INNOVATION IN PLASTICS

The Potential and Possibilities

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{ Table of Contents }

{ Message }

Dr. Raghunath Mashelkar
Honorary Emeritus Chair
Governing Council, Marico Innovation Foundation

It is not about plastic. I know the cover page says otherwise, but allow me to explain.

As a scientist, I have shaped my entire life on the single premise of possibility. Believing in the possibility of something is foundational to our existence. Only when we believe it is possible, do we venture ahead to achieve unimaginable advances—be it in space exploration, technology, healthcare, or infrastructure.

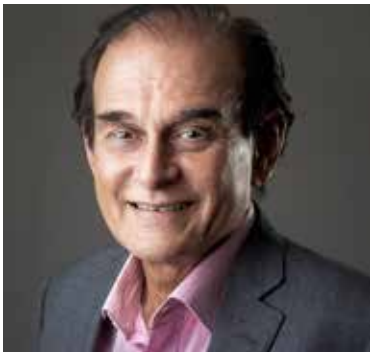
The evidence of possibility becoming reality is all around us. It serves as the impetus to breathe life into an idea, to discover a new way forward, to find novel solutions to age old problems, and to figure ways to make our future more inclusive, humane, and equitable. Possibility is the birthing ground for innovation.

At least 150 years ago, it was the possibility of finding a more malleable and diverse alternative to ivory that led us to the now-ubiquitous plastic. Over the years, we kept adding value to it: cheap, colorful, easily transportable, diverse uses for multiple products. Numerous possibilities became a reality. Plastic solved many problems for businesses and individuals alike, and was readily welcomed by them. Its rapid growth and applicability came with dire consequences to our health and environment.
Here we are today, at the crossroads of change again. As we reckon with the problems that plastic presents us with, the time has come to discuss the possibilities for change, innovation, and disruption. Innovators and enterprises are well poised to come together and explore the multiple possibilities of rethinking, reusing, recycling, and repurposing plastic to ensure a circular economy. Many stakeholders stand to gain from this renewed lens of possibility around plastic. For instance, the current waste management system provides the opportunity for the greatest innovations, as is evidenced by the promising innovators we have spotlighted in this report. They are purpose-driven and will combat the challenges of plastic waste and waste management through their unique technology prowess, continual and frugal innovation. Their resolve to create winning solutions stands to benefit our nation and the world.

The 'I' in India certainly stands for innovation. We are now ranked 40th on the World Intellectual Property Organization's Global Innovation Index, 2022. I believe India will steer significant research and development, and design innovative solutions to combat plastic waste management—paving the way for global progress.

{ Foreword }

Amit Chandra
Honorary Chairperson
Governing Council, Marico Innovation Foundation



Harsh Mariwala
Founder,
Marico Innovation Foundation

It is not about plastic but possibility—Dr. Mashelkar makes an astute observation that every entrepreneur can agree on. Often, it is not about what stares us squarely in the eye but about discovering the untapped and unseen. Dr. Mashelkar makes a case for Possibilities. We write here about Potential, a potent word that navigates unexplored areas, moves markets, designs solutions, and solves for problems.

Over the course of our careers, we have seen endless examples of how potential can be a north star for discontinuous growth. In our respective fields, we have had the opportunity to support swift, non-incremental gains by businesses, as they pole vault into their own measures of success.The key has always been measuring the potential of an idea, a product or a service.

Identifying this potential in the face of adversities makes innovators stand out. There are numerous examples that speak to the value of harnessing the potential of challenges and responding with winning, innovative solutions irrespective of market realities. Take, for instance, cab hailing services or the ease of online shopping—these were born out of ideas that held immense potential and solved a challenge.
We understand the critical need to build an ecosystem where we nurture India's disruptive potential and deliver innovative solutions for global problems. It is why Marico Innovation Foundation (MIF) came into existence, and has been at the forefront of young India's innovation story.

With this guiding principle, MIF identifies a sunrise industry every two years, which holds promising potential to solve a significant issue for India. We embark on a sector-specific intervention to hunt, recognise and scale up organisations with the potential to innovate. We launched the first sectoral intervention, **Innovate2Cultivate**, in 2018, in the agriculture sector, followed by **Innovat2BeatCovid** in 2020 to promote innovations in combating the Covid-19 pandemic.

In 2022, MIF has decided to foray into plastics which is among the largest waste-causing industries and a pressing global concern. We recognise that in order to tackle the plastic waste problem, we need to build an enabling ecosystem that will support innovative solutions. If well-backed, these innovations can address the challenges of increased plastic consumption, and a lack of circularity in the plastic value chain that fills

up our landfills and oceans. Like dozens of fintech and consumer tech companies, they can play a key role in solving a massive problem, and become Unicorns in the process.

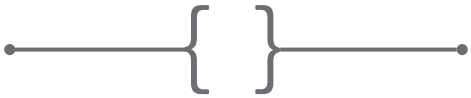
MIF's focused intervention in the plastic value chain provides ample opportunities for the innovation ecosystem to thrive, collaborate and contribute to reforming the plastics problem.

Before immersing ourselves into the sector and supporting the innovations, a subject as scientifically complex and diverse as plastic, requires a detailed understanding of the ecosystem. This first-of-its-kind report on the plastics industry provides that understanding before showcasing the potential for value that exists in the plastic innovation ecosystem.

More importantly, this report can serve as a playbook for bringing different stakeholders in the ecosystem together to solve global challenges through innovations that can reshape the future.

Exploring the true potential of these innovations would mean helping these ideas achieve scale. So, it is essential to build large-scale awareness not just about innovations in plastic waste management, but also best practices that all stakeholders—be it enterprises, MSMEs, civil society, and even state and central governments—can benefit from. The knowledge and insights here call for an honest participation from all sections of society.

The time for deliberations is over. There is an urgent need to double down on our commitment to change the way we view plastic, and unleash the full potential of innovations that can help us reimagine the future. MIF is committed to building momentum towards creating the needed impact. Over the next two years, our work will continue to gather steam as we enable and empower innovations to make a lasting change.



{ Introduction }

Indian Institute of Science & Praxis Global Alliance

It is no longer business as usual as far as plastics are concerned. It cannot be.

Our report, **Innovation in Plastics, The Potential and Possibilities** is driven by the belief that a sustainable and robust circular economy can be built in India to combat the damage created by plastic waste. All stakeholders – government, corporates, civil society, and entrepreneurs have an equally critical role in ensuring this. The report examines the plastic waste management ecosystem in India to identify the challenges and opportunities with a special emphasis on business and technological innovations.

The report presents the landscape of key innovations in plastic recycling and replacement, waste collection and sorting, and marketplaces. We profile some of India's most promising start-ups supporting the circular economy in plastics. We map them on the opportunity size, business model, operations, and technology. Further, this report highlights learnings from past innovations, initiatives undertaken at the international, national, corporate, and city level to support circularity in plastics. There are vital lessons from across the globe that can be implemented in India along with avenues for cutting down single-use plastics.

Our research methodology comprised interviews and workshops with corporate leaders, start-ups, industry experts, and scientists. The message we heard was unanimous: to surmount the challenges associated with plastic usage, India needs to focus on creating new solutions and building an enabling policy framework.

The first chapter is an overview of the present state of plastic usage and recycling in India along with the harmful impact of rising plastic waste. Over the following three chapters we focus on circularity in plastics, challenges in achieving it and potential opportunities with a focus on bioplastics and packaging.

The report has been structured in a manner that one can access and absorb it in a linear fashion or move to chapter five and six that focus deeply on innovations implemented by start-ups, research institutions, corporates, and city municipalities. Towards the end are recommendations on what each stakeholder can do to solve the plastic waste conundrum. We close with specific and vital action areas for entrepreneurs to channelize energy and resources to drive innovation in order to combat specific aspects in the plastic value chain.

The one purpose of this report is to galvanise action. We hope that the insights and ideas laid out in this document will help catalyse government, corporates,

citizens and entrepreneurs to take actions aimed at solving the plastics waste problem at scale.

The report has the requisite information to guide entrepreneurs to find inspiration and identify profitable avenues, for a corporate to invest in the right cause, for a citizen to contribute by making the right choices, and for the government machinery to legislate the right policies to create the desired ambience for innovation.

The report has been developed in collaboration with two knowledge partners, **Indian Institute of Science (IISc) and Praxis Global Alliance.**

IISc has contributed to the identification of scientific and technological basis for the problem created by plastics as well as some of the potential solutions while dispelling myths, especially on bioplastics.

Praxis has contributed by presenting a macro level and commercial perspective, analysing the status, need, and levers for change. This has been followed by an in-depth assessment of the start-up ecosystem and outlining opportunities and recommendations in the plastic waste management space.

This journey towards circularity in plastics, as envisioned in this report, will have challenges of its own. But we believe that with a concerted effort, a sustainable future can be secured for us and generations to come.

CHAPTER 1

Our World in Plastics

How India Consumes Plastic | How India Recycles Plastic | Dangers of Rising Plastic Waste

It has been over 150 years since plastics came into use, and today they are virtually irreplaceable. From a plastic cup to building materials, their existence has seeped into every human necessity. The widespread use of plastic and a high dependency on it has generated tonnes of plastic waste, causing severe environmental damage and harm to our ecosystems.

The problem is growing bigger by the day, leading to a conversation across multiple stakeholders: governments, private businesses, civil society, scientists, startups. A sustainable and holistic solution to the plastic waste problem will emerge when the plastics industry aligns with other stakeholders to target vital but often ignored aspects of plastic waste management.

THE PLASTIC VALUE CHAIN

To understand plastic waste and its overwhelming presence in our life, it is imperative to first understand the value chain of the plastic industry.

Upstream

All activities related to supplying raw material and creating plastic

Midstream

Includes manufacturing and distributing plastic products

Downstream

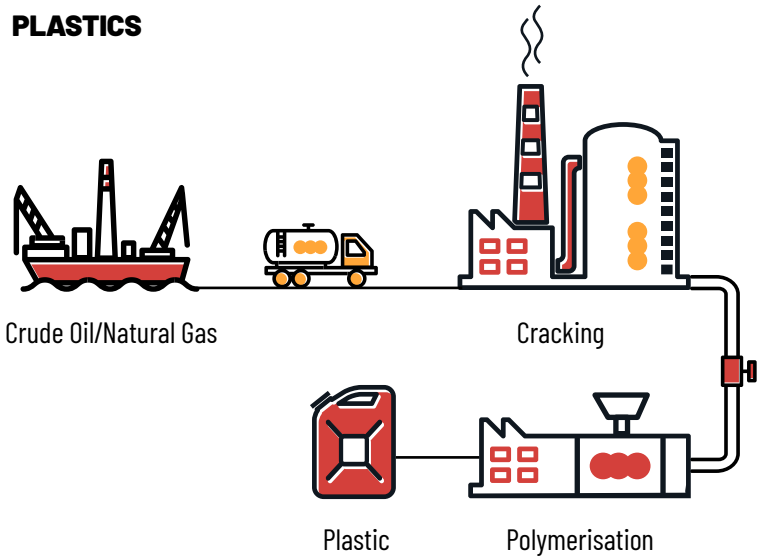
Post-manufacturing like sales & building a supply chain

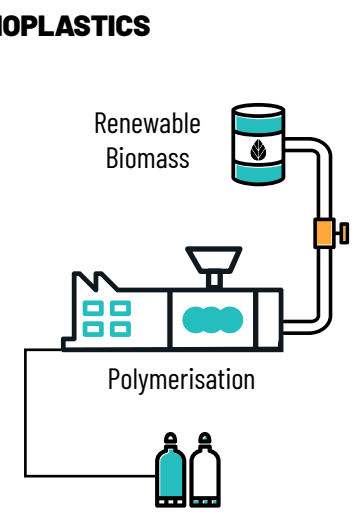
UPSTREAM: CREATION OF PLASTICS

On a large scale, plastics are made from natural gas and crude oil first by a process called cracking. This method breaks down large hydrocarbon molecules, turning the crude oil into lighter molecules by applying heat, pressure and other catalysts. These lighter molecules, or monomers, are then joined together to form various types of chain molecules called polymers. Plastics are a type of polymer, and the process to make polymers is called polymerisation. For instance, the monomer ethylene transforms into the polymer polyethylene via the process of polymerisation.

Bioplastics, or what would be more accurately called bio-based plastics are created from a range of renewable feedstocks with a different, sustainable polymerisation process.

FOR MORE ON BIOPLASTICS SEE CHAPTER 3

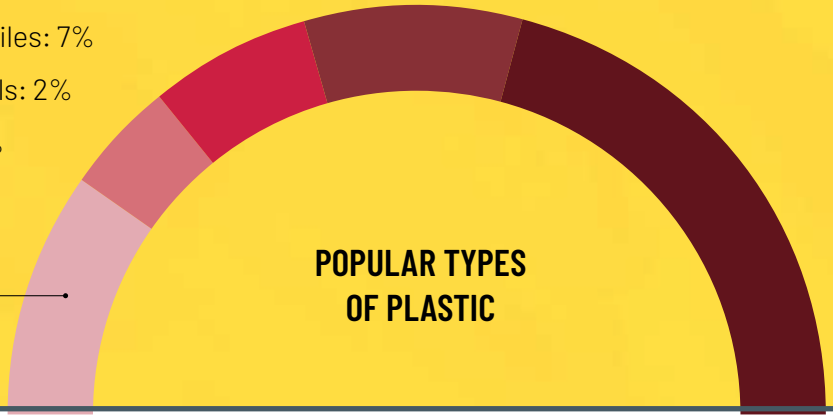




MIDSTREAM: MANUFACTURING & DISTRIBUTION

Once processed, the plastics are sent to product manufacturers for producing a variety of goods ranging from packaging to construction material and household items. This is Midstream, the second pillar of the plastic value chain.

- Flexible Packaging: **42%**
- Rigid Packaging: **17%**
- Building construction: **13%**
- Agriculture: **9%**
- Others: **19%**
  - -Households: 7%
  - -Automobiles: 7%
  - -Electricals: 2%
  - -Misc.: 3%



PROCESSED PLASTIC

PRODUCT MANUFACTURING

DISTRIBUTOR/SUPPLIER/RETAILER

DOWNSTREAM: RECYCLING & DISPOSAL

These products then move to distributors, suppliers and retailers, who then sell it to customers. Once the products are used, consumers throw them away and turn the products into plastic waste. There are various routes that plastic waste can take as it moves through the waste disposal, collection, sorting and recovery process.

INDUSTRIAL WASTE & COMMERCIAL WASTE

Formal waste collection via licensed workers

Sorting in local authority approved centres

RESIDENTIAL WASTE

Door-to-door waste collectors

Small junk shops

Middlemen

RECYCLABLE WASTE

Some plastic products can undergo a recycling or disposal process by shredding, incineration, or chemical disintegration.

1 Mechanical Recycling

2 Chemical Recycling

CRACKING & POLYMERISATION

3 Thermal Treatment

CEMENT KILNS

The residue is sent to cement kilns, where it is mixed with cement to form concrete.

NON RECYCLABLE WASTE

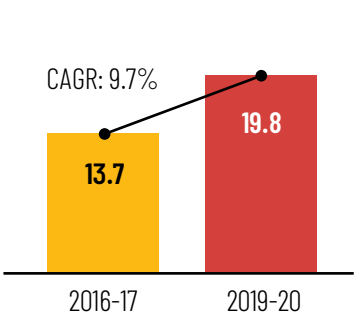
On the other hand, non-recycled plastic waste ends up either in landfills or aquatic dumps, leading to heavy ecological disruptions that harm our natural resources.

HOW INDIA USES PLASTIC

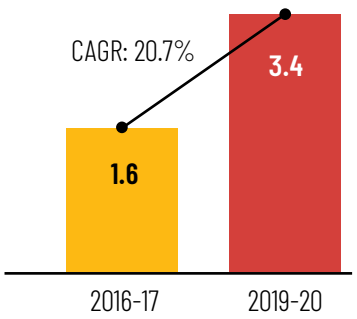
Plastic waste generation more than doubled between 2016-17 & 2019-20

The plastic consumption in India has grown at a significant pace over the past five years, and so has its waste output. The country consumed 14 million tonnes of plastic in 2016-17. This figure rose to 20 million tonnes in 2019-20, growing at a compounded annual growth rate (CAGR) of 10%. India's plastic waste output also doubled between 2016-20. Among all states, Maharashtra, Gujarat and Tamil Nadu generate the most amount of plastic waste, occupying 38% of the total waste output.

Plastic consumption in India
(in million tonnes)



Plastic waste generation in India
(in million tonnes)



HOW PLASTIC REACHES END USE SECTORS

Packaging applications consume the most amount of plastic in the country. In 2019-20, 11.5 million tonnes of plastic were used in packaging. Plastic is predominantly used in flexible packaging such as food packets and delivery boxes compared to rigid packaging such as kitchen storage containers and personal water bottles.

FEEDSTOCK → *MANUFACTURING & DISTRIBUTION* → *APPLICATION ACROSS INDUSTRIES* → *CUSTOMERS AND EXPORTS*

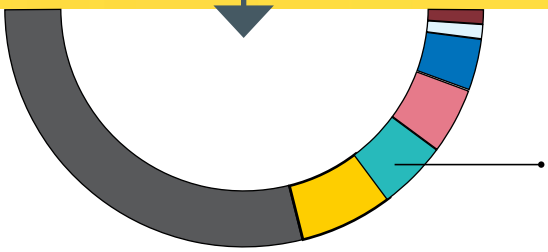
MANUFACTURING PROCESSES

3D printing | CNC Machining | Polymer casting

Extrusion | Rotational molding | Blow molding

Vacuum forming | Injection molding

APPLICATION AREAS FOR PLASTICS ACROSS VARIOUS INDUSTRIES



MISCELLANEOUS:
1.9 MN TONNES

PACKAGING 11.5 MN TONNES	**BUILDING & CONSTRUCTION** 2.6 MN TONNES	**AGRICULTURE** 1.8 MN TONNES
Multilayer films | BOPP films | Shrink & Stretch wraps | Thin wall moulding | Thermoforming | Blow moulded containers	Pipes | Storage tanks | Profiles | Geotextiles | Geomembrane | Wire and Cable	Greenhouse films | Low tunnels | Micro irrigation: Drip/Sprinkler | Mulch films | Crates | Pallets
AUTOMOTIVE 1.4 MN TONNES	**ELECTRICALS & ELECTRONICS** 0.4 MN TONNES	**HOUSEHOLDS** 0.1 MN TONNES
Bumper | Seats | Dashboard | Fuel system | Body panels | Lighting	Circuit breakers | Switch | Lighting fixtures | Cable & wire insulation | Refrigerator trays/linings | TV cabinet, etc.	FMCG products such as toiletries & cosmetics | Furniture | Toys | Luggage | Housewares and other lifestyle related products

TOTAL CONSUMPTION OF PLASTIC IN 2020: **19.8 MILLION TONNES**

HOW INDIA RECYCLES PLASTIC

While India produces 3.4 million tonnes of plastic waste in a year, only 30% of it is recycled. The rest of the plastic waste is sent to landfills or aquatic dumps. High density (durable) and low density (flexible) polyethylene used in packaging products like bottles of FMCG products, grocery bags and food wrappings contributed to the largest proportion of plastic waste at 2.3 million tonnes in 2019-20.

Most of India's plastic waste comprises polyethylene (high and low density) and polypropylene. This includes common products like containers for food, drinks, oil, bottles of toiletries and other miscellaneous items.

A majority of the 30% recycled plastic waste is shredded in India using the method of mechanical recycling. Other methods like thermal recycling (decomposition via heat) and chemical recycling (decomposition via chemicals) do not have a significant presence in the country, as they require additional infrastructure and investment.

PLASTIC WASTE GENERATION FOR EACH TYPE OF POLYMER

1. High and low density polyethylene: **2.3 mn tonne**
2. Polyvinyl chloride (PVC): **0.1 mn tonne**
3. Polyethylene terephthalate (PET/PETE): **0.3 mn tonne**
4. Polypropylene (PP): **0.3 mn tonne**
5. Polystyrene (PS): **0.2 mn tonne**
6. Others Miscellaneous category: **0.2 mn tonne**

~3.4 MILLION TONNES OF PLASTIC WASTE WAS GENERATED IN INDIA (FY 2020)

ONLY 1 MILLION TONNE WAS RECYCLED

94% OF IT WAS MECHANICALLY RECYCLED

TYPES OF POLYMERS

1

Polyethylene terephthalate (PET/PETE)

Strong and lightweight properties make it suitable to be used for water and soft drink bottles, food jars, cooking oil, oven utensils, etc.

2

High-density polyethylene (HDPE)

Stiff and hardwearing properties make it suitable to be used for milk containers, bottles of FMCG products, etc.

3

Polyvinyl chloride (PVC)

Chemical stability of material makes it preferable to be used for healthcare products like blood bags, tubing, gloves, etc. It is also used in pipes and packaging materials

4

Low-density polyethylene (LDPE)

Flexible and lightweight properties make it suitable to be used in packaging products like grocery bags, bubble foil, food wrapping, etc.

5

Polypropylene (PP)

Lightweight material used in furniture, consumer luggage, bottle caps, straws, etc.

6

Polystyrene (PS)

Cost-effective and lightweight material used indisposable cups, cutlery, packaging foam, plastic table wear, compact CD jackets, etc.

7

Others Miscellaneous categories: Materials generally used in baby bottles, headlight lenses, safety glasses, etc.

DANGERS OF RISING PLASTIC WASTE

The entire plastic value chain from production to waste disposal severely impacts the local ecologies it surrounds. This impact is wide ranging, and affects communities and ecosystems.

EXTRACTION AND TRANSPORTATION

CLIMATE	COMMUNITY
>> Releases significant greenhouse gas emissions	>> Releases toxic substances including carcinogens and neurotoxins causing several health hazards
>> Deforestation	

REFINING AND PRODUCTION

CLIMATE	COMMUNITY
>> Produces greenhouse gas emissions through cracking, polymerisation, and plasticisation	**>>** Releases heavy carcinogens, leading to reproductive, developmental and genetic issues in humans

WASTE MANAGEMENT

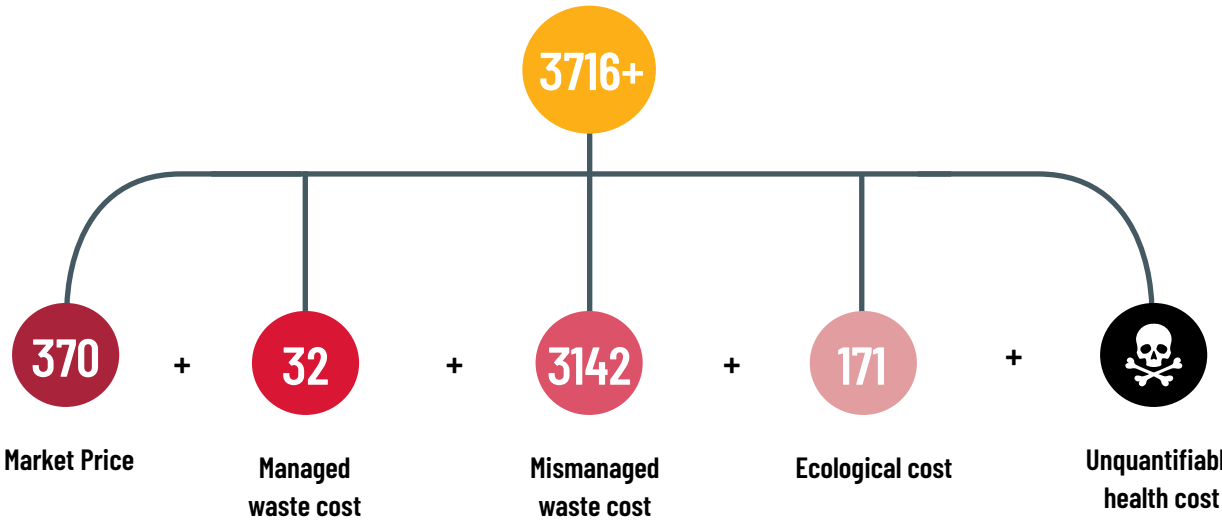
CLIMATE	COMMUNITY
>> Disposal methods like recycling, landfills dumping and incineration generate greenhouse gas emissions	**>>** Incineration releases heavy metals and toxins, a hazard for workers and communities
>> Carelessly disposed plastics degrade, releasing toxic chemicals into the environment	**>>** As plastics degrade either naturally or mechanically, it gets fragmented and the microplastics formed may cause cardiovascular diseases and autoimmune conditions
>> Threat to animals because of potential accidental ingestion	

THE REAL COST OF PLASTIC

Industries continue to produce plastic products in abundance. The economic cost of undoing the damage done by the waste generated is ecologically substantial.

Though every plastic product has a market price, the real cost is borne when it forms a mountainous landfill. This in turn affects a wider number of stakeholders – communities that live close to the landfill pay for it with their health, the government which has to clean up plastic waste with expensive technology, and citizens in the region who stand to lose a great deal due to the overarching environmental impact of plastics.

LIFETIME COST OF THE PLASTIC VALUE CHAIN IN $ BILLION



Market Price

Managed waste cost

Direct costs to government + Indirect costs to citizens due to taxes to fund waste management activities

Collection and segregation costs included

Mismanaged waste cost

Lost ecosystem service costs linked to marine plastic pollution

Paid by governments and stakeholders near the ecosystem

Includes revenue reduction from fishing and tourism and cost of clean-up activities

Ecological cost

Greenhouse gas emissions released during production and poor waste management adds to ecological costs borne by society

Unquantifiable health cost

CHAPTER 2

Circularity: The Way Forward for Plastic

Challenges in Implementing Circularity | Tracing Our Priorities | Opportunities Across Sectors

As plastics remain heavily present in our lives, there is an urgent need to cut down on generating more waste and avoiding single use plastics. A singular, smooth flow that categorically addresses and reimagines the journey of plastics from start to end has many elements. One way of reimagining the life of plastics is by adopting the circular economy approach.

A circular economy, as the name suggests is a circular framework focused on eliminating waste and reusing products and materials. This can take several forms in different industries – reusing, repairing, refurbishing or recycling. This framework is a way for stakeholders to tackle toxic waste accumulation while saving resources. It is especially necessary for industries like the plastic industry, which generate high amounts of non-biodegradable, toxic waste.

CIRCULAR ECONOMY IN PLASTICS: AN EXAMPLE

In this section, we explore what a circular framework entails for the plastics industry and varied stakeholders if they aim to implement it. It details the key opportunities and challenges that stand in the way of the circular approach such as reusing, recycling and generating less waste from plastics produced.

INTRODUCING CIRCULARITY TO THE INDIAN PLASTICS MARKET

To implement a circular approach, it is vital to understand how the plastics industry functions and how the framework can cater to the demand and supply sides. To make the plastics industry more circular, stakeholders must focus on a few key tenets:

1. Seek raw materials and production processes that release less toxins, conserve resources and protect ecosystems near production areas

2. Raise customer awareness regarding the correct way to sort, dispose and recycle plastics at home

3. Improve the logistics of plastic waste collection, sorting and recycling, while reducing reliance on land and water waste dumping

WHAT STANDS IN THE WAY OF CIRCULARITY? AN OVERVIEW OF KEY CHALLENGES

Circularity can be challenging to implement. The plastics industry, along with stakeholders such as recyclers, manufacturers, brand owners, and civic bodies must prioritise solutions and innovations that adopt a more sustainable method to achieve circularity, resulting in reduced pressure on the environment, zero waste, and newer opportunities.

1. COLLECTION AND SEGREGATION OF WASTE

>> Segregation and collection of waste at source is largely non-existent, resulting in increased recycling costs

>> Absence of technological solutions to process poor quality, unsorted plastic waste

>> Logistics related problems in waste collection and transportation

2. NASCENT CHEMICAL RECYCLING

>> High initial investments and operating costs owing to increased electricity and energy requirements due to involved chemicals and heavy equipment

>> More greenhouse gas emissions

3. HEALTH AND SAFETY HAZARDS

>> Occupational hazards linked to waste collection and recycling include the release of dioxins, which may cause cancer or reproductive health issues

4. ENFORCEMENT

>> Enforcement, monitoring and implementation of rules such as extended producer responsibility (EPR) have scope for improvement to reduce continued dependence on plastics

5. LACK OF INVESTMENT

>> Low investment in waste management infrastructure, and R&D initiatives for development of new technology and alternative feedstocks, that are not fossil fuel-based

7. MARKET ECONOMICS

>> Lack of regulatory and market-based instruments for business models to effectively function. For eg: taxes on poor waste disposal, incentives to recycle waste

>> Cost of raw materials for bio-based or recycled plastics fluctuates, making it hard to set standard prices, thereby influencing profits

8. QUALITY OF RECYCLED PLASTICS

>> 95% of plastic is recycled mechanically. The quality of recycle degrades after subsequent processes of mechanical recycling

9. DATA TRACKING AND MONITORING

>> Poor quality data on plastic waste generation, its implications, industry structure, plastics consumption, and trade limits evidence-based strategies and decisions

THE WASTE MANAGEMENT CONUNDRUM

Among all of the challenges in implementing circularity, India's plastic waste management stands out as one that has significant scope for improvement. Creating sustainable end-of-life options for plastic waste will require reworking and implementing new logistics systems. Fixing concerns for several stakeholders within the waste management system will make the transition easier and more seamless.

BOTTLENECKS IN WASTE COLLECTION: STAKEHOLDERS' PERSPECTIVE

DOOR-TO-DOOR WASTE COLLECTION

Stakeholders: Collecting agents (external/ government)

Challenges: Limited reach due to labour deficit

WASTE SEGREGATION

Stakeholders: Informal traders/waste pickers

Challenges: Manual sorting is hazardous, exposing waste pickers to medical waste, glass and metals

MIXED WASTE DUMPING

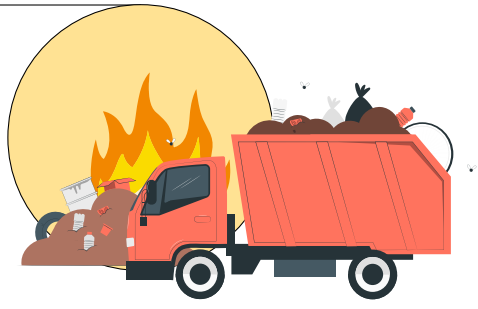
Stakeholders: Contractors

Challenges: Recyclers demand large quantities of recyclables and if this condition is not met, they pay less. As a result, collectors become less interested in collecting smaller volumes of recyclables and since they don't segregate, the mixed waste is dumped into landfills

RECOVERY AND SPACE MANAGEMENT

Stakeholders: Waste pickers/Waste collectors

Challenges: Plastic waste requires more storage space due to high volume to weight ratio. Waste pickers burn waste in open air



BOTTLENECKS IN WASTE COLLECTION: LOGISTICAL CONCERNS

1. Inadequate segregation at source, leads to contaminated plastic waste and adds volume to total waste, increasing logistics cost

2. Workers exposed to explosions, fires and collapsing landfills

3. Unscientific and inefficient ways of loading garbage lead to the underutilisation of load carrying capacity of vehicles. Lack of hydraulic pickup trucks leads to manual loading, which is more expensive

4. Outdated, open top vehicle fleets are unhygienic and lead to bad odours. No compartments for different types of waste

5. Waste collection routes are unplanned and left to the discretion of drivers

6. Landfills and collection centres are located out of town, increasing operational costs

TRACING OUR PRIORITIES

There is a need to prioritise the main challenges based on the scope and scale of their impact on the environment. Addressing them at every stage of the plastic value chain can help the industry achieve a resource efficient, circular economy for plastics.

PRIORITY CHALLENGES

PACKAGING | IMPACT: MIDSTREAM/DOWNSTREAM

1. Greatest contributor to plastic waste, 58% of total plastics consumed

2. Packaging materials like polystyrene and low density polyethylene are widely used but hard to recycle

3. Higher volume to weight ratio, making it unappealing to recyclers

4. High air content makes polystyrene hard to transport and recycle

5. Technical difficulties in recycling multi-layer and laminated packaging

RECYCLING | IMPACT: DOWNSTREAM

1. Only one million tonnes of plastic waste is treated out of 3.4 million tonnes collected annually

2. Sorting processes need to be strengthened as only highly sorted waste is mechanically recycled. Mixed plastics can only be chemically recycled which needs high energy and costs

3. No large-scale technology to recycle contaminated or mixed plastic waste

4. Recyclate quality depletes each time it is recycled

BIOPLASTICS | IMPACT: UPSTREAM

1. Lack of industrial composting facilities to properly dispose off bioplastics

2. High cost of raw materials and production

3. Lack of bio-refineries to produce bioplastics from plantation waste

FOR MORE ON BIOPLASTICS SEE CHAPTER 3

OTHER CHALLENGES

PLASTIC MANUFACTURING | IMPACT: MIDSTREAM

1. Manufacturing plastics from bio-based raw material requires high investment, compliance and logistics costs, reducing profit margins

2. Lack of environment friendly product designs that improve longevity, reusability, and waste prevention

3. Limited options to use alternative feedstock, that are not fossil fuel based

WASTE DISPOSAL & COLLECTION | IMPACT: DOWNSTREAM

1. Lower waste recovery

2. Lack of cost efficient waste collection and sorting infrastructure

3. Inefficient logistics for waste treatment

4. Health hazards to workers

AWARENESS & COLLABORATIONS | IMPACT: MULTISTREAM

1. Lack of awareness on waste disposal leads to the entry of hazardous waste into the food chain

2. Lack of training for informal sector waste workers on harmful practices and lack of awareness on new machinery that optimises operations

3. Lack of collaboration between businesses and citizens to increase awareness about circularity

AWARENESS AND KNOWLEDGE GAPS FOR STAKEHOLDERS

Without requisite knowledge and appropriate training, waste management becomes more complex than it is supposed to be. Adequate training and reliable data points are key to a well-functioning system.

CIVIL SOCIETY

1. Lack of information on waste disposal methods

2. Little research on impact of plastics on human health

3. Lack of awareness in handling hazardous waste

4. Lack of consumer awareness about recycled plastics to create demand

5. Need for training for informal sector waste collectors

GOVERNMENT

1. Limited poor-quality data on plastics usage, production, disposal and reuse

2. Inadequate data causes uncertainty for potential market entrants

3. Lack of uniformity in trade and market survey data on recycled plastics

4. Need for tools to identify scope for collaboration to address funding, skill and technological gaps

PRIVATE SECTOR

1. Improper labelling on hazardous additives, leading to uninformed purchase/ recycling choices

2. Limited understanding of sustainable product designs

3. Lack of effort on part of brands to educate customers about littering, recycling

4. Poor information of material types, causing low recycling rates

5. Lack of awareness on new machinery and methods to optimise operations

WHERE DOES CHANGE BEGIN? OPPORTUNITIES TO INTRODUCE CIRCULARITY

Introducing circularity is valuable from an economic and ecological perspective, if pursued with patience and a focus on the long-term benefits. In order to reach that goal, stakeholders must grasp opportunities to introduce steady changes within various sectors that pose challenges towards the adoption of circularity.

There are major opportunities for stakeholders for potential substitution of virgin plastics (a polymer in its pure form) used by various industry sectors. These opportunities extend on both the demand and supply sides. For example, on the demand side, packaging, building and construction, agriculture and automotive are key end use sectors that can substitute virgin plastics as they contribute to 85% of total plastic consumption. On the supply side, naturally bio-compostable plastics, bioplastics, and technologically viable substitutes like TPS (thermoplastic starch) may become valuable means to enter the industry. For stakeholders, ample opportunities exist to navigate circularity when it comes to fossil fuel based plastics, bioplastics and recycled plastics. There are challenges as well corresponding to each of them. The following table introduces each challenge and potential opportunities for stakeholders.

FOSSIL FUEL PLASTICS

DESCRIPTION

1. Made from fossil fuels

2. Can be customised by manufacturers

CHALLENGES

1. Manufacturing process emits harmful gases

2. Largely non-biodegradable

OPPORTUNITIES

1. Fossil-fuel based biodegradable polymers whose chemical structures can be broken down by microorganisms.

Examples: PBS (polybutylene succinate), PCL (polycaprolactone)

BIOPLASTICS

FOR MORE ON BIOPLASTICS SEE CHAPTER 3

DESCRIPTION

1. Made from non-fossil-fuel materials

2. No visual or toxic residue post decomposition

CHALLENGES

1. Crops used to make bioplastics are sprayed with pesticides, which may cause contamination of land and water

2. Modified land-use patterns to grow feedstock harms environment

3. Improper segregation from virgin plastics may harm recycling infrastructure

OPPORTUNITIES

1. Seaweed based plastics could be an alternative to some Polylactic acid-based bioplastics

2. They are home compostable, marine degradable and reduce the reliance on food crops.

3. Improved optical sorting technologies can effectively segregate different types of plastics to avoid batch contamination.

RECYCLED PLASTICS

DESCRIPTION

1. Created via mechanical and chemical recycling

2. Reduce dependency on virgin plastics

CHALLENGES

1. Expensive chemical recycling technologies

2. Chemical recycling consumes large amounts of energy

3. Mechanical recycling downgrades polymer quality after a few cycles

OPPORTUNITIES

1. Adopting and creating demand for **post-consumer recycled (PCR) resin*** by plastic manufacturers and brand owners

2. Design interventions to improve polymer melt quality.

3. Pilot plants for chemical and biological recycling

***Post-consumer recycled (PCR) resin** is a material made from recycled plastic like water bottles and food packaging. With high consumer awareness and initiative, it becomes an easy, sustainable alternative to creating more virgin plastics. PCR resin meets requirements and regulations for safe packaging ranging from food to medical uses. This makes them easy to manufacture and supply in the market.

BENEFITS OF USING PCR RESIN

1. Lowers the amount of virgin plastics created and wasted

2. Limits negative effects of plastic production

3. Lowers amount of energy needed to produce new plastics

4. Passes industrial safety regulations, creating a range of use cases

5. Reduction of plastic landing in the environment

WHERE DOES CHANGE BEGIN? OPPORTUNITIES ACROSS SECTORS

There is an immense scope for multiple sectors to introduce circularity into their processes. Innovation, design solutions, better communication for behavioural change, replacing FFPs (fossil fuel-based plastics) with alternatives such as bioplastics are routes stakeholders can take in isolation and through collaboration. Each change is an opportunity and needs to be mapped across time frame, impact, cost effectiveness, adoption by the consumer, potential for investment and innovation. Therefore, replacing virgin plastics is a strong possibility.

PACKAGING

Primary and secondary packaging creates the bulk of plastic waste coming in from the packaging industry. For example, cough syrup bottles are the primary packaging and the paper box they are sold in is secondary packaging.

FOR MORE ON PACKAGING SEE CHAPTER 4

OPPORTUNITIES

1. Replacing FFPs with more biodegradable PBS (polybutylene succinate) for fresh food packaging, etc

2. Designing reusable packaging solutions for business-to-consumer applications

3. Replacing plastic containers in food delivery with reusable containers

4. Including pro-environment messaging on packages to nudge customers towards responsible behaviour

5. Use of recycled plastics in non-food applications

6. Creation of packaging-free products, avoiding excess packaging

7. Replacing multi-polymer plastic packaging with single polymer plastic packaging

BUILDING & CONSTRUCTION

21% of all plastics used in construction is polyvinyl chloride (PVC), used to make flooring, heating, ventilation and air conditioning components.

OPPORTUNITIES

1. Recycled plastics can be used to make stronger concrete structures in the form of sidewalks, driveways

2. Using recycled materials like powdered polypropylene waste with plaster to form insulation materials

3. Recycled plastics can be used to make eco-friendly plywood, and can be blended with virgin plastics to reduce costs

AGRICULTURE

Plastic is used in the agricultural sector in building irrigation, drainage tools and packaging products. They are also used to create shields and nets that protect crops.

OPPORTUNITIES

1. Mulching films made from plastics are replaceable with films made from biomass

2. Plastic tree guards are replaceable with cardboard and bamboo-based guards and shelters. These products are decomposed in situ, which is convenient for farmers

3. Smart labels & tracking can help companies recycle pesticide bottles

4. Redesigning drip tape to improve recyclability and durability. Making it from a single polymer

5. Reusable rigid plastic or wooden crates can be used to protect the harvest

AUTOMOTIVE

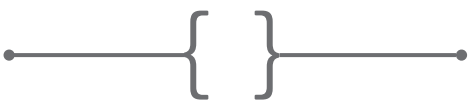
Plastics are used to build several types of automotive parts ranging from car fluid reservoirs to upholstery. Natural fibres and bioplastics may find favour with the automobile industry for their strength and biodegradability.

OPPORTUNITIES

1. Bioplastics like bio-PET (polyethylene terephthalate) and PLA (polylactic acid) based blends are useful for making headliners, sun visors, floor mats, and interior fabrics

2. Plastic fibres from recycled bottles can help create sound insulation layers in dashboards

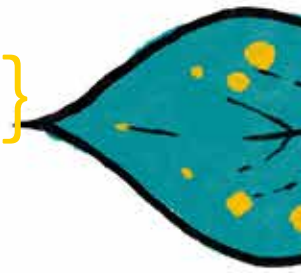
3. Recycled plastics from parts like bumpers can be used once again to create new bumpers



CHAPTER 3

The ABC of Bioplastics

Types of Bioplastics | Adopting Bioplastics in India | End-of-life Options for Bioplastics

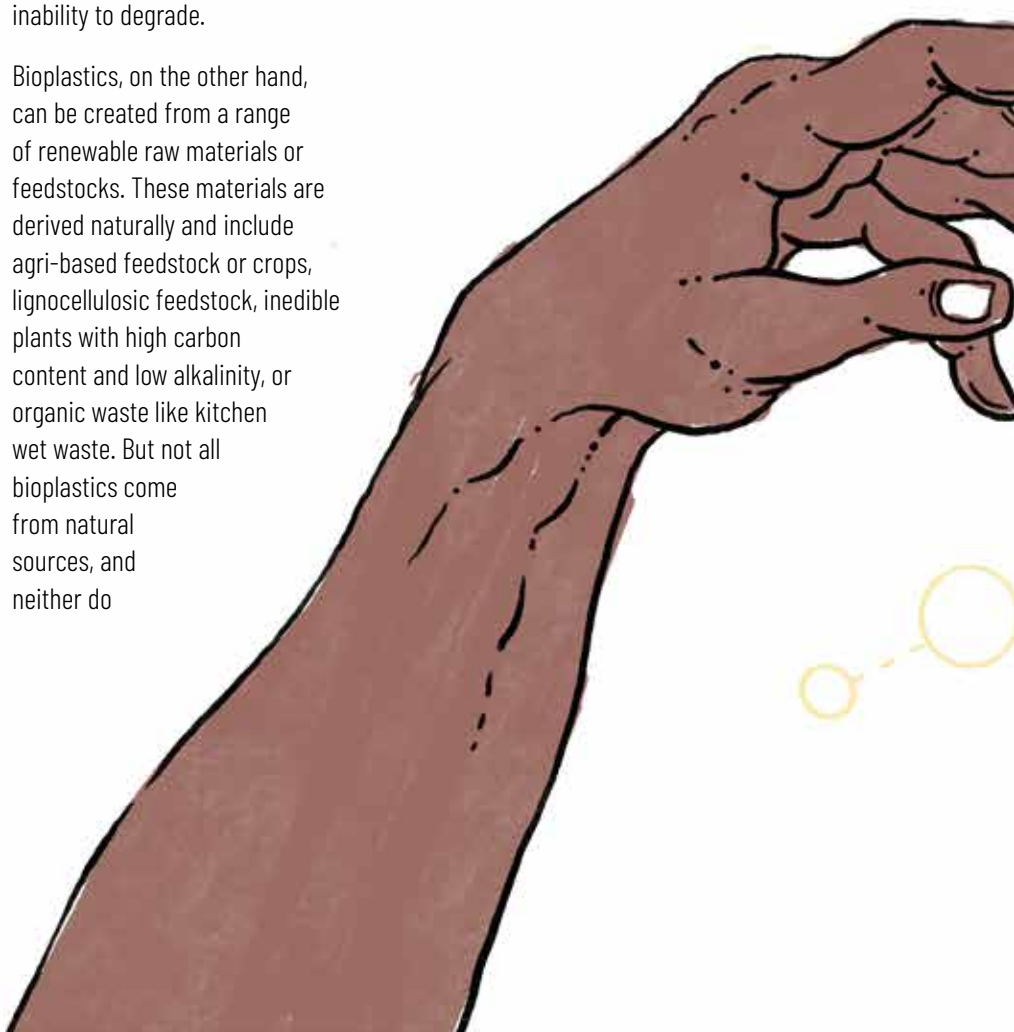


The words 'bio' and 'plastics' may initially seem at odds when placed together. 'Bio' indicates the connection with living beings, whereas 'plastics' are considered synthetic products. This is a common misconception as plastics are formed by polymers, which have existed in nature long enough.

The first plastic came from natural sources like the rubber plant. Parkesine, the first ever synthetic plastic created in the 19th century, was created from natural material.

Over time, synthetic plastics were developed as an attempt to replicate the strength, and durability of naturally existing materials like rubber, tortoise shells and animal horns. With the use of fossil fuels as raw material, plastics became durable and cheap. These FFPs (fossil fuel-based plastics) scored on convenience but came at a price to the environment due to their inability to degrade.

Bioplastics, on the other hand, can be created from a range of renewable raw materials or feedstocks. These materials are derived naturally and include agri-based feedstock or crops, lignocellulosic feedstock, inedible plants with high carbon content and low alkalinity, or organic waste like kitchen wet waste. But not all bioplastics come from natural sources, and neither do they all break down into natural components. So, it is important to classify and differentiate bioplastics to understand their efficacy and ensure optimal usage.



RAW MATERIAL FOR BIOPLASTICS

AGRO-BASED

Plants rich in carbohydrates.
Example: sugarcane, corn

LIGNOCELLULOSIC

Plants that can't be fed to animals.
Example: switchgrass, elephant grass

ORGANIC WASTE

Biodegradable plant or animal waste.
Example: Wet waste or kitchen scraps

TYPES OF BIOPLASTICS

Different types of plastics require different waste management and recycling methods due to their composition. This differentiates which plastics are more sustainable to use over others.

Within bioplastics, there are three categories. These are biodegradable, bio-compostable, and bio-based plastics. Bio-degradable and bio-compostable plastics can break down, with the latter breaking down faster due to manual composting processes. The former takes more time as its degradation process is natural. On the other hand, bio-based plastics may or may not be biodegradable depending on the type of raw material, making them hard to dispose of. In comparison to all the above, non-biodegradable plastics (including some bioplastics) do not undergo any form of degradation.

They are mostly made from fossil fuels and are the most common types of plastics available as of now.

BIODEGRADABLE	BIO-COMPOSTABLE	NON-BIODEGRADABLE	BIO-BASED
Plastics that undergo degradation 'naturally' by environmental microorganisms. They degrade into carbon dioxide, water and biomass	**Plastics** that undergo degradation under specific industrial composting conditions that include heat, humidity and specific microorganisms	**Plastics** that do not undergo degradation into carbon dioxide, water and biomass even after several years and end up as micro plastic	**Plastics** that are derived fully or partially from biological resources rather than fossil fuel-based raw materials
Slow, natural degradation process	Swift, manual degradation/ composting	Minimal degradation over a long time	May or may not degrade/ compost

WHY DO WE NEED BIOPLASTICS?

The answer to this question lies in the waste generated by FFPs. A rapid growth in the FFP industry over decades has led to a large-scale consumption of plastics and a humongous plastic waste problem. Landfills piling up in cities are the loudest testimony to this.

Presently, at least one trillion plastic bags get used worldwide each year. Almost 80% of the plastic packaging consumed is primary or secondary packaging which includes outer packaging used for consumer articles like food delivery boxes or packets of snacks, often thrown away barely 24 hours after sales.

Replacing these plastics with bio-based substitutes that could decompose faster is one potential solution to reduce the growing amount of plastic litter.

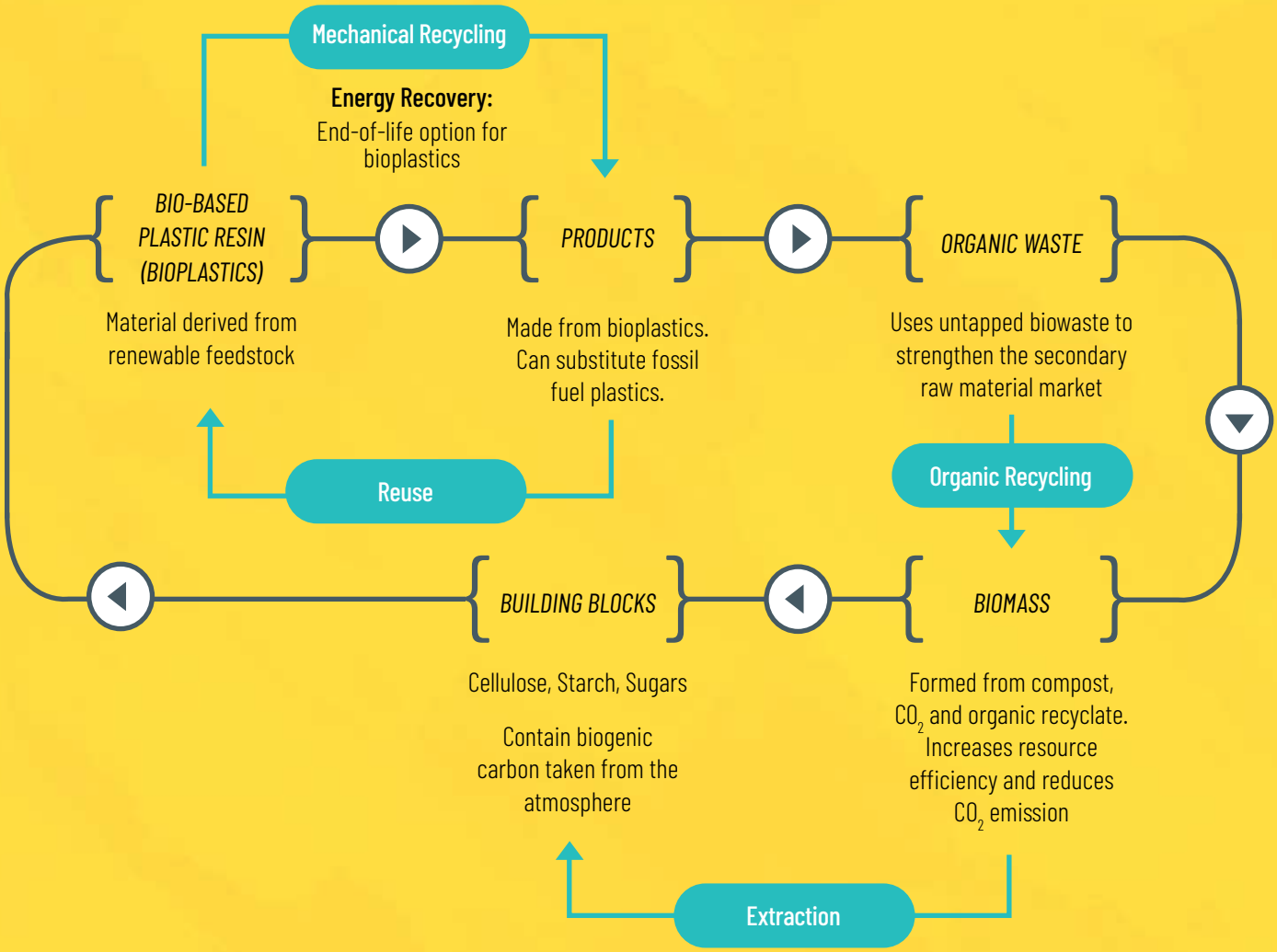
Bioplastics could have a strong hold over the next decade. According to research, the total global production capacity of bioplastics in 2021 was 2.42 million tonnes with biodegradables accounting for a major share when compared to bio-based, non-biodegradable bioplastics. It has been projected that by 2026 the total global production capacity of bioplastics could go up to 7 million tonnes worldwide with biodegradable bioplastics having a greater chunk cutting down the share of bio-based, non-biodegradable bioplastics. It has been estimated that the use of PBAT (polybutylene adipate terephthalate), a biodegradable bioplastic, would account for over 30% of the total bioplastics produced by then.

However, replacing synthetic plastics may not be as simple because they have a far superior performance, versatility, easy thermal processing, availability, and cheap pricing due to scaled manufacturing and an existing industrial presence.

In this section, we explore bioplastics and whether they can be considered an alternative to FFP based products in an Indian context. While on the face of it, bioplastics would be considered a high potential alternative, it would need a sustainable production pipeline, waste processing infrastructure, and long term consumer behaviour changes to be truly effective.

HOW DO BIOPLASTICS FIT INTO THE ECOSYSTEM?

Research on bioplastics is still developing. Tracing the life cycle of bioplastics at each stage is vital if we are to consider them as a viable and sustainable alternative to combat the growing plastic waste problem.



While most bioplastics consume less energy, many of them need specific production methods or high water requirements which could prove harmful for the environment. For instance, different types of bioplastics like PHAs (polyhydroxyalkanoates), PLA (polylactic acid), TPS (thermoplastic starch) and bioplastics made from corn zein and soy protein require industrial agricultural production methods including genetically modified crops to grow feedstock. This increases risks of exposure to pesticides that are hazardous for the ecosystem. Though bioplastics are not as strong, water-resistant, cheap and stretchable as FFPs, they are valuable because a few types are compostable.

PAVING THE WAY FOR BIOPLASTICS IN INDIA

Several challenges lie in the way of adopting bioplastics in India at present. These include high costs, unavailability of infrastructure and end-of-life options. Addressing these challenges may pave the way for success.

PROPERTIES

BCP (bio-compostable plastics) are not as effective as FFPs when it comes to strength and barrier properties. This limits their usage in areas like types of packaging. To fix this, bioplastics need to replicate FFPs like PE, PP, and PET in terms of strength, flexibility, versatility, non-reactiveness, and weight. This requires more investment, as equipment required to mould BCPs into familiar shapes need more refining before scaling up.

COSTS

BCPs are on average two times more costlier than FFPs to produce. This is mainly due to expensive feedstock. Raw materials like seaweed and algae are expensive compared to FFP-based sources. Food and agri-based feedstocks can be a strong solution, but their uses are still in the developing stage. BCPs and FFPs differ from a massive gap in production scales, resulting in higher processing costs for BCPs.

WASTE MANAGEMENT

BCPs must be segregated at source for effective composting. If BCPs contaminate the recycling batch of FFPs, it results in inferior recycled resin due to cross-material mixing. However, differentiating between BCP and FFP visually without preliminary methods like conscientious labelling is hard.

INDUSTRIAL COMPOSTING

BCPs are easily broken down by microorganisms in the right conditions, thus high investment industrial composting facilities are a must, which India currently does not have. Other modes of recycling are not an option.

PRODUCTION

At present, most of India's BCPs are imported. Without Indian manufacturing, BCPs remain expensive and unscalable. Even the non-food sources of raw material such as seaweed are imported from Indonesia or China. This pushes up the costs of BCPs even further. There is a need for local manufacturing units that utilise India's strengths such as readily available agri-waste and organic waste.

MINDSET

Plastic is a large volume, daily use material. It is used at almost every step of the routine from brushing with a plastic toothbrush to eating from plastic cutlery. Replacing plastics requires a change in the mindset. It can be slow and tedious for a developing country like India.

Read more on Bioplastics, their energy requirement and common hazards on **Page 103 & 104** of Annexure

A MARKET FOR BIOPLASTICS

To consider a future for bioplastics alongside FFPs in India there is a need to create a market for them by raising awareness of their utility, providing incentives, and innovating to solve for large scale processes and specific challenges.

APPLICATION DRIVEN SOLUTIONS

Matching the performance of FFPs with high quality features like strength and durability that aid use cases like packaging products

RESEARCH AND DEVELOPMENT

Research into Indian waste streams to develop alternatives to bioplastic production. For example, bio-refineries treating rice paddy plantation waste, coconut husks, and other organic waste

SUPPORT ADOPTION

Continuous market presence, scaled production plus segregation schemes can help lower the cost of BCP and increase its popularity

MAKE IN INDIA

Facilitate Indian production of BCP from waste streams and bulk production units to avoid imports

TECHNOLOGY DRIVEN SOLUTIONS

Focus on readily available technology to produce BCPs and its various blends, composites and derivatives. PLA, PHA, and TPS are the most viable substitutes

DISPOSAL TREATMENT

Encouraging schemes like buybacks for recycling bio-PET (polyethylene terephthalate), and bio-polyethylene and raising awareness on disposal methods for bioplastics. Awareness on manufacturer's extended production responsibility (EPR)

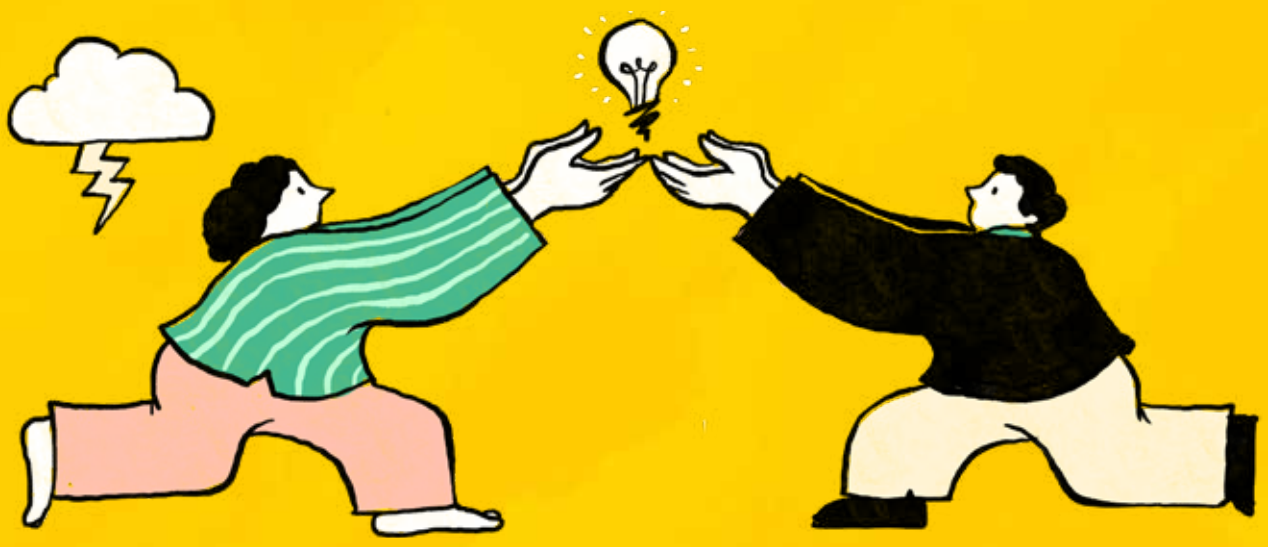
INDUSTRIAL COMPOSTING

Developing composting infrastructure focused on proper disposal of BCP and avoiding contamination with FFPs

DIVERSIFYING USAGE

Exploring popular uses like food delivery and beverage packaging to promote the use of bioplastics like PHA over FFPs

DOs & DON'Ts FOR STAKEHOLDERS



WHAT STAKEHOLDERS CAN DO

Supply Side Opportunities: Collecting agri-waste for feedstock, using it to produce bioplastics in strategic locations. Sourcing local feedstock to create bioplastics also aligns with the Indian government's Make In India initiative

Product Marketing Opportunities: Making bioplastics from base chemicals or monomers to manufacture products like packaging sheets, mulching sheets, disposable food packaging, cutlery and carry bags

Sorting and Collection Opportunities: Ensuring proper disposal of bioplastics by developing scheduled-drop box waste collection apps. Building sorting plants to separate mixed plastic waste and industrial composting facilities for quick bioplastic digestion

Citizen Involvement Opportunities: Advertising campaigns focused on the safe disposal of various plastics along with frequent public drives and incentives for citizens

WHAT STAKEHOLDERS SHOULD AVOID

Importing Bioplastics: Generate bioplastics from local raw materials, especially localised waste streams since that is more sustainable than importing

Raw Materials Competing With Food Resources: Avoid materials like corn, sugarcane and potato. Since India is an agri-centric economy, waste streams are abundant, which makes it unnecessary to dip into food resources to make bioplastics

Collecting Bioplastics With Other Garbage: Keep recyclables separate from compostables with three-way segregation

Unclear Labelling and False Advertising: Label all bioplastics with clear instructions on the type of bioplastic and its disposal methods. For non-biodecomposables made from renewable sources, state the need for recycling instead of composting

END-OF-LIFE OPTIONS FOR BIOPLASTICS

Bioplastics could occupy a significant space in the plastics sector as the Indian market is eager for a sustainable solution to tackle the waste problem. But there is a need to prioritise how it is produced and treated. This could, for instance, mean using the abundant agricultural waste in India to create bioplastics thus reducing overall waste output and financial investment.

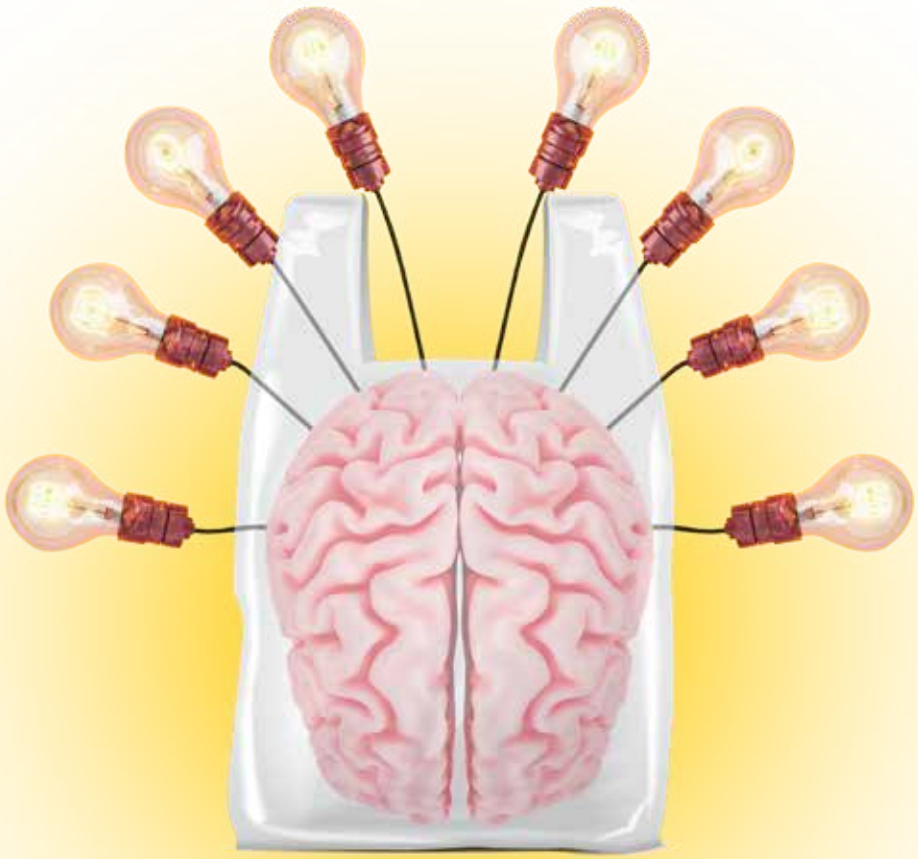
After production and use, identifying and sorting plastic waste into separate streams is a start point towards developing end-of-life options for bioplastics. These streams can either be primary recycling or energy recovery via mechanical, chemical or enzymatic routes

In order to recycle different types of plastics efficiently, it is crucial to avoid the intermixing of plastic waste. Thus, sorting it with accuracy is essential. For instance, bio-PET has the same chemical composition as FFPs, which means both types of plastic can use the same recycling plants and reactors, which already exist to recycle FFPs.

However, mixing the above plastic types with BCPs may yield poor recycled plastic resin, which impacts recycled product quality. To avoid this, future recycling plants should be equipped to recognise and sort BCP into a separate stream which can be processed for its appropriate recycling. For bio-compostable plastics, the ideal method is to separate them with organic wastes for industrial composting. This is because mechanical recycling of bio-compostable plastics causes

significant loss to strength and quality. BCPs are also compatible with chemical and biological recycling. Investing in chemical recycling opens the possibility for breaking down plastic waste into virgin monomers which can be used for plastic production again. But, chemical recycling is expensive and requires heavy investment to set up and process at a large scale. In the long term however, heavy investment in it will create cost effective, sustainable waste sorting and recycling options that will pay off well for stakeholders.

This, however, still leaves us wondering whether or not bioplastics are truly a substitute for FFPs. Despite its high potential to cause less environmental damage, would it be enough to replace what already exists without a planned waste management system?



CHAPTER 4

Rethinking Plastics in Packaging

{ Waste from Packaging | Trends and Advances | Innovation in Packaging }

Every perishable or consumable item needs protective and attractive packaging. Be it a toffee, a bottle of mineral water or goods wrapped to be exported in bulk. The cost of this packaging needs to be economical. This means that plastic in its various forms ends up being a preferred choice of packaging for several products. It is perhaps the most used item that is essential for every household or industrial product that needs to be packaged, showcased, or transported safely and effectively. Packaging takes up around 58% of the total plastic consumption in India. From this, primary and secondary packaging, including food packets and plastic crates respectively, take up a major share of all packaging applications.

TYPES OF PACKAGING

There are three types of packaging, each having unique purposes apart from protecting the product

▸ PRIMARY PACKAGING

It is in direct contact with the product, also referred to as consumer or retail packaging. Its main purpose is to protect and/or preserve, contain and inform the consumer about the product. Examples: bottles, pouches and metal cans.

▸ SECONDARY PACKAGING

The main purpose of this type of packaging is branding display, shipping and protecting/collating a group of individual units during storage. It is used by beverage, food and cosmetic sectors for displaying primary packs on shelves. This helps speed up restocking from storeroom to shelf. Examples: crates, bags, cartons.

▸ TERTIARY PACKAGING

This packaging facilitates protection, handling and transportation of a series of sales units or secondary packaging in order to group everything into unit loads during transit. Examples: plastic pallet, corrugated boxes.

PLASTICS IN PACKAGING

PET (POLYETHYLENE TEREPHTHALATE)

Snack trays, fresh vegetable domes, FMCG containers, bottles

HDPE (HIGH DENSITY POLYETHYLENE,)

Juice bottles, detergent bottles, toiletries

LDPE (LOW DENSITY POLYETHYLENE,)

Cling wrap, shrink wrap, rubbish bag

PVC (POLYVINYL CHLORIDE)

Bottle wrappers, tapes, take-away packaging

PP (POLYPROPYLENE)

Microwave dishes, chips bags, ice cream tubs

PS (POLYSTYRENE)

CD-cases, hot drink cups, foamed meat trays

A vast variety of packaging products are made from six primary plastic types: PET, HDPE, LDPE, PVC, PP and PS . Butene film, which is an LDPE, is the most commonly used packaging material from among the various kinds of plastics.

Shockingly, it will likely have the highest accumulation at more than 36,000 kilotons by 2030, according to estimates. Out of all the plastics used in the packaging industry, only PET and HDPE are widely recycled both globally and in India at present.

INDIA'S TOWERING PLASTIC WASTE CONCERNS

If there is one place where a lack of an effective recycling plan is most visible, it is the towering waste landfills in India. It is a grim picture of how far plastic consumption has gone. Our consumption, coupled with the packaging industry's growing dependence on this widely used, cost effective material could only spell worse case scenarios of plastic accumulation in the country. The total accumulation shows very few signs of slowing down unless stakeholders in the packaging industry take radical steps.

METHODOLOGY FOR ESTIMATION OF PLASTIC ACCUMULATION

The plastic consumption volume in FY21 for various packaging applications is taken as the base. The material consumption for each application category is projected up to 2030 based on growth in consumption for various material categories. The figure assumes a base recycling rate of 60% of the total plastic consumption. Based on past recycling rates witnessed in other countries such as the United States and Japan, India's future recycling rate is assumed to rise at a pace of 0.5% per year. Additionally, the consumption, leakage, and recycled volume of plastics for each year up to 2030 is computed based on the recycling rate assumption. The plastic accumulation for each year has been calculated by adding the current-year consumption and recycled plastics from the preceding year, and the process is repeated for each successive year up to 2030.

KEY TAKEAWAYS

Strikingly, this projects India's plastic accumulation will be ten times more in 2030.

The total waste leakage in the environment in the country is expected to reach around 40 million tonnes by then in the absence of any significant improvement in recycling infrastructure.

It is also worrisome that the above estimation indicates a total accumulation of 217 million tonnes of plastic waste by 2030 that will grow at a compounded annual growth rate of 13.4%.

TYPE	PACKAGING APPLICATION	TOTAL LEAKAGE BY 2030 (KT)	TOTAL ACCUMULATION BY 2030 (KT)
CONSUMER	Butene film (packaging)	6661	36520
	Packaged fresh/frozen foods and pharma sector	3638	19718
	Beverages	2909	16034
	RAFFIA (packaging)	2082	11385
	Blow moulding	1849	10112
	HD/HM Film	1332	7287
	Foodgrains and sugar packaging	1114	6057
	Wrapping fabrics	1114	6057
	HAO Film	1014	5557
	General purpose film	863	4712
	Household	779	4295
	Liquid packaging	658	3590
	Adhesive/lamination	658	3590
	Polymer packaging	405	2203
COMMODITY	Cement packaging	2633	14317
	FIBC - mainly for exports	2127	11564
	Fertilizer packaging	1418	7709
	Chemicals packaging	203	1101
PHARMA	Pharma/Hygiene	831	4581
	Blow moulding	477	2606
INDUSTRIAL	Blow moulding	2420	13297
	Butene film (packaging)	1568	8631
	Extrusion coating	946	5161
	HD/HM Film	829	4556
	Heavy duty	493	2693
	HAO Film	338	1852
	Tarpaulin	304	1652
TOTAL		39,661	2,16,838

Material: PE PP PET

Estimated plastic consumption volume for packaging applications in the financial year ending in 2021. Information obtained from the Chemicals and Petrochemicals Manufacturers' Association, and secondary sources

FACTORS INCREASING PLASTIC WASTE

Firstly, the growth of e-commerce played an essential role and opened new opportunities for packaging. It led to a greater demand for materials like shipment boxes, bubble wrap and other kinds of secondary plastic layering.

The constantly changing consumer preferences have encouraged fast fashion and product personalisation, which has led to more stock keeping units and pack sizes. It has increased the scope for using more packaging material, which profits the industry but leads to more plastic waste.

On the other hand, the industry has also seen a shift towards more sustainable packaging, with retailers and CPG companies having made commitments to reduce waste. Many retailers now want packaging made up of recycled material.

AREAS FOR INNOVATION IN PACKAGING

Innovation and research to reduce FFP usage in primary and secondary plastics packaging is critical to reducing plastic waste. Innovation is imperative in the following areas of plastic packaging and if effectively used it could reduce plastic waste by a large margin.

CONSUMER PACKAGING

Toiletries, edible oils, detergent, confectionaries, beverages, perishables, plastic bags and film-based bags

COMMODITY PACKAGING

Food, fertilisers, cement, chemicals, and export goods

PHARMACEUTICAL PACKAGING

Diapers, bed pads, disposable gloves, PPE kits, masks, disposable protective clothing (non-woven fabrics)

INDUSTRIAL PACKAGING

Rigid foams, shrink films, bubble wraps, pails, liquid and oil containers

BIOPLASTICS: A POTENTIAL SOLUTION TO THE PACKAGING CONUNDRUM?

The packaging sector, especially primary and secondary packaging sees wide plastic usage, and create the bulk of plastic waste that comes from the packaging industry. Some innovations related to bioplastics could provide alternatives if there is necessary research, a concerted effort and investment from relevant stakeholders.

Examples of bioplastics in packaging that have potential include plant-based plastics, mycelium packaging, cases made from palm leaves, seaweed-based bioplastics, wood pulp cellophane and plastics made from bamboo granules.

As the packaging industry seems poised to grow fast, with industry trends advocating for more brand-oriented filler packaging, there is an urgent need to innovate with a focus on sustainability. Without this focus, packaging waste will continue to bloat, leading to environmental damage. In this case, looking at recyclable, alternative raw materials or designing packaging to be more light-weight or with less material is a way forward.

Read more on scope for reducing virgin plastics in packaging and bioplastic-related alternatives on **Page 105 and 106** of Annexure

CHAPTER 5

Innovations: The Route Towards Circularity in Plastics

The Innovations Toolkit | Interventions from Stakeholders

Innovation is an important step towards achieving circularity in the plastic value chain. The potential for innovations is immense, and especially in underrepresented areas like chemical recycling of plastics, marketplace platforms and end-of-life treatment for bioplastics. A supportive innovation ecosystem can boost ideas and technologies that can benefit circularity.

However, a new innovation ecosystem requires steady investment and support at every step. At present, limited funding for circular economy themed startups in the plastics industry is a significant concern in India.

IMPORTANCE OF TECHNOLOGY IN INNOVATIONS

Technology-based innovations lie at the core of a circular economy for the plastic value chain. While innovation is a constant across the industry, it is not spread out evenly across key areas. Different parts within the plastic value chain hold their own advantages and disadvantages, with the latter holding the key towards future innovations.

	ADVANTAGES	LIMITATIONS	INNOVATIONS
MECHANICAL RECYCLING	Minimal impact on quality	Polymer unusable after a few recycling processes	Well designed extruders that degas, filter and soften the extrudate. This improves polymer melt quality and avoids contamination
CHEMICAL RECYCLING	Ensures product quality and ease of recycling process	Expensive, energy intensive process	Innovations in catalysts, biorefineries, reactors needed to overcome kinetic and thermodynamic limitations
NEW SORTING TECHNOLOGIES	Faster, avoids contamination	No method to differentiate food-grade plastics at scale yet	Sorting technologies like near Infrared technology, X-ray, electrostatics, selective dissolution, computer vision, fluorescent markers to determine polymer type
COLLECTION STRATEGIES	Maximum recyclability and minimise leakage to landfill, and increase reach	High quality recyclable waste collection requires segregation at source	A bubble barrier that uses a perforated tube to block plastics, directs them to the surface by pumping air through the tube and keeps rivers plastic free
DE-INKING	Energy efficient, eco-friendly	Nascent technology with limited scalability	Cellulase/ laccase can effectively be used to de-ink inked/printed papers Ozonation can remove ink from laser printed papers Chemi-enzymatic processes remove ink while using 60% less chemicals
END OF LIFE OPTIONS (PACKAGING)	Recovery of pure PE and PET via upcycling	Only 60% of the materials recovered. Contamination risk	Delamination and/or selective dissolution to separate the components of multi-layered packaging waste for effective chemical recycling Recycling to make long-term use products like furniture before incinerating

FOR MORE ON PACKAGING
SEE CHAPTER 4

THE INNOVATIONS TOOLKIT

WHAT TO PRIORITISE WHILE MOVING TOWARDS CIRCULARITY

The path towards circularity relies heavily on collaboration amongst stakeholders. Stakeholders must innovate while taking into account the funding scenario, government cooperation and consumer awareness. This means that they need to work with entrepreneurs, corporations, government entities, and venture capitalists, to create targeted interventions. Stakeholders with market experience are well-acquainted with the obstacles that stand in the way of innovation, from patenting to raising funds.

Innovation is a process that extends beyond ideation and invention. From an industry perspective, it is valuable when it has the potential to scale up. For successful eco-friendly innovations, sustainability along with scalability need to move in tandem.

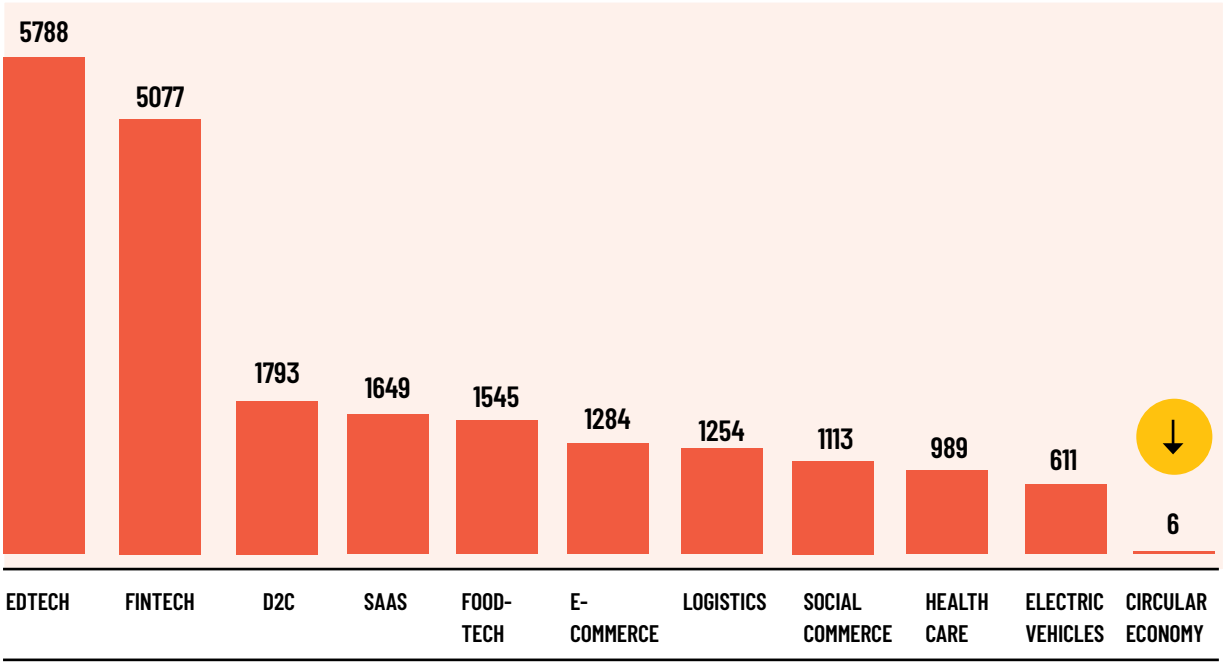
FACTORS THAT LIMIT FUNDING FOR STARTUPS

>> Lack of developed and commercialised products with a well-defined market

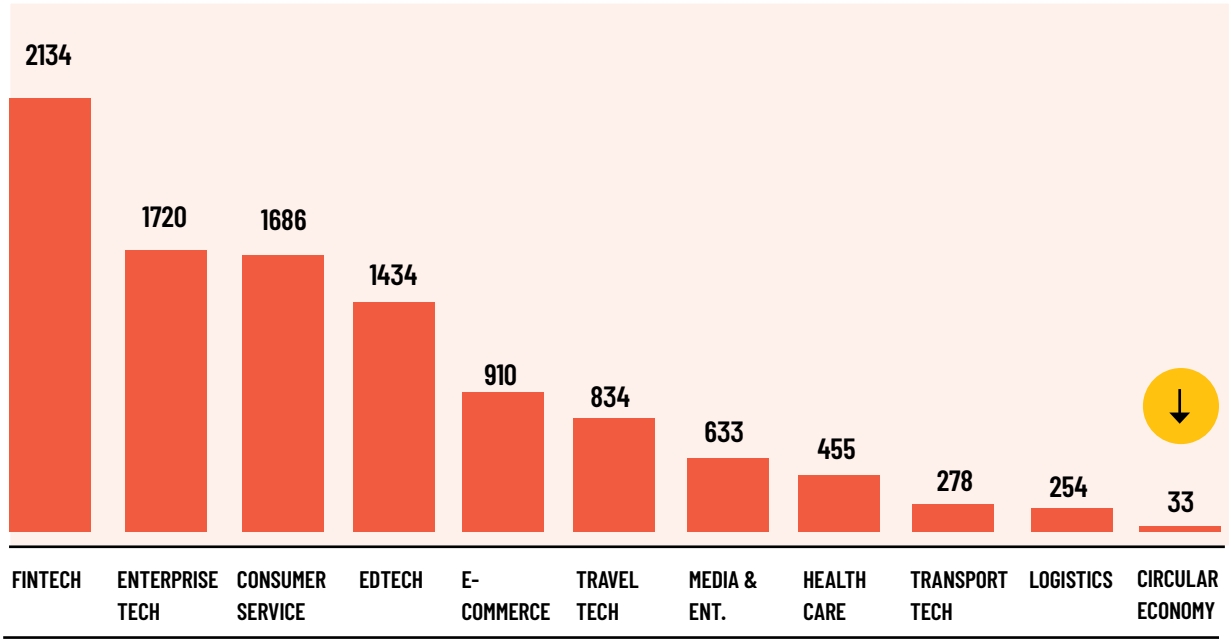
>> Lack of balance between digital & physical parts of the business model, causing asset heaviness, complexity and risk

>> Lack of value chain consolidation and effective sorting, which impacts valuations

SECTOR WISE FUNDING AMOUNT IN INDIA (CY21, IN MILLION USD)



SECTOR WISE FUNDING AMOUNT IN INDIA (CY20, IN MILLION USD)



FOR PUBLIC COMPANIES, LAST STAGE OF FUNDING IS REPORTED, SMALLER INVESTMENT (<US$ 1M) IS NOT CONSIDERED WHILE CALCULATING FUNDING FOR MATERIAL INNOVATION AND RECYCLING.

FUNDING LANDSCAPE

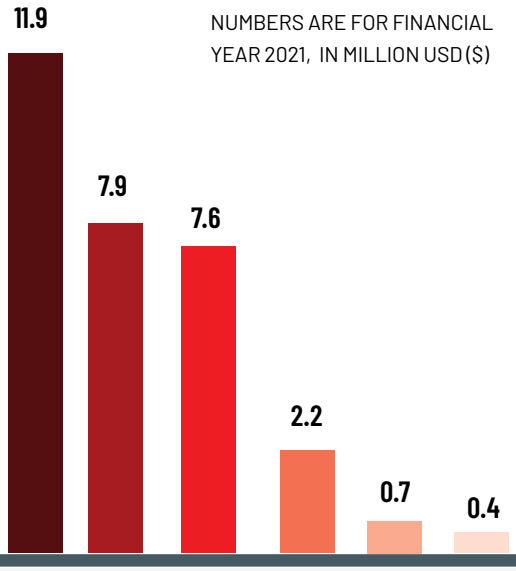
UNICORNS IN INDIA

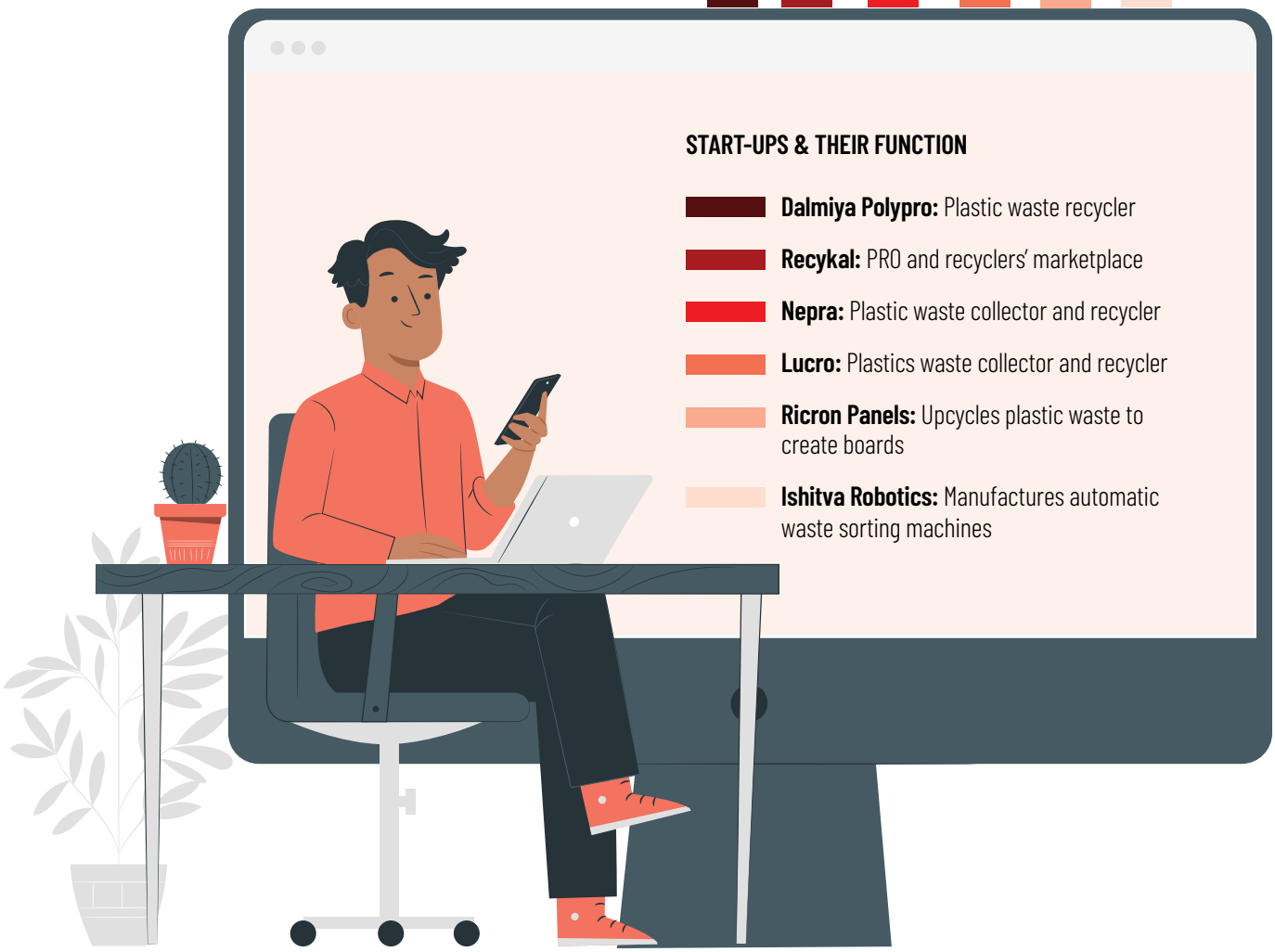
Fintech: 17	**Foodtech:** 3
E-commerce: 16	**D2C:** 3
SaaS: 16	**Gaming:** 3
Marketplace: 9	**Mobility:** 2
Edtech: 7	**Circular Economy:** 0*
Logistics: 5	**Others (Aggregator, NBFC, Proptech, Content, etc.):** 16
Healthcare: 3	

TOTAL: 100

INDIAN START-UPS REVENUE

NUMBERS ARE FOR FINANCIAL YEAR 2021, IN MILLION USD ($)

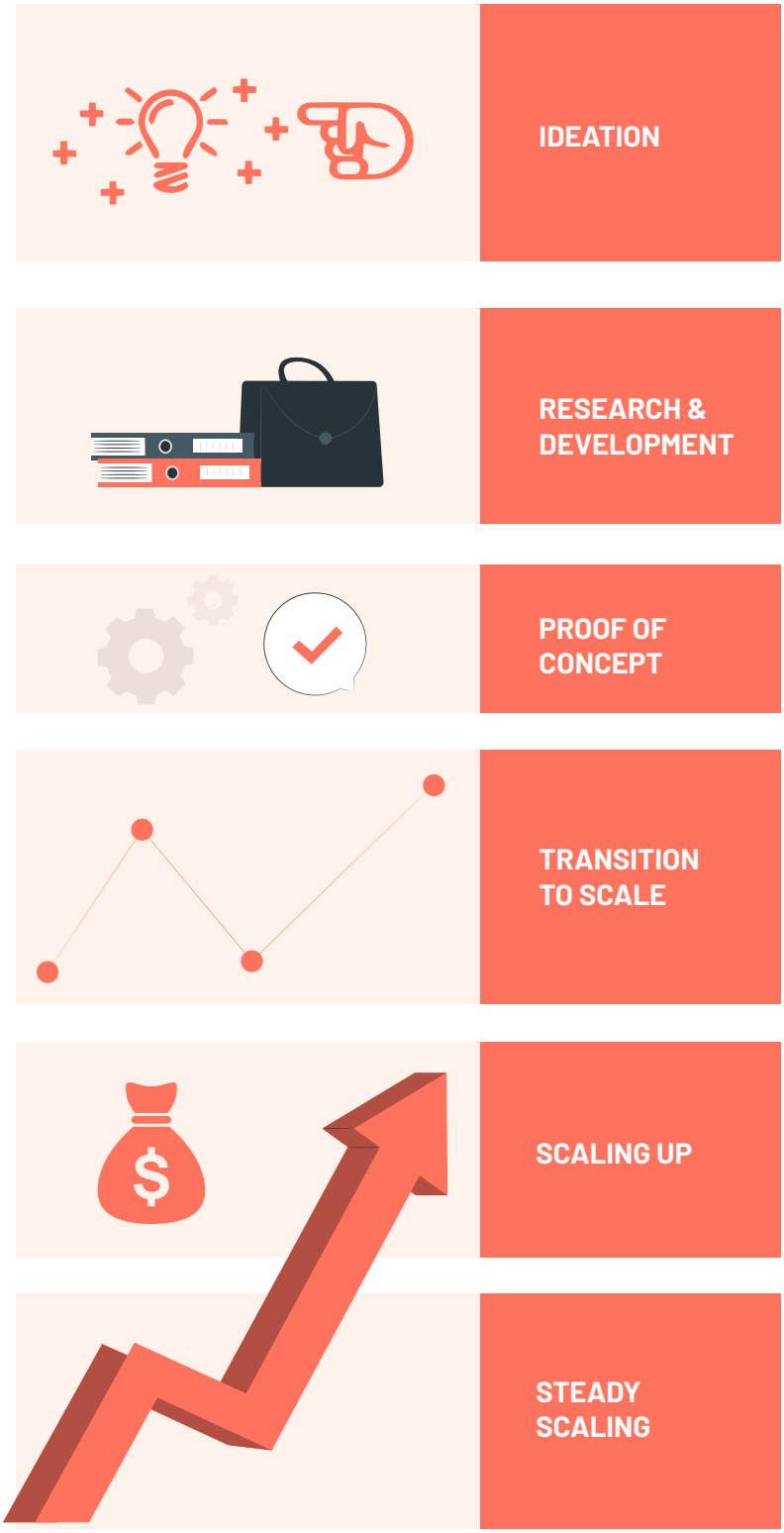




START-UPS & THEIR FUNCTION

- **Dalmiya Polypro:** Plastic waste recycler
- **Recykal:** PRO and recyclers' marketplace
- **Nepra:** Plastic waste collector and recycler
- **Lucro:** Plastics waste collector and recycler
- **Ricron Panels:** Upcycles plastic waste to create boards
- **Ishitva Robotics:** Manufactures automatic waste sorting machines

FACILITATING SCALABILITY AND SUSTAINABILITY



IDEATION

>> Gathering customer's perspective about the innovation is vital

>> Keeping a track of the various policies and laws the innovation must comply with is also critical

RESEARCH & DEVELOPMENT

>> Availability of ample financial support for uninterrupted R&D

>> Need to create a framework for sharing intellectual property with fellow entrepreneurs

PROOF OF CONCEPT

>> Need to determine product uptake and usability among consumers

TRANSITION TO SCALE

>> Increasing production to a reasonable scale for the market requires heavy investment

>> This step will also involve the need for product demonstration facilities to facilitate scaling up

SCALING UP

>> It is necessary, but difficult, to bring all stakeholders from the value chain to work efficiently together

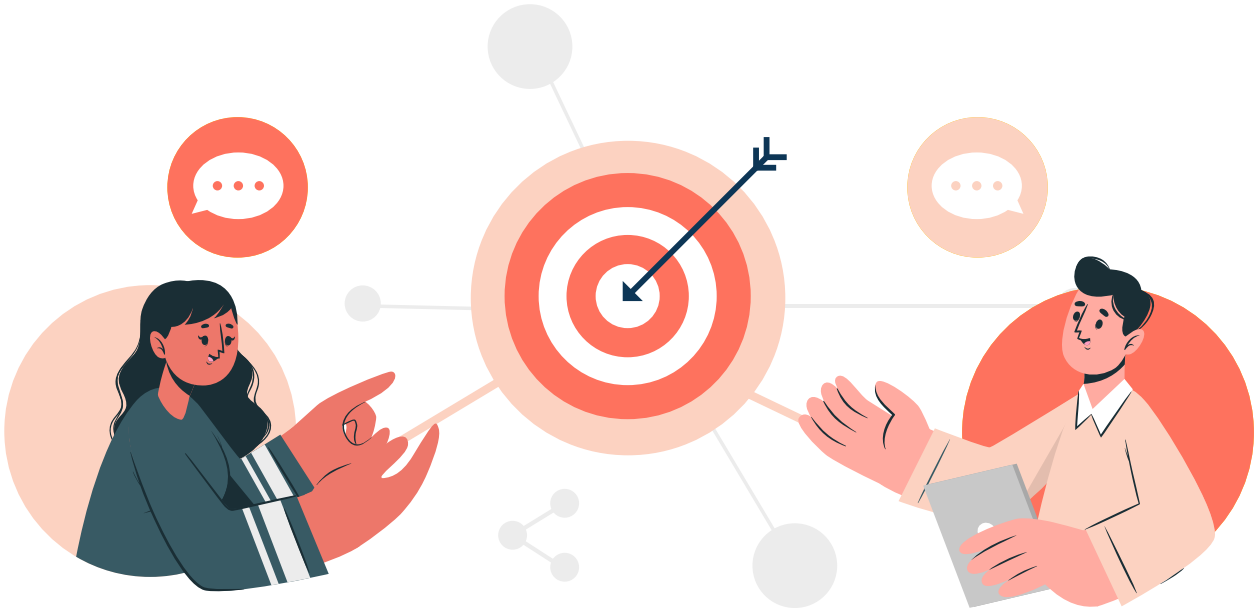
>> This step requires sufficient funding support

STEADY SCALING

>> Need to bring in new business to increase revenue and hence support corporate growth

>> Managing a venture gets increasingly challenging as a company grows

TARGETED INTERVENTIONS BY STAKEHOLDERS



Each stakeholder, whether entrepreneur, government, corporate or a venture capitalist has a distinct role to play in completing the circular path to reduce the use of virgin plastics and create sustainable alternatives. The section below details the potential targeted interventions each of them can make at various stages that will aid in creating a more circular economy.

MARKET INTERVENTIONS

Sustainable products like bamboo-based plastics or seaweed-based plastics are more expensive in comparison to virgin plastics due to high costs of raw material and processing. In order to keep prices competitive with virgin plastics, the government can intervene to offer raw material subsidies and levy lower taxes on sustainable plastic products. This helps promote sustainable plastics as a viable entrepreneurship opportunity.

VENTURE CAPITAL

Startups in India focused on sustainability face serious funding problems in comparison to their overseas counterparts. To prevent this, the government should provide access to venture capital in order to boost finance and investments.

The government can also offer funding for startups looking to scale up in exchange for equity. Countries like Taiwan offer startups 6 to 12 months of funding in exchange for equity. Malaysia has teamed up with a networking platform and a venture capital firm to connect startups with investors.

FILING PATENTS

Startups operate on their innovation strength, hence, the protection of the idea/brand in the form of a patent, trademark or design is crucial. The government should work to streamline the entire process of securing intellectual property rights. Strong measures to prevent plagiarism and intellectual property right infringement are essential.

CORPORATE SUPPORT

More large corporations should step forward to support incubators and accelerators, with the goal of making infrastructure for innovation more accessible. Large corporations should assist startups by providing technical know-how to develop better product and packaging innovations.

DEVELOPING NEW ALTERNATIVES

Startups involved in the plastics space can work towards exploring and evaluating new themes for innovations such as mushroom mycelium based packaging material, chemical recycling, AI-based collection and sorting.

CHAPTER 6

Startups: Innovating for the Future

{ Startups and Sustainability | Corporate Action Towards Sustainability | Cleaning up Our Cities }

Over the past twenty years, India has housed thousands of thriving startups across sectors. Many of these entrepreneurial ventures have created innovative technologies and business models that have supported the circular economy in plastics. These startups address key themes like recycling, waste collection, sorting, plastic alternatives, and marketplace platforms. They show strong innovation potential, which is necessary for underrepresented areas like chemical recycling of plastics, and end-of-life treatment for bioplastics.

With adequate industry support, they hold the key to transforming the country's plastic waste concerns. While some businesses do need to improve on their strategies, investors also need to explore the wider range of emerging startups in India to spot potential opportunities for investment.

METHODOLOGY FOR EVALUATING INNOVATION

While there are many innovations impacting the society, the list of 15 promising startups presented ahead in this section were shortlisted by a two-stage evaluation process. Deep research, quantitative and qualitative assessments and specific inputs gathered through interviews with the startups contributed to this evaluation. These startups can be seen as a significant group of emerging companies, innovating across various segments of the plastic value chain.

In the first stage, more than 80 startups were identified on four parameters:

OPPORTUNITY SIZE	BUSINESS MODEL	OPERATIONS	TECHNOLOGY
1. Market presence & size	1. Cost of raw materials	1. Years in operation	1. Type of technology
2. Target customers	2. Procurement process of raw materials	2. Number of employees	2. Patented products
3. Nature of product/service	3. Investment required		3. R&D cost
			4. Technological readiness
			5. Scale of operations

Beyond the core features, the startups considered for the evaluation also had to address one or more functions that fit into the circular plastics value chain.

RECYCLE

Attempt to recycle materials either into fuel or into different materials

CIRCULAR

Use waste products to create new products and services

REUSE

To use a product more than once, either for its original purpose or to fulfil a different function

REPLACE

To replace virgin plastic with more sustainable materials to create products

At the end of the two stage process the 15 startups chosen scored high on the opportunity size, low cost of operations and deployment of innovative technology. The 15 startups have been listed according to their themes which indicate where they fit in the circular value chain for plastics, as also their commercial readiness.

COMMERCIALLY READY

Startup with a scale large enough to sustain itself

FUTURE READY

Startup with products in the pilot commercialization stage or products which require more R&D before taking it to the market

HIGH TECHNOLOGY READINESS LEVEL

Innovations and research efforts that are at a high level of technological maturity

ISHITVA ROBOTIC SYSTEMS

2018

AUTOMATED AI BASED SORTING MACHINES FOR DRY WASTE SEGREGATION

Ishitva builds AI-powered sorting machinery to sort large volumes of waste faster. Its high quality automated sorting mechanism can recognise brands and has full colour recognition including the colour black.

WHAT'S NEW

ISHITVA'S product is valuable to the current market as sorting plastics with proper attention to detail leads to a slew of benefits. The automated process helps sort large volumes of waste faster, increasing efficiency and revenue for recyclers.

Ishitva's product is easy to install and reduces manual sorting. This reduces health risks that waste sorters incur while manually sorting through hazardous materials.

The machines are easy to install in existing facilities due to modular components.

WHAT THEY MAKE

1. NETRA Machine Vision System - Provides insights and instructions for material sorting operations on any conveyor belt using high-end machine vision

2. SUKA AI-Powered Air Sorting - Plug-and-play high speed mechanical sorting machine for high volumes of dry waste sorting based on type of polymer, colour, brand and size

3. YUTA AI-Powered Robotic Sorting - High speed, pick-and-place machine for recyclables, with live monitoring and data analysis capabilities, adaptable to any harsh environment

IMPACT CREATED

8000+ tonnes waste processed	**4000+** tonnes plastic reused	**3x** more cost effective than manual sorting	Up to **6 tonnes** of waste sorted per hour

COST EFFECTIVENESS: 50% COST EFFECTIVE AS COMPARED TO INTERNATIONAL COUNTERPARTS

IMPACT CREATED/POTENTIAL IMPACT HAS BEEN SOURCED THROUGH THE ORGANISATION'S WEBSITE OR OTHER SECONDARY SOURCES.

FOUNDING YEAR RECYCLE

$

Lucro
PLAST-E-CYCLE PRIVATE LIMITED
2012

INTEGRATED WASTE MANAGEMENT, RECYCLING AND MANUFACTURING COMPANY USING POST CONSUMER RESIN AND OCEAN BOUND PLASTIC WASTE

Lucro makes flexible packaging products from post consumer resin (PCR) and ocean bound waste through their trademark process 'Plast-E-cycle', which ensures savings of energy, water while diverting plastic waste from oceans. This keeps plastics within the circular economy and reduces the need for virgin plastic.

WHAT'S NEW

LUCRO optimises its operations via sourcing materials from waste pickers, NGOs and aggregators. It tries to empower ragpickers by working towards maximising their earning potential, leading to greater earnings.

All of Lucro's raw material is de-inked (removing colour), dry washed and deodorised before utilisation. Lucro can implement design aspects and personalization according to the needs of a brand. Their commitment to technology is evident in their collaboration with SATMA CE (™), a blockchain based platform that tracks every aspect of the waste management value chain such as type of waste, geographical location, the individual who picked it up, and the method of recycling.

WHAT THEY MAKE

1. Durable, tear resistant and high quality flexible packaging

2. Recycled granules from industrial and post-consumer waste that can be used as raw materials for products

3. Anti-slip, high quality durable automotive cover used during repairs to protect seats, steering wheel, gear and the floor

4. High quality compostable products derived from bacterial fermentation of plant starches and sugars and ISO17088 certified

IMPACT CREATED

28,500 tonnes of post-consumer waste collected	**38,914** tonnes of CO_2 emissions saved	**30** villages & cities supported	**31,339** people impacted

COST EFFECTIVENESS: 4-7% COST EFFECTIVE AS COMPARED TO FOSSIL FUEL BASED VIRGIN PLASTICS

IMPACT CREATED/POTENTIAL IMPACT HAS BEEN SOURCED THROUGH THE ORGANISATION'S WEBSITE OR OTHER SECONDARY SOURCES.

FOUNDING YEAR CIRCULAR

2019

PRODUCING BAMBOO BASED GRANULES AS A REPLACEMENT TO PLASTIC

IBANSS produces bamboo granules through its Biocraft Innovation Technology. These granules can be used directly in a traditional plastic machine to produce injection moulded daily use articles. Since no new machinery setup is required, there is little to no extra capital expenditure.

WHAT'S NEW

IBANSS' bamboo granules mimic plastic but are a compostable and a recyclable alternative that can replace fossil fuel based virgin plastic. They prevent significant impact on the ecosystem by using bamboo waste instead of fresh bamboo for their granules.

The IBANSS granules do not require new or a different machinery setup. They can be used in multiple industries for injection moulding, blow moulding, film drawing and textile materials.

WHAT THEY MAKE

1. Compostable, anti-bacterial, recyclable and cost effective bamboo granules, directly usable in regular plastic machines

2. Thermally stable, hydrophilic, acid resistant and eco-friendly bamboo fibres mechanically derived from renewable bamboo and other materials without using any chemicals and water

3. Bamboo granules can be used to make finished products such as plates, glasses, trays, etc.

IMPACT CREATED

Value creation from bamboo waste	Job creation through hub and spoke model	Home compostable alternatives	No discharge of water/ solid waste

COST EFFECTIVENESS: 1.5 TIMES THE COST OF FOSSIL FUEL BASED VIRGIN PLASTICS

IMPACT CREATED/POTENTIAL IMPACT HAS BEEN SOURCED THROUGH THE ORGANISATION'S WEBSITE OR OTHER SECONDARY SOURCES.

FOUNDING YEAR REPLACE

RicronPanels

2013

ECO-FRIENDLY CONSTRUCTION MATERIAL FROM LOW VALUE MULTI-LAYER PLASTIC WASTE

Ricron uses cutting edge technology to create construction material from low-value Multi-Layered Packaging (MLP) waste which acts as a perfect substitute to wood-based plywood material, thus keeping a check on deforestation.

WHAT'S NEW

RICRON is unique, as it is working towards making MLP waste less hazardous for the environment. Their recycled construction material acts as an ideal substitute for wood based plywood material, thus reducing the need to farm wood and keeping a check on deforestation.

Beyond its ecological benefits, Ricron's construction material is economical. The material has a wide range of uses, is inexpensive in comparison to plastic, which helps in providing long term utility to the building and construction industry. These applications range from paver block pallets, roofing shields, flooring and more.

WHAT THEY MAKE

1. Weatherproof, termite proof plain panels or sheets made from regenerated aluminium and plastic

2. Durable, rust resistant and cost effective eco-roof sheets as a substitute for cement, GI, metal and coated roofing sheets

IMPACT CREATED

Substitute for wood-based products	100% MLP waste conversion	Zero discharge unit

COST EFFECTIVENESS: OFFER COST EFFECTIVE BUILDING AND CONSTRUCTION PRODUCTS WITH OVERALL PROJECT SAVINGS RANGING FROM 25% TO 50%

IMPACT CREATED/POTENTIAL IMPACT HAS BEEN SOURCED THROUGH THE ORGANISATION'S WEBSITE OR OTHER SECONDARY SOURCES.

FOUNDING YEAR RECYCLE

padcare

△ 2018

NON-TOXIC, HYGIENIC METHOD TO RECYCLE USED SANITARY NAPKINS

Padcare uses a mixture of cloud technology and chemo-mechanical methods to collect and recycle sanitary napkin waste.

WHAT'S NEW

PADCARE provides a simple, yet vital solution to the growing problem of used sanitary napkin waste. The Padcare bin (used for collection and segregation of waste) is patented with 5D technology and is designed to be eco-friendly and cloud connected. This bin provides no contact waste collection to prevent the spread of infections.

After collection, the Padcare machine uses a chemo-mechanical process to process garbage without releasing smoke. Further, it recycles plastic and cellulose found in the waste after sterilisation.

WHAT THEY MAKE

1. Battery powered Padcare bin to segregate original waste from sanitary waste at source which uses vapour phase technology and is cloud connected for tracking purposes

2. Padcare automated machine generates harmless recyclable output from used sanitary napkins using patented smokeless 5D technology used to shred and clean garbage, without any smoke

IMPACT CREATED

9,500+ pads recycled	**150+** bins constructed	**5000+ kgs** carbon emission reduced	**4,000+** people reached

COST EFFECTIVENESS: 80% COST EFFECTIVE AS COMPARED TO CURRENT ALTERNATIVE OF INCINERATION

IMPACT CREATED/POTENTIAL IMPACT HAS BEEN SOURCED THROUGH THE ORGANISATION'S WEBSITE OR OTHER SECONDARY SOURCES.

FOUNDING YEAR △ RECYCLE

zerocircle

2020

BIO-ALTERNATIVES FOR PLASTIC PACKAGING

Zerocircle is a sustainable packaging company that makes bio-alternatives for plastic by using natural seaweed through a low energy, green processing technology. These alternatives are biodegradable, cost effective and durable.

WHAT'S NEW

Zerocircle creates bio-alternatives for daily use as well as large scale solutions for organisations. It uses low energy green processing technology to manufacture its products.

They focus on packaging for several use cases, including zero-waste, vegan formulations to hold food, 100% compostable shoes soles, bio-yarn based fabrics, smart and durable materials for long distance couriers and medical safety products to replace synthetic gloves and sutures.

WHAT THEY MAKE

1. Packaging for the food industry with option for UV printing labels
2. 100% compostable shoe soles
3. Bio-yarn based fabrics for high street fashion
4. Durable smart courier packaging for long distance transport
5. Safe materials to replace synthetic gloves, masks and medical sutures

POTENTIAL IMPACT

- Marine safe and ocean positive
- Prevents deforestation
- Creates carbon sinks
- 100% home compostable

COST EFFECTIVENESS: 5-10% cost effective for B2C businesses

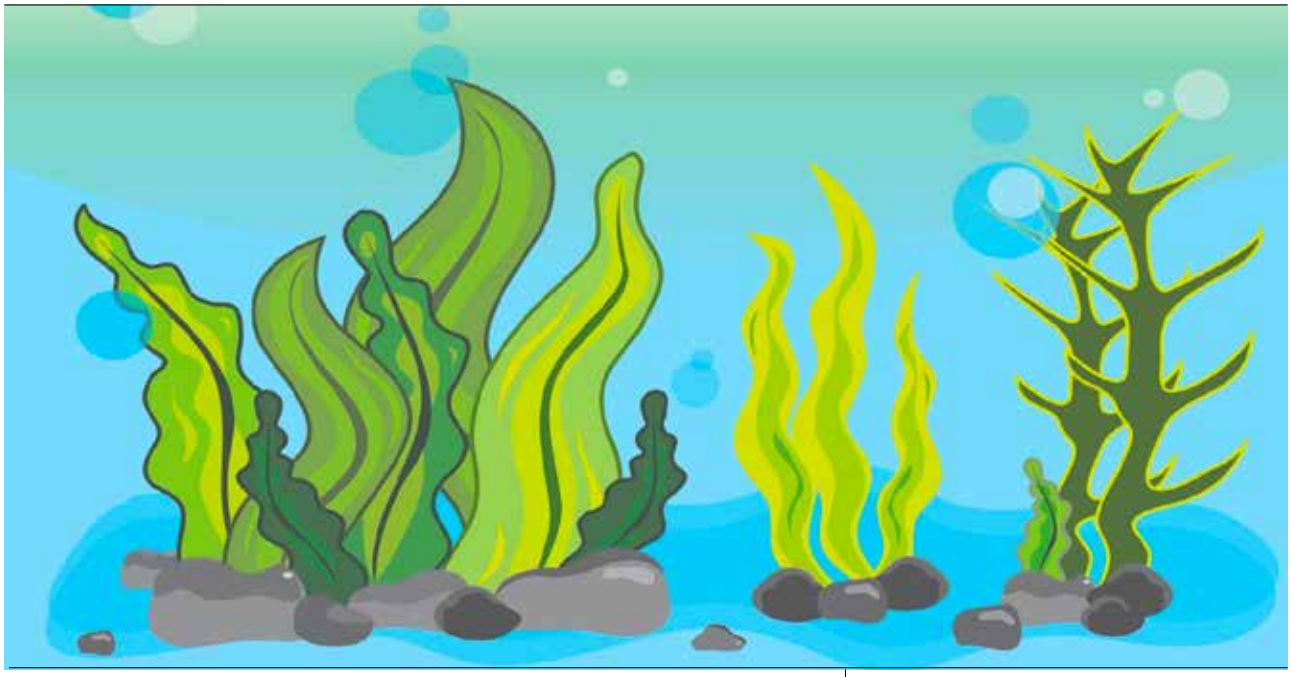
IMPACT CREATED/POTENTIAL IMPACT HAS BEEN SOURCED THROUGH THE ORGANISATION'S WEBSITE OR OTHER SECONDARY SOURCES.

FOUNDING YEAR REPLACE

2010

SUSTAINABLE PRODUCTS CREATED FROM TROPICAL SEAWEED USING LARGE SCALE AND MECHANISED OCEAN FARMING

Sea6 uses tropical seaweed to create sustainable, eco-friendly agri-products on a large scale as well as provides seaweed-based biomass to companies for bioplastics production.



WHAT'S NEW

Sea6 Energy uses automated farming for harvesting and seeding of seaweed in nutrient rich deep ocean waters.

They maintain extensive records of operations and supply chain and monitor parameters of ocean and plant to ensure consistent quality of sea plant harvests.

Sea6 is working towards developing bioplastics and biofuels which are currently in the product pipeline.

WHAT THEY MAKE

1. Biofilms and bioplastics made from seaweed

2. Biofuels made from sea plants as an alternative to fossil fuels

POTENTIAL IMPACT

Sustainable agri-products

Large scale ocean farming

Organic processes

COST EFFECTIVENESS: 2 to 2.5 times costly as compared to fossil fuel based virgin plastics

IMPACT CREATED/POTENTIAL IMPACT HAS BEEN SOURCED THROUGH THE ORGANISATION'S WEBSITE OR OTHER SECONDARY SOURCES.

FOUNDING YEAR REPLACE

2021

ECO-FRIENDLY, SUSTAINABLE, AND 100% BIODEGRADABLE BOTTLES MADE FROM BAMBOO

Kagzi is an eco-friendly alternative to single use plastics. Their biodegradable bottles are made from bamboo, instead of plastic, and are used to pack toiletries.

WHAT'S NEW

Kagzi's bottles, made from bamboo material mixed with biodegradable starch and additives, are durable for up to two years. They biodegrade in landfill and natural soil conditions within two years.

The bottles are useful to pack toiletries and do not need extra plastic lining for stability.

The company plans to develop further products using other waste materials such as paper pulp, rice or wheat straws etc.

WHAT THEY MAKE

Waterproof, durable, biodegradable bottles that hold a variety of liquids

POTENTIAL IMPACT

Biodegradable products	Low carbon footprint	Ease of use and disposal

COST EFFECTIVENESS: Two times costly as compared to fossil fuel based PET bottles

IMPACT CREATED/POTENTIAL IMPACT HAS BEEN SOURCED THROUGH THE ORGANISATION'S WEBSITE OR OTHER SECONDARY SOURCES.

FOUNDING YEAR REPLACE

STATE OF THE ART PACKAGING MATERIAL MADE FROM STUBBLE WASTE

2020

Dharaksha uses mycelium (fungi) as a medium to transform stubble waste into effective breakage-free packaging. It aims to curb stubble burning and plastic pollution.

WHAT'S NEW

Dharaksha's product attempts to replace thermocol packaging with customised, biodegradable and sustainable alternatives. They developed a nutrient media called Somras, which aids mycelia (fungus) growth and enables eight times the industry's standard production rates.

Their process avoids pollution, fumes and black liquor, a toxic byproduct of the production process. Further, rejected products can be used as raw materials again.

Dharaksha also has a commitment to social impact as they train women in Tier 2 and 3 cities to employ them as workers. This is to encourage their upskilling and empowerment.

WHAT THEY MAKE

Packaging materials that are cheaper, stronger, tougher, more durable and biodegradable compared to conventional materials

POTENTIAL IMPACT

Rs 2800/ton additional revenue for farmers

Employment generation

No pollution or fumes

COST EFFECTIVENESS: 1.5 to 2 times costly as compared to traditional thermocol

IMPACT CREATED/POTENTIAL IMPACT HAS BEEN SOURCED THROUGH THE ORGANISATION'S WEBSITE OR OTHER SECONDARY SOURCES.

FOUNDING YEAR REPLACE

ANGIRUS
Building for Sustainable Future

2018

HIGH QUALITY BRICKS AND PAVER BLOCKS MADE FROM PLASTIC WASTE

Angirus uses their patented "Angirus green waste management technology" to convert non recyclable plastic and other waste into quality, damp proof bricks for sustainable construction and development.

WHAT'S NEW

Angirus reduces the overall construction cost of a project by 20% through deriving its raw material from waste. The 'wricks' or bricks made from waste save waterproofing and repair costs in the future because of their durable nature. Further, these bricks provide a safe building structure and are manufactured quickly as compared to conventional bricks. They are available in customised shapes and size options.

WHAT THEY MAKE

Wricks - Sustainable, customisable, damp proof high quality bricks made in a day from recycled waste

POTENTIAL IMPACT

40%	80%	30%	100%
Stronger than red bricks	More waterproof	More lightweight	Waste used as raw material

COST EFFECTIVENESS: 20% cost effective as compared to traditional bricks

IMPACT CREATED/POTENTIAL IMPACT HAS BEEN SOURCED THROUGH THE ORGANISATION'S WEBSITE OR OTHER SECONDARY SOURCES.

FOUNDING YEAR RECYCLE

K K Plastic Waste Management Ltd.

2002

INNOVATIONS TO RECYCLE PLASTIC WASTE FOR ROAD ASPHALTING

KK Plastic focuses on collecting bulk waste, recycling and creating their patented poly blend used for road asphalting and making products used in construction work. They are the only company to have successfully implemented this model commercially to date.

WHAT'S NEW

KK PLASTIC has a dual focus of waste collection in bulk and supplying their patented poly blend. Collecting plastic waste from a variety of sources with attractive service prices helps them procure their raw materials economically. They offer free waste pick up service for a load above 250 kgs of waste

This waste is used to make their patented KK poly blend used in road asphalting. The blend has increased marshall stability and tensile strength, making it suitable for constructing roads.

WHAT THEY MAKE

1. Patented KK Polymer blend with 3X indirect tensile strength and increased marshall stability made out of plastic carry bags/packaging material
2. Economical Kerbside stone equivalent to M15 concrete stone
3. Plastic granular sheets for road asphalting
4. Recycled plastic granules to make sheets and pipes

IMPACT CREATED

Effectively doubles the life and quality of the road

Increased employment opportunities

COST EFFECTIVENESS: Saves Rs 10,000 per km of road constructed

IMPACT CREATED/POTENTIAL IMPACT HAS BEEN SOURCED THROUGH THE ORGANISATION'S WEBSITE OR OTHER SECONDARY SOURCES.

FOUNDING YEAR RECYCLE

paperman®
Spirit of Recycling
2010

ON DEMAND RECYCLING PLATFORM, MANAGING WASTE PROCESSING UNITS

Paperman partners with state governments and turnkey contractors to set up recycling units and other ancillary services.

WHAT'S NEW

PAPERMAN has a variety of projects and innovations to its name. One of their flagship innovations is a mobile application that connects scrap dealers to households, empowering them to work together to manage waste.

Paperman has also provided software solutions to help organisations track their sustainability efforts and fulfil their waste management requirements.

They have established material recovery facilities for waste segregation and further sell the segregated waste to recyclers, recover landfills for the government through biomining and advise on how to efficiently recycle waste.

WHAT THEY DO

1. Mobile application that connects 5,000 waste producing touch points with over 270 trash collectors within 15 minutes

2. A blockchain technology-based platform that helps corporations fulfil their Extended Producer Responsibility (EPR) compliance by providing data and analytics reports of activities of waste pickers

3. Social financing program that aids SHGs, the informal sector and other circular economy players

4. Provides recycling consulting and data for designing policies regarding waste management to government bodies

5. Designs programs to raise awareness among students and citizens about waste management

IMPACT CREATED

1,000,000 kgs
of waste recycled

270 informal sector relationships

50,000+ kg
carbon emissions saved

7,00,000
people impacted

COST EFFECTIVENESS: 40% COST EFFECTIVE AS COMPARED TO EXISTING COMPETITORS

IMPACT CREATED/POTENTIAL IMPACT HAS BEEN SOURCED THROUGH THE ORGANISATION'S WEBSITE OR OTHER SECONDARY SOURCES.

FOUNDING YEAR RECYCLE

2018

WASTE MANAGEMENT SERVICE FOR HOUSEHOLDS, AND GENERATING CONSUMER CONSUMPTION DATA FOR CORPORATES

Bintix collects and sorts door-to-door collected waste from individual households. Using machine learning algorithms they generate data on consumer behaviour in cities based on the type of waste generated, which is effectively used by brands to design sales and marketing strategies.

WHAT'S NEW

BINTIX has integrated technology with the waste management industry. It has a readily available customer service to efficiently execute door-to-door collection of household waste.

After collection and sorting of waste, Bintix analyses the consumption patterns of the consumers and provides the data to various industries in the FMCG, alcohol, electronics, apparel and health space.

Bintix also provides software as a service to organisations operating in the waste management space to make their operations efficient.

WHAT THEY DO

1. Scheduled door-to-door collection of dry, non-hazardous household waste in barcoded bags with the use of accurate digital weighing scale to avoid any bias during collection

2. They incentivise segregation at source and ensure traceability from waste producer to recycler

3. Easy to use pictorial UI/UX application for waste collectors

4. Generate data-analytics:

>> QR codes scanned for each bag collected to understand the waste type/category

>> Use of machine learning algorithm to identify images & trace its brands and source of purchase

>> Report generated on consumption pattern of consumers and shared with clients from various industries

5. Dry waste sent to certified recyclers post scanning and segregation

IMPACT CREATED

44,02,758+ kg CO_2 averted	**13,02,861+ kg** recycled
15,373+ households	**4,43,160+** pickups

COST EFFECTIVENESS: 1.4 TIMES THE COST OF TRADITIONAL METHODS

IMPACT CREATED/POTENTIAL IMPACT HAS BEEN SOURCED THROUGH THE ORGANISATION'S WEBSITE OR OTHER SECONDARY SOURCES.

FOUNDING YEAR RECYCLE

Infinity box

2019

RECYCLING AND REUSING FOOD DELIVERY BOXES

Infinity Box replaces single use plastic containers with reusable and recyclable high quality containers, creating an eco-friendly, economical alternative to disposable boxes. Their services include collecting used containers from customers via hygienic smart bins before sanitising them for reuse. They also provide information, analytics, tracking and tracing for warehouse logistics via the Infinity Box platform.

WHAT'S NEW

Infinity Box targets packaging waste, the type of plastic waste which causes the most environmental harm.

They collect the used containers directly from end consumers via smart bins and return them to restaurants, food delivery or corporate campuses after rigorous hygiene management and quality checks.

Before returning the packaging to restaurants, Infinity Box carries out a slew of tests to ensure that the product in question is safe enough to hold fresh food. This reduces both health concerns and excess spending on new packaging.

This service helps restaurants and aggregators get the eco-friendly tag.

WHAT THEY MAKE

1. Reusable and recyclable food containers in all shapes and sizes

2. Smart QR fitted bins (where customers can drop their boxes) provide for automatic waste auditing and generate insights from garbage collected

IMPACT CREATED

550+ kg plastic waste reduced	80% average adoption rate	95% containers collected	**71,000+** people reached

COST EFFECTIVENESS: 50% COST EFFECTIVE FOR RESTAURANTS OR FOOD AGGREGATOR BUSINESSES

IMPACT CREATED/POTENTIAL IMPACT HAS BEEN SOURCED THROUGH THE ORGANISATION'S WEBSITE OR OTHER SECONDARY SOURCES.

FOUNDING YEAR REUSE

DOORSTEP REFILLABLE SERVICE FOR NON-EDIBLE LIQUIDS SUCH AS DETERGENTS, CLEANERS

Refillable is a zero-waste refillable service that provides non-edible liquids like detergents and floor cleaners in customers' own bottles or reusable glass bottles purchasable at a refundable deposit.

WHAT'S NEW

Refillable creates a quick and easy introduction to a zero-waste lifestyle for customers via their products and services. They offer doorstep delivery of refillable glass bottles for a variety of products, with small quantity refills.

Refillable provides refillable glass bottles for the product categories at the doorstep in exchange for previously purchased bottles. Their portable dispensing machines can be installed in societies, retail stores, etc.

WHAT THEY PROVIDE

1. Plant-based, non-toxic, biodegradable dishwashing liquid, toilet cleaner, laundry detergent and floor cleaner

2. Soap-free, herbal and vegan hand wash

IMPACT CREATED

Pay for product, not packaging

Eliminate packaging and distribution cost

Community acceptance

COST EFFECTIVENESS: 20% COST EFFECTIVE AS COMPARED TO BUYING A NEW PRODUCT

IMPACT CREATED/POTENTIAL IMPACT HAS BEEN SOURCED THROUGH THE ORGANISATION'S WEBSITE OR OTHER SECONDARY SOURCES.

FOUNDING YEAR REUSE

HIGH TRL: INNOVATIONS AT A HIGH LEVEL OF TECHNOLOGICAL MATURITY

India has no shortage of innovations with high technology readiness levels (TRL). This is enabled by the support and encouragement from quality institutions like Indian Institute of Technology (IITs) and Council for Scientific and Industrial Research (CSIR) who incubate several such research innovations.

BIOPLASTIC UTILITY PRODUCTS

IIT Guwahati

A project that aims to develop bioplastics from waste products of oil refineries using homegrown techniques to make utility items like cutlery, decor and granules. They have currently developed bioplastics like Polylactic Acid (PLA) and Thermoplastic starch from homegrown techniques. Their plans include a pilot plant with 100 tonnes/year production capacity which will pave the way for commercial production.

BIOPLASTIC HYGIENE PRODUCTS

IIT Hyderabad

This project aims to replace super absorbent polymers from hygiene products like diapers and sanitary pads with bio-compostable material made from cellulose derived nanofibers. Their future plans include scaling their technology and processes.

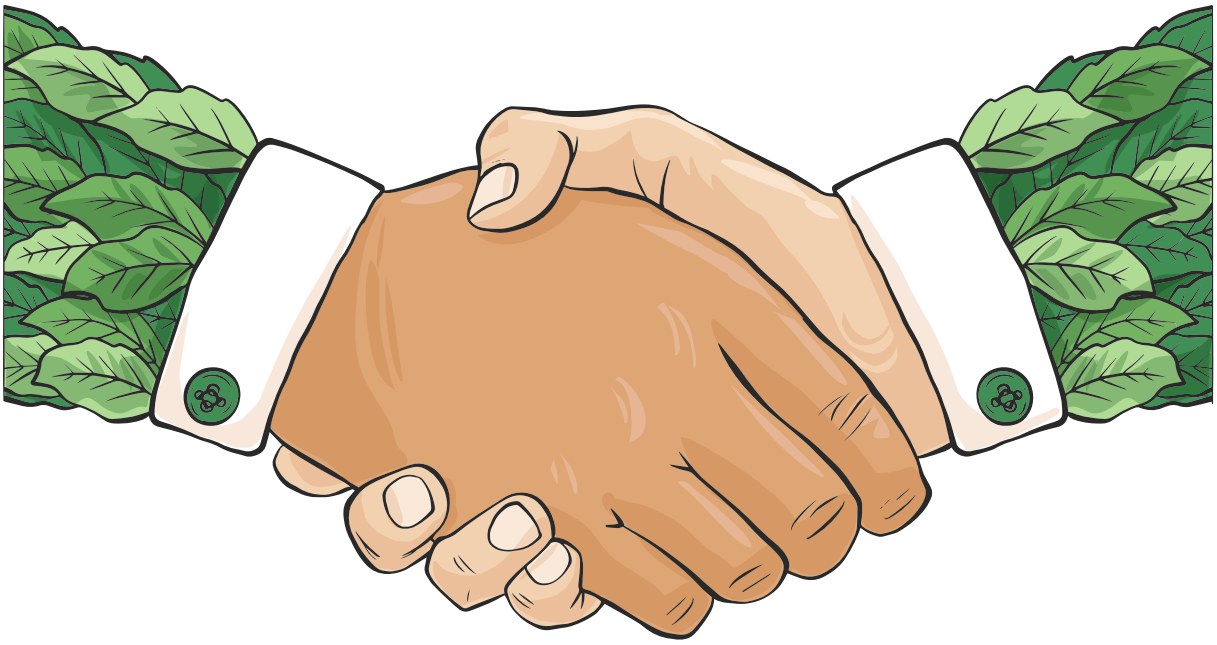
AUTOMATIC NIR-BASED SORTING

CSIR Chennai

A project developing a system to sort plastic waste moving on conveyor belts into five different types of plastics using an optical sensor to aid segregation and waste management. The sensor is currently able to sort 100 items per minute or approximately four tons of plastic in a day. Their current lab prototype has been developed, demonstrated and transferred to two entrepreneurs for commercialisation.

CORPORATES AND SUSTAINABILITY

Larger global corporations are attempting to innovate and gear themselves towards reducing plastic usage. Brands like Unilever, Nestle, Pepsico, Marico and Amazon are attempting to innovate to reduce plastic usage. These efforts range from using less virgin plastics, manufacturing sustainable packaging to adopting biodegradable materials.



INITIATIVES	CHANGES
AMAZON Amazon's initiatives are focused on increasing recycled packaging material for delivery purposes. They are eliminating plastic straws and polystyrene from brick-and-mortar store locations.	Amazon is working to improve the composition of plastic packaging solutions to ensure the use of more recycled contents. They have switched to smaller plastic produce bags at their Whole Foods stores. They had set a target to increase the recycled content of plastic film bags from 25% to 50% by 2021. For their plastic padded bags, the targeted increase was from 15% to more than 40%. Each year, these improvements are expected to save more than 25,000 metric tons of new plastic. In North America, they are expected to save 2 million pounds of plastic per year on all plastic rotisserie chicken containers that use 70% less plastic. They are expanding the use of flexible paper-based mailers across Europe and other continents and rolled out sustainable solutions made from recycled paper to keep groceries frozen during delivery at Amazon Fresh and Whole Foods market in the US. In America, Amazon's Whole Foods Market was the first national retailer to eliminate plastic straws from cafes in 2019, saving 21 million straws per year. Further, Amazon also removed all polystyrene meat trays from Whole Foods Market locations in the United States and Canada.

INITIATIVES	CHANGES
MARICO Marico's efforts led them to create the lightest weight plastic packaging for oil bottles and adopt recyclable PET material.	Marico's popular Parachute coconut oil HDPE (high density polyethylene) bottles and hair oil PET bottles are the lightest in the FMCG sector as of now after considerable effort and innovation over the years. It also intends to phase out polyvinyl chloride (PVC) usage in packaging by 2022 and have already reached 95% of that target in 2021. The PVC materials are being replaced by PET which can be easily recycled. In India and Bangladesh, Marico intends to achieve 100% recyclable packaging by 2025. As of now, they use 20% recycled HDPE in household care brands and 50% recycled LDPE (low density polyethylene) in shrink films for secondary packaging of Saffola edible oil.
NESTLE Nestle intends to reduce plastics in packaging by designing reusable, refillable and recyclable packaging. They have transitioned from using plastic-based straws to paper straws, globally.	Nestle is focused on reducing redundant plastics in packaging material by removing unnecessary packaging parts like tear-offs covering bottle caps and necks. Using this innovation in Egypt, Nestle Pure Life water eliminated 240 metric tons of PVC annually. Nestle also eliminated close to 2300 metric tons of plastic annually by removing over-cap lids from food puree tubs. Their other project, piloted in the USA, Canada and France, includes reusable and refillable dispensers for uses like pet care and soluble coffee. These containers were designed with in-built RFID (radio frequency identification) to know packaging material composition. Nestle also offers refillable packaging for dairy products. The company engages with major retailers in various countries towards efforts to shift to reusable packaging.
PEPSICO PepsiCo's innovations centre on sustainable packaging made from non-plastic materials such as aluminium cans, glass bottles and recyclable PET (polyethylene terephthalate) material.	Pepsico joined the Pulpex consortium, a global packaging technology company, to create and scale the world's first recyclable paper bottle which is currently in the research and development stage. The bottles are created from sustainably sourced pulp and designed to be recycled through standard paper streams. Pepsico intends to phase out virgin plastics from their branded beverage bottles sold across nine EU countries. The switch will save over 70,000 tonnes of conventional virgin plastics per year and reduce greenhouse gas emissions by around 40%. In America, Pepsico chose to change the packaging from plastic to aluminium cans for a sparkling water brand. They are also exploring non-fossil fuel based sources for packaging material that contain plant-based materials, which are safe, efficient and have a lighter carbon footprint than oil-based plastics. They are selling beverages in non-returnable glass bottles that are reusable by consumers.

INITIATIVES	CHANGES
PROCTER & GAMBLE The multinational corporation is looking to reduce plastic usage by innovating on product packaging, focusing on refillable products and product weight reduction.	Procter and Gamble (P&G) is working towards reducing the amount of plastic and raw materials in their products by sourcing more effective materials to reduce the average weight of their diapers. The brand has succeeded in decreasing average diaper weight by 18% while fulfilling the same utility. In Thailand, P&G reduced plastic usage with packaging redesigning innovations. They created outer packaging with carton perforations to frame the product's logo that showed if anyone had tried to open the package prior to sale, thereby replacing plastics materials that earlier worked as a seal. This simple innovation would save up to 8,000 kgs of plastic according to estimates. In the USA and Canada, P&G launched refillable packages that include one full jar of product with a recyclable refill pod. It also replaced traditional high density polyethylene (HDPE) for the packaging of Tide with cardboard material. This material can be compressed into a shipping-safe package made from 60% less plastic with design interventions to minimise leaks.
UNILEVER Unilever seeks to shift to mono-material packaging and reusable spray bottles. They also want to integrate more post-consumer resin into their packaging.	Unilever has been making changes in processes around the world to accommodate innovation. Unilever is attempting to reduce virgin plastics in Europe and develop reusable bottles and refill packs. These refill packs use 75% less plastic. Customers can use it for refilling and reuse the smaller bottles. Unilever is also increasing their use of recycled plastic and more post-consumer recycled (PCR) resin for their laundry detergent, Persil. The new packs are lightweight, use 650 tonnes less plastic across the range, with the new bottles using up to 70% recycled plastic. In Vietnam, Unilever is looking to transition from multilayer materials in packaging to mono-material packaging. They launched a trial for recyclable mono-material sachets of shampoo. After use, the recycled material is reused for items like refuse bags and containers. In America, most black coloured plastic is hard to recycle as sorting machines do not detect black pigments. To fix this, Unilever has collaborated with plastic recyclers to create new pigments that make black plastic products recyclable, to replace black plastics that were not easily detectable by waste sorting machines. Packaging for their black coloured branded products like Axe and TRESemmé have been upgraded according to this technology.

HOW INDIAN CITIES CLEANED UP

WASTE MANAGEMENT IN CITIES: AN OVERVIEW

India's waste management system is severely underperforming because of tangled logistics, lack of coordination and efficiency. This is a growing concern fuelled by various stakeholders' lack of awareness to bring about a more structured process to treat waste. The current waste management process has several flaws which results in more work and inconvenience for all stakeholders including citizens.

	CURRENT PRACTICE	RESULT OF CURRENT PRACTICE
COLLECTION	**1.** Poor door-to-door waste collection system **2.** Poor route mapping and surveillance of garbage trucks **3.** Stakeholders like ragpickers not included in waste management programs	Most waste is dumped on the streets and landfills
SEGREGATION	**1.** Waste collectors do not have access to segregation tools like colour coded containers **2.** Lack of adoption of segregation of waste at the source itself	More waste reaches landfills. Citizens do not sort waste at source, discouraged by eventual waste intermixing. Only bulk biodegradable waste makes it to processing
RECYCLING	**1.** Lack of infrastructure and resources to build city wide recycling systems **2.** Lack of efficient decentralised compost units such as trenching grounds	Poor quality compost and recycled products which fetch low revenues. Pollution is caused by waste pile up
ECONOMIC INCENTIVES	**1.** No emphasis on boosting market demand for recycled goods yet **2.** No government incentives like subsidies for recyclers **3.** Lack of well defined revenue generation streams for recycled goods	Low demand results in no incentive to produce recycled goods on a larger scale, leading to the loss of a potential revenue stream
SOCIAL HAZARDS	**1.** Uncovered public dustbins and garbage trucks **2.** Poor work conditions for waste pickers	Unpleasant waste overflow sights, bad odours adversely impact tourism and the health of citizens
CITIZEN AWARENESS	**1.** Poor awareness among citizens and stakeholders about waste management principles	Inefficient waste management and low adoption of waste management methods

LEADING THE CHANGE: HOW CITIES MANAGE THEIR WASTE

INDORE

POPULATION 2.17 MILLION

AREA 525 SQ KM

NUMBER OF HOUSEHOLDS 0.49 MILLION

SOLID WASTE GENERATED/DAY 1230 TONNES

WASTE SEGREGATED 100%

Indore's waste management system stresses on waste segregation at source and turns recyclable waste into profitable products like irrigation pipes. The city focused on creating household awareness about waste segregation by using the media.

HOW THEY DID IT

SEGREGATION OF WASTE

Waste collection vehicles are covered and divided into two portions. The collected garbage is sorted and sent to a trenching site for processing.

COMPOST UNIT

At the trenching ground microorganisms break down biodegradable trash in a controlled, aerobic setting. The resultant compost can be used as organic, low cost fertiliser.

RECYCLING NON-BIODEGRADABLE WASTE

After separation, non-biodegradable waste like plastic bags are cleaned and redirected towards briquetting (gatta) machines to form irrigation pipes. Paper cartons, glass, metals, and some plastics are cleaned, packed and resold to wholesalers.

DUSTBIN-FREE INDORE AND DOOR-TO-DOOR COLLECTION

At least 1800 secondary bins and containers have been removed after the Indore Municipal Corporation started working towards door-to-door garbage collection. Daily segregated waste collection happens from each household via 400+ tiny tippers (small garbage truck) in the city's 85 wards. For narrow lanes, the city uses 400+ cycle rickshaws and 350+ wheelbarrows

AWARENESS

Information about benefits and consequences of waste collection, transportation, segregation and disposal is communicated to citizens through films, ads, radio jingles, street engagement, NGOs, brand ambassadors and mass rallies.

BHOPAL

POPULATION 2.44 MILLION

AREA 463 SQ KM

NUMBER OF HOUSEHOLDS 0.41 MILLION

SOLID WASTE GENERATED/DAY 873 TONNES

WASTE PROCESSED 100%

Bhopal solved its problem of overflowing open garbage containers, bad odours, unmonitored and limited door-to-door waste collection, outdated garbage vehicles, and inefficient collection routes with an effective waste management plan. They divided the city into different zones to facilitate the door-to-door collection, used advanced monitoring technologies and included ragpickers in the system.

HOW THEY DID IT

DOOR-TO-DOOR COLLECTION

Bhopal is split into 19 zones for door-to-door collection of waste which is segregated at source into four categories – biodegradable, non-biodegradable, sanitary and domestic hazardous waste. This is done by 450+ auto-tipper trucks equipped with compartments to prevent mixing.

MONITORING

The government implemented facial recognition technology to monitor employees' punctuality at work and deployed a real time vehicle tracking system to monitor routes and document the same through daily reports.

UNIQUE MODEL FOR WASTE COLLECTION

Outsourced management of some recycling facilities to commercial operators who have to include rag-pickers in mainstream waste collection. The rag pickers are paid according to the volume of recyclable waste they sort. The city uses mobile apps to track inventories and pay ragpickers in an efficient manner.

NON-BIODEGRADABLE WASTE PROCESSING

Waste is collected via door-to-door collection. From this, non-biodegradable waste is sorted and transported in separate blue compartments. The waste is further segregated into 10 categories at the materials recycling facility. From this, recyclable waste is sent category wise to recycling companies and non-recyclable waste is stored as refuse derived fuel (RDF).

MYSURU

POPULATION 1.23 MILLION

AREA 155 SQ KM

NUMBER OF HOUSEHOLDS 0.29 MILLION

SOLID WASTE GENERATED/DAY 450 TONNES

WASTE PROCESSED 70%

At least 40% of Mysuru's waste was biodegradable but remained largely unsegregated and thus difficult to decompose. Growing dump sites alerted the city's municipality officials to adopt a new decentralised waste management method. This includes features like efficient collection practices, decentralised waste processing and infrastructure to handle segregated waste.

HOW THEY DID IT

MANAGING HOUSEHOLD WASTE

Biodegradable and non-biodegradable waste is collected and sorted via door-to-door waste collection. The collected biodegradable waste is moved to a decentralised compost unit outside the city and converted to compost and sold in the market.

The non-biodegradable waste is sent to 43 collection centres where it is categorised, cleaned and sold to recyclers.

WASTE HANDLING AND PROCESSING

As of now Mysuru City Corporation has one biodegradable waste processing facility. Mixed garbage is still generated in some areas and transported to this location.

ZERO-WASTE MANAGEMENT PLANT

The municipality conducts secondary segregation to ensure garbage does not mix during transit or at the plant. Segregated biodegradable trash is shipped to be processed, while leachate (percolated water found in the waste) is used for compost inoculation (adding bacteria to compost to start bacteria growth).

PUNE

POPULATION 5 MILLION

AREA 516 SQ KM

NUMBER OF HOUSEHOLDS 1.37 MILLION

SOLID WASTE GENERATED/DAY 2000 TONNES

WASTE PROCESSED 54%

The waste management process in Pune includes workers from a waste picking cooperative of self-employed individuals who perform waste collection and management services under the PMC-SWaCH model. Through its waste management model, the municipality of Pune has been able to save Rs 740 million/ year in labour costs, Rs 160 million/ year in transportation and processing costs, diverted 52% of the city's plastic waste away from landfills and reduced 50,000 tons of greenhouse gas emissions.

HOW THEY DID IT

PMC-SWACH CO-OP MODEL

The Pune Municipal Corporation (PMC) collaborated with a well-established labour union called Kagad Kach Patra Kashtakari (KKPKP) to introduce the PMC-SWaCH co-op model. A first of its kind, the model signifies collaboration and trust between the government and the union. SWaCH performs door-to-door collection and other waste management services. The recyclable items collected by the co-operative are sorted and sold. The waste pickers retain the income. The PMC aids the workers with supplies, equipment and administrative costs.

WASTE MANAGEMENT MODEL

Waste is collected at residential, commercial and institutional levels by SWaCH workers, itinerant waste pickers and buyers. It is sent to small scrap shops and large scale scrap aggregators for pre-processing. Recyclable waste is sent to small and large scale processors and recyclers. Non-recyclable waste is turned into refuse-derived fuel or sent to brick kilns/landfills. Biodegradable waste is composted.

COONOOR

POPULATION 49,000

AREA 15 SQ KM

NUMBER OF HOUSEHOLDS 13,000

SOLID WASTE GENERATED/DAY 14 TONNES

WASTE PROCESSED 58%

The hill station of Coonoor faced several challenges in sustainable waste management. A hilly terrain and city rules that forbade landfills and incineration, made waste transport and disposal difficult. The only composting centre was located in the middle of the town. The micro-composting centre was not equipped to deal with slaughterhouse and fibrous waste which was 14% of Coonoor's daily waste. The city depended on the unorganised sector to deal with dry waste, making the process erratic. Coonoor solved this through a memorandum of understanding (MOU) between the municipality and Clean Coonoor, an NGO. The alliance coordinates waste disposal through a mutually agreed upon statement of purpose. Through this agreement, the town of Coonoor has handled 3000+ tons of waste, achieved a recyclable recovery rate of 36% and a non-recyclable disposal rate of 99%.

HOW THEY DID IT

AN MOU TO THE RESCUE

Clean Coonoor is tasked with handling waste and managing the resource recovery centre. Its responsibilities include avoiding landfills and safe disposal of e-waste. The municipality provides room space, electricity, and water for operations. They also manage door-to-door waste collection and transportation of waste.

RESOURCE RECOVERY MODEL FOR DRY WASTE

In collaboration with the Coonoor Municipality, Clean Coonoor came up with a new process to handle dry waste. After sorting, the dry waste is sent to a resource recovery centre for weighing and further sorting. The dry waste is sorted into recyclables, non-recyclables and domestic hazardous waste. Recyclables are bundled and sold to aggregators for recycling.

Non-recyclables are either composted (if they contain organic impurities) or sent to landfills. The hazardous waste is incinerated in a closed-burning facility.

CHAPTER 7

Cutting Out Single Use Plastics

In July 2022, India banned the manufacture, import, stocking, distribution, sale and use of specific single use plastic products. Single use plastics (SUPs) are made from fossil fuel based raw materials. SUPs are disposed of after a single use. Some single use products include straws, cups, sachets and water bottles. They cannot be reused. Companies choose SUPs due to their low cost. Developing economies like India have also seen high SUP consumption as consumers prefer purchasing small quantity sachets as opposed to bulk quantity bottles due to limited purchasing power. However, due to their single use nature, SUPs make up a good chunk of plastic waste and litter the environment, making them more of a menace than a boon.

Replacing SUPs with eco-friendly products increases packaging costs, which leads to an increase in the overall cost of the products. Thus, banning SUPs and replacing them with eco-friendly products could have cost implications that adversely impact product pricing, affordability and demand. For example, several large companies like Dabur, Amul and Mother Dairy shifted from plastic straws to paper straws for their tetra pack beverage offerings. This led to the cost per pack to increase by Rs 0.25-1.25.

If the ban extends to single use plastic wrappings in the future, it can cover a large chunk of packaging in the FMCG (fast moving consumer goods) industry and can impact companies that sell biscuits, noodles, chips and other goods for mass consumption.

However, it is necessary to note that banning SUPs is a complex and long term undertaking. India has attempted to ban SUPs in some form or the other since 1999 at the national and state level with limited success. Learnings from the past may aid our current and future attempts.

COVERED IN THE BAN

>> Plastic sticks (earbuds, candy and ice-cream sticks, balloon sticks)

>> Thermocol (polystyrene) used in decorations

>> Plastic plates and cutlery

>> Wrapping films on sweet boxes and invitation cards

>> PVC/Plastic banners less than 100 microns

NOT COVERED IN THE BAN

>> Multi-layer packs or sachets with plastic as a predominant material

>> Packaging films and pouches used to wrap FMCG products

REPLACING SINGLE USE PLASTICS (SUPs)

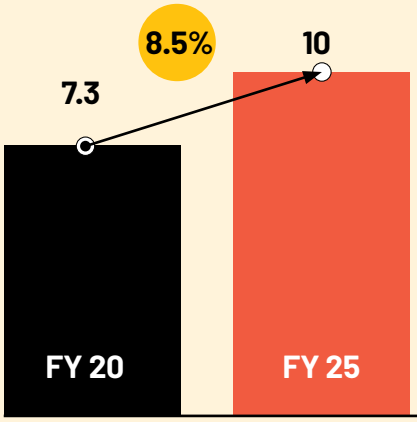
Two major alternatives exist for SUPs when it comes to daily use applications. This includes reusable plastics and non-plastic disposables. For both types of products, the major concern is competing with single use plastics in terms of cost while remaining sustainable. Currently, such alternatives to SUPs are relatively expensive due to difficulty in achieving economies of scale and therefore a challenge to adopt at a large scale.

IDENTIFIED, BANNED SUPS	EXISTING ALTERNATIVE MATERIALS
>> Plastic Sticks	>> Bamboo/wood, recycled paper sticks
>> Thermocol decorations	>> Decorative items made from cardboard, corrugated sheets, foam, plywood and cloth
>> Plastic plates	>> Fibrous agri-waste plates (arecanut leaves, rice husk, banana leaves, etc.)
>> Plastic cups, glasses	>> Kulhad, glass/metal cups
>> Plastic cutlery	>> Cutlery made from bamboo, wood, edible spoons
>> Plastic straws/trays	>> Plastic straws/trays made from fibrous agri-waste
>> Wrapping films (sweet boxes, invitation cards)	>> Paper wraps
>> Wrapping film (cigarettes)	>> Biodegradable overwraps
>> Carry bags (under 120 microns)	>> Plastic carry bags (>120 microns), cotton, jute and paper bags

OTHER PROMISING ALTERNATIVES TO SUPs

CATEGORIES	INNOVATION
Coir pith bags to replace plastic bags in nursery and horticulture	**>>** Saplings raised in coir pith pots can be planted as is, as it is a biodegradable material **>>** Coir pith absorbs and stores water, helping sapling survive dry conditions
Cutlery made from **agri-waste/ stubble waste** to replace plastic cutlery	**>>** Leak proof, biodegradable and non-toxic **>>** Made from reinforced natural fibre sourced from waste **>>** Meets packaging requirements for food products and can extend product shelf life
Sustainable packaging solutions to replace conventional plastic packaging	**>>** Natural plant fibres used to create sustainable, eco-friendly, and viable packaging alternatives **>>** Designing reusable/ refillable boxes to reduce the use of corrugated paper and paperboard
Biodegradable straws over plastic straws	**>>** Biodegradable retro straws made from wheat, rice, vegetable starches, tapioca and water **>>** Edible straws made from coconut leaves that otherwise end up burnt

INDIA'S SINGLE USE PLASTICS INDUSTRY WAS WORTH **US$ 7.3B IN FY20**; EXPECTED TO GROW AT 8.5% TILL FY25



ASSUMPTIONS:

>> The market size of India's SUP industry does not consider the impact of recent SUP ban

>> It represents the total opportunity size of replacing 100% of the single use plastics

CHAPTER 8

Recommendations for the Future

How the World Addresses Circularity | What Stakeholders Can Do | Impact and Ease of Implementation

Throughout the report, we have looked at key aspects of the plastic value chain and how they fit into the circular economy. In this section, we look at what stakeholders can do and how they can collaborate for more impact. Sustainability as a goal is attainable with focused financial, intellectual and time based investment from stakeholders.

Disrupting the plastic value chain for a more environment friendly system can be both economically rewarding and sustainable in the long term. We start by looking at how countries across the world address circularity and then lay out policies that India can adopt. Further, we engage in ways to build greater awareness, and knowledge and the role that stakeholders can play in India to support circularity and create lasting impact.

LESSONS FROM THE WORLD ON CIRCULARITY

Globally, countries have adopted policy and regulatory measures to support circularity in the plastics industry. Policymakers world over have recognised the importance of sustainability in a fast paced economy fraught with a risky and large waste output.

COUNTRY	POLICY MEASURES	DESCRIPTION
UK	Levy on packaging material Landfill Tax	Packaging plastics with less than 30% recycled content subject to GBP 200 per tonne levy from 2022 1996: A landfill tax was imposed on waste producers and the waste industry as well as local governments disposing municipal waste. As of 2021, the tax stood at GBP 96.7 per ton. Due to this tax, the garbage delivered by local governments to landfills in England has decreased by 90% since 2000
EU	Recyclate component law	All PET bottles must have 25% recycled material (2025) and all beverage bottles must contain 30% recycled material (2030)
Finland	Deposit refund system	A return system for beverage containers which establishes a deposit refund system for PET bottles and incentives on compliance, collecting and reuse was implemented. (2013) Consumers return bottles to the store and receive a refund amount. This led to Finland meeting a statutory 90% recycling and reuse target for packaging
China	Support to research and development	A biomass special equity fund to support R&D on biomass was established. The country has also aided research on PLA (polylactic acid) materials with the assistance of several local technology institutes
US	Bio-refinery establishment program	US Farm Bill (Biorefinery Assistance Program) provides grants and loan guarantees for the development, construction and retrofitting of commercial scale biorefineries. This includes funding for demonstration scale plants up to 30% of costs, and loan guarantees for commercial scale plants (up to USD 250 million per plant)

COUNTRY	POLICY MEASURES	DESCRIPTION
Belgium	Pay-As-You-Throw	Encourages individuals to sort and generate lower waste Municipalities are required by law to set variable pricing for mixed garbage pickup. The authorities can charge up to 3.3 EUR per 10kgs to users for garbage processing
France, Italy, and Canada	Modulating EPR fees	Several countries use extended producer responsibility (EPR) to encourage eco-designs. Innovations receive a benefit in the form of reduced EPR fees
Italy	Certification Rule	The rule calls for replacing typical plastic carrier bags with biodegradable and compostable bags. It is compulsory to get these bags certified as biodegradable and compostable by accredited organisations
Japan	Biotechnology Strategic Scheme	The scheme, introduced in 2020, aims to replace roughly 20% of conventional plastics (2.5 to 3 million tonnes per year) with polymers derived from renewable sources
Thailand	National Roadmap for the Development of Bioplastics Industry	Focused on the supply of biomass, accelerating technology development and establishment of supportive infrastructure Incentives to the bioplastics industry like corporate income tax exemption, import duty reduction, infrastructure construction and installation costs reduction

WHAT INDIA CAN DO TO ACHIEVE CIRCULARITY

POLICY SUGGESTIONS

India's approach towards achieving sustainability in the plastics industry is becoming more focused. Apart from the ban on single use plastic usage, the government has been working on creating a statutory framework including the use of biodegradable plastics as an alternative material. There are other effective policy interventions that can be used to create a sustained impact.

1. Landfill and incineration taxes must be levied in India. A tax ensures a tight loop circularity and little leakage in the environment. This method has been adopted in countries like Japan and Korea, to encourage recycling rather than dumping.

2. Authorise a pay-as-you-throw system, which requires citizens to pay a variable rate/kg for a bag of mixed garbage. This method is in use in Belgium and Switzerland.

3. No laws or regulations currently cover the deposit and refund system. **Deposit-refund system** is a form of purchasing fee that can be refunded when the goods are returned. Such a system has been established in Denmark and Israel. Pay-as-you-throw in combination with a deposit refund mechanism is highly effective in minimising littering and has shown an increase in waste collection rates.

4. There is a **need to regulate the entire life cycle of plastic bags**, from manufacturing or imports to disposal.

5. Specific incentives to the bioplastics industry like corporate income tax exemptions, infrastructure development support and installation cost reduction.

1. RESTRAIN DEMAND	2. DESIGN OF CIRCULARITY	3. ENHANCE RECYCLING
>> Ban/tax on single use plastics	>> Recycled content standards	>> EPR for packaging & durables
>> Promote reuse	>> Extended producer responsibility fees modulation for circular design	>> Landfill and incineration taxes
>> Remove subsidies extended to fossil fuels	>> R&D norms to reduce microplastics emission	>> Deposit and refund
	>> Product norms & hazardous chemical regulations	>> Pay-as-you-throw
4. CLOSE LEAKAGE PATHWAY	>> Incentivize alternatives such as bioplastics	**5. CLEAN UP**
>> Ban/tax on frequently littered items		>> Recover plastics in ocean & rivers
>> Collection of municipal solid waste		>> Litter clean-up campaigns
>> Sanitary disposal infrastructure		>> Extending EPR to litter clean-up

RECYCLING PLASTICS: THE FIRST STEP

Setting up the groundwork for an efficient waste recycling system is the first step towards achieving greater circularity. This requires small to large scale measures across the plastics industry value chain in India.

DISCOURAGE REDUNDANT PACKAGING

Reduce the use of plastic by removing unnecessary packaging elements (such as secondary layers). Mark and advertise health hazards of plastics to the environment.

DISCOURAGE PLASTIC BLENDING

To improve waste sorting process, introduce simple packaging designs and discourage use of contaminants like ink, adhesives and coatings.

MANDATORY TESTS FOR SPECIFIC PLASTIC PRODUCTS

Mandatory tests for plastic products regularly exposed to nature, such as construction parts, outdoor furniture, need to be developed in order to check the effects of UV/air/soil/water on the plastics and minimise microplastic pollution.

PROMOTE PLASTIC SEGREGATION AT SOURCE

Incentivise producers and consumers to sort plastic destined for recycling at source to prevent mixing.

MARKING PACKAGING PLASTICS

Industries should mark packaging plastics with molecular/visual signatures for efficient sorting. This is important for common products like bags and wrapping sheets.

PRODUCT DESIGN TRANSFORMATION

Label removers, delayering mechanisms, dye removers can help make recycling machines and processes more efficient.

CROSS SUPPLY CHAIN BUSINESS MODEL

The importance of proper segregation and sorting should be tied to the plastic value chain with appropriate incentives and subsidies.

DISCOURAGING HARD-TO-RECYCLE PRODUCTS

Opt for mono-material packaging over hard-to-recycle multi-layer plastic packaging. Run buyback programs for hard to recycle products.

UPCYCLING PLASTIC WASTE

Pilot plants for chemical and biological recycling should be tested to attempt upcycling plastic waste.

CONDUCTING SURVEYS AND DATA COLLECTION

Surveys should be conducted regularly to calculate the environmental and monetary costs of waste management models. It is important to establish systems for data gathering and analytics.

AUTOMATED SORTING INFRASTRUCTURE

Infrastructure for large scale plants with automated sorting should be facilitated.

EXTENDED PRODUCER RESPONSIBILITY

Clear end-of-life guidelines must be established for producers while advertising disposable options.

RECYCLING: INDIVIDUAL ACTIONS STAKEHOLDERS CAN TAKE

From civil society, industrialists to the government, everyone involved in the plastic value chain is a stakeholder. Achieving sustainability also demands an active involvement of citizens beyond consumption. All stakeholders must take up active roles towards creating a circular economy for plastics.

PRIVATE ORGANISATIONS

Brand owners can specify product materials, correct disposal methods and focus on shifting to sustainable packaging. They can opt for using more post-consumer recyclates in their products.

URBAN LOCAL BODIES (ULB)

Assist local recyclers and collectors by providing them land and recycling machines, bring informal waste collectors into the mainstream waste collection service, and raise awareness among the public regarding the importance of segregation at source.

GOVERNMENTS

Establish clear recycling goals and policies, prioritise investing in recycling infrastructure, encourage R&D in the plastics sector and provide access to research facilities to private businesses.

CONSUMERS AND WASTE GENERATORS

Choose products made with eco-friendly raw materials, segregate waste with care at home, and take an active role in the social effort to minimise plastic waste.

RECYCLERS

Use modern technology to boost material recovery rates, ensure hazardous additives do not enter recycling stream, and generate strong partnerships with plastics production companies to ensure consistency in supply and demand for recyclates.

WASTE PICKERS

Provide support in collection and segregation of waste between generators and material recycling facilities.

INCLUSIONARY STRATEGIES FOR INFORMAL WASTE COLLECTORS

1. Urban local bodies must take measures to include informal waste collectors in the local waste management system. ULBs can facilitate this by allowing them to provide doorstep collection service.

2. Recyclable items found can be sold by the waste pickers and the income generated be retained by them.

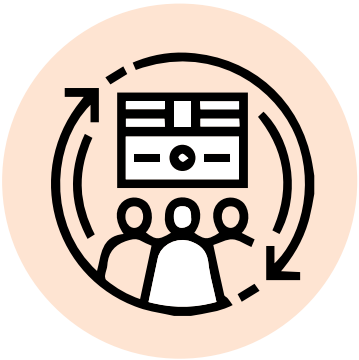
3. Governments should focus on forming more member-based waste picker organisations. This gives informal workers more collective agency and allows a transition towards secure jobs and pay.

4. ULBs should make unorganised waste pickers' work legal, treating them as legitimate service providers by providing them with ID cards.

ADDRESSING INFORMATION AND TRAINING GAPS ACROSS SECTORS

CIVIL SOCIETY

RAISING AWARENESS	EXAMPLES
>> Community engagement programs from religious leaders, NGOs, and social groups **>>** Main target groups should be students, underserved communities and societies **>>** Potential areas to focus - reusing, recycling, sorting, littering and handling hazardous substances	**>>** WWF-Vietnam + Local authorities project **>>** Established a system to sort solid waste at the source **>>** Valuable items would be utilised on site and organic waste composted **>>** Trash would be transported to a treatment site
KNOWLEDGE CREATION	**EXAMPLES**
>> Identify ways to reduce plastic consumption and/or increase the proportion of recycled or biodegradable plastic at home **>>** Develop practices for reusing packaging materials **>>** Unorganised workers should be trained on various types of materials and best practices for recovering them	The Story of Stuff Project, an NGO based out of California, provides video content and other resources on the impact of plastic on the planet and how to live a plastic free lifestyle



THE PRIVATE SECTOR

RAISING AWARENESS	EXAMPLES
>> Harmonise industry wide effort for transparent communication about chemicals used in plastics **>>** Responsible disposal plans for end-of-life plastic products **>>** Cooperation with local governments to promote sustainable purchasing, reuse, and responsible disposal of plastic products	The American Beverage Association started the Every Bottle Back initiative, a public-private partnership between several cola brands and environment leaders. Their goals were: **>>** To increase the amount of valuable recyclable plastic beverage bottles that are collected and remade into new ones **>>** To reduce the use of virgin plastics
KNOWLEDGE CREATION	**EXAMPLES**
>> Create an information bank on plastic types in different products enabling tracking of plastic movement in the economy **>>** Assessment of recycling capacity, gaps, and opportunities to identify and increase capacity utilisation **>>** Perform life cycle assessment (LCAs) of plastics in key end use sectors to determine greenhouse gas emissions from using plastics vs other alternatives **>>** Develop best practices document/guidelines in key end use sectors for resource recycling and waste minimisation practices	**>>** In 2022, Scotland became the first UK nation to implement a ban on many single use plastics like plastic cutlery, plates and stirrers **>>** India has also banned the use of some types of single use plastics starting July 2022

GOVERNMENT

RAISING AWARENESS	EXAMPLES
>> Working to create public awareness regarding health and environment hazards of mismanaged plastic waste and the need to recycle **>>** Involving local urban bodies to support targeted messaging to influence citizens	Sweden raised citizen awareness about segregating waste at the source. Here is how: **>>** Sweden separates waste into different coloured bags **>>** Non-recyclable waste is burned in plants that transform combustion into energy to provide electricity for 250,000 homes in the country
KNOWLEDGE CREATION	**EXAMPLES**
>> National (pan-India) classification of single use plastic (SUPs) **>>** Commission research to assess the quantity and composition of household plastic waste in rural areas **>>** Document best practices and guidelines for sustainable business models in India. These should be scalable and replicable in the key end-use sectors **>>** The government should focus on conducting reliable surveys and publishing most recent waste data. This will help people realise the gravity of the challenges	**>>** In 2022, Scotland became the first UK nation to implement a ban on many single use plastics like plastic cutlery, plates and stirrers **>>** India has also banned the use of some types of single use plastics starting July 2022

WHAT JOINT ACTIONS CAN STAKEHOLDERS TAKE?

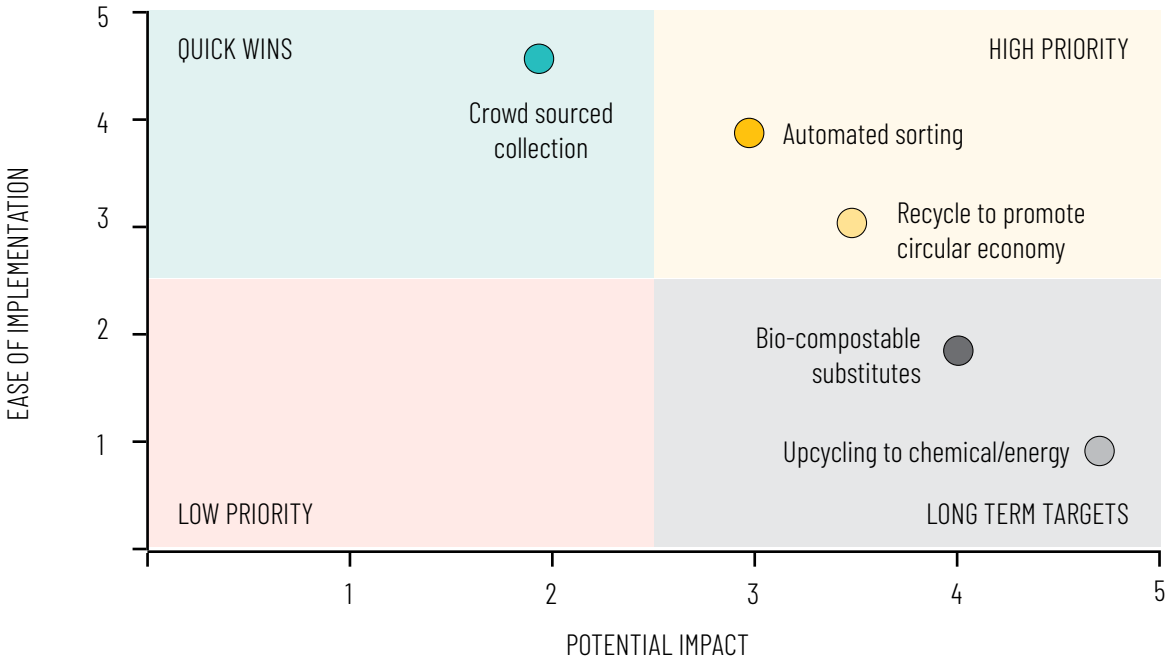
Stakeholders across the value chain, be it the government, industry or consumers need to jointly address the key challenges that hinder our path to achieving circularity.

PROCESS	GOVERNMENT	INDUSTRY	CONSUMERS
Crowd sourced collection	**>>** EPR on low recyclability packaging waste, like MLP **>>** Increase post-consumer recycled content requirement to increase its demand	**>>** Collection and sorting of plastic waste in order to integrate it with the value chain **>>** Decentralise collection to prevent leakage	Easy to follow segregation
Automated sorting		**>>** Scaled up sensor/AI driven sorting is key **>>** Direct low recyclability plastic waste to upcycling or long use applications **>>** Innovate end-of-life reprocessing technology	Segregating high recyclability plastic waste for recycling
Recycle to promote circular economy	**>>** Mandate blending of post consumer resin to non-food products **>>** EPR on halogenated plastics. E.g: PVC should be recycled for re-use or energy generation	**>>** Mechanical recycling plants to recycle HDPE, PET, PP **>>** Redesign packaging to use less plastics **>>** Distinguish between high and low quality waste to determine their correct application as post-consumer resin	Utilise takeback mechanism to return empty packaging for cleaning and reuse by the maker

PROCESS	GOVERNMENT	INDUSTRY	CONSUMERS
Upcycling to chemical energy	Mandate directing MLPs, composites, end-of-life plastic waste to recovery plants	**>>** Direct rejected waste from sorting to pyrolysis plants for fuel/energy recovery **>>** Co-pyrolysis with dry organic waste for high value feedstock chemicals **>>** Prolong life cycle by recycling to circulation before chemical recovery	
Bio-compostable substitutes	**>>** Promote development of industrial composting infrastructure **>>** Increase awareness to prevent mixing with recyclables **>>** Promote bio-compostable plastic usage in organic waste liners and sanitary products and phase down non-recyclable forms of plastics	**>>** Develop industrial composting infrastructure **>>** Make bioplastics from Indian waste streams (agri/dairy/industrial)	

PRIORITISING JOINT ACTIONS

Although there are many actions that can be undertaken towards achieving circularity, the need of the hour is to prioritise our actions based on the ease of implementation and potential impact of each action.



CROWD SOURCED COLLECTION

Potential Impact:

>> Crowd sourced collection aids in at source separation, improves recovery through recycling and can lead to high quality recyclable waste collection

>> However, this method provides relatively lower value addition to the overall waste management process

Ease of implementation:

>> Easy to implement through targeted awareness programs and appropriate incentives

AUTOMATED SORTING

Potential Impact:

>> Faster sorting based on type, colour, etc to avoid contamination of the batch leading to lesser waste to landfills and increased proportion of recycled waste

>> The composition of waste is ever changing, hence an AI-based sorting technology that can learn and adapt to the changes can have huge impact

>> However, sorting methods at scale are presently unable to differentiate food grade plastic. Plus, there is a lack of large scale automatic sorting infrastructure

Ease of implementation:

>> Technological solutions have been developed and adopted at the global level (e.g., Zenrobotics, Gray parrot) and by a few domestic players as well (E.g: Ishitva robotics systems)

>> However, new generation technologies can be expensive to develop or procure

RECYCLING

Potential Impact:

>> Increase in PCR content in packaging material has significantly reduced the use of virgin plastics in the packaging industry

>> However, mechanical recycling can only be used for certain types of polymers such as PET and polyamides. Plus, the quality of the recyclate degrades after going through subsequent processes of mechanical recycling, resulting in poor quality products

Ease of implementation:

>> Mechanical recycling is already established as a sizable business in the world's developed economies and can prove to be the largest profit pool in the future

>> However, heavy investments are required to build mechanical recycling plants, even though it is cheaper in comparison to chemical recycling. Plus, redesigning packaging can have long gestation periods due to R&D requirement and trials

CHEMICAL RECYCLING

Potential Impact:

>> Through chemical recycling, we can recycle polymers that have exhausted their potential to further get mechanically recycled

>> The quality of plastic does not change much even after repeated recycling

>> However, this process has increased electricity and energy requirements leading to an increase in greenhouse gas emissions and operational costs

Ease of implementation:

>> Petrochemical companies are taking note of plastic waste as another feedstock

>> However, there is a shortage of existing facilities both globally and domestically as of now as this process demands high capital investments and still requires innovations to maximise efficiency

BIO-COMPOSTABLE SOLUTIONS

Potential Impact:

>> BCPs can be adopted as a substitute across a wide range of plastic usage

>> They are biodegradable, leaving no visual or toxic residue post decomposition

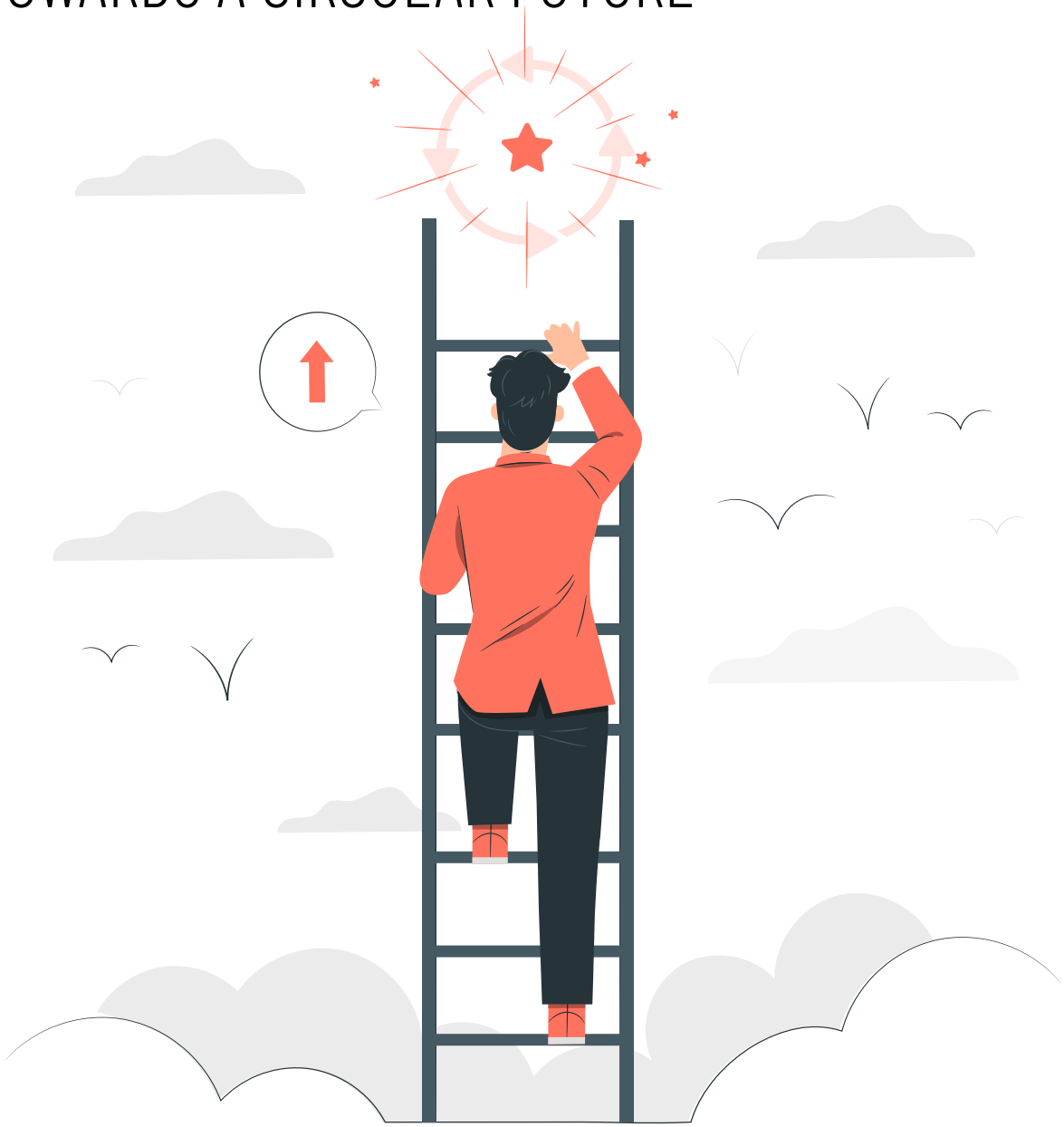
>> However, almost all BCPs cannot match polyesters in terms of their strength and barrier properties. Plus, proper guidelines, methods, and facilities to manage waste generated from BCPs are not readily available

Ease of implementation:

>> Steady research covering various types of BCPs (made from biomass, cellulose) makes the process easier to implement now compared to the past

>> However, scaling up manufacturing of BCPs would require sustainable demand. Plus, high cost of production, high market prices, lack of industrial composting infrastructure and lack of consumer interest/mindset change still stand in the way

TOWARDS A CIRCULAR FUTURE



Co-operation and understanding is key to achieving progress towards circularity in the plastics value chain. This is visible through the experiences of veteran business owners and fresh start-ups hungry to innovate. Without stakeholders working together within the various cogs of a functional industry, progress is likely to get offset by obstacles and missed opportunities.

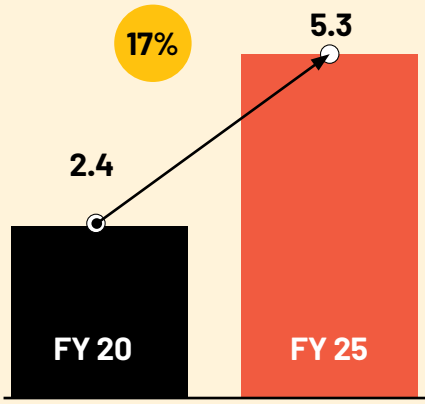
As for the types of stakeholders, the value of government interventions and consumer attention is as important as industry innovation. Without government crackdowns on plastic waste and policies towards more sustainable options, the plastics industry would not receive the additional firepower to experiment with renewable products. In the same vein, without customer awareness, interest and participation, any attempt to bring in sustainable product variants will only lead to loss. Therefore, each stakeholder holds equal value and equal responsibility towards ushering in an era of circularity.

CHAPTER 9

Opportunities for Entrepreneurs

Startups in India have immense potential to plug the gaps in the country's waste management ecosystem. This puts them in a strong position to innovate and add value as a stakeholder in the circular economy.

Indian plastic waste management industry projected to present a US$ 5.3B opportunity in FY25 growing at a CAGR of 17%



ASSUMPTIONS:

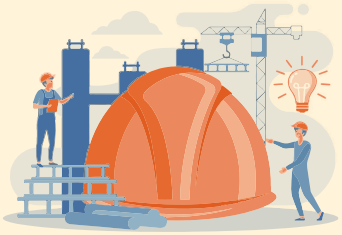
>> The opportunity in the plastic waste management market represents the revenue potential from the sale of recycled fibre, pellets, etc. minus the cost of acquiring raw material, i.e. waste collected by ragpickers, etc.

>> The market size captures the total opportunity size in the plastic waste recycling market and does not include upcycling of plastic waste or replacement of plastics

>> To realize the full potential of the industry, it is assumed that 100% of the waste generated is recycled

AI BASED SORTING

It has been projected that sorting and waste processing will be fully automated in the future. AI based robotic systems are more accurate and cost effective, especially with sorting problematic materials like MLP, bioplastics and mixed polymers.
Startups in the Segment: TrashCon, Ishitva Robotics



MATERIAL-TO-MATERIAL INNOVATION

Making products from post-consumer recycled (PCR) resin and ocean bound waste are the most sustainable ways for diverting plastics waste. These innovations are environment friendly, have lower carbon footprint and reduce product cost.
Startups in the Segment: Ricron, Lucro

ROUTE PLANNING AND OPTIMISATION SOFTWARE

Developing software for optimising routes for waste pickup, providing drivers with the most efficient routes to save costs. This coupled with smart bins could prove to be highly efficient.
Startups in the Segment: Recykal, 3R Management

BIO-COMPOSTABLE PLASTICS

Natural compound based products are less hazardous and can compete with conventional plastics, making them a disruptive innovation in the plastics industry.
Startups in the Segment: Zerocircle, Ibanss

DATA ANALYSIS AND RECYCLING WASTE MANAGEMENT SOFTWARE

Data can help track metrics like CO_2 emission rates and savings from recycling. It helps determine the most eco-friendly and economical options to adopt at an institutional level.
Startups in the Segment: Wasteful Insights, 3R Management

BLOCK CHAIN BASED EPR SERVICE

Blockchain technology can be useful for extended producer responsibility, as it can help keep track of records, has global accessibility, and provides verifiable and immutable transactions.
Startups in the Segment: Lucro, Paperman

FOCUS AREAS FOR ENTREPRENEURS

Entrepreneurs need to focus on innovating on certain key areas that can create far reaching and lasting impact.

FOCUS AREA	SERVICE MODEL CHALLENGES	AREAS FOR INNOVATION
COLLECTION	At source segregation practices not followed	Incentives and rewards for households that segregate their waste Provide cost effective waste segregation equipment to waste pickers
SORTING	Lack of large scale automatic sorting and technologies such as Near Infrared (NIR) Spectroscopy, X-ray based sorting	Development of technology to make automated sorting possible on a large scale Development of technologies such as integrated densimetric sorting, flake sorting, etc. Adoption of new technology like NIR, X-ray by partnering with international firms
RECYCLING	Only 30% of waste in India is recycled Recycling limited to HPDE, PET and PP and mainly mechanical recycling	Innovative packaging solutions that use less plastics and more bioplastics Invest in mechanical recycling plants and increase R&D on developing better quality recyclates Develop solutions to process poor quality plastics Develop inexpensive de-inking technologies
CHEMICAL RECYCLING	High investments required to fully develop chemical recycling High capital cost of production at current low levels of production	Invest in innovations in catalysts, biorefineries, reactor designs Develop upcycling opportunities across industries such as construction, agriculture and packaging Delamination and selective dissolution leading to separation of components in multi-layered plastics, which makes chemical recycling more efficient
MANUFACTURING BCPs	High capital cost of production at current low levels of production No end of life treatment infrastructure for BCPs yet	Upscale current manufacturing to lower cost of BCP production and provide large amounts of BCP at cheaper rates Invest to develop end-of-life options for BCP

MAKING WAY FOR INNOVATIONS

Indian startups offer fresh ideas and serious potential to execute them on a large scale.

What they lack is adequate support systems from both, the government and the private sector. Without this support, startups lose valuable time and energy hunting for resources required to test products, pitch ideas, and set up shop.

However, through co-operation between large stakeholders like the government and the plastics industry, entrepreneurs can build and scale startups faster, with innovations targeted towards core areas of change.

{ Annexure }

BIOPLASTICS, THEIR ENERGY REQUIREMENTS & COMMON HAZARDS

BIOPLASTICS	ENERGY REQUIREMENT & BIO-IMPACT	ENVIRONMENTAL HAZARDS	OCCUPATIONAL HEALTH & SAFETY HAZARD
POLYHYDROXYALKANOATES (PHA)	Highly compostable Estimated 30-40% less energy consumption in production compared to LDPE Emits 40-80% less CO_2 than LDPE	Use of industrial agricultural production methods including GMOs to grow feedstock Unreliable data on energy requirement	Exposure to pesticides Use of phridine, methanol, hexane or diethyl ether in physical extraction of PHA
POLYLACTIC ACID (PLA)	Usage of 30-50% less fossil energy in production Generates 50-70% less CO2 emissions than paper-based biodegradable plastic (PBP) Recyclable & compostable at temperature above 60 degrees	Use of industrial agricultural production methods including GMOs to grow feedstock Building up of organic tin & 1-octanol in living organisms which is ecotoxic	Exposure to pesticides, sulfuric acid, tin octoate, 1-octanol & urea Powerful explosions caused due to finely pulverized starch
THERMOPLASTIC STARCH (TPS)	Usage of 68% less energy in production as compared to PBP counterparts Lower CO_2 emissions than PBP Biodegradable & compostable	Use of industrial agricultural production methods including GMOs to grow feedstock	Exposure to pesticides, glycerol & urea Powerful explosions caused due to finely pulverized starch

CONTD...

BIOPLASTICS	ENERGY REQUIREMENT & BIO-IMPACT	ENVIRONMENTAL HAZARDS	OCCUPATIONAL HEALTH & SAFETY HAZARD
BIO-URETHANES (BUR)	Biodegradable via microorganisms, especially porous structures Usage of 23% less energy & 36% less GHG in production as compared to PBP	Use of industrial agricultural production methods including GMOs to grow feedstock	Exposure to pesticide, toluene diisocyanate (TDI), methylene diphenyl isocyanate (MDI), tin derivatives
CELLULOSE & LIGNIN	Lower biological degradation of lignin than cellulose Compostable	High energy & water requirements Emission of pollutants to air & water during kraft process	Exposure to elevated temperature & pressure Exposure to disulfide, sodium hydroxide, volatile toxic, flammable & malodorous sulphur emissions
NANOBIOCOMPOSITES OF CELLULOSE & LIGNIN	Biological degradation possible for composite foams with doping Relatively new materials from biomass - high energy required in production	High energy & water requirements Emission of pollutants to air & water during kraft process Toxicity issues of nanoparticles regarding to incineration, composting or recycling	Exposure to elevated temperature & pressure Exposure to disulfide, sodium hydroxide, isocyanates, volatile toxic, flammable & malodorous emissions of sulfur
POLY-TRIMETHYLENETERE-PHTALATE (PTT)	Usage of 26-50% less energy & 44% lower GHG in production than PBP counterparts No chemical additives used Biodegradable & recyclable	Use of industrial agricultural production methods including GMOs to grow feedstock	Exposure to pesticides, terephthalic acid, dimethyl terephthalate, & methanol Powerful explosions caused due to finely pulverized starch
CORN ZEIN & SOY PROTIEN	Biodegradable - release soil friendly nutrients Compostable	Use of industrial agricultural production methods including GMOs to grow feedstock	Exposure to pesticides, alcohol or volatile solvents, alkaline & acid substances, and formaldehyde and/or glutaraldehyde

SCOPE FOR REDUCING VIRGIN PLASTICS IN PACKAGING INCLUDING BIOPLASTICS

Use of recycled plastics	Post-consumer resin				
Reusable Packaging	Refillable Packaging	Bulk dispenser refilling			
Bioplastics	Plant-based plastics	Mycelium packaging	Cases made from palm leaves		
	Seaweed based bioplastics	Woodpulp cellophane	Plastics made from bamboo granules		
Redesign of packaging	Single material plastic sachet/ recycled packaging	Using reversible additives	Removing unnecessary plastic parts such as seals in water bottles		

BIOPLASTIC RELATED ALTERNATIVES TO VIRGIN PLASTICS

GENERAL PURPOSE FILM	BEVERAGES	PACKAGED FRESH / FROZEN FOODS & PHARMA SECTOR	LIQUID PACKAGING
PE	PET	PP	PE
1. Nanocellulose (NC) +PLA blend **2.** PHBV*/PBS†/PBAT‡ blends **3.** Starch PLA blends	**1.** PHA or PLA blends **2.** PLA **3.** Polyethylene Furanoate (PEF)	**1.** Poly-4-hydroxybutyrate (P4HB) blends **2.** Thermoplastic starch with PLA/PHB **3.** PHA laminated with PLA	**1.** Modified PLA **2.** BioPE **3.** Thick sheets of general purpose substitutes
1. Flexibility **2.** Transparency **3.** Strength **4.** Barrier properties	**1.** WVTR/OTR **2.** Strength	**1.** Toxicity clearance **2.** Moderate strength **3.** Specific WVTR/OTR	**1.** Strength **2.** High WVTR / OTR
>> 3% NC in PLA matrix brings WVTR/OTR down by 80% (closer to LDPE) **>>** PHBV PBS bilayer/ coextruded sheets perform well for tear resistance, seal-ability & WVTR **>>** Improved elasticity with different strength PLA/ starch with plasticizer films for general applications	**>>** Bacardi and Cove introduced bottles of PHAs as waterproof layering disappears in water/soil in 18 months **>>** PLA based beverage bottles LCA shows great promise **>>** PEF is biodegradable, bio-sourced, strong and outperforms even PET at barrier properties	**>>** P4HB is food and medical compatible, properties are tailorable **>>** PLA+ cassava starch bilayers show high barrier and strength **>>** Barrier properties improved with blends/ composites	**>>** Modifying crystallinity of PLA with additives results in flexibility **>>** BioPE properties similar to PE (renewable but not degradable) **>>** Same performance as thick LDPE flexible films

NOTES: WVTR - WATER VAPOR TRANSMISSION RATE, OTR - OXYGEN TRANSMISSION RATE, LCA T LIFE CYCLE ASSESSMENT

*PHBV: POLY(3-HYDROXYBUTYRATE-CO-3-HYDROXYVALERATE)

†PBS: POLYBUTYLENE SUCCINATE | ‡PBAT: POLYBUTYLENE ADIPATE TEREPHTHALATE

SOURCES: INDIAN INSTITUTE OF SCIENCE, PRAXIS ANALYSIS

Application | Plastic type | Possible substitutes in bioplastics | Properties required to match performance with FFPs | Rationale

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{ About }

MARICO INNOVATION FOUNDATION

With an aim to nurture and propel Indian innovations, Harsh Mariwala founded the Marico Innovation Foundation (MIF) in 2003 as a Not-For-Profit arm of the parent company, Marico Limited. Over the past 19 years, MIF has become India's coveted innovation focused platform, which recognizes disruptive Indian innovations and supports the innovative organisation's journey to scale impact through its flagship and sectoral programs such as:

Sectoral Innovation Programs: Sector specific interventions to hunt, recognize & scale up disruptive innovations to boost the innovation ecosystem of that sunrise sector by rapidly deploying winning solutions.

Scale-Up Program: A no-equity, sector agnostic rapid acceleration program for disruptive Indian innovations to scale their impact through deep-rooted mentorship.

Innovation For India Awards: The first and most prestigious Indian platform for showcasing the next big game-changing innovations of our country

{ About }

KNOWLEDGE PARTNERS

Indian Institute of Science (IISc)

The Indian Institute of Science (IISc) is a 114 year-old research institution, a nerve centre for research in the country. The institute has over 500 faculty across the disciplines of physical and chemical sciences, engineering and life sciences. In addition it has several interdisciplinary centres addressing challenges in renewables, nanomaterials, energy and others. Historically, the IISc has been a postgraduate training centre. It has started an integrated programme including undergraduate curriculum to enhance impact. Collaboration with industry is not new to IISc. Over the last two decades, the focus has been on reducing the science to practise. One of the key enablers of this has been the start up incubation activity. In addition, there are ambitious plans to develop dedicated programmes for rural and less developed areas. These are part of the Society for Innovation and Development (SID) housed within the sprawling campus at IISc.

Praxis Global Alliance

Praxis Global Alliance is the next-gen management consulting and business research services firm revolutionising how consulting projects are delivered. It delivers practical solutions to the toughest business problems by uniquely combining domain expertise, AI-led research approaches, and digital technologies. The company operates three business units, including Praxis Global Alliance Financial Investor Group (FIG), offering pre-deal support, commercial due diligence, post-acquisition value creation. Praxis Global Alliance Business Enablement and Transformation (BET) for practitioner-led business advisory and consulting, and PraxDigital™ delivering data engineering and analytics, AI, OpenData and visualisation solutions to clients across verticals.

Present in four locations in India, Praxis Global Alliance has successfully served 40+ countries with a team of over 200+ consultants and data scientists. Team Praxis works with C-suite to the frontline executives across business streams, helping them with end-to-end business enablement, organisational transformation, and revenue maximisation support in an agile environment.

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