Plastic Recycling Handbook

CARING FOR NATURE FOR A SUSTAINABLE FUTURE

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From the Desk of
The PlastIndia Foundation President

I am delighted to present the Plastic Recycling Handbook that highlights how recycling can be beneficial to the environment, the economy, and the plastic industry.

This handbook will act as a guide to plastic recycling in terms of collection, advantages, reasons of recycling, challenges faced, market size and its rules & regulation. This is an important step in making the plastic industry sustainable and environment friendly aligned to the government's vision of a clean and green India

I am confident that this Handbook will help us develop effective waste management solutions and recycling technologies that ensure proper collection and recycling of plastic waste, thus contributing to the circular economy.

Jigish Doshi
President
PlastIndia Foundation

From the Desk of
NEC Chairman PlastIndia 2023

Plastindia Foundation is committed to work towards a sustainable plastics industry that contributes significantly to the country's economic growth and this "Plastic Recycling Handbook" is a step in that direction.

This handbook is a reference point on recycling for the plastic industry highlighting its benefits, challenges and various technologies that can help recycle plastic waste. As we all know, it is not plastic but mishandling of plastic waste that leads to environmental impact and degradation. This handbook will act as a step-by-step guide on how plastic waste can be collected, transported, segregated, and recycled by using the latest technologies. We hope that the plastic industry will find this handbook beneficial in their journey to a circular economy.

My compliments to the team that has worked diligently to complete this handbook. I would also seek suggestions, views, and improvements that we could incorporate in future editions of the handbook.

Ajay Shah
Chairman
National Executive Council
PlastIndia 2023

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Preface

The idea for preparation of a Plastic Recycling Handbook germinated while on a drive from Pune to Mumbai while ideating on the environmental pavilion and activities during PlastIndia 2023.

Recycling is a widely misunderstood term with numerous connotations. Additional terminologies like upcycling and down cycling only lead to further confusion. During our research and discussions, we found a definition promulgated by the Association of Plastic Recyclers (APR), an international association representing the plastic industry which we found quite apt, an extract of which is reproduced below:

The following criteria must all be met for a package to be considered "Recyclable" per APR Definition.

- The item must have market value or be supported by a legislatively mandated program.
- The item is most likely sorted correctly into a market-ready bale of a particular plastic meeting industry standard specifications, through commonly used material recovery systems, including single-stream and dual stream Material Recovery Facility (MRF)s, Plastic Recycling Facility (PRF) systems that handle deposit system containers, grocery store rigid plastic and film collection systems.
- The item can be further processed through a typical recycling process cost effectively into a post consumer plastic feedstock suitable for use in identifiable new products.

With the focus of Waste Management now being squarely on Plastic Waste Management, it was felt that clarity in the processes of plastic recycling may provide a stimulus for young people and startups to venture into the various facets of the Plastic Waste Recycling Business in India. The Handbook also aims to give a ringside view of the existing Plastic (and recycling) market size, Plastic Waste Management regulations in force (as of Dec 2022), players and startups in the industry and the varied business models.

While there has been a sincere effort in listing most entities in the field, we humbly accept that the lists are not exhaustive, and omissions if any are unintentional.

While every effort has been made to acknowledge the source of information, omissions/ inaccuracies, if any, are purely unintentional. The trademarks and copyrights of respective individuals/ organisations continue to remain with the respective owners.

The rules for EPR (in India) and other regulation in force continue to change with time and this Handbook may not be considered as the last and binding document on the subject.

The views and opinions expressed in this handbook are of the authors and facts which have been verified to the extent possible.

The Handbook has been authored by Dr. Sameer Joshi, and Capt. Satyendra Vaidya, and co-authored by Mr. Rahul Podaar, Mr. Haren Sanghavi, Mr. Sapan Ray, and Mr. Sharang Ambadkar.

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Introduction

There probably isn't a single individual who does not encounter plastic from the time of getting out of bed in the morning to getting back into bed at night. From the toothbrush in the morning to the dinner plate in the evening, plastics is ubiquitous and all encompassing.

The word 'Plastics' has its origins in the Greek word "Plastikos" meaning mouldable. The word polymer means (poly = many) large molecules. Most are usually made up of numerous monomers (mono = one) or single molecules forming up in long chains. 'Polymers' are seen in abundance in nature, in plant cells in the form of cellulose. Proteins found in humans and all DNA or deoxyribonucleic acid, the material that carries genetic code for all species are also polymers.

"The term 'plastic' often covers a wide range of heterogeneous materials, each with differing applications that require very different physical properties. They are made from polymers, which are molecules comprising many repeating units, in formations that give plastics many of the desired qualities — such as flexibility, malleability and strength — that they often share.

Synthetic polymers have been developed only in the last one hundred and fifty years or so. These may be made from natural substances like cellulose or synthesised from fossil fuels. Synthetic or manmade polymers usually have longer chains of atoms than those found in nature. The length of the chains and the pattern in which they are arranged is what gives polymers the desired properties of high strength, flexibility, and low weight. It is these properties that have made polymers the most sought after and material of choice in numerous applications from footwear to aircraft and medical equipment to packaging.

The very nature of the material has resulted in large scale use and varied applications, packaging being the most widely used. Almost every commodity, edible or otherwise, is packed in plastic to protect it from the external environment. In the case of food and perishables, plastic is the material of choice for packaging as it has the capability to protect from all possible environmental factors that may affect the product.

Since most plastics and plastic packaging are not adversely affected by the environment, they do not decompose spontaneously and continue to remain in the environment long after they have been discarded, albeit degrading gradually in smaller and smaller particles. It may therefore be construed that all plastic products or packaging, which has been used by any individual and not disposed scientifically, continues in some form on earth or in the oceans.

Lack of proper disposal of waste plastic over the years has resulted in accumulation of plastic waste. Coupled with the ever-increasing consumption of a consumer driven society the quantum of plastic waste being generated daily around the world is mindboggling. As per some estimates plastic waste has more than doubled, from 156 MT in 2000 to 353 MT in 2019[i].

With rising concerns of Global Warming and Climate change, the increasing production of plastics is a cause of concern. It is estimated that about 3.4% of global greenhouse gases can be attributed to emissions from plastic during their lifecycle. Out of the 1.8 billion tonnes of greenhouse gas emissions from plastics, 90% have been attributed to production and conversion from fossil fuels[ii].

The requirement for use of plastics and need to reduce GHGs are both equally important.

Origins – The History of Plastics

Eduard Simon, a dispensing chemist from Berlin, distilled an oily substance from the resin of the Turkish sweetgum tree in 1839. He named the monomer styrol. However, some days later Simon observed that the styrol had thickened into a jelly like substance and he called it styrol oxide (styroloxyd) as he believed the change was due to oxidation. However, in 1845 two scientists John Buddle Blyth and August Wilhelm von Hofmann demonstrated the same conversion of styrol into styroloxyd, in the absence of oxygen. This was possibly the first artificially synthesised polymer. It was only in 1866 that another scientist Marcellin identified the conversion of styrol into styroloxyd as a process of polymerisation.

Picture 1 - Objects made from Parkesine
Source –https://blog.sciencemuseum.org.uk/alexander-parkes-materials-man-and-polymath/

Alexander Parkes invented a material in 1856 he called 'Parkesine', which is considered as the first man-made plastic. Parkes treated cellulose with nitric acid to create pyroxylin which was in turn dissolved in alcohol. Parkesine was transparent and flexible which could be moulded, shaped, and coloured when heated and cooled into a hard, durable material that could be used in various applications. As an affordable substitute for ivory, Parkesine was used for buttons, combs, and handles for cutlery.

Picture 2 - Billiard Ball made from Bakelite
by John Wesley Hyatt

John Wesley Hyatt was reportedly inspired by an offer for $10,000 by a New York firm for any person who could provide a substitute for Ivory. Hyatt improved on Parkesine by treating it with camphor to yield a substance, he named Celluloid, which could be moulded, shaped, drilled, polished, or pressed into thin sheets. While both Parkesine and Celluloid were developed from natural cellulose and synthetic materials, 'Bakelite' was the first 100% percent synthetic material, a thermoset made through the reaction of phenol and formaldehyde, in 1907.

Leo Baekeland was born in Belgium on 14 Nov 1963. Post acquiring a PhD, summa cum laude, in chemistry from Ghent University, Belgium at the age of 21 he moved to the United States of America in 1889.

He worked for the E. and H.T. Anthony photographic company for two years before setting himself up as a consulting chemist. Within a few years he invented the first commercially successful photographic paper named 'Velox'. He sold the invention to Eastman Kodak for which he himself reportedly earned $1,25,000. However, a non-compete clause in the transaction prevented him from undertaking further research in the field.

Picture 3- Bakelizer, used by Baekeland (1907- 10) to form Bakelite. Source https://www.sciencehistory.org/historical-profile/leo-hendrik-baekeland

He started working on reactions between phenol and formaldehyde and was able to make, a soluble phenol-formaldehyde which he named Novolak, as a replacement for shellac (which was made from secretion of lac beetles and widely used for insulating electric cables). However, Novolak was not a commercial success and in summer of 1907, Baekeland shifted his focus to strengthening wood by impregnating it with a synthetic resin. He named the substance as 'Bakalite'. Bakelite was good insulator, durable, and heat resistant, and could be shaped and moulded as required. Further, unlike celluloid, it could be mechanically mass produced. He marketed it as "the material of a thousand uses".

Birth of Polyolefins

The end of World War 1 saw Bakelite experiencing rapid growth. The invention of bakelite and its multifarious uses spurred further research and new polymers, like polystyrene, polyvinyl chloride, polyethylene, and nylon were invented. Plastics were finding greater applicability in clothing, movie and television sets, car accessories, etc.

Polystyrene, a light weight, water resistant and buoyant, long chain hydrocarbon was first manufactured in 1931 as a replacement for die-cast zinc. It soon became a replacement for rubber and was also used in a blend of rubber which created styrene-butadiene rubber.

In March 1933, Polyethylene was accidently invented by two chemists working in the Imperial Chemical Industries Research Laboratory, in England. While setting off a reaction between ethylene and benzaldehyde, in an autoclave, a supposed pressure leak resulted in the formation of waxy substance resembling plastic. Analysis of the experiment revealed that the primary reason for reduction in pressure was a result of polymerisation and not leakage. The material so formed was polyethylene. Seeing the potential of the newly formed polymer, it was initially kept a secret and used by the British military during World War II[iii].

As the use of plastics was getting popular, the Society of Plastic Industries was formed in the US in 1937. The society comprising various plastic manufacturers started promoting the use of plastics in everyday life.

The start of World War II spurred the production of plastics. Nylon invented by DuPont in 1939 as a synthetic silk was rationed by the US military and used to make ropes and parachutes. Dow Chemical Company created expanded polystyrene (EPS) in 1941 which was used for insulating vehicles. Everything from tent canvas to waterproof clothing and hand grenades to battle tank components were being made from polyvinylchloride. The United States invested heavily in plastic production during the war, including not only in plastic manufacturing units but also in refineries.

Picture 4- First Poly bag

The end of World War II resulted in a glut for plastics. It was then that various other uses of plastics were invented. Sten Gustaf Thulin invented the plastic bag in Sweden in 1959. During that time paper bags were being used by the people in Sweden for most packaging. However, these bags resulted in many trees being cut. Sten realised that this would cause great harm to the environment. He set upon inventing a plastic bag that would be strong, lightweight and would last a very long time so that people could keep using it again and again. While working with a company named Celloplast, he invented the polybag, which was patented in 1965.

The decades following World War II saw a great increase in the use of plastics. Plastics, because of the unique qualities of being light weight, highly durable and high strength to weight ratio have become the material of choice for a variety of applications from medical devices to food packaging.

As the quality of the polymers improved, it became the material of choice especially in packaging. It soon replaced glass even where bottles were being used. Nathaniel Whyte had joined DuPont in 1936 as a field engineer. In 1967, he started experimenting with various polymers to store soda in a plastic bottle. In 1973, he adopted Polyethylene Terephthalate (PET) as the material for bottles and got a patent for it. In 1978, the Coca Cola Company introduced the first 2 litre PET bottle into the market.

Today, plastic has taken a permanent place in the life of almost every single individual of the planet. It is found in clothing, fast moving consumer goods, tools, vehicle parts, aerospace applications, packaging, medical devices, and electronics. There probably isn't any facet of our life which has not been touched by the need of plastic.

Production of Plastics

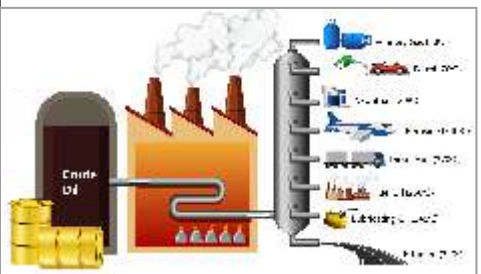

Figure 1 Crude Oil Distillation Process
(Image Source: https://www.freepik.com/free-vector/crude-oil-distillation-process-isolated-white_9956782.htm)

Plastics maybe produced from polymers synthesized from crude oil and natural gas or they may be bio-based wherein the polymers are derived from sources such as corn-starch, vegetable fats and bacteria.

Crude Oil is a sludge like substance made up of hydrocarbons and is drilled out of the Earth. This is the primary source or the raw material for making plastics. The crude oil is transported into a refinery where it undergoes various processes. Once crude oil is heated it separates the hydrocarbons into different groups, which are based on the number of atoms they possess and the resultant molecular weight. This heated crude oil is fed into the distillation tube where the heavier longer hydrocarbons sink to the bottom, and the shorter lighter hydrocarbons rise to the top. The crude oil therefore gets separated into various distinct groups of chemicals, like petroleum, gasoline, paraffin, etc., each group having hydrocarbons with similar weight and length. One such group is Naphtha, which is the feed stock for making plastics.

Naphtha contains ethane and propene, the two crucial compounds required in producing most of the plastic products. The Naphtha is subject to high heat and high pressure in the absence of oxygen. This process, referred to as thermal or steam cracking, breaks down the hydrocarbons into shorter molecules like propylene and ethylene which are also known as monomers. The next step is called polymerization. In this process individual monomers are chemically combined into long repeating chains also known as polymers. In the case of ethylene and propylene, the polymers obtained are polyethylene and polypropylene both of which are the most used polymers today.

About Us

Greengen Polymers Pvt Ltd is a tech-enabled polymer recycling company incorporated with the aim to bring corporate systems filling in the vast gap of unorganized polymer recycling industry segment in India. We provide end-to-end solution towards a circular economy along with setting high industry benchmarks for Environmental, Social and Governance (ESG) norms. It was conceptualized by industry veterans, ex-Founders and Promoters of Next Polymers Ltd (now Celanese NYSE:CE) Promoters of JP Polymers Pvt Ltd (India) and A~Star Plastics Pte Ltd (Singapore & Malaysia).

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QUALITY GRANULES

Our global network and teams give us the edge of having a world-wide connect for inputs on trends, news, product development and exposure to industry-best Recycling-Tech. We are using state-of-art, global technology that assist us in giving high performance materials with consistency of quality along with zero discharge in the environment.

Customer Proposition

- Customer can expect good quality recycled polymers or regrinds with complete traceability, certifications along with consistency in supply. Our tech ensures minimum degradation of polymers while recycling and can deliver better value in production in terms of quality and cost.
- Our products tend to be proven for mandatory recycled content addition in components as per the compliance required by MNCs and law in various applications covering automotive, consumer electronics, writing instruments, construction industry segments etc.
- We have a Pan-India distribution reach, with on ground team and warehouses in every region.

Supplier / Manufacturer Proposition

- All kinds of Polymer processors can contact us to reduce the waste impact by offering to clear the scrap, waste and end of life products that you desire to dispose or even sell.
- We commit to offer a fair market established price along with GST credit and following ethical practises for your waste disposal. We provide on-door collection service through our on-ground team of experts that help inspect, identify, segregate, value and collect in real-time through our robust Pan-India supply chain network.
- We would assist you in improving your ESG score and help you meet circular economy and sustainability goals through our certified recycling facilities.

We procure and process polymers in all forms – components, runners, regrinds, yarn, granules and recycle them, capturing the entire spectrum of Polymers such as PP, PE, PA6, PA66, ABS, PC, PMMA, POM, PPE, TPU, PPS, LCP, PBT, etc.

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Visit us at Plastindia 2023 exhibition between February 1-5, 2023 at Pragati Maidan, New Delhi. Hall No.:- 4H-FF - Stall No.:-G-27

The History of Plastic Recycling

The expansion of the plastic industry in the United States started during World War II. The need for preserving scarce natural resources necessitated the production of synthetic alternatives. Nylon, invented by Wallace Carothers in 1935 as a synthetic silk, soon found utilization in parachutes, ropes, helmet liners and even body armour to name a few. Plexiglas another plastic product was found to be a suitable replacement for windshields and aircraft windows. The increased use of plastics continued unabated slowly replacing metal in vehicles, glass and paper in packaging and wood in furniture.

With this increase in consumption, plastic debris was first noticed in the oceans around 1960. Subsequently, the first Plastic Recycling Plant was started in Conshohocken, Pennsylvania, USA in 1972. Soon thereafter the government and environment activists started educating the people and the industry about the need for recycling. The polymers HDPE and PETE were invented keeping the need for end-of-life recycling requirement.

An oil spill off the Santa Barbara coast in 1969, resulted in observance of Earth Day from 1970, as people started to worry about the adverse impact of human activity the next year. During a design contest, in 1970, Gary Anderson a 23-year-old student, designed what is now termed as the recycling triangle. As per Gary Anderson, the figure was designed as a Möbius strip to symbolize continuity within a finite entity.

Figure 2- Andersons Original Triangle
(Source - https://thedieline.com)

In 1988, the Society of Plastics Institute (SPI) developed a system of codes also known as the Resin Identification Codes and the symbol was three arrows forming a triangle with a number in the center. Over a period of time, these symbols have become synonymous with recycling and are often referred to as Recycling Symbols.[iv]

Indian Context

Recycling as a concept in India can be traced back many centuries. Since most of the material used in the society was organic in nature it would decompose naturally. In case on non-organic material like metals, they would be smelted and recast back into new objects. Since most of the commodities were consumed immediately, the packaging requirements were minimal.

The India plastic industry made a vigorous start in 1957, though at that time disposal of used plastic products into the waste stream was seen as a major problem. During the time, most of the plastics and products were imported into the country and the process of recycling started rather accidently. When supply side shortages grew the industry found ways and means of reusing/ re-purposing the available plastic.

Notably amongst the first plastics to be recycled were methyl methacrylate sheets which used to be imported and used for decorative applications in the 1940s and 50s. Used sheets were then melted and recast into sheets and other applications. Similarly, acrylic sheets were recycled into coloured sheets post use. Celluloid/ cinematographic films which had been used / rejected were recycled into bangles. All these processes were carried out in small industrial sheds located in suburbs of Mumbai, viz., Goregaon, Kandivali, and Malad. While bakelite scrap was recycled into electrical applications, cellulose acetate was recycled into spectacle frames, umbrella handles and combs. Similarly, urea formaldehyde and cellulose butyrate was recycled into buttons and fountain pens respectively.

In the 1970s, in Kolkata, ragpickers would collect PVC scrap from dump-yards and supply to small recycling units where they were converted into cheap quality buckets, mugs etc. Since these buckets would crack very easily, there was a time in the 1970s that people went back to using metal buckets. Thereafter, PE/PP/ HD/ LD started being used for moulding cheap quality buckets and mugs. During the same period, Spritz Automation was the only company supplying injection moulding machinery for moulding of recycled products.

By 1979 the market for plastics was being run by the state owned Indian Petrochemical companies. With the opening up of the economy in the mid-1990s, the advent of numerous foreign players and their products, the requirements for packaging material increased considerably.

Soft drinks were sold exclusively in glass bottles till about 1993 while cooking oil was sold in metal cans. A deposit return system was fully functional then wherein the local grocer would accept the empties and return the deposit. Even soft drink companies like Coco Cola and Parle had established reverse logistics chains for collecting and reusing these bottles. In fact, every company had a specific shape to their bottle so that it would be easy to identify and be returned to its rightful owner.

The introduction of the plastic bottle sometime in 1993-94 sounded the death knell of the deposit return system and discarded plastic bottle started becoming a nuisance in most cities and towns. Plastic bags saw a multi fold increase in use replacing paper, metal, and glass packaging. The plague scare in the city of Surat resulted in a public outcry against the poor state of public sanitation across cities and the Govt. of the day started looking into disposal techniques for waste plastic packaging in a serious way.

The guidelines for Recycling Plastic were introduced by the Bureau of Indian Standards in 1998 vide IS14534. The first Plastic Waste Management Rules promulgated in 2009 mandated that all plastic recycling be done in accordance with the Indian Standard.

Recycling

Understanding the Terms

Subsequent to the focus of the world shifting to the issue of climate change and sustainability and the propounding of the Circular Economy model by The Ellen McArthur Foundation, Recycle as term has found regular use in the international lexicon especially when addressing the issue of waste. Consequently, two new derivatives of recycle, viz., upcycle and downcycle, (both of which did not feature in dictionaries about two decades ago), are now in common use.

It is therefore necessary that the meaning of the term(s) Recycle, Upcycle and Downcycle be well understood.

The term recycle (verb) is defined in the Pocket Oxford English Dictionary as:

"return (material) to previous stage of cyclic process, esp. convert (waste) to reusable material.

On the other hand, the Collins English Dictionary define recycle (verb) as:
"reprocess (used material) for further use"

A look at the current definition in Collins dictionary available on the internet:-

1. to pass (a substance) through a system again for further treatment or use
2. to reclaim (packaging or products with a limited useful life) for further use
3. to institute a different cycle of processes or events in (a machine, system, etc)
4. to repeat (a series of operations)

As can be seen from the above, the definition may be interpreted in various ways, i.e., to process for re-use, to process for further use, to reclaim, etc.

The Cambridge Online Dictionary defines Upcycle as "to treat an item that has already been used in such a way that you make something of greater quality or value than the original item[viii]", the term Downcycle, is defined as "a time

when there is less economic activity or when prices or values of somethings are falling low[ix]" (The term is not found in the Oxford Learners Dictionary, online edition).

On the other hand, the Merriam-Webster Online dictionary has very specific definitions for both the terms:

Upcycle - to recycle (something) in such a way that the resulting product is of a higher value than the original item; to create an object of greater value from (a discarded object of lesser value).[x]

Downcycle - to recycle (something) in such a way that the resulting product is of a lower value than the original item; to create an object of lesser value from (a discarded object of higher value).[xi]

As can be seen from the various definitions, there is no clear understanding of the three terms. Deciding on value of the material / product, whether higher or lower than the one being recycled is subjective and not easily defined.

In the Environmental context, the United Nations Environment Programme (UNEP), Law and Environment Assistance Platform (LEAP) defines Recycling as -

"A resource recovery method involving the collection and treatment of a waste product for use as raw material in the manufacture of the same or a similar product[xii]".

Therefore, in terms of the environmental context, recycling of waste plastic should be such that the output can be used as raw material to manufacture plastic products.

Classification of Plastics

Before exploring the methodologies of recycling plastics, it is essential to understand the main classification of plastics insofar as the degree to which the chemical processes in manufacture of the material are reversible.

Thermoplastics do not undergo chemical changes on heating and can therefore be moulded repeatedly. Polyethylene (PE), Polypropylene (PP), Polystyrene (PS), and Polyvinyl chloride (PVC) are examples of thermoplastics.

Thermosets, or thermosetting plastic on the other hand can be melted and shaped only once. The process is irreversible in the sense that if they are reheated, they do not melt but decompose. Vulcanized rubber, Bakelite, Polyurethane, Epoxy resin and Vinyl ester resin are examples of thermoset plastics.

What is Plastic Recycling

A process in which pre-consumer and post-consumer plastic waste is treated through several processes like segregation, washing, shredding, drying, agglomerating, extruding and finally being converted into pellets or products.

However, not all waste plastic can be recycled in the above manner due reasons of contamination and material properties. The high calorific value and plasticity, inherent in plastic waste can, in such situations, be tapped to convert the waste into fuel thereby replacing use of fossil fuels in certain applications.

The stated methodologies for processing plastic as per a report published by the Central Pollution Control Board (CPCB) are: -

1. **Primary Recycling** (Conversion of waste plastics into products having performance level comparable to that of original products made from virgin plastics).

2. **Secondary Recycling** (Conversion of waste plastics into products having less demanding performance requirements than the original material).

3. **Tertiary Recycling** (The process for producing chemicals/fuels/similar products from waste plastics).

4. **Quaternary Recycling** (The process for recovering energy from waste plastics by incineration)

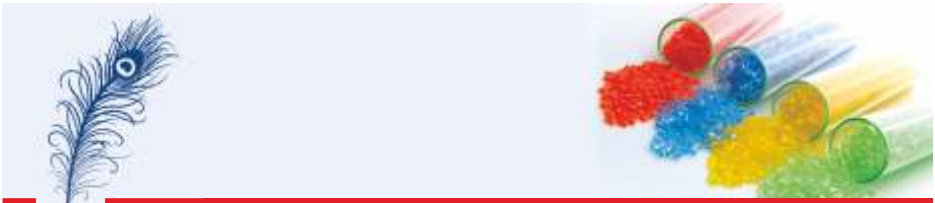
Primary Recycling

As discussed above, primary recycling refers to conversion of plastic waste to products having similar performance levels. The waste maybe processed directly into products or made into granules which can be processed into same or similar products. Ideally, closed-loop recycling takes the recovered material and uses it back in the original application. An example of primary recycling is where PET recovered from postconsumer bottles is used in the production of new bottles. Only thermoplastics can be recycled by this method.

Secondary Recycling

Recycling methods involving conversion of waste plastic to other products, like yarn, sheets, etc maybe considered as secondary recycling. In this process, the output recyclates may be used make products other than the original product. The most common form of such type of recycling is making polyester yarn from waste PETE bottles.

Both primary and secondary recycling is usually undertaken by mechanical recycling of waste plastic.



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Mechanical Recycling

Operations that aim to recover plastics through mechanical processes are known as Mechanical recycling. These processes involve Machines for segregation or sorting, cleaning (or washing), drying, agglomeration or grinding followed by extrusion. During extrusion, proper filtration of waste and compaction or venting of the contaminants are important to achieve good quality granules. Through these processes recyclates are produced which can be converted into plastics products, thereby substituting virgin plastics. Mechanical recycling is also referred to as Material Recycling, Material Recovery or Back-to-Plastic Recycling.

Collection and Sorting

Once collected the plastic waste must be segregated (sorted) based on the colour, density (type of polymer).

Cleaning and Drying

Once the plastic waste has been sorted based on density (type of polymer), the material is washed and dried.

Figure 3- Safai Saathis (waste pickers) sort materials at Swachhta Kendra facility in Patna, India. Photo: UNDP India

Agglomeration

Once the material has been sorted into a fairly homogenous stream and washed cleaned, agglomeration is carried. Agglomeration helps increase the bulk density of waste, which ensures good feeding for some plastication units.

Grinding

In some cases, grinding of the sorted and clean plastic waste is resorted to. The aim of grinding is like that of agglomeration wherein the feeding of the material into the extruder is better.

Extrusion

Once the plastic waste has been ground/ agglomerated the same is fed into an extrusion machine which yields pellets/ granules. These pellets/ granules form the raw material for new plastic products.

Tertiary Recycling

Also termed as chemical recycling, this method involves conversion of waste plastic into various types of fuels. There are many processes that are used like pyrolysis, gasification, and hydrogenation.

Quaternary Recycling

This method involves converting the plastic waste into energy, which can be used to power processes instead of using fossil fuels. Due to high calorific value of the plastic, it is used as fuel especially in cement kilns, thereby saving precious fossil fuels.

Other Methods

In addition to the recycling methods mentioned above, waste plastic is also used in road construction. In this process plastic waste from bags, cups, thermocole etc, which comprise of PE, PP and PS are separated, cleaned, and shredded so that they can pass through a 4.35 mm sieve. The aggregate (granite) used for road making is heated to a temperature of 170° C and the shredded plastic is added. The plastic softens due to heat and coats the granite. At this stage, hot bitumen is added and mixed well. The bitumen and the polymer mix well in a molten state and coat the aggregate. This mixture is used in laying roads.

Technologies for Recycling Plastic Waste

Mechanical Recycling (Extrusion)

As seen earlier mechanical recycling comprises of processes involving sorting/ segregation, washing/cleaning, drying, shredding, agglomeration, and extrusion.

Segregation/Sorting

The first step on receipt of the waste plastic at the recycling plant is sorting. There are several different types of plastic, which need to be separated from each other by recyclers. Further to that, plastics might be sorted by other properties such as colour, thickness, and use. Traditionally, in India and indeed most of Asia, sorting and segregation is undertaken manually. However, machines are now available, and this increases the efficiency of plants and avoid the contamination of end products. Multiple methods of sorting are available.

Manual Sorting

The manual sorting process is slow and labour intensive. In India, informal sector plays a big role in providing jobs for these workers. The informal plastic recycling networks are estimated to provide employment and livelihoods to about 250,000 workers and are responsible for the country's exceptionally high plastic recycling rates, estimated between 48%-60%. In this process, individuals physically sort various grades of plastic by feel and colour by sight.

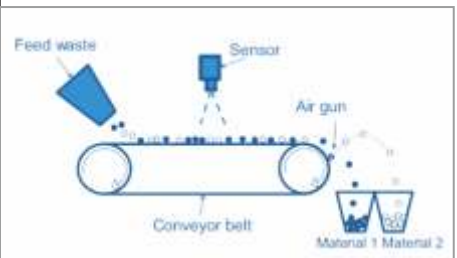


Figure 4-Air Separation of Plastic Wastes (Source: Science Direct)

Air Separation

The Air separation technology involves, fans or air guns which create a column of air moving in a specific direction to move waste items. While the waste is being moved by the column of air, low density materials are blown in one direction, and high-density materials in another direction. Light materials, like paper

and plastic bags, pass along with the air and enter a separator from where they fall out of the air stream. The strength of the air currents, the design of the air separator (e.g., zig-zag air separators) and how materials are introduced into the column all influence the quality and efficacy of the air separator. Moisture content plays an important role as it may cause some materials to stick or weigh down other materials.

Float and Sink Separator Sorting

Sink Float Separator tanks also known as Swim and Sink Tanks work on the simple principle of difference in density of different polymers are also used for sorting. The heavier polymers sink to the bottom while the lighter ones are skimmed off from the surface.

Figure 5 - Sink and Float Separator (Source - B+B Anlagenbau)

Type of Polymer	Density (g/m3)
PP	0.89 – 0.91
LDPE	0.91 – 0.93
HDPE	0.94 – 0.96
PS	1.04 – 1.11
PVC	1.20 -1.55
PET	1.38 – 1.40

Table 1 – Densities of Plastic Polymers (Source: Amesweb)

A separation liquid with its density in between the type of polymers that are to be sorted is used. Water with density of 1 g/m^3 mostly used as the separation liquid and its density changed with additives where required.

Waste plastic is introduced into the sink float tank filled with water tank by mean of a conveyor. Plastic pieces heavier than water sink to the bottom and are removed through a suitable mechanism, like a screw conveyor. The pieces of plastic which float on water exit the tank from the top. This method is also used after washing and processing to identify and separate plastics.[xvi]

Figure 6 -AI Powered Robotic Arm.(Source: Ishitva Robotics Systems)

AI Powered Robotic Sorting

Advanced machine vision systems deploy robotic arms to sort various types of plastic. Once a particular type of plastic has been identified by the machine vision system, it directs a robotic arm, which picks up the plastic material from the conveyor belt and drops it into the respective container.

Optical Sorting Systems

Optical Sorting methods are usually non-destructive, contactless and use low-energy excitation sources. Spectroscopes can reliably identify molecular identity of the waste material (spectral signature). Different type of spectroscopes like, Raman spectroscope (RS), near-infrared spectroscope (NIRS); Fourier-transform infrared spectroscope (FTIR); and terahertz spectroscope (THz) maybe used in such systems.[xvii]

Such systems also known as optical sorting systems examine the reflected light waves from different materials. Since each polymer has a unique light absorption spectrum, this can be identified by a spectrometer. Such a system can also be used to sort a mix of materials including plastic, glass, wood, paper, cardboard, etc.

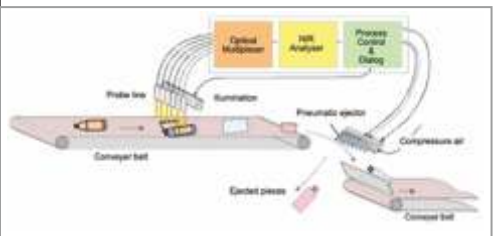


Figure 7- NIR Auto Sorting System. (Source: Ecotrade)

The system can be programmed to identify different types of plastics including PET, coloured and transparent HDPE, PVC, PP, etc. Once the plastic waste is loaded onto a conveyor belt it is moved under a bright light. A series of camera lenses record the light bouncing off the plastic material. On identification of the type of plastic, the position of the material on the conveyor belt is calculated by the system controller and a directed jet of air separates it from the belt. The ejected material is collected in specific bins.[xviii]

The Council of Scientific and Industrial Research (CSIR) Chennai Complex has developed a plastic waste sorting machine based on the Near Infrared Spectroscopy technology. The system can sort the waste plastic into five types, viz., PET, PP, PVC, PS, and PE. This helps in sorting of plastic waste for recycling.[xix]

Electrostatic Sorting

PET and PVC can be sorted based on electrostatic charge difference between the two polymer types. Hamos has developed a sorting system based on this technology. On passing through a charging unit, the PET particles get positively charged and PVC particles get negatively charged. The mixture is the moved to a high voltage field where PET and PVC pieces separate from each other due to difference in charge.[xx]

Holy Grail - Digital Watermarking Technology

A collaborative between The European Brand Association (AIM) and The Alliance to End Plastic Waste (AEPW), facilitated by the Ellen Mac Arthur Foundation with support from Procter and Gamble (P&G), Holy Grail Pioneer Project, explored various initiatives for improving post-consumer recycling by using chemical tracers and digital watermarks. Digital watermarks technology was identified to be the most promising new technology, thereby opening new possibilities for sorting. 'Intelligent packaging', has the potential to be used in other areas such as consumer engagement, supply chain visibility and retail operations. The Holy Grail Pioneer Project has been followed by Holy Grail 2.0, a cross-value chain initiative, where over 130 companies and organisations have joined forces to assess how a pioneering digital technology can enable better sorting and higher recycling rates.

Figure 8- Holy Grail Digital Watermarking Technology (Source: P&G)

PRISM Project

Nextek, Brunel University, Tomra, CCL, Mirage Inks, Johnson Matthey, Enlightened Lamp Recycling, Cleantech Europe and WARP are conducting a project named PRISM. The project aims to recover difficult to sort, high value material from packaging, which due to lack of appropriate technology is considered low in value in the recycling market or ends up in residue in MRFs.

Figure 9- Invisible Fluorescent Labels.

Invisibly coded labels with high performance luminescent compounds, easily detectable by high-speed automatic sorting equipment are being developed. The project targets recovering high value packaging material. The project aims to help brand owners ensure packaging reaches the recycling loop and boosts UK recycling performance.

Additionally, development of luminescent material from non-rare earth-based compounds as well as from materials recovered by recycling fluorescent lamps is planned. The new technology is expected to increase recycling yields by sorting materials such as food PP packaging, HDPE milk bottles, and sleeved PET.[xxi]

Washing and Shredding

To remove physical impurities, like grease, oil, dirt, glue, etc., in the waste plastic, the sorted plastic needs to be washed. This is a critical step in the plastic recycling process since impurities impede operations, or even ruin a batch of recycled plastic completely. Product labels with adhesives, dirt and food residue are the impurities targeted in this step.

While the term Washing is commonly used, the sink float separators primary aim is that of sorting the various grades of plastic waste using the water as a separation media, to separate e.g., plastics with a density lower than water (e.g., PE, PP) from plastics with a density higher than water (e.g., PET). The water density is modified (e.g., with salt) to separate polymers with a density higher than water. "Washing" is more of a side effect. [xxii]

Some of the methods for washing waste plastic are described in succeeding paragraphs.

Most plastic washing plant lines start with a shredding/crushing machine. The washing process starts inside the shredder/crusher. The shredder/crusher is used to downsize the plastic waste into a uniform size before entering the washing line. Thereafter, high speed separator(s) remove excessive water along with dirt from plastic. The plastic is then transferred to the washing pool where, polyolefin types of plastics float and heavy

contaminants sink to the bottom, which are removed. The floating plastics are usually removed manually. Once the washing process is completed, the material is dried and/ or agglomerated.

Drying

Many plastic resins like Polycarbonate, PET, nylon, etc are hygroscopic. The moisture results in reducing the length of the polymer chain due to a process known as hydrolysis. Since short chain polymers make poor products, it is necessary to remove moisture from the raw material. Processing of raw material containing moisture may result in numerous issues such as poor product quality in terms of appearance and strength. Conversely, over drying the material at very high temperature is also detrimental to product quality.

There are multiple technologies deployed for drying.

Dehumidifying Dryers.

These machines employ extremely dry air to remove moisture from the material. The air is forced through a desiccant bed. Thereafter it is heated and forced into the drying hopper which contains the material. The moisture is drawn out by the hot air and the saturated air is fed back over the desiccant to remove the moisture. This cycle continues till the required amount of moisture from the material is removed. The desiccant is removed and dried at regular intervals. Typically, regenerative, or twin tower dryers are utilised wherein once the desiccant in tower is saturated with moisture, the air is automatically fed through the other tower. In the meanwhile, the first desiccant bed is dried out and made ready for use.[xxiii]

Figure 10- Dehumidifying Dryer (Source - Reynold India Pvt Ltd)

Rotary Wheel Dryers

These dryers permit selection of the air dew point in the system, thereby obviating the chances of over-drying of the material. Additionally, these dryers are energy efficient and cost effective as compared to dehumidifying dryers. In some cases, the rotary dryers may save up to 40% in energy consumption as compared to the most efficient twin desiccant dryers.

Rotary Dryers comprise of a rotating wheel which continuously puts dry desiccant into service. This is possible due to dryers' ability to regenerate moisture saturated desiccant in the same rotational cycle. These dryers usually use three times the amount of desiccant as compared to dehumidifying dryers. Rotary dryers do not require chilled water and compressed air, thus making them cost effective.[xxiv]

Low Pressure Dryers

Figure 11- LPD Dryers (Source - Maguire)

Also called **Vacuum Dryers**, these dryers employ vacuum to lower the boiling point of water from 100 °C to 56 °C. Moisture is rapidly removed from the heated material. Low Pressure Dryers are capable of drying materials in 1/6th of the time as compared with traditional dryers. There is no desiccant used in the system and hence reduces cost and time taken to replace the desiccant). There is reduced risk of material degradation due lower drying time involved when using these machines.

Compressed Air Dryers

Figure 12- Compressed Air Dryer - Installs to Machine Throat (Source ConAir)

These dryers are compact and light in weight ad while they can be free standing, they can also be mounted on the input area of the processing machine. These dryers are usually employed when the throughput is smaller. Very similar in operation to the Dehumidifying Dryer, they utilise compressed air in lieu of electrically driven mechanical blowers.

Hot Air Dryers.

Figure 13 - Hot Air Dryer (Source - Bry-Air)

These are probably the simplest of dryers available. They are usually used when material is stored out in the open and needs to be heated along with removal of moisture. The dryer usually comprises a chamber where the material is placed, and hot air is blown through the chamber.

Prefeeding Preparation

In order to feed washed or industrial clean waste to machines there are 3 ways to do it:

Agglomeration

To make the material suitable to be fed into the extruder, a process of agglomeration is necessary. An Agglomerator is a round Mixer like chamber with five to nine stationary and two rotating blades at the bottom of the machine. The blades rotate at high speed and create friction plus heat. This process, performed at a temperature below the melting point of the material by means of frictional heat, ensures that the material properties are preserved to a great extent. In this stage, the operator sprinkles some water to shock the material and control the load of the equipment which is cutting the waste into small pieces. Once the water evaporates, the material starts to make small popcorn like pellets which are discharged from the machine. Agglomerators are also used as material drier and densifier and can reduce moisture content to less than 10%. This process also eliminates high-cost thermal drying requirements.

Figure 14 - Agglomerator (Source: Ashwin Engineers)

Densification / Cutter Compaction

It is a similar system as Agglomeration, but the process is online and the same is fixed to the extruder to feed the densified/compacted waste directly to the Extruder without human contact. This system is good for feeding light weight material like: Film, Raffia (Woven Sacks/Jumbo Bags/ Big Bags), Fibre, Filaments, Cut Fish Net, Finely Ground Injection or Blow Moulded, EPS, XPS, EPE waste. An Additional Feeding Screw in between the Densifier and Extruder can assist to compact the waste and improve consistency of output.

Forced Fed System

The Pre-Ground Waste is fed to a Silo with an Anti-bridging device which helps to feed material consistently to a Feeding Screw (Straight or Conical as per the type of Waste) to feed the ground waste to the extruder at a fixed rate

preset by a AC Drive manually programmed. This technique of feeding helps to compress the material and feed the material to the extruder thereby eliminating gases, moisture, and compacting the material which will help the Vent on the extruder to eliminate the contaminants like gases, burning, moisture, steam, vapor, etc., through the vent and also compact the material. This also helps to consistently maintain the output of the extruder at one preset output. Waste like film, raffia (woven sacks / jumbo bags / big bags), injection / blow / roto moulded, pipe, EPS, EPE, XPS waste feed well with this system.

Extrusion

Traditional Technology

The agglomerated/dried plastic flakes are then put through an extruder (single/ twin screw). The plastic raw material is plasticated by means of a screw plastication unit and the molten material is continuously pumped out through a standard orifice (die) in order to take the shape. This shape is passed through a cooling system and then sized as per requirement. An extruder converts solid plastic into a uniform melt by the effect of heating, pressurizing and shearing after which it is sent to the next process. The procedure of melting involves processes like mixing color, master-batches, blending resins and re-grinding. A typical extruder consists of a barrel with a screw (or twin screw). A heating system is provided throughout the barrel. At the end of the barrel is a die which dictates the size and shape of the plasticised material. Associated equipment for functioning of the extruder include a hopper (for loading the plastic scrap), a gear box, drive motor and cooling fans. The output of the extrusion is usually plastic granules which are used as raw material for manufacturing products.

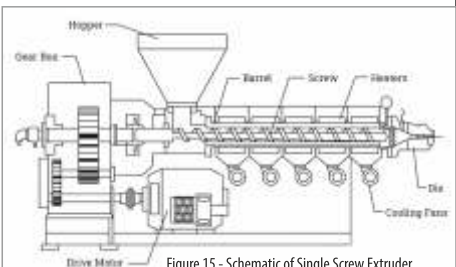


Figure 15 - Schematic of Single Screw Extruder
(Source: https://engineeringlearn.com)

Advanced Densifier / Cutter Compactor Technology Recycling

In this case the extruder is fed directly with the densifiable waste like film, raffia (woven sacks / jumbo bags), fibres, filaments, non-woven fabric, to be cut and agglomerated. In this online equipment the material does not

Figure 16- Schematic of Single Screw Densifier Type Recycling Extruder (Source https://www.recycleplastics.in)

agglomerate as much as the standard Agglomerator, and neither is water required to be sprayed at regular intervals. The Densifier cuts and feeds the material directly to the extruder or through a Feeding Screw. The Extruder converts solid plastic into a uniform melt by the effect of heating, pressurizing, and shearing after which it is compressed using a compression type Single Screw system. In the compression zone is placed a vent where the gases, moisture, steam are eliminated by gravity or using a water ring vent pump. A heating system is provided throughout the barrel. At the end of the barrel is a die which dictates the size and shape of the plasticised material or a Dieface Cutter which cuts the melt and pours the material in the cooling chamber and then a centrifugal drier which gives close to 98% dry granules.

Advanced Forced Feeding Technology Recycling:

In this case the extruder is fed directly with groud waste like Film, Raffia (Woven Sacks/ Jumbo Bags), Injection/Blow/Roto Moulded or Pipe and Agglomerated Waste. A Grinder with blower can be fixed before the Forced Feeder to feed the cut/ground waste directly to the machine without human intervention. An Anti-bridging silo is used to collect the waste received from the Grinder and fed to the Feeding Screw below the silo. The material is fed with a Feeding Screw (Straight or Conical as per waste type) directly to the extruder throat. The Extruder converts solid plastic into a uniform melt by the effect of heating, pressurizing, and shearing after which it is compressed using a compression type Single Screw system. In the compression zone is placed a vent where the gases, moisture, steam are eliminated by gravity or using a water ring vent pump. A heating system is provided throughout the barrel. At the end of the barrel is a die which dictates the size and shape of the plasticised material or a Dieface Cutter which cuts the melt and pours the material in the cooling chamber and then a centrifugal drier which gives close to 98% dry granules.

SSFigure 17- Schematic of Single Screw Forced Feeder Type Recycling Extruder (Source https://www.recycleplastics.in)

PET to Yarn

The PET waste is first sorted into clear and coloured bottle waste and then shredded into flakes. This releases the enclosed water and liquid. The flakes are then processed in a bath. Here the caps and labels which are made of Polypropylene, float and can be removed from the PET flakes. For removing the stickers and labels the flakes are treated in another bath which contains caustic soda. The flakes are then dried in rotating drum ovens (for about 8 –10 hours) to remove moisture.

Figure 18- Rotating Drum Ovens
(Source National Geographic)

Figure 19- Polyester Fiber being wound on Bobbins
(Source: National Geographic)

The flakes are then moved through an extruder. At the output end is a sieve (spinneret) through which the plastic is formed into long strings which are collected in a container. These threads solidify as they come out of the extruder. These threads are then combined and stretched several times under heat. This helps to bond the fibres together. The fibre is then torn apart and made into a fluff.

The fluff is then corded. Cording a procedure where the bonded fibres are brushed together so that all fibres lie in a similar direction.

This helps in strengthening the material. The sheet of polyester felt that emerges is then teased into thread.

Figure 20 -Extrusion through a spinneret
(Source - You Tube)

Figure 21 - Polyester Fluff being teased in fiber
(Source - National Geographic)

Emerging Technologies in Mechanical Recycling

Demetallizing of Film

GMS has developed a demetallizing technology under the brand name of PLAST CLEAN. This involves high friction washing system deployed in combination with

Figure 22 - Demetallizing of films; Before and After (Source: www.recycleplastics.in)

Figure 23- PLAST CLEAN Demetallizing Plant (Source: www.recycleplastics.in)

a specialised detergent for removal of metallized coating from films. The system is capable of handling metallized films in rolls or pre-ground flake form made from any type of polymer. The specialised detergent is non-hazardous, recyclable and can be re-used in the same process. The semi-automatic process is energy efficient and ensures complete (100%) removal of metallized coating.

De-printing of Film & Raffia Waste

Removal of print and ink from plastic waste is an important function in the process of recycling. When multiple coloured plastic waste is recycled together

the resultant granules are greyish in colour. Technology is now available for removal of ink and thereby effectively de-printing the plastic waste. Plastic waste which is processed in this way can be used for replacing natural coloured virgin material. PRINT CLEAN is one such technology developed by GMS to 'deprint' plastic waste. The technology employs a system of high friction washing in the presence of a special detergent. The technology can be used for removal of print from Raffia (Woven Sack) and films. The detergent used is non-hazardous and recyclable.

Figure 24 - PRINT CLEAN; De-Printing of Raffia (Source: www.recycleplastics.com)

Recycling of EPS/EPE/XPS

Expanded Polystyrene, Expanded Polyethylene Foam and Extruded Polystyrene are some of the difficult to recycle plastics. Thermoformed Article producers and Insulation Sheet producers were selling of their waste edge trims at very low prices and losing out expensive polymer. Technology is now available by which EPS, EPE, XPS waste can be recycled into granules with the help of fully automated machines.

Figure 25- EPS Recycling Machine from GMS (Source: www.recycleplastics.in)

A technology developed by GMS uses pre-grinder with a blower to grind the waste and feed the same to the Recycling Machine Anti-Bridging Silo. Below the Silo is a specially designed screw for feeding and simultaneously compacting the Foam Waste. The waste then goes through the Extrusion section and begins to melt with the help of thermal heating and high friction heat. The melt is then compressed in the compression zone of the Screw. Gases are sucked through the barrel vent using a special high pressure water ring vacuum pump. Once the gases are eliminated the foam waste is converted to the base polymer that is Polystyrene (PS) or Polyethylene (PE). Video Link of the Machine in operation: https://youtu.be/ 3NweBZPf4PQ

Tertiary or Chemical Recycling

We have seen methods for mechanically recycling waste plastic. Waste plastic can also be processed in what is termed as Tertiary Recycling or Chemical Recycling. This involves processes or chemical agents which can affect the chemistry of the polymers. Chemical recycling is based on three main technologies.

- Feedstock Recycling
- Depolymerisation
- Purification

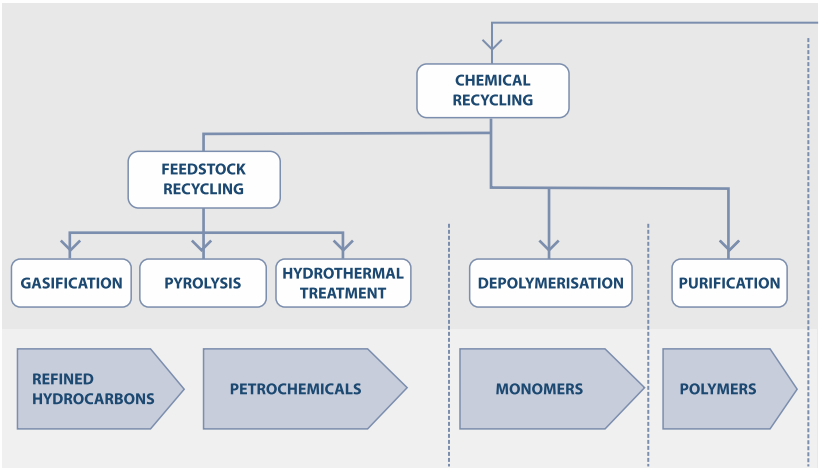


Figure 26- Chemical Recycling Processes (Source - BPF)

Feedstock Recycling

Feedstock recycling typically involves three processes.

Gasification

In this process mixed waste plastics are heated to a very high temperature (~1000 - 1500' °C) in the presence of a limited amount of oxygen. This breaks the molecules down to their simplest components to produce syngas (a mix of

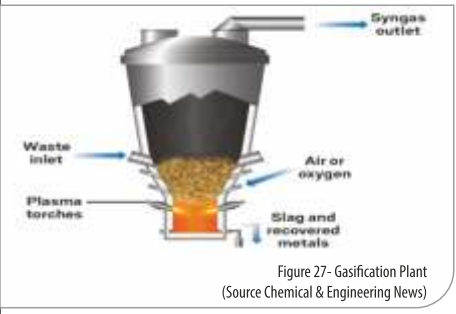


Figure 27- Gasification Plant
(Source Chemical & Engineering News)

hydrogen, carbon monoxide and some carbon dioxide). Syngas can be used to produce a variety of chemicals (e.g., methanol, ammonia, hydrocarbons, acetic acid) for plastics production as well as fuel and fertiliser.

Gasification is generally conducted in larger process units which are designed to achieve economies of scale. While the process can use mixed plastic as feedstock, it requires the feedstock to be moisture free to increase the calorific value. In order to use the syngas for chemical production, a very efficient gas cleaning system is required.

Pyrolysis

The process of breaking down plastics into basic hydrocarbons by heating in the absence of oxygen, or 'cracking' (sometimes referred to as thermal cracking) is known as pyrolysis. In this process, the total dissolved solids (TDS) which include salts, metal, anions/ cations, from water used for waste treatment, are vapourised in a low vacuum atmosphere. Surplus gas emitted in the pyrolysis process is usually used by the boilers for vapourisation. The main output from the process is hydrocarbon vapour which can be converted into various products like heavy wax, heavy and light oils, and gas by adjusting process time and temperature. These products can directly be used as fuel in furnaces, boilers, and diesel engines. A third product obtained through pyrolysis is carbon black which has a calorific value about the same as coal.

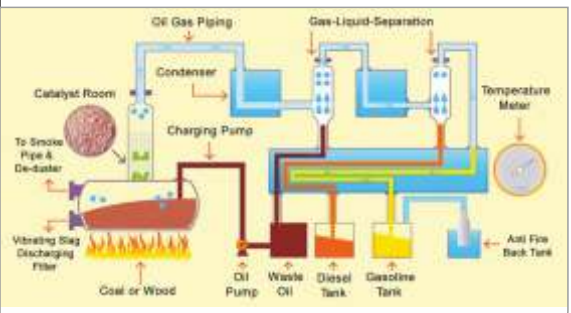


Figure 28- Pyrolysis Process (Source: British Plastic Federation)

Waste Polyolefins [Polyethylene (PE), Polypropylene (PP), Polybutylene (PB)], Polystyrene (PS) and PMMA (poly-methyl methacrylate) - acrylic glass can be processed through this method.

Hydrothermal Treatment

A reaction in which a compound is broken down by water molecules in a near-critical condition is known as Hydrolysis. The temperature of a HTT process is around 160–240 °C with the corresponding pressure to keep the water in the liquid state. The high temperature/ pressure of near-critical water makes it a good medium for dissolving organic compounds. The main reactions involved in HTT are hydrolysis, dehydration, decarboxylation, and depolymerization. The ability of near-critical water to degrade the resins and plastics in the composite wastes is largely influenced by the presence of different additives and/or co-solvents and hence the process is used for recycling of waste carbon fiber reinforced plastics (CFRP) and printed circuit boards (PCB). Hydrothermal treatment has been proposed as a solution for the separation of mixed waste (MW) into organic and inorganic substances.[xxv]

Emerging Technologies in Chemical Recycling

Purification

In this process a suitable solvent (or solvents) is deployed to dissolve plastic. Thereafter a series of purification steps are undertaken to separate the polymer from additives and contaminants. The dissolved polymer(s) can then be selectively crystallized. Selective dissolution is a process in which the solvent can dissolve either the main polymer or all the other polymers except the target one . The crucial requirement for this is to have a selective solvent. The resulting output is the precipitated polymer, which ideally remains unaffected by the process and can be reformulated into plastics. The target feedstock in this process is PVC, PS, PE and PP to make purified plastic polymers.

Technology Status

Waste plastics are collected as mixed polymers and hence it is a challenge to separate and recycle components separately. This technology is in its nascent stage and efforts are underway to scale up to a commercially viable level.[xxvii]

Depolymerisation

Also referred to as chemolysis, depolymerization is the reverse of polymerisation. The process either yield a single-monomer molecules or shorter polymer fragments known as oligomers.

The monomers so obtained are identical to those used in the preparation of polymers. As a result, the plastics prepared from depolymerisation are similar in quality to virgin monomers. However, only polymers such as PET and polyamides (also known as condensation polymers) can be processed by this method. The other polymers like PP, PE and PVC which form most of the plastic waste stream cannot be processed by depolymerisation.

Presently, PET degradation is based mainly on methanolysis and glycolysis treatments.

The Hydrolytic processes are less advanced, most of them being used at laboratory and pilot-plant scales. although several projects are being developed for commercial applications in the next few years.[xxviii]

Quaternary Recycling

Using the high calorific value in waste plastic as fuel in place of coal and gas is termed as Waste to Energy or Quaternary Recycling.

Methods for recovering syngas from the process of gasification has already been discussed earlier. Additionally waste plastic is also incinerated in cement kilns as Refuse Derived Fuel (RDF) as a substitute to coals and gas.

Materials that can and cannot be recycled

The numbers attributed to plastics are the plastic resin identification codes, which quickly indicate which type of plastic has been used int the product. The numbers range from 1 to 7, with 7 being 'other'. The general rule of thumb is, the lower the resin code, the more likely the plastic type is to be easily recyclable. The difference in the recyclability of plastic types can be down to how they are made. Many plastic types can be recycled, even if the process is not widespread. Additionally, there are many economic, environmental, and technical reasons as to why a particular plastic may not be recycled.

As mentioned earlier, thermoset plastics contain polymers that form irreversible chemical bonds and cannot be recycled, whereas thermoplastics can be re-melted and re-molded.

Recyclable Plastics

The tables below indicate the easy to recycle plastics, plastics which can be recycled at specialist facilities, and plastics which are incredibly hard to recycle.

Table 2 - Easy to Recycle Plastics

Sr.	Plastic Type	Products
a.	Polyethylene Terephthalate (PET)	Water bottles and plastic trays
b.	High Density Polyethylene (HDPE)	Milk cartons and shampoo bottles
c.	Polypropylene (PP)	Margarine tubs and ready meal trays

Table 3 - Plastics that can be recycled in specialist facilities

Sr.	Plastic Type	Products
a.	Polyvinyl Chloride (PVC)	Piping
b.	Low Density Polyethylene (LDPE)	Food bags
c.	Polystyrene (PS)	Plastic cutlery
d.	ABS (Acrylonitrile butadiene styrene)	Appliances

Table 4 - Plastics that are incredibly hard to recycle

Sr.	Plastic Type	Products
a.	Polyethylene	Carry bags
b.	Polystyrene	Ready to Eat Packs, cups
c.	Nylons	Clothes, Ropes
d.	Polycarbonate	Lenses in eye wear, Automotive parts etc
e.	Acrylic	Furniture, medical devices
f.	Acetal	Valves, manifolds

Challenge in Recycling

As brought out earlier, a considerable amount of Plastic Waste is generated every day and a large percentage of it ends up in the environment. While appropriate technology is available to recycle most plastics, global recycling of plastics is not happening at the required scale and rate.

In India, the MSW collection is more than 85%. However, segregation of the waste is still lacking in most areas and leads to contamination of recyclables including plastics. Single use and single polymer packaging, both flexible and rigid, are rendered non-recyclable due to excessive contamination. Additionally, due to low value of such contaminated plastics they are not collected and hence not recycled. There is no economic incentive for collection of such waste and thereby preventing leakage.

The Barriers to Recycling

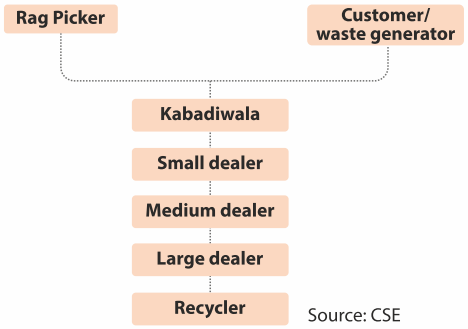


Figure 29 - Recycling Chain in Unorganized Sector (Source: CSE)

In principle, almost all plastic can be recycled. However, in practice, there are a variety of different barriers that can undermine this process. Unfortunately, it does not always make environmental, economic, or technical sense to do so. Many times, items can include multiple types of plastic and different layers which are hard to separate and make recyclability difficult and costly. Further, contamination of plastics with food or other organic/ inorganic material results in either high cost of cleaning or the recycled resins not being clean enough to be reused.

Recycling facilities cost a lot of money to build and operate can only be profitable when a huge amount of plastic is treated every day. Small quantities of plastics can therefore make recycling non-economical and non-beneficial, due to low efficiencies and high costs.

The various challenges in recycling plastic waste are enumerated in succeeding paragraphs.

Sourcing of Plastic Waste

While a considerable amount of plastic waste is seen littered in the environment, sourcing of plastic waste at a reasonable cost, for the purpose of recycling, is a tricky issue. Regular availability of clean and segregated plastic waste must be ensured for sustained operations and a viable business. Amongst the sources for plastic waste are pre-consumer industrial waste plastic, post-consumer plastic waste from NGOs/ agencies, and ULBs.

Organisational Structure

The waste pickers form the backbone of the waste management system in India. These waste pickers are individuals who scavenge the area for valuable plastic waste and then exchange it for a few rupees with the local aggregator (kabadiwalla). The kabadiwalla is the first of several intermediaries in the chain of plastic waste handling, who usually own a few shanties which also double as godowns for recyclable waste material. The lack of a formal structure makes It difficult to source uncontaminated and clean plastic waste on a regular basis.

Logistics

The cost of transportation is possibly the biggest challenge in setting up and operating a plastic recycling unit in India. As mentioned earlier, due to the informal structure of waste pickers and collection of plastic waste, the recyclables are required to be transported over long distances. Further, since the waste exchanges hands multiple times, the cost of the waste for the recycler is considerable. Additional cost of transportation usually makes the recycling proposition untenable.

Sale of Recycled Materials

Equally important is to find suitable customers for selling the recycled plastic. Recycled plastic may be sold in the form of granules or different plastic products.

Market Size

As per PlastIndia Report of 2018, there were a more than 100 organised plastic recycling units in India of which more than 42 were involved in recycling PET. The report claims that over 10,000 unorganised plastic recycling units were present. The direct manpower employed in these units has been estimated at over one lakh, while the indirect manpower (including waste-pickers) has been pegged at about 1.5 million. The report estimates that about 6 million metric tons of plastic was recycled in the year.

The Plastindia Industry Status report 2021 – 22 states that, out of the total PE demand in 2021 – 22, flexible packing made up 18% or 1178 Kilo tons whereas rigid packing comprised 52% or 3352 Kilo tons. As regards to the PP demand almost 12% or 737 kilo tons was made up by BOPP and 35% or 2143 kilo tons was for Raffia.

In the case of PET and BOPET (both of which are extensively used in packaging, the demand was of 214 kilo tons. In the case of EPS, nearly 67 kilo tons was the demand for appliance packaging. From a end use perspective, the report states that the demand for just caps and closures from PP and PE was 144 kilo tons.

Subsequent to the outcry on plastic litter, the Govt. of India issued the Plastic Waste Management Rules 2016. Subsequent amendments to the Rules have sequentially targeted plastic packaging with an emphasis on use of recycled plastic in increasing quantum in the next few years.

The Guidelines on Extended Producer Responsibility for plastic packaging notified on 16th February 2022 stipulate mandatory targets on Producers, Importers, and Brand Owners (PIBOs) for reuse of plastic packaging, minimum level of recycling of plastic packaging waste and minimum use of recycled plastic content in plastic packaging.

As per the guidelines, Brand Owners are to ensure minimum level of recycling (excluding end of life disposal) of plastic packaging waste, collected under Extended Producer Responsibility target, category-wise, as given in the table

Table 5 – Extended Producer Responsibility Targets

(% of Extended Producer Responsibility Target)

Category	2024-25	2025-26	2026-27	2027-28 onwards
I	50	60	70	80
II	30	40	50	60
III	30	40	50	60
IV	50	60	70	80

Additionally, Brand Owners using Category I (rigid) plastic packaging for their products shall have minimum obligation to reuse such packaging as given in the Table

As per the guidelines, Brand Owners are to ensure minimum level of recycling (excluding end of life disposal) of plastic packaging waste collected under Extended Producer Responsibility target, category-wise, as given in the table

Table 6 - Extended Producer Responsibility Targets

Target (%age of rigid plastic packaging in products sold annually)				
Rigid plastic packaging with volume or weight	2025-26	2026-27	2027-28	2028-29
Between 0.9 lt. (kg) and 4.9 lt. (kg)	10	15	20	25
Equal or greater than 4.9 lit (kg)	70	75	80	85

It is therefore evident, that given the scale of plastic demand and consumption, packaging and the regulations for inclusion of recycled plastic in such packaging, the requirement for recycled plastic is set to grow multifold.

Single Use Plastics (SUP) and Sustainability

Synthetic plastics have come a long way since the invention of Parkesine by Alexander Parkes in 1862. The wonder material of the 20th century is now the poster child of pollution. Its non-degradable nature—the very property that it was once admired for—has now come to haunt this material of choice. It is estimated that over 9 billion tons of plastics have been manufactured since the early 1950s. Unfortunately, over 79% (about 7 billion) of this is accumulating in landfills or lying around in the environment. By some estimates, the total amount of plastics in the environment will increase to about 12 billion if serious affirmative action against this wastage is not taken.

Plastic production consumes natural resources such as crude oil and results in emissions responsible for climate change. Serious attempts at reducing sectoral emissions during production are crucial to limit global warning to less than 2° C. However, supply side emissions can only be managed provided the demand side emissions are managed appropriately. A circular economy approach to reduce demand side requirements for virgin material will enable such a reduction in the supply.

While plastic is all pervasive in all walk's life starting from the toothbrush, we use first thing in the morning. Plastics used as products (chairs, tables, pens, stationary) are referred to as "plastic products" or as parts for other products (vehicles, consumer durables, etc.) referred to as "products containing plastic". The life of such plastics varies from about 1 year to 50 years.[xxix] On the other hand, plastic packaging has a very short life span, and some researchers believe it to be in the range of 12 minutes.

Some estimates put the plastic produced worldwide in 2021 at 380 million metric tons. It is estimated that packaging accounts for 40% of the plastic produced every year implying packaging alone accounted for about 132 million metric tons in 2021.

Unfortunately, the very properties of plastic which make them the preferred material for multifarious applications are the ones which have come to haunt it. The linear take-make-waste model, coupled with poor social behaviour in terms of waste disposal has resulted in millions of tons of plastic packaging ending in landfills, being incinerated, and clogging the environment. By some estimates, the volume of plastic packaging is set to double by 2040 (compared to 2010), flow of plastic into the oceans to triple and quantum of plastic in the ocean to reach a mindboggling 600 million tons about four times the amount present now (2010). The continuous increase in use of plastic as projected will make it impossible to ensure circulation of the plastic as it is estimated that almost half a million people would have to be connected daily to formal collection systems alone. Further, collection, scaling and infrastructure development have their limitations. Thus, just increasing clean up drives and recycling is unlikely to solve the problems of plastic waste and pollution.

The Circular Economy Model

The Circular Economy Model was put forth by the Ellen Mc Arthur Foundation. It states, "The circular economy is a systems solution framework that tackles global challenges like climate change, biodiversity loss, waste, and pollution". It aims to transform every element of the "take-make-waste" system, viz., managing our resources, manufacture, and use of products and more importantly, the end-of-life management of these products. A circular economy is regenerative and restorative by design. It is based on the principles of "Reduce – Reuse -Recycle thereby ensuring that the bare essential material is manufactured and then made to flow through a closed loop system, as against the present situation of large-scale production and discarding after use.

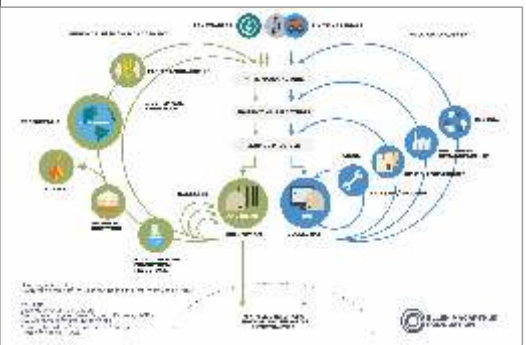
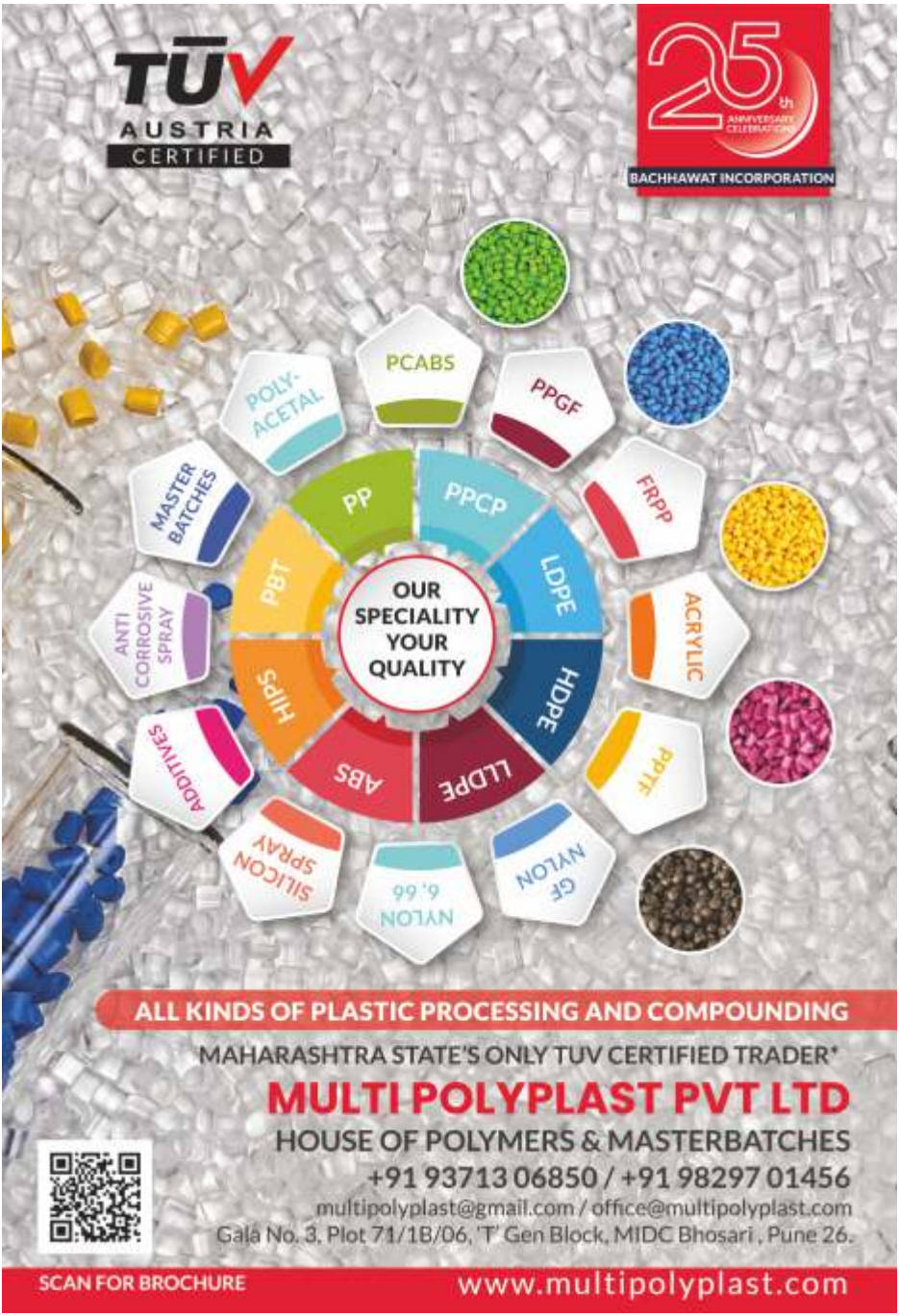


Figure 30- Circular Economy Model (Source: Ellen Mc Arthur Foundation)

A circular economy works on three main principles of Eliminate Waste and Material, Circulate Products and Material, Regenerate Nature'. The principle is best explained by the famous Butterfly Diagram of a Circular Economy.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FRPP
ACRYLIC
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SILICON SPRAY
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As can be seen from the diagram, there are two distinct sides, one comprising managing the renewables and the other managing finite materials. While managing both renewables and finite material is important the aim ultimately is to minimize the leakages and negative externalities. As can also be seen from the diagram, in case of finite resources management, maintaining/prolonging use is of prime importance while reuse, refurbish come next to ensure the material (product) stays in use for as long as possible. Recycling as per the model is the last measure when the product can no longer be reused or refurbished.

The Problem with Single Use Plastic Packaging

In the present system plastics are made from fossil fuels and comprise almost 8% of the global oil and gas produced. A significant portion of the plastic used in the midstream stage of manufacturing and design is single use and contributes significantly to waste generation. At the downstream (consumer) end again most plastics are single use, losing their value within a few minutes of reaching the consumer.[xxx]

Further, since the waste collectors (Indian context) are largely from the informal sector saddled with lack of appropriate technology, and economic incentives, coupled with inadequate capacity of ULBs, there are considerable leakages in segregated collection and proper treatment of waste plastic. Waste collectors are keen to pick up material like PET, HDPE containers, Polyvinyl Chloride (PVC) pipes as they fetch a higher price with the waste aggregators. Flexible packaging on the other hand which is voluminous, but light in weight find few or no takers and is found littered in the environment. This uncollected/ littered plastic waste poses considerable hazard to the environment as it can be carried by air into nearby water bodies, eventually ending up in rivers and the oceans.

The current model for use and end-of-life model for plastics is therefore a liner one. While efforts for educating the society in prevention of litter and thereby greater collection of waste plastic for re-cycling are being made, it is to be understood that not all plastic that is collected can be re-cycled. The term recycling itself has many connotations within the country, wherein a majority believing that repurposing waste plastic amounts to recycling, In the true sense, recycling should imply converting the waste plastic into either raw material for manufacture of the same product or converting the waste plastic into the product it was. However, this is easier said than done. The reasons for this are numerous, one of them being that the present mechanical recycling technology tends to weaken the polymer bonds and the concept of recycling the material endlessly is at present theoretical.

From Linear to A Circular Plastic Economy

As discussed above, in the present linear plastic economy worldwide, about 98% feedstock is virgin. Only 14% of the collected plastic waste is recycled. Of this 4 % is lost in processing while 8% is recycled into other low value products (cascaded recycling). Thus only 2% of the total waste plastic returns into the circular system.

The current plastic value chain has many stakeholders starting from upstream to downstream. The upstream starts with the extraction of crude oil for manufacture of raw material for plastic production and flows through multiple stakeholders who are involved at the various stages of the value chain.

To summarize the plastic value chain, it starts from the oil exploration companies, the feed stock producers at the upstream end. The midstream comprises of various manufacturers either involved in direct manufacture of plastic products or those manufacturing intermediate plastic components. The downstream comprises the consumers, the waste collectors, processors, and the recyclers (including repurpose).

As per data available (India) the largest upstream polymers consumed in India are Polyethylene (PE) and Polypropylene (PP). These polymers constitute a significant share in flexible packaging comprising pouches, shrink films, carded packaging, bags and tubes, which are also difficult to recycle and/ or collect and end up in various waste streams. As per estimates by TERI, about 42% of plastic consumed in a year stays in circulation (for a period of one year or more) whereas 58% is discarded as waste. Out of this 60% is recycled, 8.5% used for energy while 31.5% is mismanaged and ends up as litter, in garbage dumps and landfills or burnt in the open .

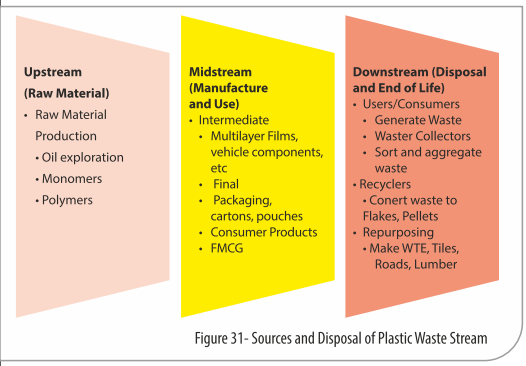


Figure 31- Sources and Disposal of Plastic Waste Stream

To make the plastic economy truly circular, a multi-pronged strategy would have to be implemented. There is a requirement to study the full value chain and decouple the production of plastics from virgin fossil fuels, while simultaneously, encouraging reuse and incentivizing the whole recycling chain.

The first and foremost requirement is the capability to process waste plastic such that it can be made into raw material for manufacture of the same or similar product. In situations where technological and material considerations preclude such conversion, the waste plastic must be turned into raw material for manufacture of other products. The aim should be to develop technologies for a major percentage of waste plastic to be so converted. As a last resort, the plastic may be used in waste to fuel plants or as refuse derived fuel in cement kilns.

The primary issue in the plastic recycling is that of segregation of plastic waste, especially in terms of the polymer and material composition of the packaging. Various sorting technologies like Near Infrared (NIR), air sorting, sink and float are presently available in the market. The problems get compounded when multiple polymers are used to make single packaging.

Design for Circular Economy

Designing for a Circular Economy as a concept was put forth by the Ellen Mc Arthur Foundation. According to the concept, there is a need to fundamentally change the approach towards manufacture of products, delivery of services and systems. The challenges faced downstream in terms of managing of plastic waste need to be tackled starting from upstream use of the plastics. The efforts should be aimed at the root cause rather than solutions at the end of life of the material. The system of manufacture of plastic products, their use and disposal should be viewed and tackled wholistically. A system where the plastic never becomes waste or a pollutant.

Eliminate Waste

Innovations to deliver the product to the consumer without generating packaging waste while still maintaining the requisite user experience are necessary. Where, plastic packaging cannot be eliminated it must be reduced and even here it should be reusable. The whole system should be dedicated to designing out waste from the system.

Standardize

Packaging across brands should be standardized to reduce production and logistic costs. Deploying standardized refillable and compact containers would also help in multiple use of these packages.

Deposit and Reward Schemes

The concept of deposit return schemes prevalent in India a few decades age, has unfortunately been lost since the advent of Use and Throw concept. Re-introduction of the system especially for plastic packaging is the need of the hour and will greatly support the circular economy function by ensuring the material stays in circulation for longer periods. In situations where the packaging cannot be re-used, it can be recycled.

Technology Development

Innovations in plastic technology should focus on ensuring that all plastic packaging is either reusable, compostable, or recyclable at scale. The packaging design should investigate all aspects including, but not limited to, material properties, its ability to be collected, sorted easily, reused sufficiently, and recycled or composted without having to greatly vary the existing infrastructure. The technology should also focus on de-coupling the generation of virgin material from finite natural resources. All virgin plastic should be made from renewable sources while at the same time, ensuring they can be managed responsibly and in an environmentally safe manner. Some issues which need consideration in the technology space to make the product circular are: -

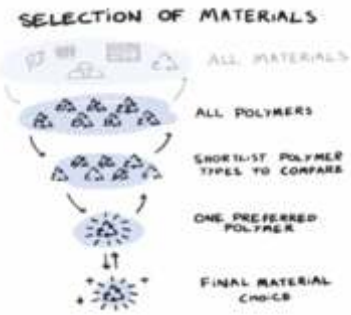


Figure 32- Chemical Perspective on Designing with Sustainable Plastics (Source: IOMC and OECD)

Table 7 - Technology Principles for Designing out Waste	
Principles for Design	Maximise resource efficiency
	Eliminate & minimise hazards & pollution
	Design systems using life cycle thinking
Selection criteria of material	Materials with inherently low risk/hazard
	Materials with a commercial afterlife
	Materials that generate no/low waste
	Material using secondary/ bopbased feedstock
Sourcing material	Materials with inherently low risk/hazard
	Materials with a commercial afterlife
	Materials that generate no/low waste
	Material using secondary/biobased feedstock
Manufacturing technique	Less emissions
	Least processing aids
	Non/ least hazardous chemicals
	Minimises worked exposure
Use Phase	Enables intended lifespan of product
	Generates minimum emissions
End of Use Phase	Minimise waste at end of use – polymer selection
	Simplify design – Single Vs Multi polymer
	Match polymer to recycling methods in intended markets
	Ways to mitigate littering
	Transparency in chemical composition

Conclusion

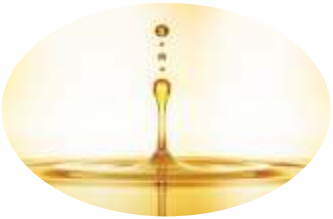
Plastics or polymers have a come a long way since they were invented in 1900 and have proved to be the material of choice. Human behaviour rather than the material has been largely responsible for plastics being called out for pollution. Consumerism, fast fashion, and greed has resulted in quick fix, short term solutions, and proliferation of single use products with complete disregard to their impact on the environment. Continuing the same trajectory will have disastrous consequences for all species on this planet.

A circular approach towards plastics, especially single use plastic products is, therefore, the need of the hour, for sustenance. Relentless use of finite natural resources in pursuit of human needs will only result in aggravating climate change and pose serious threat to survivability of species including human beings in the future.

Adoption of a circular economy approach will help ensure sustainability and improve the overall environment that we live in. Continuous efforts by every stakeholder, be it policy intervention by Governments, social behavioural change, collection, sorting, recycling and more importantly new and sustainable designs by manufacturers, can help us claw out of the situation and stabilize the damage thereby setting ourselves on a trajectory of environmental conservation and a better future for the generations to follow.

Five Elements Environmental Technologies

MIXED PLASTIC WASTE



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Rules and Regulations

In 1976, Provisions for protection and improvement of environment were incorporated into the Indian Constitution as the 42nd amendment. This provision came into effect from 3rd Jan 1977. Article 48-A was inserted in the Directive Principles of State Policy (Chapter IV of the Constitution), which enjoins the State to make endeavour for protection and improvement of the environment and for safeguarding the forest and wildlife of the country. A landmark provision of the amendment also made environment protection as one of the Fundamental Duties of every citizen of India. Article 51-A (g) of the Constitution stipulates that it shall be the duty of every citizen of India 'to protect and improve the natural environment including forests, lakes, rivers and wildlife and to have compassion for living creatures'.

The first legislative action, in series of environment protection measures, was in the form of The Environment Protection Act 1986 enacted on 23 May 1986. The Plastic Waste (Management & Handling) Rules were first promulgated on 04 Feb 2011. They have since been amended in 2016, 2018 and 2022.

Presently, Waste Management in India comes under the purview of many Central Ministries, and it is important to understand the roles of each of them.

Ministries Concerned with Waste Management

The Ministry of Housing and Urban Affairs (MoHUA)

The nodal ministry for solid waste management in urban areas is responsible for execution of the Swachh Bharat Mission (Urban)

The Ministry of Environment, Forests, and Climate Change (MOEFCC)

This is the nodal ministry for waste management in India monitoring of Air and Water Pollution through the Central Pollution Control Board (CPCB).

The Ministry of New and Renewable Energy (MNRE)

MNRE is responsible for promoting all the technology options available for setting up projects for recovery of energy in the form of biogas/BioCNG/ Electricity from agricultural, Industrial, and urban wastes of renewable nature such as municipal solid wastes, vegetable and other market wastes, slaughterhouse waste, agricultural residues and industrial/STP wastes & effluents.

The Ministry of Jal Shakti/ Dept of Drinking Water and Sanitation

The Jal Shakti Ministry is responsible for Swachh Bharat (Grameen). As per Swachh Bharat Abhiyan 2.0 (Grameen) the Ministry in coordination with MoEF&CC is the nodal ministry for Solid Waste Management in rural areas.

Central Pollution Control Board

The Central Pollution Control Board (CPCB) is a statutory organisation constituted in September 1974 under the Water (Prevention and Control of Pollution) Act, 1974. It was entrusted with the powers and functions under the Air (Prevention and Control of Pollution) Act, 1981. It provides technical services to the Ministry of Environment and Forests of the provisions of the Environment (Protection) Act, 1986

Its main functions are

(i) To promote cleanliness of streams and wells in different areas of the States by prevention, control and abatement of water pollution,

(ii) To improve the quality of air and to prevent, control or abate air pollution in the country.

Relevant Standard – IS 4534:2016 (Plastics - Guidelines for the Recovery and Recycling of Plastics Waste (First Revision))

Plastic Waste Management Rules

The Plastic Waste (Management and Handling) Rules, 2011 were promulgated by the Government of India vide notification number S.O 249 (E), on 4th February 2011 by the erstwhile Ministry of Environment and Forests. These rules provide a regulatory framework for management of plastic waste generated in the country. The Rules were reviewed in 2015 - 2016, with an aim to give thrust on plastic waste minimization, source segregation, recycling, involving waste pickers, recyclers and waste processors in collection of plastic waste fraction either from households or any other source of its generation or intermediate material recovery facility and adopt polluter's pay principle for the sustainability of the waste management system. Subsequently, the "Plastic Waste Management Rules 2016" were promulgated on 18 Mar 2016. The Rules have been further amended in 2018 and 2021.[xxxii]

Extended Producers Responsibility (EPR)

Origins

Thomas Lindhqvist a Swedish academician first introduced the concept formally in a 1990 paper to the Swedish Ministry of Environment. Several reports later, the definition of EPR emerged as follows:

EPR is an environmental protection strategy to reach an environmental objective of a decreased total environmental impact of a product, by making the manufacturer of the product responsible for the entire life cycle of the product and especially for the take-back, recycling, and final disposal.[xxxiii]

EPR is based on the principle that manufacturers (usually brand owners) have the greatest control over product design and marketing and have the greatest ability and responsibility to reduce toxicity and waste.[xxxiv] EPR may be implemented in multiple formats like buyback, recycle or even reuse

programs. Other models permit a third party, Producer Responsibility Organisation (PRO), to whom the Brand Owner (producer) may delegate the responsibility of post-consumer packaging management, paid for by the product manufacturer. This enabled a shift of responsibility from the Government to the private sector for management of post-consumer waste, because of which brand owners (producers) are encouraged to internalise waste management costs and seek solutions in the form of design, post-consumer collection and ensure safe handling of their products.

Based on the experience of a few European countries and in order to identify legal and administrative issues that OECD member countries may confront in developing/ implementing policies such as EPR, the OECD's began work on EPR in 1994[xxxv]. Germany was the first country to implement EPR in 1991, by promulgation of an ordinance "Verpackungsverordnung" (Packaging Ordinance), which was approved on 12 Jul 1991. After over eight amendments, the ordinance was finally replaced by the "Verpackungsgesetz" or Packaging Act which became a law on 01 Jan 2019[xxxvi]. Following in the footsteps of Germany many European countries like Belgium, France and Austria also introduced the EPR system.

In Asia, Japan was the first to introduce EPR in 1995. The Promotion of Sorted Collection and Recycling of Containers and Packaging ("Packaging Recycling Act") was promulgated in June 1995 and came into force in Dec 1995. The Act was a result of the manyfold increase in Municipal Solid Waste (MSW), and the limited area available to dispose it. As per the Act, Municipalities were required to promote sorted collection and storing of packaging materials and promote recycling business operators. The Act targeted containers and packaging which accounted for a large portion of MSW[xxxvii].

Indian Context

The Govt of India introduced the policy for Extended Producer Responsibility (EPR) for the first time in the Plastic Waste (Management & Handling) Rules 2011. It was for the first time that manufacturers of carry bags and multi-layered plastic were required to register with State Pollution Control Boards However, these rules were generic in nature[xxxviii].

EPR is essentially a policy approach, where the responsibility for treatment or disposal of post-consumer packaging material is that of the producers (Brand owners and Importers). The responsibility may be either financial and/or physical. Assigning such responsibility could in principle provide incentives to prevent wastes at source, promote product design for the environment and support the achievement of public recycling and materials management goals.

The PWM Rules 2016, define EPR as "responsibility of a producer for the environmentally sound management of the product until the end of its life". Thus, Extended Producer Responsibility is a concept that shifts the burden of responsibly managing plastic packaging waste from the government to producers themselves. This means that producers need to set up mechanisms for how their products are collected, reused, recycled, and disposed of at the end of their lifecycle.

Components of EPR (PWM Rules (Amended 2018, 2022))

The EPR legislation for plastic packaging in India makes it mandatory for Producers, Importers and Brand Owners (PIBOs) to establish circularity in the plastic and plastic packaging they produce, by ensuring recycling and its appropriate disposal. A broader insight has been made with the release of EPR guideline for Plastic Packaging by the Ministry of Environment, Forest, and Climate Change (MoEFCC) in February 2022.

The EPR obligations and provisions of the new guidelines applies on plastic waste processers, plastic packaging producer, importer, brand owners including online platforms/market places and supermarkets/retail chains.

Figure 33- Categories of Plastic Waste Plastic Waste Management (Second Amendment) Rules, 2022

EPR is now applicable to both pre-consumer and post-consumer plastic packaging waste.

The guidelines covers 4 categories of plastic packaging Rigid Plastic Packaging, Flexible Plastic Packaging, Multi-layered Plastic Packaging and Compostable Plastic.

The guideline sets the **targets of PIBOs to ensure recycling from 25% to 100%** into four classified categories.

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Ecogreen RECYCLERS FZC

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Pioneer in Recycling All types of Plastic

Govt. Auth

Govt. Authorised Recyclers

Global Recycled Standard	ISO 9001:2015
ISO 14001:2015	SEDEX REGISTERED

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The policy mandates to reuse rigid plastic packaging material and to reduce the use of fresh plastic material for packaging.

The guideline for plastic packaging promotes the **"Polluters Pay"** principle. Environmental Compensation will be imposed with regard to the non-fulfilment of EPR targets by PIBOs to protect and improve the quality of the environment.

An online web portal *https//www.eprplastic.cpcb.gov.in* has been launched by Central Pollution Control Board to ensure the compliance to fulfil the obligation of EPR. The portal is not just limited to the registration of the PIBOs, Recyclers/ Plastic waste processors but also acts as single point data repository for the implementation of EPR guidelines in the country.

Terminology - EPR (PWM Rules (Amended 2018, 2022))

Producer, Importers and Brand Owners (PIBOs)

Producer (P) / manufacturer of plastic packaging, Importer (I) of all imported plastic packaging and/or plastic packaging of imported products, Brand Owners (BO) including online platforms/marketplaces and supermarkets/ retail chains other than those, which are micro and small enterprises as per the criteria of Ministry of Micro, Small and Medium Enterprises, Government of India.

Plastic Waste Processors

Plastic waste processers (PWP) are the entities that are involved in processing of plastic waste through recycling, using plastic waste for energy (waste to energy), converting it to oil (waste to oil) and utilizing compostable/ biodegradable plastic in industrial composting. Such PWPs cannot carry out business unless they are registered on the online web portal by CPCB.

Roles and Responsibilities of Stake Holders

CPCB: Central Pollution Control Board.

The CPCB is required to register all relevant stakeholders (PIBOs, PWPs) when operating in more than two states. Additionally, the CPCB is to provide necessary guidance for EPR implementation, verify compliance through periodic audit and conduct composition surveys of collected MSW to establish share and categories of plastic therein twice a year. A separate web portable for EPR registration and compliance is available at *https://eprplastic.cpcb.gov.in*

SPCB: State Pollution Control Board.

The SPCB is to guide local authorities to map PWPs/recyclers/co-processing facilities/cement kilns/plastic to fuel/waste to energy facilities. They will register relevant stakeholders (PIBOs, PWPs) when operating in one or two states on the portal developed by Central Pollution Control Board. SPCBs will issue on its website an annual list of entities not complying with the EPR obligations. SPCBs are also mandated to establish a mechanism for regular dialogue between stakeholders under their jurisdiction. Additionally, SPCBs will undertake a half yearly compositional survey of MSW to establish share and categories of plastic therein, monitor implementation of EPR action plan of PIBOs within their state, and compile PIBO activities based on respective EPR action plans ad share it in the public domain.

Urban Local Bodies/Gram Panchayats.

The ULBs and GPs are required to map the registered stakeholders (WMAs/ PWPs/ Recyclers/ Co-processing facilities/Cement kilns/plastic to fuel/waste to energy) operating within 100 km of their respective boundaries. WTE, PTF and other plastic processing facilities will be registered by the ULBs/GPs. Additionally, ULBs/GPs are required to create awareness among stake holders, engage informal sector for collection and segregation of plastic waste, organise regular capacity building activities to strengthen plastic waste value chain, engage multiple PIBOs in strengthening the waste collection network, setup decentralized Plastic collection facilities/Material Recovery Facilities, ensure

that recyclable plastic is channelled to registered recyclers, ensure non-recyclable plastic waste is disposed in an environmentally sound manner. ULBs and GPs are also authorised to obtain EPR certificate/credit from PWPs and sell it to PIBOs.

PIBOs

All PIBOs are required to register on the web portal of CPCB and obtain the Registration Certification. Additionally, PIBOs are required to:

(a) Submit an action plan containing EPR target, category-wise, where applicable on the online centralized portal.

(b) Maintain & provide record of category-wise quantity of plastic purchased and sold.

(c) Develop a separate waste stream for collection of plastic packaging waste along with ULB/GP for directly fulfilling EPR obligations. Schemes such as deposit refund system or buy back or any other model can be operated to prevent mixing plastic packaging waste with solid waste.

(d) File annual returns on the plastic packaging waste collected and processed towards fulfilling obligations under Extended Producer Responsibility with the Central Pollution Control Board or concerned State Pollution Control Board.

(e) Provide a self-declaration certificate in proforma developed by CPCB verified by the local authority when plastic waste is used in road construction

Plastic Waste Processers (PWP) All PWPs are required to register on the web portal of CPCB and obtain a registration certificate. Additionally, PWPs are required to ensure:

(a) Submission of annual return of the quantity of plastic waste processed category-wise on the EPR portal.

(b) The certificate for plastic packaging waste is provided in the name of registered PIBO or Local authorities, as applicable, based upon agreed modalities.

(c) The certificate generated for plastic packaging waste recycled by the PWP shall not be more than installed capacity of the PWP.

(d) Availability of all records for inspection by the Central Pollution Control Board or the concerned State Pollution Control Board.

(e) That the recycling processes do not have any adverse effect on health and the environment.

(f) That the facility and recycling processes are in accordance with the standards or guidelines prescribed by the Central Pollution Control Board from time to time.

Appendix A

Regulatory Framework for Plastics

Policy	Year	Authority	Description
Plastics and recycled plastics manufacture, sale, and usage rules	1999	MoEFCC	Provisions pertaining to manufacture, usage and EOL management criteria for manufacturing plastic carry bags and containers.
Municipal Solid Wastes (Management and Handling) Rules, 2000	2000	MoEFCC	Amended to include declared responsibilities of authorities on national, state, and municipal levels
Plastics and recycled plastics manufacture, sale, and usage rules	2003	MoEFCC	Amendments gives specifications of virgin and recycled plastic, extend definition of vendor, and mandate registration and authorization for manufacturers, production, sale, or trade for plastic packaging
Plastic Waste Management (Amendment) Rules	2011	MoEFCC	Specify minimum thickness of plastic carry bags of 40 microns and sachets using plastic material not be used for storing, packing or selling gutkha, tobacco and pan masala

Policy	Year	Authority	Description
Municipal Solid Wastes (Management and Handling) Rules, 2016	2016	MoEFCC	Mandate source segregation of waste. Waste generators have been specified as event organizers, RWAs, market associations, gated communities, institutions, and SEZ and given responsibilities
Plastic Waste Management (Amendment) Rules	2018	MoEFCC	EPR requirements from producers/brand owners/ importers specified in detail
Guidelines for disposal of thermoset plastic waste including: Sheet Moulding Compound (SMC)/Fibre Reinforced Plastic (FRP)	201	CPCB	Minimization of use of SMC/FRP/ polycarbonate polymer products preferred option; recommends promotion of easily recyclable/ reusable/ degradable alternate material
Guidelines for coprocessing of plastic waste in cement kilns	2016	CPCB	Stakeholder protocols and co-processing plastic waste in cement kilns
Environment Protection Act (control of nonbiodegradable garbage)	2016	MoEFCC	Environmental protection through prevention of disposal of nonbiodegradable garbage in drains, roads, open spaces, and issues relevant to the same.

Policy	Year	Authority	Description
Consolidated guidelines for segregation, collection, and disposal of plastic	2017	CPCB	Responsibilities of waste stakeholders in plastic waste management and plastic waste disposal technologies. - Guidelines
Plastic Waste Management (Amendment) Rules	2018	MoEFCC	Amendment to restrict phasing out MLPs which are non-recyclable/non-energy recoverable/have no alternate use MLPs. Central registration system for registration of producer/importer/brand owner introduced.
Guidelines for disposal of nonrecyclable fraction (multi-layered) plastic	2018	CPCB	Provides source of waste non-recyclable plastic waste and management of non-recyclable plastic waste
Prohibition of import of PET flakes	2019	MoEFCC	Import of PET bottle waste/scraps PET flakes made from used PET bottles, etc. prohibited
Guideline Document: Uniform Framework for Extended Producers Responsibility (Under PWM 2016)	2020	MoEFCC	Manufacturers mandated for responsibilities of materials used beyond the sale-phase

Policy	Year	Authority	Description
Plastic Waste (Amendment) Rules 2021	2021 (12 Aug)	MoEFCC	Ban on SUP
Plastic Waste (Amendment) Rules 2021	2021 (17 Sep)	MoEFCC	Use of Recycled Plastics
Plastic Waste (Second Amendment) Rules 2022	2022 (16 Feb)	MoEFCC	Guidelines on Extended Producers Responsibility on plastic packaging
Plastic Waste (Second Amendment) Rules 2022	2022 (06 Jul)	MoEFCC	Plastic Waste Management Rules on EPR

Plastic Recycling – for Start-ups

Types of Businesses

The plastic recycling business may be further divided into two main functions. Each of these functions can be spun into a business of its own.

Collection and Sorting

In this type a business, the source of the plastic waste has to be identified. Depending on the source the procedure for sorting has to be customised. For example, if the source is post industrial waste the sorting becomes simpler as compared to post-consumer waste sourced from ULBs/ NGOs.

Once the source has been identified, it is necessary to find a recycler who will buy the sorted waste.

The basic requirement is to set up a Material Recovery Facility (MRF) wherein the waste is sorted. It may be possible that waste received from ULBs/ NGOs also contains paper/ cardboard, glass, tin, metals etc.

While a MRF may be very simple using only manual labour for sorting, a top of the range MRF set-up comprises of a Debaler or a Bag-opener, Trommel Screen, Ballistic Separator (2D/3D separation), Over Band Magnet, Eddy Current Separator, Sensor based Optical Sorters (separation of polymer by grade and/or colour, if required), series of Conveyors for material transfer & quality check, Baler(s) and Strapping Machine(s) to compact the sorted materials for transport viz. paper, cardboard, polymer fractions, textiles, metals, wood, so on & so forth.

Manpower required for the sorting will depend upon the scale of the facility and automation. The finance requirements for such a facility will range from a few lakh rupees onwards depending upon the scale and machinery planned.

Mechanical Recycling

This business involves processing of plastic waste into granules and or products. The business model typically includes machinery for washing, shredding, agglomeration, and extrusion. In case unsorted waste is sourced then sorting systems (manual or automated) will also be required.

As in the previous case, the source for plastic waste must be identified along with sources who will buy the recycled granules. The machinery requirements will depend on the scale of the recycling unit to be established. As is evident, this business will be more capital intensive than the sourcing/sorting business mentioned earlier, purely due to the requirement of machinery and associated systems like water (with an ETP), electricity, etc.

Chemical Recycling

Chemical recycling (waste to fuel) is still in its nascent stages in India mainly due the low output of Light Diesel Oil (LDO) from available technologies.

This type of business requires technical knowhow and is also capital intensive. Additionally, sources for sale of the LDO need to be identified, as the output LDO, is usually suitable only for use in furnaces and captive Diesel Generator sets.

Emissions during processing are also required to be carefully managed to ensure environmental safety standards.

Setting up the Business

Recycling of plastics can be undertaken either mechanically or chemically. The steps involved in setting up a plastic waste recycling plant are enumerated in succeeding paragraphs.

Company Registration

The setting up of the business entity is governed by the Companies (Amendment) Act 2020. Once the business has been incorporated and registered with the Registrar of Companies, the next step is to seek necessary approvals for setting up the recycling plant. GST Registration, where applicable, must be obtained.

Land Availability

Prior to seeking the necessary permissions, it is of utmost importance to identify the required land for setting up the processing unit. Depending on the size of the plant, requirement of land is decided. Typically, an enclosed shed of about 5,000 sq ft is required for setting up a small recycling plant with a capacity of processing about 500 Kg of plastic wate per day.

Identification of Machinery

Based on the capacity and nature of plastic to be processed and the method of processing, the requisite machinery must be identified. The various machinery required for mechanical recycling has been discussed I details in the Chapter on Recycling. This process is necessary as a layout of the plant is required to be provided while seeking registration from the respective Pollution Control Board.

Permissions and Authorisation

Plastic Waste processing has been categorised under the 'orange' category by the MoEFCC, implying that the plant falls under the second most polluting category[xxxix] and appropriate clearances are essential prior setting up the plant.

Procedure for registration

The procedure for registration of a recycling unit is given in the Plastic Waste Management (Amendment) Rules 2018. The first step is to seek the relevant clearances under:-

(a) The Water (Prevention and Control of Pollution) Act of 1974.

(b) The Air (Prevention and Control of Pollution) Act of 1984 (14 of 1981)

(c) Certificate of Registration issued by the District Industries Centre

The application for registration of the Unit with the respective Pollution Control Board is to be made vide Form II (Annexure 1) provided in the Plastic Waste Management (Amendment) Rules 2018. The indicative list of documents required for registration is given below:-

- Udyam Registration
- Company Incorporation Certificate (Partnership/ Proprietor/ LLP)
- Memorandum of Association (MOA) of the Company. (if applicable)
- Authorised Signatory – (Aadhaar ad PAN Card)
- Topography Map of area
- Layout Plan
- Requisite Clearance for Air and Water usage.
- Electricity and Water Bill (if available)
- Ownership/Rent Agreement

Application Process

The completed application (Form II) along with the relevant documents are to be submitted to the designated authorities (Facility for online submission is also available in some States) along with the stipulated fees.

On receipt of the application the authorities will accept the application, subject to all relevant documents being made available. The receipt of the application will be acknowledged.

SMS triggered status of the application is usually available in most states. States with online application mode also provide the status and observations on the application on the website.

Once the application has been processed the registration certificate is issued which implies that the company is authorized to commence recycling operations.

Any queries raised by the Govt., authorities are required to be answered within a specified time frame, and the application may be closed in case of delay/ default by the applicant.

In some states, if no query/communication on the application is received from the Govt., within the specified period (usually one month), the registration is deemed to have been generated.

Financing the Business

Sources of finance to set up the recycling business must be identified well in advance. In the case of a start-up, the Govt. of India provides various concessions, both in terms of tax breaks as well as compliances required, for the first few years.

Many educational institutions provide incubation for start-ups in the waste management sector. Innovative ideas in recycling of waste plastic are also supported by the Technology Development Board, Govt. of India. The Ministry of Micro, Small and Medium Industries also provides funding for small businesses. Certain banks also provide loans for MSME units while the option of funding from Venture Capitalists is also available.

Plastic Parks in India

Industrial zones have been developed in cluster approach for establishing units for plastic enterprises and allied industries to consolidate and synergize the capacities of the domestic downstream plastic processing industry. Such clusters known as Plastic Parks have the requisite infrastructure with common facilities including plastic waste management system. These parks play a key role in growth of the plastic processing community, material, and machinery suppliers, plastic processing companies, and plastic recycling companies.

The Plastic Parks are being developed by State Governments with the grant-in-aid funding support from Department of Chemicals & Petrochemicals, Ministry of Chemicals & Fertilizers. The details are as given below (Source AIPMA)

Sr.	Location	Land (Acre)/ plots	Contact Details
1.	Tamot Village Gohargunj Tehsil, Raisen, District Madhya Pradesh	122/155	M.P. Plastic Park Development Corporation Ltd. Bhopal-462016, Madhya Pradesh Email: mpppdc@gmail.com www.invest.mp.gov.in
2	Billaua, Gwalior, Madhya Pradesh	38 / 107	MP Plastic City Development Corporation Gwalior Ltd. Gwalior-474011 (MP) Email: iidcgwalior@gmail.com
3	Near Paradeep, Village Siju, Kujanga Tehsil-Kujanga, District-Jagatsinghpur, Odisha	120 / 80	Chairman cum Managing Director Bhunbaneswar-751022 (Odisha) Email: pmu@idco.in, pppl@idco.in, cmd@idco.in
4	Gellapukhuri, Tinsukia, Assam	173 / 104	General Manager (i/c), Assam Industrial Development Corporation Ltd., Guwahati-781024, Assam. Email: prasantaaidc@gmail.com
5	Devipur, Deoghar Jharkhand	93.09 / 107	General Manager (Infra) Ranchi- 834010 (Jharkhand) Email: jiidcoltd@gmail.com
6	Voyalur Village, District-Thiruvullur Tamil Nadu	257 / 79	Managing Director, Tamil Nadu, Polymer Industries Park Ltd., Chennai-600008. Email: ed@tidco.com

Additionally Plastic Recycling Clusters have also been set up in various parts of the country (Source – PlastIndia Industry Report 2018)

Plastics Recycling Clusters

- Dhoraji, Gujarat
- Daman
- Vapi, Gujarat
- Dharavi & Bhandup, Mumbai
- Indore, Madhya Pradesh
- Delhi, NCR
- Malegaon & Solapur, Maharashtra

SAVE EARTH WATER AIR
SEWA
ENVIRONMENT SEWA FOUNDATION

Creating a Sustainable Future Together

EVERY PLASTIC COUNTS

Environment SEWA Foundation is a Mumbai-based NGO that promotes responsible waste management and recycling through various activities and programs. They work with a variety of groups including corporates, schools, colleges and rural areas. SEWA also runs social campaigns and medical camps in rural areas, and holds beach clean-ups and training programs in the Mumbai region. They also install recycled products and assist anganwadis with products.

SHORT TERM PROJECTS

- Awareness campaigns (IEC)
- Medical camps
- Ration kit distribution
- Training & skill development
- Recycled product Installations
- Upcycled product
- Marathons & other such events

LONG TERM PROJECTS

- Beach/ river-front clean-ups
- Waste Management Plants
- Material Recovery facilities

15/16, Govind Bhavan, S. V. Road,
Malad West, Mumbai -400 064

Email: info@envirosewa.org
Website: www.envirosewa.org

+91 (22) 49671500 /01/02

Annexure 1

FORM – II

[SEE RULE 13 (3)]

Application Form for Registration of Units Engaged in Processing or Recycling of Plastic Waste

1	Name and Address of the unit				
2	Contact person with designation, Tel./Fax /email				
3	Date of commencement				
4	No. of workers (including contract labour)				
5	Consent Validity	• Water (Prevention & Control of Pollution) Act, 1974; Valid up to_____ • Air (Prevention & Control of Pollution) Act, 1981; Valid up to _____ • Authorization; valid up to ….			
6	Manufacturing Process	Please attach a flow diagram of the manufacturing process flow diagram for each product.			
7	Products and installed capacity of production (MTA)	Products		Installed capacity	
8	Waste Management:	S. No.	Type	Category	Qty.
	a. Waste generation in processing plastic-waste	i			
		ii			
	b. Waste Collection and transportation (attach details)				
	c. Waste Disposal details	S. No.	Type	Category	Qty.
		i			
	d. Provide details of the disposal facility, whether the facility is authorized by SPCB or PCC				
	e. Please attach analysis report of characterization of waste generated (including leachate test if applicable)				

9	Details of plastic waste proposed to be acquired through sale, auction, contract or import, as the case may be, for use as raw material	i. Name ii. Quantity required/year
10	Occupational safety and health aspects	Please provide details of facilities
11	Pollution Control Measures	
	Whether the unit has adequate pollution control systems or equipment to meet the standards of emission or effluents.	If Yes, please furnish details
	Whether unit is in compliance with conditions laid down in the said rules.	Yes/No
	Whether conditions exist or are likely to exist of the material being handled or processed posing adverse immediate or delayed impacts on the environment.	Yes/No
	Whether conditions exist (or are likely to exist) of the material being handled or processed by any means capable of yielding another material (e.g. leachate) which may possess eco-toxicity.	Yes/No
12	Any other relevant information including fire or accident mitigative measures	
13	List of enclosures as per rule	

Date :_____ Name and Signature _____

Place :_____ Designation _____

Advanced Technology & Future Trends

Importance of high-end recycling technologies

The concept of a Circular Economy is fast gaining ground in general and particularly in the field of plastics. There is therefore, a need to demonstrate that plastics can be circular, by economical use during production, and by replacing virgin feedstock to a greater extent.

This would be a game-changer; bringing a paradigm shift in the mindset of the industry. The outcome ought to show a strong demand from the plastic processors and converters for producing good quality recyclates.

With the ever-growing requirement for processing post-consumer waste there is a growing requirement for professional recycling to qualify for EPR. The approach towards recycling of plastic waste therefore ought to be different – far more advanced to meet the emerging quality standards for better reuse of recycled granules or pellets, and in quantity, eventually to close the loop.

Evolution of PET "bottle-to-bottle" recycling technologies

PET bottle recycling lead as an example, a success story, be it bottle-to-fibre or bottle-to-strapping. Data reveal, 80-90% of generated waste gets recycled. The upcoming market like bottle-to-bottle, bottle-to-sheet, bottle-to-high end fibre, especially food or human contact compliant (commonly known as FDA approved grade) certainly envisages high-end technologies in the entire value process chain – sorting, washing, recycling / pelletizing, or for that matter even solid-state polymerization (SSP) for enhancing the intrinsic viscosity (IV). One such technology is VACUNITE® being marketed by EREMA. The technology is a combination of their patented, vacuum-assisted V-LeaN Solid State

Polycondensation (SSP) coupled with high-purity nitrogen flushing to increases the quality of the rPET pellets still further to ensure its compliance for food contact.

Post 2019, Indian PET bottle recyclers gradually expanded their operation in high-end application like B2B, eventually to cater brand owners' stringent quality requirement for the rPET chips or pellets. While the European recycling systems (operating under high vacuum) treating washed, clean, dry, pre-sorted bottle flakes had already established its credentials since early 90s fulfilling the demand for decontamination, removal of leftover humidity & acceptable IV levels of FDA grade B2B rPET chips; it is the state-of-the-art pelletizing plant with solid-state polymerization (SSP) that became a new standard in recent years to fulfil emerging market demand for stringent quality norms at higher IV – for food contact compliant applications like water bottles, CSD, beverages, etc. Even the liquid-state polymerization (LSP) is being considered as a solution for B2B application.

Figure 34-Vacunite Technology (Source: Erema)

Advanced Recycling Technologies

Various custom-built plants comprising a range of systems are now available in the market. Some of the systems are given in succeeding paragraphs.

Fully Automatic & Batch Type Semi-Automatic Washing Plants:

The main purpose of this line is to obtain a high-quality washed Waste. Washing Plants are configured to each customers requirement and consists of:

- Belt Conveyors with Metal Detector,
- Shredder / Grinder,
- Screw Conveyors,
- Friction Washer (Good for Hot Wash Also),
- Floatation Tank with Online Sludge Removal Screw,
- Dewatering Drying Centrifuge,
- Hot Air Dryer,
- Squeezer Dryer.

Figure 35- Fully Automatic Washing Lines (Source- www. recycleplastics.in)

Forced Fed Recycling Pelletizing Plant. These plants usually comprise

- Grinder,
- Feeding Blower,
- Force Feeder,
- Vented Extruder,
- Online Screen Changer,
- Dieface Pelletizer.

Densifier/Cutter Compactor Type Recycling Pelletizing Plant. These plants usually comprise

- Belt Conveyor (with optional Metal Detector),
- Trim Feeder (Optional),
- Densifier / Cutter Compactor,
- Vented Extruder,
- Online Screen Changer,
- Dieface Pelletizer.

Mother-Baby (Tandem) Recycling Pelletizing Plant. A Mother and Baby Pelletizing Plan usually comprises of:

- Belt Conveyor (with Metal Detector) OR Grinder with Blower,
- Trim Feeder on Densifier / Cutter Compactor,
- Densifier / Cutter Compactor OR Forced Feeder,
- Vented Extruder (Mother & Baby),
- Vent in both stages of Extruder,
- Online Screen Changer (1 or 2 Nos),
- Dieface Pelletizer.

Figure 36 - Mother Baby Tandem Pelletizing Plant (Source: www.recycleplastics.in)

Advances in Sorting Technology

While, most of the non-critical equipment can be sourced locally, our current dependence rests on the imported Ballistic Separators (2D/3D separation of plastic products) & Sensor based Optical Sorters (commonly known as automatic sorting machines). The high-end Sorting Machines can be programmed to target desired tasks: sorting by polymer grade, colour, shape, defects, chlorine content etc. One such technology available in the European market is the Autosort by TOMRA. The technology combines a variety of leading-edge features in one machine with a flexible sensor configuration for a future-proof sorting system that meets the challenges of a dynamic market landscape. The sorting unit delivers exceptional performance and operational efficiency thanks to its homogeneous light distribution for improved detection and monitoring across the entire belt width .

Figure 37- AUTOSORT (Source - TOMRA)

When the origin of plastic waste is from of waste collectors (kabadiwala) or residue of waste processors, advanced sorting systems are necessary. Sensor based optical Sorting Machines are generally integrated within the Wash Plant for sorting out unwanted fractions, be it by polymer grade, colour or specific objective. In most cases, Flake Sorter(s) or Electrostatic Separator(s) are considered at the end of the wash line for purification or quality check. The INNOSORT™ FLAKE is by TOMRA, is an advanced sorting solution for upgrading plastics such as PET and PO applications. It is highly effective in removing significant amounts of contaminants after washing and before extrusion. The flake sorter is claimed to be easy to maintain.

Figure 38- INNOSORT FLAKE (Source - TOMRA)

Ecogreen RECYCLERS FZC

A COMPANY BASED IN DUBAI THAT IMPORTS-EXPORTS PLASTIC WASTE, NAMELY :

- § LDPE Bales 98/2 & 99/1,Grade-1 materials
- § PP/HDPE/LDPE Lumps
- § P100/P80/P63 pipe grade materials
- § Road divider Roto grade scrap
- § HDPE Drums 200 ltrs to 50 ltrs blue/black/natural
- § BOPP Rolls Printed/Non-Printed/Milky
- § PPCP Battery cases
- § ABS Battery cases
- § Paint buckets
- § Washing machines
- § Milk bottles
- § Crates
- § Pallets

www.ecogreenrecyclers.com

Ecogreen Recyclers FZC is the market leader in reprocessing all types of polymer waste. With a presence in the market since 1969 and over 50 years of experience in waste management and recycling, we have established ourselves as a trusted and reliable company in the industry.

We are strategically located in the UAE, which allows us to easily import post-industrial plastic waste from around the world and reprocess it into valuable raw materials using the best technology available. Our state-of-the-art facilities and experienced team enable us to efficiently and effectively handle a variety of plastic materials.

We take pride in our ability to create a circular economy by scientifically dealing with plastic waste and bringing it back into the system. We are dedicated to protecting the environment and promoting sustainable practices in the waste management industry.

Plot OLG 12, Phase 2, Hamriyah Freezone, Sharjah, UAE

Phone: +971-505535714
Email: akshay@ecogreenrecyclers.com

The quality of quality of recycled granules or pellets decide the admix ratio with virgin; at times even for its 100% reuse. Recyclers are increasingly inclined towards well-proven technologies from overseas, to ensure valuable returns towards the invested money.

Figure 39 - Intarema TVEplus (Source - EREMA)

Certain patented technologies are available for post-consumer plastic waste, where melt filter(s) are placed ahead of degassing or venting system, ensuring high capability in handling a higher percent of leftover contaminants at better production rates and superior product quality as compared to conventional vented extruders (melt filter after venting zone). The design and process engineering of such extruders allows effective filtration, extraordinary degassing efficiency, and an improved homogenisation, which enable processing of even fully coated, multi-layered and vacuum metalized, heavily printed plastic waste, in a single stage, to make high-quality recycled granules or pellets. The INTAEREMA TVE Plus is one such technology, which enables trouble-free processing of materials that are otherwise difficult to process. The company claims that the innovative basic principle of TVEplus® is that the melt filtration takes place upstream of extruder degassing. As a result, end products can be produced with the best quality and the highest possible recyclate content.

Figure 40 - Interema TVEplus RegrindPro (Source - EREMA)

Thick-walled input material (LDPE, HDPE, PP, ABS, PS, etc.) require specific treatment process to handle mixed polymer fractions with varying compositions, high bulk density and leftover moisture, plus strong and varying contaminants through a very wide variety of impurities. The recycled pellets need to comply with exacting quality standards in order to make end products with the requisite quality and high recyclate content. Solutions for such processes are avaiable in the market. One such solution is the Intarema TVEplus RegrindPro technology from EREMA.

Deodourizer

The typical problem of household waste is that it develops intense odours These are caused by contaminants adhering to the surface, as also by migrated odour substances caused by the packaging absorbing the odour of the food, cosmetics, or cleaning agents inside it.

Figure 41- Refresher System (Source - EREMA)

The growing demand for odour-less recycled granules necessiciates final treatment in highly efficient anti-odour technology for more value-addition. The unbeatable combination of top recycled granule or pellet quality and odour optimisation opens completely new application opportunities for recycled plastics. Such effective technologies too are available. The downstream thermal-physical ReFresher cleaning process by EREMA, attends to the low-volatile, high-molecular odour matter. EREMA's patented TVEplus® extruder system has been specifically designed to counteract the development of new odours resulting from impurities such as paper residues or silicone contaminants.

Value-added technologies – Deinking & Delamination

Circular economy drives recycling processes at closing the loop, emerging demand for producing natural like recycled granules (plain or opaque), technologies like Deinking (removal of surface print) & Delaminating (separation by structure viz. PET & PE from a laminate) got introduced. As both the applications have their own challenges to address now, practical trials are inevitable prior to recommendation of commercial plants.

Benefits of Advanced Technologies:

- Pre-Drying not required, in fact upto 3% Moisture is acceptable for processing.
- Forced Feeder which gives continuous output and feeds mostly all types of Waste with consistency and no human intervention.
- Online Cutter Compactor / Densifier / Agglomerator.
- Extruders:
  - Direct Coupled.
  - Small Screw Dia with High Speed.
  - Forced Fed.
  - Variable AC Driven.
  - Vented with Compression type Screw.
  - Heating required is less due to high Friction.
- Offline Manual or Online Fully Automatic / Cassette Type Screen Changer.
- Dieface Cutter.

Benefits and Cost of Production using Advanced Recycling Equipment:

- Very Low Power Consumption of 0.25kW to 0.37kW per kgs, due to:
  - Direct Coupling having no slippage.
  - Variable speed.
  - Consistent Output.
  - No Preheating
  - Extruder Heating low.
  - All motors running below 60% capacity.
- Labour Required are just 2 Persons including Operator, due to:
  - To Supervise, clean filter, and set parameters you need one person.
  - The person collecting Granules can also feed the Extruder.

- Vented and Compressed Extruder:
  - 3% moist or high Gassy printed material or Foam Material can be processed with ease.
  - No need for Pre-Heating the Waste.
- Online Oleo-Dynamic Screen Changer:
  - Screen Can be changed without stopping machine reducing production loss.
- Pressure sensor helps to maintain pressure and change screen when required with a push of a button.
- Dieface Cutter & its Benefits:
  - No reason for strands breaking and lumps generation.
  - Granules are all separate and free flowing helping reuse better than Strand Granules.
  - Machine does not need to stop so Granules are consistent.
  - Even Size of Granules.

Best Practises

Robust Waste Management Systems should be designed to respond to local/ regional challenges of managing waste with appropriate resources while minimizing the impact on the planet. Such systems need to be based on extant government regulations and policies. While the composition of materials will inevitably change over time, the system should cater for incremental adaptation to such changes. A robust waste management system should comprise of

- Deposit Return Schemes (DRS) for PET, metal, and glass beverage containers. This would enable such high value recyclables and maximizing captures of high carbon-intensity material.
- Segregated Collections. Source segregation of waste into various fractions like organic waste, paper, glass packaging, textiles, and e-waste will ensure the maximum carbon benefit when recycling materials. In the absence of segregated waste being collected, appropriate automated sorting solutions at MRF level will be necessary to achieve the same targets. targeted via separate collections depending on the approach or cost-effectiveness.
- EPR policies must be robust to prevent leakages and appropriate regulations should be in place to deal with non-compliant organizations/ individuals.

Deposit Return System at Kedarnath

A Hyderabad-based start-up has launched a unique Deposit Refund System at Kedarnath, a town in Uttarakhand, in collaboration with the district administration to address the problem of littering. Under the deposit refund system introduced by the start-up called Recykal, the pilgrims have to pay an additional deposit on every plastic bottle of water, beverages, soft drinks, or consumer goods packaged in plastic at the time of buying it and the amount is refunded when they return it. A scannable QR sticker is put on each bottle or plastic packet by shop owners on the way to the temple for identification[xli]. The Deposit Refund System (DRS) has been designed to solve the existing challenges of ineffective collection and channelisation of waste at Kedarnath. By placing a value on waste, thereby enabling efficient increased material recovery and better quality for recycling.

Off the Beaten Track

Individual Efforts

Alphamers a Bengaluru based startup has developed floating trash barriers which are placed in rivers to stop waste from entering the seas/oceans. Presently, they have deployed their barriers in eight locations.

Beach Cleaning

Mr. Afroz Shah, has been instrumental in cleaning up Versova beach in Mumbai. In the last few years he has cleaned up to 9 million kgs of garbage on the Versova beach[xlii].

Recycled Products

Save Earth Water Air (SEWA) an NGO working in the plastic recycling and cleanliness awareness space has been installing various products made from post-consumer recycled plastic waste to create greater awareness amongst the populace.

Conclusion

Collection, identification, classification, segregation, sorting, washing, cleaning, drying, reclaiming or recycling (need be, even deodourizing, deinking, delaminating, etc.) of plastic waste is a stupendous effort in converting it back into a "good quality" reusable product. Feasibility lies in the economic chain for an "all win" solution.

Pathways are opening for material recycling facilities, utilizing mechanical recycling methods as compared to chemical or thermal, due to several factors. Prudence lies in continuing the benefits that plastics offer, devising means to overcome its perceived drawback. Effort to reduce and reuse must be sacrosanct with the logical and sensible act to "recycle"!

Appropriate introduction of recycled plastics helps end products meet the required quality specs for which the product is designed. From today's perspective, opportunities in the field of plastic waste management & recycling are exponential. Need is to create a plastics economy - that is smart, sustainable, and circular, bringing Quality Recycling Processes or Practices (QRP).

Globally, substantial improvements in the recycling technologies and value-process chain have guaranteed increase in both - quality & quantity of recycled materials, enabling their uptake in high-end applications like food contact approved mineral water, CSD & beverage bottles, milk containers, cosmetics & healthcare products, thermoforming packaging, household & industrial products and so on. The loop ought to close in the right perspective, perceiving the recycled granules or pellets as the "new" raw material; next best to virgin!

ENVIRO RECYCLEAN

MAXIMIZING EFFICIENCY AND MINIMIZING WASTE WITH OUR TURNKEY PLASTIC RECYCLING SOLUTIONS

Selecting efficient machineries for high-quality plastic processing	Installation of machineries & setting up the operations	Annual maintenance contracts & spare parts	Guidance on sourcing of raw materials

OUR PLASTIC RECYCLING LINES

WASHING LINE

- HDPE/PP RECYCLING LINE
- PP RECYCLING LINE
- PE FILM RECYCLING LINE

EXTRUDERS

- SINGLE STAGE
- TWO STAGE
- THREE STAGE
- TWIN SCREW

ANCILLARY UNIT

- SHREDDER
- GRINDER
- AGGLOMERATOR

+91 84510 03210

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INFO@ENVIRORECYCLEAN.COM

WWW.ENVIRORECYCLEAN.COM

Association related to Plastics in India

All About EPR	www.allaboutepr.com
All India Plastic Manufacturers Association	
AIPMA	www.aipma.net
Centre for Environment Education (CEE)	www.ceeindia.org
Central Institute of Petrochemicals Engineering & Technology (CIPET)	www.cipet.gov.in
Chemicals and Petrochemicals Manufacturers' Association (CPMA)	www.cpmaindia.org in
Gujarat State Plastic Manufacturers Association (GSPMA)	www.gspma.in
Indian Centre for Plastic in the Environment (ICPE)	www.icpe.in
Indian Pollution Control Association (IPCA)	www.ipcaword.co.in
Indian Plastics Federation (IPF)	www.ipfindia.org
Indian Plastics Institute (IPI)	www.ipindia.org
Material Recycling Association of India (MRAI)	www.mrai.org.in
Organisation of Plastic Processors of India (OPPI)	www.oppindia.org
PET Packaging Association for Clean Environment (PACE)	www.paceindia.org.in www.petrecycling.in
Plastindia Foundation	www.plastindia.org
Plexcouncil	www.plexcouncil.org
Plastic Manufacturers Association of India (PMMAI)	www.pmmai.org

Institute of Packaging Machinery Manufacturers of India (IPMMI)	www.ipmmi.org
Sarthak Sanstha	www.sarthaksanstha.com
Telangana and Andhra Plastic Manufacturers Association (TAAPMA)	www.taapma.com
Tamil Nadu Plastic Manufacturer's Association (TAPMA)	www.tapma.in

Start Ups

Company	Activity
3 R Management	Provides various solutions for waste management through digital technology. www.3rmanagement.in/
Angirus	The company recycles plastic and construction waste into bricks and paver blocks. https://www.angirusind.com/
Antariksh Waste	Focuses on designing and developing Smart IoT-powered garbage bins with Load & Communication modules, to establish a smarter eco-system of waste disposal and recycling management. https://antariksh.io/
APChemi	A leading provider of chemical recycling solutions by developing sustainable pyrolysis technology for post-consumer plastic waste, including landfill plastic waste. https://www.apchemi.com/
Ashaya	A social enterprise that increases the value of waste through technological and scientific innovations in recycling. Redistributes the value to stakeholders in the supply chain, especially waste-pickers. https://ashaya.in/
Banyan Nation	Amongst India's few vertically integrated plastic recyclers. Convert waste plastic into granules. www.banyannation.com/
Bhudhaav Polymers	Upcycled and recycled material. srinivasan@bhudhaavpolymers.com
Bintix	Provides scheduled recyclable collection at doorstep while working towards a zero-landfill future, with scrap dealers and waste pickers. https://www.bintix.com/

Company	Activity
Biocrux	Reverse Vending Machines for Plastic bottles biocrux.co.in
Citizengage	A technology platform which combines latest in mobility, IoT, algorithms and analytics to measure, track, monitor, and control the entire cycle of waste to resource conversions. The platform is a single point of contact for businesses and residential complexes. www.citizengage.co/
DRI Bharat	Plastic Waste Management Projects www.dri-bharat.co.in
Earth Recycler	Provide customised waste management consulting service solutions for various sectors from corporate organizations, educational institutions, residential apartments, retail chains, urban local bodies to the general community at large https://earthrecycler.com/
Eco Chirp Sustainability School	A Sustainability School enabling the journey of individuals in the space of sustainability. guptaharshad661@gmail.com
Econiture	A dry waste management company that recycles plastic waste into furniture and home decor products. https://www.econiture.com/
Eco eMarket	A smart and innovative cloud-based digital solution that brings together sellers and recyclers on the same platform to enable seamless disposal anywhere, at any time, with transparency and the best commercials. https://ecoemarket.com/
Econscious	A social impact startup which recycles waste plastic into eco-boards and then curate innovative and functional products of multiple usage. https://www.econscious.co.in/
Enviro Recyclean	A start up involved in recycling of all types of plastic waste into granules. Also makes products like tiles and furniture from MLP. https://envirorecyclean.com/

Company	Activity
Extra Carbon	A young and energetic organisation that aims to reduce the carbon from planet through effective waste collection and its proper recycling as well as conserving energy. https://extracarbon.wordpress.com/
Feelgood Econurture LLP	The Start-up has patented a tile made from post-consumer Multilayer Plastic, in addition to other products. https://www.feelgoodeco.in
Five Element Environmental Technologies	Has developed patented technology for conversion of plastic waste into LDO, Naptha and carbon black. www.5elementsenviro.com
GEM Enviro Management	An authorised Producer Responsibility Organisation (PRO), they recycle collected plastic waste into T-shirts, caps, and bags. https://gemrecycling.com/
Gore Environmental Solutions LLP	Waste Plastic to Light Diesel Oil. www.gorepyrolsis.com
Green Aadhar	Block chain plastic credit www.greenaadhar.in
Green Worms	A company which aims to create dignified jobs through a circular economy to eradicate both plastic pollution and poverty Strategy. www.greenworms.org
Hasiru Dala	An organisation of waste workers whose mission is to improve livelihood and quality of life of waste pickers by providing comprehensive waste management services to large waste generators. https://hasirudala.in/
ICSWM	The start-up specialise in providing solutions to municipal solid waste management comprising organic and recyclable waste. www.icswm.org
Infinite Cercle CercleX	This is a cloud-based, full-stack waste management company that strives for circularity, enabling brands to achieve zero waste through circularity while also meeting their sustainability goals. https://cerclex.com/

Company	Activity
Ishitva Robotic	Designs and builds Waste Sorting Plants and Solutions using Industry 4.0 Technologies. http://ishitva.in/
Kabadiwala	Developed a technology that makes it easy for thousands of consumers to sell scrap online. www.thekabadiwala.com/
LUCRO Plast e Cycle Pvt Ltd	Post consumer waste collection and recycling it into final packaging products.
Minus Degre	Design and manufacture 100% recycled plastic products. https://minusdegre.com/
Neeman's	www.neemans.com
Novoearth	Involved in recycling the plastic waste and manufacture of 100% compostable biopolymer pellets. https://novoearth.co/
Paperman	Undertakes EPR, waste collection and awareness programmes. www.papermanfoundation.org/
Paterson Energy	A waste-to-energy company that recycles plastic waste into high-quality plastic fuel using a continuous thermochemical depolymerisation technology process. http://www.patersonenergy.com/
Patpert Teknow Systems Pvt Ltd.	Waste Plastic to Light Diesel Oil. Patpert.in
Planet First Recycling	Waste management social enterprise, uses smart waste collection mechanisms and world-class recycling machinery to reintroduce recycled waste into the supply chain in Himalayan region. www.planetfirst.in
Plastics for Change	An ethical sourcing platform to create sustainable livelihoods for the poor (Waste Collectors) while transitioning the industry to a circular economy. https://www.plasticsforchange.org/

Company	Activity
PolyCycl	Has developed multiple technologies for chemical recycling and purification of different types of waste plastics by converting non-recyclable, low-grade mixed waste plastics into petroleum fuels. https://www.polycycl.com/
Pro Earth eco Systems Pvt Ltd	Integrated waste management solutions and plastic waste collection. www.proearth.in
Raddi Dedo	A doorstep scrap collecting service that buys newspapers, magazines, metal, iron, plastic, and other items from customers doorstep. https://raddidedo.com/
ReAtmos	Manufacturer of smart reverse vending machines for collection of plastic bottles. https://www.reatmos.com/
Recircle (Formerly – Raddiconnect)	A resource recovery company diverts resources, from getting into landfills and oceans, back into the economy to be reused, recycled, or repurposed. https://recircle.in/
Recity	EPR solutions provider, they provide transparency in sourcing, traceable, high quality recyclates of all kinds of plastics including flexible, multi-layered, low value plastics. www.recity.in
RecycleX	Converts plastic waste into building materials like bricks, tiles, paver blocks, planters etc. https://www.recyclex.in/
Recykal	Developed digital technology for connecting waste producers, processors, and recyclers with each other. www.recykal.com
Rexaw Recycling	Recycles aseptic packaging material into recycled Chipboards, that are further used in making furniture. https://www.rexaw.com/
Riolo	The start-up makes jewellery, benches, and furniture from recycled plastic waste. www.riolo.in

ENVIRO RECYCLEAN

ISO 14001:2015 ISO 9001:2015 Global Recycled Standard

WASTE MANAGEMENT AGENCY & ONE OF THE LARGEST PLASTIC RECYCLING PLANT IN INDIA

We're all about Recycling & Waste Management
Started with the purpose of transforming plastics into a circular economy by recycling practically all sorts of plastic waste, with the goal of creating a more sustainable future. We have established a recycling facility in Indore, Madhya Pradesh, where we collect plastic waste material from PAN India for reprocessing from various sources such as Municipal Bodies, Scrap Traders, Kabadiwala's Industries, and others, and reprocess it into new products that can be used in a wide range of businesses.

Our Services Includes

- **Post-consumer Plastic Waste Management**
- **Recycled Plastic Products**
- **Extended Producers Responsibility (EPR)**
- **Industrial Plastic Waste Management**

+91 98207 39924 INFO@ENVIRORECYCLEAN.COM WWW.ENVIRORECYCLEAN.COM

Company	Activity
Rudra Environmental Solutions	Convert Plastic waste to fuel (light diesel oil). www.rudraenvsolution.com
Saltech Design Labs	Has developed a technology driven recycling process to convert+ post-consumer mixed plastics & industrial mineral waste into polymer composite material. https://saltech.co.in/
Samudhyoga Waste Chakra	Uses advanced technology to create value from solid and liquid waste in a decentralised, digitised, and decarbonized manner. https://www.wastechakra.com/
Scrapbuk	A waste management start-up with an online platform (mobile application) to facilitate the sale and purchase of scrap. https://scrapbuk.com/
Shahas Zero Waste	A socio-environmental enterprise with waste management experience that provides end-to-end waste management services. www.sahaszerowaste.com
Shayna EcoUnified	Involved in creating affordable structural materials like plastic tiles and furniture from the plastic waste www.shaynaecounified.com/
Skyi Innovations LLP	Bio polymers www.skyi.in/
Social Lab	A start-up working in Solid Waste Management and EPR or Plastic Waste. www.social-lab.in
Spruce Up	Spruce Up is a startup which makes true contactless garbage collection machines. https://spruceup.in/
Switch eko	B2B market place for sustainable products www.switcheko.com
The Money Bin	A waste management start-up that collects dry waste. http://themoneybin.in/

Company	Activity
Thermowaste Solutions	A plastic waste recycling company which processes both recyclable and nonrecyclable waste. https://www.thermowastesolutions.com/
Vital Waste	A start-up which buys various types of recyclable waste including PET from citizens/ organisations and connect the waste to respective recyclers. http://vitalwaste.com/
ZeroPlast Labs	An innovation-driven, sustainable materials company, developing 100% biodegradable (home compostable) alternatives to single-use, non-recyclable plastics. https://www.zeroplastlabs.com/
Zerocircle	Create bio-alternatives Packaging Bags which are heat sealable, printable, food-safe, and 100% home compostable. https://www.zerocircle.in/

Source: Internet search, industry inputs

Plastic Recyclers in India

Company Name	Web	Recycled Products
21st Century Polymers	Rajeshpahwa71@gmail.com	Granules/ Pellets
A1 Impex	https://www.a1impex.net	Flakes, Granules/ Pellets
Aashirwad Industries	https://www.aashirwadindustries.in	Granules/Pellets
ABS Polymer	https://www.abspolymers.in	Granules/Pellets
Addonn Polycompounds Pvt. Ltd.	www.addonnpolycompounds.com	Granules/Pellets
Adinath Polymers	www.absgranulesdelhi.in	Granules/Pellets
AGL Polyfil Pvt. Ltd.	www.aglpolyfil.com	Flakes
Al Mehtab Industries Pvt. Ltd.	www.almehtabindustries.com	Flakes, Granules/ Pellets
Alliance Fibres Ltd.	https://alliancefibres.com	Flakes
Allied Containers	www.alliedcontainers.in	Granules/Pellets
Amaani Polyflakes	www.amaanipolyflakes.com	Flakes
Archieve Eco Tech Pvt. Ltd.	https://archieve-eco-tech.business.site	Flakes
Ariston Ventures	www.aristonventures.com	Flakes
Arun Manufacturing Services Pvt. Ltd.	https://www.pefilms-tarps-ropes.com	Granules/Pellets
Asha International	www.ashainternational.co.in	Flakes, Granules/ Pellets
Avani industries	www.avaniindustries.co.in	Flakes, Granules/ Pellets

Company Name	Web	Recycled Products
AVS Cables & Compound Industries	www.pvccompounds.in	Granules/Pellets
B. R. Plastic Industries Pvt. Ltd.	www.brplasticindustries.com	Granules/Pellets
Balaji Trading Co.		Flakes
Bhagul Industries	https://www.bhagulind.com	Granules/Pellets
Bharat Polymer Extrusions	https://www.bharatpolymer.com	Granules/Pellets
Choudhary Plastics	https://www.choudharyplastics.in	Granules/Pellets
Crescent Polymers	www.crescentplasticindustries.com	Granules/Pellets
Dalmia Polypro Industries Pvt. Ltd.	www.dalmiapolypro.in	Flakes, Granules/ Pellets
Dhwani Plastic	www.dhwaniplastic.com	Granules/Pellets
DSA Imports	https://www.dsaimports.com	Flakes, Granules/ Pellets
Ecovision Environmental Resources LLP	www.eco-vision.co.in	Granules/Pellets
Espoir Plast India Pvt. Ltd.	www.espoirplast.com/	Flakes, Granules/ Pellets
Esprit India Polymers Pvt. Ltd.	www.espritpolymers.com	Flakes, Granules/ Pellets
Evershine Polymers	www.evershinepolymers.com	Granules/Pellets
Fouji Jain Plastic	www.absgranulesindia.com	Granules/Pellets
Ganesh Polymers & Siddhi Vinayak Industries	www.ganeshpolymers.com	Granules/Pellets

Company Name	Web	Recycled Products
Ganesha Ecosphere Ltd.	https://www.ganeshaecosphere.com	Flakes, Granules/ Pellets
Giraffe Packaging Solutions	https://www.giraffepack.com	Flakes
Global Exim	www.globaleximsin	Granules/Pellets
GM Polyplast Limited	www.gmpolyplast.com	Granules/Pellets
GoldPlast Polymers	www.goldplastpolymers.com	Granules/Pellets
Gravita India Limited	https://www.gravitaindia.com	Flakes, Granules/ Pellets
Gravure Plast	www.gravureplast.com	Granules/Pellets
Green Agro Plast Pvt. Ltd.	https://www.greenagroplast.in/	Granules/Pellets
Green India Polymers	https://www.greenindiapolymers.in	Flakes
Green Roots Solutions	https://www.grsindia.co.in/	Granules/Pellets
GSM Plastic Industries	www.gsmplastics.com	Flakes, Granules/ Pellets
Gujarat Craft Industries Limited	https://www.geomembrane manufacturers.com	Granules/Pellets
Halifax Greentech LLP	https://www.halifaxllp.com	Flakes
High Polymers	www.highpolymers.co.in	Granules/Pellets
Hindustan Plastic	https://www.hindustanplastic.com	Flakes, Granules/ Pellets
Hinglaj Plastic Industries	https://www.hplasticind.com	Granules/Pellets
Hitemp Polymers Pvt. Ltd.	www.hitemppolymers.com	Granules/Pellets

Company Name	Web	Recycled Products
Iqra Plastic	www.polycarbonategranules.in	Flakes
J.K. Engineering Polymers	www.jkengineeringpolymers.com	Granules/Pellets
J.V. Polymers	https://www.jvpolymers.in	Granules/Pellets
Jagriti Polymers	https://www.jagritipolymers.com	Granules/Pellets
Jai International	www.jai-international.com	Granules/Pellets
Jai Shree Balaji Plastic	https://www.plasticgranules.co.in	Granules/Pellets
Jain Metal Group	https://www.jainmetalgroup.com	Granules/Pellets
Jain Plastics	www.jainplastics.net	Granules/Pellets
Jairam Plastic Industries	https://jairamplastic.com	Granules/Pellets
Jairam Polymers	www.hdpegranules.com	Granules/Pellets
Jay-Kay Plastic	www.jaykayplastic.com	Granules/Pellets
Jayachandran Plastics (P) Ltd	www.jcplastics.net	Flakes, Granules/ Pellets
JB Ecotex LLP	https://www.jbecotex.com	Flakes
Jhunsons Chemicals	www.jhunsonschemicals.co.in	Granules/Pellets
Jwala Plastic	https://https://www.jwalaplastic.com	Flakes, Granules/ Pellets
K.V. Plastic Pvt. Ltd.	www.kvplasticgranules.com	Granules/Pellets
Kalpataru Polymer Pvt. Ltd.	https://www.kalpatarupolymer.com	Flakes, Granules/ Pellets
Kamal Plastics	https://www.kamalplastic.com	Granules/Pellets
Kamal Polyplast	www.kamalpolyplast.com	Granules/Pellets

Company Name	Web	Recycled Products
Kavya Polymers	https://www.kavyapolymers.com	Granules/Pellets
Keshav Enterprises	www.keshavs.in	Granules/Pellets
Key Exports	www.keyexports.in	Flakes, Granules/ Pellets
Khushii Enterprises	www.plasticgranules.net	Granules/Pellets
King Polymers	www.kingpolymers.in	Granules/Pellets
Kiran Plastics	www.kiranplastics.com	Granules/Pellets
KK Plastic Waste Management Ltd.	www.kkplasticroads.in	Flakes, Granules/ Pellets
KKalpana Industries (India) Limited	https://www.kkalpanagroup.com	Granules/Pellets
Knack Packaging Pvt. Ltd.	https://www.knackpackaging.com	Granules/Pellets
Komal Plastics	www.komalplastics.com	Granules/Pellets
Kundana Techno Tex Pvt. Ltd.	https://www.kundana. pashupatigrp.com	Flakes
Laxmi Plastic	www.laxmiplastics.in	Granules/Pellets
Luckystar Group	https://www.luckystar international.in	Granules/Pellets
Lucro Plastecycle Pvt. Ltd.	https://www.lucro.in	Granules/Pellets
M.R. Polytech	mrpolytech.com	Granules/Pellets
M/s Kapil International	www.kapilinternational.com	Flakes, Granules/ Pellets
Macpac Plastics & Packaging LLP.	https://www.macpacplastics. webnode.com	Flakes, Granules/ Pellets

Company Name	Web	Recycled Products
Nidhi Enterprises	nidhienterprises.net	Granules/Pellets
Oasis International	www.oasisinternational.co.in	Flakes, Granules/ Pellets
Oscar Polymers	https://www.oscarpolymers.co.in	Flakes, Granules/ Pellets
Panku Plastic Polymers	https://www.pankuplastic.com	Granules/Pellets
Paras Plastics	https://www.parasplastics.co.in	Granules/Pellets
Parkash Plastic	https://www.parkashplastic.com	Flakes, Granules/ Pellets
Pashupati Extrusions Pvt. Ltd.	https://excrusion.pashupatigrp.com	Granules/Pellets
Pashupati Polytex Pvt. Ltd.	https://polytex.pashupatigrp.com	Flakes
Pawan Plastics	www.pawanplastics.com	Granules/Pellets
Pearl City Recycling	https://www.pearlcityrecycling.com	Granules/Pellets
Peeco Polytech Pvt. Ltd.	www.peecopolytech.com	Granules/Pellets
Pik India	www.pikindia.com	Granules/Pellets
Plast-O-Fine Industries	www.plastofine.com	Granules/Pellets
Polyraw Enterprises India Pvt. Ltd.	https://www.polyrawent.com	Granules/Pellets
Popular Plastics	popularplast.com	Granules/Pellets
Prayosha Polyplast	prayoshapolyplast.com	Granules/Pellets
Raghushree Plast Products Pvt. Ltd.	https://www.raghushree.com	Flakes, Granules/ Pellets

cercleX

World's first digital waste management company to launch on Web3.

Cercle X a blockchain-based world's first digital waste management company to launch a waste management platform based on Web3 Technology, NFT Minting, Blockchain, Plastic Credit and Carbon Credits.

Cercle X aims to provide Smart Waste Management Solutions Across the Entire Value Chain

Few of Cercle X Services includes:

- **Smart Plastic Waste Management using Metabins.**
- **Deposit Return Scheme (DRS) – Mobile APP & Web App**

Unique Value Propositions:

- **Circularity First Approach**
- **Access to 100,000+ Planet Warriors additional PR**
- **100% Paperless Process**
- **100+ Verified stakeholders**
- **100+ Traceable**

Recent Awards

for more informaton visit our website at cerclex.com

Company Name	Web	Recycled Products
Madhusudan Durgesh Polymers Pvt. Ltd.	www.madhusudanlldpe powder.com	Granules/Pellets
Magvill Group	magvill.com	Flakes
Mahalaxmi Agroplast Industries	www.mahalaxmiagroplast.co.in	Granules/Pellets
Mahalaxmi Industries	www.mahalaxmiindustries.in	Granules/Pellets
Mahan Polymers	mahanpolymers.com	Flakes, Granules/ Pellets
Mahendra PET Scrap Supplier	www.mahendrapetscrap.com	Flakes
Markandey Polymers	www.ppdana.in	Flakes, Granules/ Pellets
Md. Israil and Sons	www.mdisrailandsons.com	Granules/Pellets
Meckla Polymers Pvt. Ltd.	www.mecklapolymers.com	Flakes
Mittal Plastic Industries	www.mpibhiwani.com	Granules/Pellets
MMR Recycling	www.mmrrecycling.in	Granules/Pellets
Modlon Polymers India Pvt. Ltd.	www.modlonpolymers.com	Granules/Pellets
MSGP Infra Tech Pvt. Ltd.	www.msgp.co.in	Granules/Pellets
MTL New Initiatives Pvt. Ltd.	www.manjushreeindia.com/ born-again.php	Granules/Pellets
Nahata Plastikos LLP	nahataplastikos.com	Granules/Pellets
Neelgiri Poly Plast	www.neelgiripolyplast.com	Granules/Pellets
New Kunal Plastic	www.ppdanadelhi.com	Granules/Pellets

Company Name	Web	Recycled Products
Raj Plastic Industries	www.rajplastic.com	Granules/Pellets
Rajesh Polytech	https://www.rajeshpolytech.com	Granules/Pellets
Ravago Manufacturing India Pvt. Ltd.	https://ravagomi.com	Granules/Pellets
Rayan Polymers LLP	https://rayanpolymersllp.com	Flakes, Granules/ Pellets
Raza Traders	https://www.razapolymers.com	Granules/Pellets
Recycling Hub	https://www.recyclinghub.in	Granules/Pellets
Rexaw Waste Management	https://www.rexaw.com	Granules/Pellets
RI Import & Export	https://rajeshwariinternational.in	Flakes, Granules/ Pellets
RK Enterprises	www.pppackingstrap.com	Flakes, Granules/ Pellets
Roto Polymers	www.rotopolymers.in	Granules/Pellets
RR Petroplast Pvt. Ltd.		Granules/Pellets
Rudraksh Polychem	www.rudrakshpolychem.com	Granules/Pellets
S Group of Industries	https://sgroupofindustries.com	Granules/Pellets
S.S.B. Polymers	www.ssbpolymers.com	Granules/Pellets
Sachin Plastic	www.sachinplastic.com	Granules/Pellets
Samridhi Industries	www.samridhiindustries.com	Granules/Pellets
Sandeep Polymers	www.sandeeppolymers.com	Granules/Pellets
Sangamam Polymers	www.sangamampolymers.com	Granules/Pellets
Santosh Plastic	https://www.santoshplastic.com	Granules/Pellets

Company Name	Web	Recycled Products
Saurabh Clean Tech Pvt. Ltd.	https://sct.pashupatigrp.com	Flakes, Granules/ Pellets
Sevenstar Polytex Pvt. Ltd.	www.sevenstarpolytex.tradeindia.com	Flakes, Granules/ Pellets
Shah Plast Management	www.shahplastmanagement.co.in	Flakes, Granules/ Pellets
Shakmbhri Polymers	https://www.shakmbhri polymers.com	Granules/Pellets
Shakti Corporation Pvt. Ltd.	www.shakticorp.co.in	Granules/Pellets
Shakti Plastic Industries	https://www.shaktiplasticinds.com	Granules/Pellets
Shakti Polymers	www.shaktipolymersindia.com	Granules/Pellets
Shiv Pooja Plastic	www.shivpoojaplastic.net	Granules/Pellets
Shivana Agropack LLP	www.shivanaagropack.com	Flakes
Shree Balaji Industries		Flakes
Shree Balaji Traders	www.plasticgranule manufacturer.com	Granules/Pellets
Shree Bhavani Engg. Works	www.plasticgranules.com	Granules/Pellets
Shree Krishna Polymers	www.shrikrishnapolymer.com	Granules/Pellets
Shree Renga Polymers	www.shreerengapolymers.com	Flakes and recycled clothes
Shree Sadguru Plastic Industries	sadguruplastics.com	Granules/Pellets
Shree Salonee	www.shreesalonee.com	Granules/Pellets
Shreeji Polyplast	https://www.shreejipolyplast.com	Granules/Pellets

Company Name	Web	Recycled Products
Shreenathji Process	https://www.shreenathjiprocess.com	Granules/Pellets
Shri Ganesh Polymer	www.shriganeshpolymer.com	Granules/Pellets
Shri Radhay Krishna Enterprises	www.srkelenobag.com	Granules/Pellets
Shubham Polymer	www.shubhampolymers.co.in	Flakes, Granules/ Pellets
Shyam Polymers	www.shyampolymers.com	Granules/Pellets
Siddhi Vinayak Industries	https://www.coolantindia.in	Granules/Pellets
Sparsh Polychem Pvt. Ltd.	www.sparshpolychem.com	Granules/Pellets
SPP Enterprises	www.sppenterprises.in	Flakes, Granules/ Pellets
SRD Polymers	https://www.srdpolymers.in	Granules/Pellets
Sri Chakra Polyplast India Pvt Ltd.	https://www.srichakra.in	Flakes, Granules/ Pellets
Strong Strap Pvt. Ltd.	strongstrap.com	Flakes
Surya Min Chem	https://www.suryaminchem.com	Granules/Pellets
Thrinetra Pet Flakes	www.thrinetrapetflakes.com	Flakes
TP Polymer Pvt. Ltd.	https://www.tppolymer.com	Granules/Pellets
Tula Packaging Pvt. Ltd.	https://tulapackaging.business.site	Granules/Pellets
Umiya Products Industries	www.umiyaproducts.co.in	Granules/Pellets
Vaishnavi Poly Plast	https://www.vaishnavipolyplast.com	Granules/Pellets
Vanshika Plastic Industries	https://www.vanshikaplastic.com	Granules/Pellets

Company Name	Web	Recycled Products
Vishal Poly Fibers Pvt. Ltd.	https://vishalpolyfibres.com	Flakes
VKS Plastic Compound Pvt. Ltd.	https://www.bajajplastic.com	Granules/Pellets
Vrindavan Plastic Industries	www.vrindavanplastics.com	Granules/Pellets
WhiteLine Thermoplast Pvt. Ltd.	www.whiteline.co.in	Granules/Pellets
Yadav Infrapolymers Pvt. Ltd.	yadavinfrapolymers.in	Granules/Pellets

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ENF Recycling; www.enfrecycling.com/
PlastIndia Foundation; www.plastindia.org

Recycling Machinery Manufacturers

Name of Company	Website
A.A.Enterprise	aaenterprises22@gmail.com
Abhi Plastic	www.abhiplastics.com
Bandera Luigi Costruzioni Meccaniche SPA	www.luigibandera.com
Bestool Manufacturing Pvt. Ltd.	www.getplasticrecycling.com
Boretech Environmental Engineering Co., Ltd.	www.vikramind.com
Clips Poly Engineering	www.clipspoly.com
Coperion GMBH	www.coperion.com
Dalmia Polypro Industries Pvt. Ltd.	www.dalmiapolypro.in
Davis-Standard LLC	www.davis-standard.com
Dollplast Machinery INC	www.dollplast.com
Enma Machinery & Recycling Technology (China) Co., ltd.	www.enma.fr
Erema Engineering Recycling Maschinen Unnd Anlagen GMBH	www.erema.com/en/home/
ESOPP	www.esopp-group.com/
Extrusiontech	www.extrusiontech.in
Famous Polymers	www.famouspolymers.com
Gaurav Engineering	www.gauravengg.com
GMS Plastic Machinery Private Limited	www.recycleplastics.in
Gneuss Kunststofftechnik GMBH	www.gneuss.com
Hangzhou Fangyuan Plastics Machinery Co. Ltd.	www.fang-yuan.com
Herbold Meckesheim GMBH	www.herbold.com
Hosokawa Alpine AG	www.hosokawa-alpine.com
HYMA APS	www.hyma.dk
I.S.T. Italia Sistemi Tecnologici SPA	www.ist.it/en

Name of Company	Website
J P Extrusiontech Private Limited	www.jpel.in
KBM Extrusions Machines Pvt. Ltd	www.kbmextrusions.com
Konark Plastomech Pvt Ltd.	www.konarkplastomech.com/
Krones AG	www.krones.com
Kraussmaffei Berstorff GMBH	www.kraussmaffei.com
Leistritz Extrusionstechnik GMBH	extruders.leistritz.com
Lohia Corp Limited	www.lohiagroup.com
Leevams Incorporated	www.leevams.in
Lung Meng Machinery Co Ltd	www.lungmeng.com.tw
Maag Germany GMBH	www.maag.com
Matila Industrial Co., Ltd.	www.matilataiwan.com
Neue Herbold Maschinen- Und Anlagenbau GMBH	www.neue-herbold.com/de/
Neoplast Engineering Private Limited	www.neoplast.com
New Orange Plastic Machinery	www.orangeplasticmachinery.com
Next Generation Recycling Maschinen GMBH	www.ngr-world.com
Panchal Plastic Machinery Pvt. Ltd.	www.panchal-plastic.com
Polystar Machinery Co. Ltd	www.polystarco.com
R.R. Plast Extrusions Pvt Ltd.	www.rrplast.com
Sesotec GMBH	www.sesotec.com
Sevenstars Machinery	www.sevenstarsgroup.cn
Shree Radhe Krishna Extrusions Pvt, Ltd.	www.radhekrishnaexports.com
Starlinger Recycling Technology	www.starlinger.com
Steer	www.steerworld.in
Technology Plastomech Private Limited	www.tpplindia.com
TOMRA	www.tomra.com
Vecoplan AG	www.vecoplan.com
Venus Sorting Technologies Private Limited	www.venuscoloursorters.com
Weima Maschinenbau GMBH	www.weima.com
Zhejiang Boretech Co.Ltd.	www.bo-re-tech.com

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ENF Recycling; www.enfrecycling.com/
PlastIndia Foundation; www.plastindia.org

Major Plastics Recycling Centres

Sr. No.	State	Location
1	Bihar	Patna
2	Chattisgarh	Raipur
3	Chattisgarh	Bilaspur
4	Daman	Daman
5	Delhi	Tikri Kalan
6	Delhi	Kamruddin Nagar
7	Delhi	Vishwas Nagar
8	Delhi	Shahdara
9	Gujarat	Dhoraji
10	Gujarat	Ahmedabad
11	Gujarat	Bhavnagar
12	Karnataka	Belgaum
13	Karnataka	Dharwad
14	Karnataka	Shivamogga
15	Karnataka	Mangaluru
16	Karnataka	Davangere
17	Karnataka	Tumakuru
18	Karnataka	Bengaluru
19	Karnataka	Mysuru
20	Kerala	Kochi
21	Madhya Pradesh	Indore
22	Madhya Pradesh	Bhopal
23	Maharashtra	Dharavi
24	Maharashtra	Malegaon
25	Maharashtra	Jalgaon
26	Maharashtra	Aurangabad

Sr. No.	State	Location
27	Maharashtra	Sholapur
28	Maharashtra	Kolhapur
29	Odisha	Bhubneshwar
30	Odisha	Cuttack
31	Odisha	Balasore
32	Punjab	Amritsar
33	Punjab	Khanna
34	Punjab	Dhuri
35	Punjab	Ludhiana
36	Punjab	Moga
37	Punjab	Jalandhar
38	Rajasthan	Jaipur
39	Tamil Nadu	Chennai
40	Tamil Nadu	Coimbatore
41	Tamil Nadu	Madurai
42	Tamil Nadu	Tiruchirappalli
43	Tamil Nadu	Tirunelveli
44	Tamil Nadu	Salem
45	Telangana	Hyderabad
46	Uttar Pradesh	Kanpur
47	Uttar Pradesh	Meerut
48	Uttar Pradesh	Lucknow
49	West Bengal	Kolkata
50	West Bengal	Siliguri
51	West Bengal	Maldah
52	West Bengal	Murshidabad

FEELGOOD ECO-NURTURE

A CIRCULAR ECONOMY ENTERPRISE

99% of CO_2 emission reduction compared to 1 kg of concrete tile

made from using **1 kg** post-consumer MLP waste

WHERE WASTE FEELS GOOD

Potential solution aimed at reducing the post-consumer plastic waste ***transported and left untreatable in the landfills.***

CIRCULAR ECONOMY · SUSTAINABLE MATERIAL · REDUCED CARBON EMISSION

High load capacity	Antistatic	Fire resistant	UV resistant	Non-toxic	Long life	Interlocking Machanism

FEW OF THE AWARDS

- FEATURED IN TOP 50 SOLUTIONS — 2020 — SDSN YOUTH
- BEST RECYCLED PRODUCT — PRCA 2.0
- AWARD UNDER START-UP CATEGORY — 2022 — ICCEF
- BUSINESS EXCELLENCE AWARD — 2022 — MSMECCII

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Additive & Masterbatch Manufacturers

Baerlocher	www.baerlocher.com
BASF	www.basf.com/in
Chroma Color Corporation	www.chromacolors.com
DOW	www.dow.com
Entec Polymers	www.entecpolymers.com
ExxonMobil	www.exxonmobilchemical.com
Fortune International Technology, LLC	www.fortuneintltech.com
RAJIV	www.rajivplastics.com
SCj Plastics	www.scjindia.net
Tosaf, Inc	www.tosaf.com

Source :
PlastIndia Foundation; www.plastindia.org

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31st Dec 2022

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Founder Members & Constituent Members

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ISO 9001:2008 Certified

OPP
Organizations of
Plastics Processors of India

Indian Plastics Institute

Indian Plastics Federation

GSPMA
Gujarat State Plastic
Manufacturers' Association

The Plastics Export
Promotion Council

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CPMA
Chemicals & Petrochemicals
Manufacturers' Association, India

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Recycling

Sustainability

Constantly innovating to meet tomorrow's challenges.

PRODUCT LINE

rPET

- rPSF
- rPET Granules (Non Food Grade)
- rPET Flakes (Non Food Grade)
- rPET Master Batch
- Specialty Fibre (Virgin and Recycled)

rPP

- rPP Regrind
- rPP Granules
- Additives Fillers
- rWoven Fabric & Sack
- Master Batch
- FIBC Bags

rPE

- rHDPE Regrind
- rHDPE Granules
- rWoven Fabric & Sacks
- rLDPE Granules

Group Companies

PASHUPATI LAMINATORS PVT. LTD. Kashipur (Uttarakhand)	**PASHUPATI POLYTEX PVT. LTD.** Kashipur (Uttarakhand)	**SHREE RAM POLYMERS** Kashipur (Uttarakhand)
PASHUPATI EXCRUSION PVT. LTD. Kashipur (Uttarakhand)	**SRM SPINNERS LTD.** Bhilwara (Rajasthan)	**KUNDANA TECHNO TEX PVT. LTD.** Hyderabad (Telangana)
SALASAR TECHNO TEX PVT. LTD. Jaipur (Rajasthan)	**SAURABH CLEAN TECH PVT. LTD.** Bhiwadi (Rajasthan)	**PASHUPATI AGENCIES** Gorakhpur (Uttar Pradesh)

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