WFPP Performance
initial operation data

Amsterdam’s experience with the 4th-generation Waste-to-Energy

M.A.J. (Marcel) van Berlo
Hanneke van Rhee
Harry de Waart

Waste & Energy Company
City of Amsterdam
info@afvalenergiebedrijf.nl

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Amsterdam Eco-port®
AEB Business Case

Design Concepts:
World’s largest WtE facility; > 1,500,000 MTPA
- WFPP® most efficient facility; > 30% (850 kWh/MT MSW)
- Overall solids recycling rate > 98%
- Robust design, 94% availability, extended life cycle
- Amongst the world’s cleanest; emissions < 20% EPA limits

Design Benefits:
- Avoided CO2; 600,000 MTPA (CFPP)
- Zero liquids discharge
- Lowest tipping fees in the Netherlands; €60/MT
- Low Nuisance Factor, Easy Permitting
WFPP® MSW handling, Grate and Boiler
WFPP® Flue-gas cleaning
Amsterdam Facility

- SNCR and Low excess air ratio
- High steam pressure and temperature: 125 bar / 440°C
- Intermediate superheating: 14 bar / 320°C
- Reduced condensation pressure: 30 mbar/ 30°C

Net electrical efficiency of > 30 %
Gros electrical efficiency of >34 %
- Waste: 2x 33.6 t/h@10MJ/kg = 1600 t/d = 530,000 t/y
- Thermal capacity: 2x 93.4 MW\textsubscript{th}
- Live steam: 125 bar / 440°C (option 480°C)
- Steam-Steam reheating: 14 bar / 330°C
- Sea water cooling: 0.03 bar condenser
- Flue gas recirculation: 25% of total air
- Excess air ratio $\lambda$: 1.39 = 6% O\textsubscript{2-dry}
- Electric efficiency: 30.6%\textsubscript{net} at acceptance test
- Flue gas cleaning: Dry + wet
WFPP status report: Milestones

- Start of construction: Jan 2004
- Hot commissioning: 19 March, 2007
- 100% Load 2 boilers: mid April, 2007
- Turbine online: mid June, 2007
- Handover: 1st August 2007
- Troubleshooting: rest of 2007
- Operational optimisation: 2008
Electricity price as driving force for efficiency increase

![Graph showing the relationship between electricity price and electrical efficiency for large and small plants. The graph indicates an increase in efficiency with rising electricity prices, with a notable bump in efficiency around 2003 and now.](image-url)
Electricity price escalation

Average price of sold base load electricity

2008 in Germany

Questions mark
850 kWh/ton = 30% of energy in waste

Energy utilisation rate = 0.91
EU formula for R1/D10 threshold

Output per ton of waste:
- Non Ferro: 5 kg
- Iron: 25 kg
- Sand: 100 kg
- Granulate: 100 kg
- Fines: 20 kg
- Salt: 7 kg
- Gypsum: 5 kg
- Fly-ash: 10 kg
- Residue: 5 kg
Greenhouse effect; Dump, Landfill, W2E & WFPP

For 530 kTon MSW / year

- Landfill
- Electricity
- Heat
- Combined heat and power

Direct CO2 emissions:
- Dumpsite
- Landfill with biogas engines
- WtE Conventional
- WtE Combined heat and power
- WFPP
- WFPP combined heat and power
- WtE heat only

Avoided CO2:
- Dumpsite
- Landfill with biogas engines
- WtE Conventional
- WtE Combined heat and power
- WFPP
- WFPP combined heat and power
- WtE heat only
Income from waste and energy

- Extra lifetime 4th-generation
- Gain on permitting
- Green Fee
- Additional Electricity
- Electricity
- Waste

Year (before/after scheduled startup)
Water / steam flow diagram
Heat transfer surfaces (relative size, boiler, turbine only)

<table>
<thead>
<tr>
<th>Estimated technical data</th>
<th>40 bar / 380 °C</th>
<th>130 bar / 440 °C</th>
<th>90 bar / 500 °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency Eta, net</td>
<td>%</td>
<td>20,6</td>
<td>28,1</td>
</tr>
<tr>
<td><strong>Economizer heat transfer surface</strong></td>
<td>m²</td>
<td>2812</td>
<td>3338</td>
</tr>
<tr>
<td><strong>Evaporator heat transfer surface</strong></td>
<td>m²</td>
<td>2322</td>
<td>1757</td>
</tr>
<tr>
<td>Membrane wall</td>
<td>m²</td>
<td>1612</td>
<td>-</td>
</tr>
<tr>
<td>Tube bundles</td>
<td>m²</td>
<td>711</td>
<td>-</td>
</tr>
<tr>
<td><strong>Superheater surface</strong></td>
<td>m²</td>
<td>1828</td>
<td>2665</td>
</tr>
<tr>
<td>Platen</td>
<td>m²</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Bundles</td>
<td>m²</td>
<td>1828</td>
<td>2665</td>
</tr>
<tr>
<td>Heat exchanger surface intermediate reheat</td>
<td>m²</td>
<td>-</td>
<td>105</td>
</tr>
<tr>
<td><strong>Total of all heat transfer surfaces</strong></td>
<td>m²</td>
<td>6961</td>
<td>7865</td>
</tr>
<tr>
<td>Inconel 625 for membrane walls</td>
<td>m²</td>
<td>-</td>
<td>583</td>
</tr>
<tr>
<td>Inconel 686 or Colmonoy 88 for platen</td>
<td>m²</td>
<td>1st+2nd Pass</td>
<td>1st Pass</td>
</tr>
<tr>
<td>superheater</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Height of boiler house</strong></td>
<td>%</td>
<td>100</td>
<td>125 (based on AEB new/old)</td>
</tr>
<tr>
<td><strong>Length of boiler house</strong></td>
<td>%</td>
<td>100</td>
<td>136 (based on AEB new/old)</td>
</tr>
</tbody>
</table>
Joint development with TU Delft

- Fully patented process

- How to capture the value? MINING

- Existing dry Bottom ash Treatment Unit
- Granulate 0-40 mm
- Fe 7.5%
- Non ferro <1%

- Non Ferro Metals
  - Base metals (Cu, Ni, Al, etc) 1.4 %
  - Precious metals (Au, Ag, Pt) 7 ppm

- Granulates
  - 20 – 40 mm granulate fraction 7 %
  - 6 – 20 mm granulate fraction 24 %
  - 2 – 6 mm granulate fraction 18 %
  - 64u – 2 mm sand fraction 35 %
  - < 64u sludge fraction 10 %
## Guarantee Measurements

<table>
<thead>
<tr>
<th></th>
<th>100% Load</th>
<th>110% Load</th>
<th>Unit</th>
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</thead>
<tbody>
<tr>
<td>Date</td>
<td>24-7-2007</td>
<td>25-7-2007</td>
<td></td>
</tr>
<tr>
<td>Timespan</td>
<td>16:00 - 22:00</td>
<td>8.00 - 14:00</td>
<td></td>
</tr>
<tr>
<td>Duration</td>
<td>6</td>
<td>6</td>
<td>h</td>
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<tr>
<td>Net Goal</td>
<td>≥30</td>
<td>&gt;30</td>
<td>%</td>
</tr>
<tr>
<td>Mesuring company</td>
<td>Supplier</td>
<td>KEMA (Tüv)</td>
<td>Supplier</td>
</tr>
<tr>
<td>Boiler efficiency (Thermal)</td>
<td>85,2</td>
<td>85,5±1</td>
<td>85,8</td>
</tr>
<tr>
<td>Net electr. Efficiency</td>
<td>30,5        * Design</td>
<td>30,6±1,6 * Measured</td>
<td>30,8</td>
</tr>
</tbody>
</table>
## Guarantee Measurements

<table>
<thead>
<tr>
<th></th>
<th>Guaranteed value</th>
<th>Guarantee measurement</th>
<th>Unit</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>boiler 35</td>
<td>boiler 36</td>
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<tr>
<td>Waste Throughput</td>
<td>33,6</td>
<td>34,89</td>
<td>34,94</td>
</tr>
<tr>
<td>Calorific value</td>
<td>10</td>
<td>9,94</td>
<td>10,26</td>
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<tr>
<td>Steam production</td>
<td>28,4</td>
<td>28,46</td>
<td>28,52</td>
</tr>
<tr>
<td></td>
<td>= 102</td>
<td>102</td>
<td>103</td>
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<tr>
<td>Boiler outlet temperature</td>
<td>180° constant</td>
<td>177,35 - 183,75</td>
<td>°C</td>
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<tr>
<td>Boiler efficiency</td>
<td>85</td>
<td>85,2</td>
<td>%</td>
</tr>
<tr>
<td>850°C residence time</td>
<td>&gt;2</td>
<td>5</td>
<td>s</td>
</tr>
<tr>
<td>Power from waste</td>
<td>93,3</td>
<td>96,9</td>
<td>97,07</td>
</tr>
<tr>
<td>Thermal boiler load</td>
<td>102,7</td>
<td>103,63</td>
<td>102,93</td>
</tr>
<tr>
<td>Own consumption</td>
<td>&lt; 850</td>
<td>498</td>
<td>kW</td>
</tr>
<tr>
<td></td>
<td>Guaranteed value</td>
<td>Guarantee measurement</td>
<td>Unit</td>
</tr>
<tr>
<td>------------------------------</td>
<td>------------------</td>
<td>------------------------</td>
<td>------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>boiler 35</td>
<td>boiler 36</td>
</tr>
<tr>
<td>Control range Steam flow</td>
<td>2</td>
<td>-0,72 / +1,18</td>
<td>-1,57 / 0,75</td>
</tr>
<tr>
<td>Control range Steam temp</td>
<td>4</td>
<td>3,87</td>
<td>1,92</td>
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<tr>
<td>O2-concentration (boiler outlet)</td>
<td>6,5</td>
<td>6,0 - 6,73</td>
<td>ø&lt;6,5</td>
</tr>
<tr>
<td>CO (boiler outlet)</td>
<td>≤30</td>
<td>6</td>
<td>mg/m3</td>
</tr>
<tr>
<td>NOx (boiler outlet)</td>
<td>70</td>
<td>66 - 68</td>
<td>mg/m3</td>
</tr>
<tr>
<td>NH3 (boiler outlet)</td>
<td>≤5</td>
<td>3</td>
<td>mg/m3</td>
</tr>
<tr>
<td>TOC in bottomash</td>
<td>≤1,5</td>
<td>0,1 - 0,66</td>
<td>%</td>
</tr>
</tbody>
</table>
Emergency condenser: Pipe rupture design failure
Steam valves: Actuator design failure
Cranes: Unreliable Electrical drive change
Flue gas cleaning -
  Blow down treatment: Size/process Lot contractor
Fabric filter Bag problem AC-dosing
Condensate pump Leakage software change
Fly ash Loading change
Empty pass fly ash Transport change
ID-fan El-drive el-brake change freq. conv
WFPP status: Problem Areas

- Automation incomplete optimise
- Feed water pump damage repair
- Cooling water water hammer modify

- Turbine axis broken civil problem 6 months repair now running part load @90%
Inconel 625:
Lifetime 5-10 years

0.1-0.3 mm/yr corrosion
add sacrificing layer

Pictures after
>8000hrs of operation
at full load.
Gemeente Amsterdam
Afval Energie Bedrijf

Net Electricity delivered to grid in 2007

Delta between two graphs is energy of steam disposed.

Steamproduction [t/h]
Net elektricity from waste [MW]
Net electrical efficiency, 2007

Monthly averages + Moving average + Best day

Electrical efficiency

- 30.6%
- 30.7%
- 31.5%
- 31.7%
- 31.5%
- 31.1%

Graph showing CO and Nox emissions for 2007 and 2008 with monthly averages and individual daily emissions.
- Plant size matters
- High electric efficiency more than pays for itself with increasing energy cost
- Metal recovery pays for the bottom ash treatment and virtually eliminates landfill cost
- High efficiency energy production and bottom ash recycling significantly reduces CO$_2$ emissions.
- Robust design means high availability and long life cycle
The Plant is doing well, Thank You

Come and visit us in Amsterdam