Plastics Waste Management
Recycling & Recovery Options

Due to its multifaceted benefits, use of plastics in variety of applications has been increasing at a galloping rate all around the world, including in India. Plastics contribute various benefits to the modern world from providing safe and hygienic packaging materials for food and pharmaceutical products, to conserving Land, Water, Forests and Energy resources to practically in all areas of our life. The list below gives a quick overview of major application areas of plastics:

- Agriculture
- Healthcare / Medical
- Education
- Pipes for Water, Gas and Sewerage
- Building & Construction – Flooring / Doors & Windows / Drainage Pipes, Water Storage Tanks, Construction Linings etc
- Cables – Electrical and Telecommunication
- Electrical & Electronics Equipments
- Thermal Insulation
- Automobile, Aviation & Railways
- Packaging
- Household
- Furniture
- Toys & Others

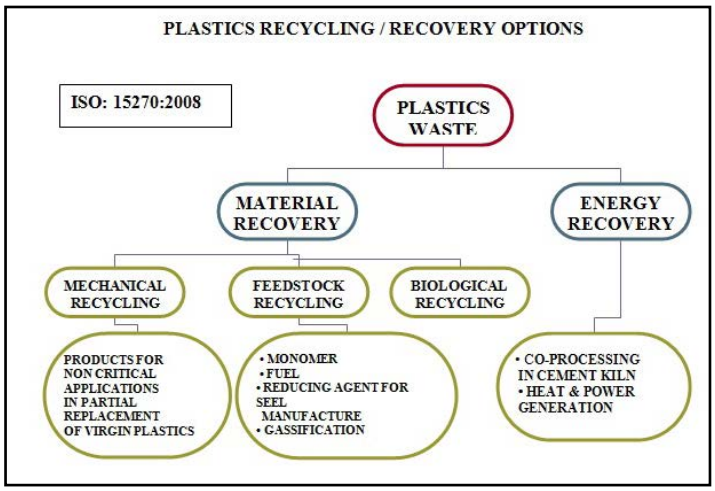
Some of these applications are for long time use and some for short term. Packaging is the single largest sector of applications of plastics which account for about 35% - 40% of consumption globally. Consumption pattern in India is similar.

Flexible packaging applications are mostly for short term use. Management of waste created by the discarded used plastics items, especially the ones used for flexible packaging applications has become a challenging task, more so in the developing countries of the world.

Developed countries have established effective infrastructure for the management of plastics waste of all kinds by adopting proper collection system and different recycling technologies. However in the developing countries the general trend is to opt for selective collection of some types of plastics waste, which are easy to recycle by Mechanical Recycling Process (referred later) abandoning a large chunk of plastics waste, which are difficult for recycling.

These find their way to the landfill or simply remain in the surroundings, creating an environmental issue (chocking of drains or creating other health issues). New technologies and economics have come to play an important role in plastics recycling. When we talk about plastics recycling, it principally refers to 'Recovery', which is divided into 'Material Recycling' and 'Energy Recovery'.

Various options for plastics recycling / recovery have been described by the International Organisation for Standardisation (ISO) in its Standard: 15270:2008.



The choice between Mechanical Recycling, Feedstock Recycling or Energy Recovery will depend on the types of plastics waste and the relative ease / difficulty in total or partial segregation of different groups of plastics materials from each other or from other waste materials / contamination.

Brief Description of the options

Mechanical Recycling

- This is most preferred and widely used recycling process.
- Cost effective.
- This process converts the waste in to products for same or new areas of application. For example a milk packaging film waste is converted in to barsati film (water proofing purpose). A broken bucket is remoulded in to a bucket or mug etc. An automotive battery is converted in to briefcase. A PET bottle waste is recycled in to fibre for further conversion in to a carpet or a T-shirt.
- Recycled material is available at 50% – 60% cost of virgin material, at a lower property though.

Requirement:

Requirement for Mechanical recycling is Homogeneous input of same type of plastics waste. When different types of plastics are mixed together, specific segregation technique is employed to accumulate similar groups of plastics materials separately. Cleaning is an important part of the process. The process flow chart is as follows:

Sequence of operations

The mechanical recycling option generally comprises the following sequence of unit operations, some of which may occur simultaneously, that are carried out as part of the recyclate preparation and production process:

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"Collection → Identification → Sorting → Grinding / Shredding with or without dust removing → Washing → Drying → Separating → Agglomerating → Extruding / Compounding → Palletizing

In some cases where the sorting process is able to group same type of plastic waste together, the "separating process" after washing and drying may not be necessary."

ISO 15270

Feedstock Recycling

This option is opted for converting plastics waste to different products:

1. Conversion to Monomer
2. Fuel
3. Reducing Agent in Blast furnace for production of iron
4. Gasification to constituent chemicals in reasonably purer form

1. Conversion to Monomer:

Some types of plastics waste have already been converted to its monomer for reusing the same as the base material for re-polymerization. At least 30 – 40% of PET waste has been re-polymerized to fresh raw material. This is a high technology process and is generally pursued by the basic plastics raw material manufacturers.

2. Fuel from plastics waste:

Waste generated out of mixed plastics, co-mingled plastics and plastics materials made out of a combination of different plastic materials are generally difficult for normal recycling (mechanical recycling) and are mostly abandoned in the waste stream as it is, and hence creates waste management problem.

Success has already been achieved in converting such plastics waste in to industrial fuel in an environmental friendly technology in some countries in the world including in India. This option has the benefit of using mixture of different types of plastics waste, mixed together, without segregation. Elaborate cleaning / washing is also not required. Industrial Fuel made out of the plastics waste is substitute of fossil fuel (LDO). This process is also used for Recycling of Electronic Waste, containing plastics.

Principles Involved

All plastics are polymers mostly containing carbon and hydrogen and few other elements like chlorine, nitrogen etc. Polymers are made up of small molecules, called monomers, which combine together and form large molecules, called polymers.

When this long chain of polymers breaks at certain points, or when lower molecular weight fractions are formed, this is termed as degradation of polymers. This is reverse of polymerization or de-Polymerisation. If such breaking of long polymeric chain or scission of bonds occurs randomly, it is called 'Random ode-Polymerisation. Here the polymer degrades to lower molecular fragments. In the process of conversion of waste plastics into fuels, random de-Polymerisation is carried out in a specially designed reactor in the absence of oxygen and in the presence certain catalytic additives. The maximum reaction temperature is around 400°C.

This process can convert all types of hydrocarbon polymers including thermo plastics and thermosetting plastics, rubber products including used automobile tyre and synthetic fibre. Economic viability depends on the volume of operation and types & cost of inputs. Commercial scale plants are already running in some parts of the country. Pilot Plant is running successfully at a Colony in the heart of New Delhi since beginning of 2014. There is a growing feeling among the civic authorities for decentralizing the treatment processes of MSW closer to the waste generation area, if possible, so that the waste need not travel a long distance. Keeping that requirement in mind, Technologies are nowadays offered so that smaller batches of waste could be treated without causing any untoward environmental nuisance in the vicinity. The model project in New Delhi has been set up keeping this as a background. The plant is based on pyrolysis technology and runs in batch process. The batch capacity is 50 Kgs. The technology helps in converting all types of synthetic polymers into liquid hydrocarbon fuel and LPG rage gas at a temperature range of 150 - 450° C with the help of a unique pyro-cracking catalyst developed and patented by the technology provider. A special characteristic of the technology is that the volatile gases from the heated polymer react with the catalyst which is packed in a cartridge placed outside the reactor. This, as per the technology provider, ensures greater safety of the whole reaction process. The gas generated during the process burns with a blue flame and can be used for domestic cooking purpose. The residue after pyro-cracking is a mixture of carbonaceous material along with some percentage of inorganic debris. This residual material has sizable calorific value and could be used as solid fuel similar to coke. Any metal part which was embedded in the plastic waste product, would settle down at the bottom of the reactor to be collected separately at the end of the reaction.

The conversion rate depends on the type of plastic waste. Typical conversion rates are:

Liquid Fuel	25 – 80 %
LPG range Gas	15 – 50 %
Soil Fuel	5 – 25 %

Some amount of water vapour formed during the reaction process evaporates while collecting the fuel. Polyethylene and Polypropylene gives highest conversion rate to fuel while polyester gives low conversion. By mixing different types of plastics together, the optimum conversion could be achieved. No untoward VOC's are emitted in the surrounding environment. The hydrocarbon fuel is in the range of Light Diesel Oil (LDO) and can be used in boilers, transformers, generators etc. Gross calorific value of the fuel is around 10, 500 cal/G.

Normally rigid plastics waste like bottles, jerry cans, broken buckets etc are mechanically recycled in plants located at

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The PLASMA TECHNOLOGY is now available in India. Due to Protocol the manufacturer's details have not been given in the article. Interested reader may contact ICPE.

Energy Recovery

1. Co-Processing of plastics waste in Cement Kilns
2. Incineration for energy recovery / power generation

As the recovery option depends on many prevailing circumstances, Life Cycle Analysis (LCA) may be applied to decide, depending on the type and composition of the plastic wastes, which options are environmentally more favourable and sustainable.

1. Co-Processing in Cement Kilns

One of the most effective methods of recycling of plastics waste for recovery of energy is its use as an alternative fuel in cement kilns. The list below gives a comparison of the calorific values of different plastic materials as compared to coal.

Polyethylene	:	46 MJ/kg
Polypropylene	:	44 MJ/kg
Polyamide (Nylons):		32 MJ/kg
PET	:	22 MJ/kg
Coal	:	29 MJ/kg

The high temperature used in the cement kilns gives a scope for use of even some type of plastics waste contaminated with toxic chemicals like pesticides and some other hazardous materials without creating any increased emissions in the air or water. No segregation or cleaning is required for such type of disposal.

Low-end plastics waste, which creates a waste management problem, may provide the vital energy to the cement industry.

Practically all types of plastic wastes can be used as an alternate fuel in cement kilns. Halogen containing plastics also can be used in kilns having suitable arrangements. It is observed that the emission levels of various gaseous substances including Dioxins and Furans, TOC, Heavy Metals, SPM, CO2, SO2 and NOx etc, either came down or remain within the acceptable norms.

This is indicative that disposal / co-processing of all types of plastic wastes in cement kiln in Indian condition is an environmentally safe option.

There are about 170 cement kilns in the country, in different zones. Out of which about 150 Cement Kilns can use plastics waste as an alternative fuel. Even if each Cement Kiln replaces about 10% of coal with plastics waste (Germany replaces more than 60% coal with plastics waste), more than half a million tons of plastics waste of the country could be disposed of scientifically and also saving close to one million ton of coal (for every Ton of coal about 0.6 MT of plastics waste is sufficient, because of higher calorific value of plastics). For using more quantities of plastics waste in the feed, certain modifications are required considering the light weight of plastics.

2. Incineration for Energy Recovery / Power Generation

After the selection of various types of plastic waste for mechanical recycling, there may still remain some types of plastic waste, heavily contaminated with various types of contaminants including different toxic chemicals or hazardous products. The best way of re-utilizing these wastes is to use the latent energy content of the plastics waste by co-processing in cement kilns or to incinerate them and recover the heat energy, instead of dumping them diffusely on landfills. This recovers their calorific values. The choice of incinerators is very important. Modern incineration technology has answers to tackle any incineration problem without polluting the environment and in many cases recovering the calorific value out of the waste being incinerated.

Heavily contaminated plastics waste collected from different waste stream can be utilized for energy recovery by waste incineration plants. Cost of this system of recovery is considered highest among all the other alternatives. When considering incineration as an option, it is to be remembered that waste incineration plants are not operated with the aim of producing energy. The main purpose is and remains to reduce the volume of waste to a considerable degree by means of incineration in an environment friendly manner. Plastics waste contain calorific values equivalent to fuel.

There are 121 energy recovery facilities operating in the United States, with a designed capacity of nearly 97,000 tons of waste per day with the capacity to generate 2,700 MW of electricity (enough to power approximately 2 million homes), saving an equivalent of 30 million barrels of oil per year and preventing the release of 40 million tons of CO_2 equivalents annually. At present more than 19 percent of the nation's MSW is processed by energy recovery facilities. A recent national survey found that 97 percent of opinion leaders support expansion of energy recovery in the United States and 89 percent would prefer remaining plastics to go to energy recovery facilities instead of landfills.

How do plastics contribute to waste-to-energy incineration?

Plastics are derived from petroleum or natural gas, giving them a stored energy value higher than any other material commonly found in the waste stream. In fact, one pound of plastics can generate twice the energy as Wyoming coal and almost as much energy as fuel oil. When plastics are processed in modern waste-to-energy facilities, they can help other waste combust more completely, leaving less ash for disposal in landfills.

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- **Use of plastics waste in the construction of asphalt road:**

Use of plastics waste in the construction of asphalt road has been demonstrated by at least two to three technologies in the country in the past 3 – 4 years. There is scope of using some types of low-end plastics waste without elaborate cleaning, for improving the property of tar road by replacing bitumen to an extent of about 10 – 15 %. Such roads have been laid in different parts of the country. Tamil Nadu took initiative in encouraging the implementation of the technology developed by a Madurai Engineering College followed by Karnataka, which adopted a technology developed by CSRI Laboratory, Central Road Research Institute, Delhi. Later ICPE also took initiative in developing a technology for laying roads with plastics waste in some other parts of the country. MoEF has recognized the benefits of this process and encourages for its wide scale adoption. Flexible plastics packaging waste can be used in the process after suitable modifications.

PLASTICS LUMBER FROM MIXED PLASTICS WASTE

Mixed plastics waste including multilayered plastics can be made into plastic lumbers, which can further be fabricated to furniture replacing conventional wood.

Mixed plastics waste can also be compression moulded in to Boards and Corrugated Sheets which find commercial applications.

Segregation / Collection and Transportation of Waste for converting it in to Wealth:

To make the whole process successful, at the first place it is important to segregate Waste in to 'Dry' and 'Wet' at the source of waste generation itself. This is the action which is taken by the waste generator – households / occupiers. Once this is done, the next step is collection of the waste, specifically the Dry Waste, for further segregation in to different types. This action can be accomplished appropriately by engaging waste separators, who segregates plastics, papers, metals, glass etc wastes separately so that the same could be forwarded to respective recycling industries for their conversion in to suitable products for use. Such practice of engaging manual workforce for segregating Dry Waste in to specific categories does exist in some parts of our country.

In Mumbai such model projects have been successfully being carried out with the initiatives of ICPE along with NGOs and fully supported by Brihanmumbai Municipal Corporation. In

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this model project, in select Mumbai Wards, about 80 (now 100) waste pickers have been engaged for collecting Dry Waste from the residential societies, shorting the waste in to different categories in the areas allotted by the Municipality Corporation and selling the shorted dry waste to Waste Dealers / Recyclers at market price. This help the waste pickers earn their livelihood and also Municipality Corporation to reduce the load in the landfills. Corporation also saves the cost of transporting the waste to far placed landfills.

Waste Management System at
Brihanmumbai Municipal Corporation :

In Mumbai, constant effort is being made to separate the Dry and Wet waste at the source itself, so that the Dry wastes could be further segregated into different types of wastes and could be sent for recycling, resulting in lesser load to the landfill, sites.

There is an increasing activity among various Local Self Government Councils to treat the wet waste also through vermiculture or similar process, to generate compost which can be used as fertilizers. ICPE along with some NGO's have joined hands with BMC in some Wards of Mumbai to propagate the Proper Solid Waste Management culture among the citizens. The results are evident in at least some Wards of Mumbai.

Here is a brief description of the work being practised:

'A' – Ward (Cuffe Parade Area):

1. BMC has given a secured area and a shed for segregation of dry waste.

2. BMC has also provided 2 nos. 1 toner vans with drivers, free of cost, to move in the locality for 8 hours to collect dry wastes from households.

3. BMC / identified NGOs have issued Identity badges to the rag pickers.

4. Rag pickers accompany the BMC vans and collect dry wastes from door steps of the households/society buildings and bring those to the BMC allotted sheds for segregation.

5. The dry wastes are product-wise segregated into : paper, plastics, metal and others. Obviously, within each product, there are different categories e.g. in metal, there would be iron, aluminum foil etc. In plastics, there would be PE, PP films, polystyrene cups, HDPE solid items / caps etc.

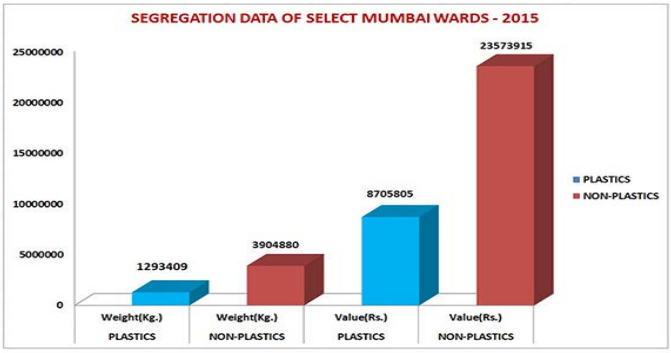
6. These segregated dry wastes are stored in the secured sheds for disposal.

7. When sufficient quantity of waste is accumulated, waste dealers come to these sheds, weigh the scraps and pay the rag pickers / co-coordinator the cost of the waste, and collect the dry waste. Generally, this collection takes place once in a week. (In some places, where the sheds are not well secured, rag pickers dispose off their segregated wastes every alternate day, or even daily to the recycles / traders)

8. The wet wastes are collected by separate BMC vans from the household localities – directly to the landfills.

In some societies, local self government council or the societies themselves are collecting the wet wastes also for composting, resulting into zero garbage concept. However, this is not yet widely practised in all parts of the country as yet.

DRY WASTE COLLECTION FIGURES



In 2015, about 120 Waste Pickers segregated more than 5198 Mts of Dry Waste & Earned Rs. 3.2 Crores (Rs. 22000/- Per Month, Per Waste Picker) by selling the segregated waste to Recyclers.

A TRUE PICTURE OF WEALTH FROM WASTE

DATA SHEET

The list below gives the comparative energy values of different plastics vis-à-vis fuel oil and coal in Btu / pound.

Energy Values

Material	Btu/pound
Plastics	
PET	10,900
HDPE	18,700
Other Plastic Containers	16,400
Other Plastics	17,900
Rubber & Leather	12,800
Newspaper	8,000
Corrugated Boxes (paper)	7,000
Textiles	9,400
Wood	7,300
Average for MSW	5,900
Yard Wastes	2,900
Food Wastes	2,900
Heat Content of Common Fuels	
Fuel Oil	20,900
Wyoming Coal	9,600

Editorial Contd.

Energy Recovery by Co-processing of all types of plastics waste in Cement Kilns is a reality in the country today. At the rate of 10% replacement of conventional coal by plastics waste, India can recycle the entire quantity of flexible plastics waste being generated today. Germany replaces more than 60% coal in cement kilns by plastics waste. Feedstock Recycling of Pyrolysis of plastics waste in to Hydrocarbon Fuel (Liquid Diesel Oil - LDO) has been commercially established in the country during last 5 – 6 years. Today it has gained wide range acceptability and popularity among the entrepreneurs as a business model. Another very effective process of utilizing plastics waste in India is its use for the construction of asphalt road. Government of India has officially issued instruction to all Government Departments and Local Bodies to use plastics waste for all bitumen road constructions. Prior permission from the Ministry is required for constructing such roads without plastics waste due to non-availability. Multilayered plastics waste and mixed plastics waste are mechanically recycled by special techniques into useful products like compressed boards, lumbers, corrugated sheets etc. Adoption of a particular method of plastics waste recycling is determined by the type, nature and volume of waste available at the place. However success and sustainability of all these different processes of plastics waste recycling depends largely on how well the waste has been segregated, preferably at the source of waste generation. While segregation of waste at source is practised at parts of some cities, it is yet to be widely followed across the country. Waste collection cost come in the way of economic viability of recycling process. Government of India, in its latest Plastics Waste Management Rules, 2016 made compulsory participation of producers and users of plastics packaging systems in sharing the cost of waste collection mechanisms with the local authorities. For all these methods, the fundamental requirement is collection and segregation of the waste, for which setting up of an infrastructure together with creating awareness on anti-littering is the starting point.

To achieve the target all stake holders including the general mass have to make their contributions in the system. It is not possible for a single agency to perform the task. While general mass has to segregate the waste at source, the local bodies have to collect and transport the source segregated waste to processing centres for further segregation and processing. Manufacturers and users of the plastics packaging system (in fact all packaging materials)need to establish a system for collecting back the plastic waste generated due to their products. Technologies are available for scientific disposal / recovery of all plastics waste. All stake holders should be ready to bear the cost for this work.