Valmet Gasification technology
Case Vaskiluodon Voima

1. Valmet in brief
2. Valmet CFB gasification technology
3. Valmet CFB Gasifier for bio- Case: Vaskiluodon Voima
4. Valmet CFB Gasifier for EfW - Case: Lahti Energia
5. Summary
Valmet

- A leading technology, automation and services provider for pulp, paper, energy industries
  - Unique offering with process technology, automation and services
- 12,000 professionals serving global customer base
- Net sales EUR 2.8 billion (illustrative for 2014)
- Delivering state of the art technology, automation and services to customers around the world
- Listed on the NASDAQ OMX Helsinki Ltd.
Valmet’s key figures

Orders received
EUR ~3,400 million

Net sales
EUR ~2,800 million

Employees ~12,000

Market position
#1-2 Services
#1-3 Pulp and paper automation
#1-2 Pulp
#1-3 Energy
#1-2 Paper, board, tissue

Net sales by business line
- Services: 36%
- Automation: 19%
- Pulp and Energy: 35%
- Paper: 11%

Net sales by geographic area
- North America: 44%
- South America: 18%
- EMEA: 15%
- China: 12%
- Asia-Pacific: 11%

1) Combination of Valmet and Metso Process Automation System figures for 2014
Strong global presence close to our customers

130 locations in 33 countries
## Valmet CFB Gasifier

**Proven Industrial Process**

<table>
<thead>
<tr>
<th>CFB Gasifier</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Size</strong></td>
</tr>
<tr>
<td>20 – 140 (300) MWth</td>
</tr>
<tr>
<td><strong>Fuel</strong></td>
</tr>
<tr>
<td>Biomass, waste</td>
</tr>
<tr>
<td><strong>Gasification media</strong></td>
</tr>
<tr>
<td>Air</td>
</tr>
<tr>
<td><strong>Operating temperature</strong></td>
</tr>
<tr>
<td>750 – 900 C</td>
</tr>
<tr>
<td><strong>Operating pressure</strong></td>
</tr>
<tr>
<td>5-30 kPa(g)</td>
</tr>
<tr>
<td><strong>Product gas heating value</strong></td>
</tr>
<tr>
<td>3-7 MJ/nm³ (LHV)</td>
</tr>
</tbody>
</table>

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Fuel moisture is effecting into:
- Gas heating value
- Process capacity
- There is no exact go/no go limit
- If moisture is over 40..50 % the merits of gasification are questionable

<table>
<thead>
<tr>
<th>Fuel moisture ( waste )</th>
<th>20%</th>
<th>30%</th>
<th>40%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasifier max output</td>
<td>100</td>
<td>89</td>
<td>77</td>
</tr>
</tbody>
</table>

Waste fuel: HHV dry 22,5 MJ/kg, Ash 7,6% CFB gasifier

Gas heat value MJ/m3n hot ( incl. sensible heat )

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Valmet CFB Gasifier

Simplistically:

- Bended steel sheets + refractory = gasifier
- Simple structure => Maximized shop fabrication
Valmet Power – CFB gasification offering

**Product gas for industrial kilns**
- Woody biomass, bark, peat also waste
- 20 – 110 MW_{fuel} units
- Typically includes a dryer
- Dusty product gas
- Also other types of kilns possible
- Gas cleaning if needed

**Product gas for power boilers**
- Woody biomass, bark, peat and waste
- Superior electricity efficiency
- Existing boilers
- 50–140 (300) MW_{fuel} units
- If needed can include a dryer
- Gas cleaning as needed

**Product gas from waste for power production**
- Waste-derived fuel
- 50 – 150 MW_{fuel}
- High electricity efficiency
- Typically a new gas boiler (existing boiler is also an option)
- Gas filtering -> clean product gas
- Corrosion free

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References
Operational and under Construction

<table>
<thead>
<tr>
<th>Start up year</th>
<th>Capacity / MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>Kymijärvi II</td>
</tr>
<tr>
<td>2013</td>
<td>Vaskiuoto</td>
</tr>
<tr>
<td>2016</td>
<td>OKI</td>
</tr>
<tr>
<td>2017</td>
<td>Äänekoski</td>
</tr>
<tr>
<td></td>
<td>Huanggang</td>
</tr>
</tbody>
</table>
References
Operational Plants

Vaskiluoto 2 Power Plant
Product Gas for Power Boilers

- Biomass receiving and pre-handling
- Large-scale belt dryer
- CFB gasifier 140 MW
- Existing PC boiler

Product Gas from Waste for Power Production

- Waste receiving and pre-handling
- CFB gasifier 2x80 MW with candle filters
- New Bio-Gas fired power boiler with Air Quality Control System
Valmet CFB Gasifier for bio
Case : Vaski luodon Voima
Vaskiluoto power plant in Vaasa, Finland

View of the plant before the fuel conversion

Vaskiluoto 2 – unit
560 MWf coal fired boiler
Pulverized fuel firing
Benson-design
185 bar/540°C + 43 bar/570°C

Output capacity
230 MWe
175 MW CHP heat

Commissioning of the unit
Boiler 1983
Turbine plant 1998

Production
Electric power 0.9 – 1.7 TWh/a
District heating heat to municipal net 450 GWh/a
Drivers for the project

European CO₂-emission trading
National feed-in tariff for power production using forest biomass
Fossil fuel tax for heat production
Market and policy trend to decrease the use of coal

Existing high efficiency production unit was decided to be converted into biomass use rather than construct a new one.

Targets
- Reduction of fossil CO₂-emissions
- Cost efficient production of power and heat
- Change large amount of coal to local biomass fuel
- Maintain 100 % coal firing possibility

Alternatives
- Pulverized feed of biofuel to PC burners
- New boiler for biofuel
- Gasify biofuel and fire the gas in the existing boiler
Fluidized bed gasification was selected

**Low Investments**
- Only minor modifications were needed for the boiler
- Investment budget 40 M€ for 140 MW fuel replacement capacity

**Low operational cost**
- Local forest biomass could be utilised
- Peat as back up fuel
- Low parasitic power consumption
- High efficiency bio => electricity

**Safe solution**
- Fall Back option secured
  - Original coal firing capacity possible to keep on-line
Vaskiluoto (Vaasa) gasification plant

Biomass feed 140 MW
- Chipped or crushed wood biomass
- Multiple sources, forest residues, industrial residues, bark, stump, round wood etc…
- Peat (local resource as back-up fuel)

Biomass gas replaces 25 to 50 % of the coal depending of the boiler load
Vaskiluoto (Vaasa) gasification plant
Power plant integration

Process integration
- Product gas to the boiler
- Low temperature heat from the power plant to the wood biomass dryer

Automation integration
- Automation 100% in the power plant automation system

Utility integration
- All utilities from the power plant
Operational experience in 2 first years
Safety and operational experiences

1. Safety and operational experiences

- The plant has met all the design criteria.
- Plant responds promptly and consistently and is easy to operate.
- No accidents or safety issues because of the use of gasifier.
- Fuel drying process operates well.

The gasifier helps to reduce 230 000 tn/a of CO2 emissions.
Operational experience in 2 first years

Availability

GASIFIER:
First operational season 2013/2014 availability was 97 %
Disturbances during the first year of operation
• Air preheater imbalance => New flow guides installed
• Torch test failed => Faulty limit switch, replaced
• Air damper leakage => Faulty seal, replaced
• Burner impeller damage => Impeller replace

No main boiler outage caused by gasifier!

Heating season 2014/2015 availability was improved to 99 %

FUEL YARD:
Several stops/outages
• Not robust enough
• Rebuilds
Operational experience in 2 first years

Emissions

- Reduction of SO2 (before the final S removal process) is close to proportional to the share of gasification power.

- CO content remains low when firing gas only, below 10 ppm.
Operational experience in 2 first years

Emissions

- NOx emissions are reduced 20 ... 30 % when the share of product gas is increased to 30 ... 50 %

- When operated only with product gas a further reduction was discovered.

Gasifier power 140 MW

No-coal test run
Operational experience in 2 first years

Maintenance

- In the main boiler there has not detected any slagging nor corrosion induced by the use of product gas.
- The lining in the gasifier is in excellent condition after two years of operation.
- There is no indication of tar condensation in the gas lines nor in instruments.
- Fuel and ash handling systems are requiring normal maintenance
- Fuel yard equipment / fuel conveyors shows erosion and extensive maintenance is required.
Valmet CFB Gasifier for EfW
Case: Lahti Energia
Benefits of waste gasification

- **Product Gas Cleaning => No corrosive components in boiler**
  - High steam parameters → high electrical efficiency
    - Lahti 120 bar, 540 C live steam
    - In condensing plant over 30 % electrical efficiency
- **Lower grade waste as a fuel**
  - LHV 9 -20 MJ/kg, as fired ; Moisture up to 40 %,
  - Tolerance for fuel quality variations → multiple fuel sources
  - Lahti fuel : Household waste (origin sorted), Industrial waste, demolition wood, waste wood from industry

1. Fuel handling
2. Gasifier
3. Gas cooling
4. Gas filter
5. Gas boiler and flue gas cleaning
Valmet Gasification Technology – Benefits
Maximized electrical efficiency from Waste

![Graph showing electrical efficiency vs. steam temperature for different firing methods.](image-url)
Lahti Energia Oy:n Kymijärvi II Operationl statistic

<table>
<thead>
<tr>
<th></th>
<th>Operational hours</th>
<th>REF</th>
<th>Rec Wood</th>
<th>Elcticity</th>
<th>Distric t Heat</th>
<th>Bottom Ash</th>
<th>Filter Ash</th>
<th>Bag house ash</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>h</td>
<td>1 000 t /GWh</td>
<td>1 000 t /GWh</td>
<td>GWh</td>
<td>GWh</td>
<td>t</td>
<td>t</td>
<td>t</td>
</tr>
<tr>
<td>2012</td>
<td>4 267</td>
<td>142 /523</td>
<td>0 / 0</td>
<td>141</td>
<td>366</td>
<td>10 538</td>
<td>9 859</td>
<td>1 784</td>
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<tr>
<td>2013</td>
<td>5 353</td>
<td>141 /550</td>
<td>43 / 137</td>
<td>188</td>
<td>422</td>
<td>12 826</td>
<td>12 465</td>
<td>2 461</td>
</tr>
<tr>
<td>2014</td>
<td>6 967</td>
<td>119 /463</td>
<td>130 /497</td>
<td>241</td>
<td>514</td>
<td>16 200</td>
<td>17 292</td>
<td>2 376</td>
</tr>
<tr>
<td>2015</td>
<td>3 938</td>
<td>59 /232</td>
<td>87 /306</td>
<td>112</td>
<td>320</td>
<td>8 600</td>
<td>9 300</td>
<td>900</td>
</tr>
<tr>
<td></td>
<td>=&gt;July</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>

23.9.2015
Fuel properties 2012-2015

- The table below present numbers of some selected fuel properties based on monthly combined samples.
- Momentary fluctuations has been even more extensive.
- The plant has been reaching full capacity with broad range of fuels
- No need of support fuel

<table>
<thead>
<tr>
<th></th>
<th>LHV, ar</th>
<th>Moisture</th>
<th>Ash</th>
<th>C</th>
<th>S</th>
<th>Cl</th>
<th>Na+K</th>
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</thead>
<tbody>
<tr>
<td>Predicted design data</td>
<td>16,1</td>
<td>21,0</td>
<td>7,6</td>
<td>55,5</td>
<td>0,15</td>
<td>0,60</td>
<td>0,20</td>
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<tr>
<td>Experienced average</td>
<td>14,2</td>
<td>26,8</td>
<td>9,4</td>
<td>50,2</td>
<td>0,3</td>
<td>0,48</td>
<td>0,16</td>
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<tr>
<td>Experienced min</td>
<td>10,8</td>
<td>19,0</td>
<td>5,3</td>
<td>44,4</td>
<td>0,2</td>
<td>0,11</td>
<td>0,09</td>
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<tr>
<td>Experienced max</td>
<td>17,5</td>
<td>37,5</td>
<td>15,5</td>
<td>57,0</td>
<td>0,6</td>
<td>1,30</td>
<td>0,35</td>
</tr>
</tbody>
</table>
Lahti Energia Oy:n Kymijärvi II
Operational experiences - corrosion

Extensive measurements in gas cooler and boiler

- No indications of corrosion or erosion
- Tube manufacturing markings visible after 13 000 hrs
- Dust/ slag in gas cooler
- Inly thin dust layer in boiler
Emissions at Kymijärvi II Plant
 Guarantee test

<table>
<thead>
<tr>
<th>Emission</th>
<th>Limit</th>
<th>Measured (Guarantee test)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOx n161 mg/m$^3$</td>
<td></td>
<td>161 mg/m$^3$</td>
</tr>
<tr>
<td>SO$_2$ n7 mg/m$^3$</td>
<td></td>
<td>7 mg/m$^3$</td>
</tr>
<tr>
<td>CO n&lt; 2 mg/m$^3$</td>
<td></td>
<td>&lt; 2 mg/m$^3$</td>
</tr>
<tr>
<td>Dust n&lt; 2 mg/m$^3$</td>
<td></td>
<td>&lt; 2 mg/m$^3$</td>
</tr>
<tr>
<td>HCl n&lt; 1 mg/m$^3$</td>
<td></td>
<td>&lt; 1 mg/m$^3$</td>
</tr>
<tr>
<td>HF n&lt; 0,5 mg/m$^3$</td>
<td></td>
<td>&lt; 0,5 mg/m$^3$</td>
</tr>
<tr>
<td>TOC n&lt; 1 mg/m$^3$</td>
<td></td>
<td>&lt; 1 mg/m$^3$</td>
</tr>
<tr>
<td>PCDD/F compounds</td>
<td>0,1 ng/m$^3$</td>
<td>&lt; 0,002 ng/m$^3$</td>
</tr>
<tr>
<td>Hg n&lt; 0,0001 mg/m$^3$</td>
<td></td>
<td>&lt; 0,0001 mg/m$^3$</td>
</tr>
<tr>
<td>Cd+Tl n&lt; 0,0003 mg/m$^3$</td>
<td></td>
<td>&lt; 0,0003 mg/m$^3$</td>
</tr>
<tr>
<td>Sb+As+Co+Cr+Cu+Mn+Ni+Pb+V</td>
<td>Total 0,5 mg/m$^3$</td>
<td>&lt; 0,03 mg/m$^3$</td>
</tr>
</tbody>
</table>

* NOx, SO$_2$, HCl are usually close to limit to minimize the cost of additives
Valmet Waste Gasification
Kymijärvi II -Experiences

- Stable and easy to control
- Capacity demonstrated
- Compliance with WID (also with 2s 850C)
  - No need for support fuel
- No corrosion detected
- Availability challenges in first year
  - Need to change hot filter operational modes (start up/shut down)
  - Fuel properties improved (metal/streamers)
  - Operational routines improved
  - Availability now improved to the target level
Valmet Waste gasification
- A New Option for Co-Firing RDF / SRF

• Co-firing of cleaned gas from waste gasification in existing boiler
• Hot gas cleanup removes corrosive and harmful compounds from gas
• Minimum impact on boiler operation, corrosion, ash quality and emissions
• Minimum boiler modifications needed
  – only new gas burners
• Utilization of existing power plant infrastructure
=> Minimum additional Investment
Valmet CFB Gasification Summary

Commercially proven solutions:

→ Partial or complete fuel change in existing power plants

→ High efficiency WtE technology for electricity production

→ Firing of Industrial Process with gasified Biofuels or Waste
Thank You

For further information:

juhani.isaksson@valmet.com
CO2 emissions from Coal/Bio co-combustion

- Typical Coal fired plant CO2 emissions:
  - 1534 lb/MWh,e
  - 1315 lb/MWh,e

- Biomass share:
  - 24%
  - 34%

Vaskiluoto