HISTORY OF PDMR DEVELOPMENT

1997
- PDMR Development Agreement - Hitachi Metals & WPC

1998
- WPC Testing – Madison PA
- Yoshii Test Plant Construction
- Eco Valley - environmental assessment

1999
- Yoshii – one year of MSW testing
- Eco Valley – 7 meetings with Residents

2000
- Yoshii – JWRF certification received in September
- Eco Valley – construction began
- Mihama-Mikata – presentation to government

2001
- Mihama-Mikata – construction began

2002
- Plasma Component Manufacturing Agreement – Hitachi Metals & WPC
- Eco Valley – commissioning
- Mihama-Mikata - commissioning

2003
- Eco Valley - operational (ASR & MSW)
- Mihama-Mikata – operational (MSW & Sludge)

2004
- Eco Valley – freeboard refractory replaced

2005
- Eco Valley – bottom shape remodeled & refractory structure of PFMR changed
- Refractory materials of Afterburner changed

2006
- Plant tours begin
- Eco Valley – refractory materials of Afterburner changed
- Mihama-Mikata – 3 year guarantee ended

2007
- Eco Valley – temperature control changed during commercial operation
ADVANTAGE OF PDMR

Gasification/melting zone combined-type shaft furnace
1. Simple structure – no internal drive unit
2. High volume of accumulated heat – MSW can also be treated
3. Melting zone 1,550° C or higher – high quality slag and metal are discharged

After burner
1. Temperature: 850~950° C
2. Residence time: 2 seconds or more
   * Dioxins are destroyed by intense heat

Plasma Torch & Coke Bed
1. Output easily adjusted
2. Smooth continuous discharge of molten slag and metal

Gasification Zone
Melting Zone
THE JAPANESE FACILITIES

Hitachi Metals’ Eco-Valley Utashinai WTE Facility

Hitachi Metals’ Mihama-Mikata WTE Facility
ECO – VALLEY UTASHINAI WTE FACILITY

- The largest facility is named Eco-Valley and is located in Utashinai, Hokkaido. Built over two years, it was commissioned in 2002 and has been fully operational since 2003.
- The Eco-Valley was designed to process MSW and auto shredder residue.
- Eco-Valley is operating with 8 Marc-3a Plasma Systems – Two operating gasification islands with four torches each.

### Specifications of the Eco-Valley, Utashinai Facility

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Capacity</td>
<td>165 metric tons/Day (24 hours) of auto-shredder residue as fuel</td>
</tr>
<tr>
<td>Number of trains</td>
<td>2 trains operating at 82.5 metric tons per 24 hours/train</td>
</tr>
<tr>
<td>Power Generated</td>
<td>7.9MW</td>
</tr>
<tr>
<td>Power Exported</td>
<td>4.3MW</td>
</tr>
</tbody>
</table>

Inside the Eco Valley, Utashinai Facility
UTASHINAI PROCESS FLOW DIAGRAM
OPERATIONAL ISSUE #1: BOTTOM DIAMETER TOO LARGE

Original

- Plasma Torches
- Blind/cold spots cause slag to harden

Modified

- Reduced Bottom Diameter
- Uniform hot zone creates continuous slag flow

Original:
- Bottom Diameter: 2300 mm
- Plasma Torches

Modified:
- Bottom Diameter: 1600 mm
- Uniform hot zone creates continuous slag flow
OPERATIONAL ISSUE #1: BOTTOM DIAMETER TOO LARGE

Slag Buildup on Reactor Bottom Section

Slag Close-up Below Torch Tuyeres

Slag Tapping – smooth flow
OPERATIONAL ISSUE #2: INCORRECT REFRACTORY

**Freeboard Zone**
- First Layer: High Almina
- Second Layer: SiO₂/Al₂O₃
- Third Layer: Insulation

**Gasification Zone**
- First Layer: High Almina
- Second Layer: SiO₂/Al₂O₃
- Third Layer: Insulation

**Melting Zone**
- First Layer: High Almina
- Second Layer: SiC

**Original**
- Freeboard Zone: 3 layers
- Gasification Zone: 3 layers
- Melting Zone: 2 layers plus water wall

**Improvement**
- Freeboard Zone: 3 layers
- Gasification Zone: 3 layers
- Melting Zone: 2 layers plus water wall

**Very short life span in the Melting and Gasification Zones**
- Life span increased to 4 years in the Melting and Gasification Zones
OPERATIONAL ISSUE #3: PARTICULATE CARRY-OVER

<table>
<thead>
<tr>
<th>Improvement</th>
<th>Method</th>
<th>Effect</th>
</tr>
</thead>
</table>
| A:          | feed pipe for prevention of short pass | • ash carry-over was reduced by 50%  
• feed pipe melted |
| B:          | Temperature Control of exiting syngas  
1000°C  
750~800°C | • not molten but accumulated inside  
• not molten and not accumulated |
OPERATIONAL ISSUE #3: PARTICULATE CARRY-OVER

Slag and Ash Accumulation Inside the Afterburner

Before modification – large accumulation

After modification – accumulation reduced
SUMMARY OF ECO VALLEY EXPERIENCE

1. Eco Valley experienced many problems with ASR in the early year of operation, which led to numerous improvements

2. Eco Valley has established the PDMR system for use with MSW

3. Eco Valley has continued commercial operation with MSW since 2003

4. Plant has proven relatively easy to operate

5. Plasma torches are proven to be reliable and robust
NEXT GENERATION GASIFER DESIGN

- Alter NRG Corp. purchased Westinghouse Plasma Corporation in 2007
- Alter worked closely with Hitachi Metals to understand operation of Utashinai
- Re-work of the original design through 2008/2009 to incorporate Utashinai experience
- Use of advanced engineering tools to enhance design further
- Strategic partnerships with engineering companies and material supply companies (e.g. refractory)
- Modifications and improvements to pilot plant in Madison WI to further prove new design elements
UTASHINAI ISSUES ADDRESSED IN NEXT GENERATION DESIGN

• Issue 1 – Bottom diameter sizing
  – Using available thermal modeling tools,
  – Comparison of existing plant data
  – Approximation of steady state heat flux to ensure internal temperature is well above ash melting point
  – Validation/testing in our pilot plant

• Issue 2 – Refractory
  – Approximation of slag freezing plane through thermal modeling work (Hatch)
  – Working with Saint Gobain on best suited materials selection → conductive inner layer, similar to Eco-Valley

• Issue 3 – Carryover issues
  – Internal partial water quench solidifies molten and sticky particulate
  – CFD work ensures that bulk gas flow is cold enough prior to any changes in direction
  – Drop tube design available for suitable feedstocks, minimizing entrainment of fines
ENHANCED GASIFIER DESIGN

FEED INPUT

GAS COOLING

GAS CLEAN-UP

SYNGAS

POWER

ETHANOL

DIESEL

HYDROGEN

STEAM

DROP TUBE

WIDE FREEBOARD

air feed

plasma torch

metal and slag output

SMALLER BOTTOM
SOLUTIONS TO PROBLEMS IN CURRENT DESIGN

Issue #1 (Bottom Diameter) & #2 (Refractory): Thermal modeling Work

Prediction of slag freezing plane (emulating Eco Valley refractory performance)

Finite Element Analysis for vessel mechanical integrity
SOLUTIONS TO PROBLEMS IN CURRENT DESIGN

Issue #3 (Particulate Carryover): CFD Modeling – gas flows, temperatures

Optimization of flow reducing High velocity zones, minimizing carryover
FURTHER INVESTIGATION OF PROBLEMS

Madison Gasification Facility (WPC)

Oxygen Blown Operation
Biomass Fed

Particulate Removal
Syngas Cleanup
Compression

Ethanol Production Facility (Coskata)
CO₂ EMISSIONS

Third party comparison of life cycle CO₂ equivalent emissions of landfill, Landfill with flaring, Waste to Energy, and Plasma Gasification Combined Cycle
Scientific Certification Systems report, January 2010

Twenty year accumulated GHG loading for four waste disposal options. Results compared on a basis of 274,550 metric tonnes of MSW per year. The zero axis on the chart represents emission level form baseload regional grid emissions in the Northeastern Power Coordinating Council (NPCC) National Energy Reliability Council (NERC) subregion.

The main advantage of PGCC is derived from its ability to operate with combined cycle power island.
# TYPICAL HEAT & MATERIAL BALANCE

## Confidential Heat and Material Balance

**SALES KIT SIMULATIONS**

Low Btu (i.e. HHV: 5000 Btu/scf) 5MW Gasification - Oxygen Blown (One 695 Gasifier)

**1 Apr 19**

### Inputs

<table>
<thead>
<tr>
<th>Feed in</th>
<th>LHV</th>
<th>HHV</th>
<th>As Received</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coke</td>
<td>10.567</td>
<td>29.34</td>
<td>12.62</td>
</tr>
<tr>
<td>Coke (Mild)</td>
<td>12.62</td>
<td>29.34</td>
<td>12.62</td>
</tr>
<tr>
<td>Total incl. coke (Mild)</td>
<td>20.1</td>
<td>29.34</td>
<td>12.62</td>
</tr>
</tbody>
</table>

### Outputs

<table>
<thead>
<tr>
<th>Raw SynGas (Excluding Solids)</th>
<th>LHV</th>
<th>HHV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw Material</td>
<td>3.85</td>
<td>10.567</td>
</tr>
<tr>
<td>Coke (Mild)</td>
<td>12.62</td>
<td>29.34</td>
</tr>
<tr>
<td>Total incl. coke (Mild)</td>
<td>20.1</td>
<td>29.34</td>
</tr>
</tbody>
</table>

### Steam

<table>
<thead>
<tr>
<th>Steam</th>
<th>Pressure</th>
<th>Temperature</th>
<th>CO2</th>
<th>NH3</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 kg/hr</td>
<td>308 kPa</td>
<td>150 °C</td>
<td>1.05%</td>
<td>0.06%</td>
</tr>
<tr>
<td>0 %</td>
<td>0 kg/hr</td>
<td>0 kg/hr</td>
<td>0 %</td>
<td>0 %</td>
</tr>
</tbody>
</table>

### Coal

<table>
<thead>
<tr>
<th>CO2</th>
<th>NH3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.05%</td>
<td>0.06%</td>
</tr>
<tr>
<td>0.056</td>
<td>0.02</td>
</tr>
</tbody>
</table>

### Steam

<table>
<thead>
<tr>
<th>Steam</th>
<th>Pressure</th>
<th>Temperature</th>
<th>CO2</th>
<th>NH3</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 kg/hr</td>
<td>308 kPa</td>
<td>150 °C</td>
<td>1.05%</td>
<td>0.06%</td>
</tr>
<tr>
<td>0 %</td>
<td>0 kg/hr</td>
<td>0 kg/hr</td>
<td>0 %</td>
<td>0 %</td>
</tr>
</tbody>
</table>

### Plasma Torch Energy

<table>
<thead>
<tr>
<th>Torch</th>
<th>Type of Torch</th>
<th>Energy Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mars 1</td>
<td>25 MW</td>
<td>2.31 MW</td>
</tr>
<tr>
<td>6</td>
<td>25 MW</td>
<td>2.31 MW</td>
</tr>
</tbody>
</table>

### Simulation Indicators

<table>
<thead>
<tr>
<th>Gas</th>
<th>CO2</th>
<th>NH3</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>0.06</td>
<td>0.05</td>
</tr>
</tbody>
</table>

### Other

<table>
<thead>
<tr>
<th>Steam</th>
<th>Pressure</th>
<th>Temperature</th>
<th>CO2</th>
<th>NH3</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 kg/hr</td>
<td>308 kPa</td>
<td>150 °C</td>
<td>1.05%</td>
<td>0.06%</td>
</tr>
<tr>
<td>0 %</td>
<td>0 kg/hr</td>
<td>0 kg/hr</td>
<td>0 %</td>
<td>0 %</td>
</tr>
</tbody>
</table>

### Heat Loss

| Heat Loss | 3.3 MW |

### Overall Energy Balance

<table>
<thead>
<tr>
<th>Steam</th>
<th>Pressure</th>
<th>Temperature</th>
<th>CO2</th>
<th>NH3</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 kg/hr</td>
<td>308 kPa</td>
<td>150 °C</td>
<td>1.05%</td>
<td>0.06%</td>
</tr>
<tr>
<td>0 %</td>
<td>0 kg/hr</td>
<td>0 kg/hr</td>
<td>0 %</td>
<td>0 %</td>
</tr>
</tbody>
</table>

### Material Balance

<table>
<thead>
<tr>
<th>Slag</th>
<th>Metals</th>
<th>Heat Loss</th>
<th>Feedstock</th>
<th>Oxidant Stream</th>
<th>Steam</th>
<th>Oxidant Streams</th>
<th>Feedstock Moisture Stream</th>
<th>Chemical</th>
<th>Gaseous</th>
<th>Heat Loss</th>
<th>Metals</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.4 MW</td>
<td>0.0 MW</td>
<td>3.3 MW</td>
<td>3.85</td>
<td>10.567</td>
<td>29.34</td>
<td>12.62</td>
<td>11.05</td>
<td>4.69</td>
<td>24.09</td>
<td>20.49</td>
<td>11.922</td>
</tr>
</tbody>
</table>

### Notes

1. All values are illustrative in nature and are provided for discussion purpose only.
2. Heat balance is provided on lower heating value (LHV) basis.
3. Quantity of carry over solids is affected by feedstock particle size distribution, which will be evaluated during detailed engineering.
4. Energy balance computed by VAMS on a heat of formation basis. LHV balance provided for display purposes only.
5. Gas will undergo a partial water quench to 850 °C.
6. Indicative heat and material balance, to be confirmed via pilot testing of actual feedstock.
7. Feedstock fuel is based on the average particle size of 125 mm and bulk density of 240 kg/m³.

---

*Heat of Vaporization Adjustment for LHV balance*
CONCLUSIONS

• Incorporated learnings from Utashinai operating issues into design
• Enhanced design tools (flow analysis, refractory, etc.)
• Utashinai gasifier running extremely well after modifications
• New design incorporates modifications resulting from operating problems experienced at Utashinai
MIHAMA-MIKATA VITRIFIED SLAG

Slag from the Mihama-Mikata facility has been put through a number of leachate tests including the Japanese JLT-46, NEN-7341 and the American TCLP analysis. These tests were conducted by two independent laboratories Shimadzu Techno-Research Inc. and ALS Laboratory Group. The results show that the Mihama-Mikata slag components are below the test detection limits and the slag is considered non-leaching. Below is a chart showing some of the results from the JLT-46 tests

<table>
<thead>
<tr>
<th>Heavy Metal</th>
<th>Unit</th>
<th>Method Detection Limit</th>
<th>Average Measured Value of Slag</th>
<th>JLT-46 Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic</td>
<td>mg/L</td>
<td>0.001</td>
<td>&lt;0.001</td>
<td>0.01</td>
</tr>
<tr>
<td>Cadmium</td>
<td>mg/L</td>
<td>0.001</td>
<td>&lt;0.001</td>
<td>0.01</td>
</tr>
<tr>
<td>Chromium VI</td>
<td>mg/L</td>
<td>0.005</td>
<td>&lt;0.005</td>
<td>0.05</td>
</tr>
<tr>
<td>Lead</td>
<td>mg/L</td>
<td>0.001</td>
<td>&lt;0.001</td>
<td>0.01</td>
</tr>
<tr>
<td>Mercury</td>
<td>mg/L</td>
<td>0.0001</td>
<td>&lt;0.0001</td>
<td>0.005</td>
</tr>
<tr>
<td>Selenium</td>
<td>mg/L</td>
<td>0.001</td>
<td>&lt;0.001</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Notes: mg/L = parts per million (PPM)
JLT-46 performed by Shimadzu Techno Research, Inc., Kyoto Japan on Mihama-Mikata slag samples received from Kamokon
# COMPARISON OF TECHNOLOGIES

<table>
<thead>
<tr>
<th></th>
<th>Plasma Gasification</th>
<th>Pyrolysis</th>
<th>Incineration</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Temperature</strong></td>
<td>2,000-2,500°F (gasification zone)</td>
<td>750-1400°F</td>
<td>Up to 2,192°F</td>
</tr>
<tr>
<td><strong>By-product</strong></td>
<td>Inert, non-hazardous glassy slag</td>
<td>Carbon char, silicon, metals and glass</td>
<td>Hazardous Fly Ash and Incinerator Bottom Ash</td>
</tr>
<tr>
<td><strong>Feedstock Preparation</strong></td>
<td>Pre-processing is minimal with shredding</td>
<td>Pre- processing is necessary in most cases as MSW is too heterogeneous</td>
<td>Sorting</td>
</tr>
<tr>
<td><strong>Feedstock</strong></td>
<td>Carbon material Coke is added to aid the reactions</td>
<td>Any carbon-based material</td>
<td>MSW, Medical Waste, Sewage Sludge</td>
</tr>
<tr>
<td><strong>Syngas Composition</strong></td>
<td>Carbon Monoxide and Hydrogen</td>
<td>Methane, Carbon Monoxide, and Hydrogen</td>
<td>Not produced</td>
</tr>
<tr>
<td><strong>Typical Size (commercially)</strong></td>
<td>Up to 250tpd (750-1000tpd in development)</td>
<td>Up to 300tpd</td>
<td>Up to 3,000tpd</td>
</tr>
<tr>
<td><strong>Typical Uses</strong></td>
<td>Melting incinerator ash, destroying hazardous and medical waste, processing municipal solid waste</td>
<td>Make charcoal from wood, process tires and produce carbon black, steel and fuel, created activated carbon</td>
<td>Waste disposal and to generate power &amp; heating</td>
</tr>
</tbody>
</table>
ENERGY RECOVERY FROM WASTE – PLASMA GASIFICATION IS CLEAN

- ENSR validated Alter NRG’s anticipated emissions levels for a 750tpd MSW integrated gasification combined cycle (IGCC) facility which concluded that emissions for NOx, PM, SO₂, HCl, CO, Hg and PCDD/PCDF would all be lower than EPA regulated standards and lower than six recently approved incineration facilities in the USA.

**Comparison of Resource Recovery Incinerator Permitted Emissions Limits to Anticipated Alter NRG IGCC WTE Emissions Levels (US EPA Units)**

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>units</th>
<th>Recently Permitted Incineration Facilities in USA (200-800 tpd MSW)</th>
<th>Canada - CCME</th>
<th>US EPA New Source Performance Standards</th>
<th>US EPA Section 111(d) Emissions Guidelines</th>
<th>Alter NRG MSW IGCC WTE (750 tpd MSW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOx</td>
<td>ppmvd</td>
<td>110-205</td>
<td>293.32</td>
<td>150</td>
<td>205</td>
<td>36.66</td>
</tr>
<tr>
<td>PM</td>
<td>mg/dscm</td>
<td>16-27</td>
<td>28.08</td>
<td>20 - 24</td>
<td>25 - 27</td>
<td>4.21</td>
</tr>
<tr>
<td>SO₂</td>
<td>ppmvd</td>
<td>26-29</td>
<td>136.94</td>
<td>30</td>
<td>29 - 31</td>
<td>1.05</td>
</tr>
<tr>
<td>HCl</td>
<td>ppmvd</td>
<td>25-29</td>
<td>69.4</td>
<td>25</td>
<td>29 - 31</td>
<td>6.48</td>
</tr>
<tr>
<td>CO</td>
<td>ppmvd</td>
<td>100</td>
<td>68.66</td>
<td>100</td>
<td>100</td>
<td>19.27</td>
</tr>
<tr>
<td>Hg</td>
<td>µg/dscm</td>
<td>28-80</td>
<td>Tier 3 Metals</td>
<td>50 - 80</td>
<td>80</td>
<td>&lt;1.4</td>
</tr>
<tr>
<td>PCDD/PCDF</td>
<td>ng/dscm</td>
<td>13-30</td>
<td>0</td>
<td>13 - 30</td>
<td>30 - 60</td>
<td>0</td>
</tr>
</tbody>
</table>