Ultra-low Emissions, European-style
Wood and Biomass Combustion Technology

Gasification and Staged Combustion - a path to lower emissions,
higher efficiency and increased market success

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Firewood and wood pellets account for 25 percent of heating energy in Austria

BLT is the leading independent certification lab in Europe for biomass-fired heating systems
Improved Energy and Environmental Performance

Of Wood and Biomass-fired Heating Systems in Austria

Decreasing emissions

Increasing CO2 in exhaust (less excess combustion air)
Wood and Biomass Emissions Standards and Actual Performance in Austria

Note: 10 mg/MJ is approximately 0.02 lb/MBtu
Total Annual Emissions from Small Wood and Biomass Combustion in Lower Austria

<table>
<thead>
<tr>
<th>Jahr</th>
<th>CO</th>
<th>NOx</th>
<th>orgC</th>
<th>Staub</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980</td>
<td>97.666</td>
<td>1.404</td>
<td>11.878</td>
<td>2.148</td>
</tr>
<tr>
<td>1995</td>
<td>86.610</td>
<td>1.756</td>
<td>9.598</td>
<td>1.753</td>
</tr>
<tr>
<td>2000</td>
<td>82.226</td>
<td>1.866</td>
<td>9.344</td>
<td>1.918</td>
</tr>
<tr>
<td>2005</td>
<td>73.842</td>
<td>1.818</td>
<td>8.099</td>
<td>1.725</td>
</tr>
</tbody>
</table>

Note: Average PM values have continued to decrease with time
Improved Energy and Environmental Performance

Of Small Wood and Biomass-fired Heating Systems in Austria

Figure 5: Efficiency of biomass boilers (log wood, chipped wood and pellets)

Increasing efficiency
Sales of Wood and Biomass Boilers in Lower Austria

Abbildung 13: Installierte Leistung an Biomassefeuerungen bis 100 kW in Niederösterreich [Furtner et Haneder, 2005]
Key Components of Clean Wood Combustion

Gasification with 20 to 40 percent of total air flow to primary combustion chamber

Maintain approximately 1200 degrees F

Low air velocity to minimize fly ash
Key Components of Clean Wood Combustion

- Pre-heated secondary combustion air and insulated secondary combustion chamber
- Significant residence time in secondary combustion chamber
Key Components of Clean Wood Combustion

Forced combustion air supply

Oxygen sensor
Key Components of Clean Wood Combustion

Large water volume in boiler or secondary storage tank
Key Components of Clean Wood Combustion

Electrostatic filter-separator
Wood gasification-type boiler imported from Denmark

No emissions data directly available but European version (with electronic air fuel ratio control) shows clean combustion performance
KWB Classicfire 20-50kW

KWB Wood       American Oil-fired

NOx          0.08                         0.10                   lb/MMBtu
CO           10 to 60                     10 - 30                  ppm
PM           0.01                         0.005                   lb/MMBtu

Note: Secondary conversion of SO2 to sulfate aerosols from oilheat not addressed here
More Examples of Gasification-type, Wood-fired Boilers

Gasification boiler manufactured in Czech Republic
Poor wood combustion shows higher PAH levels than diesel soot

Clean wood combustion eliminates most PAH formation
Verminderung der Feinstaubemissionen um 60 bis 80%:

Low-Particle-Konzept für automatische Holzfeuerungen
Swiss Study of PM Emissions in Gasification Boilers vs. Percentage Air Flow into Primary (Gasification) Combustion Chamber

Optimal: about one-third of air flow into primary combustion chamber
790 mg/m³ approximately equal to 4 gm/hr
Swiss Research - Chemical Composition of PM from Wood Combustion

Poor combustion - PM carbon-based

Clean combustion - PM inorganic salt-based

Comparison of PM filters from diesel and clean wood combustion
Zellüberlebensrate bei Staub aus autom. Holzfeuerung u. Dieselruß

Die Zellschädigung durch Dieselpartikel war deutlich größer als durch Partikel aus der automatischen Holzfeuerung. Bei einer Dieselpartikel-Konzentration von 3 mg/ml sind praktisch alle Zellen abgestorben, während bei der selben Konzentration an Partikeln aus der automatischen Holzfeuerung die Zellschädigung nah an der Nachweigrenze liegt.

Quelle: Feinstaub in Holzfeuerungen und Gesundheitsrelevanz von Holzstaub im Vergleich zum Dieselrau – Dr. Norbert Klippel u. Dr. Thomas Nussbaumer, ETH-Zürich, 20.10.2006
New emissions standards implemented in early 1990’s led to development of ultra-clean pellet combustion technology.

Bulk delivery and storage of pellets

Pellet heating system sales have skyrocketed in Austria and several other European countries.

Sales of pellet-fired systems now equal or exceed oil-fired heating systems in several regions of Europe.
Pellet Stove Testing at Brookhaven National Laboratory

USEPA CTM 39 Test Method - Dilution Tunnel Sampling

Stoves operated with automatic controls

American

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<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>NOx</td>
<td>0.150 +</td>
<td>lb/MMBtu</td>
</tr>
<tr>
<td>CO</td>
<td>300 +</td>
<td>ppm</td>
</tr>
<tr>
<td>PM 2.5</td>
<td>0.07 - 0.2</td>
<td>lb/MMBtu</td>
</tr>
</tbody>
</table>

PM 2.5 emissions 10 - 20 times higher than for oil-fired heating systems
NOx: 0.14 lb/MMBtu
CO: 10 to 25 ppm
PM: 0.01 to 0.03 lb/MMBtu

KWB

American

NOx: 0.15 lb/MMBtu
CO: 300 + ppm
PM: 0.07 - 0.2 lb/MMBtu
Electrostatic Particle Filter for Clean Wood Combustion Systems

Ruegg-Cheminee AG in Switzerland

75 - 90 percent removal efficiency
<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>PM Emissions (lb/MMBtu)</th>
<th>Energy Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>OWB standard - Phase I</td>
<td>0.44 input</td>
<td>30 - 40 %</td>
</tr>
<tr>
<td>OWB standard - Phase II</td>
<td>0.32 output</td>
<td></td>
</tr>
<tr>
<td>EPA certified woodstove (non-catalytic)</td>
<td>0.78 approx.</td>
<td>70 %</td>
</tr>
<tr>
<td>EPA certified woodstove (catalytic)</td>
<td>0.42 approx.</td>
<td></td>
</tr>
<tr>
<td>American pellet stoves</td>
<td>0.07 - 0.2</td>
<td>60 - 80 %</td>
</tr>
<tr>
<td>Austrian pellet stoves</td>
<td>0.01 - 0.02</td>
<td>80 - 90 %</td>
</tr>
<tr>
<td>Austrian wood-fired boilers</td>
<td>0.01 - 0.04</td>
<td>80 - 90 %</td>
</tr>
<tr>
<td>No. 2 oil-fired boilers</td>
<td>0.005</td>
<td>80 - 90 %</td>
</tr>
<tr>
<td>500 ppm S oil-fired boilers</td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td>500 ppm S - B20 oil-fired boilers</td>
<td>0.0008</td>
<td></td>
</tr>
<tr>
<td>15 ppm ULS oil-fired boilers</td>
<td>0.00002 - 0.00004</td>
<td></td>
</tr>
<tr>
<td>Natural gas-fired boilers</td>
<td>0.00002</td>
<td>80 - 90 %</td>
</tr>
</tbody>
</table>
For more information

Cornell University Cooperative Extension

Dept. of Crop & Soil Sciences
http://www.GrassBioenergy.org

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Switchgrass  Reed canarygrass
Crop-based solid biofuels show interesting potential but high (3 - 5 %) ash contents can cause operating challenges.

Some crop-based pellets have 0.1 % sulfur content (equivalent to high sulfur heating oil).

SO2 emissions not thoroughly tested yet.
Multi-biomass Fuel Boiler

Manufacturer claims Capability to handle high ash content fuels
Thank You!