This patented DEpolymerisation by MicrowavE TechnolOgy (DEMETO) is able to depolymerise PET materials ranging from coloured packaging to polyester textiles within 10 minutes, in a continuous process[17].
- Loop™ Industries uses catalytic thermolysis at low temperatures to form monomers dimethyl terephthalate (DMT) and monoethylene glycol (MEG) for PET[18].
- Carbios (France), with their scalable PETase technology (Enzymolysis) are converting polyester textile waste back to monomers and bottles[19]. CSIRO also developed a PETase enzyme which can proficiently break down PET to its original monomers by computational design of enzyme (King et al., 2021).

While all of these opportunities must be pursued for recycling technologies to be adopted at scale across India, there are some barriers to implementation that threaten either one, some or all of the opportunities.

14 https://pyrocore.com/technology/ (accessed 8 September 2022).
15 https://www.azocleantech.com (accessed 2022)
16 www.jeplan.co.jp (accessed 2022)
17 https://gr3n-recycling.com/technology.html (accessed 2022).
18 www.loopindustries.com (accessed 2021)
19 https://www.carbios.com/en/enzymatic-recycling (accessed 2022).

4.5 Barriers to implementation of potential solutions

The broad scope of opportunities that need to be pursued by the plastic recycling sector would be challenging enough in the best environments. However, they must overcome some equally broad barriers. Current regulations on plastic waste recycling fail to impose stricter environmental standards in plastic products, while a relatively low degree of collaboration along the value chain has contributed to a lack of awareness on the technologies, business cases and behaviours needed. A huge sector of the textile/fashion industry which utilises plastic in its production is not considered in the plastic waste flow chain in India.

Regulatory barriers

Technologies enabling plastic recycling options for secondary raw materials face regulation barriers and require infrastructure and large investments. Taxation on the use of secondary materials, market-based incentives and integrated recycling plans, coupled with sufficient waste flows, are major barriers to the implementation of a policy leading to a circular economy for plastics. De Weerdt et al. argued that waste treatment taxation and plastic-related legislation significantly contribute to reductions in plastic waste generation from industry and can increase rates of industrial plastic waste recycling (De Weerdt et al., 2020). On the flipside, a lack of positive environmental standards for inputs and products hinders the implementation of CE business models to reuse plastic waste.

Over-reliance on EPR

Policies leading to the inclusion of manufacturers in recycling need to be favoured over creating EPR obligations, as detailed in PWM rules. Presently, manufacturers are not recyclers, and producers are dependent on EPR for management of plastic waste generated by them. EPR does not emphasise recycling, and there are some loopholes in EPR implementation that need to be addressed.

Lack of awareness and connectivity among stakeholders in plastic value chain

Sustainable PWM requires stakeholder engagement, from design to product, across the plastic value chain in order to achieve a circular economy for plastics. Our discussions with stakeholders revealed a lack of understanding of recent developments in advancements in machinery and technological options for resource utilisation. Although the plastic waste to fuel quaternary option was found to be competitive, the percentage of players was only 5% of total plastic recyclers. Data and statistics on post-industrial plastic waste generation and its recycling are currently unavailable. There are neither incentives nor awareness of upcycling plastic waste, or in-house plastic waste recycling by manufacturing industries in order to break the norm of using virgin raw materials. Poor connectivity between municipalities, manufacturers and recyclers means that there is no concerted effort to build awareness across the board.

Poor business case for investment

Sustainable recycling technologies that are implemented on an industrial scale require large investments and major players, both of which are lacking in the current recycling regime. To overcome these barriers, a clear Roadmap for reinvigorating the plastic waste recycling sector that guides it through the four stages of development is required.

4.6 Recommendations to drive innovation

These recommendations are designed to fill gaps, pursue opportunities, and overcome barriers in a holistic way that builds capacity and impact. We have identified a path to sustainable plastic recycling and a true circular economy for plastics through the uptake of new technologies and design options in the short, medium and long terms.

Short-term priorities (to 2025)

- Improvise and find alternatives to the technological and legal barriers that hinder active entrepreneurship.
- Develop, and regularly update, a compendium of technologies focusing on recycling options.
- Use advanced technologies to disseminate information to stakeholders via expos, workshops, and exhibitions in line with the Skill India Mission.
- Manage source-segregated dry waste through the development of recycling infrastructure including recycling facilities and MRF.

Medium-term priorities (to 2030)

- Establish a dedicated group of statutory bodies to monitor the implementation of the PWM rules.
- Create an online platform to monitor the flow chain of polymers with the help of digitalisation (software solutions and artificial intelligence in sorting and recycling processes).
- Develop economic incentives towards a Recycling Modernisation Fund and its outreach to enhance recycling capabilities.
- Affirm the role of science in supporting industry in the development and upscaling of technologies (potentially positioning CSIR as an innovation catalyst in the Indian innovation system).
- Inventorisation of size of industry, resource consumption and pollution due to discharge of emission and effluents, for designating criteria for plastic recycling industries into red, orange or white categories pragmatically.

Long-term priorities (beyond 2030)

- Intervention of successful global technologies and innovation in machinery for optimum resource utilisation.
- Develop standards and product certification mechanisms to enable the monitoring of product quality and recycling efficiency.
- Develop a dedicated Plastics Innovation Hub to encourage young minds.

Bioplastics are not a simple solution for the single-use plastics problem

Made from renewable plastics rather than from fossil fuel sources, bioplastics are often offered as a 'green' alternative to single-use plastics.

They come with several potential limitations though:

- Some bioplastics contribute to the microplastics problem as they contain biomass that is difficult to be broken down by microorganisms. These can require high temperature industrial composting to attain complete breakdown, beyond what is possible under household composting conditions.
- There are added burdens from agriculture and chemical processing when compared with petroleum-based plastics. These include extensive land use, and additional pollutants from the use of fertilisers and pesticides.
- Their production also competes for land that could be used for food production, seen as a growing challenge for India's large population.

To ensure that bioplastics represent a safe and sustainable alternative to single-use plastics, we need:

- Strict, national level standards regarding minimum requirements for bioplastics (e.g., compostable performance, etc.).
- National laboratories to provide timely and accurate certification testing.
- Careful LCA of products to determine if they do offer a better alternative to single-use plastics.

5 Uptake of secondary materials in manufacturing and infrastructure

5.1 Introduction

The recycling of synthetic polymers and plastics in India can be improved substantially. India generates around 3.46 Mt of plastic waste annually, or 25 kg per person (CPCB, 2020), and recycles only around 50% of it. Most of the remaining material is either incinerated haphazardly or dumped in unmanaged landfill, where it is slowly released into water bodies in macro and microstructure, where it becomes embedded in the food chains of humans, marine and other terrestrial and aquatic life (Issac and Kandasubramanian, 2021). The process of recycling post-consumer plastic has many inherent challenges. To reverse the supply chain flow in a centralised model, waste plastic needs to be collected from end consumers, transported to recycling facilities and sorted into its different types before it can even be processed, making it resource intensive and impacting the already ailing supply chain system.

Incorporating plastic waste as a secondary source material in construction and infrastructure may be one solution. Several innovative uses of secondary materials can help consume plastic waste and reduce reliance on conventional raw materials, thus creating a sustainable material flow system. Plastic waste uses that are garnering interest include bitumen binder, aggregates in concrete, waste to fuel and energy, coke substitute in steel manufacturing, petroleum coke substitute in cement manufacturing and other construction products like sand brick, recycled plastic lumber and tiles. India's demand for conventional raw materials is rapidly rising as it becomes a global manufacturing hub, with a growing consumer base needing shelter, transportation and utilities (Kant et al., 2015). These demands may be addressed by incorporating plastic waste as a secondary source, mitigating the issue of PWM as well.

This chapter reviews the use of synthetic polymers (plastic) in asphalt road construction, cement and steel manufacturing, power generation and the manufacturing of some construction products. For each of these secondary uses, the chapter reviews:

- the current state of that use of waste plastic in India (with some uses such as asphalt quite advanced, while others such as power generation in their early stages), as well as any barriers to its development,
- successful global practices for that use, which may hold lessons for how those barriers may be overcome, and
- recommendations for increasing that use in India, including actions in the short, medium, and long terms.

We believe the use of plastic waste as secondary materials is a missed opportunity for India. Reusing plastic waste as secondary materials will help manage the waste stream and reduce reliance on unsustainable petrochemical industries. It will be fostered by making recycling technology available throughout India in a decentralised model, with standards and quality checks to maintain the consistency of the recycled waste stream.

5.2 Sustainable asphalt roads with waste plastic

The use of plastic waste as an alternative to conventional polymer-based bitumen binders has strong potential. Not only does it supersede the use of conventional polymer-based binders, but it seems a better alternative to pyrolysis or landfilling waste (Hoxha, 2021).

Key findings are that:

- India has been a strong adopter of plastic waste in its bitumen, driven by both free use of the technology and regulation.
- Australia and other countries are mixing plastic with other packaging and rubber in innovative new road technologies.
- However, in both existing and emerging technologies, issues such as wear, fumes and microplastic generation are still to be addressed.
- To pursue the potential of plastics in the sector, proper regulatory frameworks and guidelines are required along with processes to use all kinds of plastic waste in the bitumen. The recycling process, techno-economic analysis and feasibility of using all kinds of recycled plastic need to be carried out.

Current status of use in India

More than 98% of surfaced roads in India are reported to have bituminous topping to facilitate the country's rapid nationwide infrastructure development (Dhir, 2000). The expansion of asphalt roads has helped in economic development, but the cost incurred in the project has resulted in poorly engineered roads, with increased costs of raw materials like asphalt. This limitation can be overcome by using waste plastic as a secondary source of bitumen binder.

India has been using plastic waste to form polymer-modified asphalt since early 2000, when Jambulingam Street in Chennai was built, which showed improved durability and fewer potholes (Yuliana, 2021). Thus, the CPCB and various policymakers have been supporting the use of plastic waste in road construction since early 2000, and most states and UTs have reported the use of plastic waste in road construction as a major area of secondary consumption (CPCB, 2020). This trend has been growing, with around 100,000 km of road built with plastic waste as of 2020, and over 11 states with plans of doubling the plastic waste road policy in next fiscal year (Heriawan, 2020). The use of plastic waste in asphalt roads in India was further bolstered when the patent for using PE, PP and PS with bitumen for improved binding properties was handed to the Government of India for free (Vasudevan, 2012; Lee, 2022). In addition, as of 2015 there was a mandatory regulation for road developers to use recycled plastic in road construction within 50 km of the periphery of any city with a population of more than 500,000. In case of unavailability of recycled plastic, the developers need to request a special permit from the road transport ministry (Ministry of Road Transport and Highways, 2019).

Current global practices

Several industries are working to form standards and technologies to incorporate waste plastic streams into asphalt, which has been lacking in India, with most of the effort coming from government and regulatory bodies, despite a few exceptions of limited registered patents (Vasudevan, 2012; Lee, 2022). Austroads, an Australian-based company, has been working to develop clear guidelines for the road industry to identify and handle road-grade plastics to use in road construction with their APT6305 project (Giustozzi and Boom, 2021). Downer has been using recycled soft plastic bags and packaging and rubber from end-of-life rubber to form 'reconophalt', which has been approved by the New South Wales Environmental Protection Agency and has a comparable environmental risk to standard asphalts, in terms of BPA leaching and microplastic generation. Similarly, another Australian company, Fulton Hogan, has developed polymer-modified asphalt using recycled plastic waste, 'Plastiphalts', which follows the framework set by Austroads for recycled polymer-modified binders.

Drawbacks of current applications

The effect of using plastic waste as bitumen binder has been extensively studied in a controlled environment (Hassani, 2005; Dalhat and Al-Abdul Wahhab, 2017; Heydari et al., 2021), but more analysis of the effect of using plastic waste at an implementation scale is needed. Some simulation standards, like the Heavy Vehicle Simulator (Du Plessis, 2018) and the pavement Fatigue Carousel (Simonin et al., 2016), simulate the field environment for testing asphalt roads, but because they are run as accelerated scenarios, they do not account for factors such as microplastic generation due to tyre-induced abrasion on the road (Enfrin and Giustozzi, 2022). Similarly, the use of petroleum-derived products as bitumen binders results in production of polyaromatic hydrocarbons (PAH) and volatile organic compounds (VOC) at high temperatures (Butler, 2000), and when using plastic as a bitumen binder the risk of fuming still remains while handling the asphalt (Mo et al., 2019; Ansar et al., 2021). This can be avoided when handling plastic-based asphalt in a controlled environment, but when using it on a construction site, external factors like wind and temperature increase fume production.

Researchers have only recently begun to study the environmental effects of microplastics, who have found that using plastic-based asphalt will expose millions of tonnes of plastic to heat and ultraviolet radiation, which are the main factors for microplastic generation. There have been limited studies on microplastic generation from asphalt roads, as most samples taken for studies are roadside dust samples, which can include microplastics

originating from vehicle tyres and surroundings, as well as the asphalt road (Leads and Weinstein, 2019; Yukioka et al., 2020; O'Brien et al., 2021). There are some common techniques like pavement friction testers (Enfrin and Giustozzi, 2022), sandpaper with rotary abrader (Burghardt et al., 2022), and the wet track abrasion technique (Saghafi et al., 2019), to simulate the natural abrasion of asphalt roads and collect the microplastics, but the results are always subject to limitations such as the size and shape of the microplastic, effects of UV light and moisture, and time-induced decomposition of the plastic.

Recommendations for using plastic waste as bitumen binder

India lacks regulations and standards that clearly lay out the guidelines and framework for using waste plastic in asphalt roads. These regulations and proprietary products can be developed by both private and public entities, encouraging the development of innovative methods for incorporating waste plastic. Austroads has formulated APT6305, which outlines the process for using different types of recycled plastics, their recycling process, and their application scope in asphalt roads (Giustozzi and Boom, 2021). This framework, formulated by public and private entities, helps guide all the stakeholders in the ecosystem. Likewise, only LDPE and HDPE are currently used in asphalt, while omitting other kinds of plastics, so new technologies and guidelines need to be developed to incorporate all kinds of waste plastic into the asphalt. Similarly, there have been limited tests and studies done for asphalt application at the implementation level, with most studies being carried out in controlled environments in laboratories to analyse the production of volatile organic compounds and toxic by-products while handling the binder.

5.3 Waste plastic as fine aggregate in cementitious composites

The aggregates which form 65–80% of concrete (Faraj et al., 2019) are typically made of gravel, sand and crushed rock. With 10 billion tonnes of concrete produced annually around the world (Meyer, 2004), any substitution of recycled plastic waste is a large untapped opportunity to reduce plastic waste and reduce the extraction of conventional geological aggregates.

By using plastic aggregates, concrete structures can be made lightweight, with enhanced compressive and tensile strength (Akçaözoğlu et al., 2010). Likewise, plastic aggregates inherently have lower bulk density, a lower melting point, and lower water absorption (Choi et al., 2009). Despite the intrinsic benefits of plastic aggregates in concrete there has been very limited commercial adoption in India, with only Maharashtra using around 18,000 tonnes of waste plastic for concrete aggregate in 2020 (CPCB, 2020).

Key findings are that:

- In part to address a shortage of sand, India is experimenting with PET-bottle recycling and other aggregate materials.
- Recycled plastic use internationally focuses on uses that are not subject to heavy vehicle movements, such as footpaths, public spaces, and domestic driveways.
- Issues to be addressed by further innovation include weakness under testing, fumes and combustibility, and water porosity.

Cementitious composite application needs to be expanded to states in India other than Maharashtra, with the application scope explored in non-structural areas like pavements and driveways, due to the impact on mechanical strength with an increase in the composition of recycled plastic in the mix.

Current status of use in India

In the Indian construction market, exponentially growing urbanisation has led to a shortage of raw materials like sand, which is used as aggregate for cementitious composite, and researchers have suggested using PET bottles as a substitute, in addition to chemical admixtures to retain the compressive strength and workability of the concrete (Savoikar et al., 2015). Likewise, a team of researchers from Tamil Nadu has registered a patent that includes using recycled PET bottles to replace 70% of the sand composition of tri-arc shaped pavement blocks, with similar mechanical strength as normal blocks, as per IS 15658:2006 code (India Today Web Desk, 2022). There is commercial-scale production of plastic sand bricks, such as that carried out by Rhino machines from India which make 'Silica-Plastic Blocks' from recycled plastic

waste (20%) and foundry dust waste (80%), where the use of plastic eliminates the need for water during the mixing and curing stages. The mechanical strength of the sand bricks was found to be 2.5 times more than that of red clay bricks and used 80% less natural resources.

Current global practices

Companies like Replas, from Australia, use soft plastic (PE and PP), as partial substitutes for aggregates in the making of Polyrok Civil, which has been used in the construction of pavements, curbside, and landscaping. Likewise, Replas have been using the concrete in pilot sites like Crossing Place Trail in Wodonga, a footpath in the City of Frankston in Victoria, and Horsham Coles carpark in Victoria. These kinds of initiatives can help in the use of plastic waste as aggregate in concrete. Concrete structures that do not undergo significant stress, such as footpaths, public walkways, driveways, and structures of a similar nature, can incorporate aggregate material.

Drawbacks of current applications

The use of plastic aggregates in cementitious materials increases defects and cracks as the composition increases, and also the size and type of plastic affects the Ultrasonic Pulse Velocity (UPV) test value, which is an industry standard to check for defects, uniformity and estimate the depth of cracks in concrete structures (Qasrawi, 2000). A study done with PET has shown that increments in particle size have a negative impact on the UPV value, with uniform impact until 30% of composition by weight (Albano et al., 2009).

Concrete with plastic aggregates has higher combustibility, making it unsuitable for indoor application and more suited for outdoor structures, like pavements, highways and less strength intensive structures (Aciu et al., 2018). The combustion of plastic aggregate concrete leads to high amounts of fume generation, which can be toxic. Similarly, concrete with plastic has higher porosity, leading to higher water absorption, and carbonation of the structure, but it also acts as a good barrier to chlorine ions (Gu and Ozbakkaloglu, 2016). The shrinkage stress of the concrete is also weakened, due to the low elastic modulus of the plastic making the concrete structure weak (Gu and Ozbakkaloglu, 2016).

Recommendations for plastic waste in cementitious material

There has been limited use of recycled plastic in cementitious aggregate in India, with only PET being used in Maharashtra (CPCB, 2020). This needs to be expanded to more states to increase the uptake of waste PET as a secondary material as it has proven that the controlled addition of PET fibres can improve the tensile and flexural strength and wet and dry density of concrete structures (Rathod et al., 2021). Similarly, use cases for concrete with recycled plastic need to be explored and implemented for outdoor non-structural areas like pavements, driveways and footpaths, which have been increasing in India with its development in roads (Dhir, 2000), and urbanisation (World Bank, 2021).

5.4 Iron and steel manufacturing

Demand for steel is anticipated to continue to rise significantly. However, iron and steel are regarded as one of the most challenging industries to decarbonise in India (Kim et al., 2022), due to their high heat consumption, use of carbon as a process feed, small profit margins, huge investment intensity, lengthy asset lives and trade barriers. Recycled plastic can be explored to reduce reliance on conventional fuel sources, carbon sources, as an alloying material and as a reductant (Devasahayam et al., 2019a; Devasahayam et al., 2019b). This work suggests that:

- India has the potential to direct 8 Mt of plastics to the iron and steel sector by 2030, but the industry is in a very early stage.
- However, other nations have started using plastic waste, with promising growth in Germany, Italy and Japan.
- These projects show that there are potential emission and cost advantages in the use of secondary plastics if the stock can be de-chlorinated.

For the use of waste plastic in steel manufacturing in India to excel, the current trial approach needs to be translated to large-scale adoption, which requires a robust material flow system for the waste plastic. This can be developed by coordinating with local governments and industries.

Current status of use in India

After considerable discussion, the Indian Ministry of Steel recently announced an assessment of the potential for incorporating plastic waste in the country's iron and steel industry (Kainthola, 2022; Government of India, 2022). The applicability, benefits, and drawbacks of using plastic waste, including single-use plastics, were considered for use in areas such as coke ovens, blast furnaces, and electric arc furnaces. According to projections, 1 kg of plastic consumption will be equivalent to about 1.3 kg of coal, and the iron and steel sector has the capacity to use up to 2–3 Mt of plastic waste annually, and more than 8 Mt by 2030–2031 (Ministry of Steel, 2022b). Currently, a relatively small proportion of plastic waste produced on the sites of steel firms is used sporadically for trial purposes by the industry. The use of plastic waste as a fuel or reductant in the steel industry, which is deregulated, would depend on its technological and economic viability (Ministry of Steel, 2022a). However, even though India is the second largest steel manufacturer in the world, its use of plastic waste is still in its infancy (Das and Kandpal, 1997).

Current global practices

In contrast, steel manufacturers from other nations have started using plastic waste as fuel and carbon sources in manufacturing processes to reduce reliance on conventional materials derived from petrochemical sources.

At the Bremen Steel Works (ArcelorMittal), the first trial to introduce waste plastics into a blast furnace with a capacity of 70,000 tonnes/year was undertaken in 1994, followed by commercialisation the following year (Satyendra, 2018). The NKK (now JFE Steel) Keihin Works in Japan had the first comprehensive facility for injecting plastic waste. The manufacturing plant has a processing facility for waste plastic where solid and soft plastics can be separated, along with PVC. Solid plastics like HD/LD PE are used as reductants, while soft plastics are fed directly into a blast furnace (Satyendra, 2018; Asanuma et al., 2014; Hotta, 2003).

The world's largest plant centred on plastics injection into blast furnaces has been operated by the steel producer Voestapline. Around 220,000 tonnes of end-of-life plastics in the form of various agglomerates have been injected since 2007 as alternative reductants. The future expansion of the Torero project by ArcelorMittal may potentially use waste plastics as circular carbon sources to replace fossil fuels being injected into the blast furnace. The company also plans to use waste plastics for dry reforming by reacting with CO_2 (captured from the blast furnace) using a high temperature plasma torch to produce syngas for iron ore reduction in a blast furnace (IGAR project). NextChem and Acciaierie d'Italia (a joint venture between ArcelorMittal and Invitalia, the biggest steel producer in Italy) have agreed to conduct a viability study on the use of circular gas (syngas) at the Taranto steel mill. This circular gas is produced using NextChem's Waste-to-Chemical technology, which is based on recovering the carbon and hydrogen present in plastic and dry waste via a partial oxidation approach. Both during the production of steel and during its refinement, this specific gas can be utilised instead of natural gas or coal dust in the blast furnace (Hydrocarbon Processing, 2021; Maggio, 2022).

Nippon Steel in Japan recycles over 200,000 tonnes of plastic waste per year, collected from household and municipality waste streams. The collected waste plastics are chemically treated in coke ovens, generating around 40% hydrocarbon oil (used for plastic products), 40% coke oven gas (used as energy at steelworks) and 20% coke (used for making iron) (Nippon Steel Corporation, 2021). POSCO has invented 'Slastics', a composite material made of steel slag and plastic waste, to recycle steel slag. Slastics have a lot of promise for use in a wide range of engineering and construction applications since they are incredibly robust and durable. When plastics are recycled to make Slastics, they prevent 99% of greenhouse gas emissions compared to when they are incinerated; this is the equivalent of averting 2.33 tonnes of CO2 for every tonne of recycled plastic (Worldsteel, n.d.).

To lower their carbon footprint, steel producers are also looking into the possibility of injecting gases with a high percentage of hydrogen through tuyeres and/or in the stack. The gas might originate from waste plastics as they have a significant proportion of hydrogen in their molecular chains. The use of electric arc furnace steelmaking is gradually increasing, which also helps in the recycling of steel scrap. For instance, Polymer Injection Technology has been successfully commercialised using electric arc furnaces in different industries and hence, an engineering modification to introduce an injection lance (if not present) for waste plastics in the furnace can be considered. Another key aspect to be considered is the collection of waste plastics followed by sorting and cleaning. Industrial collaborations with plastic collection recycling units (formal and informal) are a major requirement to address this issue and work on how the ferrous industry could source waste plastics in an efficient way. Therefore, by making significant developments in alternative technologies using waste plastics, the Indian steel sector can take a leading role in moving ahead by incorporating circularity with plastic waste.

Drawbacks of current applications

The iron and steel industry is a large, worldwide sociotechnical system that profoundly affects our current lifestyle. One significant obstacle which is usually considered is that steel produced through alternative technologies initially costs more than traditional steel due to the greater expenses associated with these technologies (Muslemani et al., 2021). However, when waste materials like plastics are used to meet energy and chemical demands in a ferrous industry, the costs related to coal mining and coke making are eliminated. Thus, plastic waste does tend to cause raw material savings as well as some monetary savings if planned adequately in terms of waste plastics collection and transportation. For the fabrication of steel, the ferrous industry employs carbon-intensive primary resources. It is the greatest coal consumer, and direct reduced iron (DRI) requires hydrogen as a reductant, commonly obtained by reforming natural gas (Kim et al., 2022). Thus, by employing waste resources like plastics or generating syngas as the reductant, significant quantities of carbon coming from the natural resources can be reduced.

Another challenging aspect is meeting the global demand for steel. Recent steel production was around 1951 Mt in the year 2021 (Worldsteel, 2022). Thus, any form of change in the conventional manufacturing process will affect the supply-demand ecosystem of the steel industry. The conventional blast furnace – basic oxygen furnace route accounts for around 71% of steel production and the remainder is produced through the electric arc furnace route (Worldsteel, n.d.(a)). Hence, implementation of alternative technologies with the use of waste plastics should be carried out in a way that does not impact global demand and the collection or supply of waste plastics needs to be adequate for the manufacturing process. The

composition of mixed waste plastics will be crucial as chlorinated plastics like PVC need to be dechlorinated/ treated before being used for iron and steelmaking applications. Moreover, close coordination with steel suppliers, such as the iron ore sector or scrap sector, is crucial to ensuring carbon neutrality along the entire value chain. High expenses, prolonged investment cycles, a lack of funding, the likelihood of product quality or character changes, the risk of production interruption, an insufficient supply of skilled labour, a lack of proven technologies, and a lack of accurate and comprehensive information are all risks. Development and enhancement obstacles in energy efficiency of a particular process can be technological, informational, economical, behavioural, organisational, competency, or awareness-related (Kim et al., 2022).

Recommendations for plastic waste in iron and steel manufacture

India, being the second largest steel manufacturer in the world (Das and Kandpal, 1997), has a unique opportunity to incorporate waste plastic as a secondary source of carbon in the steel industry and thus reduce carbon consumption. Efforts are currently limited to trial runs and sporadic use of waste plastic, which need to be upscaled for commercial-scale adoption. Currently, the availability of a consistent supply of waste plastic has been a major issue for the steel industry, which needs to be addressed by creating a large-scale and robust supply chain system for waste plastic (Ministry of Steel, 2022c).

5.5 Power generation

The calorific value of plastics ranges from 30–40 MJ/ kg, which is comparable to conventional fuel sources like gasoline (46 MJ/kg), coal (30 MJ/kg) and fuel oil (43 MJ/kg) (Panda et al., 2010; Komalis et al., 2012). Thus, the opportunity of using waste plastics as a fuel source in thermal energy plants and manufacturing plants has been explored through to commercial levels.

Key findings are that:

- Pilot projects like Ocean Plastic Turned into an Opportunity in Circular Economy (OPTOCE) have been running in India, which transfer non-recyclable plastic waste as coal substitutes in energy-intensive industries.
- In India, plastic waste to fuel conversion has been limited to a few states like Punjab, Telangana and Madhya Pradesh, at pilot scale.
- Globally, there have been diversified waste to fuel approaches like Plastofuels, a densified coal-like dense plastic nugget, which is not observed in the Indian market.

The waste to fuel approach in India can be effectively implemented using a robust waste inventory and logistics system. To date, waste to fuel approaches have been mainly operated by unregulated waste bodies.

Current status of use in India

Projects such as OPTOCE aim to convert non-recyclable plastic waste into energy and coal substitutes while directing recyclable plastic waste to recycling facilities. This project is currently run in pilot phase in China, India, Vietnam, Myanmar and Thailand by the Norwegian Development Program where they have been focusing on energy-intensive cement manufacturing industries (OPTOCE, n.d.). Similarly, the CPCB annual report states that the use of plastic waste in cement manufacturing is widely applied in many states, with states like Maharashtra using around 16 tonnes of plastic waste used per annum in cement manufacturing (CPCB, 2020). The plastic waste replaces the use of petroleum coke as the energy source in cement kilns.

In India, the commercial extraction of fuel from recycled plastic has not gained momentum, compared to the global scale. All implementation has been limited to research and on a pilot scale, with only states like Telangana, Punjab and Madhya Pradesh running commercial-scale waste to fuel plants (CPCB, 2020). The Indian Institute of Petroleum (IIP), a subsidiary laboratory of the CSIR, has developed CSIR-IIP-GAIL technology, which converts waste PE and PP to diesel, and is already running in pilot scale at 1 tonne per day capacity. This technology can convert 1 kg of plastic waste (with more than 60% PE/PP composition) into approximately 700 ml gasoline, 500 ml petrochemicals, or 800 ml diesel, with LPG generated as a by-product (CSIR-IIP, n.d.).

Current global practices

Researchers from Pennsylvania University have developed a system to convert agricultural plastic waste into coal-like dense plastic nuggets called Plastofuel, which can be used with coal in thermal plants. The system can be deployed on an individual farm scale to convert the waste plastic generated at that level into Plastofuel or can be scaled up to an industrial scale (Lawrence et al., 2006). Another agricultural plastic waste focused product is Eco-clean burners, developed by GR Technologies from Korea, which use high temperature combustion to use plastic as fuel, and have been used in conjunction with Plastofuel in Pennsylvania. These burner systems have been approved by US EPA standards while monitoring carbon monoxide, nitrogen oxide, and benzofurans (Ciolkosz, 2014). Instead of direct combustion, the other technique is catalytic pyrolysis of plastics to convert it into gas, coke, and hydrocarbons, which is then fed into boilers for power generation.

There have been several commercial applications for converting plastic as a fuel source and using it for manufacturing. Linda Wang and the team from the Davidson School of Chemical Engineering have developed a supercritical water liquification method of low pressure, hydrothermal processing to convert polyolefin waste to oils with 87% yield (Jin et al., 2021). This technique has been used by Hasler Ventures LLC to develop a pilot project to

process waste polyolefins into fuels (Martin, 2021). Japan has been at the forefront in using waste plastic to generate energy, with around 380 waste-to-energy plants already deployed around the country as of 2019 (Nikkei Asia, 2019). They have companies like Mitsubishi, Hitachi Zosen, Toshiba and Environment Energy already developing technologies to convert waste to fuel, with current pilot projects in Southeast Asian countries like Vietnam, Singapore and Thailand (Matsuoka, 2021). In Australia, researchers from the University of Sydney have developed a technology called Cat-HTR, with Licella, which can treat all kinds of plastic waste using supercritical hydrothermal reactions to convert them into fossil fuels. The process is already running pilot plants in Newcastle, NSW and in England, with annual capacity of 20,000 tonnes of waste (Maschmeyer, n.d.).

Drawbacks of current applications

Though the concept of converting waste plastic to fuel is a very noble approach, it comes with some intrinsic limitations. Firstly, the waste-to-energy plant needs a consistent flow of waste plastic, which is provided by local council solid waste collectors and often has lower and varied calorific values, which can affect the efficiency of the system. Secondly, the combustion produces gases like carbon monoxide, nitrous oxide, and benzofurans based on different mixes of plastic in waste. Thirdly, the pyrolysis process can convert the plastic into fuel but most of the process requires high energy and a controlled environment, making it expensive. As reported by Nikkei Asia, Japan has been using pyrolysis technology to produce fuel from waste plastic for the past decade, but due to the complexity and cost of the technology, it has been limited to Japan (Nikkei Asia, 2019). Other innovative technologies for pyrolysis have only been deployed at pilot scale and have yet to be translated to the industrial level (Maschmeyer, n.d.). Another study has shown that the fuel produced from waste plastic tends to have higher amounts of emissions, compared to conventional fuels (Kalargaris, 2017).

Recommendations for plastic waste in power generation

Waste inventory has been a major issue in India, where most resources are invested in collecting and sorting the waste. Among these waste collection units, more than 10,000 units are operated by unregulated bodies (Krishnan, 2022). Thus, a more regulated waste collection and sorting system needs to be implemented so that a consistent supply of waste plastic can be provided to waste-to-energy plants. Likewise, unconventional waste-to-energy methods such as coal-like nuggets need to be implemented, which can collect plastic waste from micro-systems like an agricultural farm and convert it into combustible coal-like nuggets.

5.6 Other construction products

While India is under way in its use of plastic waste in asphalt roads, power generation, and steel and concrete manufacture (CPCB, 2020), other applications are gaining traction in other parts of the world. This section considers how plastic waste is being used in roof tiles, insulation, and as a timber replacement.

Roof tiling

The application of recycled plastic in roof tiles has been explored by many studies, to attain required mechanical properties, lightweight nature, reduced water porosity and UV resistance. A Kenya-based company has been manufacturing Ecoblock tiles, also called ‘Ecotiles’, which are made of recycled plastic, sand, and a UV stabilising pigment, with synthesising temperature above 220° C, allowing them to withstand high outdoor temperatures. Likewise, a US-based company, Brava, has been producing synthetic rooftiles made of compressed recycled plastic, asphalt and fibreglass, which are lighter, easy to handle, and UV fade resistant.

Insulation

Another application of recycled plastic is indoor insulation for buildings to replace the conventional fibreglass, cellulose, and mineral wool. These traditional insulation materials need special handling precautions due to the presence of small glass particles, which can lead to health hazards such as skin and eye irritation and impacts on the respiratory system with prolonged exposure (De Vuyst et al., 1995). In light of these drawbacks, recycled plastic is now being used in insulation materials. SupaSoft uses recycled polyester for insulative application, and has thermal conductivity of 0.04 $Wm^{-1}K^{-1}$, which is similar to the commonly used fibreglass wool insulation (Bharat et al., 2017). Similarly, Autex insulation also uses recycled polyester (50% composition) to make BCA fire standard compliant insulation material, which is accredited to ISO 9001 and ISO 1400 standards. In addition to that, the polymer-based insulation has 0% w/w water absorption, compared to fibreglass material which has around 2% (Bharat et al., 2017).

Lumber replacement

Recycled plastics are also used to form a wood-like structure called recycled plastic lumber. The recycled plastics are mixed with materials like wood dust, glass fibres or rubber to get different mechanical properties in the lumber and replace metals and wood in construction materials. Generally, plastics like LDPE, HDPE and PP are used for the lumber structure, comprising more than 50% of the composition, as they can act as an adhesive and accommodate materials like glass fibres to form a rigid structure (Breslin et al., 1998). The application of plastic lumber is more confined to non-load bearing structures

like fences, park benches, dock surfaces and marine piling, due to its high fluctuation in modulus of elasticity during its lifetime (Breslin et al., 1998). The recycled plastic lumber can be a superior alternative to chromium copper arsenate treated lumber for marine applications due to the leaching issue of chromium and arsenic into marine ecosystems (Breslin and Alder-Ivanbrook, 1998; Weis and Weis, 1996).

Several commercially available recycled plastic lumber products have been on the market for more than a decade. NewTechWood uses 95% recycled material, with recycled HDPE (40%) mixed with recovered hard and softwood fibres (55%) to make their metro range decking. Another UK-based company uses recycled LDPE, HDPE, PP, PVC and Styrene to make lumber. The recycled thermoplastics are shredded, melted, and moulded into desired shapes. The products are then tested under ISO 527, ISO 82, and ASTM E383-B to test their mechanical and thermal stability. These recycled plastic lumber products have been used in different applications, ranging from furniture, doors, decks and fences to other non-structural support applications.

5.7 Recommendations to increase the uptake of waste plastics

The most common challenges in using plastic waste are maintaining a consistent waste stream and meeting demand, but there are other long-term use case challenges such as microplastic generation and changes in supply chain topography. There have also been issues of production of biohazards while handling plastic waste and during the process of converting it into final products, such as the generation of monoxides and benzofurans during plastic waste-to-energy synthesis. These challenges need to be addressed to aid the incorporation of waste plastic into the manufacturing supply chain.

Short-term priorities (to 2025)

Two actions are needed to overcome the immediate barriers to the uptake of secondary waste plastics.

Standards to regulate the use of plastic waste as secondary sources in industries

The manufacturing industry relies on a consistent supply chain of raw materials to maintain the quality standards of the products. Some established waste collection and recycling infrastructure can provide the necessary waste plastic raw material to the industry, but meeting the demands of industry can demotivate consumption. Thus, plastic waste consumption standards need to be developed by stakeholders (SME and industry partners) that can regulate the quality of plastic waste, and outline the framework for plastic waste processing and the duties and responsibilities of each stakeholder in the supply chain. This will establish a blueprint for consistent material flow for the industries.

Accessible and sustainable technologies to extract a clean waste stream

Most use cases of recycled plastic waste are limited to small-scale adoption due to technological barriers. Japan has been at the forefront of plastic waste recycling technologies but their processes have largely been confined within the country due to the complexity of the technology and the cost of deploying it (Glaser et al., 2022). So, an accessible technology is required to bolster the uptake of recycled plastics as secondary sources, which can be developed in India and transform the country into the global plastic innovation hub. These sustainable technologies then can be translated to other nations to expand the influence of India on the recycling and waste industries. The immediate requirement of sustainable technology can be fulfilled by upscaling different effective pilot and small-scale projects being used by industries to large-scale adoption. The bodies like CSIR India can facilitate between the industries, government bodies and the SME to overlook the holistic approach of large-scale adaptation of the technologies.

Overcoming medium-term challenges (to 2030)

The large-scale progression of plastic waste into manufacturing will require significant upscaling of workforce and infrastructure for collection and transport to meet the growing demand for plastic waste. The relocation of workforce from the current centralised supply system can be done but geographical dislocation and skills gaps may remain a challenge.

Transition from a centralized workforce economy

The current recycling industry in India is fragmented and mostly unorganised, making it difficult to assess the workforce and resource involved, whereas the conventional supply chain system for plastic, which is based on limited oil producing areas, is an established economy (Autor et al., 2016). Transitioning from the centralized system to a more distributed system will impact the workforce economy.

The large-scale progression of plastic waste in manufacturing can be aided by gradual translocation of workforce, and by adequate training and awareness to the workforce and industry beneficiaries. For a flourishing economy like India, being a core player in this new industrial evolution with competent workforce will aid in its growth and development.

Adoption of a new form of supply-chain system

From a logistical standpoint, a new supply chain is being introduced, and since a sound manufacturing ecosystem needs a robust supply chain, more resources need to be invested. The current global supply chain systems for plastic and plastic products are based on raw materials sourced from oil producing areas and sold to industries globally. This **centralised supply system** will be disrupted

after the large-scale adoption of recycled plastic waste as a secondary source. The current plastic recycling ecosystem is fragmented, with non-existent traceability and transparency of material flows (Milios et al., 2018), making large-scale adoptability challenging. The fragmented recycling industries can be better regulated by developing standards and guidelines for existing and new recycling stakeholders, aided by regulatory policy to encourage plastic recycling capacity and using it as secondary sources of raw materials. The global manufacturing chain is evolving from economy-of-scale to economy-of-scope to adapt to diversity in consumer demand, which is more quality and use driven than mass usage. The gradual adoption of a circular economy also demands a new form of supply chain system, which can be addressed by evolving centralised manufacturing systems to distributed manufacturing.

Long-term priorities (beyond 2030)

The potential health and environmental harm of microplastics have been subject to increased scrutiny by the scientific community, and further research is needed on microplastic generation and dispersal from the use of plastic waste.

Microplastic generation and its potential health impact

Plastics, when exposed to UV for a long duration, start breaking into small fragments, which can then seamlessly infuse into the biological ecosphere. Microplastics can carry toxic chemicals on their surface and when ingested by organisms, can affect the gastrointestinal and respiratory system. Microplastics can come from plastic waste and from the plastic that is in use in, for example, building structures and textiles (Ivar do Sul and Costa, 2014). Thus, the use of plastic in manufacturing products like plastic lumber, plastic sand bricks, as bitumen binder and as fine aggregate in cementitious material can increase the generation of microplastics in the environment.

Research on microplastic generation and its effects are still limited. Extensive quantification of the sources of microplastics is very difficult to determine, making it a challenge to control their generation. Studies on the effects of microplastics are also limited, with most work based on the effects on marine life and microorganisms (Issac and Kandasubramanian, 2021; Prata et al., 2019). The early stages of microplastic investigation, and limited work done on it can be an excellent prospect for research bodies from both academia and industry to build an information base, this knowledge can help further prognosticate the incorporation of plastic waste in circular economy. Furthermore, this also serves an avenue for India to be an information hub for the microplastic research and innovation.

Evolution to distributed manufacturing to assist the distributed recycling industry

The global manufacturing chain is evolving from economy-of-scale to economy-of-scope to adapt to consumer demand. The gradual adoption of the circular economy also demands a new form of supply chain system, which can be addressed by evolving the centralised manufacturing system to distributed manufacturing, by using the potential of additive manufacturing, and thus by using decentralised recycling approaches.

The advent of the distributed manufacturing (additive manufacturing) approach can help India, which has a large consumer base and among which most of them are transitioning to upper income class gradually, by reducing reliance on centralized supply chain system to fulfill their needs. Since, the world economy is already transitioning to this new avenue, it is logical for an economic behemoth like India to have a head start on this industrial evolution. The sustainable growth of distributed manufacturing should be supported with clear frameworks developed in accordance with industries, government and SME partners.

Conclusion

Considering the current amount of plastic in circulation and the rate of mismanagement (landfilling and unmanaged dumping), the incorporation of plastic waste as secondary materials can be seen as a missed opportunity. In addition to that, for nations like India, demand for more virgin plastic materials to be fed into their manufacturing and construction industries is inevitable, which puts more stress on the already ailing and limited petroleum refineries and suppliers. Thus, by the uptake of plastic waste as secondary materials, the benefits can be reaped in two stages: PWM, which is already a global issue, and reduction in reliance on unsustainable petrochemical industries for raw materials to balance supply and demand.

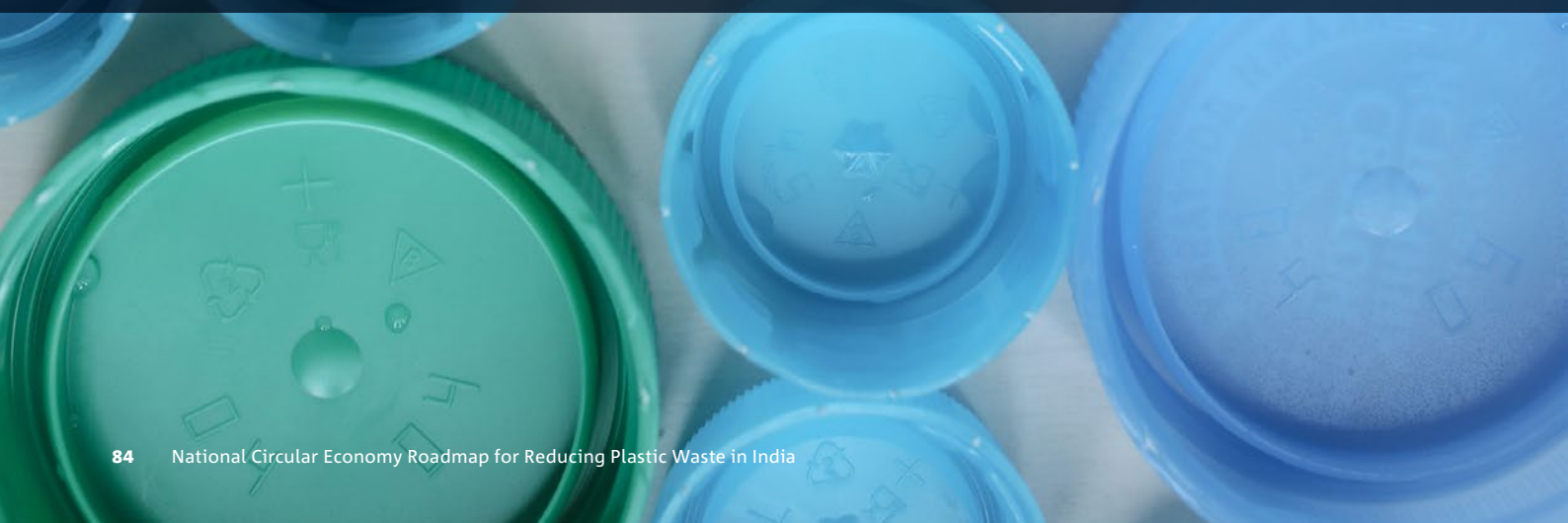
Similarly, the eventual incorporation of plastic waste into the manufacturing chain needs to be aided by developing guidelines for standardisation and quality checks in recycling industries, regulating the type of technology used in the industries and maintaining consistency in the recycled waste stream. There is also a requirement for the development of accessible recycling technology, so that adoption of effective technology can be widespread. Such technologies can be brought to global markets with help from open-source licences and not-for profit organisations. Likewise, centralised recycling industries also need to evolve to decentralised iterations, so recycling can be done in a modular manner and to an effective degree, avoiding the need for large-scale collection and recycling infrastructure, which has not been effective in addressing the PWM issue.

Integration of the informal sector is a key part of the solution

The informal sector, dominated by unregistered waste pickers and rag pickers, contributes significantly to the plastic waste value chain in India. Yet there is lack of recognition in formal mechanisms about their activities, impeding the economic and social security, human health, and social integration of informal actors. The informal sector of waste pickers and recyclers are currently excluded from formal policy support and 'consider themselves to be part of an illegal activity'. There is urgent need to recognise and engage all stakeholders, especially collaboration that must encompass the strengths and opportunities of the entire ecosystem, especially the informal sector.

To maximise the opportunities presented by the informal workforce's door-to-door waste collection network, training and upskilling is needed in order to improve environmental and social outcomes. Given that waste collection carried out by the informal sector is impacted by the market value of secondary materials, and sorting of plastic waste is mostly performed manually, there is ample scope for investing in technologies and infrastructure to enable more efficient collection, segregation and demand for secondary materials. Some key activities needed to integrate the activities of the informal sector are:

- Include the informal sector in legal frameworks to clarify their role, improve working conditions, access to finance, access to government services and benefits and supporting them in developing their own business opportunities.
- Recognise the importance of the roles undertaken by the informal sector, a significant move will be to provide basic work and hygiene conditions such as uniforms, identity cards, safety gear, adequate equipment and tools, and to provide health insurance.
- Promote and strengthen waste exchange platforms and marketplaces that reduce recovery and transportation costs for waste generators and collectors, including the use of digital platforms and IoT to connect actors across the value chain.
- Enable systems to track and monitor material flows managed by the informal waste value chain, to reduce underreporting and illegal trade.
- Provide practical guidance to leaders at municipal and community levels, in both the formal and informal economies, to enable better tracking of EPR efficacy and policy implementation, such as bans on single-use plastics.
- Strengthen markets for secondary materials by equipping informal sector recyclers with adequate technologies, material know-how and fair compensation, including reverse take-back channels through established EPR systems.
- Tailor training and awareness programs, waste-related messaging and media to suit the needs of the informal sector, and to encourage co-design of action plans to support effective policy implementation.



6 Community- and industry-led local initiatives

6.1 Introduction

Community- and industry-led local initiatives are an important component of the suite of plastic management measures taken up by India. As a signatory to the forthcoming Global Plastics Treaty, 2024, India will need to tackle the whole life cycle of plastic, from production to disposal and not just post-consumer waste. Therefore, all stakeholders in the value chain have a role to play in PWM.

This chapter focuses on community- and industry-led local initiatives implemented across the country by community organisations, industry stakeholders, the public sector and/or international organisations. Circular economy initiatives are often undertaken by communities to reduce the impacts of plastic on the local environment (UNDP, 2019). Community- and industry-led local initiatives have the potential to contribute to the transition towards a circular economy for plastics by experimenting with innovative models of action on the ground, raising awareness and facilitating behaviour change among citizens and informing policy. While they may initially be small scale, their multiplication and progressive scaling up could lead them to have broader impacts on society.

Our aim is to understand the scope and focus of community and industry led local circular economy initiatives operating in India and to further identify the success factors and the challenges they encounter(ed) during their implementation and development. This study began with an extensive review of grey literature, media articles and annual reports to identify relevant initiatives. A number of initiatives were then selected as case studies and interviews were conducted with stakeholders to gain insights into their operations. The chapter concludes with some recommendations to facilitate the development of Community- and industry-led local initiatives.

In the review, a large number of initiatives were identified (Tyagi et al., 2021) – due to our focus on local initiatives involving individuals and communities, the examples tend to focus on the management of plastic packaging and do not involve plastic management from major industries. Initiatives were characterised based on the circular economy strategy[20] they employed and the types of activities they conducted. Most focused on either the end-of-life of plastics, particularly recycling and recovery, or the beginning of the life cycle, notably refuse and reduce. In contrast, only a few examples of initiatives focused on the middle of the life cycle, such as reuse or repurpose. Six types of activities carried out by initiatives were identified, as described in Table 6.1. Each initiative conducted one or several of those types of activities.

20 The circular economy strategies framework we adopt offers ten circular economy strategies: Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle and Recover (Kirchherr et al., 2017; Potting et al., 2017).

Table 6.1 Types of activities conducted by community- and industry-led local initiatives

TYPE OF ACTIVITY	DESCRIPTION
Awareness raising and behaviour change	Initiatives that focus on raising awareness of individuals, communities and businesses and encouraging behaviour change in their local community through campaigns or plastic waste-related activities (e.g., beach clean-up, waste collection drives etc.).
Using alternatives to plastics	Initiatives that aim to replace plastic with alternative materials (e.g., glass bottles instead of plastic bottles, cloth bags instead of plastic bags).
Repurposing of plastic waste for new applications	Initiatives that aim to repurpose plastic waste by finding new applications, such as low-cost building material.
Incentivising waste segregation	Initiatives that provide financial 'rewards' for the collection of plastics (e.g., buy-back system, paying school fees with plastics).
Facilitating waste segregation, collection and recycling	Initiatives that aim to provide the logistics, infrastructure and systems to facilitate waste segregation, collection and recycling, by providing bins, drop-off points or collection drive services, coordinating actions with recyclers, developing material recovery facilities or dry waste collection centres, etc.
Building capacity of waste collectors	Initiatives that aim to improve the livelihoods and working conditions of waste collectors and support them with the development of managerial skills.

To undertake further analysis of the success factors and challenges encountered during the implementation and development of initiatives, we selected 16 case studies to represent the diversity of circular economy strategies and types of activities across different proponents and geographies.

The team conducted 14 semi-structured interviews with stakeholders involved in the 16 case study initiatives (two interviewees discussed two initiatives each). To understand the success factors and challenges encountered during the implementation and development of the initiatives, a framework was developed (Tyagi et al., 2021). This framework is composed of five categories:

- **Context:** Elements of the social, political, regulatory, cultural and economic context that enable or hinder the emergence and development of an initiative.
- **Appropriateness:** (In)adequacy of the initiative within the local context.
- **Governance and management:** Governance and management structures that enable or hinder community paricipation, social inclusion as well as the financial and organisational sustainability of the initiative.
- **Diffusion:**[21] The ability of the initiative to scale up or replicate itself.
- **Outcomes and impacts:** The ability of the initiative to meet its objectives as well as the environmental, social, and economic impacts of the initiative.

These five categories informed the structure of our interviews and were then used to identify the success factors and the challenges encountered during the implementation and development of the initiatives studied.

This chapter is structured in four parts. Firstly, we present 'what is working well', or the success factors of the initiatives. Secondly, we discuss 'what could be done differently', where we identify challenges related to the implementation and development of initiatives, as well as a few global best practice examples that could provide avenues for initiative development. Finally, we provide insights into actions that could be taken in India to facilitate the implementation and development of community- and industry-led local initiatives, with specific recommendations for the short-, medium- and long-term.

21 In the initial framework presented in a previous working paper (see reference hereafter), the 'innovation' was evaluated along with diffusion. However, this dimension will not be evaluated in this chapter. See also Tyagi A, Ruoso LE, Retamal M, Pai Panandiker A, Goswami G and Niazi Z 2021, Towards a circular economy for plastics in India: A review of community, industry and public sector initiatives. Report Number 2021–2. Development Alternatives, UTS and TERI, Australia and India.

6.2 What is working well?

In this section, we report on the successes achieved by the initiatives in terms of: i) positive environmental, social and economic outcomes, ii) implementation of sustainable governance and management (with a specific focus on partnership and collaboration, financial sustainability and community engagement), and iii) processes of scaling up and replication of initiatives. We also present elements that were mentioned less often, which are contextual enablers and alignment to local context.

Positive outcomes

Community- and industry-led local initiatives respond to problems identified by proponents concerning plastics in India. These are: i) negative impact of plastics on land, freshwater and marine ecosystems, ii) overflowing landfills generating air quality problems and fire risks, iii) poor working conditions of individuals working in the informal waste sector, iv) no or unfit waste segregation and collection systems; v) no collection of dry waste with low commercial value; vi) lack of recycling infrastructure; and vii) littering and dumping of waste. Each initiative responds to one or several of these challenges, leading to a range of positive outcomes.

Positive outcomes that were qualitatively reported by interviewees were environmental, social, economic and process-related in nature:

- Environmental outcomes relate to some degree of diversion of dry waste from landfill, improvements in the general cleanliness of the environment and improved air quality.
- Social outcomes pertain to the formalisation of the informal sector by officialising the roles of waste workers (e.g., through worker identification cards), giving them access to government services and benefits, and supporting them in developing their own business opportunities (e.g., development of material recovery facilities managed by waste pickers). Another type of social outcome is an increased awareness and a shift in practices related to waste segregation and collection, plastic avoidance and use of alternative materials by individuals, households, housing societies, schools and small businesses, even if sometimes short-lived.
- Economic outcomes are connected to the creation of new markets for plastics that are usually not collected due to their low value (e.g., thermocol is used as insulation material and multi-layered plastic is co-processed in cement factories) as well as the emergence of an industry for alternative products (e.g., bowls made of areca-nut spathe or bamboo). Other economic outcomes are: i) improved economic prospects for waste workers owing to increased segregation rates, which give them access to good quality waste they can sell for a higher value and ii) lower expenses for businesses that repurposed plastic as cheap buidling material, or adopted more durable alternative materials (e.g. glass instead of plastic bottles).
- Process-related outcomes relate to initiatives that can be used as a 'showcase' of best practice and could be reproduced elsewhere, most notably around the improvement of waste segregation and collection systems and the monitoring of waste being processed at recycling/recovery facilities.

Sustainable governance and management

Three aspects of governance and management appeared to be key to the success of initiatives: partnerships and collaboration, financial sustainability, and stakeholder engagement.

Partnership and collaboration: Several initiatives involved a range of stakeholders, including public entities (e.g., state governments, ULBs or panchayats), private actors (e.g., waste industry, companies conducting EPR and CSR programs), community or international organisations (e.g., NGOs, not-for-profits) and citizens. These partnerships and collaborations brought together stakeholders with complementary skills and capacities, notably around infrastructure provision, logistics, workforce, funding and soft skills, such as expertise in behaviour change programs. This enabled them to implement initiatives that they could not have implemented on their own.

Another type of partnership observed was cross-sectoral collaboration between waste focused organisations and those focused on other social and environmental issues, such as health and sanitation. This approach makes it possible to address the same issue from a range of perspectives. This was only observed once but it may be significant in addressing some of the multi-faceted social and environmental dimensions of plastic waste.

Finally, linking up and collaborating with existing influential organisations was found to enhance the visibility of initiatives. This was the case of one not-for-profit organisation that collaborated with a well-established philanthropic organisation, who shared information about the initiative with various government organisations.

Financial sustainability: Access to funding and financial autonomy were important aspects of the successful governance and management of initiatives. While access to funding was identified as a major challenge to sustaining and scaling up initiatives, notably for initiatives managed by NGOs and not-for-profits (as will be discussed in Section 6.3), several initiatives did manage to secure public funding and/or funding from CSR programs. Additionally, one initiative managed to gain financial autonomy by organising activities that generate income (i.e., organisation of a small business exhibition several times a year, where businesses are charged a stall fee that is then used to fund the initiative). In other cases, the initiative was designed to create economic opportunities for participants in the initiative, by selling the products they create as an alternative to single-use plastic products or by managing their own waste collection centre. This may lead to participants being able to pursue activities beyond the initiative.

Community engagement constitutes the last important aspect of the governance and management of initiatives. Several strategies for successful community engagement were identified:

- Doing the 'groundwork' to enrol community members in the project, notably by presenting the objective and vision for the project by going door-to-door,
- Demonstrating that the project is long term and will lead to continuous involvement,
- Showing the tangible outcomes of an initiative (e.g., a bench made of plastics collected during a coastal drive), and
- Tapping into existing community groups (e.g., women's groups) and local or religious leaders to contribute to and/or support the initiative.

Scaling up and replication of initiatives

The ability of initiatives to scale up or replicate is an important feature to enable widespread implementation and success in driving a circular economy. Scaling up refers to initiatives that increase in size and expand to different geographies. Replication refers to initiatives that are taken up by other organisations to be developed elsewhere. Three types of stakeholders – government, citizens and businesses – appear to be the driving force for the scaling up and replication of initiatives:

- **Government agencies** can support scaling up of initiatives by giving them formal recognition and endorsing their implementation at a larger scale (e.g., Memorandum of Understanding or any other type of formalised agreement) and can play an active role in the replication of initiatives by being the main proponent for the implementation of an existing initiative in another location.
- **Large industry stakeholders** can play a role by leveraging their resources to pilot and then scale up initiatives in the multiple geographical areas where they are established. Similar to government agencies, large industry stakeholders can also be a driver for the replication of initiatives by observing and learning from their peers.
- **Community members** can play an important role in scaling up initiatives by actively contributing to the localised management of activities implemented by an initiative, to increase its geographical coverage. They can also drive the replication of initiatives conducted by other community members in their own local area by learning from existing initiatives.

Other factors (context and appropriateness)

Context and appropriateness did not feature prominently in the interviews. However, a few important elements should be mentioned. Regarding contextual factors, two initiatives were enabled by the creation of by-laws at the city level that aligned with their objectives. Concerning appropriateness, the importance of designing initiatives that take the local context into account was mentioned twice. In one case, the importance of developing initiatives that provided economic opportunities for participants was considered important for initiatives focusing on communities that encounter financial struggles. Another initiative that focused on improving the life conditions of informal waste pickers insisted on the importance of building on the existing waste pickers industry to improve the system, rather than bringing '*businessmen from the outside*'.

6.3 What are the current challenges?

In this section, we report on the challenges encountered by initiatives, which may lead to discontinuance, poor outcomes, or impossibility for the initiative to be scaled up or replicated. We identified a range of contextual barriers and struggles with community engagement that led to suboptimal outcomes for initiatives. We also identified lack of access to funding as a fundamental barrier to the implementation of sustainable governance and management and the scaling up or replication of initiatives.

Contextual barriers impacting the outcomes of initiatives

Three contextual barriers were identified by interviewees that prevented some initiatives from reaching the expected outcomes: i) a lack of regulatory support, ii) a lack of collection and recycling centres, and iii) a lack of inexpensive reusable alternatives.

- **Lack of regulatory support** was found to hinder the implementation of initiatives related to waste segregation, collection and recycling, and the use of plastics as building materials.
  - EPR was considered by one interviewee as encouraging participants to collect plastic waste and send it to cement kilns instead of enabling source segregation and recycling. Another interviewee mentioned that the amount offered through the bidding process is too low for some stakeholders to participate.
  - Lack of support from local governments was also mentioned. In the absence of by-laws or any other form of institutional recognition of an initiative, initiatives rely on '*memories of individuals within the organisation*', making the success of an initiative vulnerable to staff movements within local government. Another barrier identified is local governments not issuing permits for the trialling of innovative practices.
- **Lack of collection and recycling centres** posed challenges to several initiatives. Some initiatives collected so much waste that existing infrastructure was insufficient to absorb the waste collected. Others did not have access to recycling and recovery centres. This meant that the waste collected by various initiatives sometimes ended up in landfill or was burnt. The reason provided to explain problems related to access was that many small corporations in cities and towns do not have logistics and recycling centres in place. Barriers to the implementation of such centres can be a lack of scale (i.e., only small quantities of plastics are collected), or a lack of infrastructure to enable the establishment of a recycling centre (e.g., a power supply).
- **Lack of inexpensive reusable alternatives** posed challenges to an initiative focusing on encouraging individuals and businesses to replace plastic with other materials.

Struggles with community engagement

Lack of community engagement was a substantial barrier identified by some initiatives focusing on the collection and segregation of waste or replacing plastic with other materials. Several hindrances were identified:

- **Inconvenience:** Using reusable alternatives or bringing waste to the collection centre is less convenient than using single-use plastics or having waste collected at home.
- **Ineffectiveness:** Individuals can perceive their actions as having no impact if the whole system of waste management is not modified too.
- **Illegitimacy:** Advice provided by initiatives may be perceived as illegitimate when it is not supported by regulations. For example, why avoid polypropylene bags if no regulation has been put in place to regulate their use?
- **Low priority:** Individuals may have other priorities, notably focusing on their livelihoods.

Providing financial incentives to facilitate community participation in initiatives: two international examples

Models developed by initiatives abroad may help to address some of the challenges in India. Here, we present two examples from Indonesia and Australia that may help overcoming some barriers relating to community engagement, notably around the issue of participation being a low-priority.

Bank Sampah (Indonesia): This is a method developed by Bank Sampah, Indonesia, to collect and recycle household solid waste (including plastic waste). In Yogyakarta, the first waste banks were established in 2008, and by 2017, Indonesia had more than 5,000 waste banks (Schlehe and Yulianto, 2020). Managed by community organisations, the waste banks aim to encourage community members to bring waste to the bank, weigh it, and register credit for it. Once a year, people are paid out an amount equal to the reported weight of waste that they brought in (Schlehe and Yulianto, 2020).

Seaside Scavenge (Australia): Seaside Scavenge is an event organised by Take 3 for the Sea, a registered charity, where waste (including plastic waste) is collected from waterways and parks. During the event, participants collect plastic waste, which is then sorted, counted and transmitted to the Australian Marine Debris database, where it is used for research on marine pollution. For every ten pieces of trash collected, participants receive a token that they can use to shop at a market selling second-hand items donated by the community (https://www.take3.org/seaside-scavenge/).

While initiatives providing financial incentives already exist in India, these two examples provide additional strategies that could be used to incentivise community participation in initiatives related to waste collection and beach cleaning.

Lack of access to funding as a fundamental barrier to sustainable governance and scaling up

Initiatives often reported that a lack of funding was a significant hindrance to the long-term governance and management of initiatives, as well as their diffusion through scaling up and replication. In one case, an initiative ceased due to a lack of access to funding beyond the pilot stage. In other cases, individuals used their personal funds to finance activities until they were able to secure modest financial or material support.

While lack of funding in general was considered a hindrance, emphasis was put, by some, on the importance of government funding. Indeed, one initiative considered government funding to be essential, as there is '*some work that the government should do*' about solid waste management, and several interviewees mentioned the need to develop collaboration with and secure funding from the government as necessary to scale up initiatives. Indeed, scaling up initiatives often involves additional capital, transportation and labour costs, which initiatives cannot bear without further financial support. However, the availability of CSR funding was perceived by one interviewee as encouraging the government not to engage in and fund those activities.

In addition to a lack of access to funding, several **other governance and management challenges were noted:**

- Difficulties in developing partnerships or collaborations with the government (i.e., the government does not regard staff from an initiative as having professional skills) or private companies (i.e., the initiative does not manage to identify companies that recycle or recover waste).
- Lack of (human) capacity within the initiative to manage it adequately and to scale it up.
- Lack of success in engaging with waste pickers (i.e., lack of access and capacity to communicate with waste pickers).

Industry led initiatives on alternative uses of plastics

Several of the observed initiatives used plastics for alternative purposes by using it in building materials or by creating new objects such as benches from plastic collected in beach drives. While these initiatives tended to be community-led and on a small-scale, Indonesia has an example of an industry-led large-scale project.

Danone AQUA's Bottle 2 Fashion (Indonesia): This venture uses recycled bottles that would otherwise end up in landfill or in the environment to make a line of children's clothing. The plastic collected is sorted, cleaned, and shredded at Danone AQUA's recycling unit in South Tangerang, close to Jakarta (Jakarta Post, 2020). The H&M production facility then converts the shredded plastic into children's clothing (Jakarta Post, 2020). H&M sells the collection both online and at a number of stores in Java, Bali, and abroad (Jakarta Post, 2020).

6.4 Recommendations

Governments and industry stakeholders at the local, state, and national levels in India can support community- and industry-led local initiatives for the circular economy. As observed in this chapter, partnership and collaboration, financial sustainability and community engagement were found to be essential to the implementation and development of initiatives. Conversely, struggling initiatives often report a lack of partnership and collaboration with government and private entities, a lack of community engagement, and a lack of access to funding. Additionally, a range of contextual barriers that hamper the implementation and development of initiatives were also identified. One type of barrier – the lack of regulatory support – can impact all types of initiatives. Other barriers apply to specific types of initiatives, such as a lack of provision of collection and recycling facilities for initiatives focusing on waste management and a lack of access to inexpensive and reusable alternatives for initiatives focusing on 'refusing' the use of plastic.

As a result, measures that facilitate partnership and collaboration, engagement with communities and the provision of funding, but also address various contextual barriers are likely to foster the implementation and continuance of a diversity of circular economy initiatives. The following measures could be considered in the short-, medium- and long-terms. They are categorised according to the following themes: i) partnership and collaboration, ii) financial sustainability, iii) fostering community support and iv) creating an enabling environment

Short-term priorities (to 2025)

Partnership and collaboration

- Support initiatives through local and state government endorsement in local media, news channels, social media, etc. This will increase community engagement by enhancing the legitimacy of initiatives.
- Develop knowledge sharing platforms and spaces where proponents and local and state governments can learn from each other. In this environment, the work of initiatives can be more systematically recorded and studied to identify potential to scale up and replicate.

Fostering community engagement

- Short-term measures suggested in the Behaviour change chapter (see Chapter 7) would also contribute to community engagement by shifting perspectives on circular economy initiatives being inconvenient, ineffective, illegitimate, or low priority.

Medium-term priorities (to 2030)

Partnership, collaboration and financial sustainability

- Establish incubators and accelerators through public-private partnership models that offer funding, connect community-led local initiatives with corporations, businesspeople, academics and professionals in the industry.
- Develop government-led programs to co-finance initiatives, and in collaboration with incubators, facilitate initiatives to develop towards financial self-sufficiency.

Fostering community engagement

- Medium-term measures suggested in the Behaviour Change chapter (see Chapter 7) also contribute to community engagement in initiatives by shifting perspective on circular economy initiatives being inconvenient, ineffective, illegitimate, or low priority.

Creating an enabling environment

- Medium-term measures suggested in the Circular Business Models chapter (see Chapter 3) contribute to the development of alternatives to single-use plastics. This can support initiatives aiming to refuse plastics.
- Governments may facilitate the acquisition of community-owned machinery (e.g., Precious Plastic, ByFusion, CMPlastik) to support community-led local initiatives that recycle plastics into usable products.

Long-term priorities (beyond 2030)

Fostering community engagement

- Implement monitoring systems to track the progress and impacts of community- and industry-led local initiatives. This is likely to help with community engagement by providing data on the effectiveness of initiatives.
- Long-term measures suggested in the Behaviour Change chapter (see Chapter 7) contribute to community engagement in initiatives by shifting perspective on circular economy initiatives being inconvenient, ineffective, illegitimate, or low priority.

Creating an enabling environment

- Enhance regulatory support through modifications to EPR rules to ensure it supports higher-order activities of the circular economy (not just refuse-derived fuel and recycling).
- Build a network of material recovery and recycling facilities in urban and rural areas to enable systematic waste collection and recycling. This can support all initiatives related to waste management.
- Long-term measures suggested in the Circular Business Models chapter (see Chapter 3) contribute to the development of alternatives to single-use plastics. This can support initiatives aiming to refuse plastics.

Resources are urgently needed to modernise India's recycling supply chain

Modernising India's recycling supply chain will meet a short-term objective of a circular economy of plastics. Modernisation, however, requires significant resources to address waste infrastructure gaps, while growing the sorting, processing and manufacturing or remanufacturing capability of the recycling sector. A Recycling Modernisation Fund could be a national initiative established in India with Government funding complemented by industry investments into new and upgraded recycling infrastructure.

Benefits of a Recycling Modernisation Fund include:

- Increased capacity and capability of the plastic resource recovery/ recycling sector.
- Attracting the latest innovations in plastic waste recycling.
- Environmental and economic benefits.
- Creation of jobs in the sector.
- Improved quality of materials for remanufacturing.
- Transformation of the waste and recycling sector.

Funding could be applied for and used by SMEs, NGOs, urban local bodies or community groups with varying sized operations in both urban and rural or regional areas. The increase in recycling capacity resulting from modernisation of the recycling sector is in line with transitioning to a circular economy by keeping more plastics in the supply chain after their initial use in the short term.

A successful plastics Recycling Modernisation Fund could be expanded to other recyclable materials transitioning to a circular economy, such as glass, paper, tyres or cardboard.

7 Behaviour change

7.1 Introduction

A circular economy for plastics requires households in India to make behavioural changes to the way they purchase, use, and dispose of plastic in their everyday lives. Plastic waste is estimated to constitute up to 8% of the total municipal solid waste generated in India (Bhattacharya et al., 2018) with plastic packaging comprising the bulk of household waste (Shaikh and Shaikh, 2021). In 2015, more than 90% of biscuits, confectionery, dried and processed food, and baked goods in the country used plastic packaging (Bheda, 2019). Plastic packaging is also the largest contributor to litter and pollution in waterways in India (Schmaltz et al., 2020, Shaikh and Shaikh, 2021, Sunitha et al., 2021). Increasing circularity behaviours at the household level towards plastic waste and plastic packaging will contribute to mitigating the impacts of the growing challenge of plastic pollution and creating economic opportunities from a circular economy for plastics.

Circular household behaviours towards plastics go beyond the traditional 3 Rs of reducing, reusing and recycling because the concept also includes responsible disposal – what we call '4 R behaviours'. The 4 R behaviours are based on the consumption cycle and groups circular household behaviours as follows:

- **Purchasing** behaviours focus on *reducing* and *avoiding* plastic consumption through switching to non-plastic alternatives, purchasing products in Environmentally Friendly Packaging (EFP)[22], purchasing products that are recyclable, and purchasing products that contain secondary or recycled materials.

Use of products and goods behaviours inclue *repair* and *reuse* of plastic products and avoidance of single-use plastic.

Disposal of products behaviours focus on keeping the value of materials circulating for as long as possible through appropriate source separation, *recycling*, participating in return schemes, and avoiding littering.

While there have been programs and initiatives in India aimed at reducing single-use plastic and increasing consumer awareness about 4 R behaviours, the extent to which households practice these behaviours across different regions in India is unclear, owing to lack of data availability (Niazi et al., 2021). Moreover, there have been very few initiatives to change the material objects and infrastructure needed to support circular household practices. Factors that hinder or enable circular household practices towards plastics are also not well understood despite their importance in furthering government policy and programs aimed at reducing plastic waste. This report addresses these shortfalls and identifies system-wide factors that, when combined, can support a cultural shift towards increased circularity of plastic in India. These factors can be divided into three groups, as shown in Figure 7.1, and each is discussed in terms of identifying barriers and enablers for increasing 4 R behaviours.

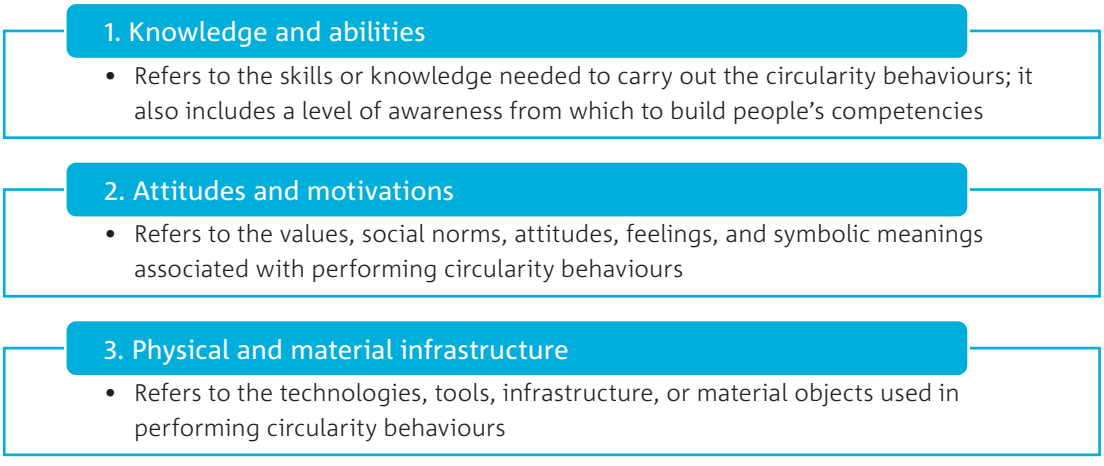


Figure 7.1 Three types of system-wide factors required for driving behavioural change in a social system

Source: Adapted from Shove et al. (2012)

22 EFP - Environmentally friendly packaging is that which can be recycled, composted, or made from recycled materials.

In this chapter, we used four research sources to address a knowledge gap about the extent of 4 R behaviours in Indian households, as well as barriers and enablers to these behaviours:

- A desktop review of websites, education programs, and academic literature pertaining to plastic waste reduction campaigns in India and other initiatives used globally to increase the circularity of plastic (Niazi et al., 2021).
- 24 semi-structured interviews conducted with municipal governments, waste aggregators, material recovery facility operators, and organisations associated with waste education programs and other waste-reduction initiatives in Haridwar, Panjim, and Agra[23].
- 558 online household surveys conducted in the same three cities as the interviews, using a quota sampling method to ensure a diverse range of households with varying levels of plastic circularity activities.
- Observations and informal interviews from site visits.

Drawing inferences from the four research sources, we identified a range of potential solutions and opportunities for improving circularity in household behaviours with regards to plastic and addressing the system-wide changes that are needed to enable and sustain desirable behavioural change.

7.2 What are current practices and what is working well to enable 4 R behaviours?

Current behaviours and the determining factors

Householders and communities in India are practising 4 R behaviours to a varying degree.

Results from the online survey shed light on the differences between households that practise high circularity of plastics (i.e., high circularity households) and those that practise to a lesser degree (i.e., low circularity households). Table 7.1 shows that low circularity households engaged in circularity activities sometimes or infrequently, whereas high circularity households engaged in plastic circularity activities almost always or often.

Table 7.1 Frequency of circularity practices reported by the different households

CIRCULARITY PRACTICES	LOW CIRCULARITY HOUSEHOLDS	HIGH CIRCULARITY HOUSEHOLDS
Buying products with EFP[1]	Sometimes	Almost always
Minimise/avoid products with plastic packaging[1]	Sometimes	Almost always
Responsibly dispose of their waste inside and outside home[1]	Sometimes	Almost always
Segregate waste at home[2]	Sometimes	Almost always
Segregate 'dry' and 'wet' waste[2]	Sometimes	Almost always
Segregate plastic from other waste[2]	Infrequently	Very often
Segregate paper from other waste[2]	Infrequently	Often
Segregate glass from other waste[2]	Very infrequently	Sometimes

Note: [1] Measured on a 5-point Likert scale with 1 being never and 5 almost always; [2] Questions were asked in yes/no or yes/not sure/no answer formats; Percentages of people who affirmed the practice: >=90% as 'almost always', 70%–89% as 'very often', 60%–69% as 'often', 45%–59% as 'sometimes', 44%–35% as 'infrequently', <35% as 'very infrequently'.

The online survey delved further into how households in India dispose of their different plastic packaging at home, as shown in Figure 7.2. Across all plastic packaging waste, low circularity households were more likely to dispose of their plastic waste in landfill. High circularity households were most likely to segregate and send their various plastic waste streams to recycling. The high circularity households were also more inclined to segregate their plastic waste and sell for money than lower circular households. Soft plastic food packaging was the most likely plastic waste to be disposed of to landfill by both low and high circularity households. Food residue in plastic packaging was reported as making it impractical to recycle these materials.

23 These cities were chosen because of their differences in size, geographic locations, and outcomes in the Swachh Survekshan Survey of 2021. Each area is connected to tourism, though this is experienced differently – Haridwar at the base of the river Ganges is a holy city and popular as a pilgrimage destination; Agra, home to the Taj Mahal, has a major problem managing plastic waste; and Panjim, considered one of the cleanest cities in India and capital city of Goa is one of India's main tourist destinations. The Swachh Survekshan Survey 2021 results for each city also varied considerably: Haridwar ranked 285; Agra ranked 24; and Panjim ranked 3. This cross-section of cities provided a diverse range of experiences and insights from which we could identify opportunities and barriers to underpin our recommendations for increasing circularity behaviours.

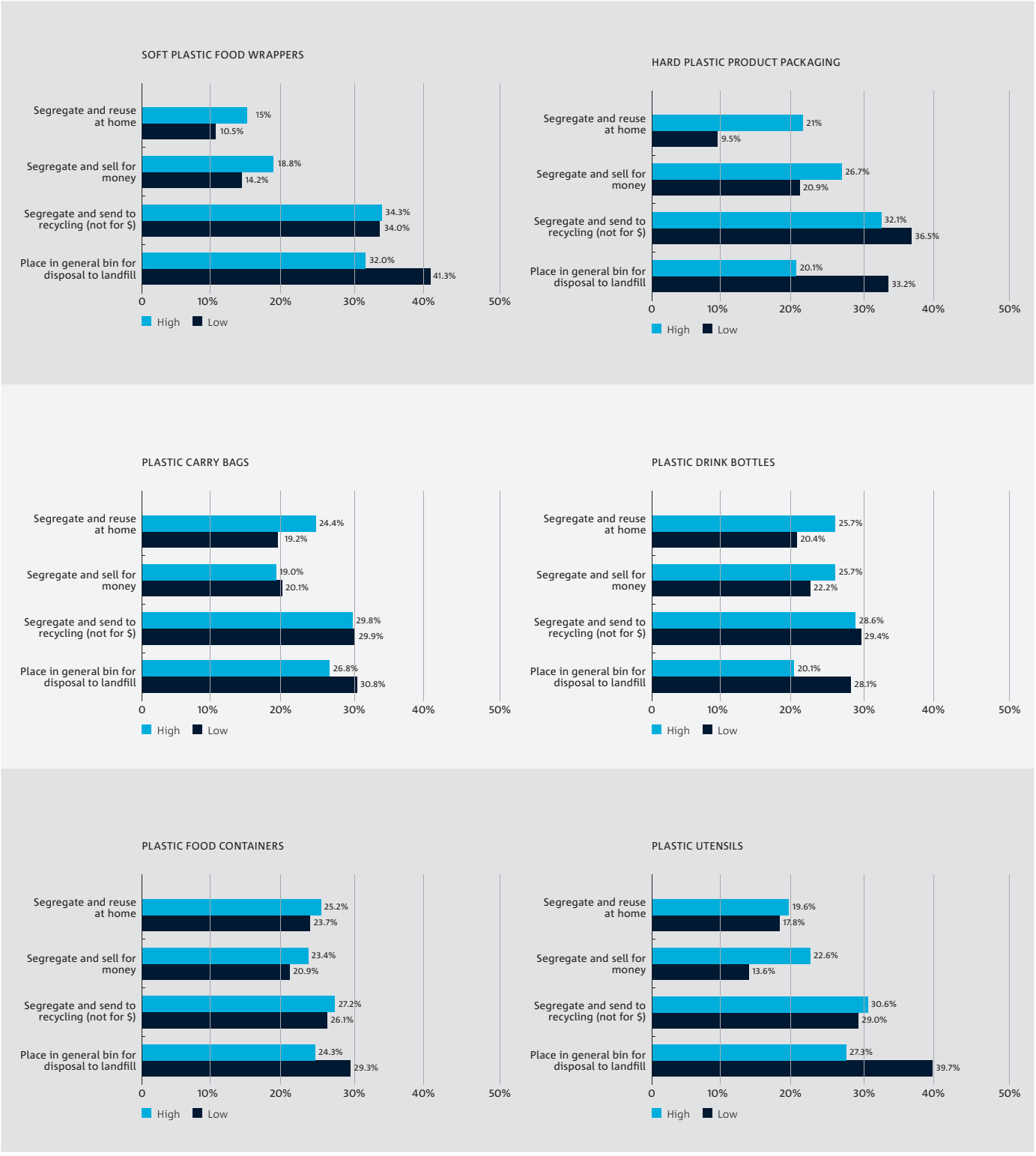


Figure 7.2 Household management of different types of plastic waste in India

Note: Households were presented with each type of plastic packaging and asked what they did with the waste, choosing any of the four options: (1) place in general bin for disposal to landfill; (2) segregate and send to recycling; (3) segregate and sell for money; and (4) segregate and reuse at home. Percentages of responses are shown for each plastic type of packaging waste.

Information and differences in circularity behaviours

In addition, both low and high circularity households reported some differences in terms of the types of information that they had previously received about household waste management. Figure 7.3 shows that high circularity households had received significantly more information on household waste management than low circularity households. Of all information types, most households in the two circularity groups had received information about the types of waste that can be recycled.

Low and high circularity households differed in the ways in which they performed the two plastic circularity behaviours investigated in the study: (1) minimising/avoiding packaging waste, which included buying products with EFP, and (2) responsible waste disposal inside and outside of the home. The two household groups differed significantly in their knowledge and know-how for undertaking these two circularity behaviours (competencies), their access to and affordability of the materials and infrastructure needed (materials), and the social or normative influences shaping their behaviours (meanings). Figure 7.4 provides a summary of factors that were significantly different between the high and low circularity households.

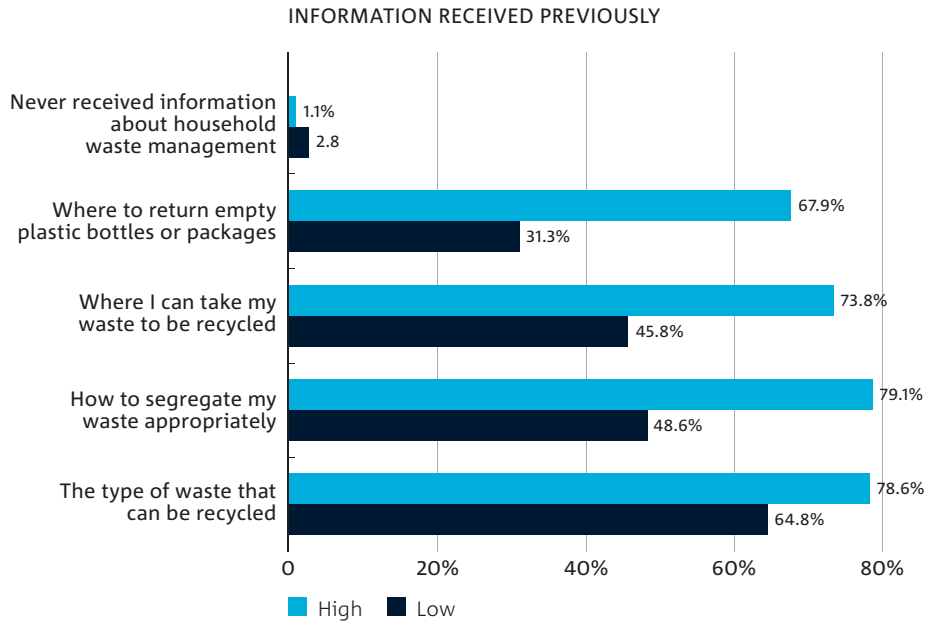


Figure 7.3 The types of household waste management information received by households

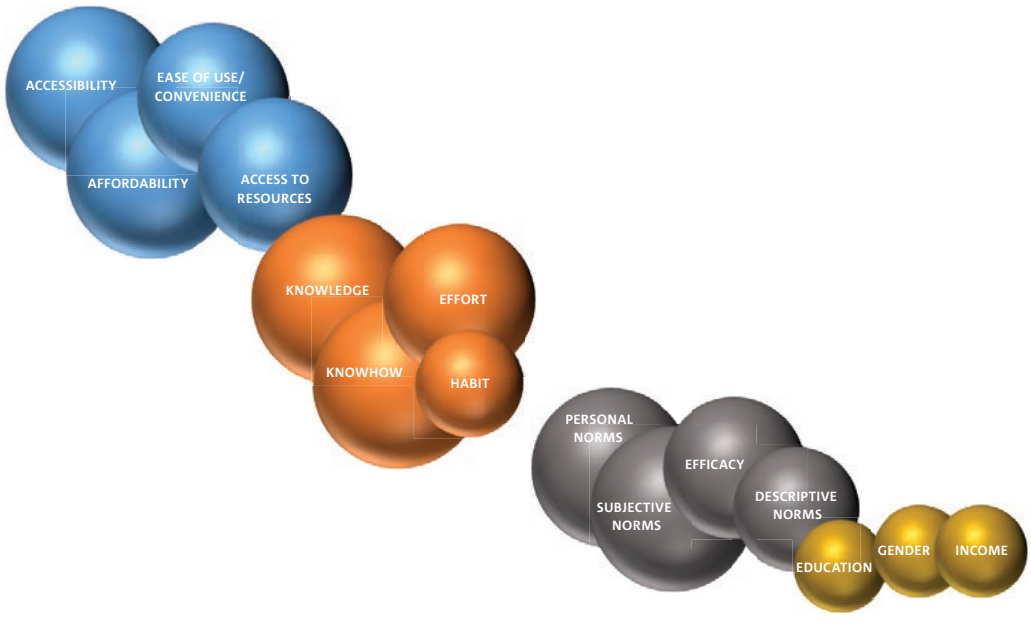


Figure 7.4 Factors that were significantly different between high and low circularity households

Note: Blue bubbles represent materials factors, orange bubbles represent competence factors, grey bubbles represent meaning factors and yellow bubbles are socio-demographic variables.

High circularity individuals reported more access to shops that sell products with EFP and affordability of such products than low circularity households. High circularity households also had higher levels of knowledge and know-how about buying products with EFP. They had strong convictions about buying products with EFP and felt that their significant others would support them to do so. High circularity households were also more inclined to think that other people in India would buy products with EFP than low circularity households. In addition, high circularity households had better materials and competencies that allowed them to practise responsible waste disposal inside and outside their home. High circularity households also attached strong meaning to practising responsible waste disposal behaviours. Influences of some socio-demographic variables are also noteworthy, with key findings including:

- Households with higher income and educational levels were often correlated with plastic circularity behaviours.
- Likewise, individuals with higher income and education levels also reported higher levels of the necessary materials and infrastructure, and knowledge and skills to undertake the behaviours. They also attached stronger meanings to circularity behaviours.
- Females were found to be more likely to practise these circular behaviours than males. Compared to males, females would more often buy products with EFP and minimise or avoid plastic packaging. Females were also more likely to practise responsible waste disposal inside and outside of their home. Females thought separating plastic waste and responsibly disposing of it to be easier and more convenient than males did.
- Households with children reported higher levels of knowledge and know-how about purchasing products with EFP.

7.3 What are the barriers?

Key barriers constraining 4 R behaviours in households can be grouped into a framework of three elements: knowledge and know-how; motivations and meanings; and materials and infrastructure. Details of these barriers are summarised in Figure 7.5.

Knowledge and know-how barriers

Even though education programs and awareness campaigns have been the main focus in changing household behaviours towards plastics in India, a range of factors limit their overall effectiveness. These factors include limited access to information and education programs, particularly in rural areas, not all campaigns being translated into local languages, and limited implementation and availability of the materials and infrastructure

Knowledge and know-how

- Lack of knowledge and understanding of how to source separate
- Lack of understanding about the extent of the plastic pollution problem
- Lack of access to education and awareness programs through language barriers, geography etc
- Lack of monotoring data
- Lack of knowledge of plastic alternatives

Motivations and Meanings

- No incentives to increase recycling
- A use and throw culture (prefer to throw away into waste bins)
- Concerns over hygiene and health risks associated with recycling process and using recycled materials
- Too much time and effort
- Distrust or unsatisfaction with waste collectors' service,
- Certain features of EFP, or products in EFP perceived as inferior
- Social influence (discouragement from others)
- Not responsible for recycling in the household

Materials and Infrastructure

- Lack of availability, accessibility, and affordability to switch to non-plastic alternatives or to products that will reduce plastic waste, e.g., environmentally friendly products
- Lack of space and infrastructure in homes to support source segregation
- Lack of waste collection services that will collect recycleables
- Some plastics are not suitable for recycling such as those contaminated by food residues
- Inconvenience of recycling
- Inadequate financial incentive to send plastics to collectors

Figure 7.5 Summary of barriers to households practising 4 R behaviours

needed to support source segregation, recycling initiatives and use of alternatives to plastics. Knowledge of affordable alternatives to plastic is sporadic in India. Consumers are often limited to certain plastic alternatives depending on where they shop. In circumstances where alternatives to plastics are available, the labelling of products with EFP is unclear and this hinders the uptake of alternatives.

There is also a lack of monitoring data to evaluate the extent to which an intervention is effective in changing a behaviour, and changes in public awareness over time. An exception is the *Swachh Survekshan survey*, which is conducted annually at the municipality level and uses a rating and ranking system to provide feedback to citizens about their state and municipality's ranking of 'cleanliness'. Even though the *Swachh Survekshan* survey does not measure the effectiveness of behavioural interventions, nor do the results give an indication of the types of programs implemented in the leading cities, the results provide a broad indication of the state of the urban landscape, including ratings and certification for being a 'Garbage Free' city.

Knowledge of the impacts of plastic pollution and circular behaviours towards plastic appears to be limited among everyday people in India. The lack of monitoring data on intervention effects and public awareness compounds these challenges because authorities are limited in their ability to convey the extent and severity of the plastic pollution problem to motivate householders improving the circularity of their behaviours towards plastics.

Motivation and meanings barriers

The detrimental effects of plastic pollution on the natural environment and human health are not at the forefront of people's minds when they use or purchase products comprising plastic. The general perception of plastic being cheap and easy, to be disposed of anywhere, is a barrier to adopting new circularity behaviours. For many people in India, a 'use and throw' culture seems apparent. It is unclear the extent to which income influences a use and throw culture. Higher income levels potentially exacerbate this attitude due to increased access to resources and purchasing power. On the other hand, lower economic groups are potentially more likely to contribute to waste leaking into the environment due to limited access to waste collection services. The caste system may also contribute to motivational barriers for undertaking recycling behaviours in households. Recyclable materials including plastics have previously been handled by a socially perceived lower caste and therefore there is a perception in the wider community that these materials are contaminated, or 'yucky', and can never be 'cleaned' because of this association.

The SUP ban aims to reduce the use of plastic carry bags for shopping; however, for some shoppers, there remains a reluctance to use a cloth bag as an alternative to plastic carrying bags. This observation relates more to male shoppers than female shoppers. In many cases, women appear to be the key decision makers regarding purchasing and recycling plastic, but there is limited information about factors that may hinder or constrain women in these activities.

Segregating plastic waste for recycling is a relatively new activity in India and has not yet become part of long-standing household routines, as is the way with newspapers, which in many cases have been separated and sold to ragpickers for many years. Source separation is influenced by such factors as available space in the house, age of family members, education and income levels, and nature of the residence (i.e., permanent vs. temporary). The survey found that females thought source separation to be easy and that they are better at source separation and responsible waste disposal than males. The survey also indicated that if people perceived the task as requiring too much time and effort, then it acted as a demotivator and a barrier to performing the behaviour. We note that, for some individuals, the lack of available time to undertake circularity behaviours such as cleaning used plastic for recycling or travelling further to purchase products in EFP is a capacity constraint rather than a matter of attitude and motivation. Furthermore, if the individual felt they were not responsible for managing waste within the household, they were less inclined to undertake circularity behaviours.

Perceptions of health and safety risks and concerns about hygiene and cleanliness related to recycling practices and recycled materials also act as barriers for people in adopting behaviours that would increase the circularity of plastics. For example, contamination risk to food, ink from newspaper wrapping that may leak and spoil products, and potential risk of disease transmission such as COVID-19 all detract from involvement with reusing materials and recycled products.

The social acceptability of purchasing and gifting recycled products or products in EFP is still developing in India. Consumers have not yet associated recycled products and products in EFP with quality and prestige and these factors are important to the purchasing decisions of the survey respondents, especially in purchasing gifts for family and friends, by friends, family or store merchants.

Materials and infrastructure barriers

Lack of accessibility, availability, and affordability of environmentally friendly alternatives to plastic is deemed a barrier for many people, particularly those on lower incomes. These factors also limit the effectiveness of SUP bans as vendors continue to use banned plastics. Vendors indicated in interviews that they would be prepared to switch to non-plastic alternatives if they were provided with options that were available and affordable. As a result, many consumers continue to prefer cheaper single-use polythene bags. Furthermore, non-plastic alternatives seem to be limited to metropolitan cities and large vendors with smaller markets, and other vendors are unable to afford such options, which is typical of non-metropolitan areas.

Many people also perceive that products are not designed or produced in a way to support waste avoidance; for example, products produced with a reduced shelf life or designed such that they cannot be recycled. These shortcomings compound the 'use and throw' culture that seems to exist among many consumers.

A lack of waste management and recycling services and infrastructure, the insufficient capacity of existing infrastructure, and a shortage of labour to sort and segregate waste are all factors limiting collection and recycling options for many households, particularly for those located in wards on the periphery of municipal areas. These shortfalls also lead to increased littering in these locations. In addition, a hesitance by banks to fund businesses in the waste management and recycling sector and the impact of the COVID-19 pandemic on labour shortages has further exacerbated these challenges. In many instances, sorting in waste aggregation businesses largely fell to women labourers during the COVID-19 pandemic over the past three years.

Inconveniences such as lack of automation or lack of online platforms for finding where to sell recyclable materials were also identified as barriers, as well as inadequate financial incentives to send plastics to collectors. Some plastics are perceived to be unsuitable for recycling because they contain food residues, such as bottles with liquid, and dirty utensils and food containers. This perception points to an infrastructure barrier of not being able to include plastics with food residues in dry waste, as well as a motivation barrier of being disinterested by cleaning efforts involved in recycling.

7.4 What are the enablers?

The key enablers for supporting increased circularity behaviours correspond, in many cases, to overcoming the identified barriers. In addition, some enablers reflect gaps in interventions that have been successfully reported in other countries, or in the academic literature, or as effective behaviour change strategies used in other contexts to improve pro-environmental behaviours such as reducing energy or water use. The enablers are again discussed as three groupings related to knowledge and know-how, motivations and meanings, and materials and infrastructure, and are summarised in Figure 7.6.

Knowledge and know-how

- Democratisation of information – translated into a range of languages, written in an easy to understand way, made available and accessible
- Extend people's understanding of the plastic problem including environmental and health effects
- Extend education programs in schools
- Clearer product labels to inform purchasing decisions and recyling behaviour
- Measures to make recycling and recycled products safe and hygienic and infrom the public of such measures

Motivations and Meanings

- Use of social influence and social pressure to help drive behaviour change for avoiding and reducing plastic and increasing recycling and responsible disposal have been underutilised as a potential enabler
- Growing concerns for the environment (nature, pollution and climate change)
- Use of incentives to encourage increased circular behaviours
- Use of data to monitor and provide targets and feedback to towns, municipailities and wherever possible to households so that improved behaviour is recognised and rewarded
- Draw on people's sense of civic duty, social responsibility and altruistic motivations to encourage increased circularity behaviours

Materials and Infrastructure

- Ensure non-plastic substitutes or alternatives are available and their use are supported
- Ensure the necessary infrastructure is available for source segragation in households, waste collection and recycling within communities
- Ensure places with less capacity are also provided opportunity and support to transition to less plastic consumption so the process is 'just and fair'
- Introduce laws and regulations to support repair of products, improved design and improved recyclability of products.
- Provide better financial incentives, or give promotions for EFP products

Figure 7.6 Summary of enablers to households practising 4 R behaviours

Knowledge and know-how

Awareness programs need to go beyond building increased consciousness of plastic-related issues and instil a deeper understanding of the plastic problem, and increase capacity in households and neighbourhoods to undertake circular plastic behaviours. This includes building knowledge around environmental impacts and potential health effects, as well as the necessary behaviours needed to reduce plastic waste. In addition, messaging that addresses specific concerns around hygiene and safety issues associated with recycling and recycled products would help in the uptake of 4 R behaviours. It will be critical to ensure information is provided in a range of languages, communicated in an easy to understand and not too scientific way, and made available and accessible including in rural areas.

Using digital platforms to increase access to information about where to recycle, and the most economically beneficial options for recycling, would also help behavioural change and reduce the time and effort barriers associated with information seeking. Digital technology at the home could also be used to support waste collectors and the waste management system more generally through the use of 'smart' technology to help improve efficiency of collection. However, public awareness campaigns and education would be needed to accompany such interventions so that households can build trust and confidence in the benefits of the 'smart' technology.

Extending education programs to schools and college students would build capacity in young people and foster their personal values to protect their environment. Many view young people as the main agents of change in families. Through helping to model and teach family members who may have less knowledge about 4 R behaviours, there is an opportunity for younger people to improve decision making around product choices and other circularity behaviours. In addition, ensuring products include clear labels for buyers regarding packaging materials and how these can be recycled would further support more circular product choices and consumer decision making.

Motivation and meanings

Social influences and pressure from family and friends can be used to create motivation for reducing plastic consumption and improving recycling and responsible disposal. This can be achieved through a variety of social means, such as the use of celebrities and 'in-groups' to shape behaviour, social learning where the desired behaviour is witnessed and copied, and community-based or bottom-up initiatives that create momentum for change. Social influences can also be used to dissuade undesired behaviours.

There was a sense among the interviewees and survey respondents that providing financial value for recyclable materials and segregated waste can incentivise households to sort their waste at source. Understanding how much financial incentive is adequate for different behaviours and households and how to implement the incentive effectively requires further research.

Targets and feedback on recycling or waste reduction outcomes can also be used to drive the behaviour of households, neighbourhoods, towns, or municipalities. Incentives, policies, and regulations can further drive desired behaviours. However, many of these initiatives are underpinned by good data, which can be used to monitor or measure behaviour over time, and to identify the effectiveness of specific interventions.

Many people feel a growing concern for the environment, and this can be used to foster motivation to alter plastic consumption and help drive the uptake of circular plastic behaviours. A sense of moral conviction, civic duty, and other altruistic motivations can be used to influence individuals and their social groups to practise 4 R behaviours.

Materials and infrastructure

Ensuring the accessibility, availability and affordability of non-plastic alternatives will enable many people to switch from plastic to a substitute. The use of the substitute may also need to be supported for the change to be effective. For example, ensuring hygiene issues are addressed if disposable cutlery is to be replaced with non-disposable and reusable alternatives. Introducing laws, policies, and regulations to support the repair of products, improved design, and improved recyclability of products would further ensure households are able to reduce their overall consumption of plastic. Businesses, including international companies and local merchants, are perceived as being responsible for making it easier for households to buy EFP products. For example, some survey respondents suggested that merchants could create specific sections in their stores for EFP products and open shops dedicated to selling EFP products. Financial incentives or reduced costs of non-plastic alternatives, products with recycled content, or products in non-plastic packaging, would also help drive increased circular purchasing behaviours.

Some towns and cities lack the capacity and infrastructure to deliver waste collection services and recycling. Many households also lack space and the necessary bins for source segregation; moreover, appropriate bins that are inaccessible to stray animals are needed if bins are to be placed outside of dwellings. In many towns, there is also a lack of public bins to prevent littering. Ensuring the necessary infrastructure as broadly as possible across India, including in rural areas and areas with lower-income households, would ensure a just and fair transition to achieve a more circular economy for plastics. Furthermore, convenience is a key consideration; the more convenient the access to recycling, waste separation, and waste bins in public spaces, the more successful behaviour change is likely to be.

7.5 Recommendations

Short-term priorities (to 2025)

The short-term recommendations focus on six main areas:

1. Augment and re-focus messages used in awareness and education campaigns
   - Include information on the size of the plastic pollution problem, potential impacts from plastic pollution on the environment and community wellbeing, and what is required of citizens (the 'why' and the 'how').
   - Ensure that information is available in a range of languages and communication channels.
   - Utilise schools and colleges as primary places for delivering awareness and education programs.
   - Increase information and training on how to read packaging labels to make better choices at the time of purchase and to dispose of packaging responsibly.
   - Increase knowledge and capacity among informal workers, such as ragpickers, waste collectors, and shopkeepers, to pass on correct information (e.g., health and environmental impacts of plastic pollution) to consumers because, in many cases, the informal sector is the primary source of information for households.
   - Extend digital options for improving access to information and different types of information, such as where to recycle in a given neighbourhood.
2. Extend incentives and disincentives to reinforce desired behaviours
   - Encourage consumers to sell their waste directly to sorting centres if there is no collection system.
   - Provide incentives and recognition to consumers for segregated materials.
   - Provide incentives to establish innovative non-plastic packaging options.
   - Use disincentives to foster desired behaviours in segregating, recycling, and disposal.
3. Support households to participate in source segregation and recycling
   - Roll out a program for household collection bins.
   - Develop innovative solutions for multi-unit dwellings.
   - Develop a monitoring plan to help households maintain their source segregation efforts.
   - Identify solutions for segregating waste in very small dwellings.
4. Utilise collective social processes to create and maintain momentum for behavioural change
   - Provide targets and feedback mechanisms for households, neighbourhoods, cities and municipalities on recycling and littering rates.
   - Create recognition and award programs for clean neighbourhoods, towns, and cities.
   - Utilise groups within society to encourage and be exemplars of 4 R actions, e.g., religious groups, sporting groups, and school communities.
   - Encourage clean-up drives and awareness days in cities and municipalities.
5. Build a new meaning and positive image to recycle and use recycled products
   - Provide incentive programs so that recycling and using recycled products become desirable behaviours in the community.
   - Shift consumer perceptions about the quality and prestige of products packaged in eco-friendly packaging, that is, they are not inferior.
   - Place coloured bins in public areas to allow source separation and as an avenue to raise public awareness of source separation and how this separation helps the environment.
   - Identify solutions that address concerns about hygiene related to substitutes for single-use plastic. For example, the cleanliness and 'purity' of cutlery and crockery that are cleaned and kept hygienic.
   - Create a marketing plan to mainstream the use of recycled products so they can gradually be disassociated with the 'unclean' image, and the image of being products limited to lower segments of the population.
6. Establish monitoring, evaluation, and learning throughout the system in order to:
   - Monitor the types and levels of plastic waste in landfill.
   - Examine the effectiveness of plastic circularity programs to promote learning from others.
   - Establish a national database (or knowledge base) of effective plastic circularity intervention programs.
   - Support a platform for shared learning and knowledge building.

Medium-term priorities (to 2030)

Medium-term recommendations are underpinned by research, innovation, policy, regulation, and improved data collection. These recommendations are broad and focus on four main areas: improving product design and labelling; improving waste management and resource recovery capacity and service delivery; extending monitoring, evaluation, and learning throughout the system; and supporting additional research.

1. Improving product and packaging design, affordability, and labelling
   - Increase access and availability of eco-packaged products where packaging can be composted, collected, or recycled easily.
   - Increase availability and affordability of non-plastic alternatives for everyday items such as disposable utensils, carry bags, and sticks for food and non-food items.
   - Increase availability of products that are fully recyclable at the end of product life.
   - Increase labelling, use of standards, and certification on products and packaging to allow consumers to make improved product purchase choices and to know how to responsibly dispose of products at the end of their life, e.g., whether to recycle, return to producer, or participate in a collection refund scheme.
2. Improving waste management and resource recovery capacity and service delivery
   - Create formal employment opportunities for ragpickers and garbage collectors to improve their skills and livelihoods.
   - Modify current infrastructure or build new infrastructure to cater for source segregation and minimise leakage points in collection systems (e.g., most of the fleet used by municipalities for collection of household waste does not support source-segregated waste).
3. Extending monitoring, evaluation, and learning throughout the system
   - Expand capability to track and monitor flows of plastic.
   - Extend evaluation of plastic circularity programs to include targets and feedback mechanisms.
   - Extend the national database (or knowledge base) of effective plastic circularity intervention programs to include learnings from international initiatives.
   - Extend opportunities for shared learning and knowledge building.
4. Supporting additional funding and investment in:
   - Research and development programs for plastic packaging alternatives that are affordable, accessible, and socially acceptable.
   - Education and awareness programs in the informal sector to increase collection and recycling.
   - Technological solutions to improve responsible waste disposal inside and outside of the home.

Long-term priorities (beyond 2030)

1. Fostering a cultural shift
   - Support a cultural shift in the way citizens think about waste and the workers who work in the waste management and resource recovery sector.
   - Support a shift away from a ‘use and throw’ approach to product consumption by consumers.
2. Continual progress
   - Continue to improve programs and initiatives that foster and enable social and behavioural change to support increased circularity of plastic in India.

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Appendix A Methods

The Roadmap was compiled from a synthesis of research findings from a range of studies conducted across six domains and primarily in three phases. These domains included: data and metrics, policy frameworks, circular economy business models, plastic recycling technologies, community and industry led local initiatives initiatives, and social and behavioural change approaches. The phases involved an initial literature review, followed by development of strategies, and a final refinement and testing of findings.

A.1 Phase 1 Literature review

In 2021, each domain conducted an initial literature review to provide an in-depth understanding of the state of play in India and the initiatives that were being undertaken both domestically and globally with respect to the circular economy for plastics. These reviews have been compiled into individual reports and journal articles, and are available on the project website, Reducing Plastic Waste in India, https://research.csiro.au/rpwi/?

Reports

- A material flow analysis of polymers and plastics in India (Report 2021-1) – https://research.csiro.au/rpwi/wp-content/uploads/sites/412/2023/03/A-material-flow-analysis-of-polymers-and-plastics-in-India-Final-2021-1.pdf
- Towards a circular economy for plastics in India: A review of community, industry and public sector initiatives (Report 2021-2) – https://research.csiro.au/rpwi/wp-content/uploads/sites/412/2023/03/Community-Industry-Initiatives-Report-Final-2021-2.pdf
- Circular business models for plastics in India: Literature and practice review (Report 2021-3) – https://research.csiro.au/rpwi/wp-content/uploads/sites/412/2023/03/Circular-Business-Models-for-Plastics-in-India-Final-2021-3.pdf
- Enabling behaviour change towards a circular economy for plastics in India: A review of social and behavioural enablers (Report 2021-4) – https://research.csiro.au/rpwi/wp-content/uploads/sites/412/2023/03/Enabling-behaviour-change-towards-a-circular-economy-for-plastics-in-India-Final-2021-4.pdf
- A review of the policy framework for a circular economy for plastics in India (Report 2021-5) – https://research.csiro.au/rpwi/wp-content/uploads/sites/412/2023/03/Policy-Framework-for-a-CE-for-Plastics-in-India-Final-2021-5.pdf

Journal articles

- Plastic Waste Management in India: Challenges, Opportunities, and Roadmap for Circular Economy – https://doi.org/10.3390/su14084425
- Plastic waste recycling: existing Indian scenario and future opportunities – https://doi.org/10.1007/s13762-022-04079-x
- A circular economy framework for plastics: A semi-systematic review – https://doi.org/10.1016/j.jclepro.2022.132503
- Full circle: Challenges and prospects for plastic waste management in Australia to achieve circular economy – https://doi.org/10.1016/j.jclepro.2022.133127

A.2 Phase 2 Development of strategies

During 2022, each domain proceeded to further investigate solutions and strategies for the Roadmap by examining challenges, barriers, opportunities, and enablers needed to progress the circularity of plastic in India through improvements and changes in their domain areas. This stage involved interviews, surveys, and secondary data sources to further collect evidence to inform the roadmap's strategies and priorities. Details of each domain's methods and data sources are outlined in the following sections of this Appendix.

A.3 Phase 3 Refining the roadmap

The Roadmap priorities were tested at three roundtable events, which included stakeholders from government, industry, and non-government organisations. At these events, the seven Roadmap strategies were shared and discussed, and salient feedback was integrated into the final version of the roadmap.

A.4 Details of Phase 2: Methods and data sources for each domain

A variety of methods and data sources were used to collect and analyse data for each domain. These inputs provided evidence from which to draw research findings, which were then synthesised into the roadmap's key strategies and priorities.

Table A.1 summarises the interview methods used for four of the domain areas: policy frameworks, CBMs, community-led initiatives, and approaches to social and behavioural change. Table A.2 contains additional details on whether interviews were undertaken individually by domain group or jointly with two or more domain groups. Table A.3 summarises the number of interviews conducted with each stakeholder group. The interviews and survey research received ethical approval from the Human Research Ethics Committees from CSIRO or the University of Technology, Sydney (depending on which organisation was leading the specific data collection activity) and complies with the Australian National Statement on Ethical Conduct in Human Research.

Table A.1 Overview of interview methods

DOMAIN GROUPS				
	POLICY FRAMEWORKS	CIRCULAR BUSINESS MODELS	COMMUNITY AND INDUSTRY LED LOCAL INITIATIVES	SOCIAL AND BEHAVIOURAL CHANGE APPROACHES
Number, type of interview 24	17 semi-structured interviews	16 semi-structured interviews	14 semi-structured interviews	24 semi-structured interviews
Sampling strategy	Interviews with stakeholders across the plastic value chain who are responsible for plastic policy design and implementing regulations on the ground	Interviews with businesses led by framework of business model types, and internet search for businesses	Interviews with diverse proponents of community-level initiatives	Key informant interviews focused on three cities in India: Haridwar, Panjim, and Agra. The sample aligned with cities where household surveys were undertaken
Stakeholder groups	Industry bodies, Central Ministries, ULB, academia, state-level entities, think tanks, international multilateral organisations	Businesses	Not-for-profit, NGO, social enterprise, private sector (hospitality and FMCG), government and international organisations	Government, waste management and resource recovery sector, NGOs, education providers
Recruitment of participants	Via email and phone	Via email and phone	Via email, phone and LinkedIn	Participants identified through publicly available websites and professional networks. Contacted by email and phone
Geographical focus	India	India	India	Haridwar, Panjim, and Agra – chosen for differences in size, geographic locations, and outcomes in the Swachh Survekshan Survey
Analysis	Qualitative, thematic analysis using Dedoose	Qualitative, thematic analysis using Dedoose	Qualitative thematic analysis using Dedoose	Qualitative thematic analysis using Dedoose

Table A.2 Breakdown of interviews by domain group including combined interviews

	DOMAIN GROUPS INTERVIEWS				COMBINED INTERVIEWS	
	Policy frameworks	Circular business models	Community and industry led local initiatives	Social and behavioural change approaches	Policy frameworks + Community and industry led local initiatives + Social and behavioural change approaches	Policy frameworks + Social and behavioural change approaches
Number, type of interview	11 semi-structured	16 semi-structured	13 semi-structured	18 semi-structured	1 semi-structured	5 semi-structured

Table A.3 Number of interviews by stakeholder type

STAKEHOLDER GROUP	NUMBER OF INTERVIEWS
Businesses	31
Community groups/NGOs/Action think tanks	15
Government and ULBs	8
Academics	3
Industry bodies	4
International multilateral organisations	3
TOTAL INTERVIEWS	**64**

24 Some interviews were conducted jointly by two or more domain groups as shown in Table A.2.

A.2 Method summaries

In this section we provide short summaries of the methods relevant to the following Roadmap chapters:

Chapter 1 – Data transparency

Chapter 2 – Policy frameworks for a circular economy for plastics in India

Chapter 3 – Circular business models

Chapter 4 – Plastic recycling technologies

Chapter 6 – Community- and industry-led local initiatives

Chapter 7 – Behaviour change.

Chapter 1 – Data transparency

In Chapter 1, we investigated the flows of different polymers through the Indian economy using Material Flow Analysis (MFA). MFA is one of the most widely used approaches for measuring flows and stocks of materials within a specified spatial-temporal boundary and following the mass-balance principle (Brunner and Rechberger, 2016). The results can be useful to decision makers because the mass-balance approach can identify ways to improve raw material efficiency, contribute to saving natural resources, reduce environmental impacts, and thus help to achieve SDGs (Gao et al., 2020).

In Chapter 1, we have compiled data for plastics based on the systematic approach of Baynes et al. (2011), who reconciled incomplete and incongruently disaggregated records to construct a complete and coherent material flow account. This approach involves: collecting primary data sources; comparing the different data using common categorisation; consolidating the data into a final data set; and completing the data set, which may involve extrapolation or other inference to fill any data gaps. Similar approaches have been used to develop economy-wide MFA; West et al. (2021) has a recent update of the methodology which was used to assemble the database underlying the UN's Global Material Flows Database (Schandl et al., 2018).

Chapter 2 – Policy frameworks for a circular economy for plastics in India

The research for Chapter 2 comprised two parts: i) a literature review of the policy frameworks relevant to the circular economy for plastics in India, and ii) stakeholder interviews and workshops to understand the enablers of and barriers to a circular economy for plastics in India.

The literature review included peer-reviewed academic journal articles, news sources in India, websites and reports published by various government ministries and departments such as the MoEFCC, CPCB, Department for Promotion of Industry and Internal Trade (DPIIT), and publications by specialised agencies such as the NITI Aayog and TERI, UNEP, and the OECD. The review also included industry reports, websites and news from peak-body institutions such as the All India Plastics Manufacturers' Association (AIPMA) and FICCI.

To examine policy progress in India, the policy instruments and effectiveness frameworks proposed by Dovers and Hussey (2013) were chosen. These frameworks were used as the basis for characterising relevant policy instruments in India, with further evaluation of the effectiveness of major recent policies. This research identified gaps in policy design from a plastics value chain perspective, noting the need to assess barriers and enablers for effective implementation of policy alongside the institutional and technical levers required to support a just transition.

Between January and August 2022, the research team conducted 17 interviews with stakeholders in India, comprising think tanks, local, state, and federal government actors, policy makers, academicians, industry peak bodies, and community organisations, to assess perspectives about the effectiveness of current policy, challenges and gaps that need to be addressed, and strategies to improve implementation and effectiveness in order to drive a circular economy for plastics in India. The perspectives and insights of experts and policy makers were shared with the research team during one meeting organised with the NITI Aayog and three round table workshops held between 2021 and 2023, attended by members from academia, civil society, municipal actors, waste management organisations and businesses.

Chapter 3 – Circular business models

In Chapter 3, we investigated CBMs in India to characterise the types of CBMs that are being used and to understand the challenges these businesses encounter and how they can be further enabled and scaled up. To begin with, we compared CBM frameworks from the literature and adapted a framework to suit the context of India and the focus on plastics. The framework identifies four major categories of CBMs which are shown in Table A.4 below along with plastic relevant examples.

Using this framework, we undertook a review of academic literature, and then a review of current practice (Retamal et al., 2021) by searching for each business type online and identifying businesses currently operating in India that fit with the framework for plastics. We subsequently conducted semi-structured interviews with 16 businesses in India, with the aim of sampling for diversity across the four categories. Finally, we undertook a qualitative analysis of interviews using Dedoose software[25]. We employed a mix of inductive and deductive approaches to identify key themes and, in particular, the barriers and enablers for CBMs in India.

Chapter 4 – Plastic recycling technologies

The methods for Chapter 4 focused on plastic recycling technologies and involved the following steps:

Identifying stakeholders

This included obtaining consent for sharing information and collecting primary data from identified recycling industries. The study was carried out in five clusters across India, including Nagpur district and Pune (Maharashtra), Chennai (Tamil Nadu), Haldwani (Uttarakhand) and Delhi. Mechanical recycling units in these cluster areas were identified and contacted to obtain consent for stakeholder engagement, field visits and primary data collection.

Preparing a comprehensive questionnaire

The questionnaire was designed for conducting semi-structured interviews with stakeholders and to acquire data on various criteria and indices. The hierarchical system was based on four criteria: economic, technical, resource utilisation, and environmental.

Visiting industries and qualitative and quantitative collection of data

Sixteen and seven semi-structured interviews were conducted in mechanical recycling and chemical recycling units, respectively. Three PWM-using PROs were also visited.

Data from the stakeholder engagement was collected and analysed using an Analytical Hierarchy Process (AHP) and a Multi-Criteria Decision Analysis (MCDA).

Ranking of technological options

Ranking of technological options based on expert opinion was performed for MCDA design frameworks.

Identifying research gaps, barriers, and opportunities to improve and increase plastic recycling, future perspectives and advanced technological options.

Table A.4 Circular business model framework

TYPOLOGY	PLASTIC RELEVANT EXAMPLES
Substituting	Replacing plastic packaging with non-plastic alternatives
Extending	Long warranty electrical and electronics, upgradable mobile phones, repair of e-products, second-hand sales, reusable packaging
Intensifying	Car rental/sharing, internet cafes, computer and phone leasing, toy, tool and equipment libraries, agricultural equipment cooperatives, ride-pooling, taxis (instead of owning a car)
Cycling	Upcycling plastic products, take-back schemes, recycling plastics, industrial parks using waste plastics as inputs

Adapted from Geissdoerfer et al. (2020) and Bocken et al. (2014, 2016)

25 Dedoose Version 9.0.90, cloud application for managing, analyzing, and presenting qualitative and mixed method research data (2023). Los Angeles, CA: SocioCultural Research Consultants, LLC www.dedoose.com.

Chapter 6 – Community- and industry-led local initiatives

In Chapter 6, we described the scope and focus of various community- and industry-led local initiatives along with the success factors and challenges to their implementation and development. To do so, we identified a range of initiatives by conducting an initial review of the grey literature, media articles and annual reports from organisations in India. We focused on community- and industry-led local initiatives conducted by community organisations (e.g. not-for-profit organisations, NGOs, social enterprises and research organisations), industry stakeholders (e.g. CSR), the public sector, and to a lesser extent, international organisations. We classified those initiatives based on the types of proponents leading them, the circular economy strategies they used, the types of activities they conducted, and their geographical location. We then selected case studies that represented the diversity of initiatives according to those criteria.

Our data collection consisted of 14 semi-structured interviews with stakeholders involved in 16 case studies (two interviewees discussed two case studies). Nine case study initiatives were identified during our initial review of publicly available information, while the remaining seven were either other initiatives conducted and discussed by interviewees from the first ten case studies or additional initiatives identified during our data collection phase.

Our frame of analysis for this chapter is a composite evaluation framework built on existing evaluation frameworks for community-based and circular economy initiatives. The framework is divided into five categories:

- Context: Elements of the social, political, regulatory, cultural and economic context that enabled or hindered the emergence and development of an initiative.
- Appropriateness: (In)adequacy of the project within the local context.
- Governance and management: Governance and management structures that enabled or hindered participation, social inclusion, financial, and organisational sustainability of the initiative.
- Diffusion: The initiative's ability to scale up or replicate itself.
- Outcomes and impacts: The initiative's ability to meet its objectives, and the environmental, social, and economic impacts of the initiative.

The data was then qualitatively analysed using Dedoose software. The five categories of the framework were used to deductively code data. Additionally, inductive coding was used to code any data that did not fit into the framework.

Chapter 7 – Behaviour change

Chapter 7's research findings were informed by four main data sources: a desktop review and literature review report; key informant interviews; a household survey; and observations during site visits.

The key informant interviews and household surveys were conducted in 2022 and focused on three cities in India: Haridwar, Panjim, and Agra. These cities were chosen because of their differences in size, geographic locations, and outcomes in the Swachh Survekshan survey of 2021. This cross-section of cities provided a diverse range of experiences and insights from which we could identify opportunities and barriers to underpin our recommendations for increasing circularity behaviours.

The interviews and survey research received ethical approval from the CSIRO Human Research Ethics Committee, which complies with Australian National Statement on Ethical Conduct in Human Research.

The approach of the four methods was as follows

1. Desktop review and literature review report
   - A review of government websites and reports, education programs, NGO initiatives and other information pertaining to plastic waste reduction campaigns in India.
   - A review of the academic literature had previously been undertaken which included behaviour change initiatives used globally for increasing the circularity of plastic (Niazi et al., 2021
2. Key informant interviews
   - Twenty-four interviews were conducted with key informants from municipal governments, the waste management sector, education, and the not-for-profit sector.
   - The interviews were semi-structured and lasted approximately 45 minutes. Interview topics included perceived barriers, challenges, opportunities, and enablers needed to support improved circularity of plastic.
   - The interviews were recorded, transcribed, and analysed using a thematic analysis approach and Dedoose software for data management. Key themes were identified and integrated into the findings outlined in Chapter 7.

3. Online survey methodology

The online survey was designed to understand factors that would influence the way households perceive and manage plastic waste inside and outside their homes.

- The survey, conducted in May and June of 2022, was administered through Qualtrics, an online survey company, using their panel participants in India.
- Qualtrics invited their panel participants to the survey by providing general information about the survey length and possible incentives. A range of incentives were typically offered to participants, including points, cash incentives, and gift cards. Potential participants were not provided with the survey goals or content to avoid potential self-selection biases in the sample.
- The three target cities Agra, Haridwar and Panjim were chosen for the reasons stated above.
- A quota sampling technique was employed to ensure that participants were evenly distributed across the three targeted locations, and into three groups of plastic waste recycling behaviours (lower, medium or higher recycling groups). Categorising participants into the different recycling behaviour groups helped shed light on how these groups may differ in their resources, abilities and perceptions in relation to PWM.
- A total of 558 surveys were obtained: 34.4% from Agra, 32.4% from Haridwar and 33.2% from Panjim. Across the recycling groups, 32.1% of the participants were in the lower, 34.4% in the medium and 33.5% in the higher recycling groups.
- 62.5% of participants were males and 37.5% were females. Most participants (96.2%) were aged 45 or younger (50.5% in 18 to 25 age group; 32.6% in 26 to 35 age group; and 13.1% in 36 to 45 age group). Very few participants (3.9%) were aged 46 and over.
- The responses for five open-ended questions about barriers and enablers for responsible disposal, recycling and purchasing of environmentally friendly packages were manually coded using a thematic analysis approach. Code definitions were refined iteratively to minimise overlaps and combined when appropriate. Each code was classified into one of three system-wide factors based on the social practice theory: knowledge and know-how; motivation and meanings; materials and infrastructure.

4. Observations at site visits

- Site visits provided the research team with a deeper understanding of the context in which the waste sector operated.
- Site visits included a municipal transfer station, a material recycling facility, a landfill, and a waste collection system.

The visit to a municipal Command and Control Centre of the Agra Smart City enabled an understanding of the present and potential data and IoT-based tools for influencing consumer behaviours towards reduction and segregation of plastics.

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Appendix B Collaboration Research Team

Over 50 researchers contributed to the project and development of the Roadmap over the life of the three-year collaboration. Listed below are the current and past member of the research team.

Neha Agarwal, MSc in Environment and Water Resources Engineering, Civil Engineering, was Manager, Research & Analysis at Development Alternatives Group, New Delhi, India.

Sagiruddin Ahmed, MA (English), Master of Library and Information Science is a Corporate Communication Executive, Knowledge Management at Development Alternatives Group, New Delhi, India.

Aparajita Amita Mathew, MA in Social Anthropology, Post Graduate Program in Development Studies, was a Project Executive, Green and Inclusive Entrepreneurship at Development Alternatives Group, New Delhi, India.

Kavya Arora, MSc in Environmental Studies and Resource Management, was a Senior Manager at Development Alternatives Group, New Delhi, India.

Nitin Bajpai, MTech in Energy Systems, was a Research Associate at the Centre for Resource Efficiency and Governance Division (CREG) in TERI, based in New Delhi, India.

Er Snehal Balbudhe, MTech in Chemical Engineering, was a Project Associate in CSIR-NEERI, based in Nagpur, India.

Dr Tim Baynes, PhD in Physics, was a senior science leader at CSIRO, based in Sydney, Australia.

Souvik Bhattacharjya, MEcon with a specialty in World Economy, is a Senior Fellow and Associate Director at the Centre for Resource Efficiency and Governance Division (CREG) in TERI based in, New Delhi, India.

Dr Smitirupa Biswal, PhD in Material Science and Engineering and BTech(H) in Metallurgical and Materials Science Engineering, is a researcher at the Centre for Sustainable Materials Research & Technology (SMaRT), UNSW in Sydney, Australia.

Dr Rita Dhodapkar, PhD and MSc in Chemical Sciences, is the Science Secretary and Senior Researcher at CSIR-NEERI based in Nagpur, India.

Elsa Dominish, Master of Environmental Management is a Research Principal at UTS-ISF in Sydney, Australia.

Dr Narges Emami, PhD in Civil Engineering and Masters in Civil Engineering (specialising in Renewable Energy), is a research scientist at CSIRO based in Canberra, Australia.

Dr Nick Florin, PhD in Chemical Engineering, is an Associate Professor at UTS-ISF in Sydney, Australia.

Dr John Gardner, PhD in Organisational Psychology, is a senior science leader at CSIRO based in Brisbane, Australia.

Anirban Ghose, BEng in Mechatronics, Hons and BSc in Nanoscience and Technology is a Microfactory Engineer at the Centre for Sustainable Materials Research & Technology (SMaRT), UNSW in Sydney, Australia.

Gitika Goswami, MSc in Geology and Certification Course on Environment Management and Sustainable Development, is Associate Vice President & Lead, Policy Research & Planning at Development Alternatives Group, New Delhi, India.

Anisha Gupta, MSc in Natural Resource Management, is Deputy Manager at Development Alternatives Group, New Delhi, India.

Alpana Gupta, Master of Planning in Environment Planning, was a researcher at Development Alternatives Group, New Delhi, India.

Dr Rumana Hossain, PhD in Material Science and Engineering and MEng in Advanced Engineering Management, is a Research Associate at the Centre for Sustainable Materials Research & Technology (SMaRT), UNSW in Sydney, Australia.

Dr Md Tasbirul Islam, PhD in Engineering and MA in comparative local development (Sociology, Political Science, Economics), was a researcher at the Centre for Sustainable Materials Research & Technology (SMaRT), UNSW in Sydney, Australia.

Er Jowin Joseph, MTech in Environmental Engineering, is a Senior Scientist at CSIR-NEERI, based in Nagpur, India.

Sarada Kapilavai, MSc in Climate Science and Policy, was a Project Executive, Green and Inclusive Entrepreneurship at Development Alternatives Group, New Delhi, India.

Bharti Kapoor, MA in Hindi, is Senior Manager, Knowledge Management at Development Alternatives Group, New Delhi, India.

Dr Shilpi Kapur Bakshi, PhD in Economics, was a senior fellow in the Centre for Waste Management in TERI based in New Delhi, India.

Karminder Kaur, MA in Development Studies, is a Research Associate at Development Alternatives Group, New Delhi, India.

Trinayana Kaushik, MSc in Climate Science and Policy, is a Research Associate in the Centre for Resource Efficiency and Governance (CREG) in TERI based in New Delhi, India.

Dr Debishree Khan, PhD and Masters in Environmental Science, is a Scientist at CSIR-NEERI, based in Nagpur, India.

Dr Sarah King, PhD in Innovation Networks and Masters in Corporate Environmental and Sustainability Management, was a research scientist at CSIRO, based in Melbourne, Australia.

Dr Taryn Kong, PhD in Natural Resources Studies (with a minor in Anthropology), is a research scientist at CSIRO, based in Brisbane, Australia.

Dr Asha Lalwani, PhD and Masters in Statistics, is a Principal Scientist at CSIR-NEERI, based in Nagpur, India.

Dr Katherine Locock, PhD in Pharmacology, is a senior science leader at CSIRO, based in Melbourne, Australia.

Priti Mukhopadhyay, MA in Library and Information Science, was a Fellow, Knowledge Management Unit at Development Alternatives Group, New Delhi, India.

Zeenat Niazi, MArch, is Senior Vice President, Chief Knowledge Officer at Development Alternatives Group, New Delhi, India.

Dr Sushma Pardeshi, PhD and MSc in Chemical Sciences, is a Senior Project Associate at CSIR-NEERI, based in Nagpur, India.

Ms Murni Po, BSc in Psychology, is a senior experimental scientist at CSIRO based in Canberra, Australia.

Ms Natasha Porter, BSc in Natural Resource Management, is an experimental scientist and project manager at CSIRO based in Perth, Australia.

Farhana Rahman, PhD Candidate at the Institute for Sustainable Futures is based at UTS-ISF in Sydney, Australia.

Dr Monique Retamal, PhD in Environment & Society and Masters in Water Resources, is a Research Director at UTS-ISF, based in Canberra, Australia.

Dr Laure-Elise Ruoso, PhD in Sustainable Futures and Master of Environmental Science, is a Senior Research Consultant at UTS-ISF in Sydney, Australia.

Sudhir Sah, BTech in Mechanical Engineering, is a Program Officer, Sustainable Enterprises at Development Alternatives Group, New Delhi, India.

Australian Research Council (ARC) Laureate **Professor Veena Sahajwalla** (FAA FTSE HonFIEAust CPEng), is the founding Director of the Centre for Sustainable Materials Research & Technology (SMaRT), UNSW in Sydney, Australia.

Dr Heinz Schandl, PhD in sociology and MA in social and economic sciences, is a senior science leader at CSIRO based in Canberra, Australia.

Ms Riya Shanker, MSc in Environmental Sciences and BSc in Biotechnology, was a Project Associate in CSIR-NEERI, based in Nagpur, India.

Ms Radhika Sharma, MSc in Environmental Sciences and BSc in Zoology, was a Project Associate in CSIR-NEERI, based in Nagpur, India.

Mandavi Singh, MSc in Environmental Sciences, is a Project Associate in the Centre for Resource Efficiency and Governance (CREG) in TERI based in New Delhi, India.

Dr Ria Sinha, PhD in Business Sustainability, was an Associate Fellow in the Resource Efficiency and Governance Division (CREG) in TERI, based in New Delhi, India.

Dr Simran Talwar, PhD and Masters in Management, is a Research Principal at UTS-ISF in Sydney.

Dr Sorada Tapsuwan, PhD in Economics and MSc in environmental and natural resource economics, is a senior research scientist at CSIRO based in Canberra, Australia.

Dr Andrew Terhorst, PhD in Business Studies and Masters in Marine Geology, is a senior experimental scientist at CSIRO based in Sandy Bay, Australia.

Sherine Thandu Parakkal, BTech in Civil Engineering, Post Graduate Program (Contemporary Smart City Development and Management), Certificate of Continuing Professional Development (Public Policy Analysis), Candidate PGD (Environmental Law) is Deputy Manager, Resource Efficiency and Circular Economy at Development Alternatives Group, New Delhi, India.

Anshul Tyagi, MA in Environmental Sciences, was a Fellow at Development Alternatives Group, New Delhi, India.

Aakriti Uttam, MA in Social Work, is a Program Officer, Capacity Building and Livelihoods at Development Alternatives Group, New Delhi, India.

Dr K Vijayalakshmi, PhD in Organic Chemistry, was Vice President at Development Alternatives Group, New Delhi, India.

Dr Andrea Walton, PhD in furthering household sustainability behaviour, is a senior science leader at CSIRO based in Brisbane, Australia

Appendix C Organisations who engaged with the Roadmap development

Many organisations were engaged with the project over the three-year collaboration, via roundtable discussions, semi-structured interviews, site visits, and other activities.

7to9 Green Store
Agra Nagar Nigam
Akshar Foundation
Arannya Environment Research Organisation
Aspirelabs
Athak Foundation
ATREE, Delhi
Banyan Nation
Central Institute of Petrochemicals Engineering & Technology (CIPET), Ahmedabad, India
Central Pollution Control Board (CPCB), India
Centre for Environment Education, India
Chintan
CII
Corporation of the City of Panjim
CPHEEO, MoHUA
DD Traders
Department of Science and Technology, India
Federation of Indian Chambers of Commerce & Industry, India
Fisheries Co-operative Society
Goa Cutlery Bank
Goa State Pollution Control Board
Goa Waste Management Corporation
Haridwar Municipality
Hasiru Dala
Iamgurgaon
IIM Ahmedabad
IIT Kharagpur
India Plastics Institute
Insignia Projects
Institute of Chemical Technology (ICT), Mumbai, India
ITC MRF
Kabadiwalla Connect
KleenCup
Lions Services
LUCRO
Mahila Mandal
MD Traders
Ministry of Environment, Forest, and Climate Change (MoEF&CC), India
Ministry of Housing and Urban Affairs, India
Ministry of Micro, Small, and Medium Enterprises, India
National Institute of Urban Affairs, India
National Productivity Council, India
NITI Aayog, India
Premsons Plastics Pvt Ltd, Ex-AIPMA
Project Mumbai
Recykal, Hyderabad, Telangana, India
RO Water Enterprise
Rudra Environmental Solution, Pune, Maharashtra, India
Samarpan Foundation, Delhi
Saraswathi Plastic Industries, Chennai, Tamilnadu, India
Shakti Plastic Industries, Mumbai, Maharashtra, India
Shri Bhubhneshwari Mahila Ashram (SBMA)
Swayambhu Solutions Pvt Ltd
Taj Group of Hotels
Tent Service Provider
The Confederation of Indian Industry, India
Toxics Link
UNDP
United Nations Environment Programme, India
Waste Aggregators
Waste Warriors
XLRI Jamshedpur
Yes In My BackYard (YIMBY)

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