

Year 1 Research Activity Products

Report Executive summaries

A material flow analysis of polymers and plastics in India

Baynes TM, Kapur-Bakshi S, Emami N, Bhattacharja S, Tapsuwan S, Joseph S, Locock K, Kaur M, Sinha R, Bajpai N, and Talwar S (2021) A material flow analysis of polymers and plastics in India. CSIRO, Australia.

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Executive Summary

India's compound annual growth in apparent consumption of major commodity plastics has been nearly 7% for a decade. However, a complete material flow analysis (MFA) of Indian plastics has not been conducted since Mutha et al. (2006) compiled data from the year 2000. We present a 20-year update, including the current features of plastic production and end use by polymers and in sectors; a complete account of national plastics material flows; and an analysis of key drivers of change into the medium-term future.

In an ideal situation, there would be data on three flows: plastic consumed and disposed of by sectors (including households) within a reporting year; plastic retained in long-lived products in the same sectors; and plastic waste from end-of-life of products made in earlier years.

There are significant and inherent data gaps, notably around the collection and treatment of post-consumption flows and their ultimate fate. Acknowledging these uncertainties, we have developed a self-consistent MFA model, representing available data on national flows for 2018–19, estimating data where primary sources were unavailable.

The MFA depends on assumptions and modelling to span the direct data gaps regarding plastic production, consumption and waste flows. These include the proportion of production going into long-lived (>1 year) stocks; the fate of waste flows from long-lived stocks; and the connection between recycled or reutilised flows and their return point into the Indian economy.

To estimate flows from end-of-life for different use sectors we have used expert judgement on the proportion of long-lived products that come out of service, assuming that 10 to 25% of long-lived products enter the waste stream in a given year of consumption/use.

The proportion of e-waste plastic recycling and reutilisation are both assumed to be 10%, and likewise, household plastic waste is assumed to be reutilised or mismanaged in the ratio 50/50. These remain our best judgements and there are some data from state and city level information that can inform the boundaries of possible recovered flows, though sometimes urban or regional reporting is incomplete.

Although we have estimated the flows to recycling and reutilisation, we do not attempt to quantify recycled flows back into production. Except for the flow of recycled PET back for use as fibre, there is a complete absence of data on existing flows of recyclates back into the production system.

This is a major data gap for future work and one that we expect links to flows of low-value secondary plastic products that cater to the demand of the poorer sections of Indian society. These products will likely have a high percentage of recycled inputs as mechanical recycling of plastic waste into new moulded products often happens in the informal sector.

Leakages of plastic waste into the environment, and their connection to mismanaged plastic waste, are likely to remain data-scarce topics and may only be understood from the MFA balance, when all other flows are reasonably accounted for.

Total domestic production of plastic amounted to 14.24 Mt for the year 2018–19, while the trade in plastic polymers is relatively significant: 46.5% of total domestic production is either imported or exported. However, India remains a net importer, with a negative balance of 1.3 Mt. For the consumption of plastic and plastic-containing products by sector, flexible packaging accounts for 42%, followed by rigid packaging (17%), and buildings and construction (14%).

Additions to stock were concentrated in buildings and construction, agriculture, household and automotive sectors (totalling 4.72 Mt). Approximately 9.73 Mt of plastic waste was generated in 2018–19, a majority of which was packaging products (6.24 Mt of flexible packaging and 2.44 Mt of rigid packaging). Based on collected inputs from industry experts, and considering the composition of plastic types used in different sectors, we estimated the distribution of waste occurs between recycling (61%), reutilising (12%) and mismanagement (27%).

Future consumption was projected based on demand elasticities until 2035, which show that demand is likely to remain strong, driven by consumption in major sectors including construction, electronics and packaging, among others. Per capita plastic consumption is predicted to grow substantially from a historical 8 kg per person in 2010 to around 29 kg per person by 2035. At this rate, total plastic consumption in India will grow from 9.9Mt in 2010 to 44.8 Mt by 2035.

There is a growing agreement among stakeholders that future demand will be significantly shaped by the changes in the policy environment as envisioned under the draft Plastic Waste Management (Amendment) Rules, 2021, and stricter enforcement of extended producer responsibility.

Towards a circular economy for plastics in India. A review of community, industry and public sector initiatives.

Tyagi A, Ruoso LE, Retamal M, Pai Panandiker A, Goswami G, Niazi N (2021) Towards a circular economy for plastics in India: A review of community, industry and public sector initiatives. Development Alternatives, UTS and TERI, Australia and India.

Report soon to be available at - <https://research.csiro.au/rpwi/products/>

Executive summary

The India-Australia Plastics Research Initiative, conceived in June 2020 by the Indian and Australian Prime Ministers, brings together research and industry partners in the two countries to work on reducing plastic waste and driving a circular economy for plastics in India. The project aims to take a holistic approach to understand plastic flows and supply chains, circular economy technologies and circular economy enablers including public policy, circular business models and initiatives led by communities and industries. This working paper is focused on the role of community and industry-led initiatives to drive change towards a circular economy for plastics.

India is currently facing a substantial plastic challenge. While its plastic consumption per capita remains low, its production of plastic waste in absolute terms makes it the 15th largest producer of plastic waste in the world. A substantial proportion of this waste is mismanaged with negative consequences on the natural environment and human health. While top-down policies are known to play an essential role in tackling plastic related issues, less is known regarding the role of bottom-up initiatives conducted by communities and industry. However, sustainability transitions literature argues that bottom-up initiatives can play a central role in driving sustainability transitions, by developing niche initiatives that can enter the mainstream and potentially lead to regime shifts.

This working paper is focused on initiatives led by communities, industry stakeholders, as well as initiatives led by government and implemented on the ground. It aims at building an understanding of initiatives that have been implemented in India to address plastic waste and support a circular economy for plastics, and to learn from them to inform subsequent programs. In this first iteration of the paper we:

- i) identify a range of initiatives implemented in India through a literature and practice review;
- ii) characterise them according to their potential contribution to circularity;
- iii) identify knowledge gaps;
- iv) select a sub-set of initiatives for further inquiry; and
- v) develop an evaluation framework to assess the effectiveness, contribution to circularity and sustainability of a selected group of initiatives, as well as their ability to contribute to transformative change.

The findings from our initial characterisation of initiatives - based on their potential contribution to circularity - shows that, across the board, initiatives primarily focus on the end of the plastics life cycle, that is: facilitating the collection, recycling and recovery of waste. The second area of focus is the beginning of the plastic lifecycle, notably refusing the use of single use plastics and reducing its use. In contrast, very few initiatives target the extension of the product lifetime, such as reuse, repair and repurposing.

With regard to the types of approaches adopted by stakeholders, community-based initiatives mainly focus on education and awareness raising, as well as on the provision of incentives for recycling, while industry and public initiatives focus on substituting plastics for another material, as well as on facilitating waste collection and recycling, notably by collaborating with the informal sector.

The main knowledge gaps identified in this initial characterisation of initiatives were as follows:

- While the objectives of the initiatives are stated, very little information is currently available on the outcomes and impacts of those initiatives
- Similarly, little to no information is available on the factors that explain the success or failure of an initiative, particularly with regard to its ability to sustain itself in the long-term and to scale up.
- There appears to be a dearth of initiatives focusing on extending product lifetime, with little information on why that is the case.
- Finally, there is a lack of understanding of the contextual factors (notably policies and government interventions) that enable/hinder the emergence of those initiatives.

Building on the knowledge gaps identified, we formulated five research questions:

- What are the drivers (regulatory, policy-related economic, social, technical etc.) for plastics related initiatives in India?
- What are the social, economic and environmental outcomes/impacts of existing initiatives?
- What are the factors that explain the longevity of an initiative (its ability to sustain itself) or on the contrary its failure to do so?
- What are the factors that explain the ability of an initiative to replicate or scale up?
- Why are there a lack of initiatives targeting lifetime extension, such as reuse, repair and repurposing of plastics products?

We identified nine potential case studies based on a range of criteria including: initiatives driven by different proponents, in diverse geographies, using a range of circular economy strategies and approaches; and initiatives that have seen varying levels of success and failure at different scales. We will evaluate those case studies to answer our research questions and provide insights on how initiatives can be better supported.

To do so, we drew on literature on circular economy, social innovation, and community-based initiatives to develop an evaluation framework composed of five main dimensions: i) Context – contextual elements that enabled or hindered initiatives, ii) Appropriateness – (In)adequacy of the project with the local context, iii) Governance and management – governance and management structures that enabled or hindered the project (i.e. participation, inclusion, organisational and financial sustainability), iv) Innovativeness & diffusion - The degree to which the initiative develops innovative products and services, and its ability to diffuse them through replicating or scaling up and v) Outcomes & impacts – environmental, social and economic outcomes and impacts.

The next step of the research will be to conduct stakeholder engagement, starting with stakeholders directly involved with the case study initiatives and then snowballing to include a range of broadly relevant stakeholders from the public, private and non-government sectors.

Circular business models for plastics in India. Literature and practice review.

Retamal M, Pai Panandiker A, Talwar S, Sah S, and King S (2021) Circular business models for plastics in India: Literature and practice review. UTS, TERI, Development Alternatives and CSIRO, Australia and India.

Report soon to be available at - <https://research.csiro.au/rpwi/products/>

Executive summary

This paper reviews circular economy business models within the context of India and its plastics value chain. The circular economy sets out to create a regenerative system of resource use through strategies including: long-lasting design, repair, reuse, remanufacturing and recycling (Geissdoerfer et al., 2017). Research estimates suggest half-a-trillion dollars of economic opportunity can be realised for India by 2030 through the adoption of circular economy business models. It is anticipated that this could be achieved through a range of strategies, including by reducing waste, improving utilization of products and capital assets, product life extension, and value recovery strategies (Fiksel, Sanjay and Raman, 2021).

India is a significant producer and consumer of plastic polymers and materials. The plastics value chain represents a diverse range of industry actors, including a few large producers who control domestic polymer and feedstock supply, and a heavy reliance on imports of plastic and chemical industry raw materials. Downstream plastic processing and manufacturing is fragmented, consisting mainly of micro, small and medium enterprises (MSME); this also extends to plastic product manufacturers, machinery and mould manufacturers. The recycling industry in India comprises many small processors, is fragmented and highly unorganized, with large participation from informal waste collectors and recyclers.

In this working paper, we have reviewed the literature regarding circular business model (CBM) definitions and typologies and have established a CBM typology that is applicable to plastics and the Indian context. We have subsequently undertaken a practice review of CBMs for plastics that are currently operating in India and have developed several short case studies that will be investigated in more detail. Towards the end of the working paper, we also reviewed the literature regarding the barriers and enablers to implementation of CBMs and through this review we have developed a framework to guide our case study investigations in the next steps.

To align with the context and focus of this research, we adapted CBM typologies developed in the literature to examine four CE business model strategies: i) substituting; ii) extending; iii) intensifying; and iv) cycling. We undertook a review of circular business models in India, which revealed 55 operational CBMs that engage across different circular economy strategies and varied stages of the plastics value chain. Based on this practice review, we have developed nine short business case studies. These short case studies will inform the next phase of research, involving stakeholder consultation and empirical data collection for plastics CBM in India.

The results of our practice review show the majority of business examples (27) were engaged in the business model strategy of 'cycling', such as remanufacturing, recycling, and reverse logistics. The most common business model types in India related to substitution of plastic materials, recycling and technology platforms to facilitate extended producer responsibility (EPR) schemes. This is similar to the international literature, where the most examples were oriented towards recycling and substituting plastics for bio-based materials. The least common business models in our practice review related to 'intensifying' (sharing models, rental/leasing/access models, user cooperatives, creative commons, pooling models). Established circular business models in India include repair, reuse and second-hand sales; services to avoid packaging; recycling plants and waste to energy plants. Emerging, or relatively new examples of CBMs involve substitution of plastic materials with alternatives and renewables; remanufacturing; and technology platforms for EPR.

Our literature review of barriers to CBM implementation found a few common themes, these are: a lack of capital and high investment costs; lack of awareness and knowledge for businesses and consumers; market issues including rigidity of existing supply chains; a lack of government incentives and regulatory enforcement; technological or system related barriers; a lack of required organisational culture; and commercial issues. Common enablers were the availability of green markets and supply chains; networks to support collaboration with stakeholders; commercial incentives; consumer awareness and demand; financial drivers; and the environmental awareness and commitment of organisations.

Overall, there are broad efforts to support CE in India through several government and industry initiatives; yet there are gaps in understanding which factors might drive, enable, and facilitate greater uptake of the full range of circular business models available, and how the barriers for businesses in India can be overcome. Current downstream business solutions involve consumers, the informal sector, formalised recyclers, and ultimately major producers. In the long-term, it will be important for larger polymer manufacturers (who are also oil & gas producers) to diversify and draw on recycled production inputs, to drive greater circularity and reduction in extraction and production of virgin plastics.

A review of the policy framework for a circular economy for plastics in India. Literature Review.

Talwar S, Thanduparakkal S, Arora K, Niazi Z and Retamal M (2021). A review of the policy framework for a circular economy for plastics in India. UTS and Development Alternatives, Australia and India.

Report soon to be available at - <https://research.csiro.au/rpwi/products/>

Executive summary

This study examines the dynamically evolving policy framework relevant to plastics management in India, with the intention to support the transition to a circular economy for plastics in the country. Our analysis draws upon Dovers and Hussey (2013) framework for environmental policy design in order to characterise the policy instruments in use and the effectiveness of their design with reference to the aims of a circular economy. We adopted a value chain approach in the characterisation of key policies relevant to plastics and the circular economy in India, in order to map the plastic value chain stages most closely addressed by current policy, as well as to identify opportunities for future policy direction. Lastly, in the absence of an overarching CE policy and action plan for India, we applied the circular economy strategies framework by Kirchherr et al. (2017) to identify the circular economy potential and actions supported by India's policy framework.

To complement the above categorisation of policy instruments, we also examined the effectiveness potential of select policies. For this, we adapted the analytical framework for policy effectiveness by Dovers and Hussey (2013). Five framework criteria were included:

- i) efficiency in achieving outcomes
- ii) corrective action focus
- iii) systemic potential
- iv) flexibility
- v) complexity and cross-sectoral influence

Our examination spanned key national policies, such as the Swachh Bharat Mission, Plastic Waste Management Rules, single-use plastic bans in different states, draft National Resource Efficiency Policy, Smart Cities Initiative and Bureau of Indian Standards (BIS), International Organization for Standardization (ISO) standards related to plastic use and packaging. Some sub-national policy instruments such as the Goa Resource Efficiency Strategy (2020) were also included in the review as these reflect recent circular economy advances and unique consultative mechanisms for policy design in India. With the focus on formal institutions and national level policies, the informal sector has not been included in this review, however, it will be explored in future research.

The analysis of published reports and policies from the public information portals of national and sub-national governance levels revealed that most policies and institutions addressed the consumption, waste generation and resource recovery phases of the plastics value chain. There is inadequate policy guidance for upstream efforts for sustainable production and reduction or the expansion of alternatives to single use plastics. The vast majority of policy instruments were focused on end-of-life management including recycling and reprocessing activities.

Multi-dimensional policy instruments such as the Swachh Bharat Mission and the Swachh Survekshan have a positive role in enhancing citizen engagement and generating awareness on the issues of solid and plastic waste management. Such initiatives supported by stronger implementation of EPR regulations and SWM rules at local level, consumer awareness, innovations in the product and packaging material, creating sustainable procurement and markets for circular plastic value chains would enable key waste management policies to achieve the desired outcomes.

Our research points to policy gaps that address ‘product, process and business design’ aspects and may foster circularity in the plastics value chain. We identified gaps with respect to incentives, regulations and fiscal measures that may drive reduction of virgin fossil-based polymers, promote the use of biopolymers and the use of secondary plastics in products. Additionally, we found that mechanisms for Extended Producer Responsibility are weak and upstream actions to support ‘reduction’ and ‘reuse’ strategies are largely absent. Green Public Procurement is another area that merits urgent attention, supported by policies and efficient data management systems to strengthen the role of government in fostering circular economy practices. The effectiveness of policy instruments is a more complex issue and must reflect both in its design and in its implementation. As a next step, we will undertake stakeholder engagement at different governance levels to understand the effectiveness of policies relevant to the plastics circular economy in India.

The findings of this working paper are expected to inform policy design in India in relation to addressing gaps for achieving a circular economy for plastics and seeking alignment between circular economy actions targeted at different stages of the plastics value chain. This paper also set out to examine the effectiveness of recent policy instruments in terms of their design, according to specific criteria including: efficiency in achieving outcomes, corrective focus, systemic potential, flexibility in implementation, and cross-sectoral influence (Dovers and Hussey, 2013). Together, these findings will be used to design a field study and stakeholder engagement process, to understand implementation effectiveness of current policy mechanisms in India, and to inform future policy design and support for wider adoption of circular economy strategies.

Enabling behaviour change towards a circular economy for plastics in India. A review of social and behavioural enablers.

Niazi, Z., Walton, A., & Gardner, J. (2021). Enabling behaviour change towards a circular economy for plastics in India: A review of social and behavioural enablers. CSIRO, Australia.

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Executive summary

The India-Australia Plastics Research Initiative, conceived in June 2020 by the Indian and Australian Prime Ministers, brings together research and industry partners in the two countries to work on reducing plastic waste and driving a circular economy for plastics in India. The project aims to take a holistic approach to understand plastic flows and supply chains, circular economy technologies and circular economy enablers including public policy, circular business models, behaviour change programs, and initiatives led by communities and industries. The project will use insights and strategies from these wide-ranging enablers to develop a roadmap that sets out a pathway for achieving change towards a circular economy for plastics in India.

This report focuses on behaviour change programs and provides evidence to guide the design and implementation of strategies and action plans to roll out a road map for the circular economy of plastics in India. The report analyses existing initiatives that have been undertaken in India: i) to improve people's knowledge and awareness of problems related to plastic pollution, and ii) to promote changes in behaviours needed to mitigate these problems. In addition, the report draws from other research literature to identify a range of alternative behaviour change strategies that could be used to support change, thus identifying gaps and opportunities for the Indian context.

Using a comprehensive framework for understanding the various behaviours related to the consumption of plastic, the analysis and findings consider strategies that address the key components of social practice theory: people's skills and competencies; the materials, infrastructure and physical aspects related to plastic consumption; and the symbolic or social meanings of how plastic is consumed and how this can be changed. This approach has identified knowledge-based interventions, technological and structural interventions, and social interventions as new opportunities for enabling behaviours that would support increased circularity of plastic.

This report focuses on four key types of consumption behaviours associated with plastic: the 3'R's of reducing, reusing, recycling, along with responsible disposal, which are collectively referred to as the 'R-behaviours' in the report. In addition to avoidance of plastic consumption, 'Reducing' behaviours include purchase choices, such as 'green' purchasing, and product switching to non-plastic substitutes. 'Responsible disposal' behaviours include litter avoidance. This report identifies the motivators, drivers, barriers, and enablers from a consumer's perspective that are needed to be incorporated or addressed in future behaviour change strategies to encourage the circular economy of plastic.

Findings

Analysis showed that programs and initiatives in India that are aimed at increasing consumer awareness about plastic pollution and R-behaviours are promulgated through a wide range of channels: national announcements, the media, civil society, various state and local governments, and school education. Most of the information-based initiatives focused on two elements underpinning behaviour. One, changing citizens' attitudes and motivations through increasing their awareness as to the extent of plastic pollution and its harm to the environment, and two, improving skills and competencies for undertaking R-behaviours by increasing people's knowledge about how to recycle or how to substitute for single-use plastic. However, the associated changes to the necessary materials and infrastructure needed to support the behaviour change were not often addressed. In addition, the extent to which behaviours changed was unable to be determined due to a lack of evaluation and lack of available data.

Knowledge gaps and intervention opportunities

Knowledge gaps and intervention opportunities represent potential initiatives and ideas to enable the increased circularity of plastic through more sustainable consumption practices. The opportunities emerged from identifying strengths and weaknesses in the initiatives that have been undertaken to date in India, and from approaches that have been used in other parts of the world or in other resource conservation domains that are so far underutilised in the Indian context. Both the gaps and opportunities provide avenues for further exploration of their possible use in implementing India's roadmap for a circular economy of plastics.

A number of key gaps in knowledge were identified that warrant further investigation in future studies:

- A lack of understanding about the consumption practices of rural citizens, as most research has focused on urban settings.
- A lack of research involving SMEs and the contributions that this sector could make to improved labelling and consequent reducing, recycling, and disposal behaviours.
- A lack of understanding about the specific role of women and their decision making, as they are often the key determiners of household plastic consumption, particularly purchasing and recycling.
- Reuse behaviours have been under-researched and are particularly relevant in a developing country context.
- A lack of data on the effectiveness of interventions that attempt to change habits and maintain these changes over time.
- Limited studies that document the outcomes of interventions, and studies that evaluate the effectiveness of different behaviour change strategies, particularly those targeted to children and young consumers.

A range of potential opportunities and interventions for supporting the R-behaviours necessary for the sustainable consumption of plastic were identified and grouped into three categories.

1. Opportunities and interventions to **improve citizens' skills and competencies** for undertaking R-behaviours. These opportunities are based largely around augmenting existing consumer awareness and education programs and extending the effectiveness of knowledge platforms and portals.
 - Improve the quality and targeting of information provided. Ensure that information targets a particular behaviour and a particular demographic or stakeholder group.
 - Extend single-use plastic information initiatives to ensure that information addresses all types of single-use plastic.
 - Utilise industry to support broader educational initiatives about waste and recycling of plastic, especially through the increased involvement of polymer manufacturers, which has been an underutilised industry sector to date.
 - Strengthen the ENVIS portals with up-to-date, credible, scientific and easy to understand information about the management of plastics in the environment, using different languages to increase popularity and usefulness among NGOs, schools, universities, think tanks and municipalities.
 - Develop information and communication products specific to improving circularity for plastic.
2. Opportunities and interventions to **drive changes in people's motivations and social meanings** associated with sustainable consumption behaviours. These opportunities are aimed at using information and other mechanisms for nudging social norms and shifting attitudes, and to use social influences to drive and reinforce changes in behaviour.

- *Reduce the 'yuck factor' to improve attitudes towards correct waste disposal and recycling.*
 - Utilise social influencers to champion green purchasing, recycling, and waste disposal behaviours.
 - Incorporate more emotional cues into sustainable consumption messaging.
 - Use targets and feedback mechanisms to increase incentives for R-behaviours.
 - Empower consumers with a sense that their actions can make a difference.
3. Opportunities and interventions to **provide the materials and infrastructure needed** to undertake sustainable consumption of plastic. These opportunities are aimed at providing increased access and opportunities for consumers to undertake greener purchasing choices and other reducing, reusing, and recycling behaviours, and to reduce littering and leakage of plastic to the environment.
- Facilitate a category-wide shift in sustainable packaging.
 - Extend industry initiatives to focus on rural areas, smaller cities, and towns.
 - Support behaviour shifts through targeted infrastructure improvements that encourage improved collection systems for households.

In summary, this working paper identifies gaps in knowledge that need more research but potentially offer prospects for promoting future improvement in R-behaviours. There are also opportunities for extending the effectiveness of initiatives currently undertaken and to incorporate new initiatives that have not yet been tried. The next steps in the research will be to build on these knowledge gaps and potential opportunities so that future initiatives and interventions will create greater impact and change in consumers' R-behaviours.

To this end the next research phase will comprise a qualitative study incorporating key informant interviews to investigate opportunities for enabling behaviour change in a comprehensive and holistic approach: influencing social meanings and attitudes, addressing materials and infrastructure aspects, and improving skills and competencies. The next study will also identify ways for improving tailoring and targeting of initiatives to maximise impact, to understand issues that impede or enhance program implementation, and to identify potential data for program evaluation. These insights will contribute to the recommendations and priorities for the national roadmap designed to deliver and drive change towards a circular economy for plastics in India.

Draft Journal Manuscript Abstracts

Plastic waste management in India: Challenges, opportunities, and roadmap for circular economy

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Highlights

- Production, consumption, and waste management of plastic in the Indian context are reviewed
- One of the earliest reviews comprehensively assessing the Indian plastic industry
- Critical discussion areas reveal the steps required to achieve circular plastic economy in India.

Abstract

Plastic waste (PW) is one of the most rapid-growing waste streams in municipal solid waste all over the world. India has become a global player in the plastic value chain. Despite low consumption, domestic generation and imports create a significant burden on the overall waste management system, which requires in-depth understanding of the scenario and pathways to mitigate the crisis. Although Indian researchers have widely researched technology-related issues in academic papers, a substantial knowledge gap exists in understanding the problem's depth and possible solutions. This review article focuses on current plastic production, consumption, and waste generation in India. This review article mainly analyzes data and information on Indian PW management and highlights some critical issues such as reverse supply chain, effective PW management, source-specific recovery, and PW rules in India. Comprehensively, this review will help identify implementable strategies for policymakers and research opportunities for future researchers in holistic PW management and recycling in India, focusing on circular economy and sustainable development goals.

Keywords: circular plastic economy, resource efficiency, extended producer responsibility, literature review, India.

Plastic Waste Recycling: Existing Indian Scenario and Future Opportunities

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Abstract

The aim of this review article is to suggest recycling technological options in India. The paper also illustrates plastic recycling clusters and reprocessing infrastructure for plastic waste recycling in India. The study shows that a majority of states in India are engaged in recycling, road construction and co-processing in cement kilns, while reprocessing capabilities among the re-processors are highest for polypropylene (PP) and polyethylene (PE) polymer materials. Of the technologies reviewed as part of this study, it appears that there are key opportunities for mechanical recycling, manufacturing, chemical recycling, and waste to energy approaches to deliver impact to India's plastic waste (PW) problem. On the hand, overall, polyurethane (PUR), nylon and PET (polyethylene terephthalate) appear most competitive for chemical recycling. Compared to conventional fossil fuel energy sources, PE, PP, and polystyrene (PS) are the three main polymers with higher calorific value suitable for energy production. Given that food packaging constitutes a large portion of PW in India, significant impact could be delivered for the country if a switch were made to more sustainable bio-based polymers. Contaminated collection reduces the recyclability of other PW streams, which should be considered as part of bio-based PW management. Also, multi-sensor-based AI and block chain technology and digitization for the plastic waste recycling can prove to be the future for India in waste flow chain and its management. Overall, for a circular plastic economy in India, there is a necessity for a technology-enabled accountable quality-assured collaborative supply chain of virgin and recycled material.

Keywords: Informal and formal sector, Biological recycling, chemical recycling, mechanical recycling, digitization, block chain technology