EMISSIONS FROM BIOMASS COMBUSTION

Jaap Koppejan
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• Biomass heating in Ukraine

• (Particle) emissions from biomass combustion

• State of the art in combustion technology and flue gas cleaning

• Emission limits in Europe

• Growing bio-energy sector with lower emissions?
Heat sector in Ukraine

- 137 GW of boiler capacity in heat sector
- 435 PJ of fuel consumption (mainly natural gas)
- 60% of all heat now through DH systems

<table>
<thead>
<tr>
<th>MW</th>
<th>number</th>
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<td>&lt;3</td>
<td>31.106</td>
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<td>3..23</td>
<td>3.508</td>
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<tr>
<td>23..116</td>
<td>619</td>
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<tr>
<td>&gt;116</td>
<td>191</td>
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<tr>
<td>Total</td>
<td>35.424</td>
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</table>
Biomass Combustion in Ukraine

- About 30 PJ woody biomass for heat production
- Industrial boilers for woodchips and wood waste
- Over 60 straw fired boilers
- Biomass combustion may reduce dependency on natural gas
- At least one 6 MWe CHP plant in all 30 districts?

750 kW heat plant in Ukraine (KARA) 18 MWe CHP plant in Ivankiev
Environmental impacts of biomass combustion

• Particles: carbon, hydrocarbons inorganic

• $\text{NO}_x$

• Organic Gaseous Compounds

• Heavy metals

• $\text{SO}_2$
PM emissions may vary a lot between different devices

- Stoves: organic aerosols and soot
- Boilers: inorganic aerosols (salts)
<table>
<thead>
<tr>
<th>Country</th>
<th>P min MWth</th>
<th>P max MWth</th>
<th>Dust mg/m³</th>
<th>Nox mg/m³</th>
<th>CO mg/m³</th>
<th>SO2 mg/m³</th>
<th>CxHy mg/m³</th>
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<td>wood processing residues</td>
<td>136</td>
<td><strong>273</strong></td>
<td>682</td>
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<td>1</td>
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<td>wood processing residues</td>
<td>55</td>
<td><strong>273</strong></td>
<td>682</td>
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<td>wood processing residues</td>
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<td><strong>273</strong></td>
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<td>Switzerland</td>
<td>0</td>
<td>0,07</td>
<td>If NOx emission exceeds 2500 g/h</td>
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<td>469</td>
<td>7,500</td>
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<td>If NOx emission exceeds 2500 g/h</td>
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<td>If NOx emission exceeds 2500 g/h</td>
<td>38</td>
<td>469</td>
<td>938</td>
<td>-</td>
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<td>Switzerland</td>
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<td>250</td>
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<td>38</td>
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<td>750</td>
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<td>Austria</td>
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<td>Article 15a B-VG for boilers &lt; 400 kW, from 2015 onwards</td>
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<td>263</td>
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<td>ECODESIGN for biomass boilers (from 2020 onwards)</td>
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<td>682</td>
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<tr>
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<td>ECODESIGN for biomass boilers (from 2020 onwards)</td>
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<tr>
<td>EU</td>
<td>1</td>
<td>5</td>
<td>Proposal for EU MCP Directive, from 2030 onwards</td>
<td><strong>20</strong></td>
<td>300</td>
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<td>EU</td>
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<td>Proposal for EU MCP Directive, from 2025 onwards</td>
<td>25</td>
<td>300</td>
<td>-</td>
<td><strong>200</strong></td>
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</tbody>
</table>

Dutch emission limits now are most strict in Europe, and can already comply with future EU limits.
Biomass boilers have become much better over the years

- Efficiency has gone up

Small scale boilers on the market. By TFZ, Straubing
CO emission has come down
NOx is fuel bound, hardly any influence
Dust emission has come down
Emission reduction in biomass combustion

- Correct (CFD aided) design
- Optimised air staging and good burnout (temp, time, turbulence) → formation of organic aerosols and soot can be reduced to almost neglectable levels, NOx at minimum
- Low fuel bed temperatures → reduction of inorganic aerosol formation due to reduced K release from the fuel to the gas phase
- Proper control systems
- Correct dimensioning with minimum partload operation
- User training
- Secondary measures:
  - Particle filters with (wet)ESP, baghouse filters, flue gas condensation
  - NOx reduction with SNCR/SCR
# PM removal technologies

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Baghouse filters</th>
<th>Dry Electrostatic precipitators</th>
<th>Wet ESP</th>
<th>Flue gas condensation</th>
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</thead>
<tbody>
<tr>
<td>Dry fuel</td>
<td>++</td>
<td>++</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Wet fuel</td>
<td>– 1)</td>
<td>+</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>Continuous plant operation</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Intermittent plant operation</td>
<td>–</td>
<td>+</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Typical emission after cleaning (mg/Nm³ at 11 Vol.-% O₂)</td>
<td>1 – 5</td>
<td>5 – 50</td>
<td>5 – 20</td>
<td>≥ 50</td>
</tr>
<tr>
<td>Separation efficiency &gt; 95 %</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>30% – 90% 2)</td>
</tr>
<tr>
<td>Separation efficiency &gt; 99 %</td>
<td>++</td>
<td>+ 3)</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Option to use additives for removal of HCl, SOₓ and PCDD/F 4)</td>
<td>++</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Pressure loss (kPa)</td>
<td>1 – 2</td>
<td>0,15 – 0,3</td>
<td>0,5 – 1</td>
<td>0,5 – 1,5</td>
</tr>
<tr>
<td>Energy consumption (kWhₑv/MWhₜₜ)</td>
<td>14 – 17</td>
<td>2 – 5</td>
<td>5 – 10</td>
<td>5 – 10</td>
</tr>
<tr>
<td>Space requirements</td>
<td>average</td>
<td>high</td>
<td>high</td>
<td>Average</td>
</tr>
<tr>
<td>Flue gas temperature</td>
<td>180°C 5) – 220°C</td>
<td>130°C – 250°C</td>
<td>40°C – 60°C 6)</td>
<td>40°C – 60°C 7)</td>
</tr>
<tr>
<td>Bypass required?</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Sensitivity for sparks</td>
<td>hoog</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Investment costs</td>
<td>Average</td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
</tbody>
</table>
Fine particle removal techniques are available for different applications

- Dry ESP (KARA)
- Wet ESP (Scheuch)
- Bag filter (Scheuch)
NOx reduction is sometimes needed: SNCR using ureum injection
Base case scenario (NEV):
20 PJ final biomass consumption in 2020
PM reduces even with increasing amount of renewable energy
(6% share of national emissions in 2013)
### Results of scenario analysis (2014→2020)

<table>
<thead>
<tr>
<th></th>
<th>2014</th>
<th>Base case</th>
<th>Replace 2% of natural gas for heating by biomass every year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat production (TJ)</td>
<td>11.0</td>
<td>14.8</td>
<td>32.4</td>
</tr>
<tr>
<td>Biomass consumption (TJ)</td>
<td>16.8</td>
<td>20.4</td>
<td>39.9</td>
</tr>
<tr>
<td>CO (kton/year)</td>
<td>48.0</td>
<td>45.6</td>
<td>56.5</td>
</tr>
<tr>
<td>PM10 (kton/year)</td>
<td>1.6</td>
<td>1.4</td>
<td>1.8</td>
</tr>
<tr>
<td>NOx (kton/year)</td>
<td>2.1</td>
<td>2.3</td>
<td>3.9</td>
</tr>
<tr>
<td>CxHy (kton/year)</td>
<td>4.9</td>
<td>4.4</td>
<td>5.2</td>
</tr>
</tbody>
</table>

Three times more heat, with almost the same PM emission as today.
Summary and conclusions

• Good potential for biomass fired boilers in Ukraine

• Very large difference in combustion quality and emissions between obsolete and modern biomass boilers. Health impact of particles from bad biomass combustion is much worse than that of good quality combustion.

• New EU emission limits are coming up for both stoves and boilers

• State of the art combustion technology (e.g. from KARA) can already meet future EU emission limits (ECODESIGN/MCP directive) today. Dutch emission limits today are more strict.