An Introduction to Plastic Recycling

2016

Plastic Waste Management Institute
INTRODUCTION

World population, which surpassed 7 billion in 2011, is forecast to exceed 9 billion by 2050. It is feared that the growing demand for resources will facilitate an increase in resource consumption and waste generation, contribute to deterioration of the natural environment and climate change, and impact future generations. To solve poverty, hunger, and environmental problems and achieve sustainable development in diverse ways while dealing with this increase in world population, it is generally acknowledged that a multifaceted approach that integrates economic, social, and environmental aspects is needed.

In the quest for a solution, 2015 is considered to be a milestone year of great significance toward the realization of a sustainable society for the entire world. Specifically, this was the year of the 21st Conference of the Parties to the United Nations Framework Convention on Climate Change (COP21). At this meeting, all participating countries adopted the epoch-making Paris Agreement that set long-term targets and obligated all countries to update and enhance their reduction targets for greenhouse gas emissions every five years. In addition, the 2030 Agenda for Sustainable Development adopted by the U.N. General Assembly established Sustainable Development Goals (SDGs) as new and comprehensive global targets toward 2030.

Based on these movements, the G7 Toyama Environment Ministers’ Meeting held in May 2016 adopted the Toyama Framework on Material Cycles and agreed upon a G7 Common Vision to enhance resource efficiency and promote the 3Rs (Reduce, Reuse, Recycle) and on common guidelines on future actions. The meeting also confirmed that activities related to resource efficiency and the 3Rs would contribute to the control and reduction of marine litter from land-based sources and plastic litter in particular.

Plastic has become something that we cannot live without, but it is based on finite resources such as petroleum. Consequently, if plastic waste can be used again as a resource, it should be possible to solve this problem in terms of both resource saving and waste processing.

Progress in the development of recycling technologies over many years has led to techniques like mechanical recycling and feedstock recycling that are now widely used for reusing post-use plastic as plastic products, as fuels for use in the chemical industry, etc.

Based on Japan’s Basic Law for Establishing the Recycling-based Society, the Third Fundamental Plan for Establishing a Sound Material-Cycle Society states that “measures with regard to waste shall be promoted as far as they are technologically and economically viable according to the priority stipulated in the Basic Law (1: reduction of waste generation, 2: reuse, 3: recycled use, 4: heat recovery, 5: appropriate disposal).” However, it also states “a more appropriate method shall be selected without regard to this priority if environmental loads can be reduced by doing so, and measures shall place importance on Life Cycle Assessment (LCA).” In addition, moves to promote energy recovery techniques for incinerating plastic waste and using it as thermal energy are progressing.

Japan’s effective plastic utilization rate is steadily improving, reaching 83% in 2014. This is a top-class figure even by world standards, which reflects Japan’s high recycling consciousness.

In this publication we consider the question of waste from a number of angles and present the very latest data on processing of waste plastic and its use as a raw material. Environmental and waste issues are composed of a great number of factors, which makes a scientific, multifaceted approach essential to their solution. The reader, we hope, will find that “An Introduction to Plastic Recycling” throws light on waste problems and in particular on the issue of plastic waste.

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Industrial waste emissions level off

**Emissions and recycling of industrial waste**

- **Recycled**
- **Reduced**
- **Landfill**

**Content of emissions**

- Glass, concrete and ceramic: 1.7%
- Wood: 1.8%
- Metal: 2.0%
- Soot and dust: 4.4%
- Slag: 4.4%
- Demolition: 16.4%
- Animal excrement: 21.5%
- Sludge: 42.7%
- Plastics: 1.6%
- Waste oil: 0.8%
- Other industrial waste: 2.8%

**State of processing**

- Landfill disposal: 3.1%
- Reduced: 43.6%
- Total: 385 million tons
- Recycled: 53.2%

**Approximately 3% disposed of by landfill**

Industrial waste is waste emitted as a result of business activities at construction sites, livestock farms, factories, and other business-related establishments. Japan produces a little less than 400 million tons of industrial waste per year, and a breakdown reveals a little more than 40% of the total to be sludge, followed by animal excrement and demolition waste.

These three categories account for around 80% of the total. Urban infrastructure industries (i.e. electricity, gas, heating and water utilities), agriculture/forestry and construction produce almost 70% of the total. Kanto region produces 26%, Chubu region produces 15%, Kinki and Kyushu region produce 14%, respectively.

We can see from the State of processing graph that the total increased by 5.56 million tons, and the breakdown reveals the amount of recycling decreased by 2.15 million tons and the amount of waste disposed of in landfill decreased 1.38 million tons, the amount of reducing increased by 9.09 million tons. It is remarkable that the decreasing of the amount of recycling and the increasing of the amount of reducing. The amount of material going to landfill is around 3% in FY 2013, final disposal remaining capacity for industrial waste is 170 million m³, and 14.7 years across the entire nation, especially 5.2 years in the Tokyo metropolitan area, so the landfill situation is particularly severe.

(Source: Ministry of the Environment, Emissions and Processing of Industrial Waste, 1 April 2014)
Decrease in domestic waste emissions bottom out

The amount of domestic waste discharged in Japan in FY 2014 was 44,320 kt (*kt = thousand tons), which is nearly 10,000 kt less than the peak value reached in FY 2000. This value equates to 947g of discharged waste per person, which represents a drop of about 20% over the same period. Although the amount of domestic waste has been steadily decreasing since FY 2000, there are troubling signs that this trend is beginning to bottom out. Breaking down domestic waste reveals 28,740 kt of everyday garbage, 13,070 kt of business garbage, and 2,500 kt of garbage from group collections, with household garbage making up 65% of all domestic waste.

On examining the composition of garbage, a survey conducted by the Ministry of the Environment found that paper and kitchen waste made up 34% and 32%, respectively, followed by plastics at 12% and glass, fiber, wood/bamboo/grass, and metal at 3-5% in terms of percentage wet weight. Since kitchen waste makes up about 30% of garbage, it can be assumed that water makes up much of the weight of this type of waste.

The total amount of domestic waste processed in FY 2014 came to 41,840 kt, but as shown by the State of Processing graph, most of this waste(80%) was processed by incineration. In addition, final disposal was 4,300 kt (520 kt direct + 3,780 kt after intermediate treatment), which means that about 100 g of waste per person per day ended up as landfill. There are 1,698 final disposal sites (landfills) in Japan with a remaining capacity of 106 million m³, which equates to a national average of 20.1 remaining years**. In addition, the number of remaining years for landfill disposal in the Tokyo metropolitan area and Kinki region became 21.8 (2.0 years more than the previous year) and 19.0 (1.1 years more than the previous year), respectively. There are also 305 municipalities (cities, towns, and villages) with no landfills of their own, and around 18% of municipalities in Japan consign final disposal of domestic waste to private landfills. Securing landfill space and prolonging the number of remaining years for landfill disposal is major problem considering Japan's small size.

Domestic waste carried outside prefectural and city governments to which local governments belong for the purpose of final disposal came to about 260 kt (6.1% of the total amount of final disposal), most of which was from the Kanto and Chubu regions. To secure final disposal sites and extend the number of remaining years of landfill disposal, it is therefore important the three Rs (reduce, reuse, recycle) in order to reduce the quantity of landfill disposal.

** In May 2013, the Japanese cabinet approved a “Waste Treatment Facility Development Plan” (2013 – 2017) that, with regard to the number of remaining years of final disposal sites for domestic waste, will “promote the establishment or upgrading of final disposal sites and the provision of final disposal sites for domestic waste owing to reduced capacity of existing landfills, etc.” so as to maintain the FY2012 level (20 remaining years).
Waste emissions

State of global domestic waste emissions

As a result of expanding economies and a growing pattern of mass production, mass consumption, and mass disposal, these last decades have seen an increase in the discharge of domestic waste on a global basis. For example, the volume of discharge by the member countries of the Organization for Economic Cooperation and Development (OECD) as of 2013 was 660,000 kt annually or 520 kg per person. Compared with 1990, this was an increase of about 40,000 kt. Also of interest here is that the volume of domestic waste discharged by the United States itself exceeded 200,000 kt or 730 kg per person per year, a volume that overwhelmed those of other countries. This makes the small volume of garbage discharged per person per year in Japan (about 350 kg) stand out.

*According to the “World Bank” report, ten years ago, there were 2,900 million city residents, they discharged 0.64kg of waste per person in a day. At present, there are 3,000 million city residents, they discharge 1.42kg of waste per person in a day and at 2025, there will be 4,300 million city residents, they will discharge 1.42kg of waste per person in a day.

Garbage discharge in major countries around the world

As a result of expanding economies and a growing pattern of mass production, mass consumption, and mass disposal, these last decades have seen an increase in the discharge of domestic waste on a global basis. For example, the volume of discharge by the member countries of the Organization for Economic Cooperation and Development (OECD) as of 2013 was 660,000 kt annually or 520 kg per person. Compared with 1990, this was an increase of about 40,000 kt. Also of interest here is that the volume of domestic waste discharged by the United States itself exceeded 200,000 kt or 730 kg per person per year, a volume that overwhelmed those of other countries. This makes the small volume of garbage discharged per person per year in Japan (about 350 kg) stand out.

Increase of waste on a global scale

The amount of waste discharge is increasing on a global scale. On entering the 21st century, this trend got only stronger. According to the World Bank report cited earlier, the amount of municipal solid waste (MSW) was about 680,000 kt per year ten years ago but 1,300,000 kt at present with a forecast of 2,200,000 kt by 2025. This growth in waste discharge is particularly noticeable in Asia, where many countries in the region experienced a rapid demographic shift to the cities and stimulation of production activities over a relatively short period of time accompanying economic growth. As a result, finding a means of processing this massive amount of waste is now a major issue in these countries. Failure to suitably process this waste will trigger a wide variety of problems on a global scale, such as soil, air, ocean, and river pollution, global warming, nature and ecosystem destruction, and wasting of finite resources. Of these, concern about marine litter has been growing in recent years. Much research is focusing on plastics that turn into marine litter, and it is said that marine litter from land-based sources is considerable as a result of outflows from landfills or inflows to rivers as a result of flooding. Meanwhile, it is said that marine litter from ocean-based sources is caused by the disposing of fishing gear such as nets and the illegal ocean dumping of waste.

Many international organizations such as United Nations Environment Program (UNEP) and NPOs are actively engaged in solving this problem. Furthermore, at the 2015 G7 Summit held at Schloss Elmau, Germany, an agreement was reached on a “G7 Action Plan to Combat Marine Litter” in which advanced economies would take the lead on addressing the marine litter problem. This initiative was reaffirmed at the 2016 G7 Ise-Shima Summit held in Japan. To appropriately manage waste and to promote the reduction, reuse, and recycling of waste, individual transformation of behavior is desired.
Effective use of plastic waste increases steadily

(1) Resin production increased by only 10 kt (+0.1%) relative to 2013, which means that it was essentially the same as the previous year. Domestic plastic products consumption increased by 110 kt (+1.1%).

(2) Total plastic waste discharge decreased by 140 kt (-1.5%) relative to the previous year to 9,260 kt.

(3) Effectively used plastic waste increased by 10 kt (+0.1%) relative to the previous year to 7,680 kt pushing the effective plastic utilization rate up to 83%, one point higher than the previous year.
Flowchart of plastic products, plastic waste and resource recovery

Resin production, resin processing, and marketing of products

**Resin production, resin processing, and marketing of products**

Resin production 10,610 kt

- Resin export 3,520 kt
- Resin import 2,630 kt
- Product export 810 kt
- Product import 1,970 kt
- Liquid resin, etc. 810 kt
- Resin processing waste 550 kt
- Resin production waste 170 kt

Reclaimed products 250 kt

Domestic plastic products consumption 9,770 kt

- Production and processing waste 720 kt
- Non-use

Production and processing waste discharge 720 kt

Post-use products discharge 8,530 kt

Total plastic waste discharge 9,260 kt

**Discharge**

In 2014, resin production was practically unchanged from the previous year at 10,610 kt (+10 kt relative to 2013; +0.1%).

Resin export, resin import, product export, and product import, meanwhile, increased to 3,520 kt (+80 kt; +2.3%), 2,630 kt (+170 kt; +6.8%), 810 kt (+20 kt; +2.0%), and 1,970 kt (+40 kt; +2.3%), respectively. As a result, domestic plastic products consumption increased to 9,770 kt (+110 kt; +1.1%).

Total plastic waste discharge decreased to 9,260 kt (-140 kt; -1.5%). This result can be broken down into domestic (general) plastic waste at 4,420 kt (-120 kt; -2.5%) and industrial plastic waste at 4,830 kt (-30 kt; -0.5%).

As for disposal and recovery methods, the portion of total plastic waste discharge applied to mechanical recycling decreased to 1,990 kt (-40 kt; -1.7%) and that to feedstock recycling*1 increased to 340 kt (+40 kt; +15.8%). The portion applied to total energy recovery*2 came to 5,340 kt (-10 kt; -0.2%).

*1 Effective utilization of plastic waste rises to 83%

The quantity shown this year for reclaimed products is based on that of mechanical recycling excluding exported portion (1,680 kt) and the amount used for fiber from PET bottles (90 kt).

Some figures may not exactly match due to rounding.
The percentage contributions to the effective plastic utilization rate by mechanical recycling, feedstock recycling, and energy recovery approximately were 22%, 4%, and 58%, respectively, showing that the plastic utilization rate increased by one point overall to 83% relative to 2013.

The breakdown for the mechanical recycling 1990kt reveals 1390kt (70%) of recycled material and 600kt (60%) of recycled products, and exports of plastic waste for mechanical recycling were decreased by 170kt to 1510kt (76%).

*1. feedstock recycling = blast/coke furnaces + gasification + liquefaction
*2. energy recovery = densified-refuse derived fuel and cement material/fuel + incineration with power generation + incineration with heat utilization facility
Recovery systems supporting mechanical recycling

Breakdown of mechanical recycling (1,990 kt / page 7)

Breakdown of post-use products for mechanical recycling (1,270 kt)

Easily usable industrial plastic waste

The quantity of plastic waste used in mechanical recycling (i.e., the production of new plastic products using plastic waste as a raw material) decreased 40 kt (kt = thousand tons) from the previous year to 1,990 kt in 2014. Of this amount, 650 kt was accounted for by domestic plastic waste (15% of domestic plastic waste). In contrast, about 2 times this amount of industrial plastic waste (1,340 kt or 28% of the total) was mechanically recycled. This is because a large proportion of industrial plastic waste is suitable for mechanical recycling due to its quality and comparative stability of supply.

A breakdown of the waste used for mechanical recycling reveals in recycling of used products to 1,270 kt and the loss in production and processing to 720 kt respectively. This is due to the continued smooth transition to recycling containers and packing, household appliances, and cars in 2014. The success of the various recycling laws can be seen in breakdown of the 1,270 kt of used products: 470 kt of PET bottles, 230 kt of wrapping film, 170 kt of home electric-appliance housings, etc., 80 kt of agricultural plastics, 70 kt of expanded polystyrene packing material, and 70 kt of electric wire coating material. The efficient operation of the recycling systems of each industrial area and associated groups is striking.
### Breakdown of plastic waste

#### Composition of plastic garbage (percentage)

<table>
<thead>
<tr>
<th>Shape</th>
<th>Use and Contents</th>
<th>Type of Resin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beverage bottles</td>
<td>Yogurt, milk</td>
<td>Polystyrene, PET, polyethylene</td>
</tr>
<tr>
<td>Plastic bottles</td>
<td>Juice, cola, drinking water, tea, alcoholic beverages</td>
<td>PET</td>
</tr>
<tr>
<td>Condiment tubes</td>
<td>Mayonnaise, ketchup, dressings, wasabi and mustard paste</td>
<td>Composite materials</td>
</tr>
<tr>
<td>Bottles and tubes</td>
<td>Toiletries, gardening supplies, car supplies, liquid detergent, fabric softener, toothpaste, cosmetics, hair shampoo, hair conditioner, bleach and body shampoo</td>
<td>PET, composite materials, polyethylene, polypropylene</td>
</tr>
<tr>
<td>Food packs (EPS and non-EPS packs)</td>
<td>Margarine, tofu, natto (fermented soybeans), fruit, vegetables, processed foods, packed lunches</td>
<td>EPS Polystyrene, PET</td>
</tr>
<tr>
<td>Food cups (EPS and non-EPS packs)</td>
<td>Miso (soybean paste), tamago-dofu (steamed egg custard), miso soup, yogurt, ramen, yakisoba (fried noodle), jelly, custard pudding, desserts food cups</td>
<td>EPS Polystyrene, polypropylene, PET, polystyrene, composite materials</td>
</tr>
<tr>
<td>Cup and pack lids</td>
<td>Meat, fish, saashimi (slices of raw fish), sliced ham, vegetables, processed foods</td>
<td>EPS Polystyrene, PET, polypropylene, polyethylene, composite materials</td>
</tr>
<tr>
<td>EPS and non-EPS trays</td>
<td>Drugs (tablets), processed meat and fish products, roast ham, bacon, curry roux, household tools, toothbrushes, cosmetics</td>
<td>PET, polystyrene, polypropylene, PET, polystyrene, PVC resin</td>
</tr>
<tr>
<td>Blister packs</td>
<td>Rice, gardening bags, fish, fruit, confectionery, frozen foods, ramen, vacuum-packed foods, pickles, food boiled in soy, miso, bread, dried fish, cleaning</td>
<td>Polyethylene, polypropylene, PET, composite material</td>
</tr>
<tr>
<td>Large, medium and plain bags</td>
<td>Beverages, foods, daily necessities, other plastic bottles</td>
<td>Polypropylene, polyethylene</td>
</tr>
<tr>
<td>Carrier bags</td>
<td>Quail’s eggs, ginger, pickles, condiments, ramen stock, wagashi (Japanese confectionery), candy, wafers, chocolate</td>
<td>Polypropylene, polyethylene, composite material, PET</td>
</tr>
<tr>
<td>Rubbish bags</td>
<td>Beetles, caps</td>
<td>Polystyrene, polyethylene, PET, polystyrene</td>
</tr>
<tr>
<td>Rapping film</td>
<td>Tofu, curry roux, plastic food decorations, wagashi (Japanese confectionery), cheese, frozen foods, cod roe, sausages, frozen noodles</td>
<td>Polypropylene, polyethylene, composite material</td>
</tr>
<tr>
<td>Packaging film</td>
<td>Detergent boxes lids, foods, underwear, powder compacts, lotion cases, dehumidifiers, deodorizers</td>
<td>Polypropylene, polyethylene, polyethylene, PVC resin</td>
</tr>
<tr>
<td>Labels</td>
<td>Urethane sponge, foam products, nets, air caps</td>
<td>Polyethylene, polyethylene</td>
</tr>
<tr>
<td>Other</td>
<td>Baskets, handles, multi-packs, sieves, replanting pots</td>
<td>Polyethylene, PET, polypropylene, PVC resin, polystyrene</td>
</tr>
</tbody>
</table>

**Note:** The types of resin indicated in the table are those mainly used.

**Source:** Plastic Waste Management Institute (PWMI) “Basic Survey for Recycling of Municipal Solid Waste” (March 1999)

Recent advances in the development of high-function containers and packaging materials have led to the use of laminated film (multi-laminates) in many products. Laminated film is achieved by layering a wide variety of film-shaped resins each with different properties, which enables the advantages or disadvantages of individual films to be exploited or compensated for, respectively. For example, a layer that blocks the passage of moisture or oxygen, a layer that cuts off ultraviolet rays, and a layer with heat-resistant properties can be skillfully combined to create a film that hinders the deterioration or decay of the package content. On the other hand, to sufficiently manifest desired functions in laminated film, the constituent film-shaped resins must be closely affixed to each other, which make laminated film unsuitable for mechanical recycling. It can therefore be said that feedstock recycling or energy recovery should be promoted for the recycling of multi-laminates.
Information about plastics

Manufacture of plastics from petroleum

Crude oil use and production by product type (2014)

Petroleum products
- Volatile oil
- Naphtha
- Kerosene
- Gas oil
- Fuel oil
- Imported naphtha

Basic petrochemical products
- Ethylene 6,650 kt
- Propylene 5,670 kt
- Butane/Butylene 2,850 kt
- Aromatic series 14,940 kt
- Others

Plastics
- Polyethylene 2,640 kt
- Polypropylene 2,350 kt
- PVC resin 1,480 kt
- Polystyrene 1,160 kt
- Other thermoplastic resins 1,790 kt
- Thermosetting resins 920 kt
- Other resins 230 kt

Total of plastic raw materials is 10,570 kt

Chemical raw materials other than plastics

Plastics are made from naphtha

Plastics are mainly highly polymerized compounds consisting of carbon and hydrogen, made from substances such as petroleum and natural gas. In Japan, naphtha (crude gasoline) produced by refining crude oil is used as the raw material for making plastics.

Naphtha produced by distilling crude oil is first heated and cracked to extract substances with a simpler structure (i.e., compounds with low molecular weight) such as ethylene and propylene. The molecules obtained are then chemically coupled (polymerized) to form substances with new properties, such as polyethylene and propylene, which are called synthetic resins and polymers. As the newly formed polyethylene and other such substances are difficult to handle in powder or lump form, they are first melted, additives added to make them easier to process, and they are formed into pellets. (It is from this stage that they are normally called plastics.) They are then shipped to the molding plant to be manufactured into plastic products.

Plastics account for just several % of total petroleum consumption

Japan presently uses around 200 million kiloliters of crude oil per year. Most crude oil is refined into gasoline, kerosene, gas oil, and fuel oil; less than 10% is turned into naphtha. In 2014, 18.3 million kiloliters of naphtha was produced from 191.14 million kiloliters of crude oil. Combined with imported naphtha, 25.86 million kiloliters of naphtha was used as the raw material for basic petrochemical products such as ethylene, propylene, butane/butylene, etc. Of this amount, 10,570 kt of naphtha (*kt = thousand tons) was used in the production of plastic materials.

The quantity used to produce plastic products accounts for around 5.9% of combined crude oil and imported naphtha used per year.

The amount of crude oil used in plastics is around 2.7% of the total amount – most crude oil is burned and consumed as thermal energy.
Breakdown of plastic production by resin type and use

**Breakdown of production by resin type**

- Polyethylene (24.1%)
- Polypropylene (23.1%)
- Polystyrene (13.3%)
- PVC resins (15.2%)
- ABS resins (3.5%)
- PET resins (4.0%)
- Polycarbonates (8.0%)
- Polyethylene-vinylacetate copolymer (1.8%)
- Epoxy resins (11.2%)
- Reinforced products (2.0%)
- Synthetic leather (1.0%)
- Daily necessities and sundries (5.2%)
- Building materials (5.3%)
- Equipment and machinery parts (11.2%)
- Containers (13.6%)
- Film and sheet (43.3%)
- Others (4.9%)
- Others (1.3%)

**Breakdown of “Others”**

- Epoxy resins 1.1%
- Unsaturated polyester resins 0.9%
- Melamine resins 0.7%
- Urea resins 0.6%
- Bakelite resins 0.5%

Note: The large difference between resin production (10,830 kt) and production by use (5,600 kt) in the graphs is because production by use was calculated according to the following parameters:

1. Only primary products directly molded and processed were included.
2. Only products made by business establishments with 50 or more works were included.
3. Secondary processed products, plants, adhesives, wiring and cables, synthetic fibers and urethane foam, etc. were excluded.

**Half of production is polyethylene and polypropylene**

Different plastics have different characteristics and are accordingly put to different uses.

A large proportion of production is of polyethylene and polypropylene, and these two combined account for around half of total output. This is because around 40% of plastic consumption is for bags, packaging such as cling film, and sheeting for construction and building materials, which polyethylene and polypropylene are ideally suited for.

**Thermoplastic and thermosetting plastics**

Plastics are divided into two main types according to how they behave when heated: thermoplastic plastics and thermosetting plastics.

- **Thermoplastic plastics**
  - Thermoplastic plastics undergo strong molecular motion when heated, which causes them to soften. They harden when cooled, and repeated heating and cooling allows them to be molded into a variety of different shapes. Uses include containers and packaging material (film, sheet, bottles), daily necessities, household appliances and automobiles.
  - Thermosetting plastics
    - Thermosetting plastics undergo relatively weak molecular motion but once softened by heat and treated they undergo a chemical reaction which causes them to form a high molecular weight 3D matrix structure. This means that once they have set they cannot be softened again by heat. Uses include food containers, circuit boards for electrical equipment, shafts for golf clubs and tennis rackets, and fiber-reinforced plastic boats.

Source: Tabulated by the Japan Plastics Industry Federation from monthly reports issued by the Research and Statistics Department, Ministry’s Secretariat, Ministry of Economy, Trade and Industry.
Plastics as the foundation of industry and modern lifestyles

◆ Advantages of plastics

- **Light and robust**
  Plastics can be used to make light yet strong products, unlike metal and ceramics.
- **Resistant to rust and corrosion**
  Most plastics are resistant to acid, alkalies and oil and do not rust or corrode.
- **Transparent and freely colorable**
  Some types of plastics are highly transparent and can be easily colored, making it possible to create bright, attractive products.
- **Mass producible**
  Many types of plastics that can be molded and processed by a variety of methods, so products with complex shapes can be efficiently mass-produced, helping to bring down costs.
- **Excellent electrical and electronic properties**
  Their outstanding insulation properties and dimensional stability allows plastics to be used in components and electrical and electronic products.
- **High heat-insulation efficiency**
  Plastics conduct heat poorly, and foam is a particularly good heat-insulating material.
- **Hygienic with a strong gas barrier**
  Plastics are clean and impermeable to oxygen and water, effectively protecting foods from contamination by microorganisms.

◆ Drawbacks of plastics

- **Susceptible to heat**
  Some types of plastics deform when placed near a flame or heat source.
- **Susceptible to scratchers and dirt**
  Plastics have a soft surface compared to metal and glass and are easily scratched. They are also susceptible to static electricity and stains are highly visible.
- **Vulnerable to petroleum benzine and thinner**
  Some plastics melt or discolor if exposed to petroleum benzine, thinner or alcohol.

1. Household appliances: LCD televisions
   Liquid crystal display (LCD) televisions with their vivid and detailed high picture quality wide angle screens are made up of a number of plastics layered together: polarizing film, phase contrast film and a diffuser panel for the backlight. Plastics are also used in electrical components, circuits and housings.

2. Automobiles: Gasoline tanks
   Four different resins are applied in six layers to prevent fuel from permeating through the tank, which can be molded in a single stage into a complex shape that frees up space inside the car. Plastic tanks are lighter and also compatible with biofuels, which are expected to come into widespread use. They meet the US safety standards for use over 15 years or 150,000 miles (286,000km).
3. Food containers and packaging: pouches, refillable packs, cups

There is a food container for every need, from heat sterilization to frozen storage. Plastic containers are light and can be formed into retort pouches, sealed and re-sealable containers, or lined with aluminum or a barrier resin to keep out oxygen and UV radiation and extend the shelf life of food.

4. Medicine: Bags for transferring liquids (containers for nutrient fluid and dialysis drugs)

Plastic containers have good heat resistance making them suitable for heat sterilization, are light and flexible so they drain without the need for venting, and can be used in a closed system (to prevent hospital infections). Some drugs are supplied in a double-bag kit, which prevents errors in drug administration by making them easy to mix.

5. Construction materials: PVC windows

Energy loss through windows can be reduced by 1/3 by using PVC sashes and low emissivity double glazing, as compared to aluminum sashes and normal glass windows. They can also prevent condensation and are widely used in Europe as a way to save energy. Japan is expected to adopt them for the same reason.
# Main characteristics and uses of plastics

<table>
<thead>
<tr>
<th>JIS abbr.</th>
<th>Resin name</th>
<th>Standard thermal resistance (°C)</th>
<th>Acid resistance</th>
<th>Alkali resistance</th>
<th>Alcohol resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>PE</td>
<td>Polyethylene</td>
<td><strong>Low density polyethylene</strong></td>
<td>70~90</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>PE</td>
<td>Polyethylene</td>
<td><strong>High density polyethylene</strong></td>
<td>90~110</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>EVAC</td>
<td>EVA resin</td>
<td>70~90</td>
<td>Some products somewhat vulnerable</td>
<td>Some products somewhat vulnerable</td>
<td>Good</td>
</tr>
<tr>
<td>PP</td>
<td>Polypropylene</td>
<td>100~140</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>PVC</td>
<td>Polyvinyl chloride</td>
<td>60~80</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>PS</td>
<td>Polystyrene (styrene resin)</td>
<td><strong>Polystyrene</strong></td>
<td>70~90</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>PS</td>
<td>Polystyrene (styrene resin)</td>
<td><strong>Expanded polystyrene</strong></td>
<td>70~90</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>SAN</td>
<td>AS resin</td>
<td>80~100</td>
<td>Good</td>
<td>Good</td>
<td>Repeated use renders opaque</td>
</tr>
<tr>
<td>ABS</td>
<td>ABS resin</td>
<td>70~100</td>
<td>Good</td>
<td>Good</td>
<td>Swells over long period</td>
</tr>
<tr>
<td>PET</td>
<td>Polyethylene terephthalate (PET resin)</td>
<td><strong>Stretched film around 200 °C</strong></td>
<td>Good</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td>PET</td>
<td>Polyethylene terephthalate (PET resin)</td>
<td>Un-stretched film around 60 °C</td>
<td>Good</td>
<td>Good (except strong alkali)</td>
<td>Good</td>
</tr>
<tr>
<td>PET</td>
<td>Polyethylene terephthalate (PET resin)</td>
<td>Heat-resistant bottle around 85 °C</td>
<td>Good</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td>PMMA</td>
<td>Methacrylic resin (acrylic resin)</td>
<td>70~90</td>
<td>Good</td>
<td>Good</td>
<td>Dissolves at a low saponification point</td>
</tr>
<tr>
<td>PVAL</td>
<td>Polyvinyl alcohol</td>
<td>40~80</td>
<td>Softens or dissolves</td>
<td>Softens or dissolves</td>
<td></td>
</tr>
<tr>
<td>PVDC</td>
<td>Polyvinylidene chloride</td>
<td>130~150</td>
<td>Good</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td>PC</td>
<td>Polycarbonate</td>
<td>120~130</td>
<td>Good</td>
<td>Some products somewhat vulnerable (e.g. detergents)</td>
<td>Good</td>
</tr>
<tr>
<td>PA</td>
<td>Polyamide (nylon)</td>
<td>80~140</td>
<td>Some products somewhat vulnerable</td>
<td>Good</td>
<td>Possible infiltration</td>
</tr>
<tr>
<td>POM</td>
<td>Acetal resin (polyacetal)</td>
<td>80~120</td>
<td>Some products somewhat vulnerable</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>PBT</td>
<td>Polytetraphenylene terephthalate (PBT resin)</td>
<td>60~140</td>
<td>Good</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td>PTFE</td>
<td>Fluorocarbon resin</td>
<td>260</td>
<td>Good</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td>PF</td>
<td>Phenol resin</td>
<td>150</td>
<td>Good</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td>MF</td>
<td>Melamine resin</td>
<td>110~130</td>
<td>Good</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td>UF</td>
<td>Urea resin</td>
<td>90</td>
<td>Stable or very slight change</td>
<td>Very slight change</td>
<td>Good</td>
</tr>
<tr>
<td>PUR</td>
<td>Polyurethane</td>
<td>90~130</td>
<td>Somewhat vulnerable</td>
<td>Somewhat vulnerable</td>
<td>Good</td>
</tr>
<tr>
<td>EP</td>
<td>Epoxy resin</td>
<td>150~200</td>
<td>Good</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td>UP</td>
<td>Unsaturated polyester resin</td>
<td>130~150</td>
<td>Good</td>
<td>Good</td>
<td></td>
</tr>
</tbody>
</table>

Standard thermal resistance (°C) is the heat resistance of each resin type in normal use. It does not apply to generic resins, engineering plastics or thermosetting resins. The entries on this table have been arranged into standard grades to give a rough idea of their physical properties. Consult the manufacturer if you require particular physical properties for product design.
<table>
<thead>
<tr>
<th>Resistance to cooking oil</th>
<th>Characteristics</th>
<th>Main uses</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Good</strong></td>
<td>Lighter than water (relative density &lt;0.94), excellent electrical insulation, water resistance, chemical resistance and environmental adaptability, but poor thermal resistance. Mechanically strong but soft, does not become brittle even at low temperatures.</td>
<td>Packaging (bags, cling film, food containers), agricultural film, wire covering, film within milk carton</td>
</tr>
<tr>
<td><strong>Good</strong></td>
<td>Slightly heavier than low-density polyethylene but still lighter than water (relative density ≥0.94). Excellent electrical insulation, water resistance, and chemical resistance, higher thermal resistance and more rigid than low-density polyethylene. Whiteish and opaque.</td>
<td>Containers and packaging (film, bags, food containers), shampoo and conditioner bottles, sundries (paddles, washbowls, etc.), gasoline tanks, kerosene containers, containers, popes</td>
</tr>
<tr>
<td><strong>Good</strong></td>
<td>Transparent and flexible, with rubbery elasticity that gives it excellent resistance at low temperatures. Some items have excellent adhesive properties. Poor thermal resistance.</td>
<td>Agricultural film, stretch film</td>
</tr>
<tr>
<td><strong>Good</strong></td>
<td>Low relative density (0.9-0.91). Relatively high thermal resistance. Excellent mechanical strength.</td>
<td>Automobile parts, household appliance parts, wrapping film, food containers, caps, trays, containers, pallets, clothing boxes, textiles, medical instruments, daily necessities, trash containers.</td>
</tr>
<tr>
<td><strong>Good</strong></td>
<td>Does not burn easily. Soft and hard varieties. Sinks in water (relative density of 1.4). Excellent glossy surface shine, well suited to painting.</td>
<td>Over and underwater pipes, joints, guttering, corrugated sheeting, window sashes, flooring, wallpaper, synthetic leather, hoses, agricultural film, wrapping film, wire covering</td>
</tr>
<tr>
<td><strong>Vulnerable to some fatty oils such as terpene oil from citrus fruits and perilla oil</strong></td>
<td>Comes in a transparent, rigid general purpose (GP) grade and a milky white shock-resistant high impact grade (HI). Easily colored. Good electrical insulating properties. Dissolves in petroleum benzene and thinner.</td>
<td>Office appliance and TV casing, CD cases, food containers.</td>
</tr>
<tr>
<td><strong>Vulnerable to some fatty oils such as terpene oil from citrus fruits and perilla oil</strong></td>
<td>Light and rigid. Good thermal insulting properties. Dissolves in petroleum benzene thinner.</td>
<td>Packaging, fish boxes, food trays, cup noodle containers, tatami mat padding</td>
</tr>
<tr>
<td><strong>Good</strong></td>
<td>Excellent transparency and thermal resistance.</td>
<td>Tableware, disposal lighters, electrical equipment (fan blades, juicers), food storage, containers, toys, cosmetic containers.</td>
</tr>
<tr>
<td><strong>Good</strong></td>
<td>Excellent shock-resistance and glossy appearance.</td>
<td>Office appliances, automobile parts (interior and exterior), games, consoles, building components (internal), electrical equipment (air conditioners, refrigerators).</td>
</tr>
<tr>
<td><strong>Good</strong></td>
<td>Excellent transparency, rigid, excellent gas barrier properties.</td>
<td>Insulating material, functional optical film, electromagnetic tape, camera film, wrapping film</td>
</tr>
<tr>
<td><strong>Good</strong></td>
<td>Excellent transparency, oil-resistant, excellent chemical resistance.</td>
<td>Containers for foodstuffs, food boiled in soy sauce, fruit, salad and cakes, drinks cups, clear bottles, various kinds of transparent packaging (APET).</td>
</tr>
<tr>
<td><strong>Good</strong></td>
<td>Transparent and rigid, excellent gas barrier.</td>
<td>Containers for drinks, soy sauce, alcohol, tea, and drinking water (PET bottles).</td>
</tr>
<tr>
<td><strong>Good</strong></td>
<td>Colorless, transparent, glossy. Dissolves in petroleum benzene and thinner.</td>
<td>Automobile headlight lenses, tableware, lighting boards, water tank plates, contact lenses.</td>
</tr>
<tr>
<td><strong>Good</strong></td>
<td>Colorless, transparent, good chemical resistance, excellent gas barrier.</td>
<td>Cling film, ham and sausage casing, film coating.</td>
</tr>
<tr>
<td><strong>Good</strong></td>
<td>Colorless and transparent, highly resistant to acids but vulnerable to alkalis. Excellent resistance to shocks and heat.</td>
<td>DVDs and CDs, electronic part housings (e.g. mobile phones), automobile headlight lenses, camera lenses and housings, transparent roofing materials.</td>
</tr>
<tr>
<td><strong>Good</strong></td>
<td>Milky white, scratch-resistant resistant to low temperatures, good shock resistance.</td>
<td>Automobile parts (air inlet pipes, radiator tanks, cooling fans, etc.), food film, fishing line and monofilament, gears, fasteners.</td>
</tr>
<tr>
<td><strong>Good</strong></td>
<td>White, opaque, excellent shock resistance and good abrasion resistance.</td>
<td>Gears (DVD player, etc.), automobile parts (fuel pumps, etc.), fasteners and clips.</td>
</tr>
<tr>
<td><strong>Good</strong></td>
<td>White, opaque, good balance of electrical and other physical properties.</td>
<td>Electrical parts, automobile parts.</td>
</tr>
<tr>
<td><strong>Good</strong></td>
<td>Milky white and thermally resistant, high chemical resistance with non-stick properties.</td>
<td>Frying pan coatings, insulating materials, bearings, gaskets, all kinds of packing material, filters, semiconductor industry applications, wire coverings.</td>
</tr>
<tr>
<td><strong>Good</strong></td>
<td>Good electrical insulating properties, acid resistance, heat resistance and water resistance. Does not burn easily.</td>
<td>Printed circuit boards, iron handles, distribution board breakers, pan and kettle handles and knobs, plywood adhesive.</td>
</tr>
<tr>
<td><strong>Good</strong></td>
<td>Resembles melamine resin, but cheaper and more difficult to burn.</td>
<td>Buttons, caps, electrical products (wiring accessories), plywood adhesive.</td>
</tr>
<tr>
<td><strong>Good</strong></td>
<td>A wide variety of physical properties can be obtained from the resin, from flexible to rigid. Excellent adhesive and scratch-resistant properties, foam also has many desirable physical properties.</td>
<td>Foam is mainly used for cushions, automobile seats and heat insulation. Non-foam variety is used for industrial roll packaging belts, coatings, waterproofing materials, spandex textiles.</td>
</tr>
<tr>
<td><strong>Good</strong></td>
<td>Excellent physical, chemical and electrical properties. Products reinforced with carbon fiber are particularly strong.</td>
<td>Electrical products (IC sealant, printed circuit boards), paints, adhesives, all kinds of laminates.</td>
</tr>
<tr>
<td><strong>Good</strong></td>
<td>Good electrical insulating properties, heat resistance and chemical resistance. Products reinforced with glass and carbon fiber are particularly strong.</td>
<td>Baths, corrugated sheeting, cooling towers, fishing boat, buttons, helmets, fishing rods, coatings, septic tanks.</td>
</tr>
</tbody>
</table>

Source: The Japan Plastics Industry Federation “Hello Plastics !” (Partly revised by PWMI)
### Three forms of recycling

<table>
<thead>
<tr>
<th>Category (in Japan)</th>
<th>Method of recycling</th>
<th>ISO 15270</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material recycling</td>
<td>Recycling to make: Plastic raw materials Plastic products</td>
<td>Mechanical recycling</td>
</tr>
<tr>
<td>Chemical recycling</td>
<td>Monomerization, Blast furnace reducing agent, Coke oven chemical feedstock recycling, Gasification, Liquefaction</td>
<td>Feedstock recycling</td>
</tr>
<tr>
<td>Thermal recycling</td>
<td>Cement kiln, Waste power generation RPF(*1), RDF(*2)</td>
<td>Energy Recovery</td>
</tr>
</tbody>
</table>

*1. Refuse Paper & Plastic Fuel (high-calorie solid fuel made from waste paper & plastic)  
*2. Refuse Derived Fuel (solid fuel made from burnable waste, plastic waste, etc.)*

**The true goal of recycling**

Many years of technological development now allow plastic waste to be recycled by a number of methods. They can be grouped into three main categories (note 1).

1. Mechanical recycling
2. Feedstock recycling (monomerization, blast furnace reducing agent, coke oven chemical feedstock recycling, gasification, liquefaction, etc.)
3. Thermal recycling (cement kiln, waste power generation, RPF, RDF)

Recycling technology has advanced tremendously and its use is spreading, but recycling is not an end in itself. As the Basic Law for Promoting the Creation of a Recycling-oriented Society enacted in 2000 made explicit, the purpose of recycling is to curb consumption of finite natural resources such as oil and minimize the burden on the environment through the cyclical use of resources. This means it is necessary to carefully consider whether the method used reduces inputs of new resources or limits the burden on the environment when promoting recycling.

It is important to select the recycling method for plastics that imposes the least social cost as well as limiting environmental impact given the situation of the plastic waste to be recycled.

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**note 1:** The methods of recycling currently recognized by the Container and Packaging Recycling Law are mechanical recycling, feedstock recycling (monomerization, liquefaction, use as a blast furnace reducing agent, coke oven chemical feedstock recycling and conversion to chemical feedstock by gasification) and thermal recycling (liquefaction and gasification). Under the amendment in 2006, RDF and other forms of thermal recycling were added as supplementary methods, albeit with some limitations.

**note 2:** In classes specified by JIS Z 0130 established in 2015 to incorporate environmental considerations in packaging applications, feedstock recycling is included in mechanical recycling.

**JIS Z 0130 List of classes**

<table>
<thead>
<tr>
<th>Category (in Japan)</th>
<th>JIS Z 0130 (targeting packaging)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material recycling</td>
<td>Material recycling (JIS Z 0130-4)</td>
</tr>
<tr>
<td>Chemical recycling</td>
<td></td>
</tr>
<tr>
<td>Thermal recycling</td>
<td>Energy Recovery (JIS Z 0130-5)</td>
</tr>
</tbody>
</table>
Mechanical recycling is a way of making new products out of unmodified plastic waste. It was developed in the 1970s, and is now used by several hundred manufactures around Japan.

Mechanically recycled waste has until now consisted largely of industrial plastic waste.

Industrial plastic waste generated in the manufacture, processing and distribution of plastic products is well suited for use as the raw material for mechanical recycling thanks to clear separation of different types of resins, a low level of dirt and impurities and availability in large quantities. Used plastics from households, stores and offices are now being mechanically recycled as a result of the entry into effect of the Container and Packaging Recycling Law and the Home Appliance Recycling Law.

All kinds of recycled products are made from industrial plastic waste, including containers, benches and fences, children’s play equipment, construction sheeting, products for packaging, transportation, construction, homes, parks, roads, railways, and other goods and facilities for agriculture, forestry and fisheries.

Recycled products have a number of attractive characteristics: they are durable, light, easy to process and easy to cut and join, just like wood. We can expect greater adoption of recycled products with these features being used in place of other materials, such as steel, concrete and wood.

Central reservation blocks were added to the list of items covered by the Green Purchasing Law in 2008.

Used plastics emitted from the home, such as PET bottles and expanded polystyrene, are turned into textile products, packaging materials, bottles, stationery, daily necessities, video cassettes and similar products.
Mechanical recycling process

From the collection of PET bottles to recycling into new products

Play your part in recycling resources!

Sorted collection Cleaning

Pellets

PET flakes

Selection

Compression

Shredding

Consumer

Recycling businesses

Municipality

Recycled product manufacturing process

End product

Textiles

Melting/spinning

Sewing

Working-clothes, uniforms

Shirts

Raw cotton

Yarn

Fruit trays

Sheeting

Formation into sheets

Vacuum molding

Stationery

Injection molding

Molding

Assembly

Injection molding

Stretch blow molding

Plastic bottles for the kitchen

Source: Council for PET Bottle Recycling

Re-melted to make products

PET bottles from sorted household waste are collected, compressed and packed by municipalities for transportation to plants operated by recycling businesses. At the recycling plant, the waste is sorted to remove impurities, and the remaining PET bottles then shredded and cleaned, foreign bodies and non-resins are removed and the remainder turned into flakes and pellets (made from flakes, thermally processed by an extruder) for recycling. The recycled materials are then sent to textile and sheet-making plants, where they are again melted down to make into textile and sheet products.

Mechanical recycling of other plastic waste follows the same basic process.

Resin molding techniques

(1) Extrusion molding

Resin is melted and continually extruded through a mold by a screw to form a molded product. Products include pipes, sheets, film and wire covering.

(2) Injection molding

Heated melted resin is injected into a mold and solidifies to form a molded product. Products made this way range from washbowls, buckets and plastic models to larger products such as bumpers and pliers.

(3) Blow molding

A parison obtained by extrusion or injection molding is clamped into a mold and inflated with air to make bottles for all kinds of uses, such as shampoo bottles. PET bottles are made by stretch blow molding so as to make them less likely to rupture.

(4) Vacuum molding

A heat-soften sheet is sandwiched in a mold and the space between the sheet and mold sealed and evacuated to form products such as cups and trays.

(5) Inflation molding

This is a type of extrusion molding where a melted resin is inflated into a cylinder to form a film. This method is used to make products such as shopping bags.
Monomerization

Process outline

Input of used PET bottle flakes

Methanol

H₂O

Ester exchange

DMT separation refinement

TPA production

EG

BHET refinement (de-coloration/distillation etc.)

Liquid-state polymerization

Solid-state polymerization

Resin for PET bottles

PET resins

BHET

DMT

EG

TPA

Reference: Teijin Ltd. and Aies Co., Ltd. pamphlet

PET bottles to PET bottles

While PET bottles can be recycled to make textiles and sheeting, they cannot be used to make PET drinks bottles. This is because used PET bottles are unsuitable for use as raw materials for soft drink, alcohol or soy sauce bottles for reasons of hygiene and smell. However, converting PET bottles back to an earlier state of processing is a more economic use of resources than making PET resin from scratch out of petroleum and naphtha. A "bottle to bottle" scheme to make recycled resin equivalent to newly made resin suitable for drinks bottles started in 2003 on this basis.

The method chemically decomposes the used PET bottles into their component monomers (de-polymerization), and they are made into new PET bottles from this stage.

Teijin Ltd. already uses its own proprietary decomposition method, combining ethylene glycol (EG) and methanol to break waste PET resin down into DMT (dimethyl terephthalate) to turn it the raw material used to make textiles and film. This technique was improved upon to break PET bottles down further from DMT to PTA (purified terephthalic acid) to make PET resin, and Teijin Fiber Ltd. commenced operation of a facility with the capacity to process around 62 kt (*kt = thousand tons) a year in 2003. The resin produced was judged suitable for use in food containers by the Japanese Food Safety Commission in 2004, and bottle-to-bottle production started in April with the approval of the Ministry of Health, Labor and Welfare.

Aies Co., Ltd. has also developed a technique for manufacturing resin by breaking it down into high-purity BHET (bis hydroxyethyl-terephthalate) monomer using a new method of de-polymerization using EG. It established a new company, PET Reveres Co., Ltd. in 2004 which can process around 27.5 kt per year. However, a shortage in raw materials due to a dramatic increase in the export of waste PET bottles gave Teijin Fiber no alternative but to withdraw from bottle-to-bottle production. PET Reverse, meanwhile, has had to undergo a restructuring, and their bottle-to-bottle business is being carried on by PET Refine Technology Co., Ltd., a member of the Toyo Seikan Co., Ltd. group.
At steel mills, iron ore, coke and auxiliary raw materials are fed into a blast furnace and the iron ore melted to produce pig iron. Coke is used as fuel to elevate the temperature in the furnace, and also acts as a reducing agent by removing the oxygen from iron oxide, one of the main constituents of iron ore. As plastics are made from petroleum and natural gas, their main constituents are carbon and hydrogen. This means that it should be possible to devise a means of using them instead of coke as a reducing agent in the blast furnace process.

The process by which plastics are used as a reducing agent is as follows. Plastic waste collected from factories and households is cleansed of non-combustible matter and other impurities such as metals, then finely pulverized and packed to reduce its volume. Plastics that do not contain PVC are granulated, then fed into the blast furnace with coke. Plastics that contain PVC are fed into the blast furnace after first separating the hydrogen chloride at a high temperature of around 350°C in the absence of oxygen, as the emission of hydrogen chloride can damage a furnace. The hydrogen chloride thus extracted is recovered as hydrochloric acid and put to other uses, such as acid scrubbing lines for hot rolling at steel mills.

This dehydrochlorination method was developed by the Plastic Waste Management Institute (PWMI), Japan PVC Environmental Affairs Council, Vinyl Environmental Council and JFE Steel Corporation (formerly NKK) at the request of the New Energy and Industrial Technology Development Organization (NEDO). JFE Plastic Resource Corporation (founded in November 2005) has been applying this process in full-scale operations.
Coke oven chemical feedstock recycling

◆ Plastic waste reused in coke ovens

Coke is made by baking coal, and the process also generates volatile compounds which produce hydrocarbon oil and coke oven gas. However, coke, hydrocarbon oil and coke oven gas can also be produced from plastic waste. Nippon Steel & Sumitomo Metal Corporation has developed facilities at most of its steel mills to use plastic waste as cokes, chemical feedstock and fuel, and it is now in use in its Nagoya, Kimitsu, Muroran, Yawata and Oita sites.

This system begins by crushing plastic waste obtained from local governments and removing iron and other impurities and PVC. It then heats the plastics to 100°C and forms it into granules, which are then mixed with crushed and granulated coal at a ratio of 1–2% before being fed to the carbonization chamber of the coke oven.

The carbonization chamber has combustion chambers on both sides which heat the content indirectly. The plastic waste does not combust inside the chamber due to lack of oxygen, but it is instead cracked thermally at a high temperature to produce coke for use as the reducing agent in coke ovens, hydrocarbon oil.

This process results in 40% hydrocarbon oil for use as chemical feedstock, 20% coke for use as a blast-furnace reducing agent, and 40% coke oven gas for generating power.
Plastics are composed mainly of carbon and hydrogen and therefore normally produce carbon dioxide and water when combusted. The gasification process involves heating plastics and adding a supply of oxygen and steam. The supply of oxygen is limited, which means that much of the plastics turn into hydrocarbon, carbon monoxide and water.

Sand heated to 600-800°C is circulated inside a first-stage low-temperature gasification furnace. Plastics introduced into the furnace break down on contact with the sand to form hydrocarbon, carbon monoxide, hydrogen and char. If the plastics contain chlorine, they produce hydrogen chloride. If plastic products contain metal or glass, these are recovered as noncombustible matter.

The gas from the low-temperature gasification furnace is reacted with steam at a temperature of 1,300-1,500°C in a second-stage high-temperature gasification furnace to produce a gas composed mainly of carbon monoxide and oxygen. At the furnace outlet, the gas is rapidly cooled to 200°C or below to prevent the formation of dioxins. The granulated blast furnace slag also produced is used in civil engineering and construction materials.

The gas then passes through a gas scrubber and any remaining hydrogen chloride is neutralized by alkalis and removed from the synthetic gas. This synthetic gas is used as a raw material in the chemical industry to produce chemicals such as hydrogen, methanol, ammonia and acetic acid.

The Plastic Waste Management Institute (PWMI) was commissioned by New Energy and Industrial Technology Development Organization (NEDO) to conduct trials of this technology, which were performed with the cooperation of Ebara Corporation and Ube Industries, Ltd. EUP Co., Ltd. had a plastic gasification plant in full operation in Ube city in January 2001.

Although EUP began full operation of this gasification process in 2001, difficulties in procuring raw plastic waste forced the company to withdraw from this business in May 2010.

Showa Denko K.K. opened a facility in Kawasaki in 2003 using the same technology.

Additionally, Japan Recycling Corporation Co., Ltd. implemented the JFE Thermoselect process in 2000 with the aim of using plastic waste as clean fuel gas. The same process was adopted in the form of a private financial initiative (PFI) waste business by Mizushima Eco-works Co., Ltd in 2005 and by ORIX Environmental Resources Management Corporation in 2006.
Liquefaction process

Plastic waste from households (various plastic composites) → Pre-treatment → Hydrochlorination unit

Dehydrochlorination unit → Hydrogen chloride gas

Exhaust gas combustion (hydrothermolysis and condensation and recovery)

Recovered hydrochloric acid

Good quality product oil

Residue extraction and energy recovery → Residence extraction

Residue

Steam

Waste heat boiler

Water

Deaerating tank

Pyrolysis tank

Exhaust gas combustion (hydrochloric and condensed and recovery)

Recovered hydrochloric acid

Good quality product oil

Residue

Power generation

Exhaust gas combustion

Hydrogen chloride gas

Product

Melted plastics

Cooling (product oil recovery)

liquefaction process and countermeasures to that risk must be taken. For the above reasons, many large-scale liquefaction facilities could not achieve profitability and were forced to withdraw from the business before the second half of the 2000s.

Sapporo Plastic Recycling Co., Ltd. had been working to establish a liquefaction business with large-scale facilities, but they withdrew from the business in 2010.

The research and development of plastic-waste liquefaction technology has had some achievements, but many issues remain, such as how to achieve a scale of business that is commercially viable and how to reduce costs. At present, any new ventures in the liquefaction business face difficult conditions. The above problems and issues must be thoroughly studied by any enterprise looking to adopt this technology.


In Japan, there are many facilities applying the chemical recycle technology. Figure shows that the facilities of chemical recycle using the collected plastics under the containers and packaging recycling law. In 2015, there are 13 facilities of monomerization, blast furnace feedstock recycling, coke oven chemical feedstock recycling and gasification in Japan.
Waste plastics are currently collected and processed differently by different municipalities, but the Ministry of the Environment is unifying the previously separate categories of waste into one (“burnable”), with an amendment to the Waste Disposal Law on May 2005 which changes its basic policy to state that “first, emission of waste plastic should be reduced, after which recycling should be promoted; any remaining waste plastic should not go to landfill as it is suitable for use in thermal recovery”. In a similar move, the Tokyo municipal area, which had since 1973 been putting household waste plastics into landfill as non-burnable garbage, set a goal in 2008 of sending zero household waste plastic to landfill and instead using it for incineration and thermal recycling by default.

As a result, data on the effective use of heat energy for FY 2014 as recorded by the Clean Association of TOKYO23 showed that total generated power came to 1,130 million kWh, electricity sold came to 590 million kWh, and supplied heat (fee-based) came to 526,000 gigajoule(GJ), the income of electricity and heat sold came to 10.6 billion yen.

Thermal recycling encompasses liquefaction, gasification and solid fuel (RPF, etc.), which are all recognized under the Container and Packaging Recycling Law, but also waste power generation, conversion to cement kiln fuel and solid fuel made from waste (RDF).

Typical waste incineration systems in use today include stoker incinerators, fluidized-bed incinerators, and gasification melting furnaces.

A stoker incinerator burns refuse while transporting it along a stoker. It consists of a drying section for evaporating moisture in the refuse, a combustion section for vigorously burning the refuse, and a post-combustion section to fully burn the refuse. A fluidized-bed incinerator, on the other hand, burns refuse by adding it to heated sand that swirls about much like boiling water by air forced in from below. A gasification melting furnace, meanwhile, decomposes refuse into gas at high temperatures and recovers the resulting pyrolysis gas and char for use as fuel to drive a steam turbine and generate electricity. The char is melted into slug at this time.

In any of the above systems, the heat and exhaust gas generated by incinerating refuse can be used as new sources of energy.

Refuse can also be effectively used as a raw material for cement kilns thanks to its high calorific value and good combustibility. The demand for refuse paper and plastic fuel (RPF)—a mixture of plastic waste and used paper—has also been growing among pulp manufacturers as an alternative fuel to oil.
The use of waste as a source of energy is increasing steadily. About two thirds of all waste incineration facilities in Japan are now using residual heat in some form. For example, the hot water and steam generated by boilers at these facilities can be supplied to local health spas for general heating and for heating baths and swimming pools. Recently, however, the use of waste for generating electric power has been attracting attention, and as of FY 2014, the number of waste incineration sites equipped with power generating facilities came to 338 or about 29% of all waste incineration sites in Japan. The total power generating capacity of these sites was 1,907 MW. At 7,958 GWh in FY 2014, the total amount of power generated in this way could cover the power needs of about 2,450,000 households (calculated on the basis of 271.2 kWh/month/household as estimated by the Federation of Electric Power Companies (FEPC), FY 2013).

However, the efficiency of waste power generation is still less than satisfactory: there are only 24 sites with a power generation efficiency of 20% or greater. Additionally, there are 217 small-scale sites with a power generating capacity less than 5,000 kW, or 65% of all sites. This figure reflects the need for improving the efficiency of waste power generation by consolidating facilities, upgrading equipment, deploying new incineration technology, etc.

Against this background, the Japanese cabinet approved a “Waste Treatment Facility Development Plan” (2013 – 2017) in May 2013 with the aim of establishing waste treatment facilities that incorporate measures to prevent global warming and promote energy creation. This would include, for example, the promotion of large-scale facilities to secure a sufficient level of energy recovery. The plan states, in particular: “Based on the basic principle of cyclic use and disposal of garbage as specified in the Basic Act for the Promotion of the Recycling-Oriented Society and taking into account recent advances in thermal recovery technologies, thermal recovery from waste destined for incineration will be performed while securing a fixed thermal recovery rate or better to contribute to energy savings and energy creation in regional waste treatment systems.” In conjunction with the above, the plan sets a specific target for improving the average power generation efficiency of garbage incineration facilities established in this period from 16% (FY2012 estimated value) to 21% (FY2017).
High calories provide a valuable energy resource

<table>
<thead>
<tr>
<th>Group</th>
<th>Material</th>
<th>Unit</th>
<th>MJ</th>
<th>kcal</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel</td>
<td>Coal for coke ovens</td>
<td>kg</td>
<td>29.1</td>
<td>6,952</td>
<td>Based on &quot;Study on Standard Calorific Values Applied since FY 2005 and Revised Values,&quot; Agency for Natural Resources and Energy, May 2007</td>
</tr>
<tr>
<td></td>
<td>Imported fuel coal</td>
<td>kg</td>
<td>25.7</td>
<td>6,139</td>
<td><em>Ecological efficiency analysis on the processing of plastic containers and packaging</em> Plastic Waste Management Institute (PWMI), September 2006</td>
</tr>
<tr>
<td></td>
<td>Kerosene</td>
<td>Liter</td>
<td>36.7</td>
<td>8,767</td>
<td>Website of the Council for Pet bottle Recycling</td>
</tr>
<tr>
<td></td>
<td>Fuel oil A</td>
<td>Liter</td>
<td>39.1</td>
<td>9,341</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LPG</td>
<td>kg</td>
<td>50.8</td>
<td>12,136</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Manufactured gas</td>
<td>Nm³</td>
<td>44.8</td>
<td>10,702</td>
<td></td>
</tr>
<tr>
<td>Plastics</td>
<td>PVC resins</td>
<td>kg</td>
<td>24.1</td>
<td>5,760</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Polystyrene</td>
<td>kg</td>
<td>40.2</td>
<td>9,600</td>
<td>Council for the best technology for plastic waste processing (Eds), Processing and Disposal of Plastic Waste, Nippon co., ltd.1995</td>
</tr>
<tr>
<td></td>
<td>Polylpropylene</td>
<td>kg</td>
<td>44.0</td>
<td>10,500</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Polylethylene</td>
<td>kg</td>
<td>46.0</td>
<td>11,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PET</td>
<td>kg</td>
<td>23.0</td>
<td>5,500</td>
<td></td>
</tr>
<tr>
<td>Waste (damp)</td>
<td>Paper</td>
<td>kg</td>
<td>13.2</td>
<td>3,160</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kitchen waste</td>
<td>kg</td>
<td>3.9</td>
<td>930</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Textiles</td>
<td>kg</td>
<td>16.3</td>
<td>3,900</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wood, grass</td>
<td>kg</td>
<td>6.6</td>
<td>1,570</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Incineration waste</td>
<td>kg</td>
<td>10.0</td>
<td>2,390</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Waste plastic</td>
<td>kg</td>
<td>36.2</td>
<td>8,650</td>
<td></td>
</tr>
</tbody>
</table>

(MJ/kg**)

**Note : 1MJ=239kcal, 1kcal=4.18605kJ

Calorie on a par with coal and oil

The waste collected at waste incineration facilities consists of a variety of materials. The graph above compares the calories of combustible waste substances, and you can see that plastic has twice the calories of paper waste and that some plastics with the highest calories, polyethylene, polypolystyrene, are on a par with coal and oil.

Waste containing high calorie plastics is thus a valuable energy resource, and it is expected to be used more effectively in future.
In 2001, the Waste Management Law was amended to require that waste be incinerated using incinerators designed in accordance with the enforcement regulations for the Waste Management Law and by a method determined by the Minister of the Environment. According to the Ministry of the Environment, estimated total dioxin emissions from waste incineration facilities in 2013 was 49g, which represents a fall to almost 1/133 th of the amount emitted in 1997.

(Particulate matter) : Emissions of particulate matter are regulated in Japan by the Air Pollution Control Law. Some local governments also have their own stricter standards. Methods of eliminating of pollutants include physical collection systems such as bag filters and electrical dust collectors, effective against NOx, SOx, HCL, dust and soot; and chemical reaction systems using substances such as ammonia, caustic soda and calcium hydroxide.

### Sharp decrease in dioxins

Incinerators used for burning municipal waste emit gases containing pollutants, but under Japan’s strict standards, efforts have been made to suppress these emissions by upgrading incineration facilities and implementing new technologies. As a result, emission of pollutants has been brought well under the values specified by the relevant regulations and standards.

(Dioxins) : Standards to limit the emissions of dioxins were introduced in 1997, and the Law Concerning Special Measures against Dioxins was introduced in January 2000, tightening controls on emissions from existing as well as new facilities. This law lays down standards concerning the tolerable daily intake of dioxins, environmental standards and regulations concerning exhaust gas and water emissions. Emission standards are provided for waste incinerators of a total incineration capacity of at least 50kg/hour or a total hearth area of at least 0.5m².

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### Changes in the type and amount of dioxins emitted by waste processing facilities

<table>
<thead>
<tr>
<th>Year</th>
<th>Total quantity</th>
<th>Domestic waste incineration facility</th>
<th>Industrial plastic waste incineration facility</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997</td>
<td>6500</td>
<td>5000</td>
<td>1500</td>
</tr>
<tr>
<td>1999</td>
<td>2040</td>
<td>1350</td>
<td>690</td>
</tr>
<tr>
<td>2001</td>
<td>1345</td>
<td>812</td>
<td>533</td>
</tr>
<tr>
<td>2003</td>
<td>145</td>
<td>71</td>
<td>74</td>
</tr>
<tr>
<td>2005</td>
<td>135</td>
<td>62</td>
<td>73</td>
</tr>
<tr>
<td>2007</td>
<td>110</td>
<td>52</td>
<td>58</td>
</tr>
<tr>
<td>2009</td>
<td>68</td>
<td>36</td>
<td>33</td>
</tr>
<tr>
<td>2011</td>
<td>59</td>
<td>32</td>
<td>27</td>
</tr>
<tr>
<td>2013</td>
<td>49</td>
<td>30</td>
<td>19</td>
</tr>
</tbody>
</table>

Unit : g-TEQ/year

### Dioxin concentration standards

<table>
<thead>
<tr>
<th>Combustion chamber processing capacity</th>
<th>New facilities</th>
<th>Existing facilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 tons/hour or more</td>
<td>0.1ng-TEQ/m³N</td>
<td>1ng-TEQ/m³N</td>
</tr>
<tr>
<td>2-4 tons/hour</td>
<td>1ng-TEQ/m³N</td>
<td>5ng-TEQ/m³N</td>
</tr>
<tr>
<td>Under 2 tons/hour</td>
<td>5ng-TEQ/m³N</td>
<td>10ng-TEQ/m³N</td>
</tr>
</tbody>
</table>

Note: Dioxins concentration is converted to toxicity equivalent (TEQ. m³N is at 0℃ and atmosphere of pressure.)

TEQ means the power of dioxin toxicity.

Source : Ministry of the Environment

### Control of exhaust from waste processing facilities (Clean Authority of TOKYO)

1. **Cooling tower**
   - Cools high-temperature exhaust emitted from the incinerator to around 150 degrees Celsius, for preventing the re-composition of dioxins.

2. **Bag filter**
   - Removes soot and dust, dioxins, mercury, hydrogen chlorides and sulfur oxides from exhaust.

3. **Gas scrubber**
   - Exhaust is cleaned with water and chemicals, for removing mercury, hydrogen chlorides and sulfur oxides.

4. **Catalyst reaction tower**
   - Decomposes dioxins and nitrogen oxides in exhaust using catalysts.

5. **Induced Draft Fan**
   - Exhaust is sent to the stack.

6. **Stack**
   - Exhaust that is free of hazardous substances or odor is released into the air.


(partly revised by PWMI)
Life Cycle Assessment

What is life cycle assessment

Life cycle assessment (LCA) is a technique for scientifically, quantitatively, and qualitatively assessing the overall environmental burden of a product across all related processes (life cycle) from the gathering of resources to the manufacture of raw materials, processing of those materials, assembly of components, product use, and disposal.

LCA is performed in four stages: (1) establishment of goals and scope of survey (2) calculation of environment data (CO₂, energy consumption, etc.) at each step of the product’s life cycle, (3) environmental impact assessment (inventory analysis) for various items (resource reduction effect, etc.), and (4) measurement of impact on the environment. These four LCA stages can be used to consider policies on reducing environmental load in a stepwise manner. In addition to tangible products, LCA can also be applied to services, systems, and other intangible items. Furthermore, the application of LCA to even organizations has recently come to be studied.

History of LCA

LCA is said to have begun in 1969 with research conducted by a beverage company in the United States on techniques for assessing the environmental load of returnable bottles and beverage cans. In Japan, full-scale LCA activities began with the founding of the Life Cycle Assessment Society of Japan in 1995, and the establishment of LCA techniques and the construction, expansion, and spread of LCA databases were promoted by two LCA national projects overseen by the Ministry of Economy, Trade and Industry (METI). Then, in 2004, The Institute of Life Cycle Assessment, Japan was founded, and collaborative relationships in LCA from an academic viewpoint have since been formed and strengthened as a result.

LCA mechanism and approach

LCA is a technique for scientifically, quantitatively, and qualitatively assessing the overall environmental load of a product (or service, system, etc.) across all related processes (life cycle), from the gathering of resources for product manufacture all the way to product disposal. Taking a plastic product for example, we consider that crude oil—the ultimate source of such a product—will be extracted from the Earth, transported to a port via a pipeline, and carried to Japan on a tanker. Then, once in Japan, this crude oil will be turned into a variety of petroleum products at oil-company rectification plants, and among these products, naphtha will be turned into polyethylene (PE), polypropylene (PP), polystyrene (PS) and other types of plastics through cracking and polymerization. Such plastics will serve as the raw material for manufacturing the plastic product. Next, the manufactured plastic product will be transported to market, used by a consumer, and disposed of as waste when it no longer serves its purpose. Finally, the disposed plastic product will be recycled, incinerated, or buried in a landfill. This is the life cycle of a plastic product, which can be represented by the flow chart shown below.

Extraction of crude oil → (Transport) → Refining of oil → (Transport) → Manufacture of plastic raw material (pellets) → (Transport) → Manufacture of plastic product (processing of plastic raw material) → (Transport) → Use and disposal of plastic product → (Transport) → Final disposal (recycling, incineration, or landfill)

LCA and LCI analysis

METI and New Energy and Industrial Technology Development Organization (NEDO) have constructed an LCA database and released the results of this work. At the same time, diverse types of data have come to be provided by various organizations and research institutions, and PWMI itself has released the results of a number of inventory surveys related to plastics. These various types of data can be used to perform life cycle inventory (LCI) analysis.

![Diagram of the cycle and environmental burden from the Ministry of the Environment](source)

Note: The figures give for resource energy are the thermal values for the fossil resources used as raw materials.

(PWMI : Inventory Data Survey Report on Resin Processing, December 2011.)
For example, the amount of energy/resources used in the manufacturing of one ton of bags by inflation molding using LDPE can be calculated as follows.

1. Resource energy (originating in resin raw material and additives) $\times 1.066$ (basic unit) = 49,151 MJ/t
2. Process energy (originating in resin raw material and additives) $\times 1.066$ (basic unit) = 27,861 MJ/t
3. Process energy (of that process) = 7,696 MJ/t

(1) + (2) + (3) = 84,709 MJ/t

In general, (1) represents the total amount of heat generated by LDPE resin (pellets), (2) the amount of process-related energy from the gathering of resin raw material (crude oil) to the refining of naphtha and manufacture of LDPE resin (pellets), and (3) the amount of energy used for turning resin (LDPE) pellets into a product (manufacture of bags by inflation molding) at the bag-making company.

### Life Cycle Assessment

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### Rethinking recycling with LCA

#### Evaluating recycling techniques

How, then, should recycling techniques for plastic products be compared and evaluated?

To evaluate recycling techniques, some type of criterion must first be created. For example, it is meaningless to compare the making of buckets by material recycling and the making of clothing by chemical recycling to determine which is the better recycling technique. Buckets and clothing are prepared by different processes and are used in different ways, and are thus not easy to compare. In other words, recycling techniques cannot be evaluated on the basis of the product resulting from the recycling process. On the other hand, recycling by some technique can be compared with doing no recycling at all to determine which approach reduces environmental load. For example, if 1 t of CO₂ emissions results from disposing waste without recycling, and if CO₂ emissions can be reduced to 0.5 t and 0.3 t by recycling technique A and recycling technique B, respectively, recycling technique B can be said to be the better approach.

#### Using LCA to determine whether to recycle

LCA is a useful technique for calculating environmental load for the cases of recycling and no recycling. This means calculating environmental load for individual processes from the disposal of a product as plastic waste to recycling, use of the recycled product, and disposal of the product for a second time. We give the following example.

Each process results in the generation of CO₂ emissions, so calculating the total of these amounts gives the environmental load for recycling in terms of CO₂. What then do we do for the case of “no recycling?” An easy mistake to make here would be to consider the case of “no recycling” to consist only of the “waste disposal” step. If so, the amount of CO₂ generated for this case would be extremely small and the “no recycling” option would end up being the most “eco.” Is this really the case? In actuality, there is a huge error in this assumption. Manufacturing a recycled product means that there is no need to manufacture a new product of the same kind. In other words, disposing a product as waste without recycling means that a new product having the same function as that product made by material recycling must be manufactured.

That is to say, if choosing the “no recycling” option, the amount of CO₂ generated must be calculated not only for the waste-disposal process but also for the gathering of resources (crude oil) for manufacturing the new product, the refining of naphtha, the manufacturing of resin raw material (pellets), the processing of those pellets, the manufacturing of the pallet, use of the pallet, and waste disposal of the pallet. The total amount of generated CO₂ must be calculated in this way to determine which of “recycling” or “no recycling” is “eco.”
Legislation and arrangement for the creation of a recycling-oriented society

Basic law and recycling laws

Fundamental Law for Establishing a Sound Material-Cycle Society (basic framework law)
- Basic principles
- Obligations of the national and local governments, businesses and citizens
- Measures to be taken by the national government

Fundamental Plan for Establishing a Sound Material-Cycle Society: Basis of other national plans

Proper waste management

Promotion of the 3Rs

Wasted Management Law
1. Proper waste management
2. Regulations for setting up waste disposal facilities
3. Regulations on waste disposal businesses
4. Establishment of standards for wasted management
5. Measures to control improper disposal
6. Development of facilities through participation of the public sector

[Establishment of a general scheme]
Amended in June 2006
Put into force in January 2001

Law for Promotion of Effective Utilization of Resources
1. Reduction and recycling of by-products
2. Utilization of recyclable resources and reusable parts
3. Product design and manufacturing with awareness of the 3Rs
4. Product labeling for separate collection of waste
5. Voluntary take-back and recycling of used products
6. Promotion of effective utilization of by-products

[Regulations in accordance with the characteristics of specific products]

Containers and Packaging Recycling Law
Put into force in April 2000
Amended in June 2006

Home Appliance Recycling Law
Put into force in April 2001
Amended in June 2007

Food Recycling Law
Put into force in May 2001

Construction Material Recycling Law
Put into force in May 2002

End-of-Life Vehicles Recycling Law
Put into force in January 2005

Small Home Appliance Recycling Act
Put into force in January 2010

Green Purchasing Law
The national government shall take the initiative in promoting procurement of recycled products, etc.
Put into force in April 2001

Source: Towards a 3R-Oriented, Sustainable Society: Legislation and Trends 2010, etc. Ministry of Economy, Trade and Industry.

Clarification of the roles of central and local government, businesses and consumers

The creation of a recycling-oriented society is the biggest challenge facing Japan in the 21st century. A recycling-oriented society is defined by the Basic Law for Promoting the Creation of a Recycling-oriented Society as a society that limits consumption of natural resources and minimizes the burden on the environment through ① curbing waste emissions, ② recycling resources and ③ disposing of waste appropriately.

Declaring 2000 as the start of the development of a recycling-oriented society, the government enacted six recycling-related laws based around the Basic Law for Promoting the Creation of a Recycling-oriented Society. This basic law lays down the basic principles for the formation of a recycling-oriented society, delineates the division of roles among the government, municipalities, businesses and consumers, and specifies the measures to be taken by central government.

Building on the framework laid down by this law, a number of individual recycling laws such as the Law for Promotion of Effective Utilization of Resources, were enacted, amended and strengthened. These laws provide the concrete framework in each field for effectively promoting the three Rs, i.e. reduction and reuse as well as recycling of the waste generated by society.
### Containers and Packaging Recycling Law and identification marks

#### Recycling flow through a designated corporation (plastic containers and packaging)

- **Consumer**
  - Sorted discarding based on identification marks

- **Specified business (food manufacturer)**
  - Product provision

- **Specified business (plastic container maker)**
  - Pay recycling fee (obligatory)

- **Recycling business (recycler)**
  - Pay outsourcing fee

- **Japan Containers and Packaging Recycling Association**
  - Competitive bidding

- **Municipality**
  - Sorted collection of post-use containers and packaging

- **Pickup contract**
  - Hand over bales collected at designated storage facilities (*Transport to plant is handled by recycler*)

- **Delivery of containers**
  - Pay recycling fee (obligatory)

- **Sale of recycled materials**
  - Manufacture of products by business users of recycled material

#### General product labeling

- **PET drinks**
  - PET Bottle
  - Cap, label

- **Cup noodles**
  - Cup, outer film, stock sachet
  - Lid

---

### Identification marks and material labeling to assist sorted collection

The Law for Promotion of Sorted Collection and Recycling of Containers and Packaging, known as the Containers and Packaging Recycling Law for short, aims to promote recycling and reduce the amount of container and packaging waste produced by households, which accounts for 60% of its volume and 20-30% of its weight.

Under this law, consumers, municipalities and businesses are each required to play their part in reducing emissions and recycling waste. Changes from the amendment in 2006 include promotion of emission reductions, high quality sorted collections (contributing funds to municipalities) and altering the PET bottle category (to include containers such as noodle broth bottles).

#### Role of consumers:

- Consumers must reduce their waste emissions through making reasonable choices of containers and packaging and sort their container and packaging waste for collection.

#### Role of businesses:

- Businesses that manufacture or use products covered by the law are required to recycle those products. Businesses may also contract out recycling work for a recycling fee to the Japan Containers and Packaging Recycling Association.

#### Role of municipalities:

- Municipalities must establish sorted collection plans and take the necessary measures to collect container and packaging waste separately in their areas.

In order to assist sorted collection, containers and packaging are also required by law to be labeled with identification marks. Because of the wide variety of materials from which plastic products are made, it is recommended that such products also bear a “material mark” as well as an identification mark.

As well as the identification and material marks specified by the Containers and Packaging Recycling Law, the symbols below are sometimes seen. They are the material identification SPI codes used on containers in the USA. (※)

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(※) Note that this display differs from the Japanese system and should be used with that in mind.
Home Appliance Recycling Law and End-of-Life Vehicle Recycling Law

The Law for Recycling of Specified Kinds of Home Appliances, known as the Home Appliance Recycling Law for short, covers the recycling of home appliances (TVs, refrigerators, washing machines and air conditioners), and since April 2009 it also covers LCD and plasma TVs and clothes dryers. It imposes the following duties on manufacturers, importers, retailers, municipalities and consumers.

● Manufactures and importers:
  Manufacturers and importers are required to take back, if requested, products that they manufactured or imported and that are covered by the law, and to provide an appropriate location for this purpose. They must also recycle the waste from these products.

● Retailers:
  Retailers must under certain conditions and if so requested take back products covered by the law. These products are then passed on to the manufacturer or importer (or designated recycler).

● Municipality:
  Municipalities must drop off collected products covered by the law to the manufacturer or importer (or designated recycler) or recycle such products themselves.

● Consumers:
  Consumers must take waste products back to the retailer and pay a charge for collection, transportation and recycling.

The End-of-life Vehicles Recycling Law requires that manufacturers and others recover, recycle and appropriately dispose of the CFCs in car air conditioners, shredder dust from scrapped cars and airbags from end-of-life vehicles (ELVs).

● Manufactures and importers:
  Businesses must take back and recycle the CFCs, airbags and shredder dust from ELVs. (CFCs must be broken down).

● Handling agents:
  Handling agents take ELVs back from vehicle owners and pass them on to CFC recovery operators and dismantlers for recycling.

● CFC recovery operators:
  CFC recovery operators are required to appropriately recover CFCs and pass them on to automakers. (A recovery charge may be made for this service).

● Dismantlers:
  Dismantlers must appropriately recycle and process dismantled vehicles (ELV shells) and pass on the shredder dust to automakers.

● Shredders:
  Shredders must appropriately recycle and process dismantled vehicles (ELV shells) and pass on the shredder dust to automakers.

● Owners:
  Owners must hand over used vehicles to handling agents and pay a recycling fee.
ABOUT PWMI

History :

Originally founded in December 1971 as the Plastic Management Research Association, the Plastic Waste Management Institute (PWMI) received its current name in July of the following year as operations expanded. For the last 40 years or so, PWMI has endeavored to research and develop technology for the optimal processing and effective use of plastic waste and to publicize its findings.

In addition, PWMI re-defined its mission in April 2013 as Through conducting researches relating to cyclical use of plastic aiming to contribute to the reduction of environmental impact through the life cycle of plastic, PWMI well contribute to the construction of a sustainable society as well as healthy development of plastic related industries.

Business Content :

(1) LCA based study on environmental impact of plastic and its products.
(2) Research and study relating to cyclical use of plastic, generation of plastic waste etc.
(3) Enhancing public awareness and supporting school education about plastic.

Activities :

The three core activities of PWMI are summarized below.

(1) Provision of life cycle assessment (LCA) base data and LCA evaluation of recycling & recovery (R&R) technologies

PWMI provides scientific and high-reliability data for widespread use by related industries and general citizens for application to carbon footprint systems, etc. It also works to solve technical issues so that the effective use of plastic waste can be evaluated by LCA.

(2) Preparation of the Flowchart of Plastic Products, Plastic Waste and Resource Recovery and ongoing improvements to its accuracy

PWMI strives to obtain a clear understanding of the entire lifecycle of plastic from its production stage to its disposal and R&R and to prepare and provide a highly accurate flowchart of this process.

(3) Support of environmental education

PWMI continues to hold instructor training courses and on-site classes and works to raise the level of consciousness in society regarding the usefulness of plastic. In addition to holding on-site classes on plastic R&R at primary and middle schools especially in Japan’s Kanto region, PWMI will honor as much as possible requests for instructor training courses in line with new teaching guidelines and for lectures at universities specializing in environmental science.
An Introduction to Plastic Recycling