PLASTIC RECYCLING DECODED

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PLASTIC RECYCLING DECODED

Contents

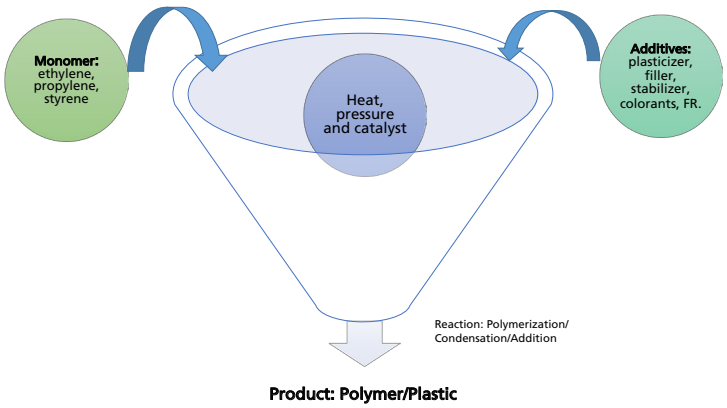
What are plastics?

Over the last 70 years, there has been an exponential rise in the production of plastics. Plastics have become an omnipresent part of the everyday life of billions of people. Properties like low cost, low weight, durability and barrier tendency have gradually raised the demand for plastic materials and it is bound to increase further in the coming years. However, the very same properties make plastic waste an unreasonable prospect when it comes to waste management. To solve the problem of plastics then, we first have to fully understand what they are.

Plastics are made up of synthetic or semi-synthetic organic (carbon containing) compounds called monomers, mostly derived from natural gas and crude oil. This organic fraction is then blended with inorganics. When this concoction is subjected to certain specific reaction parameters in the presence of a catalyst, it yields a polymer that we broadly know as plastic.

The kind of reaction and the type and amount of additives that are added to the monomer make it possible to produce plastics with specific properties: opaque or transparent; flexible or rigid (see *Figure 1: Plastic production process)* Additives are mostly chemicals which are added to plastics to improve and enhance their properties. Additives like fillers and stabilizers make the plastics heavy and durable and additives like plasticizers make the plastic more flexible. Additives are however known to be harmful for both the environment as well as human health. They can migrate from the material and enter into our water and food, and they are also released into the environment when recycling. Sometimes, addition of these additives makes plastic recycling even more difficult.

Figure 1: Plastic production process



Source: CSE 2021

The trigger for the mass spread of plastics was the discovery that it could be made from waste (Naptha) of the petrochemical industry. The petrochemical industry did not miss out on the opportunity to turn a waste product into profit; and the way plastic has been invading every aspect of our lives since 1950 only goes to show that they used the opportunity well.

In 2018, 359 million tonnes of plastic were produced worldwide.[1] India's contribution in the same year was 18.45 million tonnes, approximately 5 per cent. Hypothetically, all plastic should be recycled but unfortunately the ground reality is different.

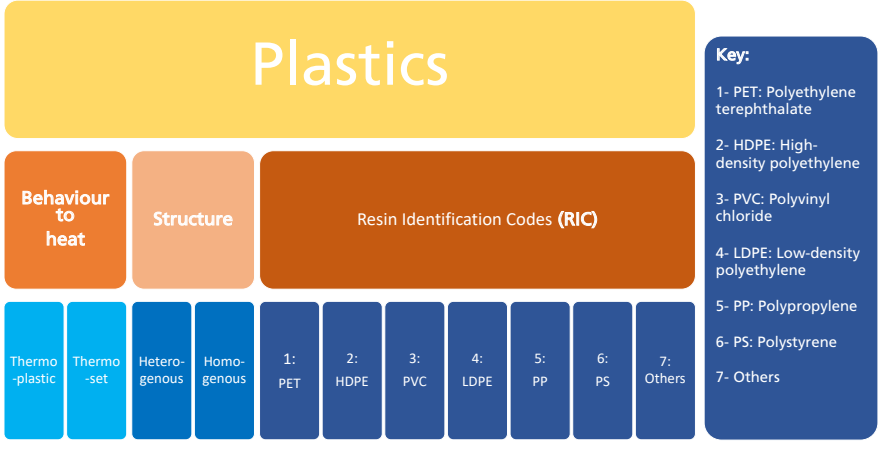
How do we classify plastics?

The word 'plastics' is used to refer to wide variety of objects which can primarily be classified on the basis of three criteria:

- Behaviour to heat:
  - The way a certain type of plastic physically reacts to heat—i.e. melts or becomes irreversibly rigid—and based on whether it can be further remoulded into a desired shape, it is classified into thermo-plastic or thermoset.
  - Out of the total plastic waste generated, around 94 per cent comprises of thermoplastic content (such as PET, LDPE, HDPE, PVC, etc.) which is recyclable (see *Figure 2*: *Classification of Plastics)*. The remaining 6 per cent belongs to a family of thermoset and other categories of plastics (such as sheet moulding compound—SMC, fibre reinforced plastic—FRP, etc.) which are non-recyclable.[2]

- Chemical structure:
  - The types of monomers in a certain polymer (plastic) can be used to categorize a polymer as homo-polymer (same monomer running across the polymeric chain) or hetero-polymer (more than one monomer running across the polymeric chain).
  - Theoretically and practically, if a plastic is made up of a single type of monomer, it would be much easier to process and recycle (assuming that it is not contaminated). Presence of more than one type of monomer in a plastic make the process of recycling difficult.

Figure 2: Classification of plastics



Source: CSE 2021

- Resin Identification Codes (RIC)
  - In 1988, the USA Society of the Plastic Industry developed a RIC for rigid packaging which has become mandatory in many US states, has been adopted in Canada, Japan and Australia, and has also been endorsed by many organizations across Europe for the identification of plastic packaging materials. Its use has been extended beyond rigid plastic packaging.
  - Most widely used plastic identification codes which can be found on most packaging products sold in the market.

ALTERNATIVE PLASTICS

When talking about alternative plastics, there are a set of words that are often confused or used indistinguishably. Let's try and understand what these alternatives are and how they are different from each other as well as from conventional plastics?

Bioplastics are plastics made from organic materials such as corn starch, and often made up of Poly Lactic Acid (PLA). PLA has properties similar to polypropylene (PP) and polyethylene (PE) and looks just like ordinary plastic. Theoretically, it breaks down in a matter of weeks and does so without leaching toxic chemicals into the soil and water table. Like most organic material, its decomposition yields methane gas, a greenhouse gas many times more potent than carbon dioxide. Therefore, PLA-based bioplastics should be taken to a commercial composting facility where it can be broken down in a controlled environment by microbes.

Biodegradable plastics, on the other hand, refer to petroleum-based plastics that are combined with an additive that makes them break down quickly. This term is often very ambiguous and used interchangeably with bioplastics when the two are chemically quite different.

'Compostable Plastics', the only alternative plastic defined by the Plastic Waste Management Rules, 2016 (India), 'means plastic that undergoes degradation by biological processes during composting to yield Carbon-di-oxide (CO_2), water (H_2O), inorganic compounds and biomass at rate consistent with other known compostable materials, excluding conventional petro-based plastics, and does not leave visible, distinguishable or toxic residue.'

At first glance, bioplastics seem like an appealing alternative to regular plastics. They look, feel, and perform like plastic, but they get their shape and sturdiness from renewable sources—like corn starch, sugarcane, and plastic-producing microorganisms—instead of petroleum. Further, some scientists estimate that while regular plastics will linger in landfills for hundreds of years, some bioplastics will break down in weeks or months under certain conditions. These plastics are often labelled 'compostable' or 'biodegradable'—two terms that give you a sense of relief and security. Some and certain are the words we should focus on, though. 'Bioplastic' is actually an umbrella term that encompasses several categories of plastic that differ in how they're made and how much of their content comes from renewable sources. First and foremost, not all bioplastics are biodegradable (able to naturally break down into smaller molecules) or compostable (able to biodegrade in controlled environments—industrial composting).

It's worthwhile to note that these alternatives are not a part of the solution, but rather are paving a path for another problem, primarily in regions where basic source segregation is not being followed. When mixed with conventional plastics, they are practically difficult to distinguish; this way they potentially contaminate the recycling feedstock, leading to dumping or landfilling of the entire feedstock that's rendered useless due to the contamination.

Of all the plastics produced annually, about 1 per cent (or 2.1 million metric tonnes) are bioplastics, according to the industry association European Bioplastics. Although this represents a small fraction of plastic production, bioplastic production is projected to increase by 300,000 metric tonnes between 2019 and 2024. Bioplastics could help reduce the demand for fossil fuels, but they do nothing to address plastic pollution, especially in marine environments. So what should consumers choose at supermarkets? When possible, bring your own refillable containers or look for plastic-free alternatives.

Source: Excerpts from Emily Petsko, Recycling myth of the month, Oceana; PWM rules 2016

How much plastic waste are we generating?

According to the 2015 Central Pollution Control Board (CPCB) report—*Assessment and Quantification of Plastic Waste Generation in Major Cities*—which extrapolated data based on findings from 60 cities in India, some 15,342 tonnes of plastic was generated per day in these 60 cities, which is approximately 5.6 million tonnes per annum (MTA). The CPCB extrapolated to the rest of the country to estimate that some 25,940 tonnes of plastic waste is generated per day, which is roughly 9.4 MTA. It also found that 70 per cent of plastic packaging of products was converted into waste in a short span.

The 2015 study estimated plastic waste from the municipal waste dumping sites. It collected (from 60 cities) one tonne of waste from municipal/other dump sites to check the quantum of plastic waste that is ending up in them. It found that on an average in these cities, some 7 per cent of the waste in dumpsites was plastic waste. In some cities like Delhi, Kolkata, Surat, Raipur, etc. over 10 per cent of the total solid waste in dumpsites was plastic. This would be an underestimate as it is well known that a lot of the more 'valuable' plastic is taken out of the waste stream much before it reaches the landfill.

On the contrary, the latest annual report on plastic waste management published by the CPCB for the year 2018–19 puts the plastic waste generated as 3.3 MTA, which is roughly 9,200 metric tonnes per day (TPD). Given that the total municipal solid waste (MSW) generation for the year 2018–19 was 55.5 MTA, this would mean that plastic waste is approximately 6 per cent of the total solid waste generated in the country. However, The *SBM Plastic Waste Book on Plastic waste management—Issues, Solutions and Case studies* released by the Ministry of Housing and Urban Affairs (MoHUA) in March 2019 mentions that the country generates approximately 9.49 MTA of plastic waste, which amounts to 26,000 TPD.[3]

It can hence be established that the amount of plastic waste generated in the country is uncertain. If the 2015 CPCB study is considered in concurrence with the CPCB annual report of 2018–19, then in a span of four years the reported generation of plastic waste has gone down by almost 60 per cent. This is not persuasive, especially since the e-commerce sector that uses huge amounts of single use plastics as packaging material has gained higher social acceptance in the same time period. In this report we will consider the plastic waste generation of the country to be 9.5 MTA for further discussions and estimations.

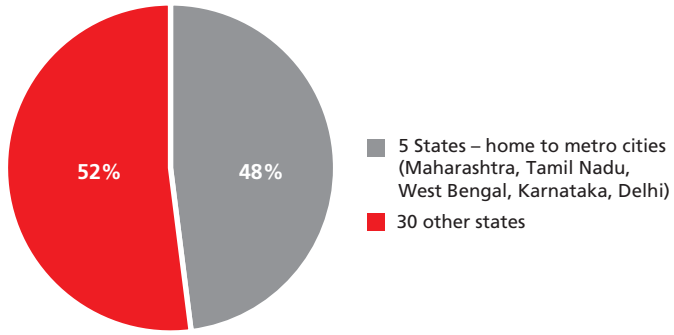
Plastic waste management is a global as well as a national agenda. However, we have very limited data available on the amount of plastic waste that we are generating. The two CPCB studies mentioned above happen to be the only national level surveys that have been conducted and the findings with respect to plastic waste generation distinctly contradict the exponential growth in plastic production (in terms of plastic products), which increased from 6.8 million metric tonnes in 2010 to 18.45 million metric tonnes in 2018.[4] This leads us to the conclusion that the survey studies conducted by CPCB and the figures provided with respect to plastic waste generation are not credible.

Where does our plastic waste come from?

Sources are divided on the basis of data availability—1) states, 2) sectors, and 3) brand owners

States: CSE's report titled 'Managing Plastic Waste in India—Challenges and Agenda' has highlighted that 66 per cent of the plastic waste generated in the country is being generated in seven states alone, with the remaining 28 states and union territories generating the other 34 per cent. States like Maharashtra, Tamil Nadu, Karnataka, West Bengal and Delhi, which have metro cities with highly consumerist lifestyles, generate 48 per cent of the total plastic waste (see *Graph 1: Contribution by states to plastic waste generation)*. This indicates that plastic consumption increases with affluence, possibly due to higher disposable income, widespread and easy availability of packaged products, and lack of responsible consumption.

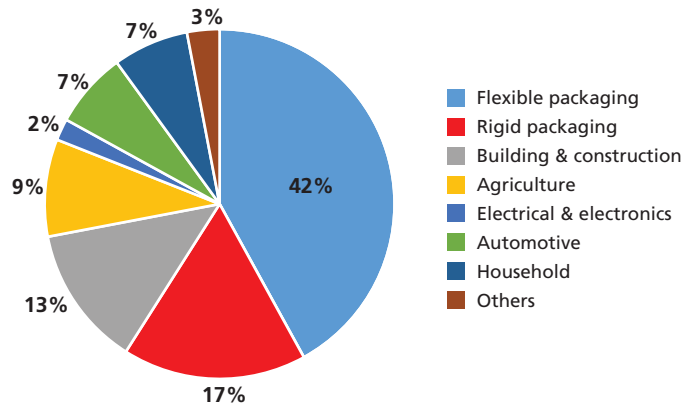
Graph 1: Contribution by states to plastic waste generation



Source: CPCB Annual report 2018–19

Sectors: Consumer brands and other companies (synonymous with brand owners and producers) which rely on rigid and flexible packaging material contribute 59 per cent of the total plastics across various sectors (see *Graph 2: Sector-wise percentage contribution of plastics*). There is a shift within the packaging sector from rigid packaging to flexible packaging, most of which is discarded minutes after it is sold. Flexible packaging is usually low value and low weight, due to which it gets littered and is not collected by the waste-pickers and other stakeholders who can potentially channelize it for re-processing.

Graph 2: Sector-wise percentage contribution of plastics



Source: PlastIndia Foundation Report, 2020

Brand owners and producers: As per the PWM Rules, 2016—which were diluted by amendment in 2018 due to intense lobbying by associations like All India Plastic Manufacturers Association (AIPMA) and PET Packaging Association for Clean Environment (PACE)[5]—it is the responsibility of the producers and brand owners to develop a waste collection (reverse logistics) system based on the concept of Extended Producer Responsibility (EPR). The PWM Rules, 2016 also say in clause 9(2) that the 'Primary responsibility for collection of used multi-layered plastic, sachets, pouches or packaging is of the Producers, Importers and Brand Owners (PIBO) who introduce this product in the market. They need to establish a system for collecting back the plastic waste generated due to their products'.

Also as per the PWM Rules, 2016, any producers operating in more than two states/union territories shall register with the CPCB and any producer operating in one or two states shall register with the prescribed authority. As of 06 April 2021, only 89 brand owners and four producers have registered under the EPR scheme with the CPCB. CPCB and State Pollution Control Boards (SPCB)/Pollution Control Committee (PCC) have not made any data available in the public domain that would help us understand the amount of plastic these producers or brand owners are putting out on the market. Nor is this data revealed by these companies in their sustainability reports, business responsibility reports, or annual reports. The data opacity by the producers and weak data collection and management systems on the part of the authorities have led to producers and brand owners announcing voluntary initiatives and pilot projects to collect back plastics. These 'voluntary' schemes have worked to influence legislation over the years in favour of the industry

One such pilot is 'Waste Efficient Collection and Recycling' (WECARE) spearheaded by Indian Pollution Control Association (IPCA), funded by PepsiCo India Holdings Pvt. Ltd, Nestle India Ltd, Perfetti Van Melle India Pvt. Ltd, Dabur India Ltd, and Dharampal Satyapal Ltd. It was launched on 28 November 2017, with support from CPCB, East Delhi Municipal Corporation (EDMC), IL&FS Environmental Infrastructure & Services Ltd, and Geo-cycle. It was piloted in 10 cities across India. The primary objective of the pilot was to channelize the collected and sub-segregated multi-layered plastic (MLP) packaging waste for co-processing in cement kilns and waste-to-energy (WtE) plants for energy recovery. The duration of the pilot was three months during which it claimed to collect and process approximately 700 tonnes of MLP. When seen in retrospect, this pilot exercise was executed to influence legislations in favour of not phasing out MLP, which the PWM Rules, 2016 had mandated in a period of two years. The claims that are made as part of socio-economic and environmental impacts of such pilots are difficult to verify.

Since credible data from authentic sources is not to be found, we have to look further to understand the contribution of consumer brands towards plastic waste. One such source is Break Free from Plastics (BFFP)—a global movement envisioning a future free from plastic pollution. Some of its key agendas include pushing for corporate accountability and building zero-waste communities. Since its launch in 2016, BFFP change-makers gather each year to reveal the top plastic polluters trashing our communities.[6] For brand audits, volunteers collect plastic waste and document the brand on each item. The corporations polluting the most places with the most plastics are named the world's worst plastic polluters. In 2020, 15,000 volunteers from 55 countries organized brand audits—waste pickers also participated and highlighted how low value plastic packaging makes it hard for them to earn a living.

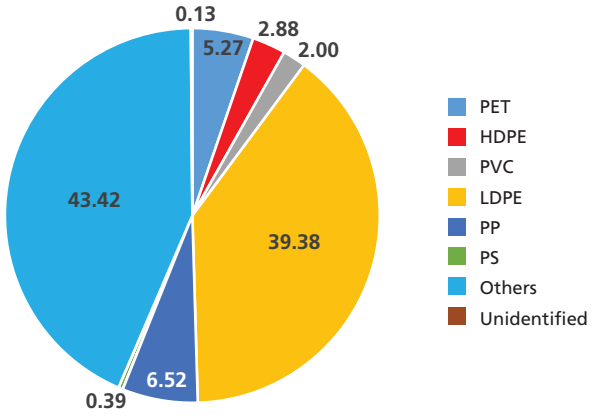
In 2020 the world worst polluters were:

a. Coca-cola
b. PepsiCo
c. Nestle
d. Unilever
e. Mondelez international

All these brands have a strong presence in the Indian market. However, in the last three years (2018–2020) when the brand audit reports have been conducted in India, some of the most popular brands with pan-India presence that have emerged as the worst polluters in India are PepsiCo (2018), Britannia (2019, 2020) and Unilever (2020).

In 2020, BFFP conducted 56 brand audits in India with the help of 353 volunteers and collected 16,973 units of plastic packaging material put on the market by 348 brand owners and producers across the 7 RIC codes of plastics.[7] (see *Graph 3: Percentage distribution of plastic type as per RIC codes*)

Graph 3: Percentage distribution of plastic type as per RIC codes



Source: Break free from plastic, 2020

As can be seen here, the 'others' plastic category (Type 7 as per the RIC code) is used extensively by brand owners and gets littered due to the composite material, low value, and non-recyclability when compared to the rest of the types of plastics. This study may not give a sense of the overall plastic waste generation in the country due to limitations of scale, but what it does do is act as an eye-opener in terms of understanding the kinds and types of plastics that are being pushed into the market.

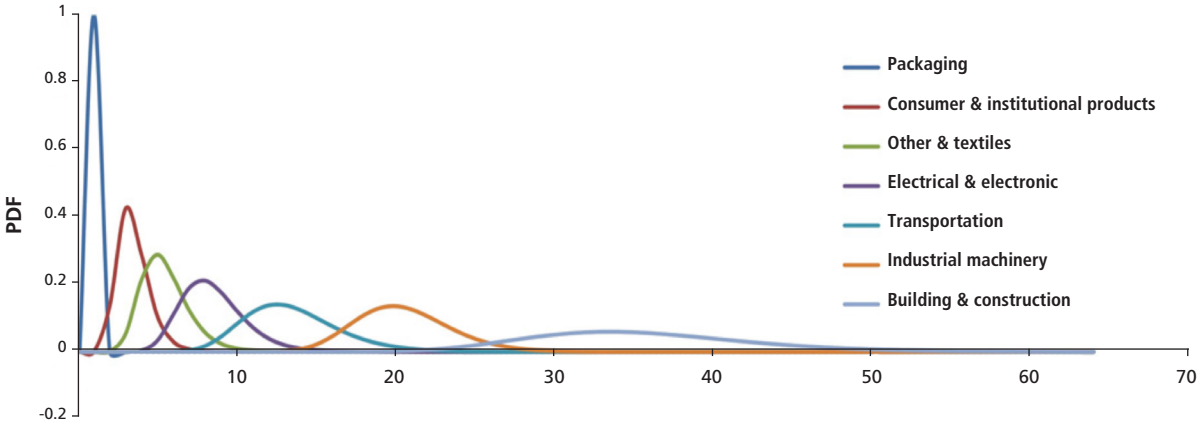
It is thus imperative to create a database of information on the amount and type of plastics that are consumed by brand owners in order to put their products on the market. What is the amount of plastic waste that they are supposed to collect back and through what channels? The PWM Rules, 2016 mandated an action plan to be submitted to the prescribed authority by each of the brand owners by early 2017. There has been no update on this ever since and we are still oblivious to the amount and type of plastic waste we are generating and managing each year. There are multiple reasons as to why this is not possible, one is the unwillingness of the brands to publically disclose their plastic usage and waste management modalities, second is the incapacity of the prescribed authorities to understand the modalities and come up with counter questions to build such a plastic waste inventory, and the third is the wide-spread collusion between the industry, recyclers and the prescribed authorities. Data sets like these, if built, will help us strategize and come up with region-wise key actionable points to improve plastic waste management in the country.

Fates of plastic waste: Where does our plastic waste go?

The vast majority of monomers used to make plastics, such as ethylene and propylene, are derived from fossil hydrocarbons. None of the commonly used plastics are biodegradable. As a result, they accumulate, rather than decompose, in landfills or the natural environment.[8] A study published in the journal Science Advances highlights, industry wise, the time in which a plastic product serves its purpose before it is discarded or reaches its end of life. It also proposes a modelling approach to estimate the waste generation for specific materials. However, the study also points out that for many countries this data is not available in the required detail and quality for the analysis.[9]

Packaging industry and its plastic use again emerge as one of the key concerns and main polluters, since the amount of time plastic is actually put to its intended use is insubstantial when it is used for packaging. Packaging industry is followed by consumer and institutional products and then by the textile sector which is now dominated by the polymer industry. The graph (see *Graph 4: Product lifetime distributions*) highlights the probability distribution functions (PDF) against time, which, simply put, means the probability of discarding a certain plastic in a certain amount of time (in years).

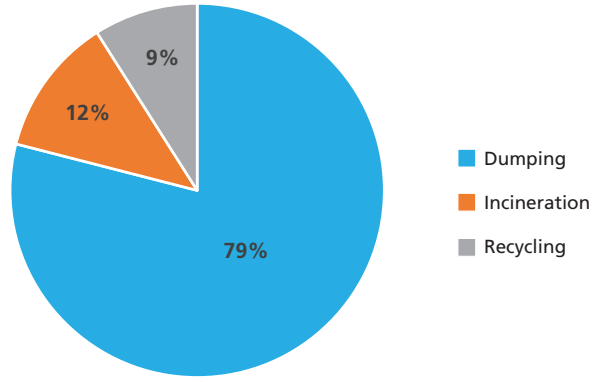
Graph 4: Product lifetime distributions



Source: Ronald Geyer et al 2017. "Production, use, and fate of all plastics ever made." Science Advances Vol. 3 No. 7.

The study has also put together the world's first material balance of plastics. It estimates that of all the plastic produced across the world, 80 per cent is plastic waste; of this, 79 per cent has been dumped in our landfills and dumpsites or has ended up in the waterbodies and oceans; 12 per cent has been incinerated, indicating that it was used for energy recovery; and a scanty 9 per cent has been recycled; of this 9 per cent, only 10 per cent has been recycled more than once (see *Graph 5: Fates of plastic waste across the globe*).

Graph 5: Fates of plastic waste across the globe



Source: Ronald Geyer et al 2017. "Production, use, and fate of all plastics ever made." Science Advances Vol. 3 No. 7.

Contrary to the data presented by the study, MoHUA claims that India recycles 60 per cent of its plastic waste[10], which would be the highest in the world, mostly through the informal sector—which ironically is not defined in the plastic legislations of the country. The recycling percentage of India happens to be greater than most of the champion countries like Germany and Austria which claim to be recycling just a little over 50 per cent of their plastic waste each. The only challenge with India claiming to recycle 60 per cent of its plastic waste is the fact that this claim is not supported by data, which is not the case with other countries. Moreover, in India energy/resource recovery, alternate use, incineration, burning in waste-to-energy plants, etc. is all put into the bucket of recycling, which is technically wrong.

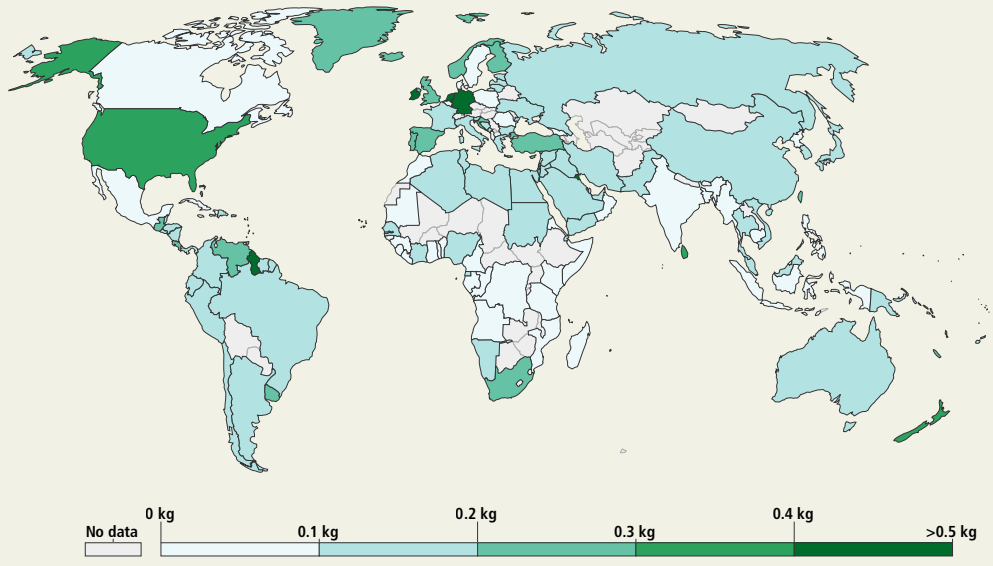
Mismanaged plastic waste ends up becoming marine pollution most of the time, which is a growing concern. High income countries generate more plastic waste per capita, however, it is the management of plastic waste that determines the risk of plastic entering the ocean.

A study by Jambeck et al. in 2015 has put the burden of global mismanaged plastic on East Asia Pacific (60 per cent) and South Asia (11 per cent)—what is not clear though is the consideration of the fact that the developed countries were shipping most of their contaminated plastic waste to Southeast Asia and especially China, before its National Sword policy was enacted in January 2018 that reset the acceptable plastic contamination rates from 5 per cent to 0.5 per cent—which no material recovery facility (MRF) in the developed world could meet. Post this, the load has shifted to only the Southeast Asian countries like Malaysia, Indonesia and Vietnam. It is only of late that some of these countries have reportedly started to send back the non-recyclable and contaminated waste to the country of its origin. Although, there's still a huge amount of transboundary movement of contaminated and non-recyclable plastic waste that comes to the Global South due to low-cost shipping, and cheap and easy labour availability. These factors have made East Asia Pacific and South Asia leak most of the non-valuable and non-recyclable material into the oceans. The study has also estimated marine plastic pollution is largely done by waste which is generated within 50 kilometres of the coastline.

PLASTIC PRODUCED, SHIPPED AND LEAKED

PLASTIC WASTE GENERATION PER PERSON, 2010

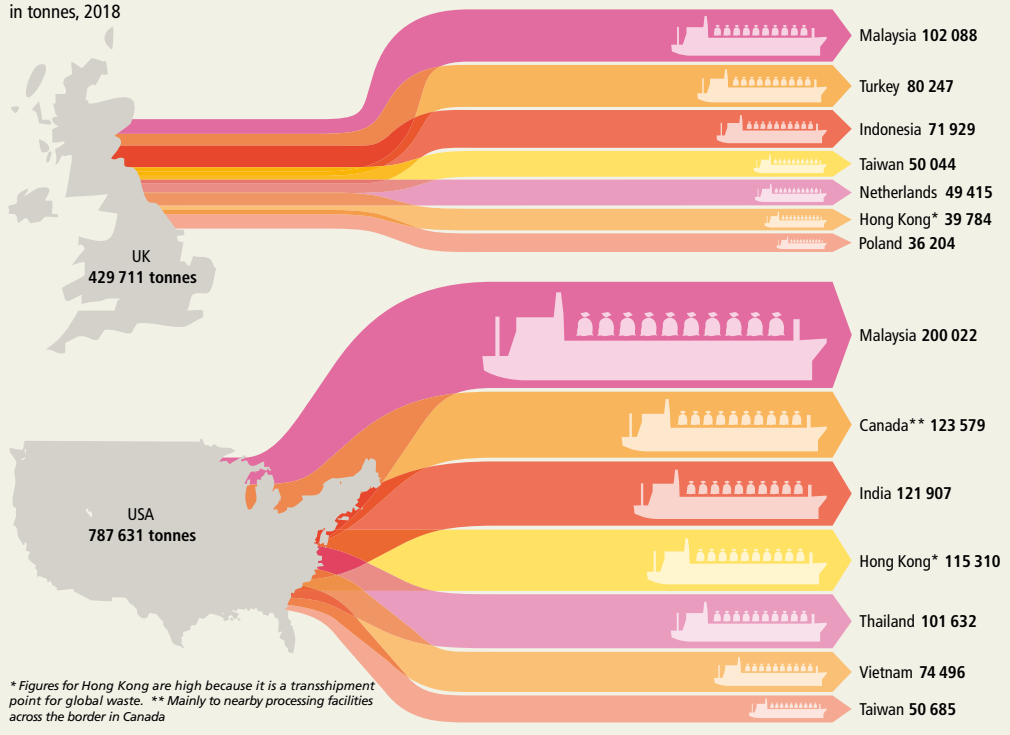
Daily plastic waste generation per person, measured in kilograms per person per day. This measures the overall per capita plastic waste generation rate prior to waste management, recycling or incineration. It does not therefore directly indicate the risk of pollution to waterways or marine environments.



Source: Jambeck et al. (2015)

WHERE BRITAIN AND AMERICA SEND THEIR PLASTIC SCRAP

Total plastic waste exports and seven largest destinations, in tonnes, 2018



** Figures for Hong Kong are high because it is a transshipment point for global waste. ** Mainly to nearby processing facilities across the border in Canada*

Source: Plastic Atlas, 2019

What can be recycled and how many times?

Global scenario

Three arrows running after each other in a triangular coil—since 1988, consumers have accepted this symbol as an assurance that this plastic packaging can be recycled. However, the perceived notion of the consumer and the commitment of the brand using those arrows is false, as most plastic products—except for those with the numbers one and two on the bottom—are not practically recycled in any significant amount and the rest are practically down-cycled to a low-grade plastic product.

ASTM international, the organization that administers the RIC system, has mentioned on its website—*Resin Identification Codes are not 'recycle codes'*. There is a clear disconnect between the brand owners/producers and the plastic waste processing sector which misleads and causes ambiguity amongst consumers.

In most parts of the world, the notion in the minds of consumers is that if the plastic actually reaches the MRF, then it can be recycled; but that's not the case. In India, a major fraction of the plastic that reaches the MRF is sent further to dumpsites, where it stays for a fairly long amount of time before it is mined and sent to various facilities for burning.

There are several international reports which claim that plastic with RIC system code 1 and code 2 are widely recycled in significant amounts[11], while a Greenpeace report takes it a step further arguing that they are the only plastics that can legitimately be called recycled and labelled as such.[12] In general, while code 1 and code 2 are considered recylcable by everyone across the board, code 3 and code 5 are termed 'often not recyclable' due to chemical properties but, at times, they may be recycled locally depending on empirical conditions. Code 4 cannot be recycled due to failure under stress, code 6 may or may not be recycled locally and code 7 is not recyclable due to the diversity of materials being used as well as the composite nature of this particular plastic.[13] Recyclability is based on common recycling schemes but can vary between countries as well as regionally within countries, and one is encouraged to check local recycling practices before arriving at any specific answer.

It is a common misconception that plastic can be recycled over and over again. A report by Geyer et al. emphasizes that recycling delays rather than avoids final disposal. In practice, majority of the plastics are recycled once or twice before being disposed of in landfills or for energy recovery. Future plastic waste generation can be reduced only by displacement of virgin material by recycled material in primary production. However, because of its counterfactual nature, this displacement is extremely difficult to establish.[14]

The Indian scenario

Recycling of plastics has an enormous potential to mitigate the consequences of plastic use and consumption. Using recycled plastics for downstream applications can reduce our reliance on fossil fuels. A study estimates that we save approximately 3.8 barrels of petroleum by recycling a tonne of plastic waste.[15]

Recycling of plastics usually involves 'down-cycling' into lower-quality products. The starting point of recycling is the sorting of plastic waste (based on colour, transparency, hardness, density and opacity of the scrap). The sorted waste is then cleaned and washed before being sent to granulators to obtain granules, pellets or agglomerates using traditional mechanical techniques. The converters use these granules to make finished plastic products. The majority of such units (granulators and convertors) are often located in slums, and function as single-machine extruding units. Scrap storage is done in the backyards, and washing is done in open drums. These activities are often termed as backyard recycling. The technologies used in these industries are also old, local and polluting in nature.

According to the Indian Plastic Industry Report, 2019 by PlastIndia Foundation—the apex body of associations, institutions and organizations concerned with the plastic industry—6 million metric tonnes of plastic was recycled in 2018. What is surprising though is that the report, when compared with its predecessor reports, highlights that the organized recycling units have gone down by 97 per cent from over 3500 in 2018 to a scanty 100+ in 2019, while the unorganized recycling units have increased by 60 per cent from over 4000 in 2018 to more than 10,000 in 2019 (see *Table 1: Distribution of organized and unorganized plastic recyclers*).[16]

Table 1: Distribution of organized and unorganized plastic recyclers

Parameter	2018 report	2019 report	Percentage growth
Number of organized recycling units	3500	100	-97%
Number of unorganized recycling units	4000	10,000	60%
Direct manpower	600,000	100,000	-83%
Indirect manpower (including waste pickers)	1 million	1–1.5 million	50% (considering upper limit)
Quantum of plastic recycled	5.5 million metric tonnes	6 million metric tonnes	8.3%

Source: PlastIndia Foundation

The SBM Plastic Waste Book—Plastic Waste Management, Issues, Solutions aThe SBM plastic waste book—*Plastic Waste Management, Issues, Solutions and Case Studies* published by MoHUA in 2019—contradicts this data shared by PlastIndia Foundation. While the amount of plastic waste that is being recycled in the country matches PlastIndia's claim of 60 per cent; according

to MoHUA, 70 per cent of this is recycled in registered or organized facilities which have declined by 97 per cent in a year (2018–19), 20 per cent is recycled by unorganized sector which has increased by 60 per cent and the remaining 10 per cent is recycled at home—which means using the plastic waste for alternate use in a domestic setup.

According to a report by Federation of Indian Chambers of Commerce and Industry (FICCI) and Accenture, there is almost $133 billion worth of plastic material value that will be lost in the next 10 years till 2030 due to unsustainable packaging in India. Almost 75 per cent of this, i.e. $100 billion worth of this value can be recovered.[17]

As per the CPCB annual report 2018–19 for plastic waste management, all the 35 states and union territories have submitted their data and information, especially with respect to plastic waste generation. On taking a closer look, we find out that the data received, compiled and released by the CPCB is far from complete as it does not show the difference between plastic producers and plastic recyclers. It may be the case that some of the producers are engaged in recycling activities, but the distinction between the two should be clearly laid out, which is something that the annual report completely fails to establish. In total, there are 4773 registered units, of which only 300 are distinctly mentioned as recyclers and 290 are distinctly mentioned as producers by states and union territories in their annual reports, the rest being left open for assumption and interpretation. It is unclear that 4183 out of 4773 units are producers or recyclers or both (see *Table 2: State-wise observations on plastic waste recycling*). Similarly, in the case of unregistered units, it is specified that out of the 'under-reported' 1084 unregistered facilities, only 335 units are distinctly mentioned as recyclers, 571 units are distinctly mentioned as producers/brand owners, while it is unclear whether 178 units are producers/brand owners or recyclers or both.

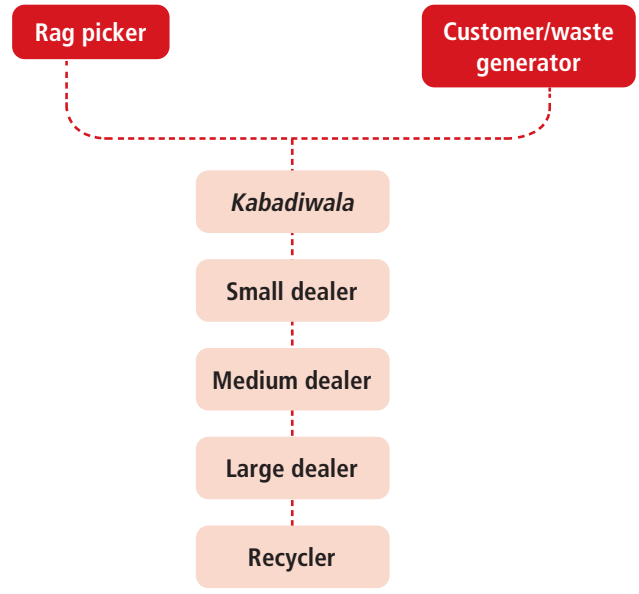
For collection, the recycling industry depends heavily on the unorganized sector such as waste pickers and waste collectors; this sector channelizes the items to small dealers/aggregators, from where they reach a medium/large dealer and finally go to the recycling units (see *Figure 4: The unorganized recycling sector value chain*). Also, some unorganized players get involved in unit operations like shredding, flaking and washing as plastic waste moves up the value chain due to which the value of the processed plastic also increases.

Table 2: State-wise observations on plastic waste recycling

State/Union territory	Plastic waste generated 2018–19 (tonnes per annum)	No. of registered plastic units		No. of unregistered units
		Producers	Recyclers	
Andaman and Nicobar Islands	1850	0		0
Andhra Pradesh	66,314	80	6	0
Arunachal Pradesh	3787.37	0		0
Assam	32,277.87	17		1
Bihar	68,903.328	0	0	36
Chandigarh	11,715.4		7	0
Chhattisgarh	6000	8	8	Not provided
Daman Diu and Dadra Nagar Haveli	1947.7	261		Not provided
Delhi	2,24,810	18		Not provided
Goa	32,580.52	34		0
Gujarat	35,6873	1002		0
Haryana	68,735.26	0		0
Himachal Pradesh	3672	Not provided		0
Jammu & Kashmir	34,367.37	275		72
Jharkhand	51,454.53	59		0
Karnataka	2,72,776	95		43
Kerala	1,33,316	1403		0
Lakshadweep	148	0		0
Madhya Pradesh	72,327.39	45	63	0
Maharashtra	4,09,630	276		19
Manipur	12,453.8	1	3	0
Meghalaya	1263	4		0
Mizoram	13.306	0	0	0
Nagaland	268.18	6		0
Odisha	90,138.98	8		0
Punjab	1,19,414.64	129		16
Puducherry	8433	49		42
Rajasthan	1,04,704.383	2		0
Sikkim	5.66	0	0	0
Tamil Nadu	4,01,091	91	98	280
Telangana	1,83,014.65	27	215	0
Tripura	26.2	23	0	0
Uttarakhand	31,093	30		Not provided
Uttar Pradesh	2,54,401.8	56		23
West Bengal	3,00,236.12	84		Not provided
Total	33,60,043.457	4483		532

Source: Annual Report for 2018–19 on Implementation of Plastic Waste Management Rules, CPCB

Figure 4: The unorganized recycling sector value chain



Source: CSE

The good news is that India is actually recycling a lot (especially by type) and in fact most of its plastic is dealt with by the informal sector. CSE ground survey revealed that plastics are recycled at least 5–8 times in India and almost all types of plastics, from type 1 to type 6, were found being channelized and pre-processed by the informal sector before being passed to the formal sector to make finished plastic products. Some type 7 plastics like Acrylonitrile Butadiene Styrene (ABS), Polycarbonate (PC), and Nylon (Polyamide) also get recycled. The local market for recycling in India is quite strong. While the informal sector may lack the technology and scientific background, their techniques and knowledge can be harvested if they are recognized and integrated into the value chain of recycling. While they are a part of the value chain right from the start, they are not able to reap the benefits of their hard work as the end of the value chain is is dominated and controlled by the formal sector.

Options for plastic waste management

he flow of plastic waste in the country has various pathways—recyclers get their plastic waste from door-to-door collection by the Urban Local Bodies (ULBs) as well as through waste pickers/collectors who pick up recyclable waste from the streets and even the dumping grounds. Informal recyclers also have various sections amongst them; some of them receive post-consumer recyclables (PCR) or contaminated plastic waste from households, while the others manage to get the valuable, non-contaminated plastic waste sourced directly from the commercial hubs and industrial estates.

According to the waste hierarchy, the option of reuse should be explored before channelizing waste for recycling. Reuse is already quite prevalent in Indian society as most of the plastics that are re-usable are put to alternate use in households in forms like planters, sheets, do-it-yourself (DIY) home decorations, etc.

In terms of recycling and energy recovery, there are currently three available options:

- First, plastic waste can be recycled or reprocessed using primary and secondary recycling options into a secondary plastic material. In most cases, this secondary material is of lower quality or economic value, due to which it does not displace the primary product. So, all recycling does is delay the final disposal of the product. This is called mechanical recycling.

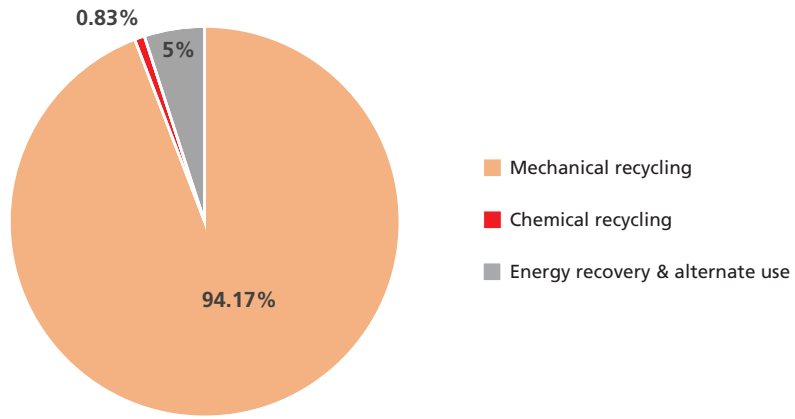
- Second, plastic waste can be recycled by tertiary recycling options through which the plastic waste can be converted to oil, gas or its monomeric constituents by chemical conversion which can then be used as fuel. This is termed as chemical/feedstock recycling.

- Third, there is the option of quaternary recycling. It offers two possibilities of energy recovery and alternate use and technically cannot be put under the basket of recycling.
  (i) Energy recovery in WtE plants and incineration facilities or co-processing in cement kilns. But unless there is expensive pollution control equipment installed, all this does is convert land-based pollution to water and air pollution.
  (ii) Alternate use which means use of material for a purpose other than for which it was conceived—like road making with plastic waste, which is now a mandate as per the Indian Road Congress (IRC).

Primary recycling is the most preferred as it technically is free from any contamination and hence the number of unit operations would be less, leading to less energy and resources being consumed. It is followed by secondary recycling where the units operations increase primarily due to operations like de-dusting, washing and cleaning. Both primary and secondary recycling

(mechanical recycling) are the most prevalent form of recycling in India. 94.17 per cent of the plastic waste is recycled using mechanical recycling. Feedstock/ chemical recycling is a less preferred option due to the high capital and operational expenditure, it is also limited due to non-availability of scalable technologies, especially in India. Only 0.83 per cent of the plastic waste is treated using chemical recycling. Quaternary recycling which involves energy recovery and alternate use is the least preferred (but preferable over dumping/ landfilling) option due to high capital and operational cost, ambiguity around suitability and acceptability of the technology, and the negative potential to convert land-based pollution to air and water pollution. Currently, India is managing 5 per cent of its waste using these technologies and an increasing number of business and authorities (local, state and national) are moving towards this approach, as it offers false and interim solutions for plastic waste which is non-recyclable or difficult to recycle (see *Graph 6: Percentage distribution of recycling options*).

Graph 6: Percentage distribution of recycling options



Source: PlastIndia Foundation

Primary and secondary recycling—Mechanical recycling

Mechanical recycling of plastics refers to the processing of plastic waste into secondary raw material or products without significantly changing the chemical structure of the material. In theory or principle, all types of thermoplastics can be mechanically recycled with little or no quality impairment. Mechanical recycling is an essential tool in an environmentally and economically sustainable economy of plastics, but current mechanical recycling processes are limited by cost, degradation of mechanical properties, and inconsistent quality of products. The share of mechanical recycling as per the plastic industry estimates is the highest, combining both the formal/ organized and the informal/unorganized recycling sectors. As per CSE ground survey, most of it happens in the unorganized sector.

Plastic waste input streams that can easily provide clean plastic of a single type in large quantities are ideal for mechanical recycling and represent an ideal situation from an environmental and economic perspective. Environmental

benefits from substituting virgin material generally exceed the environmental burden from collection, sorting, transport and recycling operations, while the costs of such operations can be outweighed by potential revenues from selling recyclates on the market.

The thermal conduction and viscous shearing applied to polymers within an extruder in a mechanical recycling system leads to thermo-oxidative and shear-induced chain scission, chain branching or crosslinking of the material.[18] This chain degradation reduces the polymer chain length and in turn lowers its mechanical properties and processability.[19] It is due to this fact that plastics can only be recycled for a specific number of times. Different sources claim varying numbers of times that a plastic can be recycled.

Plastics and plastics-containing waste that cannot be mechanically recycled to the required sustainability standard from an economic and environmental perspective provide a valuable resource for other recovery solutions such as feedstock recycling and energy recovery to maximize the recovery of its embedded energy and resources.

Tertiary recycling—Feedstock/Chemical recycling

Feedstock recycling (or chemical recycling) is a process that changes the chemical structure of plastic waste, converting it into shorter molecules, ready to be used for new chemical reactions. For instance, processes such as gasification and pyrolysis break down plastic waste to produce synthesis gas (syngas is a mixture of carbon monoxide (CO) and hydrogen (H) and can be used a fuel) as well as other liquid and semi-liquid products. In addition, new re-polymerization processes are under development to convert some types of plastics back into monomers for the production of virgin plastics.

Feedstock recycling is a complementary technology that can help divert certain plastic wastes, which cannot be sustainably recycled by mechanical processes, from landfills. Examples of suitable streams for feedstock recycling include laminated and composite plastics, low quality mixed plastics and contaminated plastics.

> Despite the industry hype, the European Union Commission has said that re-polymerization technology is at least ten years away from commercial application—far too long to tackle the climate and pollution issues posed by plastics.

A recent report by Global Alliance for Incineration Alternatives (GAIA) has tried to demystify chemical recycling.[20] It defines chemical recycling as a 'greenwash' term used to lump together various plastic-to-fuel and plastic-to-plastic technologies. These processes turn plastic into liquids or gases which could be used to make new plastic but in practice are usually burned. Whatever the process is called, if the end products are burned, its plastic-to-fuel. In principle, the liquids and gases can be turned back into plastic, a process which is better called re-polymerization. However, this is at present technically challenging and uneconomical. Industry uses the term chemical

recycling to deliberately blur the distinction between recycling (plastic to plastic re-polymerization) and incineration (plastic-to-fuel). Most plants that claim to do chemical recycling are turning plastic into fuel. A few pilot-scale projects do produce plastic, but they handle relatively limited inputs, not the full range of plastic waste. Many such plants use pyrolysis, which is not a new technology; it has been around for decades, but has never been technically or commercially successful.

Quaternary recycling—Energy recovery

Energy recovery is a valuable alternative for plastics-rich waste fractions that cannot be sustainably recycled. Some plastics cannot be recycled in an eco-efficient manner because of factors such as:

- The amount, cleanliness and composition of the collected waste streams.
- The available technologies for sorting.
- Market driven requirements on quality and standards for recycled material that may limit the appropriateness of plastic recycling.

For these plastics, energy recovery is the most resource-efficient solution available. In India, most of the plastic waste treated using this method is co-processed in cement plants or sent to WtE plants to be used as an alternative fuel in the incineration process.

As per the SWM Rules, 2016, 'co-processing' means use of non-biodegradable and non-recyclable solid waste with a calorific value exceeding 1500 Kcal/Kg as raw material or as a source of energy or both to replace or supplement the natural mineral resources and fossil fuels in industrial processes. Also, the Rules define RDF as fuel derived from combustible waste fraction of solid waste like plastic, wood, pulp or organic waste, other than chlorinated materials, in the form of pellets or fluff produced by drying, shredding, dehydrating and compacting of solid waste. This material can be utilized for co-processing in various industries like cement plants, etc.

National Green Tribunal (NGT) observed in 2018 that none of the states had considered clause j of schedule I in Solid Waste Management Rules, 2016 as an option for dealing with their dumpsites; post which it issued a directive for bio-mining, and use of non-recyclable dry waste in cement plants and low value plastic in road construction.

It is worth noting here that a majority of the plastics reach these cement plants in the form of SCF that is recovered from the dumpsites, where these plastics had been buried along with municipal solid waste for years on end, thus affecting the calorific value which in many cases does not meet a minimum requirement of 1500 Kcal/Kg due to contamination, leaching, environmental degradation and seasonal variation. Apart from this, there are other issues. For example, cement plants are not willing to pay for low quality RDF nor for its transportation since the prices and quality cannot compete

with that of coal. Instances have also surfaced of ULB's dumping their SCF/RDF in ecologically sensitive regions due to its low demand and shortage of storage area.

Cities like Delhi and Hyderabad rely very heavily on WtE technologies. These technologies have also been seen as a silver bullet and a one stop solution to all our plastic woes. CSE, in its interaction with high level city officials of various cities, has found that these technologies are being pushed into the Indian market not as a solution/alternative for non-recyclable plastic waste, but for burning the non-segregated municipal solid waste. There are claims that these technologies work just fine in developed countries, but what we constantly miss out on is the fact that developed countries generally have a higher non-biodegradable fraction of waste like paper and plastics, which increases the overall calorific value of the waste. Also, most of the countries that rely on WtE follow very strict basic waste segregation, which ensures that the biodegradable fraction is not mixed with the high calorific value material like paper and plastics.

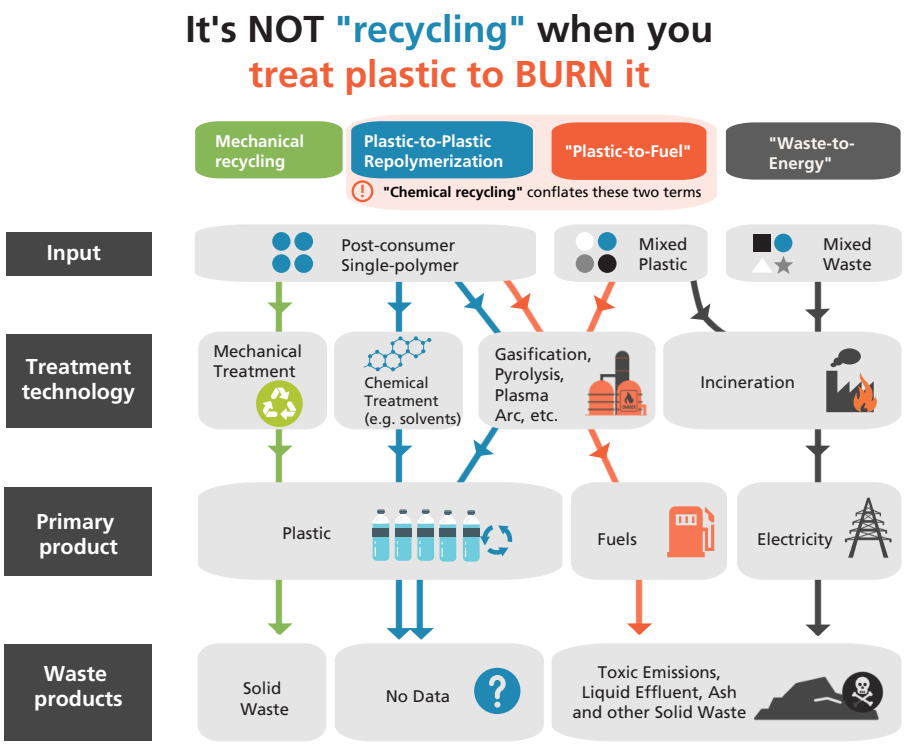
Alternate use

Alternate use refers to using the plastic waste in any other way apart from the possibilities discussed above. One classic example of alternate use is the use of plastics in bitumen roadmaking that has been mandated at a minimum of 5 per cent of the weight of the bitumen being used. This process, however, has its limitations in terms of feedstock—this process cannot take black plastic which is a result of repeated recycling and does not have the desired binding properties, and PVC should not be used due to presence of chlorine, which on being subject to high temperatures may potentially release dioxins. One key finding by CSE has been that in some places, contractors pay for the shredded plastic waste as mandated by the IRC, but do not procure and use it in their roadmaking activities, due to an increased labour requirement and hence overall cost.

Other alternate uses are paver blocks, and re-use in household setup, but the term 'alternate use' needs to be defined better. More research is needed to understand the long-term effects of plastic being used for alternate purposes in various set-ups to recognize and address questions like leaching, environmental degradation potential, micro-plastic forming potential and other effects on human health.

Clearly, there is a need to redefine recycling in the country. We have created too many pseudo-options and pathways for 'disposal' of plastics, but the enforcement, monitoring, and stakeholder dialogue in each of them is lax. We have to stop labelling every other available solution as recycling and think of bifurcating the solutions according to the waste hierarchy. Only in absence of an environmentally feasible solution like mechanical recycling should we move down the hierarchy to 'band-aid' solutions like chemical recycling (P2F) and energy recovery. We also have to move towards producing and consuming less plastics as we clearly cannot recycle our way out of the plastic menace (see *Figure 5: Demystifying plastic recycling*).

Figure 5: Demystifying plastic recycling



Hazards and Issues

Toxic emissions	Low	?	High	High
GHG emissions	Low	High	High	High
Ash and residues	Low	?	High	High
Cost	Low	High	High	High
Other	Downcycling Lack of markets	Real-world feasibility Lack of markets	Produces a fossil fuel Energy-intensive	Lock-in effect Low efficiency

Source: GAIA, 2019

Who recycles our plastic waste?

According to the SBM plastic waste book released by MoHUA in 2019, out of the 60 per cent plastic waste that India recycles:

- 10% of the plastic waste is recycled at household level
- 20% of the plastic waste is recycled by informal sector
- 70% of the plastic waste is recycled by formal sector

10 per cent recycled at household level

This is a false notion that plastic waste gets recycled at the household level. Indian households traditionally try and recover as much value/use as possible from a product, be it plastic or otherwise. Commodities are mostly reused or stored before being sold off to the scrap dealer to get full monetary value for money out of them. This section should actually be put under the bracket of reuse and technically cannot be labelled as recycling.

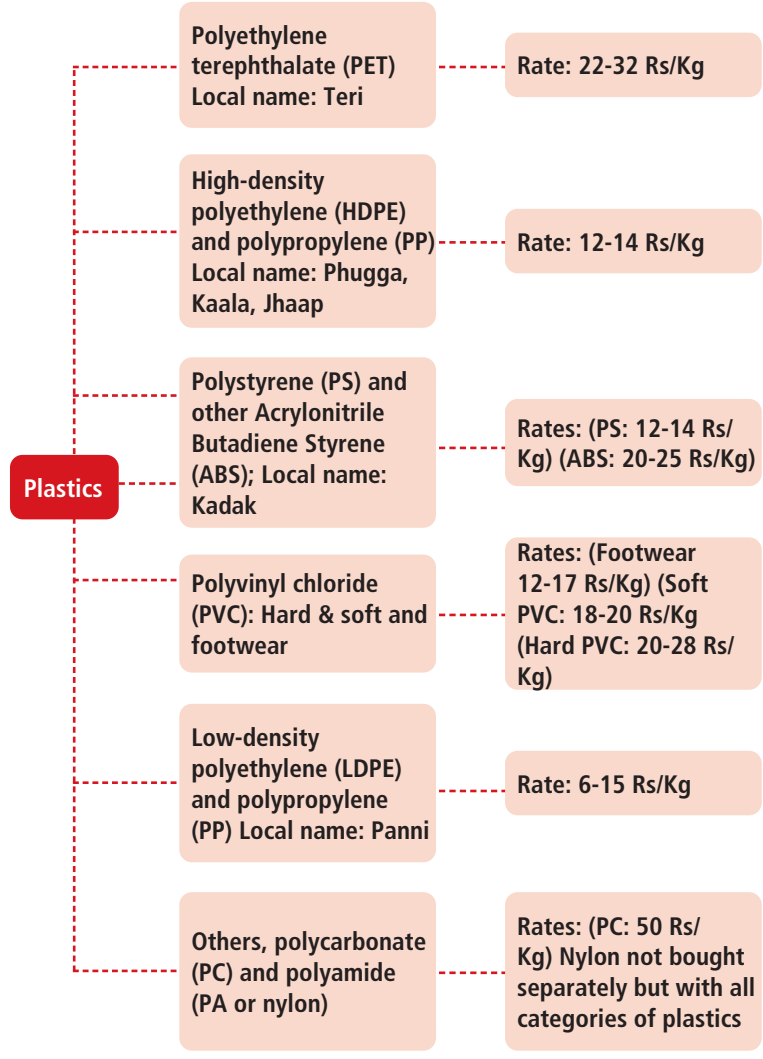
20 per cent recycled by the informal sector

On paper this sector recycles 20 per cent of the plastic waste. CSE with the support of Sanjeevani S3, a waste management social enterprise based in Mumbai, conducted a survey of all the kinds of plastics that can be and are being recycled by the informal sector.

A female worker sub-segregates plastics at an informal recycling facility

It was found that most of the types of plastic waste are collected, sorted, sold and pre-processed by the informal sector. Every category of plastic waste has a local name (see *Figure 6: Basic Plastic categories, local names and purchase prices by the informal sector*). The price for the plastic commodity increases as it undergoes unit operations and moves across the value chain.

Figure 6: Basic plastic categories, local names and purchase prices by the informal sector



Source: CSE

Most of the recycling that happens in the informal sector is labour intensive, primarily due to the sub-segregation and sorting which happens at a huge scale in the informal sector, which is also the key that makes recycling possible to the extent that it happens in India. This is followed by cleaning which can be done either using water or vibrator screens depending on the type of plastic that is being dealt with. Apart from PVC and carry bags (PP & PE), every other type of plastic is cleaned using a water based mechanism. In some low-end facilities, even washing is done manually.

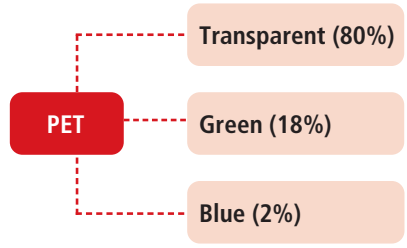
Machines like vibrators, washing systems, pelletizers and agglomerators are also operated by the labour and in most cases are semi-automated. The informal sector also generates waste when recycling plastics. The quantum of waste depends on the type and quantum of plastic that is being dealt with by the facility. This waste is not handed over to municipal collection systems, but burnt at night either to recover metals, to get rid of the waste without paying for it, or seasonally to keep warm. We will follow the unit operations of each and every category of plastic along with the various sub-types in the market. In some cases, the percentage distribution could be determined, but due to the dynamic nature of the market, the percentage distribution could not be ascertained for each and every type of plastic.

1. Polyethylene terephthalate (PET)

PET is known as '*Teri*' in the local market and has an independent market of its own. It is purchased by the local scrap dealers at a rate of Rs 22–32/Kg. The price per kilo of PET decreases and reaches its lowest point during the summers as demand decreases. The price hits a peak and crosses Rs 30/Kg during the winter season as demand increases due to utilization of PET fibres in making apparels, blankets and other winter wear like fleeces with recycled plastic content. The PET market is divided into three categories, primarily on the basis of the colour of the bottle (see *Figure 7: Percentage distribution and categories of PET on basis of colour*). Transparent PET dominates the market, followed by the coloured PET bottles which are primarily a result of additives to increase brand recognition by a handful of companies.

PET bottles are majorly used for packaging of beverages

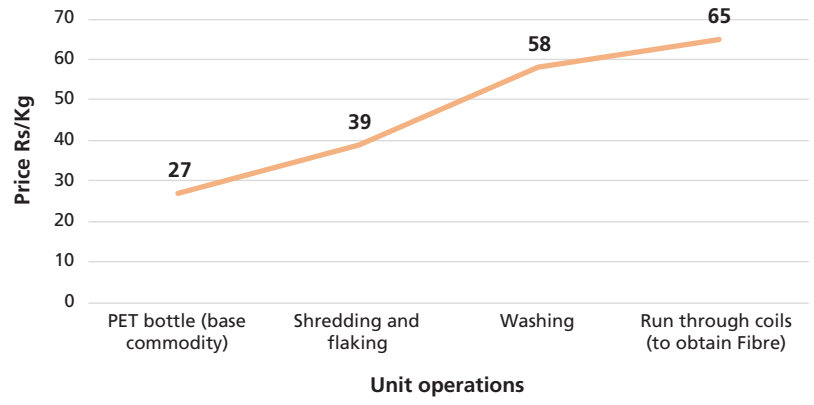
Figure 7: Percentage distribution and categories of PET on basis of colour



Source: CSE

As the PET bottle moves through unit operations, the acceptability in the formal market increases and hence the price of the pre-processed commodity also increases (see *Graph 7: Increase in price of PET with unit operations*). PET is probably the only resin where the colour does not affect the price of the commodity, and the price rise is linear and standard for all the three categories. Different unit operations happen in separate facilities and transportation is involved between them.

Graph 7: Increase in price of PET with unit operations



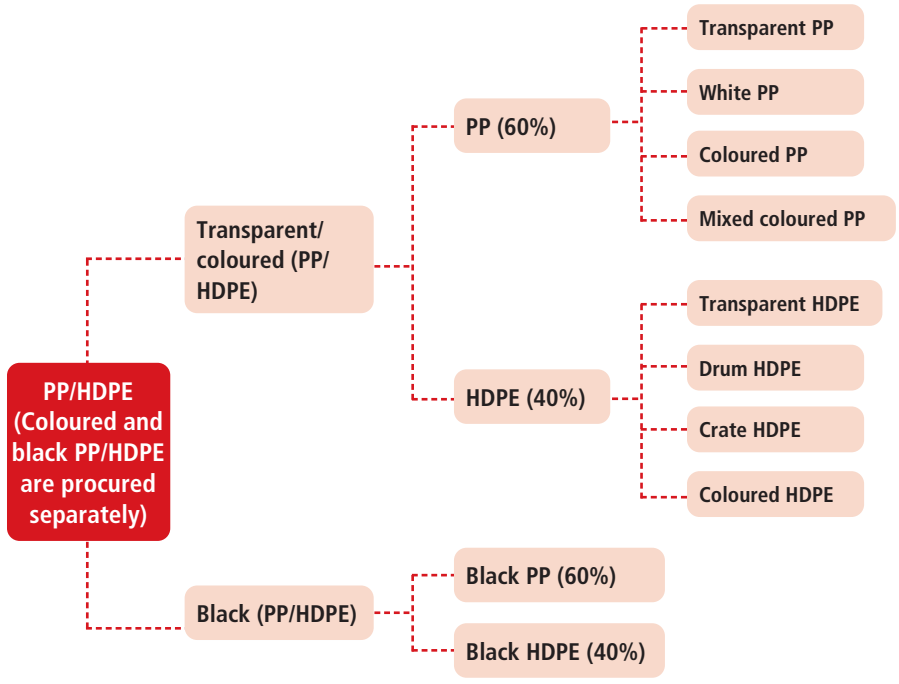
Source: CSE

2. Polypropylene (PP) and High-density polyethylene (HDPE)

HDPE and PP are often collected together by the local scrap dealers to balance and recover the cost of collection, sorting and pre-processing. There are two types of HDPE and PP that are collected. PP is locally known as '*Phugga*', while HDPE is locally known as '*Jhaap*' and is available in transparent shade as well as a variety of colours; the ones that are black in colour are locally known as '*Kaala*'. The transparent PP/HDPE generally has a higher value and the transparency gets compromised with the number of times it is recycled. Ones the plastic turns white, it can be changed to any colour on addition of colourants, post which it eventually turns black. Black PP can also be made from virgin plastic; it will have a peculiar shine which is not the case with black PP made from recycled plastic. Collection of black plastic happens separately. Since the transparent and coloured plastics are collected together, they have

to be sorted out, which in most cases is a manual operation. PP happens to be 60 per cent of the procured mixture most of the times while the rest 40 per cent is HDPE. This holds true for the black PP/HDPE as well (see *Figure 8: Percentage distribution of PP/HDPE*).

Figure 8: Percentage distribution of PP/HDPE made from virgin and recycled plastic

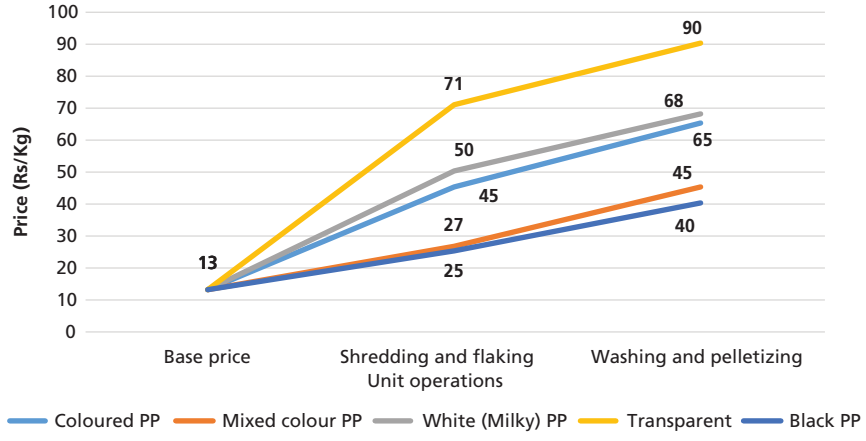


Source: CSE

PP is further divided into coloured, mixed colour, white, transparent and recycled categories. While the resin in each of these categories is the same, they need to be sorted post collection and subjected to unit operations independently to avoid contamination, primarily of colour, and also to ensure that the good quality resin do not get contaminated with the low grade short chain polymer. When PP is made from virgin material, it is transparent and hence the demand and value of the transparent PP is high. When transparent PP is recycled it gets a greyish tinge and the output is white PP which has a lesser demand. When it is further processed and additives like colorants are added, a variety of beautiful colours are obtained but the value diminishes. On further recycling, we obtain a mixed colour PP which on subsequent recycling ultimately turns into black PP or *Kaala*. Like PET, the value of the commodity changes as it goes through a series of unit operations (see *Graph 8: Increase in price of PP with unit operations*). A considerable amount of waste is produced by the recycler themselves as the quality of the feed goes on degrading. The percentage distribution of each of the type of PP could not be ascertained as it is dynamic.

Polypropylene containers

Graph 8: Increase in price of PP with unit operations



Source: CSE

HDPE, just like PP, is further divided into sub-categories. It is further divided into crates, drums, and transparent and coloured HDPE plastics. Each sub-category is treated separately and different unit operations happen in separate facilities. The most valuable sub-category in HDPE is drum, primarily due to its thickness, followed by transparent HDPE containers, crate HDPE, coloured HDPE and finally the black HDPE (see *Graph 9: Increase in price of HDPE with unit operations*). A mixed lot of PP & HDPE will have roughly 40 per cent of HDPE, of which the percentage contribution of the crate sub-category was found to be the highest, and lowest percentage contribution was that of transparent (see *Table 3: Percentage contribution of sub-categories of HDPE plastic*).

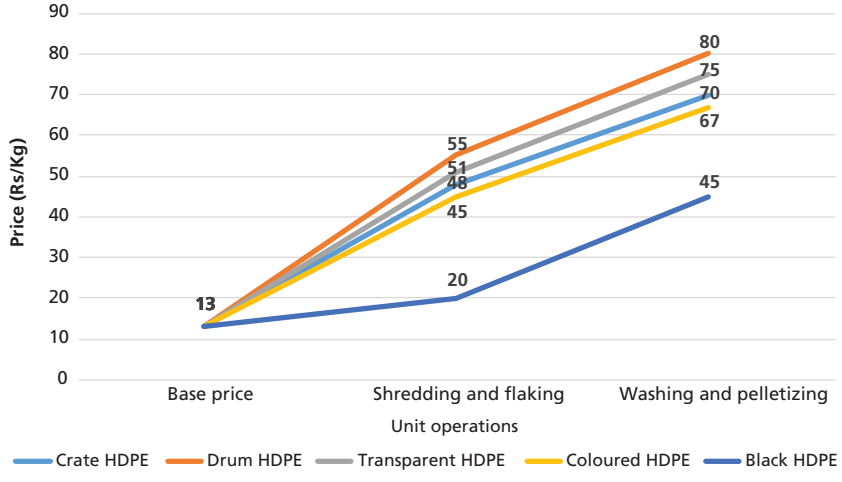
HDPE crates (left), shredded and flaked HDPE (centre) and HDPE drums (right)

Table 3: Percentage contribution of sub-categories of HDPE plastic

HDPE sub-category	Percentage Distribution (of the 40% HDPE)
Crate	40%
Coloured HDPE	20%
Drum	16%
Transparent	4%
Black	20%

Source: CSE

Graph 9: Increase in price of HDPE with unit operations

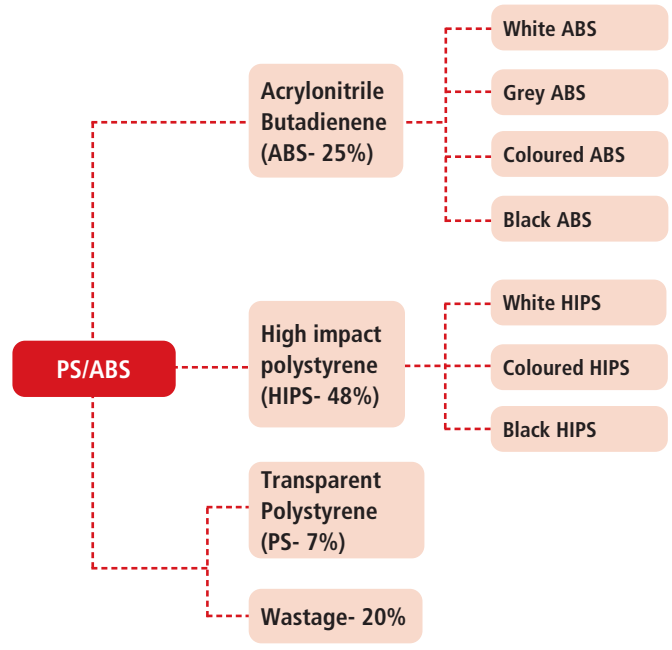


Source: CSE

3. Polystyrene (PS), High-impact polystyrene (HIPS) and Acrylonitrile butadiene styrene (ABS)

Transparent PS and HIPS are collected together at a rate of Rs 12–14/Kg to recover costs and ABS (a certain styrene based plastic that falls in the others or type 7 category) is collected separately at a rate of Rs 20–25/Kg by the local scrap dealers. Both these plastics are made from the same monomer, i.e. styrene, but are converted to different categories mostly due to the process itself as well as the additives. Locally, this category is named as '*Kadak*'.

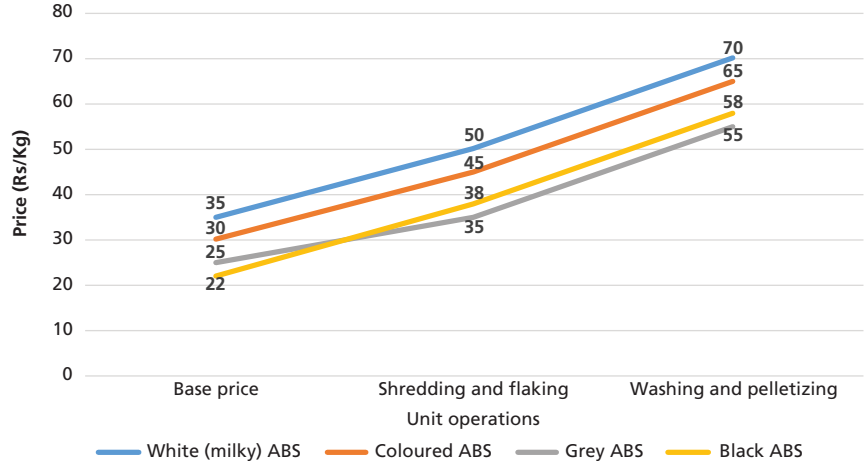
Figure 9: Percentage distribution of styrene based plastics



Source: CSE

ABS is used widely to make light, rigid, moulded products such as pipes, automotive body parts, enclosures and protective head gear. It is also found in the outer body of electrical appliances like air-conditioners and telephones. ABS contributes 25 per cent to the overall styrene based plastic market. Like any other category of plastics, it is available in various colours which are an outcome of its movements through a number of recycling processes. Unlike other plastics, ABS base price varies across its sub-categories (see *Graph 10: Increase in price of ABS with unit operations*).

Graph 10: Increase in price of ABS with unit operations

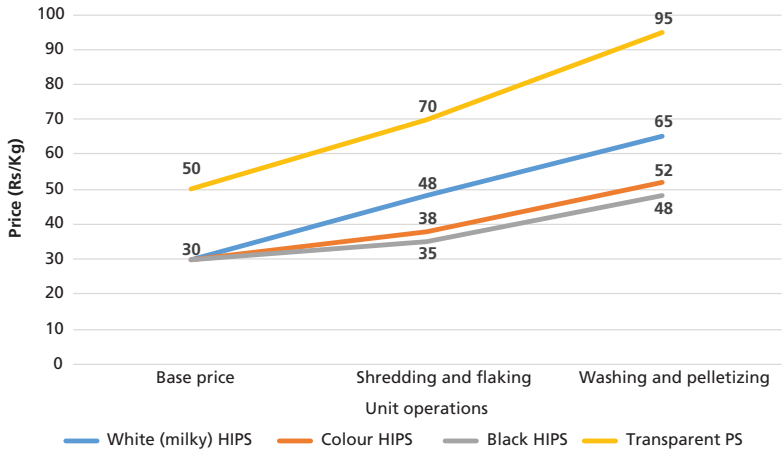


Source: CSE

Stored and packed ABS at an informal recycling facility

HIPS (48%) and transparent PS (7%) together make up more than half of the styrene based plastic products. Transparent PS is the purest form of PS and closest to the virgin plastic, it is used in electrical and insulation applications. The HIPS plastic categories are used mostly as packaging material in the consumer goods sector, its percentage contribution is less due to the low weight of the packaging material as compared to transparent PS, which also takes up a lot of space for storage (see *Graph 11: Increase in price of PS with unit operations*).

Graph 11: Increase in price of PS with unit operations

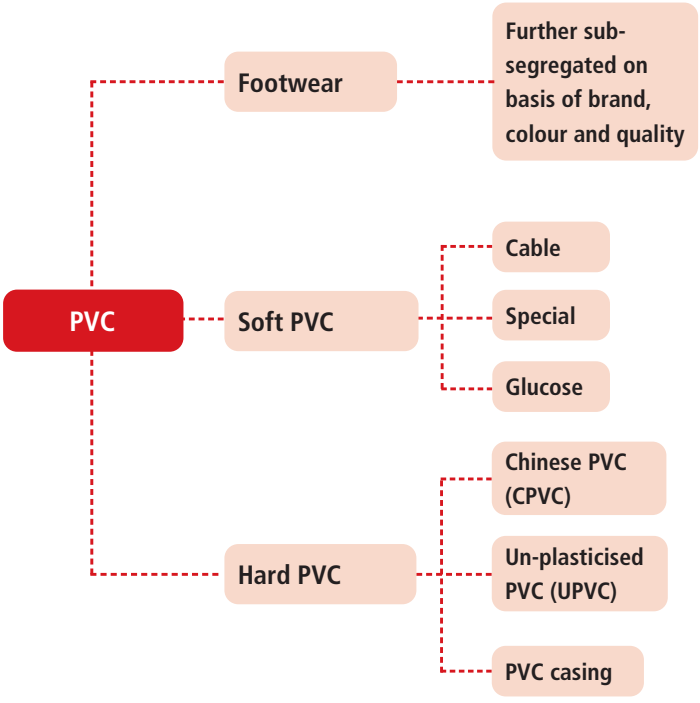


Source: CSE

4. Polyvinyl chloride (PVC)

PVC can be further divided into hard PVC, soft PVC and footwear. They are closely related in terms of the resin being used in the making of these products. These are bought by local scrap dealers separately. Sometimes, soft PVC and footwear may be bought together. Footwear, soft PVC and hard PVC are always treated by different sets of people and in different facilities, and they move across the value chain like any other stream of plastic (See *Figure 10: Classification of PVC in the informal sector*).

Figure 10: Classification of PVC in the informal sector

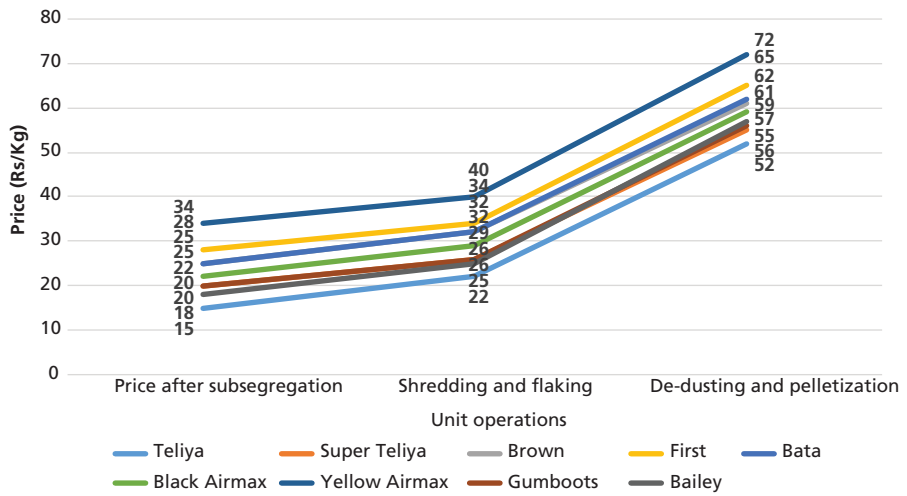


Source: CSE

Footwear is procured at a rate of Rs 12–17/Kg and is further sub-segregated on the basis of brand, colour, and quality of the resin. The uppers of the footwear are generally not recyclable and are a waste of the sorting and pre-processing phase of the entire mechanism; similarly, leather is generally not accepted and is a contamination in the system. It is only waste like this, for which we do not have a solution at this point of time, that should be channelized to WtE plants for recovery of embedded energy as they have high calorific values. Scientific names of each of the categories could not be found and hence we have used local names that are used by the informal recyclers. The change of the price as per the unit operations is shown below (see *Graph 12: Increase in price of footwear with unit operations*). One very important aspect that has to be noted during the pre-processing of footwear PVC is that this category of plastic is not subjected to the unit operation of washing with the help of water, due to the presence of chloride in this particular plastic type. Instead of using water, a vibrating machine (locally known as *Jhatka* machine) with a mesh is used to get rid of any contamination in the sub-segregated plastic.

PVC Footwear lying at an informal recycling centre

Graph 12: Increase in price of footwear with unit operations

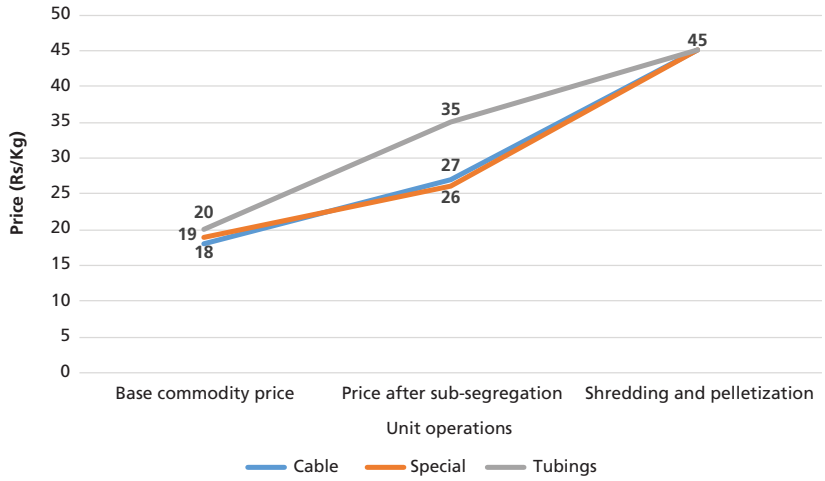


Source: CSE

Soft PVC is found in electrical cables and tubing used in healthcare facility to administer drugs and for other purposes. These are procured at a rate of Rs 18–20/Kg, followed by which they are sub-segregated and subjected to unit operations (See *Graph 13: Increase in price of soft PVC with unit operations*). The worthwhile point to note here is that this category of PVC plastic dos not have to go through a process of de-dusting, since it is usually obtained from businesses like construction, healthcare facilities/healthcare waste treatment facilities, etc.

PVC cable stored at an informal facility

Graph 13: Increase in price of soft PVC with unit operations

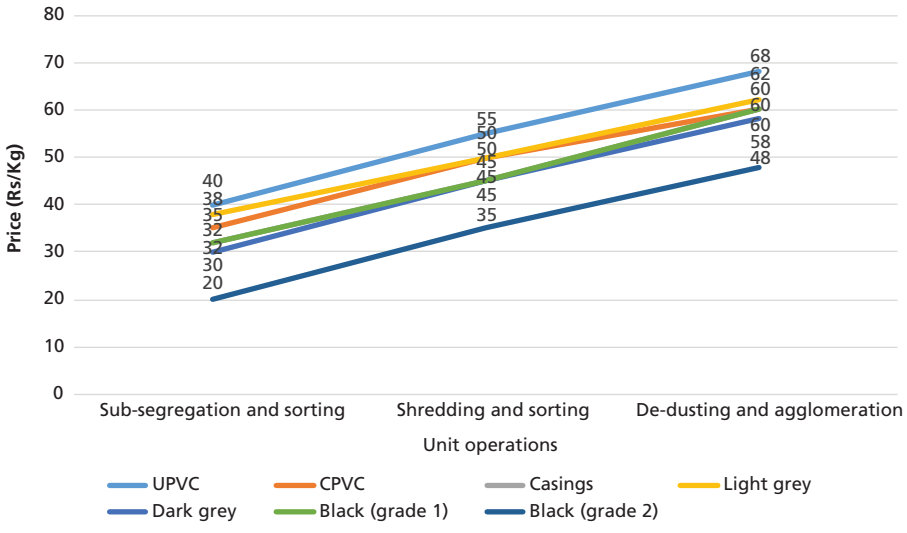


Source: CSE

Hard PVCs are used widely in water pipes, doors and window panes, electrical insulations, and other home appliances. Hard mixed PVC is procured by local scrap dealers at a rate of Rs 20–28/Kg. When further sub-segregated and subjected to unit operations, the price increases as depicted below (see *Graph 14: Increase in price of hard PVC with unit operations*). CPVC is considered to be a lower grade of PVC as compared to UPVC and casings, and as it degrades after undergoing recycling, it starts to be used as a binder in the other PVC plastics which contributes to darkening of the colour. Also, as the PVC plastics go through the process of recycling, the colour of the plastic starts to turn grey, which darkens further as the PVC plastic undergoes more iterations of the recycling process.

PVC casings lying at an informal recycling facility

Graph 14: Increase in price of hard PVC with unit operations



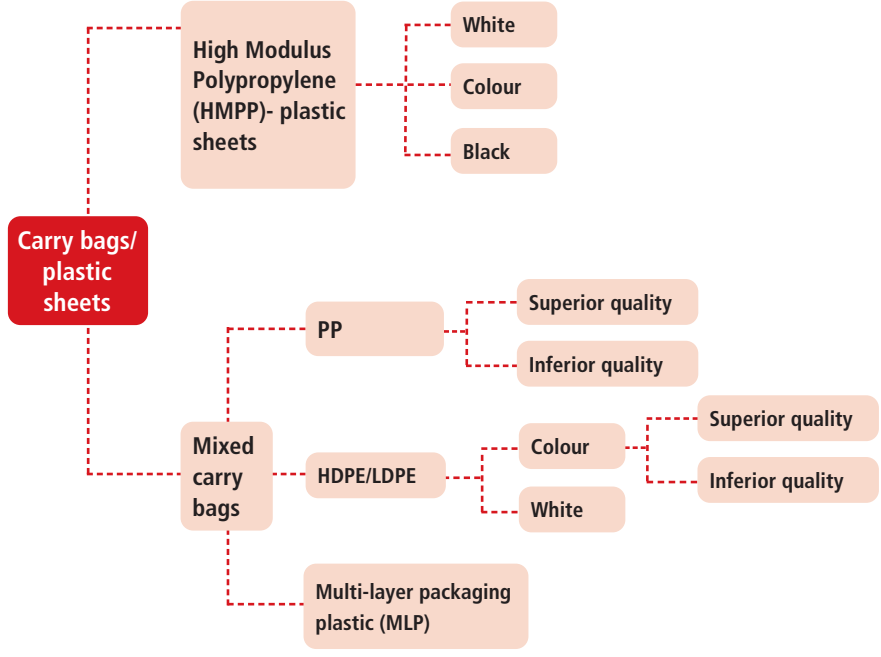
Source: CSE

5. Plastic sheets and carry bags

Plastic sheets are known as *panni* in the local markets. These plastic sheets are made up of plastic types ranging from LDPE, PP and HDPE. These are procured at a rate of Rs 6–15/Kg by the local scrap dealers as mixed plastic bags and sheets. Carry bags and sheets are further sub-segregated manually to be channelized to the relevant pre-processing and treatment facility. There are two sources through which these kinds of plastic waste are sourced to the local scrap dealers (see *Figure 11: Classification of carry bags and plastic sheets in the informal sector*). First is the post-consumer recyclable waste, which due to

the contamination as a result of poor waste management practices is inferior in quality and the second one is directly obtained from commercial establishments and is superior in quality. Even multi-layered packaging plastic is obtained in this type of waste, but it is sold for almost Rs 4–5/Kg after it is sub-segregated from the mixed plastic. Even the informal sector which can literally make use of any type of plastic finds it difficult to deal with this type of plastic waste. They mostly use MLP's as an additive to increase the binding capabilities in the inferior plastic, but the low demand, high supply and cheaper alternatives to MLP that serve the same purpose make it a non-lucrative proposition. In some cases, these MLPs are being used to prepare woven carry bags, with high carrying capacity as compared to the regular plastic carry bags, but here the cheap cost and high demand of the carry bags scores in its favour. It can hence be established that there is no feasible solution for MLPs and we have to look beyond routing them to WtE plants and cement co-processing units.

Figure 11: Classification of carry bags and plastic sheets in the informal sector

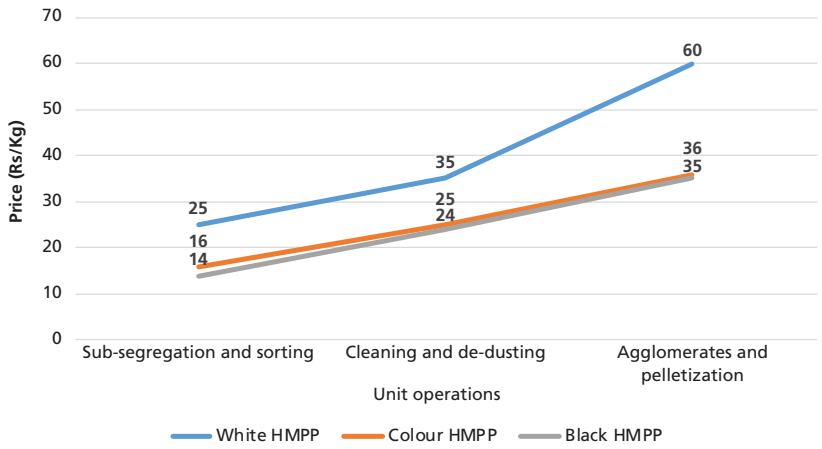


Source: CSE

Plastic sheets and carry bags made up of High Modulus Poly-propylene (HMPP) are locally known as '*Jabla*' and can be further sub-segregated on the basis of colour into white, coloured and black plastic sheets and carry bags. They are subjected to unit operations and pellets or agglomerates are made which can further be transformed to carry bags and plastic sheets (see *Graph 15: Increase in price of HMPP with unit operations*). Use of water is avoided to clean this plastic to avoid weight errors while trading. De-dusting is done using a vibrating screen to get rid of contamination.

Workers sub-segregating plastic sheets and carry bags at an informal facility

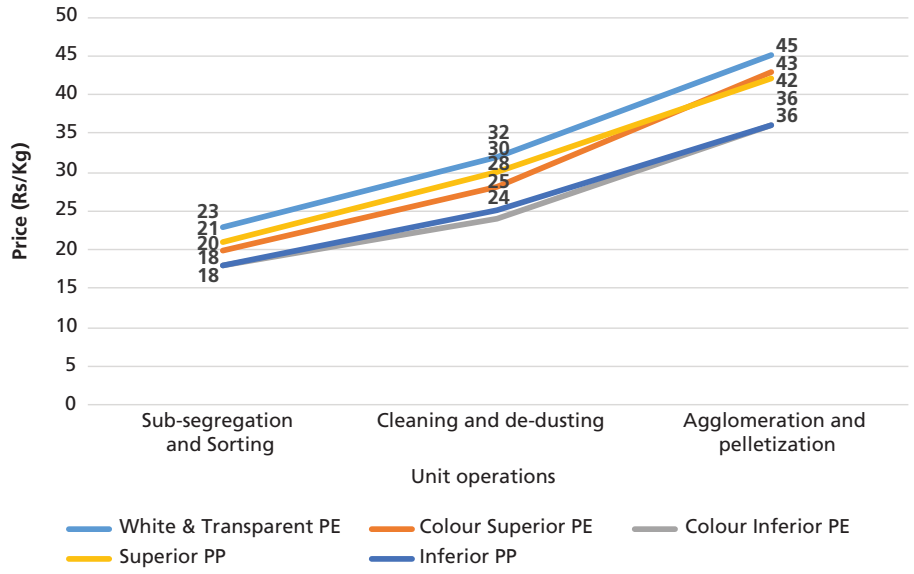
Graph 15: Increase in price of HMPP with unit operations



Source: CSE

Mixed carry bags are obtained from plastic sheets and carry bags after the HMPP has been taken out of them. We are left primarily with PE and PP plastics—these are further sub-segregated on the basis of colour and quality to manufacture agglomerates and pellets (see *Graph 16: Increase in price of carry bags with unit operations*).

Graph 16: Increase in price of carry bags with unit operations



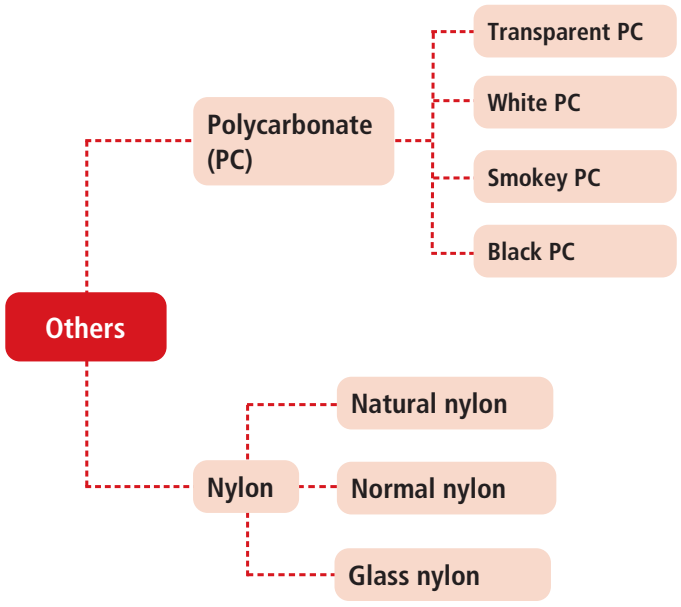
Source: CSE

6. 'Others' category of plastics

The harsh reality of the 'others' category of plastics is that whatever does not fall under first six categories of plastic is simply and conveniently labelled as the seventh category and put in the bucket of 'others'. The others category of plastic is a very broad domain which contains many types of plastics, some of which have already been covered in our earlier analysis (for instance—ABS and MLP) due to the overlapping nature of monomers or functionality. In this section, we will focus on two more categories of plastics, which are dealt with by the informal sector very widely. These categories are polycarbonate (PC) and nylon (see *Figure 12: Classification of 'others' plastics widely dealt by informal sector*).

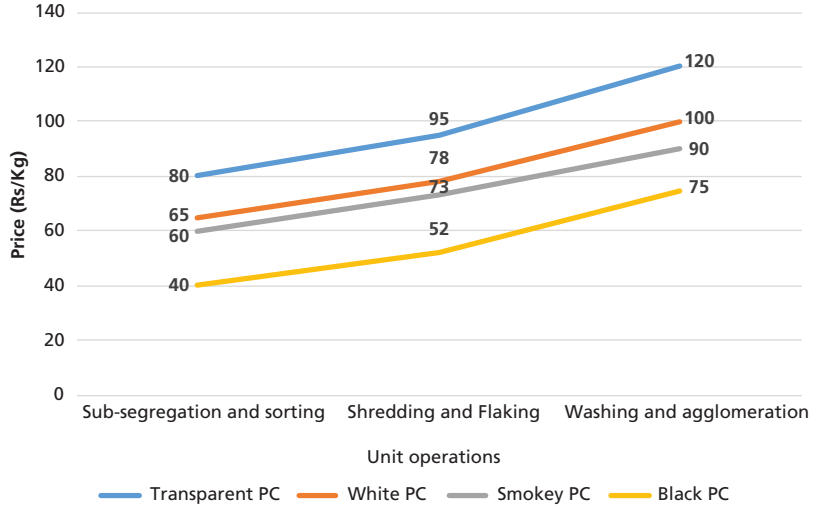
Polycarbonates are thermoplastics bought by the scrap dealers at a rate of Rs 50/kg, and they are used in engineering as they are tough materials and some grades are optically transparent, which makes them resemble properties of glass without the brittleness. The optical transparency gets diminished over multiple cycles of recycling but it can still be used for engineering purposes (see *Graph 17: Increase in price of polycarbonates with unit operations*).

Figure 12: Classification of 'others' plastics widely dealt by informal sector



Source: CSE

Graph 17: Increase in price of polycarbonates with unit operations



Source: CSE

Nylon, which is also known as polyamide (PA), is widely used in household plastic items like clothing, toothbrushes and also has industrial uses like in conveyor belts and as machinery parts. It is usually procured along with various types of plastics and then sub-segregated and sorted manually to be further sold to processors at a rate of Rs 20–35/Kg depending on the type and quality of the material (see *Graph 18: Increase in price of nylon (PA) with unit operations*).

THE TALE OF TIKRI KALAN: A CASE STUDY

The Tikri Kalan PVC market in Delhi, Asia's biggest, is a formal trading area sprawled over 7–8 square kilometres. On a daily basis, more than 385 kinds of plastic waste products including pipes, brushes, car fittings, etc. are managed by this trading site, which has a trading capacity of 100 tonnes per day. The site's market association says there are roughly 1 lakh people engaged in this business here.

How is the plastic waste collected, processed and transported?

The market receives plastic scrap from kabadiwallahs operating in or outside Delhi; the scrap is sold depending on its resin quality. The collection and transportation of the waste is primarily driven by small trading operators. Chugnewallahs (rubble segregators) sell their ware to panni dealers; kabadiwallahs sell to kabadi shops. The panni dealers and kabadi shops, in turn, sell to bigger kabadiwallahs, who sell it further to the traders in the PVC market.

Usually, kabadiwallahs sell their plastic scraps in the market after asking traders if they are keen to buy it for a negotiable amount. Sometimes, the traders themselves demand a particular resin (HDPE, PP, LDPE or PVC). When the mixed waste arrives in the market, workers segregate materials according to resin and colour of the plastic scrap. Dismantling is followed by grinding, washing and drying. Notably, the sorting unit of the market is specialized in black PP scrap trading; it can segregate PP into three different categories—namely good, medium and low—depending on its quality. The first category (good) of PP is hard and, seemingly, 'pure'. The second (medium) is one which has already passed through a recycling process. Both these categories can be sent to factories for pellet formation. The third category (low) contains different varieties of plastics that cannot be separated; hence, it is sent to WtE plants or the brick-kiln industries. In recycling factories in Narela, Bawana and Bahadurgarh, higher grade plastic scraps are recycled

into pellets and are used to make equivalent lower quality of plastic products. For instance, cheaper shoes and furniture are made from PVC grains; inferior buckets, mugs and jugs from PP grains. Low quality spectacles and pens are the by-products from acetate.

What determines plastic scrap prices?

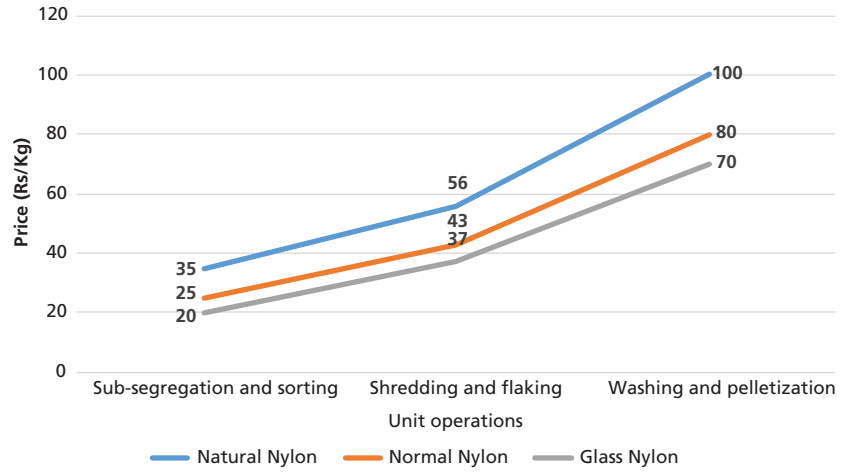
The daily 'market rate' of plastic scrap is decided by the retail markets of Delhi, such as Sadar Bazar and Inderlok; traders in these markets are specialized in trading in wholesale quantities of items made from recycled plastic grains. This rate sets the price slab from which appropriate prices for plastic scrap are deduced at every stage of the value chain (from manual segregation of scrap to the finally recycled pellets). Communication about the market rates passes through multiple mediums, from commissioning agents to traders based all over India. Suppliers share the information on prices when they do their rounds for collection from their kabadi shops.

The information thus rapidly channelizes down the value chain to all scrap traders in the PVC market and elsewhere. Two of the key parameters that influence plastic scrap prices are the price of crude oil and the changing season. When crude oil price is low, plastic scrap prices also go down. In winter, prices are usually high (compared to in summers), while the monsoon period exercises a big impact on the operation of the market as all trading activities get reduced. The commodity becomes wet which changes its bulk mass due to seepage of water inside the bags, and therefore, cannot be sold.

How green is this trading site?

Local communities have been up in arms against the PVC market. In 2018, the NGT—on behalf of the residents of village Mundka—filed a petition in the Delhi High Court. The petition said pollution caused by burning of plastics, leather, rubber, motor engine oil and other waste materials and continuous operation of illegal industrial units dealing with such articles on agricultural lands was impacting the environment adversely. In another petition, residents of village Neelwal complained of pollution caused by illegal and unauthorized industrial activities of shredding, cleaning, recycling and burning of plastics, rubber articles and other waste materials in the villages of Nangloi, Ghewara, Neelwal, Mundka, Kamruddin Nagar, Tikri Kalan, Ranhaula, etc. spread along the Delhi–Haryana border. The cases remain under arbitration.

Graph 18: Increase in price of nylon (PA) with unit operations



Source: CSE

70 per cent recycled by the formal sector

This is a figure that is debatable. As discussed in earlier sections—Table 1 and Table 2—we have established that we are certain that the number of organized/formal recyclers has declined. Moreover, the data shared by CPCB in its annual report has highlighted that we are not aware of the total number of plastic recyclers in every state, their capacity, or the type of resin/plastic waste they deal with. PlastIndia Foundation's report has included informal recycling hotspots like Tikri-Kalan, Delhi and Dharavi, Mumbai as recyclers of plastic waste. There are reports which claim that Dharavi (a cluster of informal facilities in the heart of the city) recycles 85 per cent of all the plastic waste generated in Mumbai.[21]

As per the estimate, the informal sector recycles 20 per cent of the recyclable component of municipal solid waste collected in India. It has to be mentioned that this number excludes the amount of waste recycled from MSW prior to doorstep collection, which is commonly not accounted for and can amount to approximately four times the quantity recycled from officially collected MSW. This implies an estimated overall recycling of 56 per cent of recyclable waste generated.[22] What this also implies is that the contribution of the formal sector in plastic recycling is meagre and limited to machinery-based processing.

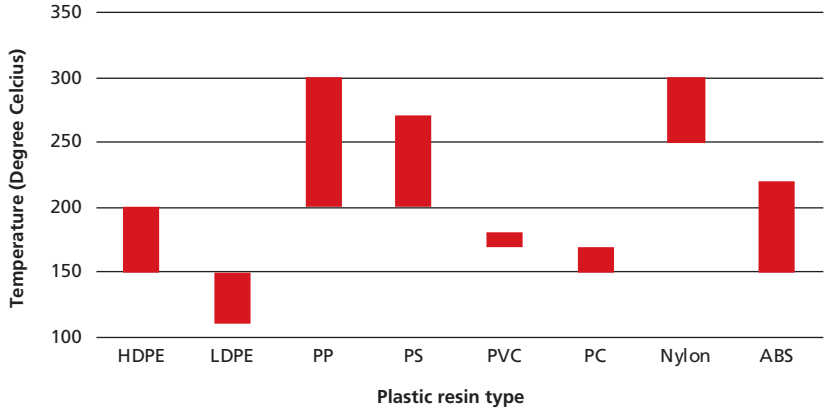
According to the ground survey by CSE, it was found that most of the plastics are recycled by the informal sector, which converts them into pellets and agglomerates before passing them on to the formal sector for moulding, dyeing and branding. So, it can be established that the formal/organized sector has outsourced the collection, sorting, de-dusting, washing, pelletization, agglomeration and similar unit operations to the informal/unorganized sector. The unorganized/informal sector has its own channel through which the plastic waste moves up the value chain before it ultimately is converted to a new (recycled) plastic product with branding. In some instances, just the branding without any other unit operation of the recycled plastic product increases its cost by Rs 12–15/Kg.

So the formal and the informal sector are not separate and they do not compete with each other for the waste, they are rather cohesive and inter-dependant. The formal recyclers are able to work because the informal sector does the difficult part and brings back the processable plastic waste in forms of agglomerates, pellets and, in a handful of cases, even the end product to the formal sector. The informal sector needs the formal sector as they are the ones who buy their end products. Also, the informal sector is limited by financial capacity and ability to invest in space and machinery to make the final product by themselves. The relationship between formal and the informal sector is symbiotic and neither can survive without the other one.

Once the plastic pellets and agglomerates that are manufactured in the informal facilities reach the desired formal facility, it goes through a process of moulding, which is followed by dyeing. Moulding is a part of the manufacturing process where the plastic is shaped: there are a number of moulding options available in the market depending on the desired end product. Some best-known examples of moulding are: rotational, injection, blow, compression and extrusion. Each of the process gives a plastic product which has different sets of properties. The last step is using dyes which is done to achieve a specific shape. This may or may not be required for all the plastics after moulding has been done.

During the moulding and dyeing process, the temperature is of great importance. The temperature varies on the basis of two major factors: the type of resin being recycled and the desired thickness of the end product being manufactured (see *Graph 19: Plastic types and temperature range during processing*). The lower the thickness requirement, the higher is the temperature required. The thickness is measured in terms of microns or grams per square meter (GSM). To manufacture a lower micron thickness plastic requires less pellets/agglomerates (by weight) and a higher temperature during the moulding and dyeing process.

Graph 19: Plastic types and temperature range during processing



Source: CSE

This is how most of the plastics that we use are recycled and sold back into the market. However, the cost of recycled plastics and products made out of them makes it difficult to compete with the products made from virgin material. There are two prime reasons for this. One, the raw material used for virgin plastic production is a waste material from the petroleum industry and hence available at throw-away cost. Second, the fact that the unorganized recycling business is labour dependant and intensive, primarily due to sub-segregation and sorting which is not done at source in the country.

Goods and Services Tax (GST) and plastic recycling

The imposition of GST has had a telling impact on the plastic recycling sector. Before GST came in, there existed a gap in the taxation between recycled and virgin products. For example, recycled polyester staple fibre (PSF) enjoyed a 2 per cent excise duty, while virgin PSF had 12.5 per cent excise duty. The coming of GST upset the apple-cart: taxes stood at 18 per cent for both virgin and recycled plastics. Input costs escalated by 16 per cent due to the new tax regime. In an environment where market linkages for recycled products are weak and plastic scrap availability is intermittent, the business model of the recycling sector struggles to break even. It affects plastic recyclers more if the plastic scrap is imported. These input cost escalations due to GST and customs duties are passed on by the recyclers to the secondary waste collectors by reducing the rates of waste plastic.

In 2017, GST rates for domestic plastic scrap were reduced from 18 per cent to 5 per cent. However, per unit rate of waste plastic is still not at par with what it was in the pre-GST era. The reason is simple: in the pre-GST taxation regime, domestic plastic scrap was tax-free. The selling prices for recycled granules have been affected by similar GST rates on virgin and recycled granules. Recyclers are compelled to keep the selling price low to stay competitive with virgin granules. This has affected the revenue of recyclers; it also restricts market scale-up of recycled granules.

The informal sector—consisting of ragpickers, kabadiwalas, and small and medium dealers—is feeling the pinch in a big way. With most of the plastic scrap selling at cheaper rates post-GST, it has hit the bottom line of the most vulnerable segment in the business.

Challenges

The challenges with respect to plastic waste and its recycling are immense and encountered at every level from classification of plastics, quantification of plastics, identification of sources of plastic waste, the fates of plastic waste and options of dealing with them, recycling as a whole, and finally the current GST framework.

In terms of classification, the RIC codes are the most widely accepted and recognized. However, most of us confuse them as a promise that the plastic will be recycled. Moreover, the resin codes can help us identify the type of resin that was used for making the plastic, but it is almost impossible to establish if a plastic product has been made using virgin material, recycled material, or the so-called compostable and biodegradable plastics. Consumers have to heavily rely on the message communicated to them by producers and brand owners through their packaging, and there is no way to verify the claims made by them in terms of the kind of plastic they are using.

The quantification of plastic waste is an even bigger challenge. Until and unless we have a 'realistic' number to which all stakeholders can agree, this discussion should be the top-most priority. The current situation and available documents only tell us how the various government agencies themselves have published contradictory data in terms of plastic waste generation and we are nowhere close to the actual figure.

As mentioned in the PWM Rules, 2016, the producers and brand owners have been entrusted with the management of plastic waste that is generated as a result of their products. Due to the sensitive issue that plastic waste is, most brand owners shy away from revealing the amount of plastic they use for packaging their products. Their reports try to convey and communicate how they are trying to replace their existing packaging material with sustainable alternatives and these reports are simply used as a tool to greenwash the brand image. The brand owners have limited the consumer in terms of the choices of packaging material available on the shelves, and the buck is conveniently passed to the consumers wrapped in the name of public demand.

The fate that plastic waste meets with once it has been disposed is discussed at length. While options for managing plastic waste are available, the actual solutions are limited to certain kinds of plastics. The rest of the plastics which are being produced in an unsustainable manner, at massive scales and without any strategy for their end-of-life fate, are an issue of grave concern. Burning of MLPs and other non-recyclable plastics (in WtE plants and cement co-processing facilities) has conveniently been labelled as recycling even though it is nothing of the sort.

The informal sector is the only reason why we have not drowned in our own waste. While they do most of the work and make it possible to bring everything back into the value chain, they have not been recognized as an institution/organization and that makes them all the more vulnerable and prevents them from having the right to bargain. On second thought, this may be a deliberate arrangement for the formal players to steal the cream after all the churning has been done. The PWM Rules, 2016 have also recognized the waste-picker but not the entire sector as a whole. The losses that the informal sector has had to suffer because of GST have also been highlighted time and again. While plastic waste channelized for recycling is subject to 5 per cent GST, non-recyclable plastic waste which is sent to WtE plants and cement plants for co-processing is procured by these plants free of cost, and is delivered to their doorstep.

Policy recommendations

- **Regulate the quantity of plastic that can be produced in the country, sector-wise depending on the requirement:**
  The amount of plastic that is used, especially by the packaging sector, has to be regulated. Brand owners should be allowed to put only a certain percentage of their packaged products in plastic packaging, offering consumers with more options on the shelves. Milestones in term of cutting down on plastic packaging should be worked out starting with at least 5 per cent of alternate packaging options for consumers.

- **Define single use platic and bring MLP under the ambit of single use plastic and bring back the agenda of phasing out MLPs:**
  Single use plastic needs to be defined in the plastic waste amendment rules, 2021. Technically, MLPs are plastic packaging which are used once before being discarded and even the informal sector in India, which is literally capable of recycling almost everything, finds it difficult to incorporate it in their value chain. The only stakeholders benefitting from this are the brand owners and producers. They should be asked to pay extra taxes for putting on the market plastic waste that is not recyclable and which can only be burnt.

- **Mandate 50 per cent use of recycled plastic in non-food applications of plastic:**
  The PWM Rules, 2016 in clause 4(b) state that 'Carry bags made of recycled plastic or products made of recycled plastic shall not be used for storing, carrying, dispensing or packaging ready to eat or drink food stuff'. While this is important since we have limited studies to understand leaching and environmental degradation of recycled plastic in foodstuff, it is also imperative to mandate the use of recycled plastics in non-food applications like beauty products, cleaning agents, hand-wash, electronics equipment, etc.

- **Invest in R&D for understanding leaching of plastics and its additives, environmental degradation, and micro-plastics:**
  Since plastics are mixed with additives, which impart to them the properties they exhibit, we do not understand how plastic will behave when exposed to environmental degradation under natural conditions. Yet, we promote technologies like bitumen roads, paver blocks and other alternate use applications using plastics without understanding the potential for micro-plastic formation. There has only been one study conducted in India on micro-plastics in our major waterbodies.

- **Define informal sector and invest in protection of labour working in informal factories:**
  Almost all the government reports acknowledge the presence, involvement and contribution of the informal sector which recycles most of the plastic

waste in the country. What they fail to do is recognize and include them in the value chain. The first step to do so will be to define and address who they are, not individually but as unions and organizations, in the plastic waste amendment rules, 2021. This will make them less vulnerable, give them rights to bargain, and get the right price for plastics they deal with.

- **Standardize recycled products, and help consumers to identify products made out of recycled plastics:**
  Currently, there is no way we can identify if recycled plastic has been used to manufacture the packaged product. This system needs to be built and established. Recycling facilities of plastic should be monitored and evaluated by the prescribed authority. Standards for recycled plastic should be announced and they should be met by all manufacturers of recycled plastics.

- **Rescind GST on plastic scraps:**
  It has been established that levying GST on plastic scrap does not affect the formal businesses as they recover their costs from the informal sector. Only finished plastic products should be taxable as the formal sector will have to pay those taxes, this will also help in integrating the informal sector.

- **States should allot land for recycling in development master plans:**
  Given the fact that recycling is a very important aspect of a planned city and its dwellers, primarily due to urbanization and consumerist behaviour, it's time we incorporate them in our master plans for development.

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Over the last 70 years, there has been an exponential rise in the production and consumption of plastics. Plastics have not only become an omnipresent part of the everyday life of billions of people but have also became an omnipresent environmental problem. Since it is not possible to reduce the use of plastic all at once, we have to focus on recycling plastic as much as possible. This report explains plastic recycling in detail while laying out the possibilities and limitations of the recycling approach.

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