In LCA / LCM in Washington D.C.

Recycling and Disposal Systems in Japan and Eco-efficiency Analysis of Plastic Waste

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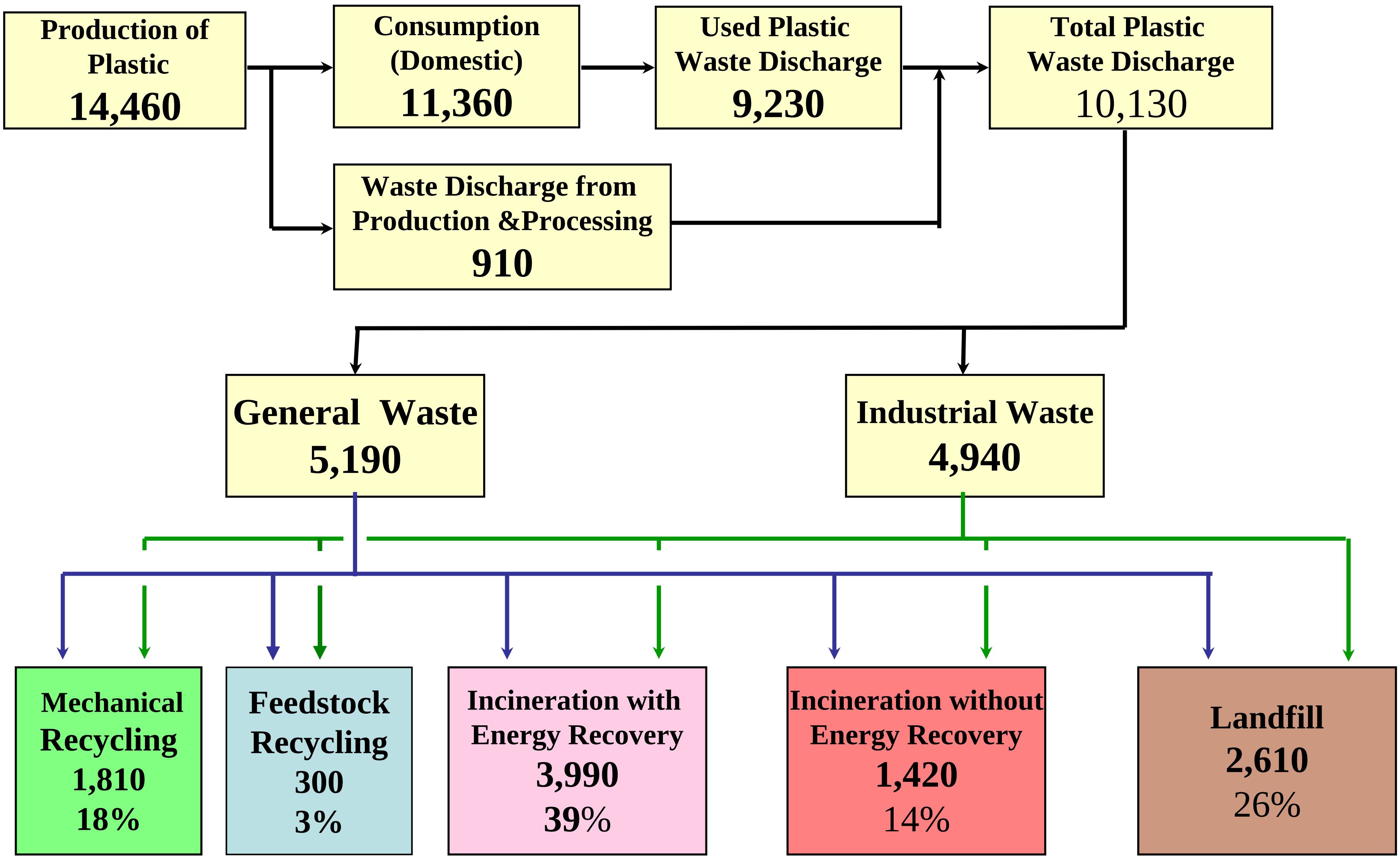
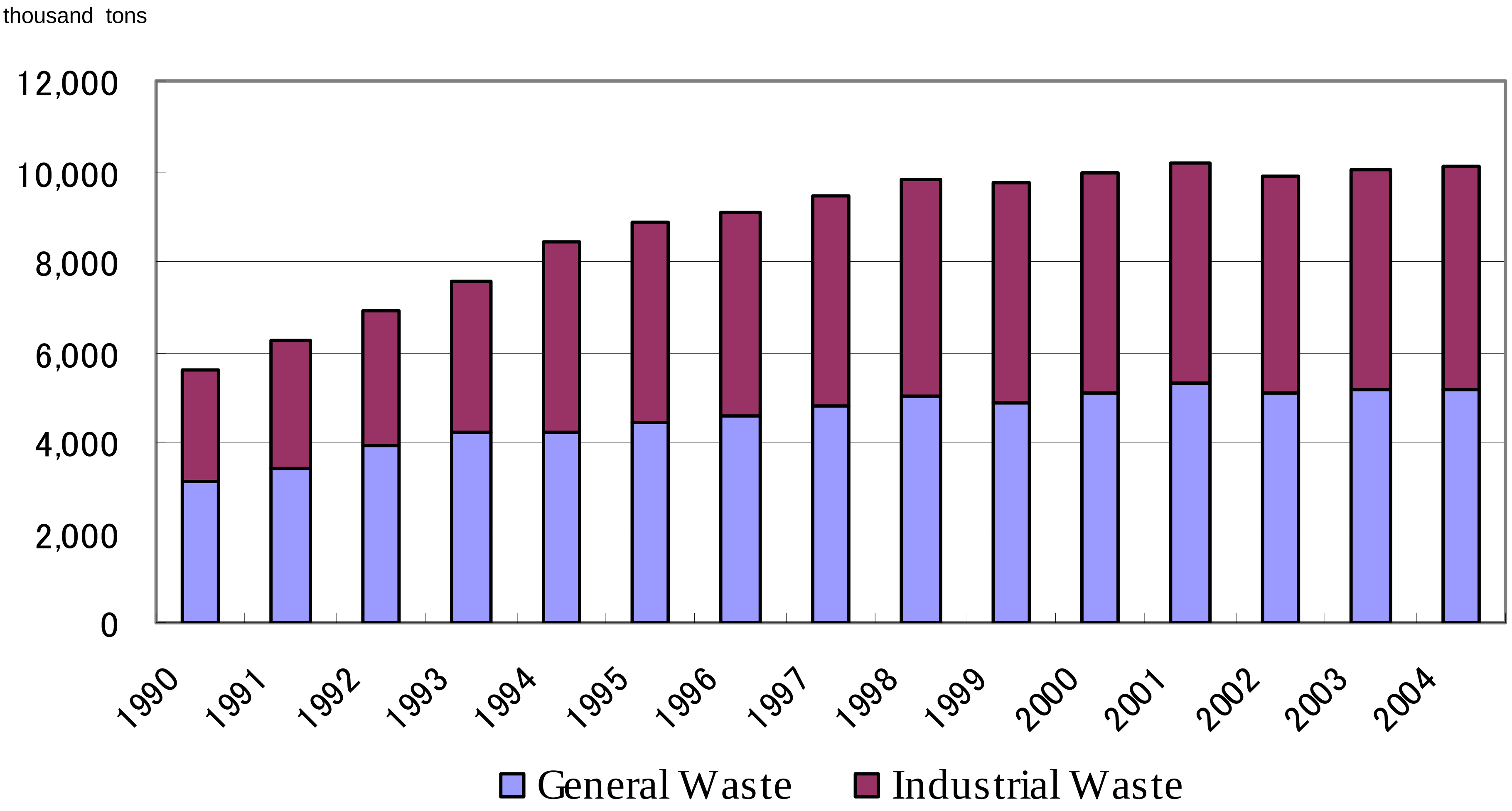
Quantitative Plastic Life Cycle Chart in Japan (2004)

Source : PWMI

unit: 1,000 t

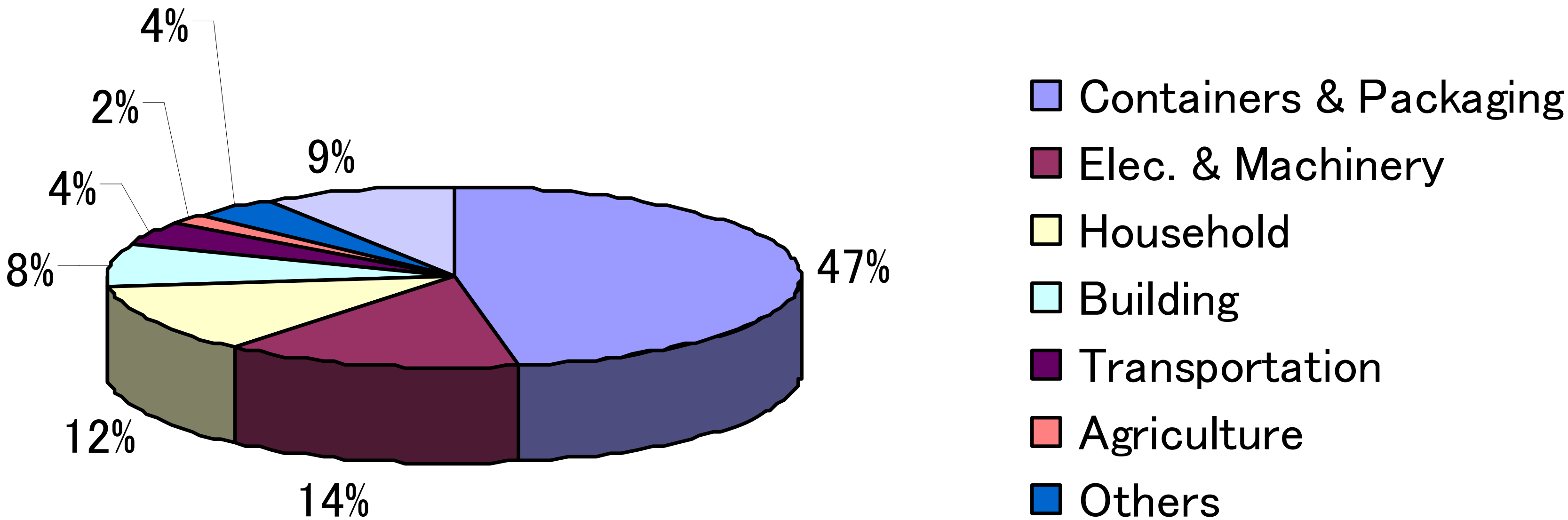


Amount of Plastic Waste Discharge in Japan

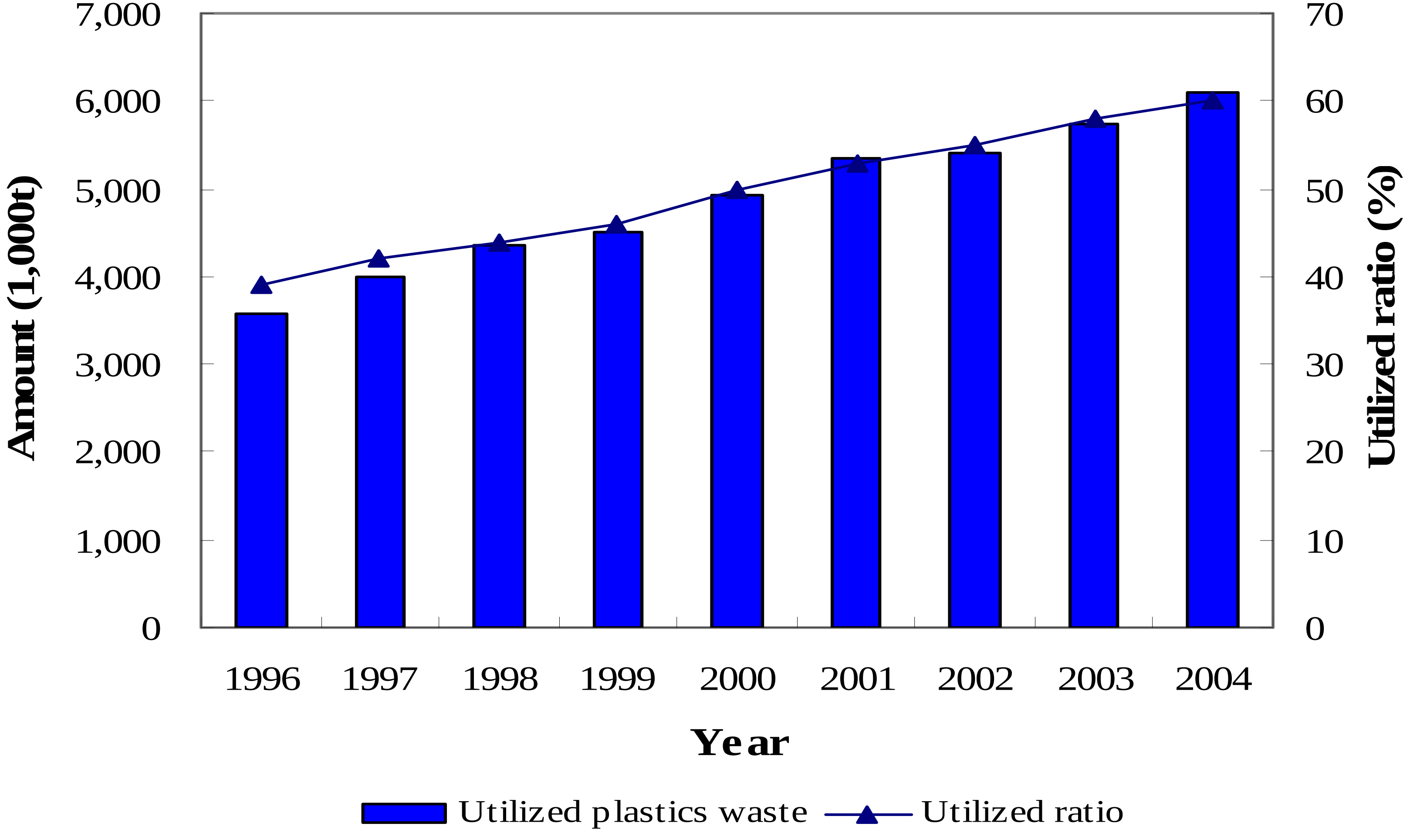


Amount Ratio of Plastic Waste Discharge on Categories of Use

Total Amount : 10,130 tons

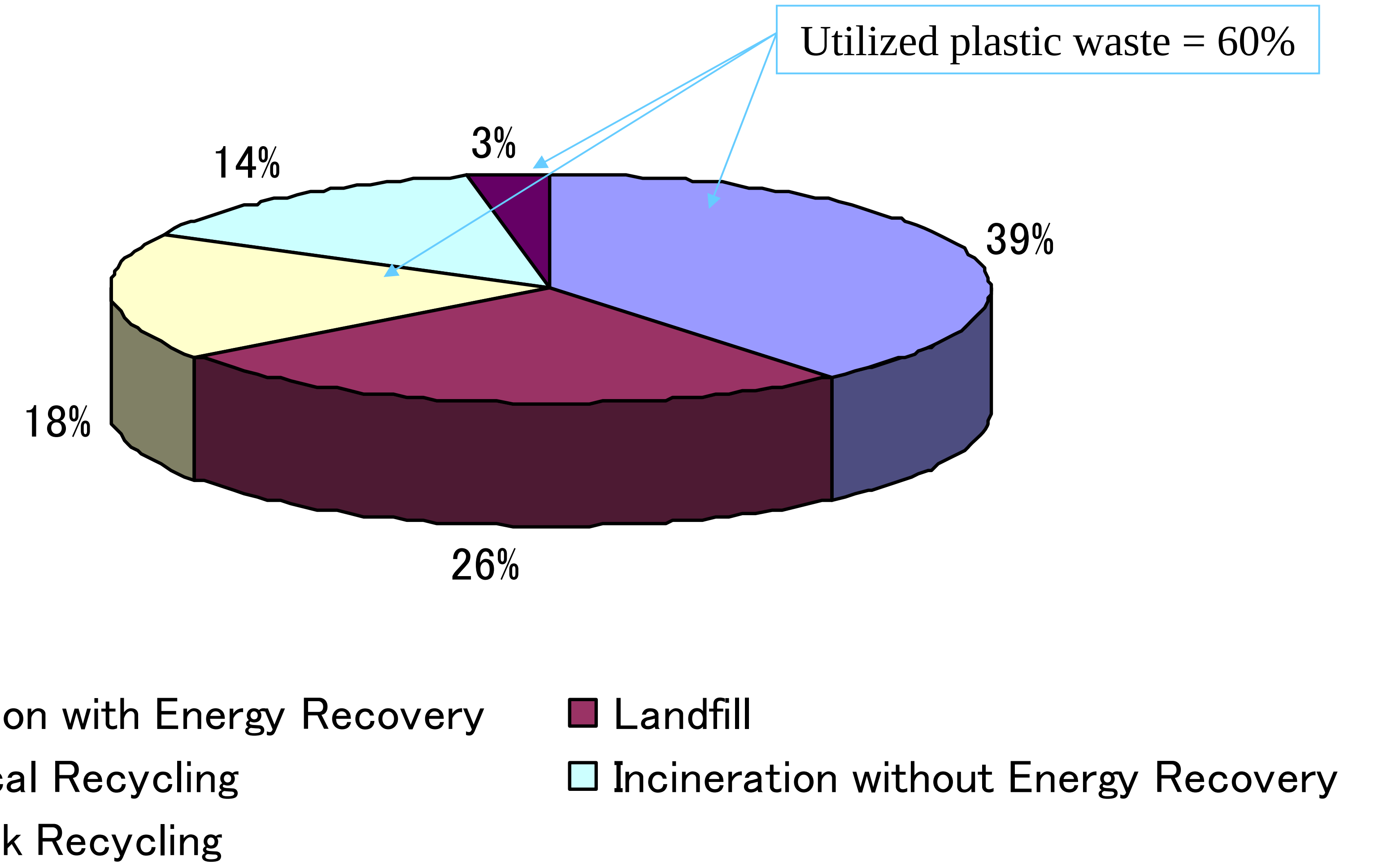


Trend of Plastic Waste Utilization

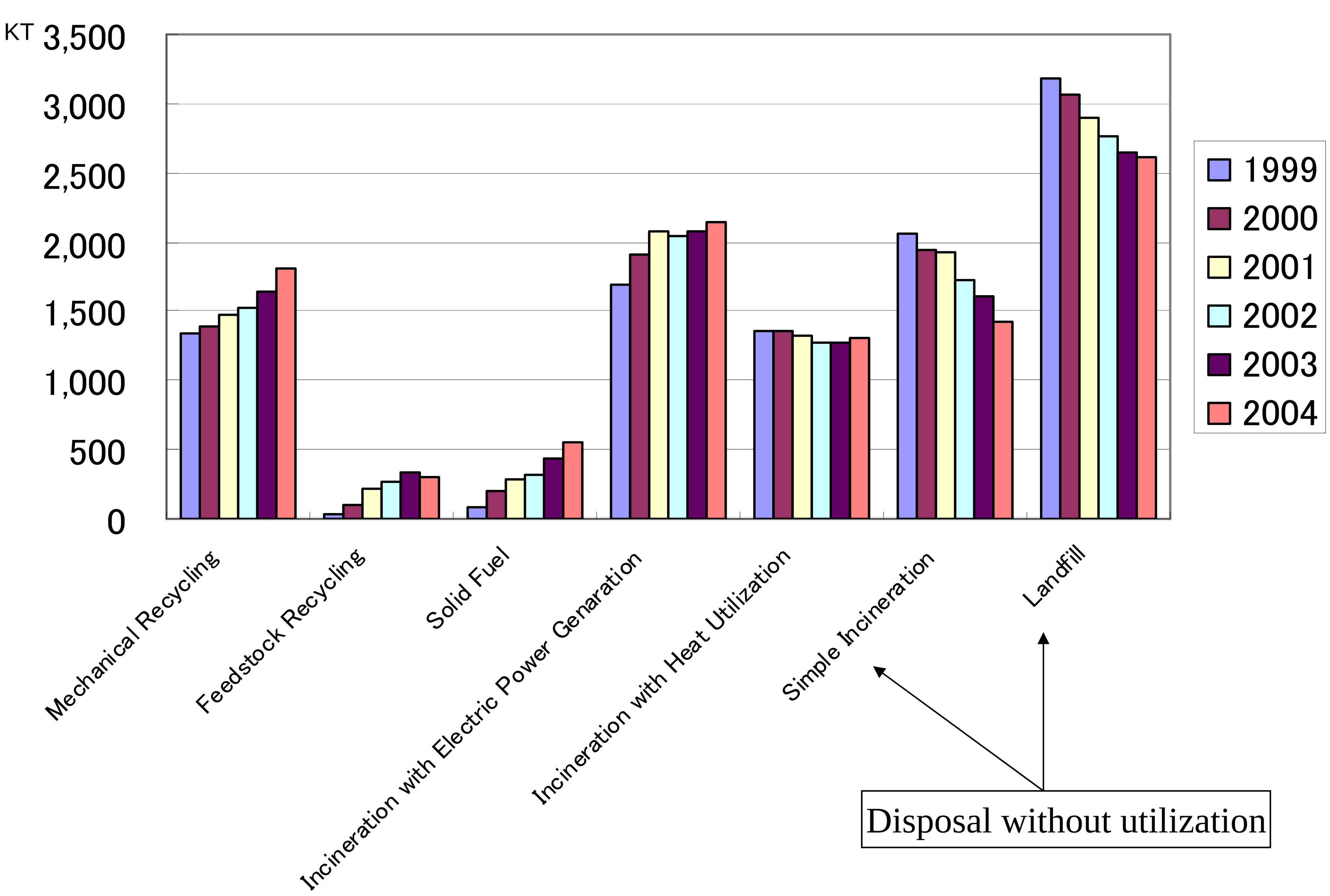


Amount Ratio of Plastic Waste on Treating Method (2004)

Total Amount : 10,130 tons



Trend of Treated Amount by Recycling, Energy Recovery and Disposal



Legislation for Establishing a Sustainable Society in Japan

Fundamental Law for Establishing a Sustainable Society
(enacted 2000, entered effect 2001)

<Promotion of Recycling>

Law for Promotion of Effective Utilization of Resources
(entered effect 2001)

<Appropriate Disposal of Waste>

Waste Management Law
(entered effect 2001)

Green Purchasing Law
(entered effect 2001)

<Laws on Individual Product Categories>

- **Containers and Packaging Recycling Law**
(enacted 1995, entered full effect 2000)
- **Household Electrical Appliances Recycling Law**
(entered effect 2001)
- **Food Recycling Law**
(entered effect 2001)
- **Construction Materials Recycling Law**
(entered effect 2002)
- **Automotive Recycling Law**
(enacted 2002, entered effect 2005)

Source : Nippo Co. Ltd. website

Treatment systems of C&P plastic waste in Japan

<table>
<tr><th>Category</th><th colspan="2">Treatment System</th><th>Positioning under the Japanese Law</th></tr>
<tr><td>Mechanical Recycling</td><td colspan="2">Mechanical Recycling (Recycling to Plastic Pellets or to Articles)</td><td rowspan="5">Specified as Recycling Systems under the present Japanese Law</td></tr>
<tr><td rowspan="4">Feedstock Recycling</td><td colspan="2">Degradation to Monomers</td></tr>
<tr><td colspan="2">Blast Furnace (as Reducing Agent)</td></tr>
<tr><td colspan="2">Coke oven</td></tr>
<tr><td rowspan="2">Gasification
Liquefaction</td><td>Chemical material</td></tr>
<tr><td rowspan="4">Energy Recovery</td><td>Fuel</td><td rowspan="4">Not Specified as Recycling Systems under the present Japanese Law</td></tr>
<tr><td colspan="2">Cement Kiln</td></tr>
<tr><td colspan="2">Incineration with Electric Power Generation, Heat Utilization</td></tr>
<tr><td colspan="2">Solid Fuel (RDF,RPF)</td></tr>
</table>

* Mechanical recycling are given priority over others in bidding .

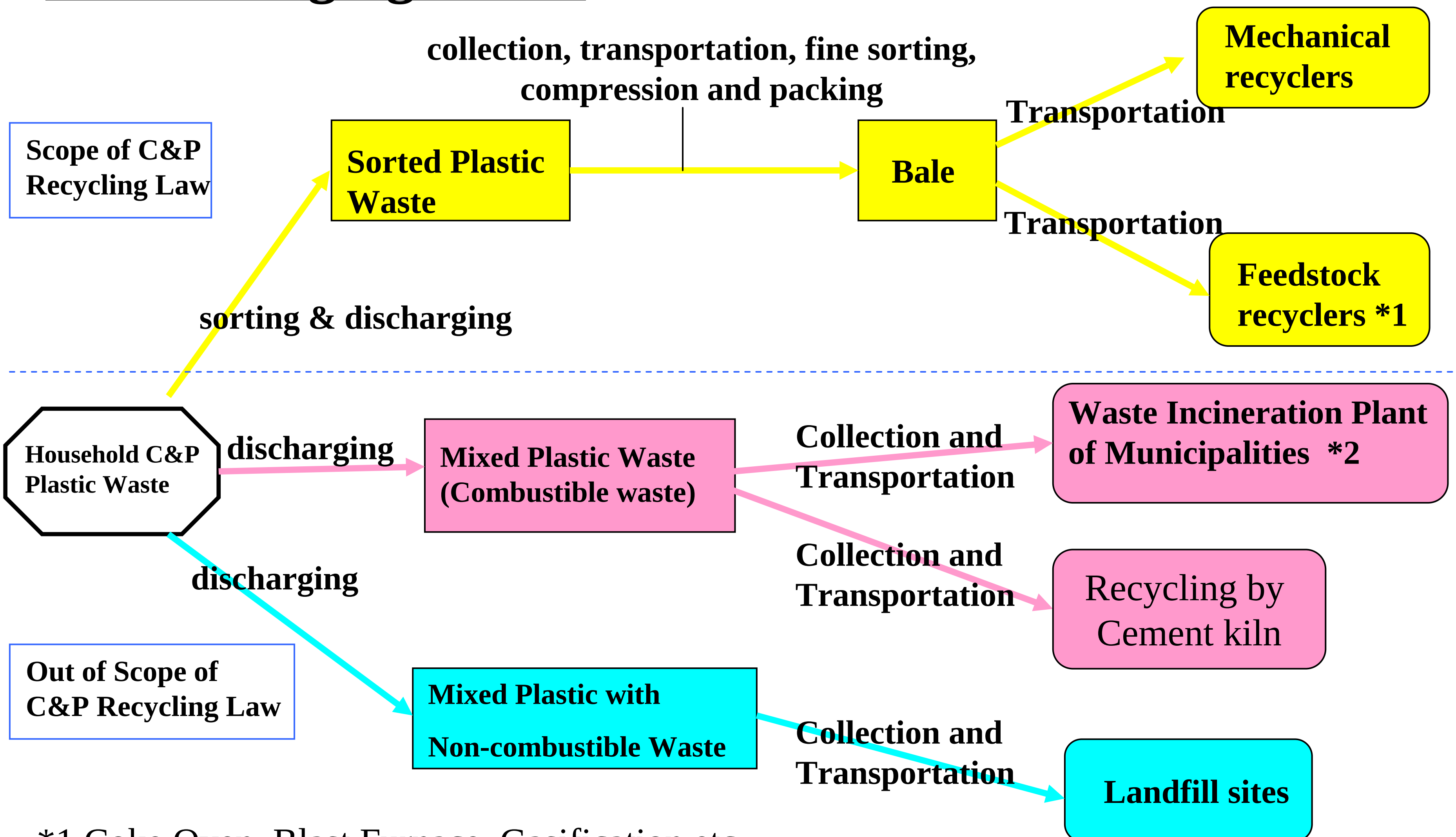
Eco-Efficiency Analysis of Plastic Waste Recycling and Disposal Systems

History of LCA activity of PWMI

－LCI DATA accumulated / LCA analysis－

	Resource mining - Manufacturing	Processing	Article	Waste Treatment / Disposal
Fundamental research	Study of concept & technique 1992 Overseas information / Translation into Japanese			
	Europe Plastic LCI 1995,2000			German LCA of discharged plastics of containers & packaging 1999
LCI DATA accumulation	LCI of Plastics LDPE,HDPE,PP,PS, EPS,PVC,PET 1999	LCI of Processing Injection, Film, foam 2000		
LCA (evaluation of environmental impact)			Environmental effectiveness of plastic use Packaging of liquid soap, Packaging of drinks, Automobile parts 2004 Compare of environmental Impact of materials of bottle & tray 1995	Environmental effectiveness of energy recovery LCA of discharged plastics of containers & packaging 2001,2002 Environmental effectiveness of mechanical recycling of industrial plastic waste LCA of discharged plastics of copying machine, automobile bumper, ATM etc. 2006
Eco-efficiency analysis (environmental impact / economy)				Environmental & economical effectiveness of energy recovery Eco-efficiency analysis of discharged plastics of containers & packaging 2003,2005

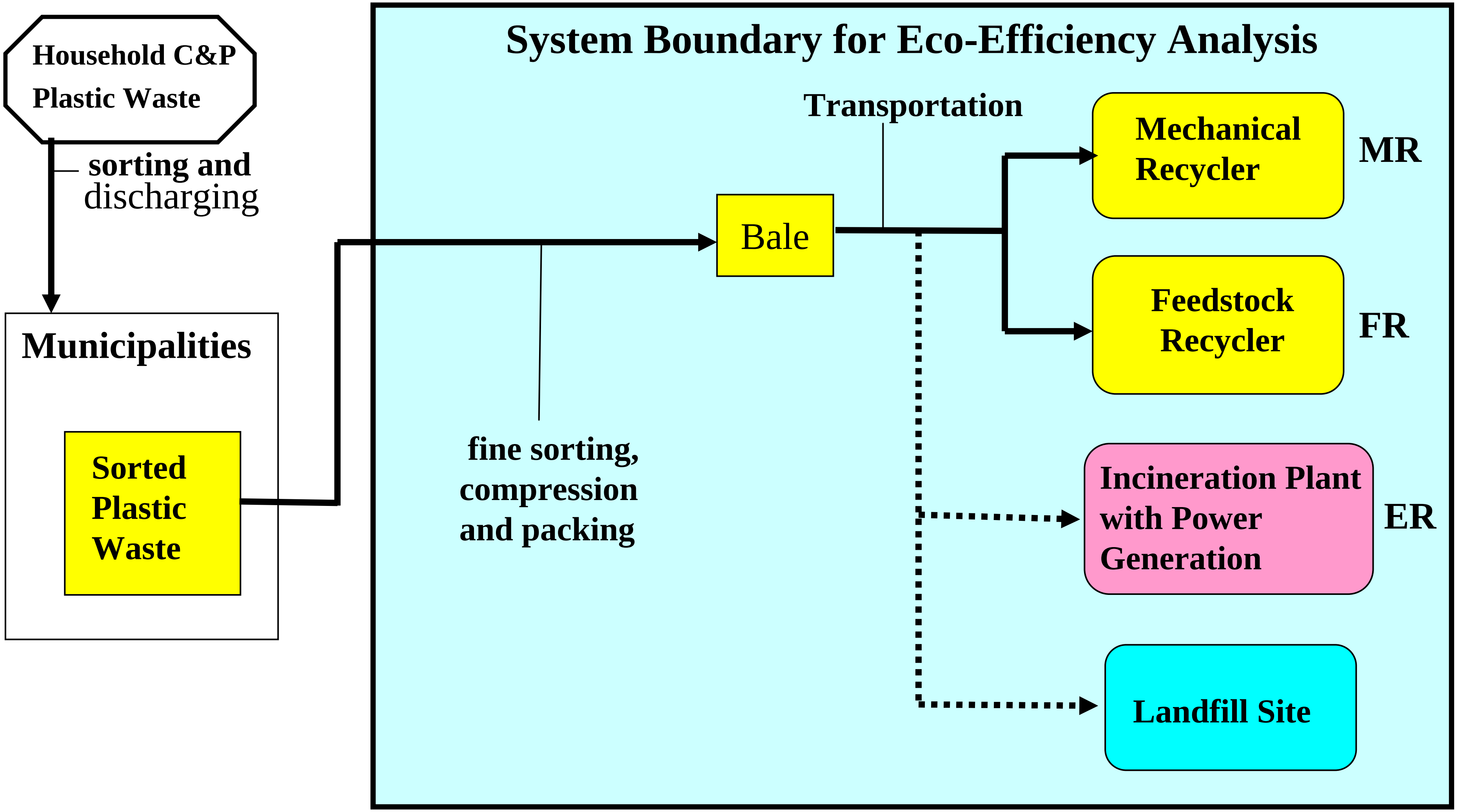
Systems of Recycling and Disposal of Plastic Container and Packaging Waste



*1 Coke Oven, Blast Furnace, Gasification etc.

*2 Incineration with Energy Recovery

System Boundary for Eco-Efficiency Analysis



The seven recycling and disposal systems were analyzed by eco-efficiency method for plastic waste under C&P recycling law.

Category	System	Abbreviation
Mechanical Recycling	Mechanical Recycling	MR
Feedstock Recycling	Recycling by Blast Furnace	FR1
	Recycling by Coke Oven	FR2
	Recycling of Gasification	FR3
Energy Recovery	Incineration with Electrical Power Generation	ER1
	Recycling by Cement Kiln	ER2
Landfill	Landfill	LF

Concept of the Basket Analysis Method

1) Systems of recycling, energy recovery, disposal have different outputs to each other.

2) So, to evaluate the eco-efficiency of the systems, we have to make the outputs of each system be equivalent to each other.

3) We took the “basket analysis method” to solve this problem.

4) The “basket analysis method” consists of
   (1) assuming outputs equivalent to the actual outputs
   (2) designing the system units be equivalent to each other by adding assumed outputs

1) Assumed Outputs thought to be equivalent to the actual outputs

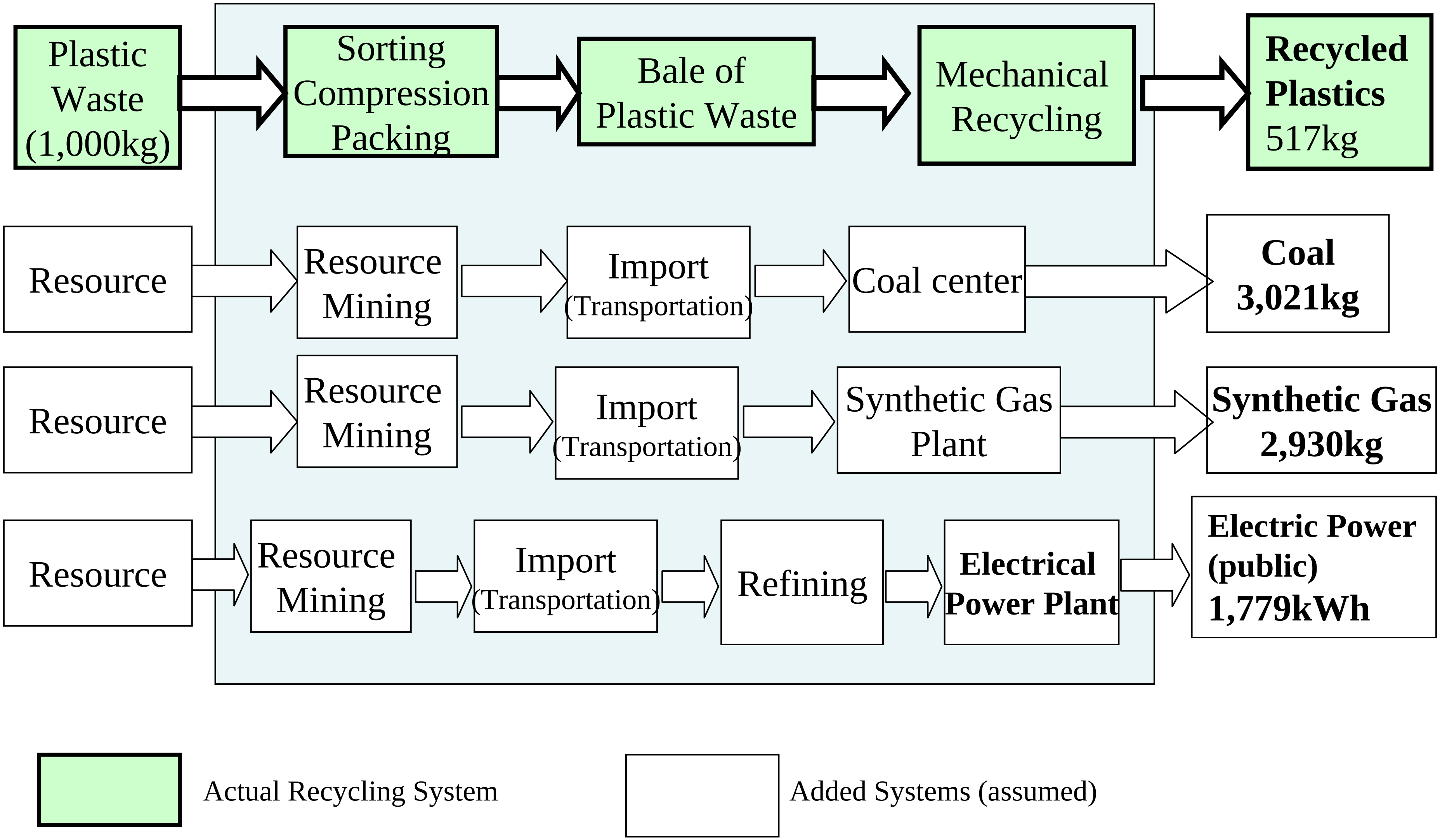
System	Output (actual)	Equivalent Output (assumed)
Material Recycling (MR)	Recycled Plastics 517kg	Virgin Plastics 155kg
Blast Furnace (FR1)	Raw Material for Blast Furnace 754kg	Coal 973kg
Coke Oven (FR2)	Raw Material for Coke Oven 793kg	Coal 1,024kg
Gasification (FR3)	Gas 2,930kg	Synthetic Gas 2,930kg
Incineration with Electrical Power Generation (ER1)	Electric Power 1,779kwh	Electric Power (Public) 1,779kwh
Cement Kiln (ER2)	Raw Material for Cement Kiln 793kg	Coal 1,024kg
Landfill	-	-

2) System units made equivalent to each other by adding assumed outputs

System units	Outputs					
MR	Recycled Plastics (517kg)	Raw material for blast furnace (coal : 973kg)	Raw material for coke oven (coal : 1024kg)	Synthetic gas (2930kg)	Electric power (Public : 1779kwh)	Raw material for cement kiln (coal : 1024kg)
FR1	Virgin Plastics (155kg)	Raw material for blast furnace (754kg)	Raw material for coke oven (coal : 1024kg)	Synthetic gas (2930kg)	Electric power (Public : 1779kwh)	Raw material for cement kiln (coal : 1024kg)
FR2	Virgin Plastics (155kg)	Raw material for blast furnace (coal : 973kg)	Raw material for coke oven (793kg)	Synthetic gas (2930kg)	Electric power (Public : 1779kwh)	Raw material for cement kiln (coal : 1024kg)
FR3	Virgin Plastics (155kg)	Raw material for blast furnace (coal : 973kg)	Raw material for coke oven (coal : 1024kg)	Gas (2930kg)	Electric power (Public : 1779kwh)	Raw material for cement kiln (coal : 1024kg)
ER1	Virgin Plastics (155kg)	Raw material for blast furnace (coal : 973kg)	Raw material for coke oven (coal : 1024kg)	Synthetic gas (2930kg)	Electric power (1779kwh)	Raw material for cement kiln (coal : 1024kg)
ER2	Virgin Plastics (155kg)	Raw material for blast furnace (coal : 973kg)	Raw material for coke oven (coal : 1024kg)	Synthetic gas (2930kg)	Electric power (Public : 1779kwh)	Raw material for cement kiln (793kg)
LF	Virgin Plastics (155kg)	Raw material for blast furnace (coal : 973kg)	Raw material for coke oven (coal : 1024kg)	Synthetic gas (2930kg)	Electric power (Public : 1779kwh)	Raw material for cement kiln (coal : 1024kg)

[shaded box] : actual outputs   [white box] : assumed outputs to be thought equivalent to the actual outputs

Mechanical Recycling System Unit (MR)



Assumptions for analysis

- The recycled plastic produced by MR cannot be regarded as being of the same value as virgin plastic in terms of factors such as its physical properties, processability and appearance. For this study, a parity index of the substitution rate of recycled plastic for virgin plastic (expressed as a percentage equivalent of virgin plastic) was adopted as the reduction in value. This analysis used 30% as a standard case assuming that up to about 30% of recycled plastic could be used in virgin plastic.
- Blast furnace feedstock plastic produced by FR would substitute coal in energy conversion.
- Electricity generated through plastic waste energy by municipal solid waste incinerator at a power generation efficiency of 20% would substitute public electricity.

Category analyzed

- **Resource consumption**
- **Required energy**
- **Emission into atmosphere**

  CO_2 (global warming)

  SO_X and NO_X (acidification)
- **Emission into soil**

  Landfill disposal of solid waste

Social potentials adopted for weighting

Resource Consumption		25%		
Required Energy		25%		
Emission into Environment	Emission into Atmosphere	35%	CO_2	83%
			SO_x+NO_x	17%
	Emission into Soil	15%		

The social potentials adopted for weighting were set, after consideration of data from sources including the Fraunhofer Institute and APME

Method of calculation

Normalization, weighting and integration were effected by the following approach

Integrated index = SUM (a, b, c, d)

(a) Resource consumption parameter

= (resource consumption / total annual Japanese use) × 0.25

(b) Required energy parameter

= (required energy / total annual Japanese use) × 0.25

(c) Emission parameter into atmosphere

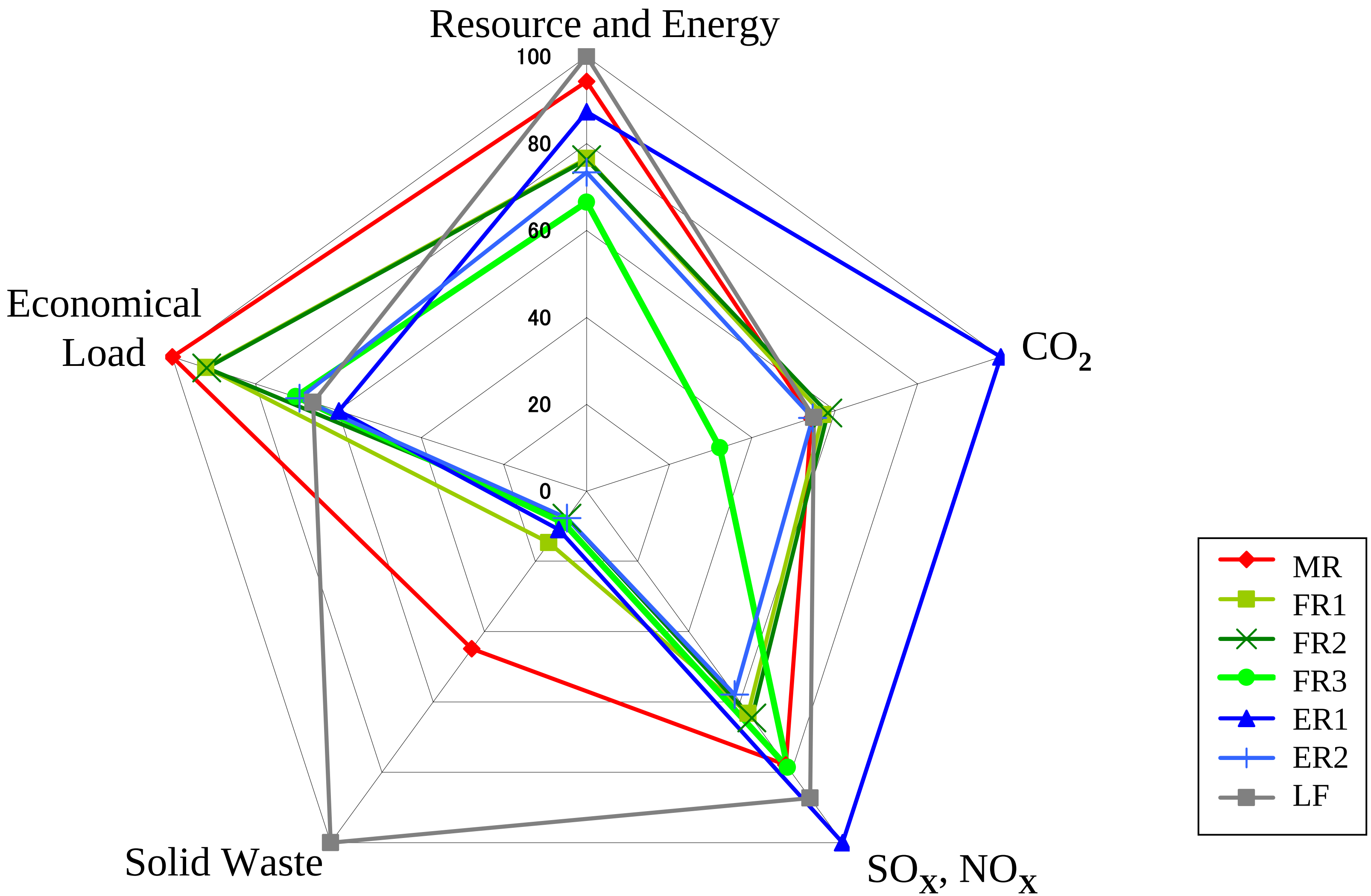
= (CO_2 / total annual Japanese emissions × 1 × 0.83 + ((NO x / total annual Japanese emissions × 0.7) + (SO x / total annual Japanese emissions × 1.0)) × 0.17) × 0.35

(d) Emission parameter into soil

= (landfill disposal / total annual Japanese landfill disposal) × 0.15

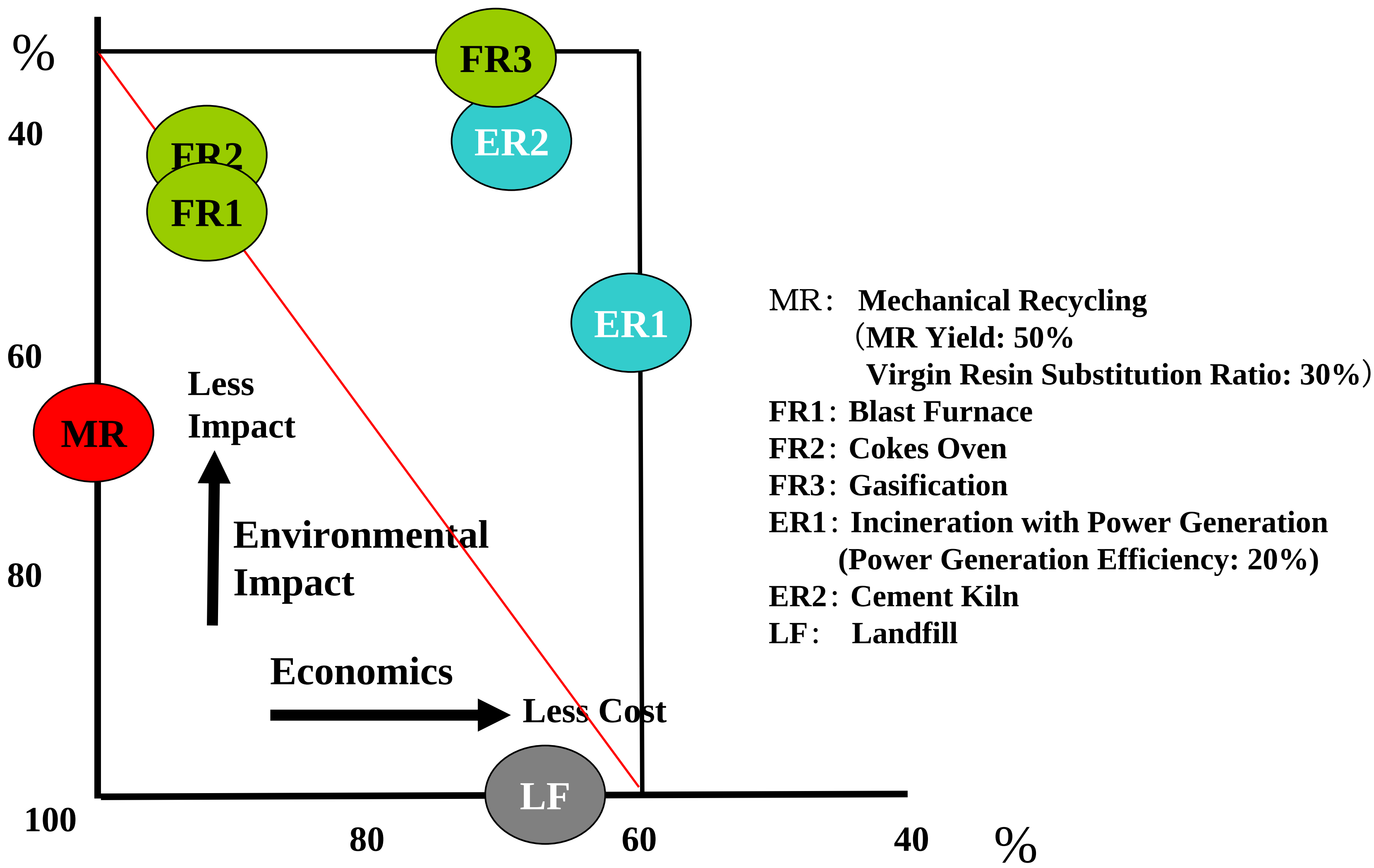
Summary of economic data

Category	Treatment Fee	Category	Price
MR	105,500 \ton	Plastic (Virgin)	121,000 \ton
FR	76,700 \ton	Coal	4,040 \ton
ER1	38,350 \ton	Oil	30,300 \kl
ER2	38,350 \ton	Synthesis Gas	7 \Nm^3
LF	28,500 \ton	Electricity	12 \kwh

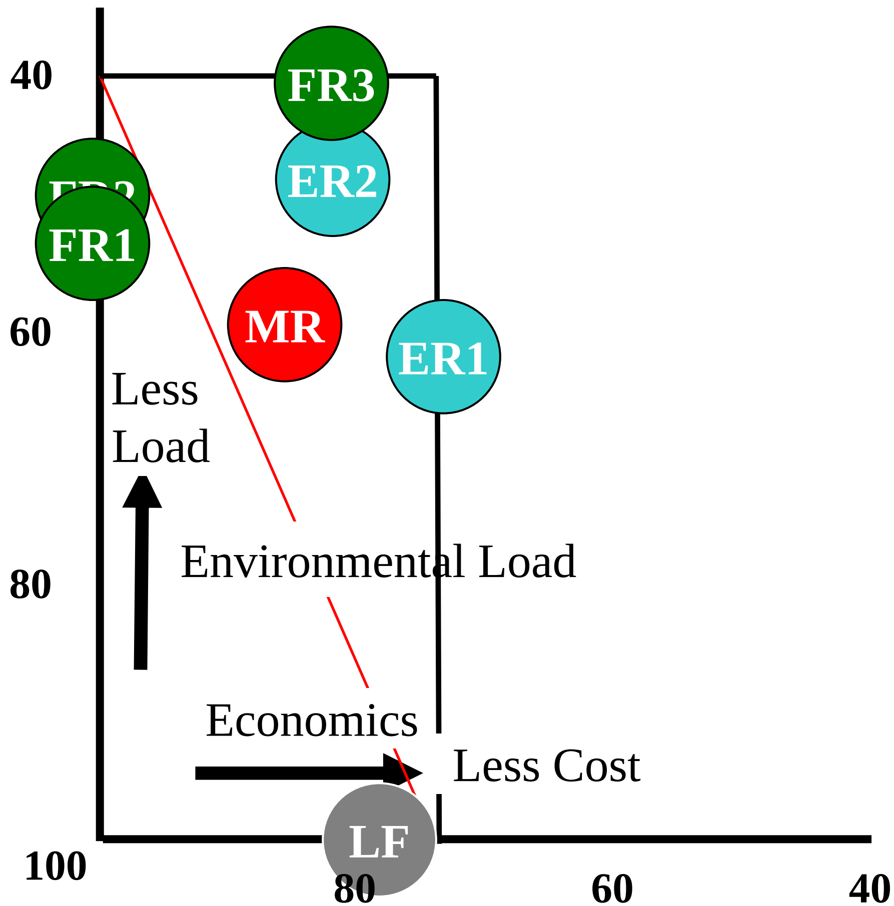


Resource and Energy
100
80
60
40
20
0
CO2
SOx, NOx
Solid Waste
Economical Load
MR
FR1
FR2
FR3
ER1
ER2
LF

Eco-Efficiency of Plastic C&P Waste Treatment



An assessment of Eco-Efficiency of MR by means of Virgin Plastic Substitution Ratio



MR： **Mechanical Recycling**
（MR Yield: 50%
Virgin Resin Substitution Ratio:100%）
FR1：Blast Furnace
FR2：Cokes Oven
FR3：Gasification
ER1：Incineration with Power Generation
(Power Generation Efficiency: 20%)
ER2：Cement Kiln
LF： Landfill

Conclusion of Analysis (1)

An eco-efficiency analysis of recycling techniques of plastic containers and packaging waste was made using a product basket method.

- **ER1 (Incineration with power generation), ER2(Cement kiln), FR3(Gasification) are the most desirable techniques in terms of eco-efficiency.**
- **FR1(Blast furnace), FR2(Cokes oven) are slightly better than ER1 in terms of the environment, but are high in treatment fee , so that the eco-efficiency of them are lower than ER1.**
- **The eco-efficiency of MR is about the same as that of LF assuming that virgin resin alternative rate is 30% .**
- **LF is the worst choice among all cases.**

Conclusion of Analysis (2)

The following improvement are desired for the recycling techniques of plastic containers and packaging waste .

- **Emission of CO_2 is a problem in ER1 (Incineration with power generation). By further enhancing the efficiency of waste power generation, emission of CO_2 produced by the thermal power generation should be reduced as much as possible.**
- **FR1, FR2 are techniques that are well balanced in terms of the environment, but an improvement in economical efficiency is desired.**
- **MR has to surmount many problems such as reduction in solid waste, development of uses that promise high value added and improved economical efficiency.**