Waste to Energy – Heat recovery from waste

Hitachi Zosen Corporation

February 25, 2015
Hitachi Zosen Corporation Company Profile

A major global player in the business domains of Renewable Energy, Social Infrastructure and Disaster Prevention

We have developed a wide range of technologies based on strong capabilities in the Waste to Energy market worldwide.

Corporate Data and Business

<p>| | |</p>
<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Founded</td>
<td>1881</td>
</tr>
<tr>
<td>Incorporated</td>
<td>1934</td>
</tr>
<tr>
<td>Employees</td>
<td>9,171 (consolidated)*</td>
</tr>
<tr>
<td>Paid-in Capital</td>
<td>45 billion yen (483 million US$) *</td>
</tr>
<tr>
<td>Net Sales</td>
<td>333 billion yen (2,822 million US$) *</td>
</tr>
<tr>
<td>Headquarters</td>
<td>Osaka and Tokyo</td>
</tr>
</tbody>
</table>

Environmental Systems
- Waste to Energy plants
- Material recycle system
- Water & sludge treatment etc.

Industrial Plants
- Desalination Plants
- Power generation facilities
- Renewable energy etc.

Infrastructure
- Shield tunneling machines
- Bridges
- Disaster prevention systems etc.

Process Equipment
- Pressure vessels
- Spent nuclear fuel storage cask & canister(container) etc.

Machinery
- Marine diesel engines
- Press machines
- Precision machinery etc.

*(As of March 31, 2014)
1. WASTE TO ENERGY
Waste to Energy Plant

- Incinerator & Boiler
- Power Generation
- Flue gas treatment
- Waste receiving and feeding
- Ash treatment
Process Flow Diagram
Why to combust Mixed Waste

- Less landfill space required
- Thermal Utilization of Energy Content
- No ground leakages
- No uncontrolled gas emissions
- Reduction of green house gas emissions
- Material Utilization
- Reduction of transportation distances

Many industrialized countries have banned MSW landfills
Some Fact about WtE

- Sanitary waste treatment ➔ Improvement residential environment and Health
- Mass treatment possibility
- Good adaptability for treatment of various wastes
- Volume reduction of Waste (over 90%) ➔ Landfill life-extension

- WtE is considered as Green Energy / Renewable Energy world wide.
- Waste heat utilization & Power Generation
- Stable clean energy

- Greenhouse Gas Reduction (Carbon emission credits)
- It meets all Environmental norms in Japan or in Europe
Power Generation by WtE installation in Japan

Electrical Power Generation 1,754MW in 2012

Resource: Ministry of Environment
Power Generation Efficiency by WtE in Japan

Resource: Ministry of Environment
Global reference of WtE

**Riverside (London), United Kingdom**

- Largest EfW facility in the UK
- Hitachi Zosen Inova was full turnkey contractor including jetty and road works
- 80% of waste delivery via barges from Thames River
- Highly efficient plant (27%) at higher steam conditions
- Steam goes to 72.4 MW_{el} turbine
- Plant operation during first 4 years carried out by Hitachi Zosen Inova

**Key Data**

<table>
<thead>
<tr>
<th>Client</th>
<th>Riverside Resource Recovery Ltd.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start-up</td>
<td>2010</td>
</tr>
</tbody>
</table>

**Technology**

- Furnace: Grate furnace (air-cooled)
- Energy recovery: 4-pass boiler, turbine
- Flue gas treatment: SNCR, semi-dry process

**Technical Data**

- Fuel: Municipal waste
- Waste capacity: 2,290t/d (763t, 3 lines)
- Net calorific value: 9.0 MJ/kg
- Thermal capacity: 3 x 79.5 MW
- Steam: 3 x 54 t/h (72 bar, 427°C)
Flow sheet of London Riverside plant
### Global reference of WtE

- Hitachi Zosen is EPC contractor for Turn-key basis excluding building works
- Highly efficient plant (20.4% @ DP) even though wet scrubber and SCR in flue gas treatment system
- Hitachi Zosen providing Periodical Maintenance Services since start-up.

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### Osaka Hitashiyodo, Japan

<table>
<thead>
<tr>
<th>Key Data</th>
<th>Client</th>
<th>Osaka city</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start-up</td>
<td></td>
<td>2010</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Technology</th>
<th>Grate furnace (air cooled)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4-pass-boiler</td>
</tr>
<tr>
<td></td>
<td>dry + wet scrubber, SCR</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Technical Data</th>
<th>Municipal waste</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>400 t/day (200t/d, 2 lines)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Waste capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2 x 29 MW</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Thermal capacity</th>
<th>Power output</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 x 74 t/h (40 bar, 400° C)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Steam</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 x 74 t/h (40 bar, 400° C)</td>
</tr>
</tbody>
</table>
Flow sheet of Osaka Higashiyodo plant

- Capacity: 200t/D x 2 units
- Steam Condition: 4MPa x 400℃
- Power Generation Capacity: 10,000kW
- Generating Efficiency: 20.4%

Refuse Ash/Residue Flue gas Combustion air Steam Condensate Waste water

1 Tipping hall
2 Waste pit
3 Waste crane
4 Feed hopper
5 Reciprocating incineration grate
6 Bottom ash discharger
7 Bottom ash pit
8 Bottom ash crane
9 3-pass steam generator
10 Economizer
11 Fabric filter
12 Wet scrubber
13 Gas reheater
14 SCR
15 IDF
16 Stack
17 Combustion air preheater
18 Turbine Generator
19 Air cooled steam condenser
20 Condensate tank
21 Available waste heat facility
22 Residue screening system
23 Fly ash treatment system
24 Waste water treatment system
## Power generation efficiency at WtE in India

Hitachi Zosen India has developed standard WtE plant for Indian market: LoCal Plus

**Design Point:**
- Waste throughput: 600t/d
- Net calorific value: 1650 kcal/kg
- Power generation: 11.5MW

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total waste quantity: W kg/h</td>
<td>= 25,000 kg/h = 600t/d</td>
</tr>
<tr>
<td>Net Calorific Value: NCV kcal/kg.</td>
<td>= 1,650 kcal/kg</td>
</tr>
<tr>
<td>Energy recovery potential (kWh)</td>
<td>= 1.16 x 10^{-3} x NCV x W</td>
</tr>
<tr>
<td></td>
<td>= 1.16 x 10^{-3} x 1,650 x 25,000</td>
</tr>
<tr>
<td></td>
<td>= 47,850 kW</td>
</tr>
<tr>
<td>Power generation (kW)</td>
<td>= 11,500 kW</td>
</tr>
<tr>
<td>Power generation efficiency (%)</td>
<td>= 11,500 / 47,850 x 100 = 24.0</td>
</tr>
</tbody>
</table>
Electric Power

**Main Features**
- Only electricity production without heat utilization

**Efficiency**
- Up to 27%
Combined Heat and Power

**Main Process**
- Combined heat and power with high heat demand and heat export throughout all or most of the year

**Efficiency**
- Up to 84%

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**Main Process**
- Combined heat and power with moderate heat demand part time or throughout the whole year

**Efficiency**
- Up to 62%
Combined Cold and Power

Main Process
• Combined cold and power with moderate heat demand part time or throughout the whole year

Efficiency
• Up to 50%
## Reference of Heat Utilization

<table>
<thead>
<tr>
<th>Name</th>
<th>Heat source</th>
<th>Method</th>
<th>Medium</th>
<th>Temp.</th>
<th>Heat recovery amount</th>
<th>Heat user</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hikarigaoka, Tokyo</td>
<td>Turbine exhaust</td>
<td>Water condenser</td>
<td>Hot water</td>
<td>45°C</td>
<td>36GJ/h</td>
<td>District heating and cooling, Greenhouse</td>
</tr>
<tr>
<td>Nakatsugawa</td>
<td>Melting furnace cooling water</td>
<td>Trans heat container</td>
<td>Heat medium</td>
<td>70°C</td>
<td>3.6GJ/container</td>
<td>Hot water supply and air conditioning at hospital</td>
</tr>
<tr>
<td>Taishou, Osaka</td>
<td>Boiler steam</td>
<td>Trans heat container</td>
<td>Heat medium</td>
<td>130°C</td>
<td>0.9GJ/container</td>
<td>Hot spring, Steelworks, District heating and cooling</td>
</tr>
<tr>
<td></td>
<td>Turbine exhaust</td>
<td>Binary generation</td>
<td>Electricity</td>
<td>-</td>
<td>155kW (Net)</td>
<td>Power provider</td>
</tr>
<tr>
<td>Morinomiya, Osaka</td>
<td>Boiler steam</td>
<td>Boiler</td>
<td>Steam</td>
<td>220°C</td>
<td>150GJ/h</td>
<td>District heating and cooling</td>
</tr>
<tr>
<td>Ichihara</td>
<td>Turbine exhaust</td>
<td>Water condenser</td>
<td>Hot water</td>
<td>80°C</td>
<td>7.0GJ/h</td>
<td>Greenhouse for agricalcure</td>
</tr>
<tr>
<td>Higashi Saitama</td>
<td>Turbine exhaust</td>
<td>Heat pump</td>
<td>Hot water</td>
<td>90°C</td>
<td>20.9GJ/h</td>
<td>Swimming pool</td>
</tr>
<tr>
<td>Toubu, Kobe</td>
<td>Scrubber exhaust heat</td>
<td>Heat exchanger</td>
<td>Hot water</td>
<td>45-60°C</td>
<td>19.88GJ/h</td>
<td>Hot water provider in Rokkou island CITY</td>
</tr>
</tbody>
</table>

From 廃棄物処理施設における高効率熱利用（2014.12）廃棄物対応技術検討懇親会報告書
**Case1: Hikarigaoka, Tokyo**

### Client
Clean Association of Tokyo 23
Hikarigaoka, Tokyo
1983

### Start-up
Tokyo heat supply Co., Ltd.
Greenhouse
District heating and cooling.

### Technology
Furnace
Grate furnace

### Technical Data
- **Waste capacity**: 300 t/day (150t/d, 2 lines)
- **Power output**: 4,000kW

#### Diagram:
- **Incineration & Boiler**
  - High Temperature Water, 130℃
  - heat exchanger
  - Water-cooled condenser
  - Low Temperature Water, 45℃
- **STG**
- **Electricity**
- **Gymnasium**
- **Tokyo heat supply Co., Ltd.**
- **Greenhouse**
- **District heating and cooling**

#### Text:
- **Low-temperature water** recover heat from turbine exhaust with a water-cool-condenser.
- **Low-temperature water** is supplied to Tokyo heat supply Co., Ltd. and greenhouse.
- **Tokyo heat supply Co., Ltd.** supply to district heating and cooling.
- **High-temperature water** recover heat from the steam with a heat exchanger.
- **High-temperature water** is supplied to gymnasium and elderly facility.

From 廃棄物処理施設における高効率熱利用（2014.12）廃棄物対応技術検討懇親会報告書
Case2: Nakatsugawa

Client
Environment Center
Nakatsugawa, Gifu

Start-up
Nakatsugawa, Gifu
2004

Technology
Furnace

Gasifying and melting furnace

Technical Data
Waste capacity
98 t/day (49t/d, 2 lines)

Power output
900kW

- The exhaust heat generated from the facility accumulates in a heat storage container.
  Heat is supplied to the city hospital.
- Metal cooling water is 70-80 °C, supplied heat is 40-50°C.
- Transport distance of the container is 3km.
- Heat storage capacity for one container is 1.0MWh. It makes 1-2 times of heat storage a day.

From 廃棄物処理施設における高効率熱利用 (2014.12) 廃棄物対応技術検討懇親会報告書
Case3: Taishou, Osaka

Client
Osaka City Environment Bureau
Taishou, Osaka

Start-up
1980

Technology
Grate furnace

Technical Data
Waste capacity: 600 t/day (300t/d, 2 lines)
Power output: 3,000kW (Steam turbine)
250kW (Binary generation)

- Binary generation is carried out by the turbine exhaust steam of facility.
- Heat storage transportation is carried out by boiler steam.
- The electricity which generated by binary generation is sold and the heat supplied to Hot spring, Steelworks, District heating and cooling by the heat storage transportation.
- Transport distance of the containers is 2-7km.

From 廃棄物処理施設における高効率熱利用（2014.12）廃棄物対応技術検討懇親会報告書
2. CO-GENERATION SYSTEM
<table>
<thead>
<tr>
<th>(MW)</th>
<th>0.5</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas Turbine</td>
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<tr>
<td></td>
<td>501Kb7S</td>
<td>VHP6</td>
<td></td>
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<tr>
<td>Gas Engine</td>
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<td>TCG2020V16</td>
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<tr>
<td>Diesel Engine</td>
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<td>W18V32</td>
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</table>

Hitachi Zosen Power Plant Line-Up

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Co-Generation System

• Power generation system with a total efficiency exceeding 80% achieved with heat recovery from exhaust gas.
• Environmental-friendly system by reducing GHG emissions.
• Self-standing power generating system even in the grid black-out situation.
• Peak-cut operation is possible

![Diagram showing power generation efficiency]
## Gas Turbine Cogeneration - Achievement

<table>
<thead>
<tr>
<th>Gas Turbine</th>
<th>Number of Plants</th>
<th>Number of Engines</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>GT-10 (4,000kW)</td>
<td>10</td>
<td>16</td>
<td>54,300kW</td>
</tr>
<tr>
<td>GT-13 (5,000kW)</td>
<td>3</td>
<td>3</td>
<td>14,500kW</td>
</tr>
<tr>
<td>GT-15 (6,000kW)</td>
<td>1</td>
<td>3</td>
<td>16,200kW</td>
</tr>
<tr>
<td>VHP6 (6,000kW)</td>
<td>27</td>
<td>34</td>
<td>208,280kW</td>
</tr>
<tr>
<td>LM-2500 (22,000kW)</td>
<td>3</td>
<td>4</td>
<td>106,100kW</td>
</tr>
<tr>
<td>Others</td>
<td>12</td>
<td>21</td>
<td>335,800kW</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>56</strong></td>
<td><strong>81</strong></td>
<td><strong>735,180kW</strong></td>
</tr>
</tbody>
</table>
Middle Class Gas Turbine – Line Up

**GT-10**
RRC 501-KB5S
- Power Output: 4,100 kW (Simple Cycle)
- Steam: 11.0 t/h
- Efficiency:
  - Electricity: 27.0%
  - Steam: 50.8%
  - Total: 77.8%

**GT-13**
RRC 501-KB7S
- Power Output: 5,490 kW (Simple Cycle)
- Steam: 12.2 t/h
- Efficiency:
  - Electricity: 29.5%
  - Steam: 45.2%
  - Total: 75.4%

**VHP-6**
RRC 501-KH5
- Power Output: 6,100～4,200 kW (Variable)
- Steam: 0.4～8.7 t/h
- Efficiency:
  - Electricity: 39.0～29.9%
  - Steam: 1.9～46.6%
  - Total: 40.9～76.5%
Middle Class Gas Turbine – Features

• Controlled by Hitachi Zosen’s Original Governors ‘Hicot’
• Powered by Rolls–Royce Aero Derivative Gas Turbine
  ✓ Light Weight & Compact but High Performance
• High Reliability
  ✓ More than 13,000 units for Aero, 1,900 units for Power Generation
• Easy Maintenance
  ✓ Sectioned in 6 modules
  ✓ Spare Engines available, anytime dispatchable for an emergency GT replacement work (only few hours)
• Durable for Daily Start & Stop operation
  ✓ Designed for frequent Start & Stop operation inherited by Aero industry
  ✓ Not affected in operational hours by the number of starts & stops
Difference between VHP6 and Simple Cycle

- **VHP6**

  Variable Heat and Power Operation is Possible by Steam Injection

- **SIMPLE CYCLE**

  Constant ratio of Heat and Power Operation
Feature of VHP System

- **Variable heat and power operation is possible without shut down.**

  When you need more power and less steam (e.g. Summer season), you can generate 6MW power with 0.4t/h steam by injecting excess steam to gas turbine to increase power.

  When you need more steam and less power (e.g. Winter season), you can generate 4MW power with 10t/h steam by no injection of steam to gas turbine.

### Performance Comparison

<table>
<thead>
<tr>
<th>Mark</th>
<th>Ambient Temp. (℃)</th>
<th>Power Output (kW)</th>
<th>Steam for GT (kg/h)</th>
<th>Steam for Factory (kg/h)</th>
<th>Fuel Consumption (kcal/kW)</th>
<th>Electrical Efficiency (%)</th>
<th>Efficiency incl. Steam (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mark I</td>
<td>15</td>
<td>6,100</td>
<td>9,792</td>
<td>400</td>
<td>2,207</td>
<td>39.0</td>
<td>40.9</td>
</tr>
<tr>
<td>Mark II</td>
<td>15</td>
<td>6,120</td>
<td>9,792</td>
<td>3,500</td>
<td>2,370</td>
<td>36.3</td>
<td>51.9</td>
</tr>
</tbody>
</table>

### Performance Comparison

<table>
<thead>
<tr>
<th>Mark</th>
<th>Ambient Temp. (℃)</th>
<th>Power Output (kW)</th>
<th>Steam for GT (kg/h)</th>
<th>Steam for Factory (kg/h)</th>
<th>Fuel Consumption (kcal/kW)</th>
<th>Electrical Efficiency (%)</th>
<th>Efficiency incl. Steam (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mark I</td>
<td>15</td>
<td>4,200</td>
<td>2,052</td>
<td>8,678</td>
<td>2,878</td>
<td>29.9</td>
<td>76.5</td>
</tr>
<tr>
<td>Mark II</td>
<td>15</td>
<td>4,220</td>
<td>2,054</td>
<td>9,408</td>
<td>2,881</td>
<td>29.9</td>
<td>81.4</td>
</tr>
</tbody>
</table>

**NO Energy is Wasted!!**
501-KH5 Gas Turbine for VHP6

Air Compressor

Gas Turbine

Steam Injection Hole (Down Stream)

Steam Injection Hole (Upper Stream)
Gas Turbine Generator Package

Air Intake housing

Exhaust Gas to Heat Recovery Boiler

Generator

Reduction Gear

Gas Turbine
Hitz VHP6(1)

6MW-VHP6 Gas Turbine Power System (Himeji, Japan)
Hitz VHP6(2)
1. 24hours On-Line monitoring system
2. Monitored by Hitachi Zosen technicians for 24hours
3. Advisory service for Preventive Maintenance is available
4. Share the same information by both parties, Customer and Hitachi Zosen regardless the plants location for initial diagnosis
Thank You