An Introduction to Plastic Recycling

Plastic Waste Management Institute

Introduction

Waste is now a global problem, and one that must be addressed in order to solve the world's resource and energy challenges. Plastics are made from limited resources such as petroleum, and huge advances are being made in the development of technologies to recycle plastic waste among other resources. Mechanical recycling methods to make plastic products and feedstock recycling methods that use plastic as a raw material in the chemical industry have been widely adopted, and awareness has also grown recently of the importance of Thermal recycling as a means of using plastics as an energy source to conserve petroleum resources.

Japan is pursuing measures to create a recycling-oriented society in order to achieve sustainable development. Since the Basic Law for Promoting the Creation of a Recycling-oriented Society was enacted in 2000, a number of recycling-related laws have been enacted, come into force, been reviewed and amended. Based on this framework, action to promote the "three Rs" - i.e. reduction and reuse as well as recycling of waste - has been stepped up to ensure a more effective use of resources.

Meanwhile, the Ministry of the Environment continues to restrict final disposal sites and to direct incineration plants and similar sites that can emit toxins such as dioxins. Now that these are recognized as safe, the basic policy stated in the Waste Disposal Law was amended in May 2005 to say 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". This means that the former two basic categories of burnable and non-burnable waste are now both classed as "burnable". Later on in May 2004, the Tokyo Metropolitan Waste Management Council delivered a similar response, and finally as of 2008 Tokyo's 23 city wards have started a new sorted collection which aims to reduce plastic waste landfill to zero by using plastics as a raw material or for incineration and Thermal recycling by default. Then in June 2006 the Container and Packaging Recycling Law was amended to give thermal recycling limited recognition as a form of recycling plastic containers and packaging. The processing of waste plastics has seen huge advances, not only becoming less burdensome on the environment but also socially and economically effective and efficient.

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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Plastic Waste Management Institute

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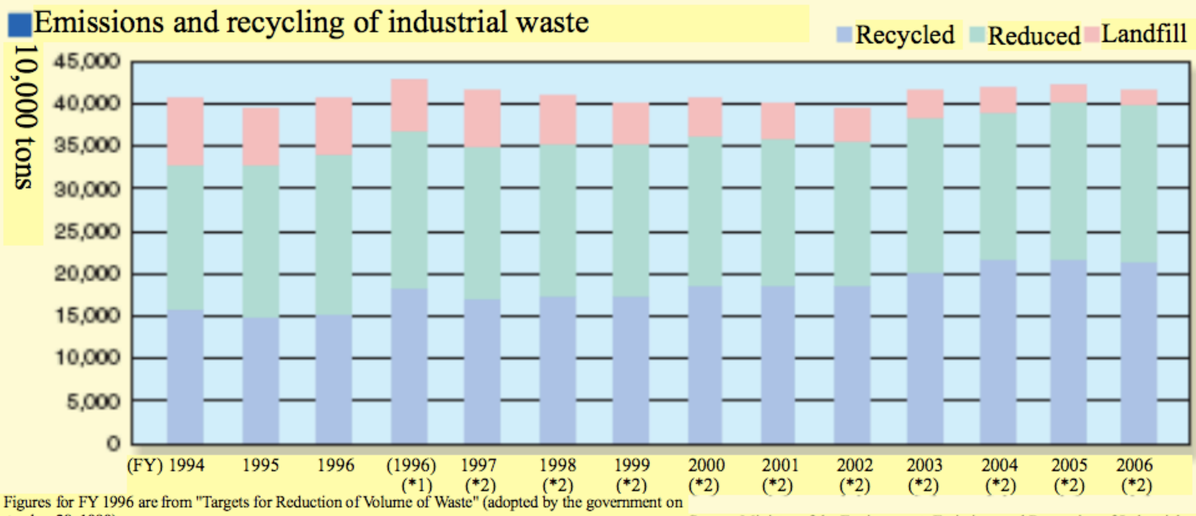
[1] Waste emissions

● Industrial waste emissions level off

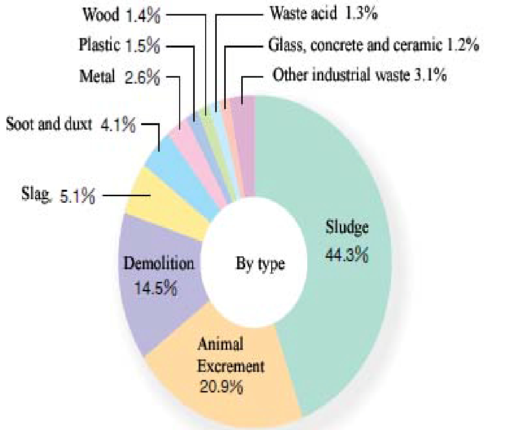
■ Emissions and recycling of industrial waste

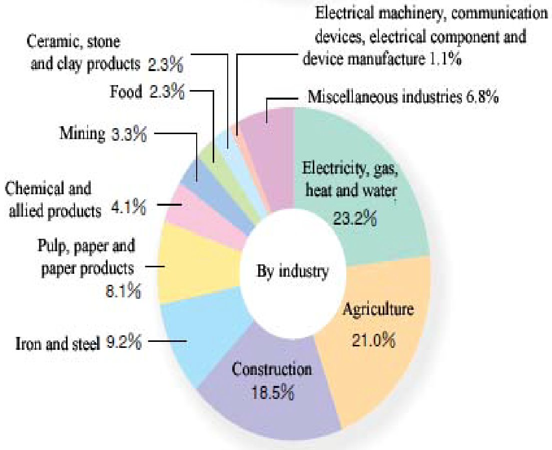


*1 Figures for FY 1996 are from "Targets for Reduction of Volume of Waste" (adopted by the government on September 28, 1999).
*2 Emissions for FY 1996 onward are calculated by the same method as 1.

Source: Ministry of the Environment, Emissions and Processing of Industrial Waste, FY 2006

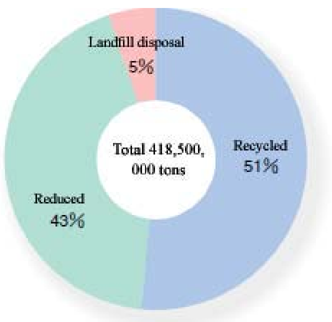
■ Content of emissions





Source: Ministry of the Environment, Emissions and Processing of Industrial Waste, FY 2006

■ State of processing



◆ Approximately 5% disposed of by landfill

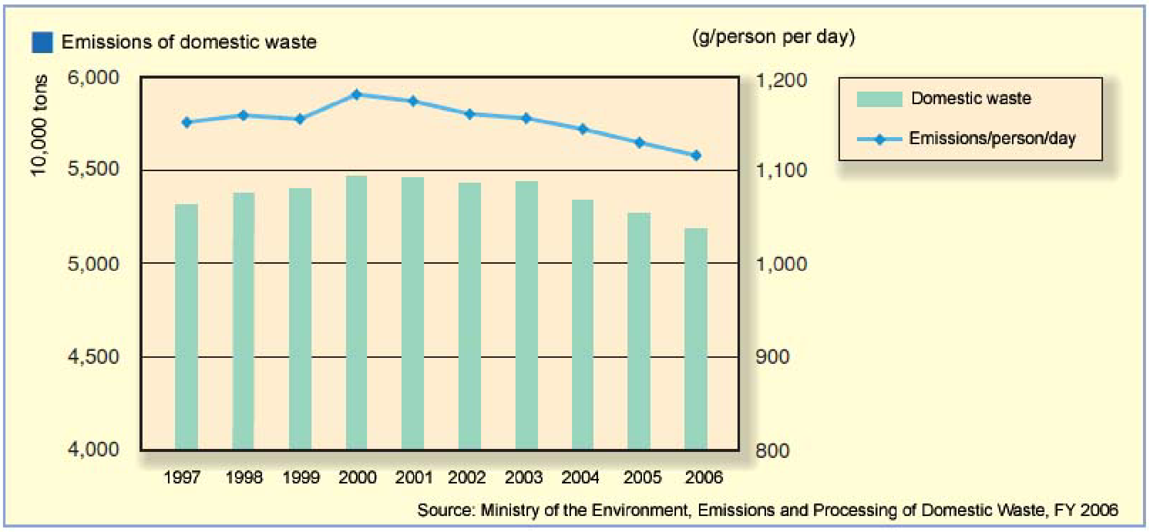
Industrial waste is waste emitted as a result of business activities at factories and other business-related establishments. Japan produces approximately 400 million tons of industrial waste per year, and

a breakdown reveals almost half 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 and construction produce over 60% of the total.

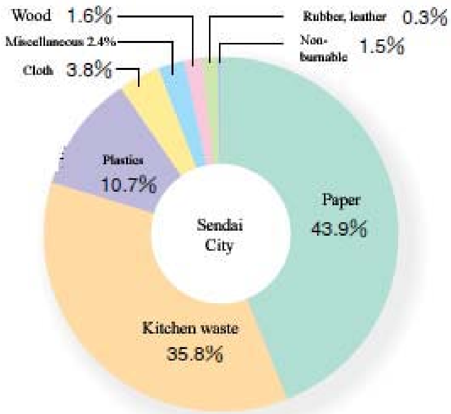
We can see from the State of Processing graph that the amount of waste disposed of in landfill is falling, and the amount recycled increasing. The amount of material going to landfill has decreased to just 5%. The national average remaining capacity for industrial landfill is is 7.7 years, 6.2 years in the Kinki region. The situation is particularly severe in the Tokyo metropolitan area, with only 3.4 years remaining.

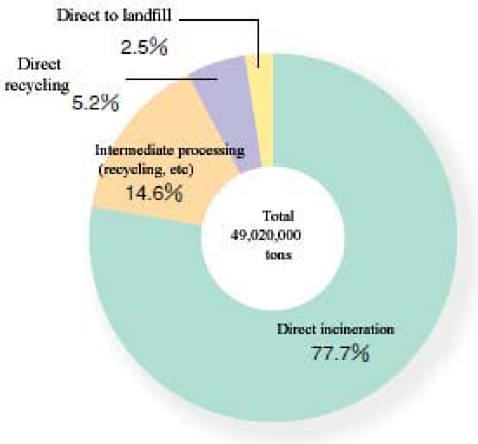
Source: Ministry of the Environment, Emissions and Processing of Industrial Waste, 1 April 2007

● Nearly 50 million tons of domestic waste



State of processing





◆ Majority disposed of by incineration

Domestic waste consists mainly of waste emitted by households. However, it also includes some business waste produced by restaurants and other business establishments. Processing is the responsibility of the local municipality.

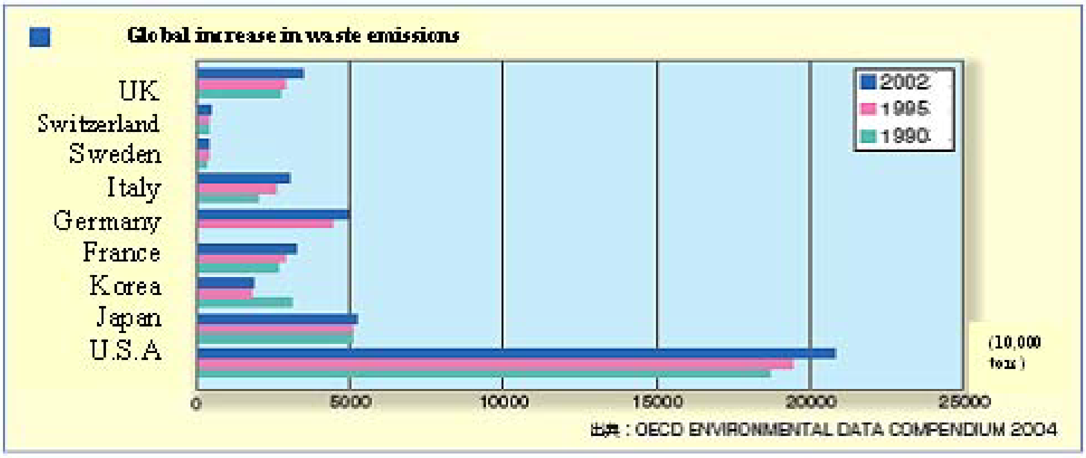
The amount of household waste generated in Japan in FY 2007 was 50,000,000 tons, which equates to 1.12kg per person. There has been a continual reduction in this figure since 2001 and a target baseline of the 1997 total of 53,100,000 tons was achieved and exceeded in 2006. The amount of waste generated per person has fallen by 6% since its peak in 2000.

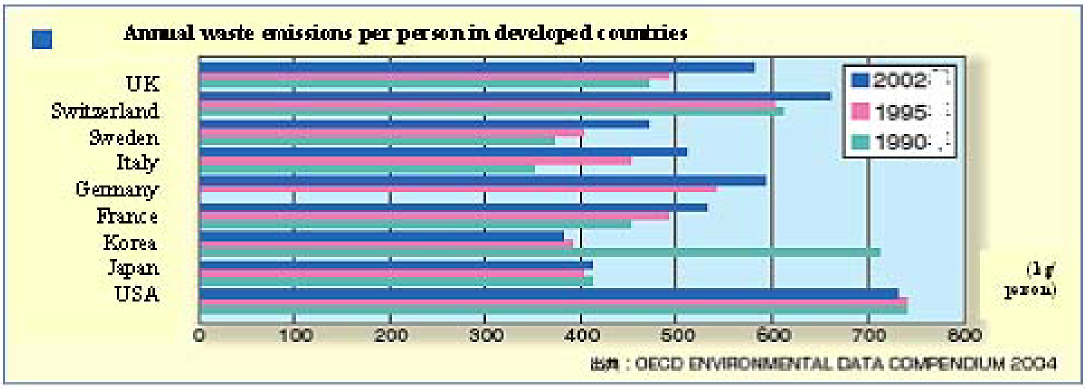
A breakdown shows most domestic waste to be made up of paper, kitchen waste and plastics.

The majority of domestic waste is disposed of by incineration. Landfill (final disposal sites) have an average of 15.6 years of capacity remaining, 17 years in the greater Tokyo metropolitan area and 12.5 years in the Kinki region. The increase in landfill capacity in the Tokyo metropolitan area from 11.9 years in 2004 is thanks to highly accurate aerial surveys which discovered areas with residual capacity. (Ministry of the Environment, domestic waste statistics 2006)

Securing landfill space is a major problem considering Japan's small size. It is therefore important to implement the three Rs (reduce, reuse, recycle) in order to reduce the quantity of landfill disposal.

● Global increase in waste emissions





● Global increase in waste emissions

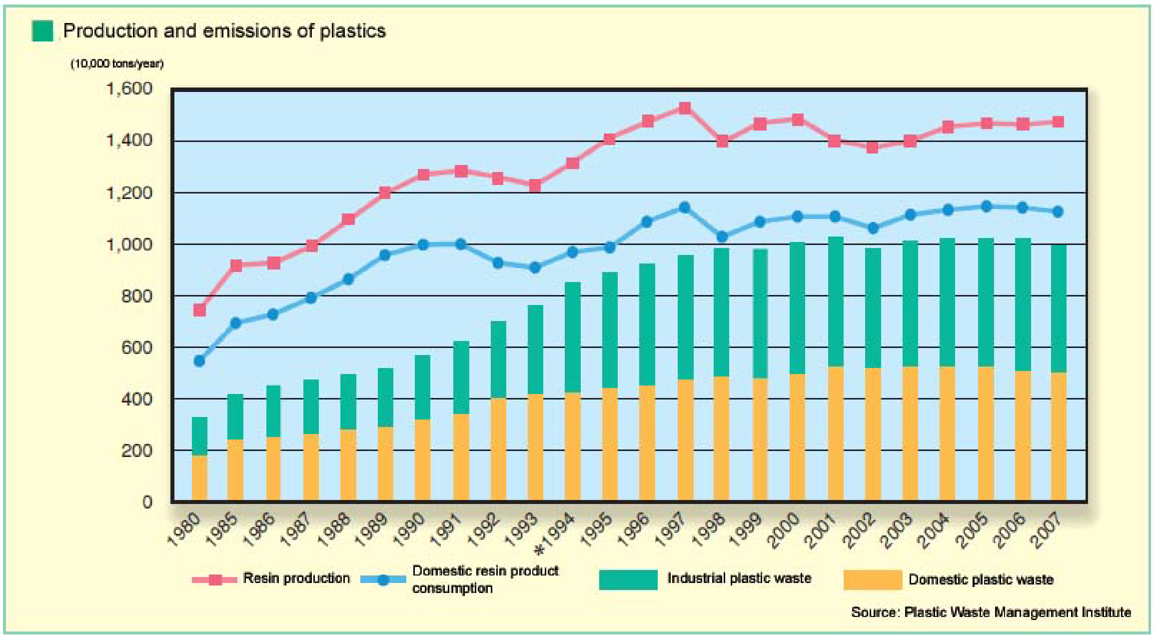
Economic expansion and the spread of patterns of mass production, mass consumption and mass processing have led to a steady increase in worldwide emissions of domestic waste over the past 20 years. Annual waste emissions of OECD members in 1997, for example,
came to 540 million tons in total and around 500kg per person. This is an increase of approximately 40% overall and 22% per person compared with 1980. In the OECD, emissions are projected to rise by a further 43% by 2020 to an annual total of 770 million tons and 640kg per person.

◆ EU waste packaging directive

The EU issued a directive on packaging and packaging waste in December 1994 (Directive 94／62／EC) to prevent and reduce its impact on the environment. The directive applies to all packaging and places that use it (factories, businesses, offices, shops, services, homes, etc.) in the EU's internal market, and also includes packaging materials. It aims to see the rate of recovery (including thermal recycling) in participating states increase to over 50%, with the rate of mechanical recycling increasing to over 15%. Having succeeded in reducing greenhouse gases and conserving resources, an amended directive (Directive 2004／12／EC) was issued in 2004 with even more stringent goals. The aim is now to increase recovery (including thermal recycling) to at least 60%, raise the material recycling rate for glass and paper to a minimum of 60%, metals 50%, plastics 22.5% and wood 15%. The deadline for meeting these targets was December 2008, but new member states will have until 2015 to comply.

[2]Processing and recycling of plastic waste

● Major progress in effective utilization of plastic waste



Production and emissions of plastics

Source: Plastic Waste Management Institute

■ Trends in quantity and rate of effective utilization of plastic waste

Year		1990	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Total waste plastic emissions		557	884	909	949	984	976	997	1,016	990	1,001	1,013	1,006	1,005	994
Effective utilization (10,000 tons)	Mechanical reycling	59	95	103	113	122	134	139	147	152	164	181	185	204	213
	Feedstock recycling				1	4	4	10	21	25	33	30	29	28	29
	Thermal recycling	85	126	255	285	309	314	345	368	364	387	399	414	489	481
Total		144	221	358	399	435	452	494	535	542	584	611	628	721	722
Effective utilization (%)		26	25	39	42	44	46	50	53	55	58	60	62	72	73

Source: Plastic Waste Management Institute

◆ Plastic waste emissions level off

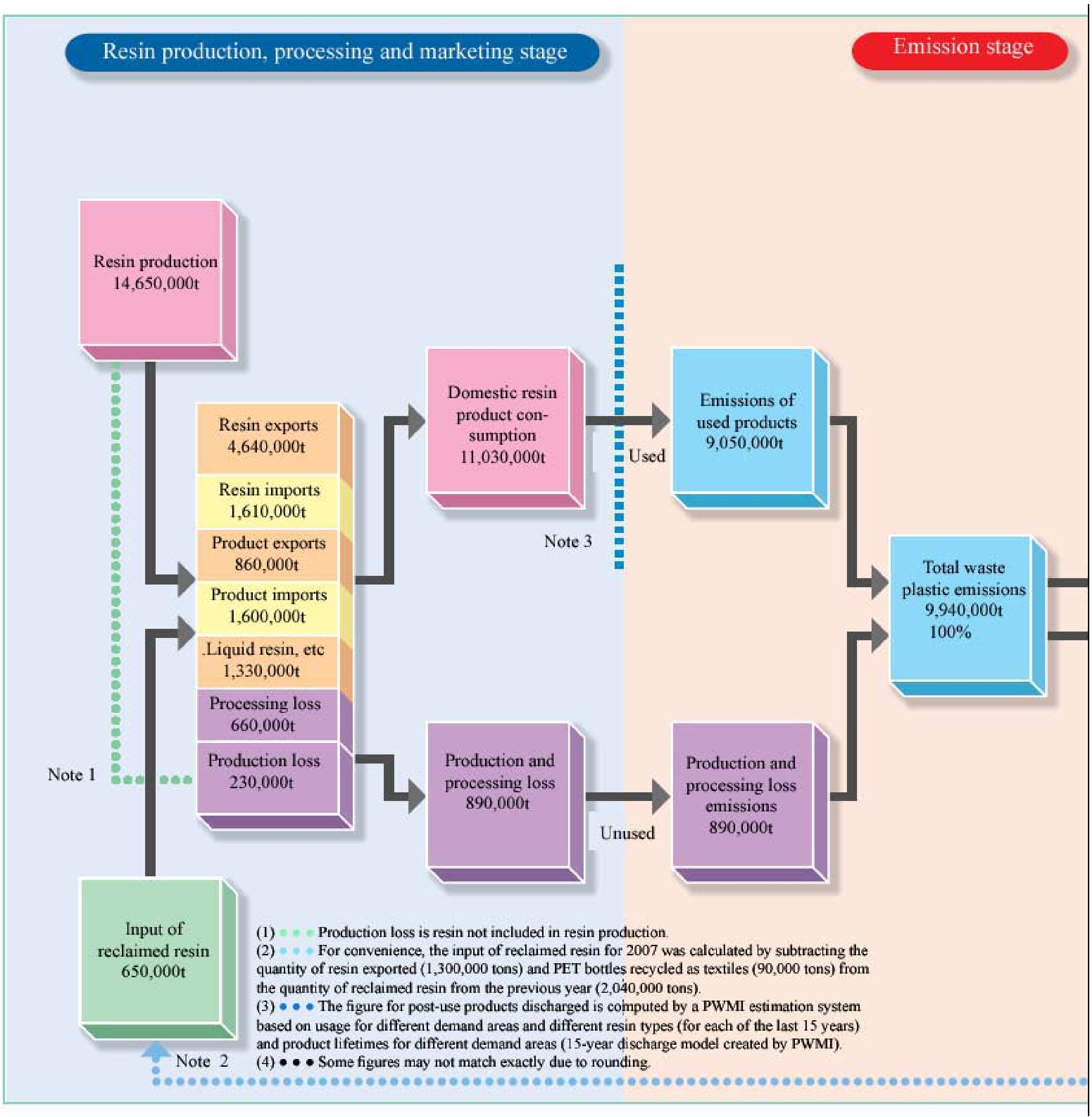
The amount of plastic produced in Japan has come down from its 1997 peak of 15,210,000 tons but remained level for a number of years, with 14,650,000 tons produced in 2007. The total amount of waste plastic has also remained stable, with 9,940,000 tons emitted in 2007. Household waste accounted for 5,020,000 tons (down 60,000 tons) of this, with industrial waste at 4,920,000 tons (down 60,000 tons) The amount of plastic waste emitted by households fell slightly in line with the decrease in production of resins for household containers and packaging. Industrial plastic waste also decreased slightly, with the number of cars being recycled after the passing of the Automobile Recycling Law stabilizing after an increase of 20,000 tons.

◆ Effective reutilization increases every year

As well as mechanical and feedstock recycling, the creation of solid fuel from waste, waste power generation, heat-utilizing incineration and other methods of thermal recycling have brought the total of reutilized waste to 7,220,000 tons - an increase of 1,800,000 tons over 2002.

However, the 1,520,000 tons of plastic waste exported to Hong Kong and China among other destinations, which accounts for 70% of all mechanically recycled waste, poses a serious problem in terms of the international flow of recycling and the sustainability of Japan's own recycling systems.

● Flow of plastic products, waste and recycling (2007)

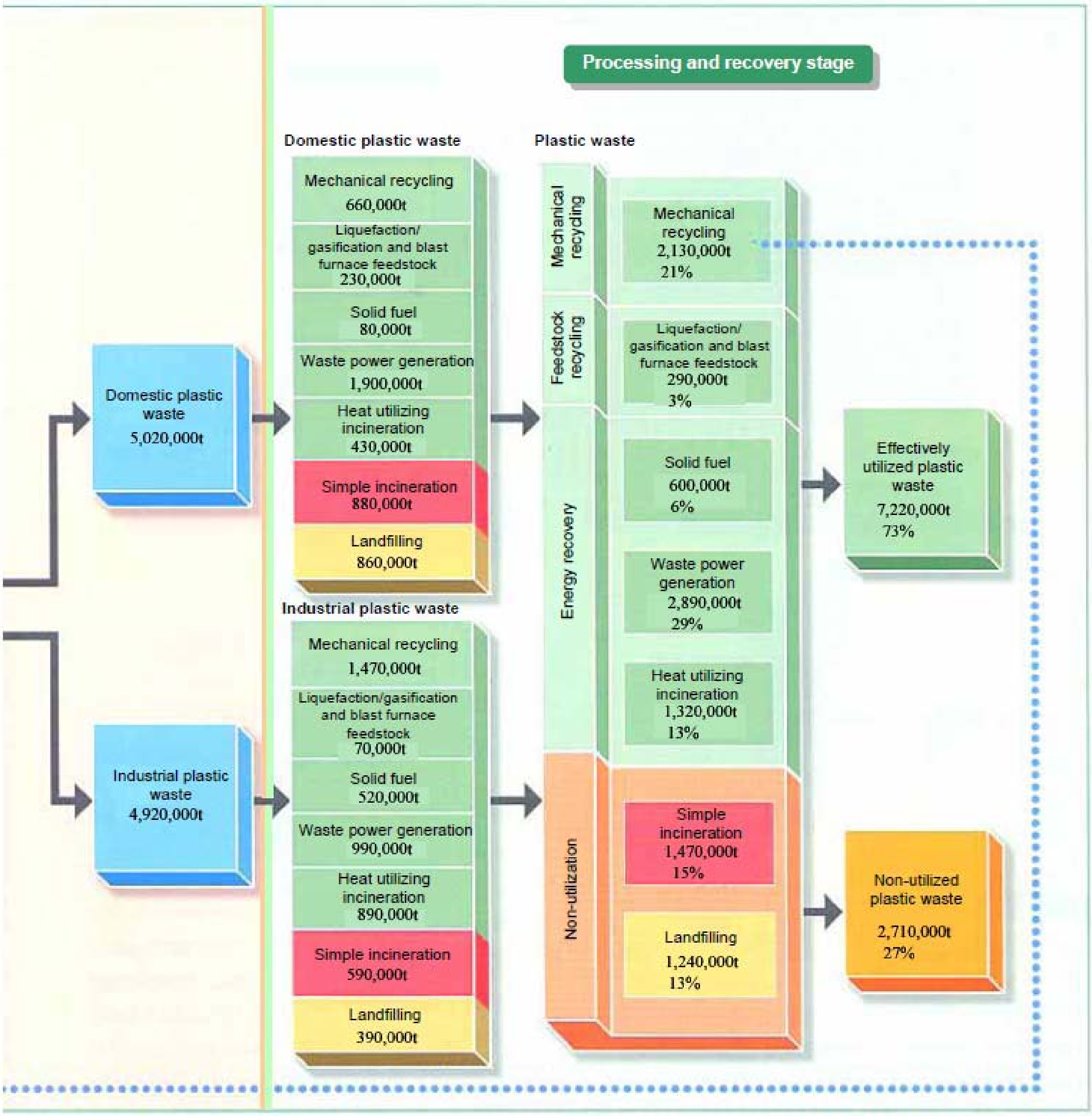


◆ Effective utilization of plastic waste rises to 73%

The large-scale survey of industrial waste plastics conducted every 5 years shows that the quantity of waste plastics being sent to landfill has dropped dramatically. This is reflected in the figures for 2006. With 2,130,000 tons being mechanically recycled (up 90,000 tons on the previous year) and 4,810,000 tons used for thermal recycling (down 80,000 tons from the previous year), the effective utilization of plastic waste has risen to 73% (up one point on the previous year).

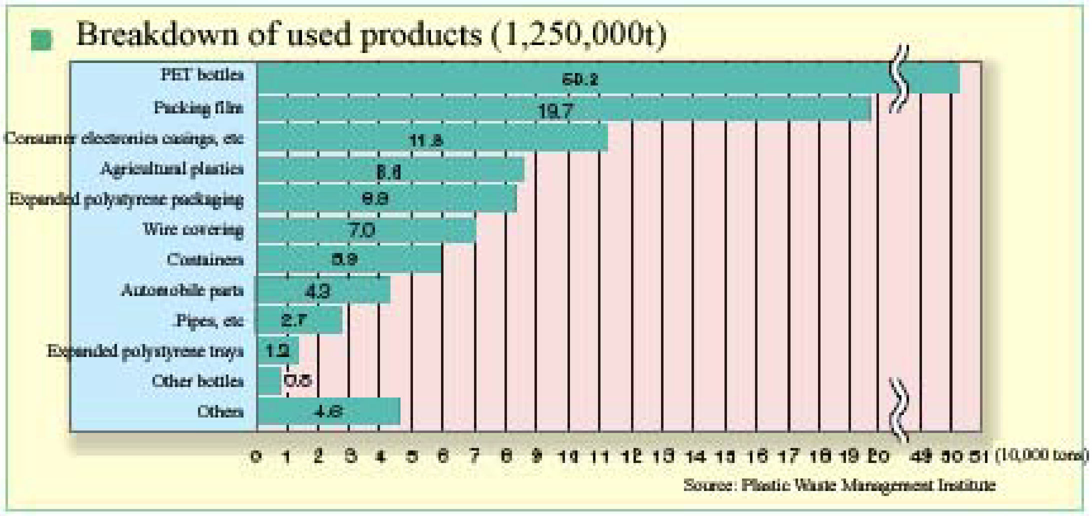
(Follow Chart)

Processing and recycling of plastic waste



Source: Plastic Waste Management Institute.

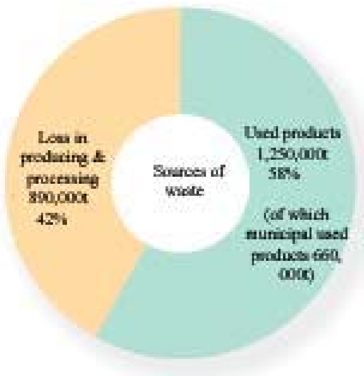
● Recovery systems supporting mechanical recycling

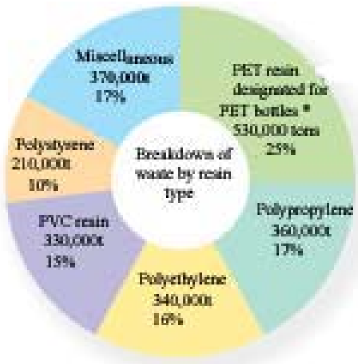


■ Breakdown of used products (1,250,000t)

Source: Plastic Waste Management Institute

■ Breakdown of sources of mechanical recycled waste (2,130,000t)





★ The category of PET resin was previously included in "Miscellaneous" and contains the category "PET resin for use as PET bottles", clarified in the Container and Packaging Recycling Law

◆ 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) increased 90,000 tons from the previous year to 2,130,000 tons in 2007. Of this amount, 660,000 tons was accounted for by domestic plastic waste (13.1% of domestic plastic waste). In contrast, 2.2 times this amount of industrial plastic waste (1,470,000 tons or 29.9% 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 a 110,000 ton increase from the previous year in recycling of used products to 1,250,000 tons. This is due to the continued smooth transition to recycling containers and packaging, household appliances and cars in 2007.

The success of the various recycling laws can be seen in a breakdown of the 1,250,000 tons of used products: 502,000 tons of PET bottles, 197,000 tons of packaging film, 113,000 tons of household appliances, 86,000 tons of agricultural plastics and 83,000 tons of expanded styrofoam packing. The efficient operation of the recycling systems of each industrial area and associated groups is striking.

● Breakdown of plastic waste

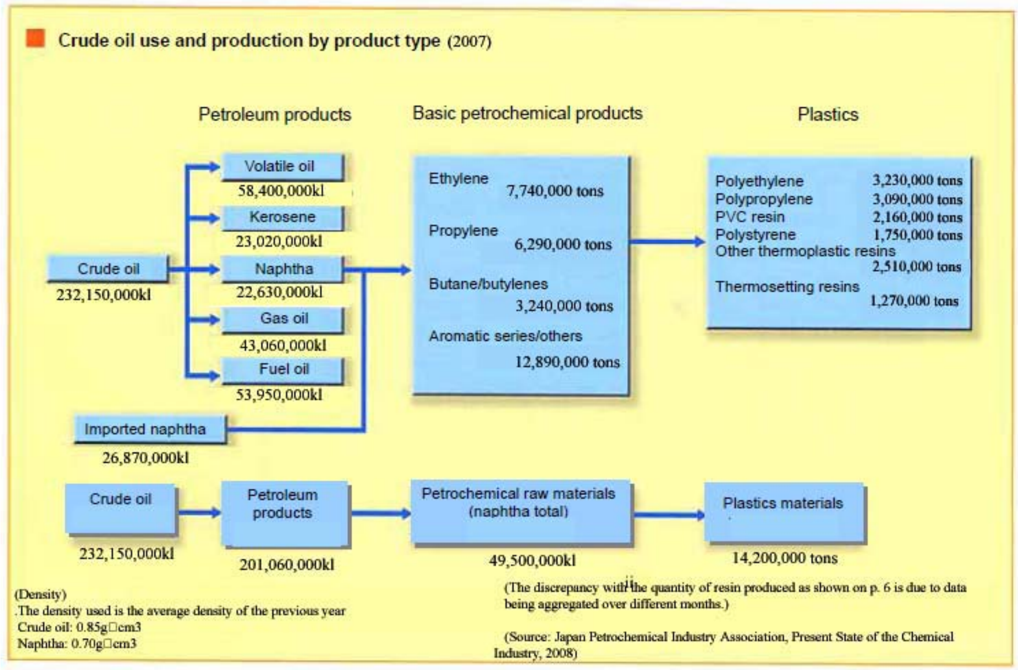
	Shape		Use and contents	Type of resin	
Bottles and tubes	Beverage bottles	Soft drinks	Juice, cola, drinking water, tea, alcoholic beverages	PET	
		Lactic acid beverages	Yogurt	Polystyrene	
	Food and condiment bottles		Tempura and salad oil, soy sauce, mirin, sauce	PET, polyethylene, polypropylene	
	Condiment tubes		Mayonnaise, ketchup, dressings, wasabi and mustard paste	Polyethylene, polypropylene	
	Bottles and tubes for daily necessities		Toiletries, gardening supplies, car supplies, liquid detergent, fabric softener, toothpaste, cosmetics, shampoo, hair conditioner, bleach, body shampoo	PET, composite materials, polyethylene, polypropylene	
Packs and cups	Food packs (EPS and non-EPS packs)		Margarine, tofu, natto, fruit, vegetables, processed foods, prepared foods, packed lunches	EPS	Polystyrene
				Non-EPS	Polystyrene, polypropylene, PET
	Food cups (EPS and non-EPS cups)		Miso, steamed egg custard, miso soup, yogurt, ramen, yakisoba, jelly, custard pudding, desserts Food cups	EPS	Polystyrene
				Non-EPS	Polystyrene, polyethylene, PET, polypropylene
	Cup and pack lids			Polystyrene, PET, polypropylene, polyethylene	
Trays and blister packs	ESP and non-EPS trays)		Meat, fish, sashimi, sliced ham, vegetables, processed foods	EPS	Polystyrene
				Non-EPS	Polystyrene, polypropylene, PET
	Blister packs		Drugs (tablets), processed meat and fish products, roast ham, bacon, curry roux, household tools, toothbrushes, cosmetics	Polyethylene, polypropylene, PET, polystyrene, PVC resin	
	Egg boxes			PET, polystyrene	
Bags	Large, medium and plain bags		Rice, gardening bags, fish, fruit, confectionery, frozen foods, ramen, vacuum-packed foods, pickles, food boiled in soy, miso, bread, dried fish, cleaning	Polyethylene, polypropylene	
	Carrier bags			Polyethylene	
	Rubbish bags			Polyethylene	
	Small bags		Quail's eggs, ginger, pickles, condiments, ramen stock, Japanese confectionery, candy, wafers, chocolate	Polypropylene, polyethylene, composite material	
Caps and stoppers			Beverages, foods, daily necessities, other plastic bottles	Polypropylene, polyethylene Polypropylene, polyethylene	
Cellophane and film	Cellophane			Polyvinyl chloride resin, PVC resin, polyethylene	
	Film		Tofu, curry roux, plastic food decorations, Japanese confectionery, cheese, frozen foods, cod roe, sausages, frozen noodles	Polypropylene, polyethylene, composite material	
	Labels		Bottles, caps	Polystyrene, polyethylene, PET, polypropylene	
Boxes and cases			Detergent boxes and lids, foods, underwear, powder compacts, lotion cases, dehumidifiers, deodorizers	Polypropylene, polystyrene, polyethylene, PVC resin	
Protection and fixing			Urethane sponge, foam products, nets, air caps	Polystyrene, polyethylene	
Others			Baskets, handles, multi-packs, sieves, replanting pots	Polyethylene, PET, polypropylene, PVC resin, polystyrene	

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

Source: Plastic Waste Management Institute, Basic Survey for Recycling of Municipal solid waste (March 1999)

[3]Information about plastics

● Manufacture of plastics from petroleum



◆ 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 a 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 polypropylene, 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, an additive is 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.

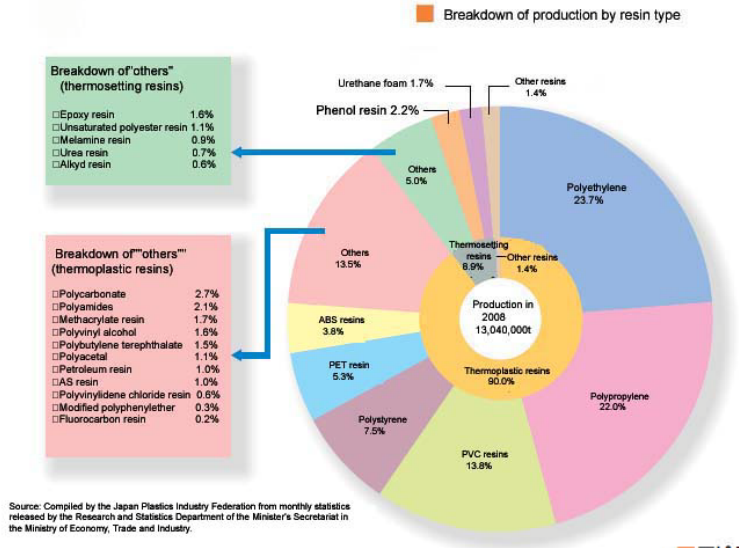
◆ Plastics account for 6.5% of total petroleum consumption

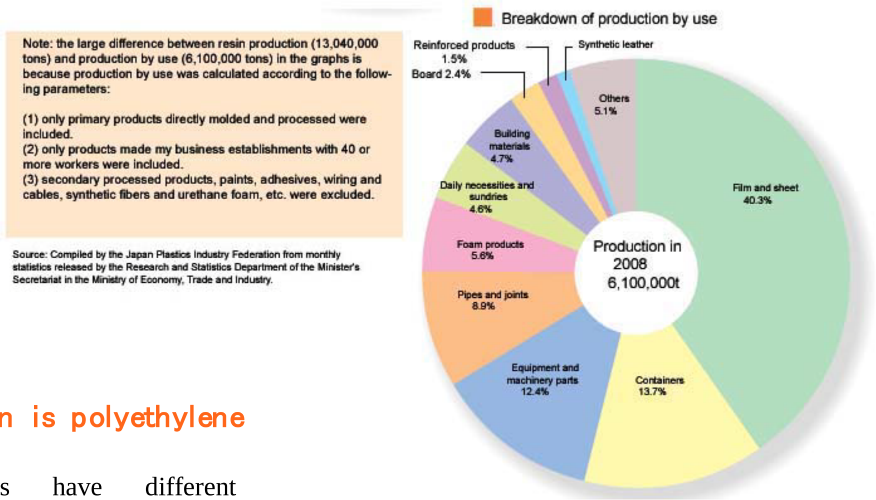
Japan presently uses around 230 million kiloliters of crude oil per year. In 2007, 22,630,000 kiloliters of naphtha was produced from 232.2 million kiloliters of crude oil. Combined with imported naphtha, 49,500,000 kiloliters of naphtha was used as the raw material for basic petrochemical products such as ethylene. This is approximately 16% by weight of the total amount of crude oil and imported naphtha used per year. The quantity used to produce plastic products accounts for around 6.5% of combined crude oil and imported naphtha used per year.

While plastics are made from crude oil through a number of chemical reactions, their production

requires less resources and energy than iron and steel, aluminum and glass.

● Breakdown of plastic production by resin type and use





◆ 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.

● 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, alkalis and oil and do not rust or corrode.

・Transparent and freely colorable

Some types of plastic are highly transparent and can be easily colored, making it possible to create bright, attractive products.

・Mass producible

Many types of plastic 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 plastic deform when placed near a flame or heat source.

・Susceptible to scratches 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

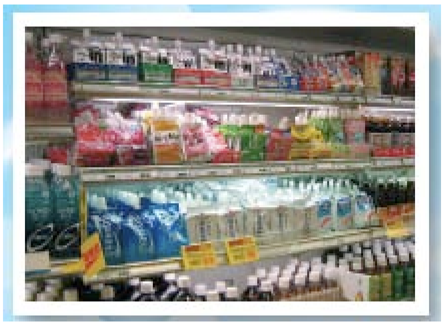
Liquid crystal display (LCD) televisions with their vivid and detailed high picture quality wide angle screens are made up of a number of plastics layered together: polarizing film, phase contrast film and a diffuser panel for the backlight. Plastic is also used in electrical components, circuits and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

Photo: Japan Polyethylene Corporation

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 resealable containers, or lined with aluminum or a barrier resin to keep out oxygen and UV radiation and extend the shelf life of food.

Photo: Hosokawa Yoko Co. medical packaging division

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.

Photo: Vinyl Environmental Council, Council for the Promotion of PVC Sash Windows

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

		JIS abbr.	Resin name		Standard thermal resistance (℃)	Acid resistance	Alkali resistance	Alcohol resistance
Thermoplastic resins	Generic plastics	PE	Polyethylene	Low density polyethylene	70-90	Good	Good	Good
				High density polyethylene	90-110			
		EVAC	EVA resin		70-90	Good	Good	Good
		PP	Polypropylene		100-140	Some products somewhat vulnerable	Some products somewhat vulnerable	Good
		PVC	Polyvinyl chloride		60-80	Good	Good	Good
		PS	Polystyrene (styrene resin)	Polystyrene	70-90	Good	Good	Taste of contents changes if stored for a long time
				Expanded polystyrene	70-90	Good	Good	Taste of contents changes if stored for a long time
		SAN	AS resin		80-100	Good	Good	Repeated use renders opaque
		ABS	ABS resin		70-100	Good	Good	Swells over long periods
		PET	Polybutylene terephthalate (PET resin)		Stretched film around 200	Good	Good	Good
					Unstretched film around 60			
					Heat-resistant bottle around 85			
		PMMA	Methacrylic resin (acrylic resin)		70-90	Good	Good	Gives contents a slight foreign odor
		PVAL	Polyvinyl alcohol		40-80	Softens or dissolves	Softens or dissolves	Dissolves at a low saponification point
		PVDC	Polyvinylidene chloride		130-150	Good	Good	Good
	Engineering plastics	PC	Polycarbonate		120-130	Good	Some products somewhat vulnerable (e.g. detergents)	Good
		PA	Polyamide (nylon)		80-140	Some products somewhat vulnerable	Good	Possible infiltration
		POM	Acetal resin (polyacetal)		80-120	Some products somewhat vulnerable	Good	Good
		PBT	Polybutylene terephthalate (PBT resin)		60-140	Good	Good	Good
		PTFE	Fluorocarbon resin		260	Good	Good	Good
Thermosetting resins		PF	Phenol resin		150	Good	Good	Good
		MF	Melamine resin		110-130	Good	Good	Good
		UF	Urea resin		90	Stable or very slight change	Very slight change	Good
		PUR	Polyurethane		90-130	Somewhat vulnerable	Somewhat vulnerable	Good
		EP	Epoxy resin		150-200	Good	Good	Good
		UP	Unsaturated polyester resin		130-150	Good	Good	Good

Standard thermal resistance (℃) is the heat resistance of each resin type in normal use. It does not apply to generic resins, engineering plasticsor thermosetting resins. (Generic resins are measured in terms of short term thermal resistance, and engineering plastics and thermosetting resins in terms of long-term thermal resistance.)
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.

Information about plastics

Resistance to cooking oil	Characteristics	Main uses
Good	Lighter than water (relative density <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.	Packaging (bags, cling film, food containers), agricultural film, wire covering
Good	Slightly heavier than low-density polystyrene 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 polystyrene. Whitish and opaque.	Containers and packaging (film, bags, food containers), shampoo and conditioner bottles, sundries (packets, washbowls, etc.), gasoline tanks, kerosene containers, containers, pipes
Good	Transparent and flexible, with rubbery elasticity that gives it excellent resistance at low temperatures. Some items have excellent adhesive properties. Poor thermal resistance.	Agricultural film, stretch film
Good	Low relative density (0.0-0.91). Relatively high thermal resistance. Excellent mechanical strength.	Automobile parts, household appliance parts, wrapping film, food containers, caps, trays, containers, pallets, clothing boxes, textiles, medical instruments, daily necessities, trash containers
Good	Does not burn easily. Soft and hard varieties. Sinks in water (relative density of 1.4). Excellent glossy surface shine, well suited to printing.	Over and underwater pipes, joints, guttering, corrugated sheeting, window sashes, flooring, wallpaper, synthetic leather, hoses, agricultural film, wrapping film, wire covering
Vulnerable to some fatty oils such as terpene oil from citrus fruits and perilla oil	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 benzine and thinner.	Office appliance and TV casings, CD cases, food containers.
Vulnerable to some fatty oils such as terpene oil from citrus fruits and perilla oil	Light and rigid. Good thermal insulating properties. Dissolves in petroleum benzine and thinner.	Packaging, fish boxes, food trays, cup noodle containers, tatami mat padding.
Good	Excellent transparency and thermal resistance.	Tableware, disposable lighters, electrical equipment (fan blades, juicers), food storage containers, toys, cosmetics containers
Good	Excellent shock-resistance and glossy appearance.	Office appliances, automobile parts (interior and exterior), games consoles, building components (internal), electrical equipment (air conditioners, refrigerators)
Good	Excellent transparency, rigid, excellent gas barrier properties.	Insulating material, functional optical film, electromagnetic tape, camera film, wrapping film
	Excellent transparency, oil-resistant, excellent chemical resistance.	Containers for foodstuffs, food boiled in soy sauce, fruit, salad and cakes, drinks cups, clear bottles, various kinds of transparent packaging (APET)
	Transparent and rigid, excellent gas barrier.	Containers for drinks, soy sauce, alcohol, tea and drinking water (PET bottles)
Good	Colorless, transparent, glossy. Dissolves in petroleum benzine and thinner.	Automobile headlight lenses, tableware, lighting boards, water tank plates, contact lenses.
Good	Water-soluble, film-forming, adhesive, chemically resistant, excellent gas barrier.	Water-soluble, film-forming, adhesive, chemically resistant, excellent gas barrier. Vinylon fabric, films, paper coating agents, adhesives, PVC suspension stabilizing agent, automobile safety glass
Good	Colorless, transparent, good chemical resistance, excellent gas barrier.	Cling film, ham and sausage casing, film coating.
Good	Colorless and transparent, highly resistant to acids but vulnerable to alkalis. Excellent resistance to shocks and heat.	DVDs and CDs, electronic part housings (e.g. mobile phones), automobile headlight lenses, camera lenses and housings, transparent roofing materials
Good	Milky white, scratch-resistant, resistant to low temperatures, good shock resistance.	Automobile parts (air inlet pipes, radiator tanks, cooling fans, etc.), food film, fishing line and monofilament, gears, fasteners
Good	White, opaque, excellent shock resistance and good abrasion resistance.	Gears (DVD players, etc.), automobile parts (fuel pumps, etc.), fasteners and clips
Good	White, opaque, good balance of electrical and other physical properties.	Electrical parts, automobile parts.
Good	Milky white and thermally resistant, high chemical resistance with non-stick properties.	Frying pan coatings, insulating materials, bearings, gaskets, all kinds of packing material, filters, semiconductor industry applications, wire coverings
Good	Good electrical insulating properties, acid resistance, heat resistance and water resistance. Does not burn easily.	Printed circuit boards, iron handles, distribution board breakers, pan and kettle handles and knobs, plywood adhesive.
Good	Good water resistance. Resembles ceramic. Hard surface.	Tableware, decorative laminate, plywood adhesive, paint.
Good	Resembles melamine resin, but cheaper and more difficult to burn.	Buttons, caps, electrical products (wiring accessories), plywood adhesive.
Good	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.	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.
Good	Excellent physical, chemical and electrical properties. Products reinforced with carbon fiber are particularly strong.	Electrical products (IC sealant, printed circuit boards), paints, adhesives, all kinds of laminates.
Good	Good electrical insulating properties, heat resistance and chemical resistance. Products reinforced with glass and carbon fiber are particularly strong.	Baths, corrugated sheeting, cooling towers, fishing boats, buttons, helmets, fishing rods, coatings, septic tanks

Source: The Japan Plastics Industry Federation, Hello Plastics!

[4] Methods of Plastic Recycling

● Three forms of recycling

<table>
<tr><th>Category (in Japan)</th><th colspan="2">Method of recycling</th><th>Method of recycling
Category (in Europe)</th></tr>
<tr><td>Material recycling</td><td colspan="2">Recycling to make: Plastic raw materials
Plastic products</td><td>Mechanical recycling
Recycling to make:
Plastic raw materials
Plastic products</td></tr>
<tr><td rowspan="4">Chemical recycling</td><td colspan="2">Monmerization</td><td rowspan="4">Monmerization
Feedstock recycling</td></tr>
<tr><td colspan="2">Blast furnace reducing agent</td></tr>
<tr><td colspan="2">Coke oven chemical feedstock recycling</td></tr>
<tr><td rowspan="2">Gasification Liquefaction</td><td>Chemical feedstock</td></tr>
<tr><td rowspan="2">Thermal recycling</td><td>Fuel</td><td rowspan="2">Thermal recycling</td></tr>
<tr><td colspan="2">Cement kiln
Waste power generation
RDF *1 RPF *2</td></tr>
</table>

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

◆ 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.*

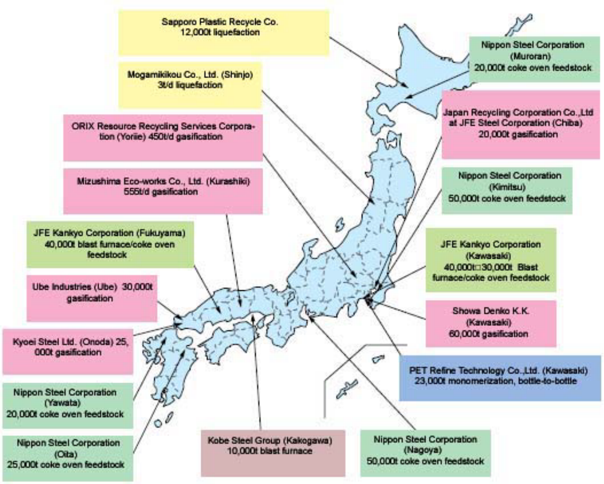
(1) Mechanical recycling
(2) Feedstock recycling (monomerization, blast furnace reducing agent, coke oven chemical feedstock recycling, liquefaction, etc.)
(3) Thermal recycling (cement kilns, waste power generation, RDF, RPF)

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.

* 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.

Large scale feedstock recycling facilities (under the Container and Packaging Recycling Law) (2009)



● Mechanical recycling

① Washbowl ②road bollard ③imitation woodpost ④ pallet ⑤anti-weed sheeting ⑥ heat/sound insulating sheeting ⑦PVC pipe ⑧water butt lid ⑨colored box⑩ central reservation block ⑪parking block ⑫duckboard ⑬survey and boundary markers ⑭bricks ⑮crossties for steel products ⑯video cassettes
⑰weight for colored cone ⑱ plant pots

◆ Used for containers, benches, building materials, textiles, sheeting...

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 manufacturers 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.

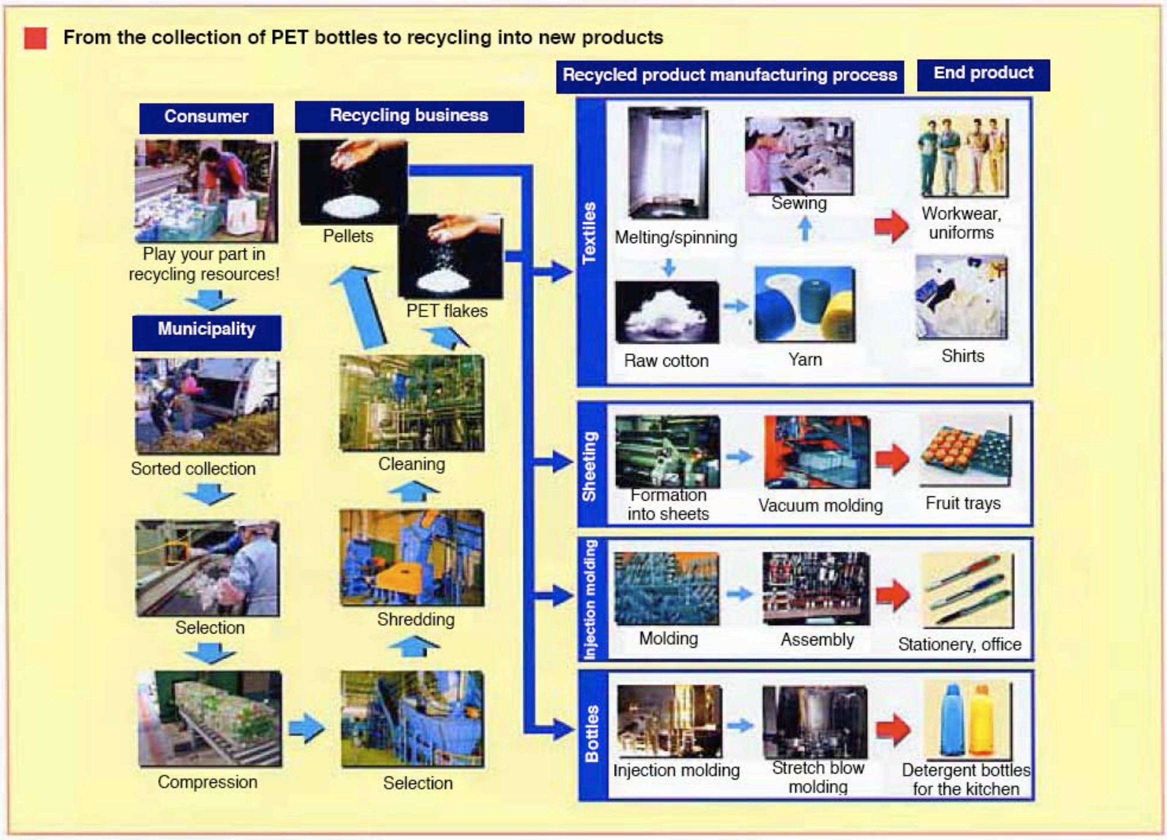
All kinds of recycled products are made from industrial plastic, including containers, benches and fences, children's play equipment, construction sheeting, products for packaging, transportation, construction, homes, parks, roads, railways, and other goods and facilities for agriculture, forestry and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



Source: Council for PET Bottle Recycling

◆ Remelted 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 are non-resins are removed and the remainder turned into flakes and pellets (granules made from flakes, thermally processed by a granulator) 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.

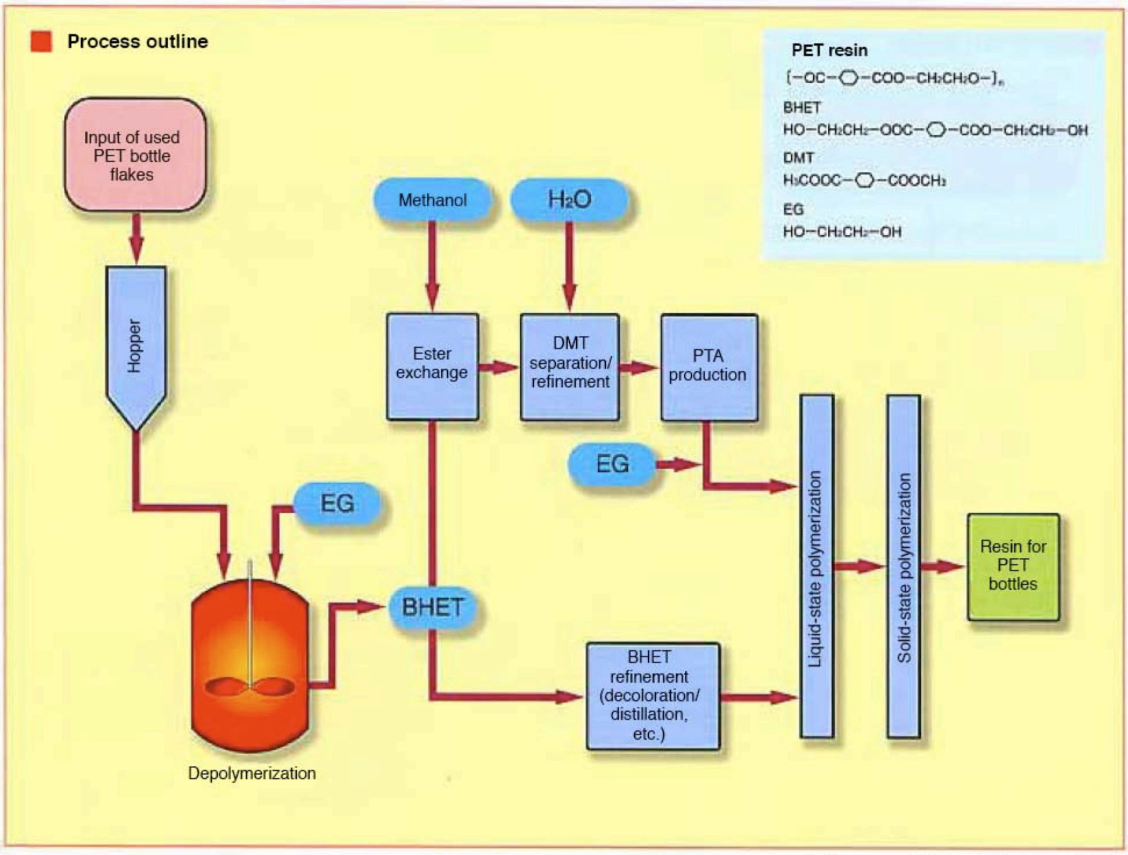
(2) Injection molding
Heated melted resin is injected into a mold and solidifies to form a molded product. Products made this way range from washbowls, buckets and plastic models to larger products such as bumpers and pliers.

(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-softened 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 method
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



Reference: Teijin and Aies pamphlets

◆ From PET bottles to PET bottles

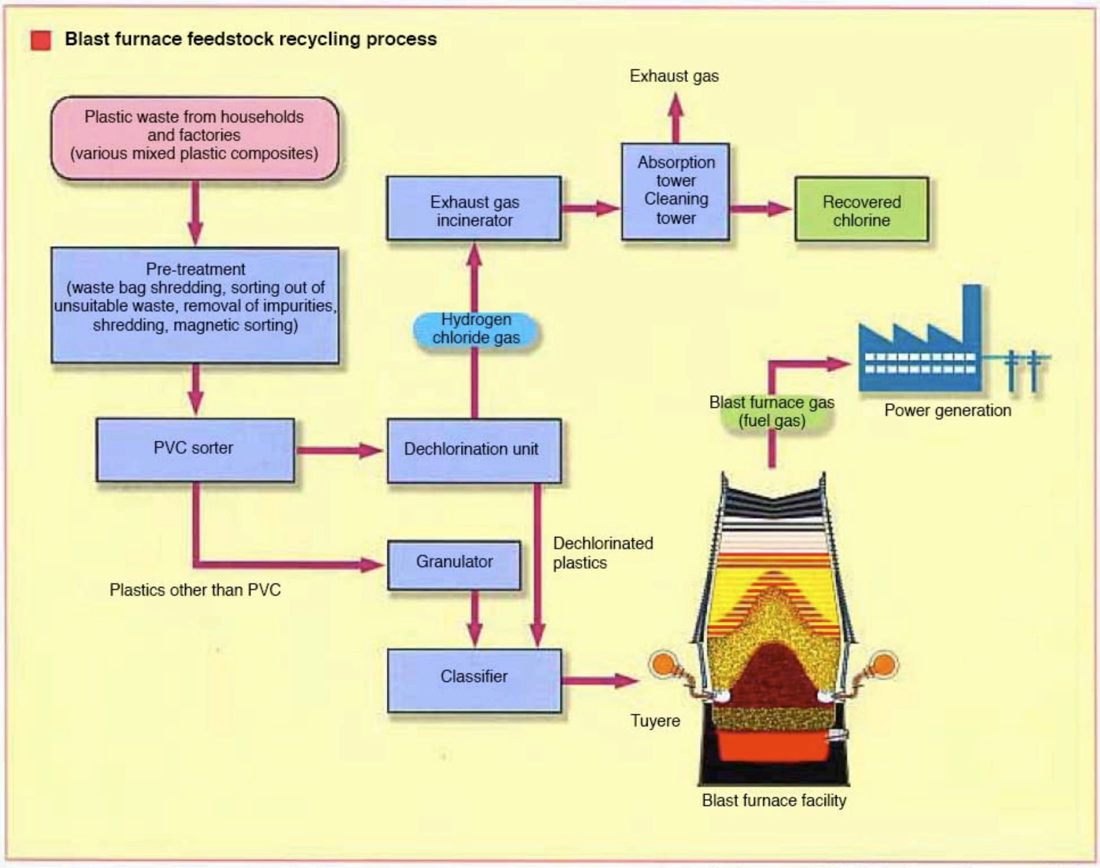
While PET bottles can be recycled to make textiles and sheeting, they cannot be used to make PET drinks bottles. This is because used PET bottles are unsuitable for use as raw materials for soft drink, alcohol or soy sauce bottles for reasons of hygiene and smell. However, converting PET bottles back 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 (depolymerization), and they are made into new PET bottles from this stage.

Tenjin 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 terephtalic acid) to make PET resin, and Tenjin Fiber Ltd. commenced operation of a facility with the capacity to process around 62,000 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 depolymerization using EG. It established a new company, PET Reverse Co., Ltd, in 2004 which can process around 23,000 tons per year. However, the dramatic rise in exports of waste PET bottles caused a shortage of raw materials and Tenjin Fiber Ltd. has already withdrawn from bottle-to-bottle production, while PET Reverse Co., Ltd.'s business is being carried on by Toyo Seikan Kaisha, Ltd. (PET Refine Technology Co., Ltd.).

● Blast furnace feedstock recycling



Reference: JFE Steel Corporation. pamphlet

◆ Plastics used as a reducing agent

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.

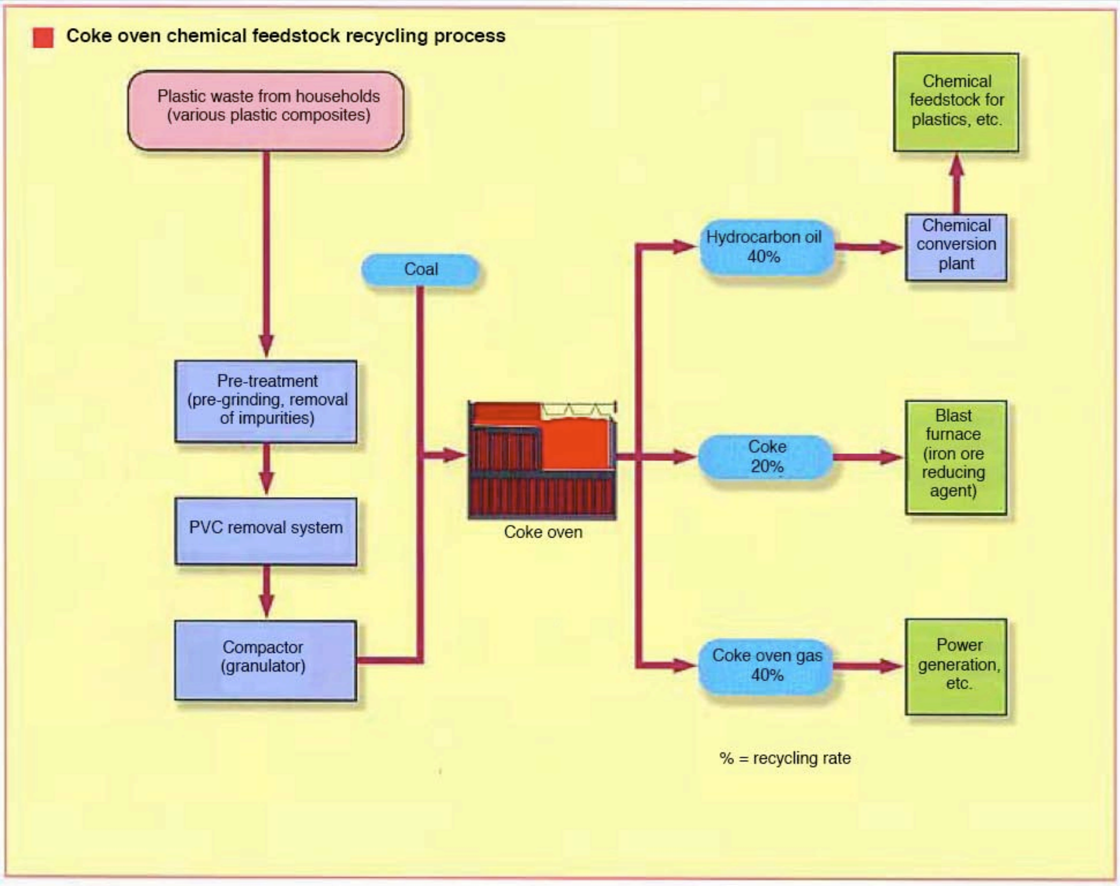
As plastics are made from petroleum and natural gas, their main constituents are carbon and hydrogen.

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 homes 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 do contain PVC are fed into the blast furnace after first separating the hydrogen chloride at a high temperature of around 350℃ 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, 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 Steel Corporation started a full-scale operation in May 2004 with a processing capacity of 30,000,000 tons.

● Coke oven chemical feedstock recycling



Reference: Nippon Steel Corporation pamphlet

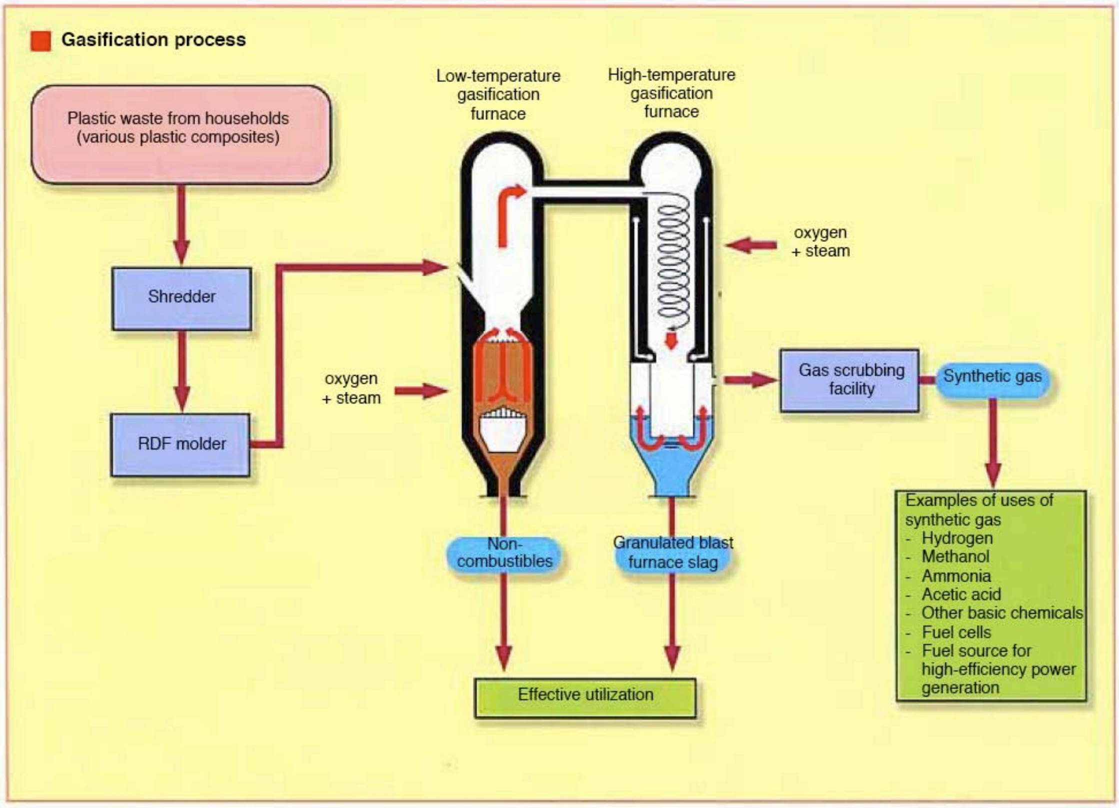
◆ Plastic waste reused in coke ovens

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 Corporation has developed facilities at most of its steel mills to use plastic waste as chemical feedstock and fuel, and it is now in use in its Nagoya, Kimitsu, Muroran and Yawata sites.

At these plants, plastic waste collected from households is first shredded and impurities such as iron are removed. PVC is removed before the plastics are heated to 100℃ and granulated, then mixed with coal and fed into the carbonization chamber of a coke oven.

The carbonization chamber has combustion chambers on both sides which heat the content indirectly. The waste plastic 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 which is used as chemical feedstock, and coke oven gas which is used to generate electricity.

● Gasification



Source: Plastic Waste Management Institute

◆ Plastics are converted to gas for use as a raw material in the chemical industry

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℃ 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 non-combustible matter.

The gas from the low-temperature gasification furnace is reacted with steam at a temperature of 1,300-1,500℃ 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℃ or below to prevent the formation of dioxins. The granulated blast furnace slag also produced is used in civil engineering and construction materials.

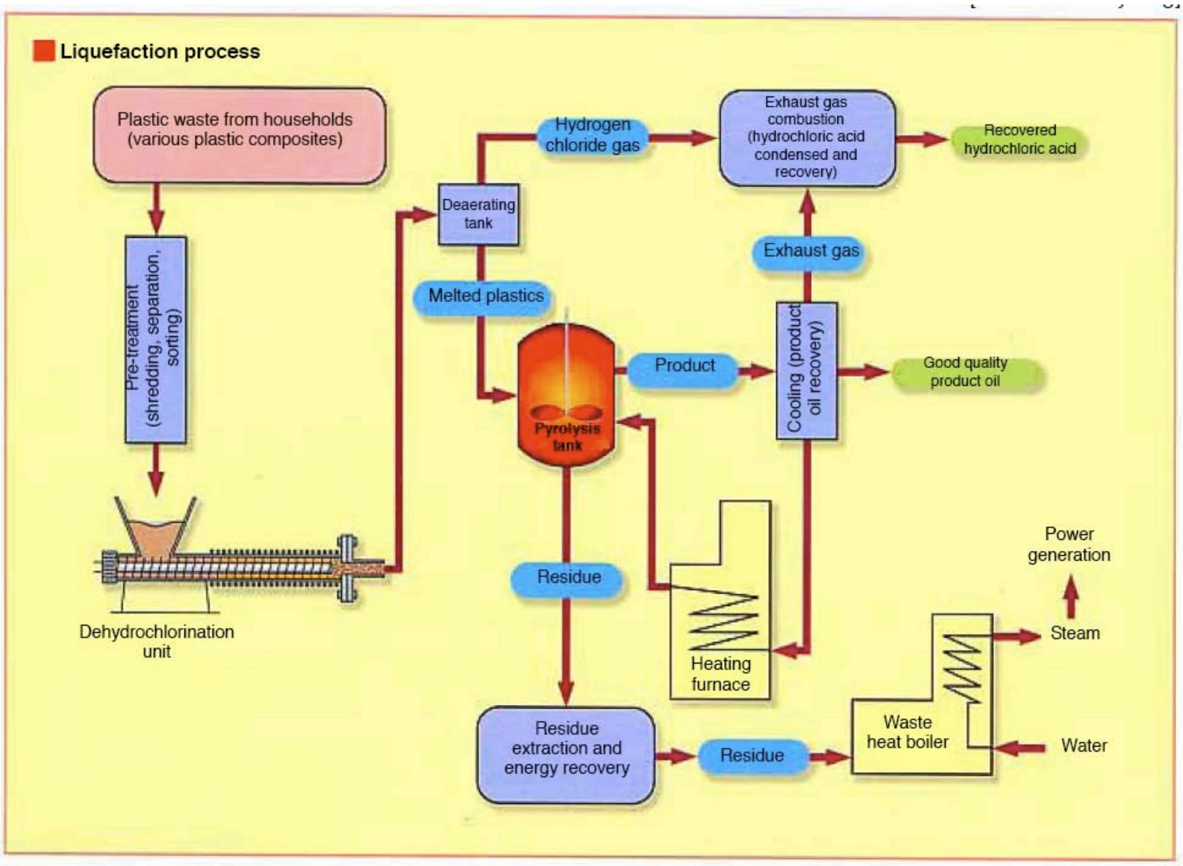
The gas then passes through a gas scrubber and any remaining hydrogen chloride is neutralized by alkalis and removed from the synthetic gas. This synthetic gas is used as a raw material in the chemical industry to produce chemicals such as hydrogen, methanol, ammonia and acetic acid.

The Plastic Waste Management Institute was commissioned by NEDO to conduct trials of this technology, which were performed with the cooperation of Ebara Corporation and Ube Industries, Ltd.. EUP had a plastic gasification plant in full operation in Ube City in January 2001. As of March 2008 Ube Industries is carrying on the business by itself.

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

Japan Recycling Corporation Co., Ltd has been operating since 2000 using JFE Steel Corporation's Thermoselect system, which has also been used for a private financial initiative waste business at Mizushima Eco-works Co., Ltd since 2005.

● Liquefaction



Source: Plastic Waste Management Institute

◆ Waste plastic converted back to oil

As plastics are produced from petroleum, it should be possible to produce petroleum from them by reversing the process by which they are manufactured. The Plastic Waste Management Institute has established a technique to convert plastic waste back to oil following development work initiated in the late 1970s.

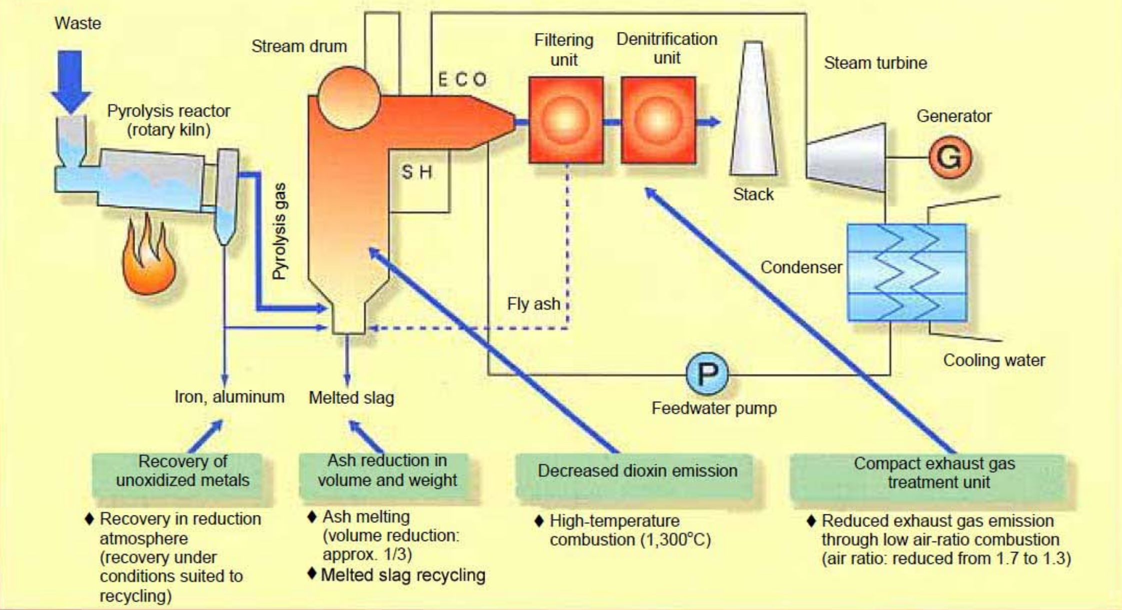
With the assistance of a grant from the Ministry of International Trade and Industry (now the Ministry of Economy, Trade and Industry), the Plastic Waste Management Institute undertook a successful three-year project from FY 1995, called the Next-Generation Plastic Waste Liquefaction Technology Development Project, to develop a method of effectively converting plastic waste of a variety of types to oil (i.e. liquefying them).

To trial the technology, the Niigata Plastic Liquefaction Center was established in Niigata City by Rekisei Kouyu Co., Ltd. to process all kinds of household plastic waste. Applying the Plastic Waste Management Institute's own findings from the above project, the center entered trial operation in December 1997 and commercial operation in May 1999. The conversion of different types of waste plastic back to oil was thus put into practical operation, but the business closed down in 2006 after issues bidding for containers under the Container and Packaging Recycling Law.

A similar large-scale facility was built by Sapporo Plastic Recycling Co., Ltd. in Sapporo and entered operation in April 2000. Japan Energy Corp. started operating a plant to covert recycled plastic waste oil from Sapporo Plastic Recycle Co., Ltd. into naphtha in 2004.

● Thermal recycling

■ Gasification and melting furnace power generation system (rotary kiln plus combustion-melting furnace)



◆ From waste plastic and landfill to thermal recycling

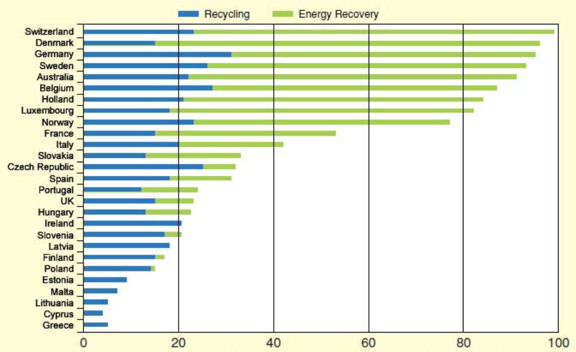
Waste plastics are currently collected and processed differently by different municipalities, but the Ministry for the Environment is unifying the previously separate categories of waste into one ("burnable"), with an amendment to the Waste Disposal Law on 26 May 2005 which changes its basic policy to 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.

Many EU countries already use waste plastics for thermal recycling as part of their recycling programs.

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).

Current widely used methods of power generation from waste incineration are stoker incineration, gasification with melting furnace, and gasification with reformer furnace.

■ Waste plastic recycling in EU member states(2006)
(Material which previously went to landfill is now being used mainly for energy recovery)

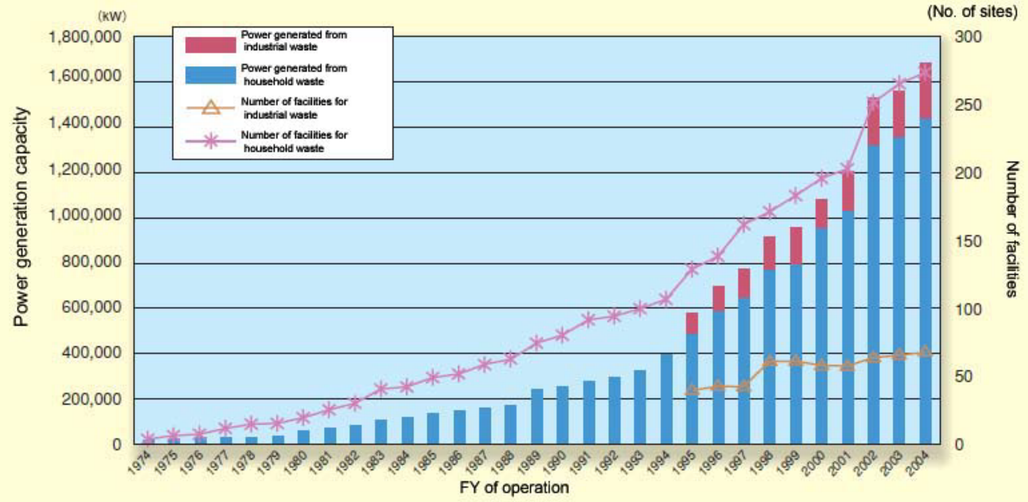


Note: Recycling = マテリアルリサイクル+ケミカルリサイクル
Energy Recovery = 日本ではサーマルリサイクル
Source: Plastics Europe HP The Compelling Fact About Plastics P.15

Gasification with melting furnace waste power generation first converts waste to gas at a high temperature, then uses the emitted pyrolysis gas and char as fuel to turn a steam turbine and generate power. This method turns the burned ash into a solid. Gasification with reformer furnace power generation subjects the waste to pyrolysis, then adds oxygen to the resulting gas, carbonized solids, tar and other substances. Gas rich in carbon monoxide and steam is recovered and used as fuel for power generation or as chemical feedstock. Any method of gasification for waste material can be used with shaft furnaces, fluidized bed furnaces or rotary kilns. Also, power can be generated not only via steam turbines, but also with high efficiency gas engines, gas turbines and fuel cells.

● Steady increase in waste power generation

■ Trend in waste power generation facility processing capacity (excluding super waste electric power generation)



Source: NEDO, Introduction and Spread of Waste Power Generation and Waste Gasification and Power Generation Facilities, January 2006

◆ Power generation capacity to support 2.1 million households

The use of waste as an energy source is steadily increasing. Many waste incinerators in Japan are now equipped with boilers to enable them to supply the hot water and steam they generate to facilities such as local health spas, facilities for the elderly, heating systems, bath houses and heated swimming pools. Another method of use now attracting attention is waste power generation. At the time of writing in March 2005, the number of incineration facilities in Japan that also generate power from waste amounted to 270 using household waste (out of approximately 1,400 sites or 20% of the total) and 70 using industrial waste (out of approximately 1,600 sites or 4% of the total). We can see from this that there is little interest in recovering industrial waste. These facilities have a combined power generating capacity of 1.06 million kilowatts, which is enough to supply around 2.1 million households assuming an annual power consumption of 5,000kWh per household.

Furthermore, although waste power generation has until now had a generating efficiency of only around 5-15%, progress is being made on the practical use of a method of re-powering generation that combines the use of steam generated by waste incineration with high-temperature waste heat from a gas turbine, which is used to superheat the steam to increase the output of the steam turbine resulting in a power generation efficiency of 25% or more. Also currently under development is a means of directly combusting the gas from gasification furnaces to generate power through a gas engine or gas turbine to further raise the efficiency of power generation.

Internationally, waste power generation is rapidly gaining in popularity, particularly in industrialized countries. In countries such as Holland, Germany, Sweden and the USA, power generation capacity per facility is high and further steps are being taken to improve efficiency by increasing the scale of facilities.

■ Waste power generation of selected countries

Country	Power generation capacity	No. of facilities
Japan	10,580,000kw	210
Holland	1,800,000kw	5
Switzerland	1,000,000kw	30
Sweden	1,000,000kw	3
France	1,600,000kw	90
Germany	10,000,000kw	50
UK	2,300,000kw	11
USA	28,200,000kw	102

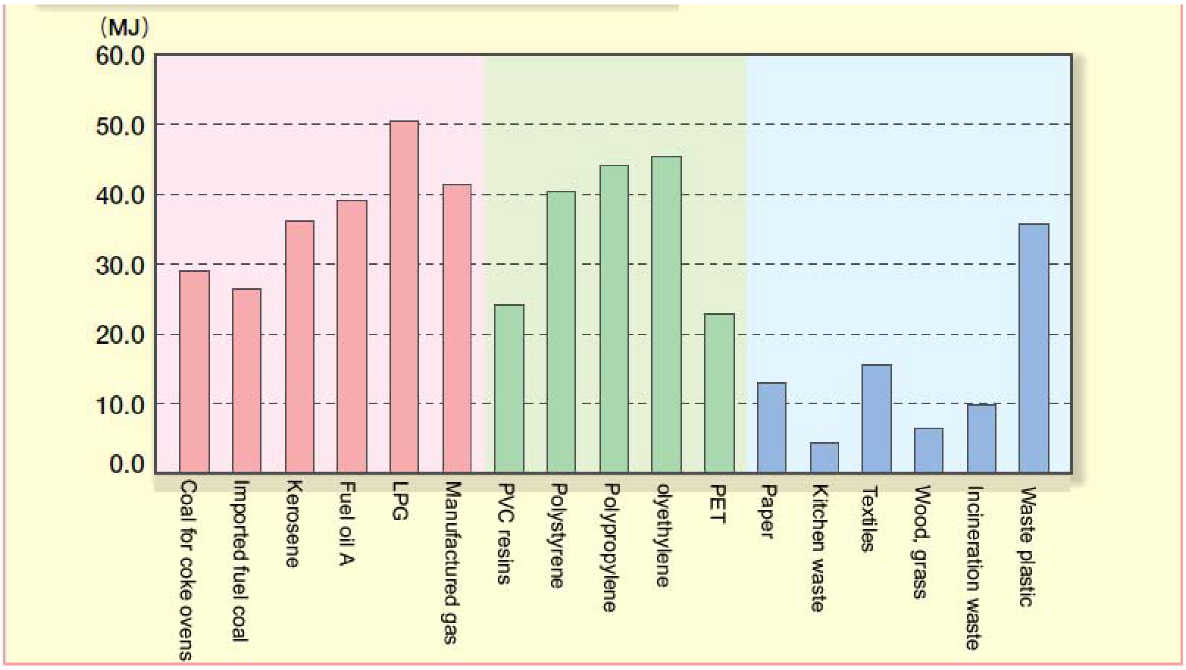
Note: Figures for Japan are based on FY 2001 (Ministry of Economy, Trade and industry), figures for the USA are from 2002, and figures for other countries are from FY 1990-1993. All waste used was household waste.
Source: New Energy and Industrial Technology Development Organization (NEDO) using data from the Institute of Applied Energy.

● High calories provide a valuable energy resource

■ Calorie comparison

Group	Material	Unit	MJ	kcal	Source
Fuel	Coal for coke ovens	kg	29.1	6952	Energy lectures from the Institute of Applied Energy website.
	Imported fuel coal	kg	26.6	6354	
	Kerosene	Liter	36.7	9126	
	Fuel oil A	Liter	39.1	9962	
	LPG	kg	50.2	11992	
	Manufactured gas	Nm3	41.1	9818	
Plastics	PVC resins	kg	24.1	5760	Ecological efficiency analysis on the processing of plastic containers and packaging Plastic Waste Management Institute, September 2006
	Polystyrene	kg	40.2	9600	
	Polypropylene	kg	44	10500	
	Polyethylene	kg	46	11000	
	PET	kg	23	5500	Homepage of the Council for PET Bottle Recycling: http://www.petbottle-rec.gr.jp/qanda/index.html
Waste (damp)	Paper	kg	13.2	3160	Council for the Best Technology for Plastic Waste Processing (Eds), Processing and Disposal of Plastic Waste, Nippo Co., Ltd., 1995
	Kitchen waste	kg	3.9	930	
	Textiles	kg	16.3	3900	
	Wood, grass	kg	6.6	1570	
	Incineration waste	kg	10	2390	
	Waste plastic	kg	36.2	8650	Ecological efficiency analysis on the processing of plastic containers and packaging, Plastic Waste Management Institute, September 2006

Note: 1MJ (megajoule) is equal to 239kcal where 1kcal is 4.18605 kJ.



◆ Calories 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 the plastic with the highest calories, polyethylene, is 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.

● Waste incineration and pollutants

■ Dioxin concentration standards

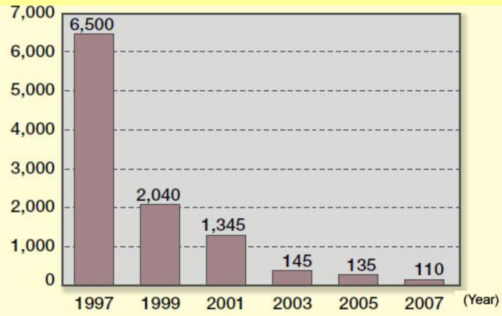
	New facilities	Existing facilities Existing facilities Existing facilities		
Combustion chamber processing capacity	(from Monday, December 01, 1997)	Up to one year later (Monday, December 01, 1997 to November 30, 1998)	1-5 years later (December 1, 1998 to November 30, 2002)	5 years later or more (from December 1, 2002)
4 tons/hour or more	1ng／Nm3	Deferment of application of standards	80ng／Nm3	1ng／Nm3
2-4 tons/hour	0.1ng／Nm3			5ng／Nm3
Under 2 tons/hour	5ng／Nm3			10ng／Nm3

Note: dioxin concentration is converted to toxicity equivalent (TEQ. Nm3 is at 0℃ and 1 atmosphere of pressure).

Source: Ministry of the Environment

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

Year	Total quantity	Domestic waste incineration facility	Industrial plastic waste incineration facility
1997	6,500	5,000	1,500
1999	2,040	1,350	690
2001	1,345	812	533
2003	145	71	74
2005	135	62	73
2007	110	52	58



Source: Ministry of the Environment

◆ Tightened regulation of dioxin emissions

Combustion of municipal solid waste results in gas emissions containing pollutants.

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.

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 2007 was 110g, which represents a fall to almost 1/60th of the amount emitted in 1997. Total dioxin emissions in 2010 fell by another 15% relative to 2003.

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 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.

[5] Life Cycle Assessment

● What is life cycle assessment

Life cycle assessment, or LCA, calculates environmental impact over a product's entire life cycle from mining of resources to use of raw materials, manufacturing, use of the finished product and disposal, then uses scientific, quantitative and objective methods to evaluate how the process reduces the burden on the environment. It is made up of four stages: ① definition of goal and scope ② calculation of environmental data for each stage (CO_2 emissions, energy consumption, etc.), ③ environmental impact assessment in various categories (limiting use of resources, etc.), ④ calculating and weighing up the impact on the environment.

LCA can be applied not only to objects such as products, but also to systems such as services, manufacturing processes and waste management processes.

■ Life cycle and environmental burden

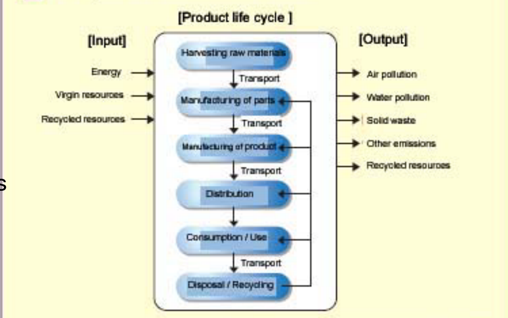


Diagram of life cycle and environmental burden from the Ministry of the Environment website.

◆ Investigation of the environmental impact of different forms of recycling for plastic containers and packaging

The Container and Packaging Recycling Law recognizes mechanical recycling (MR), and four types of feedstock recycling (FR): liquefaction, gasification, use as a blast furnace reducing agent, and use as coke oven feedstock. As of 2007, the Law also recognizes thermal recycling (ER) in the form of use of waste-derived solid fuel as an emergency or complementary method. However, looking at current bid tendering, MR is far ahead of other methods, and the ability of all methods to reduce the load on the environment and limit the consumption of resources is in need of objective evaluation and comparison. The Plastic Waste Management Institute acted as Secretary (alongside the Japan Containers and Packaging Recycling Association) at the 2006 Committee on Evaluating Environmental Impacts of Used and Discharged Containers and Packaging Plastic Treatment, chaired by Professor Masanori Ishikawa of Kobe University). This Committee carried out an investigation into each method of recycling and issued its findings in 2007. A brief overview of the results is presented in this table.

■ Composition of a bale of recycled plastic containers and packaging

PE	PP	PS	PET	PVC	Others	Metals	Moisture	Total
30.2%	21.1%	17.7%	13.8%	4.9%	2.4%	2.6%	7.3%	100.0%

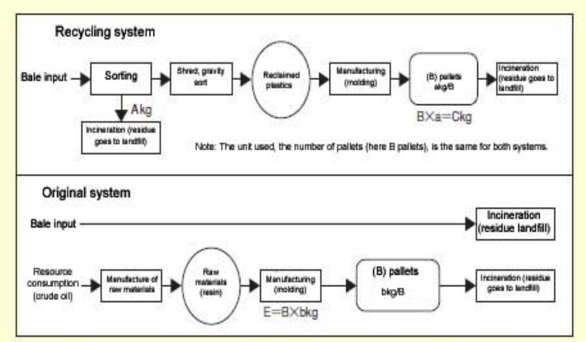
This investigation took standard bales from sorted collection by municipalities entering recycling facilities as its starting point for evaluation, treating them as the raw material and treating the steps in the recycling process as the recycling system. Where no recycling took place, the bales input were of products that could have otherwise come from recycling which were then processed solely by incineration or being put into landfill. This was called the original system. The recycling effectiveness of the methods (reducing environmental impact, limiting consumption of raw materials) was calculated as the difference between the recycling system and the original system.

As the composition of the bales changes depending on yearly bids to the municipalities, and within the same year due to compositional variation,
this investigation is based on values from the latest reports by the Plastic Waste Management Institute.

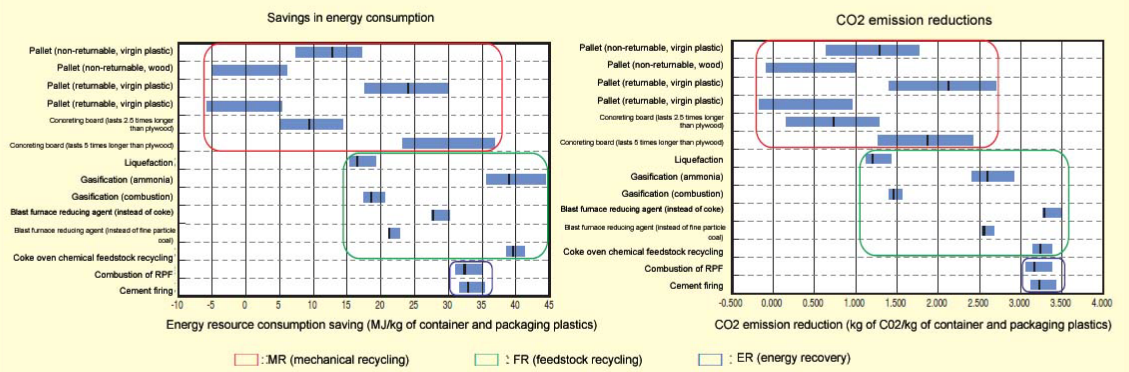
The fact that recycled resin obtained through MR is equivalent in quality to virgin resin cannot be overlooked. To put the functionality of the recycling system and original system at the same level, efforts have been made to treat products made from recycled materials and products made from original raw materials as of equivalent value as far as possible.

According to the latest publications, MR is no more effective in terms of its ability to reduce energy consumption and CO_2 emissions, etc., than FR or ER.

Evaluation of recycling effectiveness by LCA
■ Example of a non-returnable pallet produced via mechanical recycling



Reference: Documents of the Committee on Evaluating Environmental Impacts of Used and Discharged Containers and Packaging Plastic Treatment, June 2007



Reference: Documents of the Committee on Evaluating Environmental Impacts of Used and Discharged Containers and Packaging Plastic Treatment, June 2007

◆ Eco-efficiency analysis (environmental burden and economic efficiency)

The investigations carried out by the Committee on Evaluating Environmental Impacts of Used and Discharged Containers and Packaging Plastic Treatment compared the case of not recycling to the various methods of recycling, but the Plastic Waste Management Institute evaluated several recycling methods against landfill in terms of their normalized and weighted totals of resource consumption, energy consumption CO2, SOx, NOx and ground emissions, on the two criteria of their summary measure of environmental burden and economic efficiency.

The input for all recycling systems and the landfill system was the bale generated by municipal sorted collections, but the output (recycled products and landfilling without producing anything) is different for each system.

As recycled products were under-represented when compared to other systems, this was compensated for by treating their products as newly manufactured ones.

This allowed the output of all systems to be equalized and therefore made it possible to compare and analyze the systems for the first time.

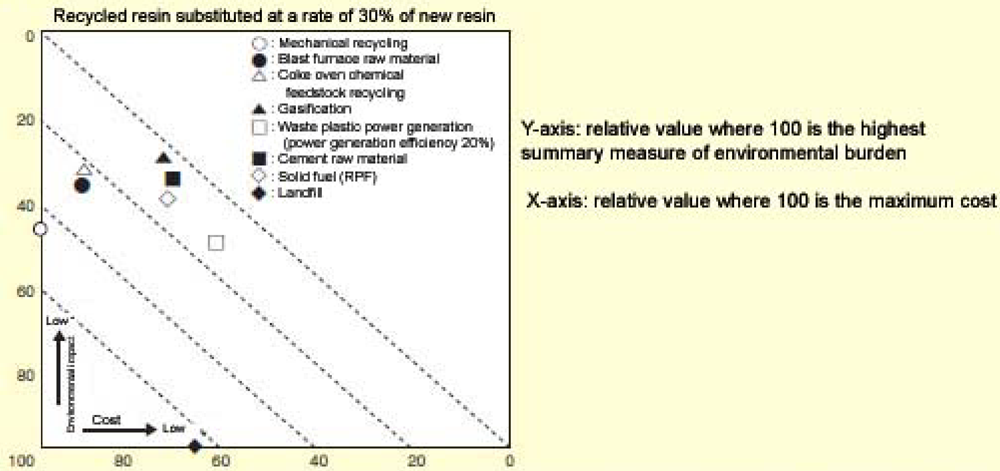
■ Recycling processing systems where total output is set to have equivalent value

Recycling processing system		Output						
MR	*Mechanical recycling*	**Recycled resin (520kg)**	*Coal (1045kg)*	*Coal (1171kg)*	*Newly synthesized gas (2930kg)*	*Public energy (1793kW h)*	*Coal (1171kg)*	*Coal (755kg)*
FR	Blast furnace reducing agent	Virgin resin (156kg)	**Blast furnace raw material (754kg)**	Coal (1171kg)	Newly synthesized gas (2930kg)	Public energy (1793kW h)	Coal (1171kg)	Coal (755kg)
	Coke oven chemical feedstock recycling	*Virgin resin (156kg)*	*Coal (1045kg)*	**Coke oven raw material (845kg)**	*Newly synthesized gas (2930kg)*	*Public energy (1793kW h)*	*Coal (1171kg)*	*Coal (755kg)*
	Gasification	Virgin resin (156kg)	Coal (1045kg)	Coal (1171kg)	**Pyrolysis gas (2930kg)**	Public energy (1793kW h)	Coal (1171kg)	Coal (755kg)
ER	*Waste plastic power generation*	*Virgin resin (156kg)*	*Coal (1045kg)*	*Coal (1171kg)*	*Newly synthesized gas (2930kg)*	**Power (1793kW h)**	*Coal (1171kg)*	*Coal (755kg)*
	Cement raw material	Virgin resin (156kg)	Coal (1045kg)	Coal (1171kg)	Newly synthesized gas (2930kg)	Public energy (1793kW h)	**Fuel for cement production (845kg)**	Coal (755kg)
	Solid fuel (RPF)	*Virgin resin (156kg)*	*Coal (1045kg)*	*Coal (1171kg)*	*Newly synthesized gas (2930kg)*	*Public energy (1793kW h)*	*Coal (1171kg)*	**RPF (634kg)**
LF	Landfill	Virgin resin (156kg)	Coal (1045kg)	Coal (1171kg)	Newly synthesized gas (2930kg)	Public energy (1793kW h)	Coal (1171kg)	Coal (755kg)

Bold text: Real output *Italic text* : Real output and value assumed to be equivalent value

The results of this investigation showed that the cost of recycled resin from mechanical recycling is 30% of that of virgin resin. This value differs depending on the product, but is calculated to be 10-50%. If we take the efficiency of waste power generation to be 20%, that places gasification, use as fuel for cement production and conversion into RPF into the same general region.
The results of this investigation are in line with those of the Committee on Evaluating Environmental Impacts of Used and Discharged Containers and Packaging Plastic Treatment.
Thermal recycling was also placed in a favorable position.

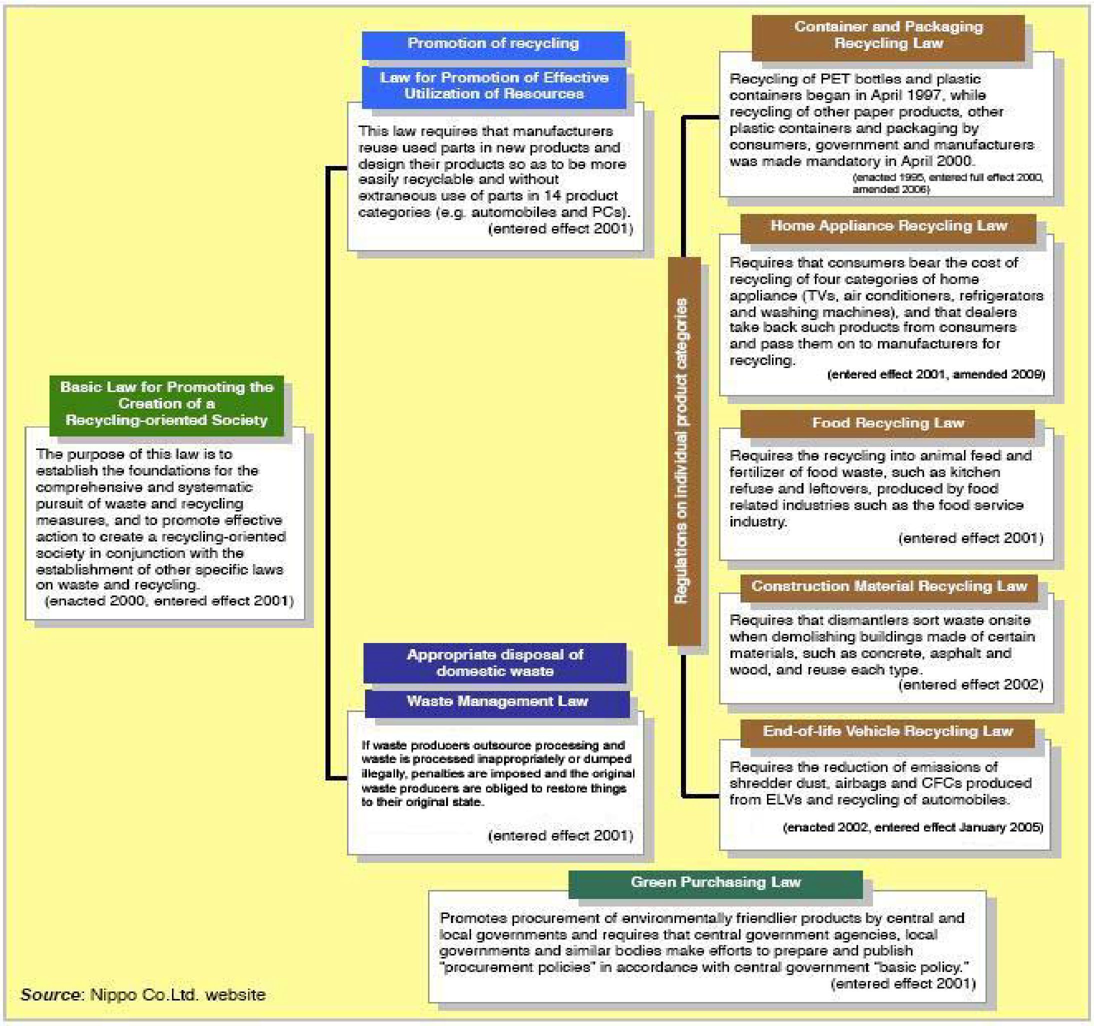
Eco-efficiency analysis results (Eco-map)



Reference: Ecological efficiency analysis on the processing of plastic containers and packaging, Plastic Waste Management Institute, FY 2006

[6] Legislation and arrangements for the creation of a recycling-oriented society

● Basic law and recycling laws



Source: Nippo Co.Ltd. website

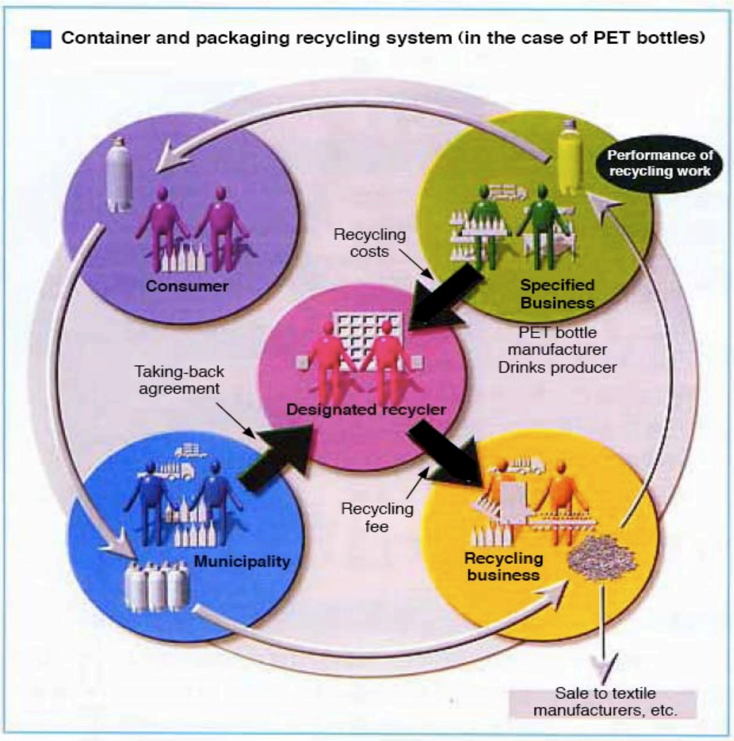
◆ Clarification of the roles of central and local government, businesses and consumers

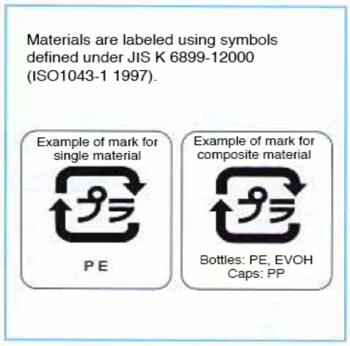
The creation of a recycling-oriented society is the biggest challenge facing Japan in the 21st century. A recycling-oriented society is defined by the Basic Law for Promoting the Creation of a Recycling-oriented Society as a society that limits consumption of natural resources and minimizes the burden 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.

● Container and Packaging Recycling Law and identification marks





◆ 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 Container 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.

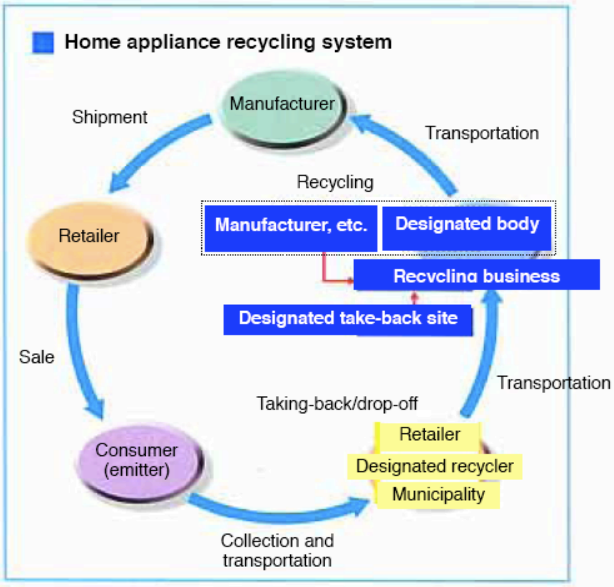
● **Role of businesses:** Businesses that manufacture or use products covered by the law are required to recycle those products. Businesses may also contract out recycling work for a recycling fee to the Japan Containers and Packaging Recycling Association.

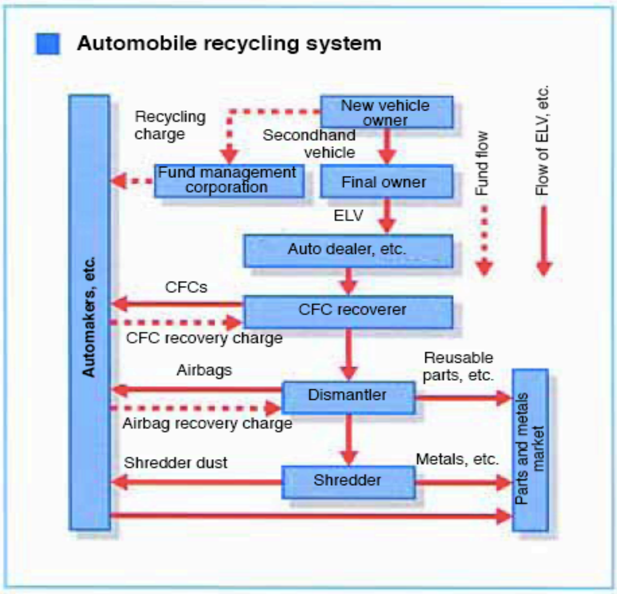
● **Role of municipalities:** Municipalities must establish sorted collection plans and take the necessary measures to collect container and packaging waste separately in their areas.

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 Container and Packaging Recycling Law, the symbols below are sometimes seen. They are the material identification SPI codes used on containers in the USA.

● Home Appliance Recycling Law and Automobile Recycling Law





◆ TVs, refrigerators, washing machines and air conditioners covered

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.

● **Manufacturers and importers:** Manufacturers and importers are required to take back, if requested, products that they manufactured or imported adn 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.

◆ CFCs, shredded waste and airbags covered

The Law on Recycling of End-of-Life Vehicles, popularly known as the Automobile 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).

● **Manufacturers 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 recoverers and dismantlers for recycling.

● **CFC recoverers:** CFC recoverers 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 ELVs and pass on airbags to automakers. (A recovery charge may be made for this service.)

● **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.