Gasification and Liquefaction Alternatives to Incineration for MSW Recycling Developed and Commercialized in Japan

Kunio Yoshikawa

Professor
Frontier Research Center
Tokyo Institute of Technology
Japan

Background

- In Japan, about 40 million tons of Municipal Solid Wastes (MSW) are incinerated each year.

- Among them, about 20 million tons MSW/year are used for power generation and totally about 1000MW of electric power is produced from MSW.

- Most of Waste-to-Energy (WTE) plants are installed for large-scale MSW treatment exceeding 200tons/day scale

- The major technologies used in WTE plants in Japan are stoker type mass burning of as received MSW, where final residues such as ash are landfilled.

- But shortage of landfilling area together with new regulations for dioxin emission control and detoxifying ash enforced in 2004 drove many municipalities to accept relatively novel processes such as direct gasification and smelting and the ash-melting combined with rotary kiln or fluidized bed gasification processes.

There were about 30 Japanese companies engaged in the development of gasification and ash melting systems, which can be divided into three main types:

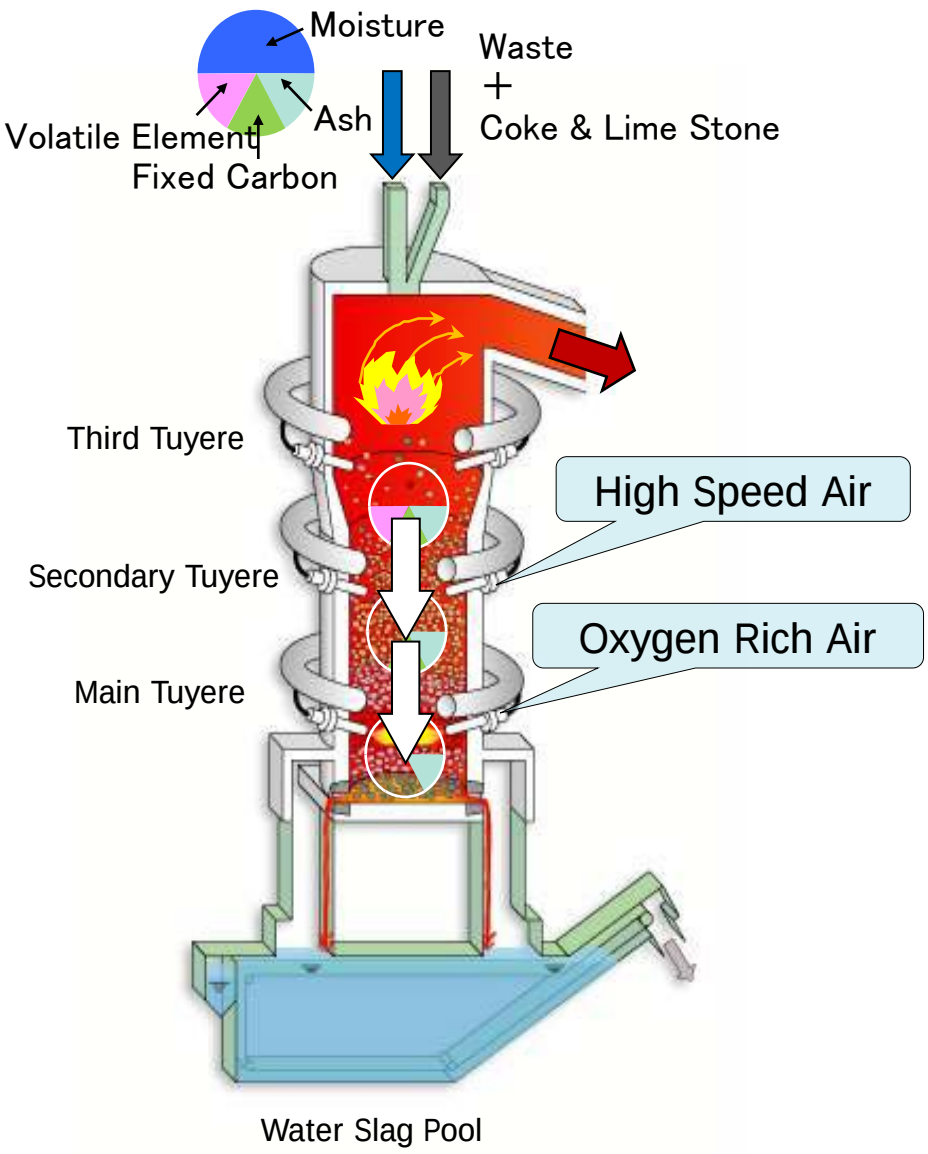
1. The shaft types that melt the entire amount of wastes directly (JFE High Temperature Gasifying and Direct Melting Process)
2. The fluidized bed types that gasify the wastes directly with slagging (EBARA Fluidized Bed Gasification and Ash-melting Process)
3. The kiln types that gasify the wastes indirectly with slagging

- On the other hand, many municipalities started segregation and collection of plastic materials contained in MSW under the Japanese Containers and Packaging Recycling Law enacted in 1995.

- The segregated plastic materials are recycled by way of three methods: the material recycling, the chemical recycling and the solid fuel production.

- One of technologies in the category of the chemical recycling is the waste plastic liquefaction (TOSHIBA Waste Plastics Liquefaction Process).

JFE High Temperature Gasifying and Direct Melting Process



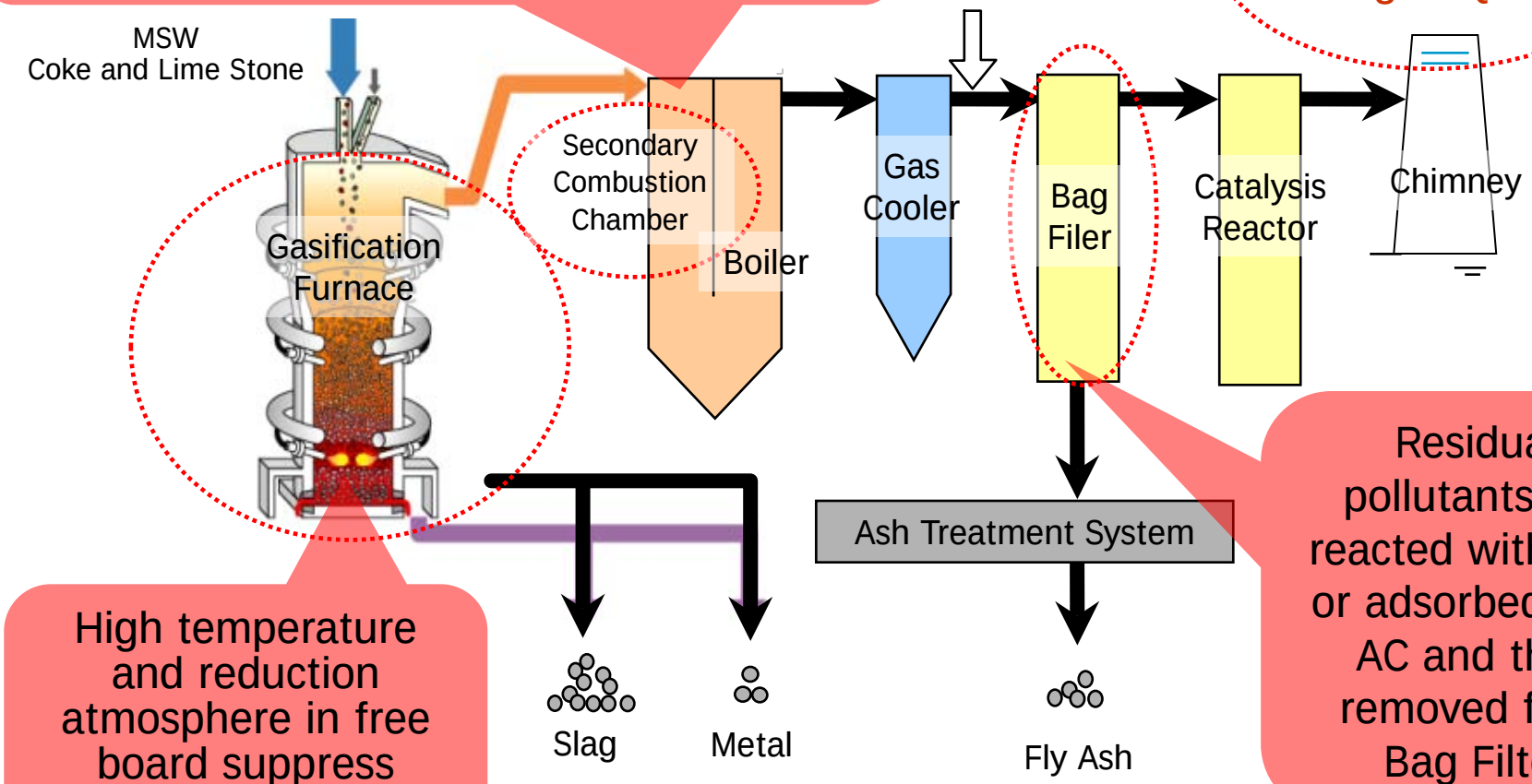
Free Board (Gas Reforming Zone)

- Outlet of Free Board temperature is controlled at 850℃
- Dioxins and ar are decomposed at high temperature and reduction atmosphere
- Ample space at free board stabilizes gas flow and reduces the velocity resulting lower dust emission

Decomposing dioxins by high temperature and appropriate resident time in secondary combustion chamber

Lime and Activated Carbon

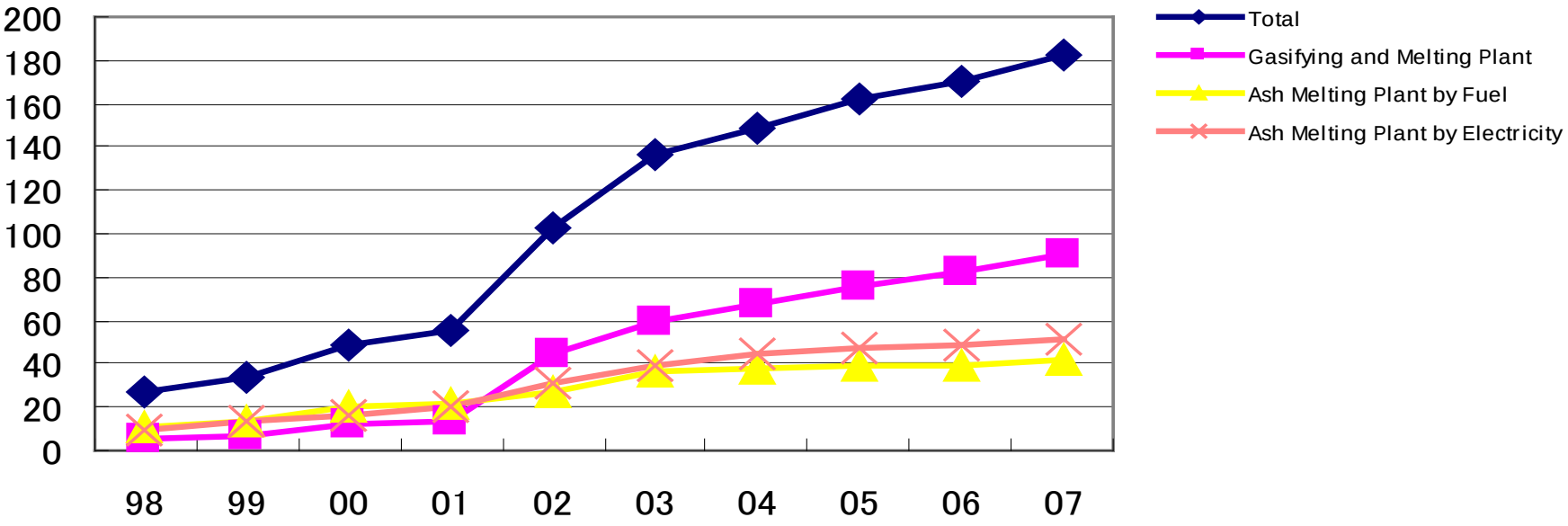
Dioxins content less than 0.01ng-TEQ/m^3N



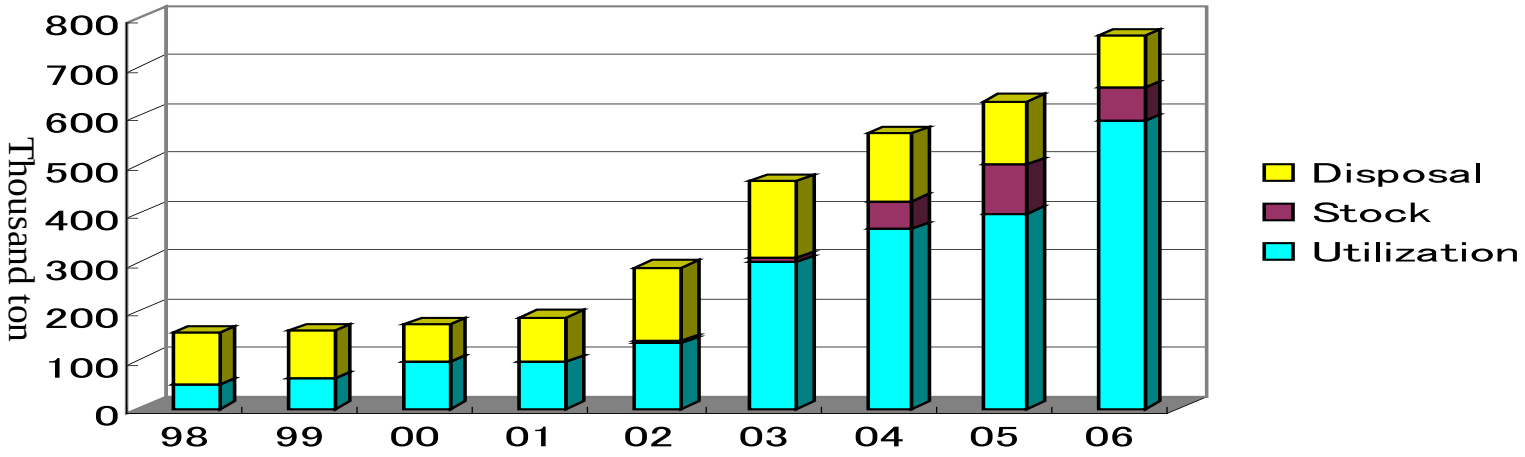
High temperature and reduction atmosphere in free board suppress dioxins formation

Residual pollutants are reacted with lime or adsorbed with AC and then removed from Bag Filter

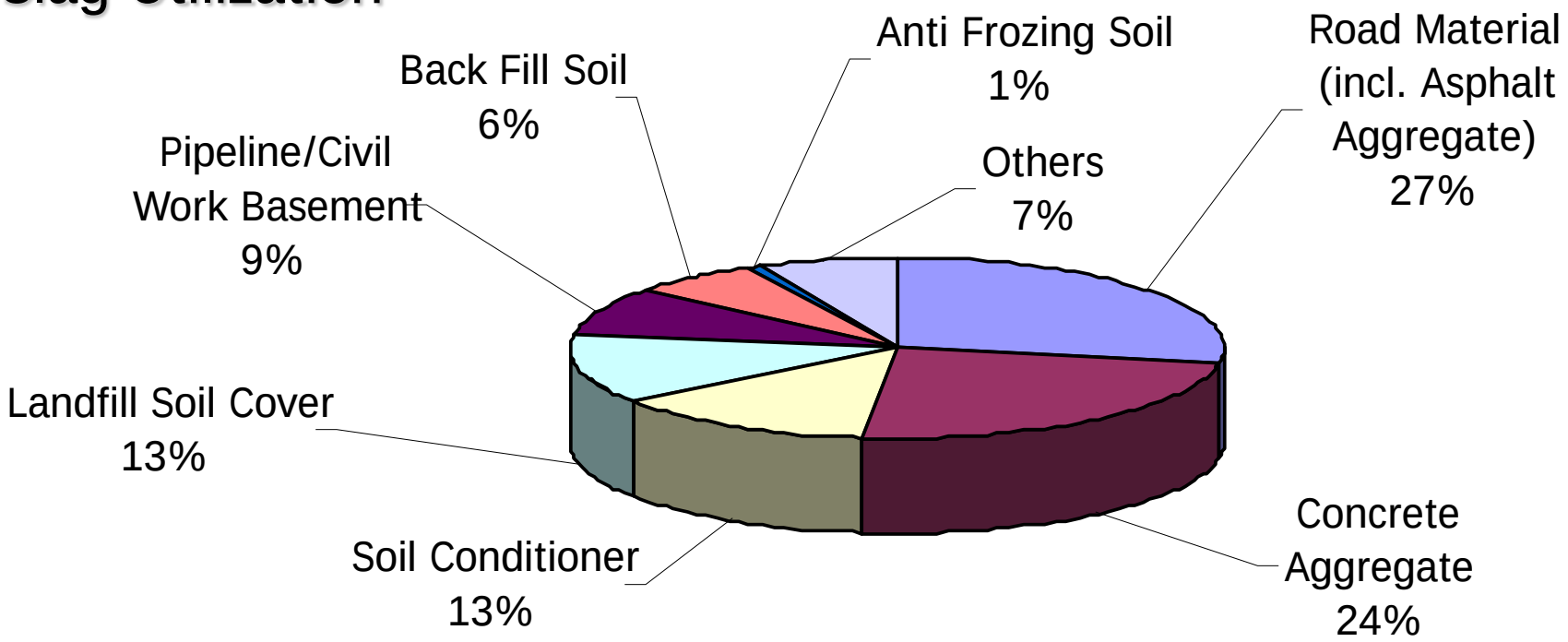
Number of Melting Furnace Plant



Slag Utilization



Slag Utilization



Reference Plants

	Municipality/Owner	Capacity x Line	Input Waste	Completion
①	**Kagamihara City, GIFU**	192t/d （ 64t/d×3）	MSW (incl. Bulky Wastes)	2003.03
②	**Amagi/Asakura/Mitsui Association, FUKUOKA**	120t/d （ 60t/d×2）	MSW (incl. Bulky Wastes)	2003.03
③	**Hidaka-chubu Association, HOKKAIDO**	38t/d （ 19t/d×2）	MSW (incl. Bulky Wastes)	2003.02
④	**Morioka/Shiwa Area Association, IWATE**	160t/d （ 80t/d×2）	MSW (incl. Bulky Wastes)	2003.03
⑤	**Saiki Area Association, OITA**	110t/d （ 55t/d×2）	MSW (incl. Bulky Wastes)	2003.03
⑥	**Fukuyama Recycle Power Corp., HIROSHIMA**	314t/d （314t/d×1）	RDF	2004.02
⑦	**Ibaraki Environment Protection Foundation, IBARAKI**	145t/d （72.5t/d×2）	MSW and Industrial Waste (incl. Bottom Ash)	2006.03
⑧	**Aki Area Association, KOCHI**	80t/d （ 40t/d×2）	MSW (incl. Bulky Wastes, Landfill-Wastes）	2006.03
⑨	**Hamada Area Association, SHIMANE**	98t/d （ 49t/d×2）	MSW (incl. Bulky Wastes)	2006.11
⑩	**Chikushino/Ogori/Motoyama Association, FUKUOKA**	250t/d (125t/d×2)	MSW (incl. Bulky Wastes, Disaster Wastes)	2008.03

Reference Facilities

CHIKUSHINO Waste to Energy Plant

OUTWARD

Completion	**2008. Mar**
Capacity	**250 t/d (125t/d x 2lines)**
Boiler and Steam Turbine	**3.9 MPa / 400 deg-C Elect.Power Gen. : 4,990 kw**
FlueGas Treat.	**Dry type + SCR**

Design Condition of Waste		
Min. LHV 5,860 kJ / kg 1,400 kcal/kg	**Ave. LHV 9,210 kJ/kg** 2,200 kcal/kg	**Max. LHV 14,230 kJ/kg** 3,400 kcal/kg

FURNACE

SUB-MATERIAL CRANE

SUB-MATERIAL BUNKER

SLAG CONVEYOR

Recovered material	Amount of emergence (t)	Ratio (wt%)
Slag	5 502	11.1
Metal	352	0.7
Fly ash	1 116	2.3

Mass balance
(Total MSW disposal was 49,348t)

Item	Electric power (MWh)
Generated	22 349
Purchased	989
Sold	9 070
Consumed	14 268

Electric power balance
(Including recycling center)
200kWh/MSW ton consumption

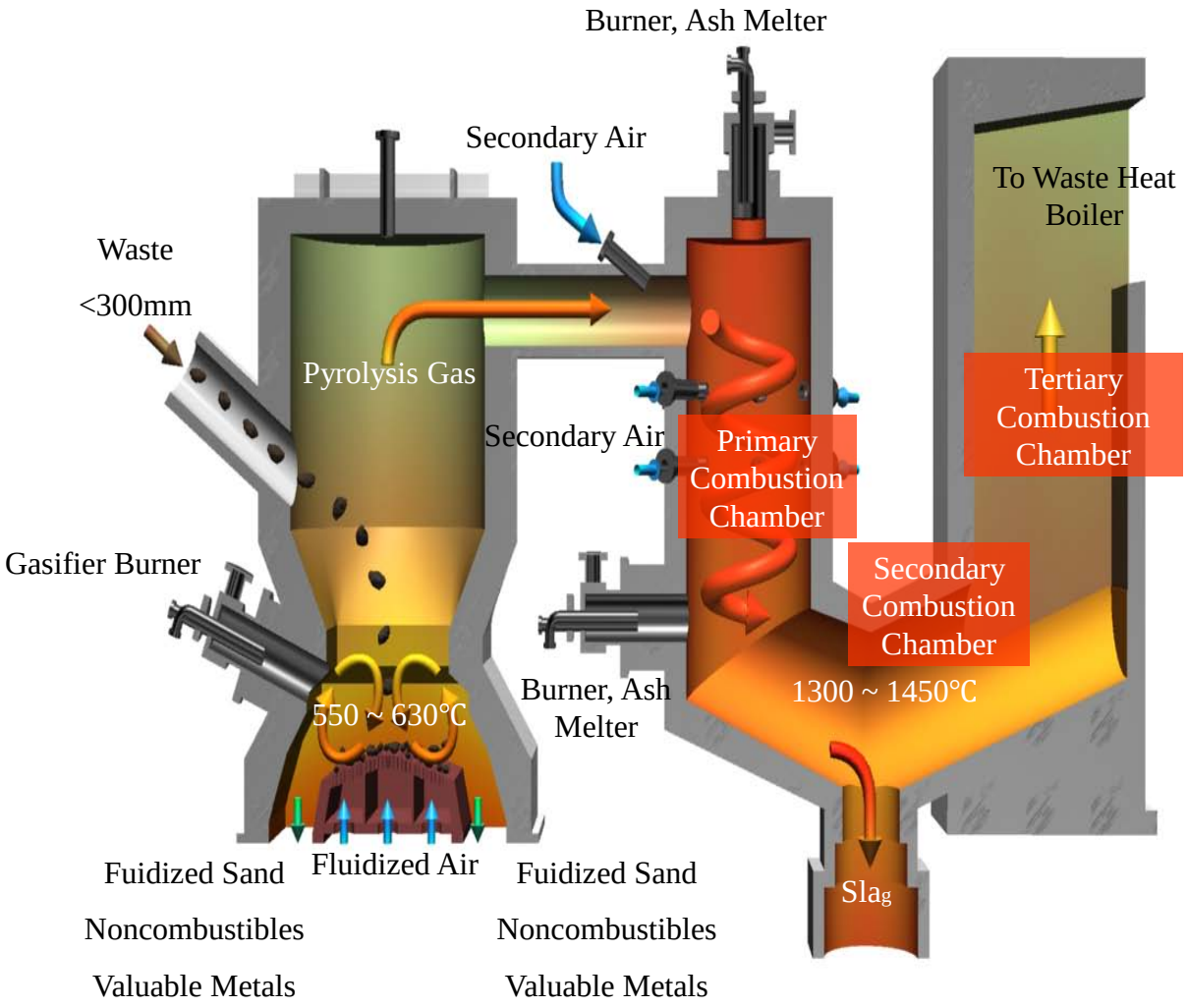
Item	Regulation value	Analysis value
Dust (g/m^{3}N)	<0.02	<0.005
SOx (ppm)	<50	0.3–6.0
NOx (ppm)	<50	6.0–32.0
HCl (ppm)	<50	<8.6
CO (ppm)	<30	2–7
Dioxins (ng-TEQ/m^{3}N)	<0.05	0.000 000 09–0.004 8

Exhaust gas emission data

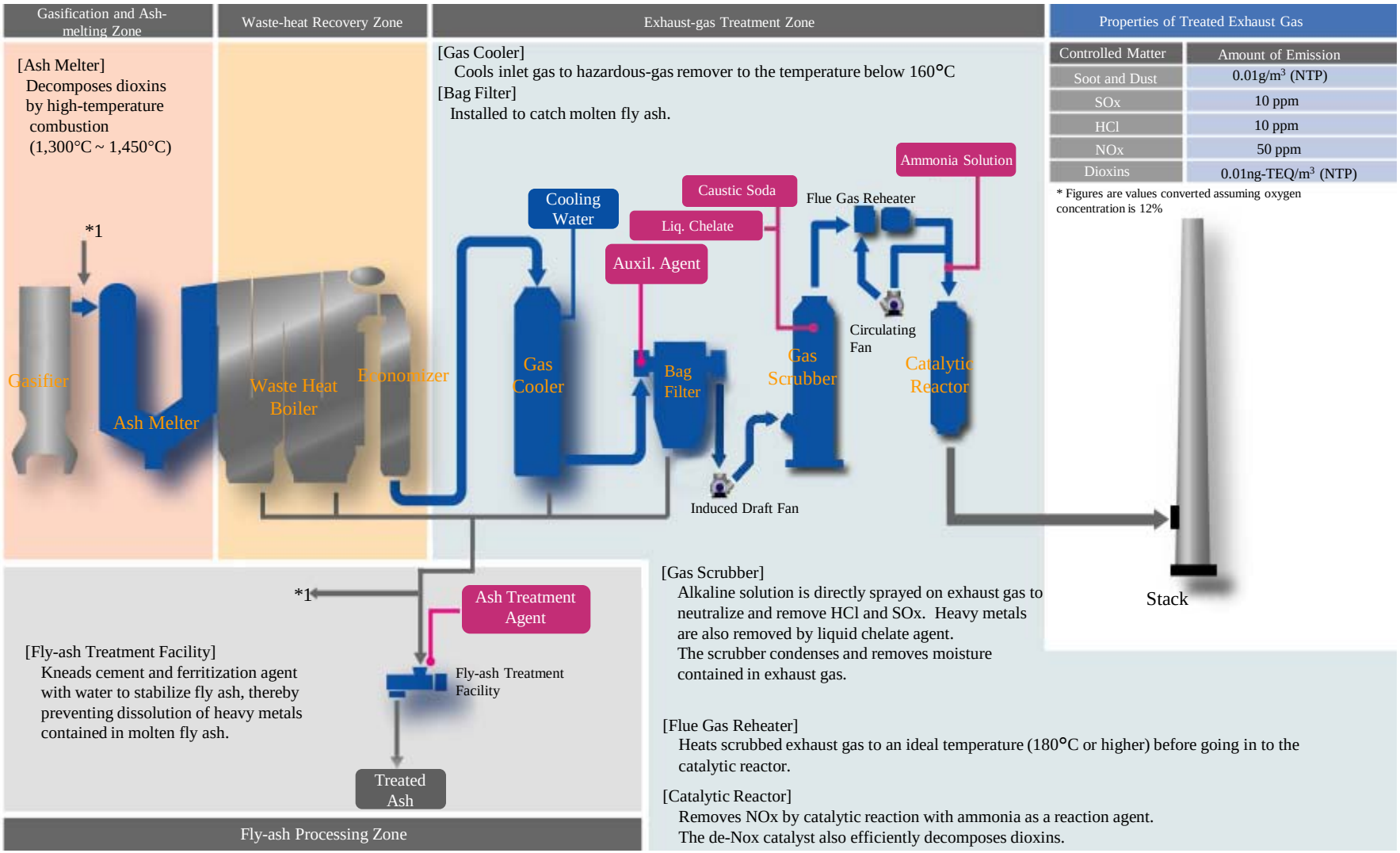
	Elution (Standard value, mg/l)	Content (Standard value, mg/kg)
Cd	<0.005 (<0.01)	<10 (<150)
Pb	<0.005 (<0.01)	<10 (<150)
Cr^{6+}	<0.04 (<0.05)	<10 (<250)
As	<0.005 (<0.01)	<10 (<150)
T-Hg	<0.000 5 (<0.005)	<0.1 (<15)
Se	<0.005 (<0.01)	<10 (<150)
F	<0.08 (<0.8)	150 (<4 000)
B	<0.1 (<1.0)	150 (<4 000)

Result of slag measurement
(example)

EBARA Fluidized Bed Gasification and Ash-melting Process


Burner, Ash Melter
Secondary Air
To Waste Heat Boiler
Waste
<300mm
Pyrolysis Gas
Secondary Air
Primary Combustion Chamber
Tertiary Combustion Chamber
Gasifier Burner
Secondary Combustion Chamber
Burner, Ash Melter
550 ~ 630℃
1300 ~ 1450℃
Fuidized Sand
Noncombustibles
Valuable Metals
Fluidized Air
Fuidized Sand
Noncombustibles
Valuable Metals
Slag

Pollution Control Measures in the Process Flow



Properties of Treated Exhaust Gas

Controlled Matter	Amount of Emission
Soot and Dust	0.01g/m^3 (NTP)
SOx	10 ppm
HCl	10 ppm
NOx	50 ppm
Dioxins	0.01ng-TEQ/m^3 (NTP)

* Figures are values converted assuming oxygen concentration is 12%

Municipal Waste

No.	Customer	Location	Capacity	Type	Inst -year	Electricity kw	
1	Joetsu Union	Niigata	15.7t/24h	TIFG	Mar.2000	45	Nightsoil sludge
2	Sakata Clean Union	Yamagata	196t/24h	TIFG	Mar.2002	1990	
3	Kawaguchi City	Saitama	420t/24h	TIFG	Nov.2002	12000	
4	Ube City	Yamaguchi	198t/24h	TIFG	Nov.2002	4100	
5	Chuno Union	Gifu	168t/24h	TIFG	Mar.2003	1980	
6	Minami-Shinshu Union	Nagano	93t/24h	TIFG	Mar.2003	800	
7	Nagareyama City	Chiba	207t/24h	TIFG	Feb.2004	3000	
8	Chubu Clean Union	Shiga	180t/24h	TIFG	Mar.2007	3000	
9	Dalsung	Korea	70t/24h	TIFG	Jun.2008	-	(HEEC License)
10	Eunpyeong	Korea	48t/24h	TIFG	Sep.2009	-	(HEEC License)
11	Hwasung	Korea	300t/24h	TIFG	Mar.2010	4400	(HEEC License)
12	Kurahama Clean Union	Okinawa	309t/24h	TIFG	Mar.2010	6000	

Industrial Waste

No.	Customer	Location	Capacity	Type	Inst -year	Electricity kw	
1	RER Aomori Renewable Energy Recycling Co.,Ltd.	Aomori	450t/24h	TIFG	Nov-02	17800	Shredder dust, Sludge
2	Nikko Mikkaichi Recycling Co. Ltd.	Toyama	63t/24h	TIFG	Jun-01	-	Shredder dust, Waste plastic
3	Tokyo Waterfront Recycle Power Co., Ltd.	Tokyo	550t/24h	TIFG	Aug-06	23000	Industrial waste

Kawaguchi Municipality

Tokyo Waterfront Recycle Power Co., Ltd.
(Plastic wastes and crushed/separated residue of construction wastes)

TOSHIBA Waste Plastics Liquefaction Process

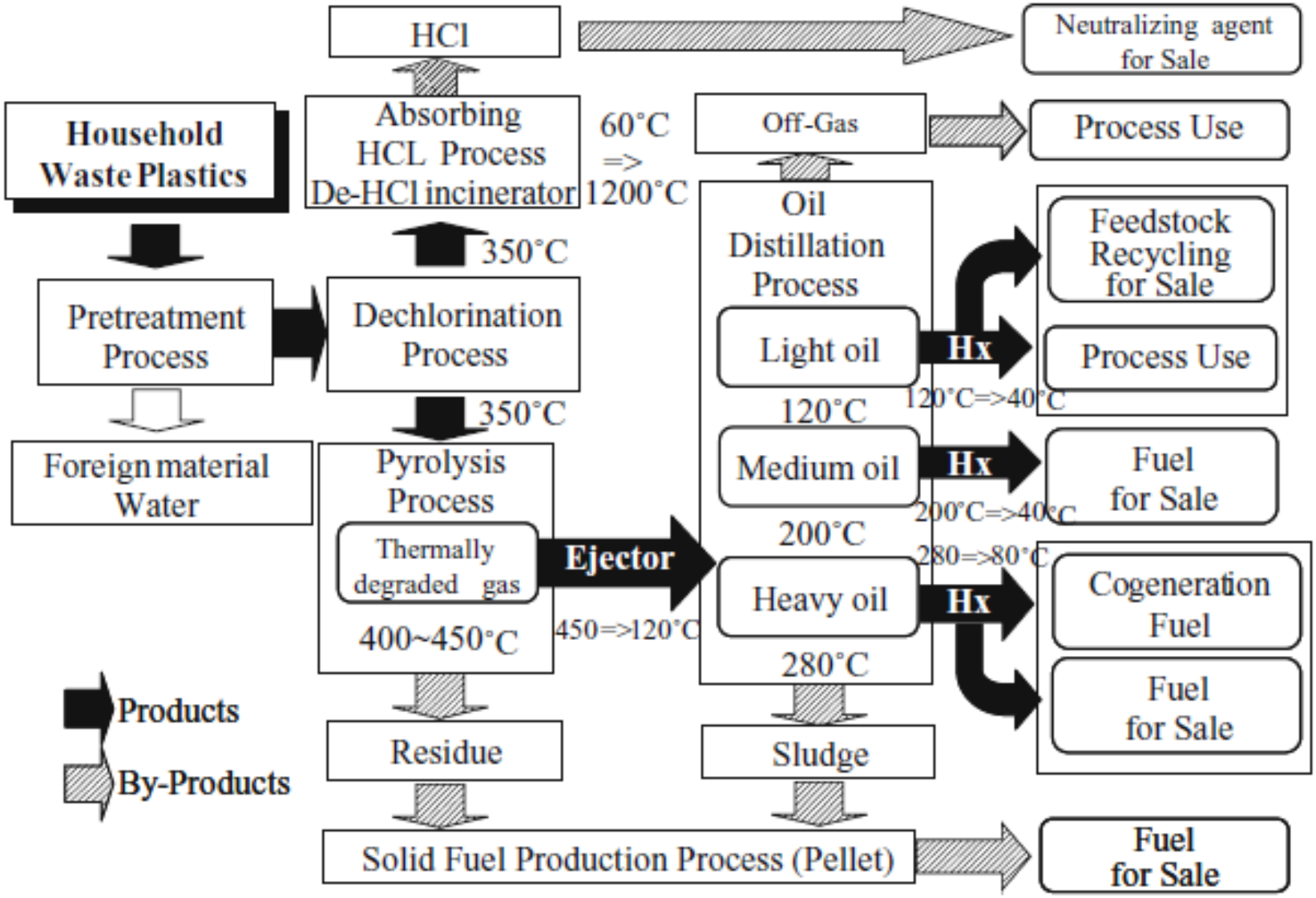
- The quantity of plastic containers and wrapping among household waste plastic was 550,000t, of which 23% (130,000t) and 46% (250,000t) were reclaimed by material recycling operations and chemical recycling operations, respectively, under the Container and Packaging Recycling Law; the remaining 31% was incinerated or landfilled.
- The breakdown of chemical recycling activities (250,000t) in 2006 were coke ovens (61%), gasification (22%), blast furnaces (15%), and liquefaction (2%).

Second Commercial Plant (Sapporo) (2000, 40t/day, MSW, US$45 million)

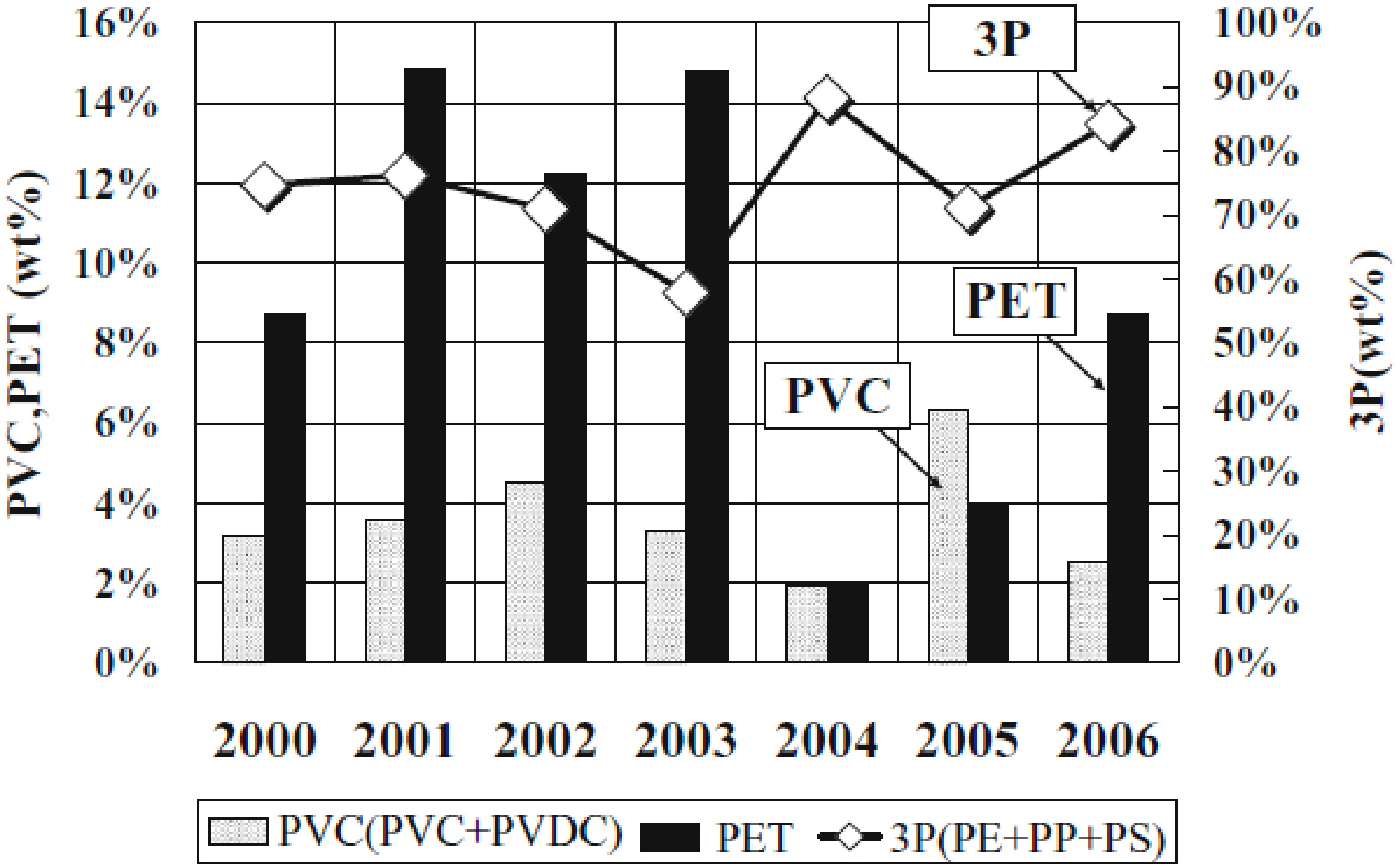
札幌プラスチック（株） 油化処理施設

プラスチック油化処理装置

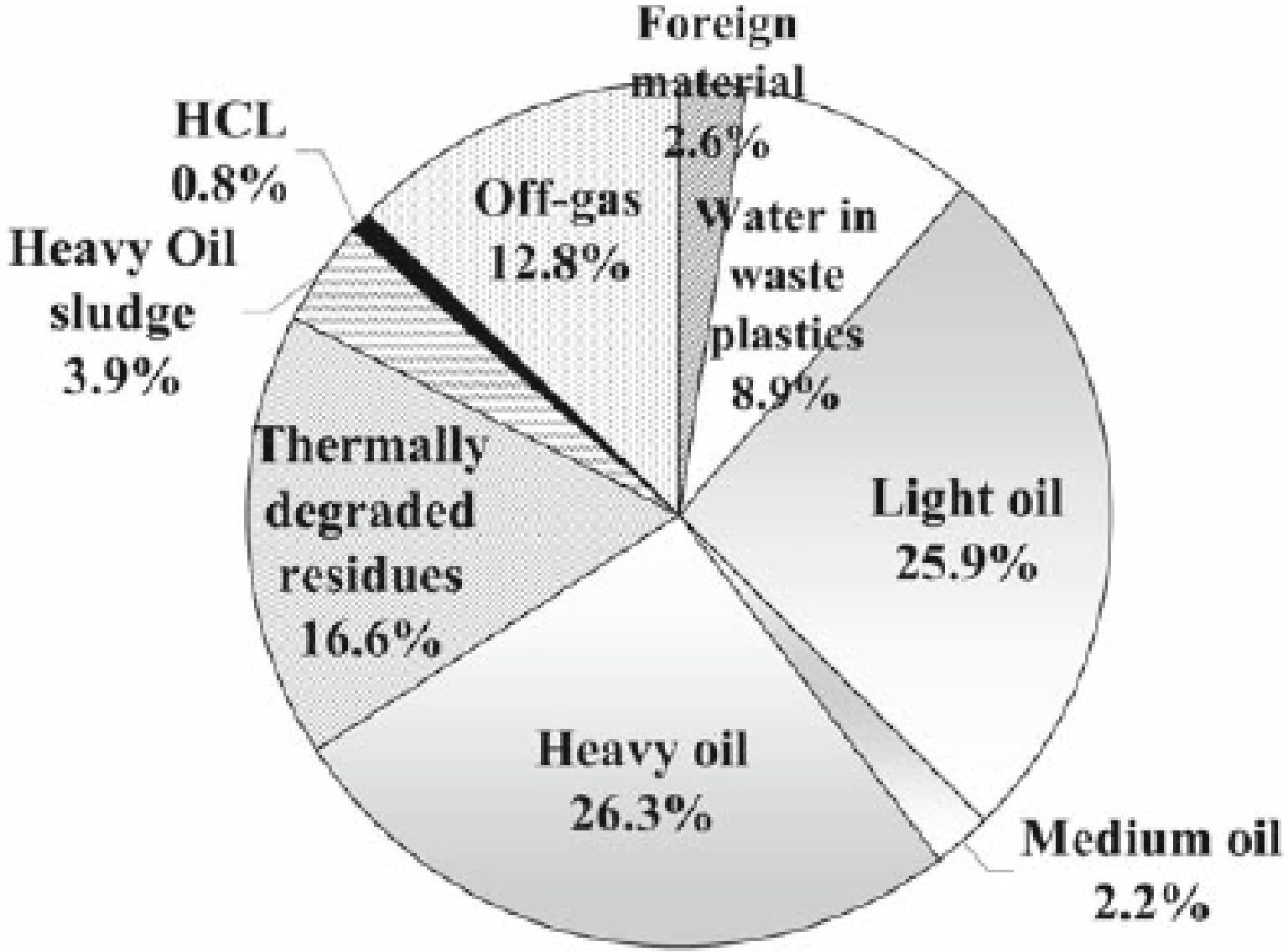
Process Flow



Composition of municipal waste plastics



Actual Recycling Rate of the Plant in 2006



Properties of the reclaimed oil

Property		Light oil	Medium oil	Heavy oil	JIS TS Z0025 (Japanese Technical Standard)
Density	g/cm3 (15°C)	0.814	0.824	0.856	
Flash point	°C	<21	78	114	
Pour point	°C	<−50	−35.0	47.5	
Reaction	pH	Neutral	Neutral	Neutral	
Ash	wt%	<0.001	<0.01	<0.01	≦0.05
Sulfur	wt%	0.002	0.03	0.08	≦0.2
Nitrogen	wt%	0.08	0.14	0.1	≦0.2
Chlorine	wtppm	50	70	60	≦100
Gross heating value	kj/kg	42070	45040	45360	

Properties of the solid fuel

Property	Solid fuel (Eco Pellet)	Degradation residue	Sludge
Lower heating value (kJ/kg)	15160	17570	31650
Carbon (wt%)	41.8	45.6	67.5
Sulfur (wt%)	0.09	0.06	0.04
Nitrogen (wt%)	0.43	0.4	0.39
Hydrogen (wt%)	5.7	2.6	6.3
Calcium (mg/kg)	88000	125000	46700
Silicon (mg/kg)	12000	52300	19800
Aluminum (mg/kg)	13000	12700	940
Total chlorine (wt%)	2.82	4.96	1.42
Inorganic chlorine (wt%)	2.82	4.79	1.42
Bulk specific gravity (kg/l)	0.72	0.389	0.868

Properties of gas emitted from the off-gas fired furnace

Periodic survery (twice a year)	Result of measurement	Emission Standard	Date
Dust (particulates)	<0.02 g/Nm^3	0.15 g/Nm^3	2007/11/21
Sulfur oxide (SOx)	<0.05 Nm^3/h	3.12 Nm^3/h	2007/11/21
Nitrogen oxide (NOx)	95 vol ppm	150 vol ppm	2007/11/21
Optional survey			
Hydrogen chloride (HCl)	2.3 mg/Nm^3	80 mg/Nm^3	2004/1/13
Dioxin	0.000018 ng-TEQ/Nm^3	0.0006 ng-TEQ/Nm^3	2004/1/20

TEQ, Toxicity Equivalency Quantity; Nm3, Gas volume at 1 atm and 0°C