Current Recycling Technologies for Plastic Waste in Japan

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1. Law for Recycling of Containers and Package

Figure 1

- **Consumers**
  - Sorted discharge
  - Supply

- **Municipalities**
  - Sorted collection
  - Declaration for amount of sorting plastic waste
  - Bidding price
  - Payment of recycling costs
  - Supply

- **Recyclers**
  - Transportation and recycling of “items to meet sorting criteria”

- **Payment of recycling costs**
  - The Japan C&P Recycling Association

- **Designated manufactures/users**
  - Payment of recycling costs

Figure 2

**Actual performance related to plastics other than PET bottles**

- **Y-axis:** Amount of Collection of C & P Plastic (thousand ton)
- **X-axis:** Fiscal year
Trends in bidding for the various recycling methods for plastics other than PET bottles

- **Kobe Steel (Kakogawa)**
  - Blast furnace: 10,000t

- **Nihon Steel (Yahata)**
  - Coke Oven: 20,000t

- **Nihon Steel (Oita)**
  - Coke Oven: 25,000t

- **Teijin Fiber (Tokuyama)**
  - Monomer B to F: 62,000t

- **Nihon Steel (Nagoya)**
  - Coke Oven: 50,000t

- **JFE Steel (Chiba)**
  - Gasification: 20,000t

- **Kyoei Steel (Onoda)**
  - Gasification: 25,000t

- **Nihon Steel (Yahata)**
  - Coke Oven: 20,000t

- **Nihon Steel (Oita)**
  - Coke Oven: 25,000t

- **Showa Denko (Kawasaki)**
  - Gasification: 60,000t

- **JFE Steel (Kawasaki)**
  - Gasification: 40,000t/30,000t
  - Blast furnace/Coke Oven

- **Orix Resource Recycling Service (Yoroi)**
  - Gasification: 450t/d

- **Mogami Kiko (Sinjyo)**
  - Liquefaction: 3t/d

- **Sapporo Plastic Recycling**
  - Liquefaction: 14,800t
  - Coke Oven: 20,000t

- **Nippon Steel (Muratoran)**
  - Coke Oven: 20,000t

- **Ube (Ube)**
  - Gasification: 30,000t

- **Mizushima Eco-Works (Kurashiki)**
  - Gasification: 555t/d

- **JFE Steel (Fukuyama)**
  - Blast furnace: 40,000t

- **Kyoei Steel (Onoda)**
  - Gasification: 25,000t

- **Nihon Steel (Tokuyama)**
  - Monomer B to F: 62,000t

- **Kobe Steel (Kakogawa)**
  - Blast furnace: 10,000t

- **Nihon Steel (Nagoya)**
  - Coke Oven: 50,000t

Large Scaled Chemical Recycling Facilities

19 Facilities:
- Monomer 2
- Blast furnace 3
- Coke oven 6
- Gasification 6
- Liquefaction 2

- **Mogami Kiko (Sinjyo)**
  - Liquefaction: 3t/d

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Figure 3

Figure 4

Large Scaled Chemical Recycling Facilities

(Complied with C&P recycling law, 2009)
2. Recycling technologies

Figure 5  The flow seat of utilization for blast furnace reducing agents

Source: JFE Steel Co.

Figure 6  The flow seat of utilization for coke oven fuels

Source: Nippon Steel Co.
Figure 7

Carbonization room

Source: Nippon Steel Co.

Figure 8

Pressurized Two Stage Gasification Process for Waste Plastics

Capacity: 10,000 t/y for household plastic waste including PVC. Producing hydrogen gas for synthesizing ammonia. Demonstration operation was completed in Sept 2000. Commercial operation has started in January 2001. (NEDO authorized technology development in cooperation with Ube Industries Ltd and Ehara Corporation)

*No real generation of Dioxins
*Plastics containing Chlorine can be used for raw materials
*Chlorine will be collected as NH4Cl

Source: Ube Industries Ltd.
**Figure 11**

*Recycling under C&S Recycling Law*

**RPF (Refuse Paper & Plastic Fuel)**

*Appearance of RPF*

- **Diameter:** 5 – 50 mm
- **Calorie:** 5,000 – 10,000 kcal/kg (Can be adjusted by varying paper content.)
- **Ash content:** 7 % max.
- **Application:** Boiler fuel, RPF power generator, etc.

**RPF Production process**

- Use paper and plastic waste from elimination waste system
- Primary crusher
- Magnetic separator
- Manual sorting
- Aluminum separator
- Vinyl chloride removal
- RPF material

<table>
<thead>
<tr>
<th>Demand for RPF</th>
<th>2006</th>
<th>1,050 Kt</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>1,310 Kt</td>
<td></td>
</tr>
<tr>
<td>Production</td>
<td>2006</td>
<td>700 Kt</td>
</tr>
</tbody>
</table>

*Source: Japan RPF Association, The Recycling Economy Times*

**Figure 12**

*Cement Kiln*

- Raw meal
- Waste plastics inlet
- Gas stream
- Material stream
- Preheater
- Precaliner
- Kiln end
- Rotary kiln
- Clinker cooler
- Cooling air
- Clinker

*Source: Japan Cement Association*
3. New recycling technologies

Figure 13
Liquefaction by Catalyst Cracking using Spent FCC Catalyst

| Source: The University of Kitakyusyu |

Table 1

<table>
<thead>
<tr>
<th>Composition</th>
<th>Waste FCC Ce(N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>n-Paraffin</td>
<td>40</td>
</tr>
<tr>
<td>C90</td>
<td>32.5</td>
</tr>
<tr>
<td>r-Paraffin</td>
<td>33</td>
</tr>
<tr>
<td>Aromatic</td>
<td>1-2</td>
</tr>
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</table>

Table 2

<table>
<thead>
<tr>
<th>Component</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paraffin(m%)</td>
<td>19.3</td>
</tr>
<tr>
<td>Olefin(m%)</td>
<td>24.7</td>
</tr>
<tr>
<td>Irving-aromatic(m%)</td>
<td>41.8</td>
</tr>
<tr>
<td>D-ring-aromatic(m%)</td>
<td>6.6</td>
</tr>
<tr>
<td>S-ring-aromatic(m%)</td>
<td>7.8</td>
</tr>
</tbody>
</table>

Source: The University of Kitakyusyu
Figure 14

Source: The University of Kitakyusyu

Figure 15

Moving-bed reactor (bench plant)

### Table 3

**Comparison of the Moving-Bed Reactor with a Tank Reactor**

<table>
<thead>
<tr>
<th></th>
<th>Moving-Bed&lt;sup&gt;1)&lt;/sup&gt;</th>
<th>Tank&lt;sup&gt;1),3)&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity, t/d</td>
<td>2.4</td>
<td>0.9</td>
</tr>
<tr>
<td>Oil yield, wt%&lt;sup&gt;2)&lt;/sup&gt;</td>
<td>99</td>
<td>85</td>
</tr>
<tr>
<td>Coke recovery, wt%&lt;sup&gt;2)&lt;/sup&gt;</td>
<td>1</td>
<td>10~15</td>
</tr>
<tr>
<td>Fuel consumption, wt%&lt;sup&gt;2)&lt;/sup&gt;</td>
<td>12~13</td>
<td>30~35</td>
</tr>
<tr>
<td>Heat-transfer area, m²</td>
<td>2.09</td>
<td>1.93</td>
</tr>
</tbody>
</table>

<sup>1)</sup> Feed: Polystyrene. <sup>2)</sup> To feed. <sup>3)</sup> 1200mm H × 1000mm Dia. Source: AIST

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**Figure 16**

**Tomakomai Thermal Power Station: Facility Flow for Generation of Electric Power**

![Diagram of Tomakomai Thermal Power Station Facility Flow](image)

- Plastic Fuel
- Fuel Preparation and Processing Plant
- Chipping Device
- Plastic Fuel Supply Facility
- Pneumatic transportation
- Boiler
- Stack
- Bag Filter
- Steam
- Air Cooled Condenser
- TG-Central Control Room
- Transmission Line
- Turbine
- Generator
- Transformer
Tomakomai Thermal Power Station: Schematic Diagram

Plant Capacity
1. Output: 74MW
   (at Generator Terminal)
2. Fuel Consumption: 710k/h/day
3. Steam Condition:
   Temperature: 400℃
   Pressure: 6.08 MPa
4. Thermal Efficiency: 27.3% (gross)
5. Boiler: Two (2)
6. Turbine: One (1)
7. Ambient Condition (Design):
   1) Dry Bulb Temp: 18℃
   2) Relative Humidity: 75%
8. Barometric Pressure: 760mmHg

No2 Boiler

Flow
- Steam
- Water
- Exhaust Gas
- Air
- Fuel/Chemicals
- Ash

No1 Circulating Fluidized Bed Boiler

Plastic Fuel
Silica
Dolomite

"A" Heavy Oil for Start Up

Gas Air Heater

Bag Filter

Forced Draft Fan

Induced Draft Fan

Stack

Source: Sanix Inc.
4. Waste to Energy

Table 4

Increasing Trend Field and Future Prospect

Source: PWMI

<table>
<thead>
<tr>
<th></th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>Future</th>
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</thead>
<tbody>
<tr>
<td>Material Recycling</td>
<td>1,464</td>
<td>1,522</td>
<td>1,643</td>
<td>1,831</td>
<td>1,841</td>
<td>++</td>
</tr>
<tr>
<td>Liquidification</td>
<td>17</td>
<td>17</td>
<td>17</td>
<td>13</td>
<td>8</td>
<td>-</td>
</tr>
<tr>
<td>Gasification</td>
<td>24</td>
<td>35</td>
<td>62</td>
<td>98</td>
<td>67</td>
<td>±</td>
</tr>
<tr>
<td>Blast Furnace &amp; Coke Oven Raw material</td>
<td>158</td>
<td>202</td>
<td>251</td>
<td>192</td>
<td>208</td>
<td>+</td>
</tr>
<tr>
<td>RDF + RPF</td>
<td>289</td>
<td>322</td>
<td>434</td>
<td>552</td>
<td>617</td>
<td>++</td>
</tr>
<tr>
<td>Waste Power Generation</td>
<td>2,065</td>
<td>2,043</td>
<td>2,164</td>
<td>2,151</td>
<td>2,315</td>
<td>++</td>
</tr>
</tbody>
</table>

Figure 18

Gasification process for ELV

Source: Toyota Motor Co.
Summary of Waste to Energy

1. Trend of waste plastic treatment in Japan
   • Material recycling and energy recovery are increasing rapidly.
   • Ministry of the environment and Tokyo metropolitan make a policy that waste plastic treatment should be changed from landfill to energy recovery.

2. Relation of energy recovery to recycling laws
   • Home appliance recycling law excluding (now)
   • End of Life Vehicles recycling law including (main technology)
   • Containers and Packaging recycling law including (liquefaction, gasification, RPF)
   Thinking that best available waste plastics treatment is energy recovery is expanding.

5. Conclusion
   • Over 500 thousands tons waste plastics were recycled and 19 large size chemical recycling plants were operated under the Containers and Packaging Recycling Law.
   • Several kind of technologies were developed such as, blast furnace reducing agent, coke oven fuels, gasification, liquefaction.
   • New technologies are developing such as, liquefaction by catalyst cracking using spent FCC Catalyst, fuel oil production using a moving-bed reactor, new technology of energy recovery process for waste plastics using circulated fluid bed boiler, next generation stoker furnaces for municipal waste and so on.
   • Material recycling, energy recovery as RDF including RPF and waste power generation is prospected to increase rapidly.
   • Thinking that best available waste plastics treatment is energy recovery is now expanding in Japan, and all kind of recycling laws except Home Appliance recycling law are permitted to utilize energy recovery technologies.