European Low-emissions High-efficiency Biomass-fired Technologies

NESCAUM Directors Meeting
Boston, MA
June 26, 2008

Raymond J. Albrecht, P.E.
New York State Energy Research and Development Authority
Albany, New York

Lisa Rector
Senior Policy Analyst
NESCAUM
Boston, MA
Biomass Combustion

Take Home Message

Low emissions      Possibly
Energy efficiency   Possibly
Economic benefits  Yes
The Concern
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
Swiss Study of Relative Toxicity of Wood Smoke vs. Diesel Soot

- Wood stove with bad operation
  - Toxicity = 10

- Diesel car without particle filter
  - Toxicity = 1

- Automatic wood furnace
  - Toxicity < 0.2

- Wood soot and tar (condens.)
- Diesel soot
- Ash particles = salts
Comparison between Diesel and wood particle toxicity

Both wood and Diesel particles applied to culture of lung cells of Chinese hamster (V79 standard cells)
Are European Boilers Cleaner???
## Comparative Emissions

<table>
<thead>
<tr>
<th></th>
<th>Energy Efficiency (%)</th>
<th>Fine particle emissions (lb/MMBtu)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Commercial boilers</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>US Conventional wood chip</td>
<td>70-75</td>
<td>0.2</td>
</tr>
<tr>
<td>European high efficiency and low emission chip or pellet (residential and commercial)</td>
<td>85-90</td>
<td>0.01-0.07</td>
</tr>
<tr>
<td>European high efficiency and low emission chip or pellet w/ ESP or baghouse</td>
<td>85-90</td>
<td>0.002-.02</td>
</tr>
<tr>
<td>No. 2 oil (2500 ppm S)</td>
<td>80-85</td>
<td>0.005</td>
</tr>
<tr>
<td>No. 2 oil (500 ppm S)</td>
<td>80-85</td>
<td>0.001</td>
</tr>
<tr>
<td>NO. 2 oil (15 ppm S)</td>
<td>85-93</td>
<td>0.00002-0.00004</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>80-90</td>
<td>0.00002</td>
</tr>
</tbody>
</table>
Improved Energy and Environmental Performance
Of Wood and Biomass-fired Heating Systems

Decreasing emissions
Increasing efficiency

Figure 6: CO emissions of (log wood, chipped wood and pellet) boilers
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
Potential Markets for Wood and Biomass-fired Systems

- Schools
- Businesses
- District Heating
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.

Austrian Bio-Energy Centre works with industry on R&D challenges.
Gasification and Staged Combustion - separate paths for primary and secondary combustion air. About 40 or 50 percent primary air.

Maintain about 1200 deg F in gasification chamber. Lower temperature gasification helps to reduce soot formation by reducing fuel rich, high temperature zones in flame. Also reduces ash-based particle formation.
Technology Requirements for Low Emissions Wood Combustion

- Pre-heated combustion air
- Insulated secondary combustion chamber
- Residence time in secondary combustion chamber
- Oxygen sensor to automatically control Air/Fuel Ratio
- Forced combustion air supply to control firing rate
- Computer aided analysis to optimize firebox design
European Woodstove Manufacturers

- RIKA
- The Eco-plus
  - Modulated air flow
  - CFD air flow models
Specht – Twinfire
## Swiss Woodstove Emissions Research

<table>
<thead>
<tr>
<th>Field Emissions</th>
<th>Type 1 Pre – NSPS g/hr</th>
<th>Type 2 ceramic. g/hr</th>
<th>Type 3 Staged Comb. g/hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filterable PM</td>
<td>24.8</td>
<td>0.7</td>
<td>0.3</td>
</tr>
<tr>
<td>TOC</td>
<td>37.0</td>
<td>2.7</td>
<td>&lt;0.02</td>
</tr>
<tr>
<td>Secondary filter</td>
<td>8.6</td>
<td>0.6</td>
<td>&lt;.005</td>
</tr>
<tr>
<td>Total condensables</td>
<td>45.6</td>
<td>3.3</td>
<td>&lt;0.03</td>
</tr>
<tr>
<td>Total PM</td>
<td>69.9</td>
<td>4.0</td>
<td>0.40</td>
</tr>
</tbody>
</table>

0.40 g/hr = 0.13 lb/mmBtu
Residential furnaces

• KWB
  – wood boiler systems from 10 – 300kW
  – Standard features include automatic ignition, automatic boiler cleaning and automatic ash and soot extraction

• Other industry leaders include Kohlbach and Urbas
Typical Emissions from European Wood-fired Boilers up to 1 or 2 MMBtu/hr

European Wood       American Oil-fired

NOx       0.08       0.10       lb/MMBtu
CO        10 to 60   10 - 30    ppm
PM        0.01 - 0.07 0.005     lb/MMBtu
Commercial Units

- **Stricter emission standards in Europe**
  - In Switzerland, new units over 1.8mmBtu required to have ESP now. By 2012 existing units must have ESP or equivalent controls.
  - Before controls (ESP or baghouse), total PM emissions range from 0.01 to 0.07 lb/mmBtu.
  - Most units are equipped with multi-cyclone and baghouse or ESP.

- **European systems capable of meeting standards, US units would not**
Comparison of European and US Wood Emission Standards
lb/mmBtu

- Current Swiss: 0.054
- Current Germany: 0.054
- Germany 2015: 0.01
- NY limit: 0.6
- NH limit: 0.3
- VT limit: 0.25
- RI limit: 0.2
- MA: 0.1
• Industry leaders in Europe include:
  – Schmid
    http://www.holzfeuerung.ch
  – Kohlbach
    http://www.kohlbach.at
  – Bertsch
    http://www.bertsch.at
  – Standard
Post - Combustion Treatment

In Europe use of advanced controls is commonplace!!

- Cyclones – used as first stage of control to eliminate coarse particles but not viewed as adequate control

- Baghouses – used but expensive and require maintenance

- ESPs – commonly used and effective with fine particles but are vulnerable to fouling under heavy load conditions
Electrostatic Particle Filter for Clean Wood Combustion Systems

Ruegg-Cheminee AG in Switzerland
So what else is happening in Europe???
Pellet Heating Systems
In Austria

New emissions standards implemented in early 1990's led to development of ultra-clean pellet combustion

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

Fuel standards for pellets – size, makeup, binders, etc
Micro CHP
Integration with Solar Thermal Energy
Agricultural-based Fuels

For more information

Cornell University Cooperative Extension

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

J.H. Cherry
E.V. Baker Professor of Agriculture
JHCS@cornell.edu

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.
Oeko Therm - manufacturer of biomass boilers for fuels with high ash content

Located in southern Germany
Sales of Wood and Biomass Boilers

Abbildung 13: Installierte Leistung an Biomassefeuerungen bis 100 kW in Niederösterreich [Furtner et Haneder, 2005]
Questions???