The European Experience for NOx-removal from WTE process gas – SNCR or SCR

Bettina Kamuk
Market Director WtE, Rambøll

Rambøll
Teknikerbyen 31
DK 2830 Virum
tel: +45 4598 6000
bkc@ramboll.dk
www.ramboll.dk
Rambøll Denmark

- Established i 1945
- Ramboll consulting group: more than 8,500 employees
- Leading waste-to-energy consultant with >50 specialists within WtE
- Independent consulting services
Waste-to-energy plant references - Rambøll

Denmark, 14 plants
Norway, Tromsø
Norway, Trondheim
Norway, Hamar
Norway, Oslo
Norway, Bergen
Norway, Kristiansand

Sweden, Uddevalla
Sweden, Halmstad
Sweden, Malmö
Sweden, Uppsala

Russia, Murmansk
Russia, St. Petersburg
Russia, Moscow

Ukraine, Kiev

Iceland, Reykjavik
Faroe Islands, Torshavn + Leirvik

Norway, Oslo
Norway, Bergen
Norway, Kristiansand

Canada, Environment Canada
Canada, Halton
Canada, Durham/York

US, York
US, Bristol (CT)
US, NMWDA Frederic County (MD)

Portugal, Oporto
The Netherlands, Rotterdam
Gibraltar
Spain, Mallorca

Bermuda

China, Guangzhou
Taiwan, Kaohsiung
Hong Kong
Philippines, Manila

Egypt, Cairo
Mauritius

Hungary, Budapest
Austria, Vienna
Germany, Kiel
Germany, Düsseldorf
Italy, Brescia

October 2008
Status - WtE in Europe

- Total number of plants: ~450
- Total treated waste in million tonnes/year: ~60

Termally treated waste in million tons/year

*Estimate based in Eurostat (data also included cement kilns)
## WTE in Europe

<table>
<thead>
<tr>
<th>Company</th>
<th>Number of Plants</th>
<th>Total capacity tpd</th>
<th>Average capacity tpd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Martin (2000-2010)</td>
<td>53</td>
<td>27900</td>
<td>526</td>
</tr>
<tr>
<td>Von Roll (2000-2011)</td>
<td>40</td>
<td>23130</td>
<td>578</td>
</tr>
<tr>
<td>Fisia Babcock (2000-2011)</td>
<td>24</td>
<td>14750</td>
<td>615</td>
</tr>
<tr>
<td>Babcock &amp; Wilcox Vølund (2002-2011)</td>
<td>20</td>
<td>7080</td>
<td>354</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>137</strong></td>
<td><strong>72860</strong></td>
<td><strong>532</strong></td>
</tr>
</tbody>
</table>
NOx Emission Level in Europe

EU Directive 2000/76/EF on Waste Incineration

- 135 ppmv, 7% O2 (200 mg/Nm3, 11% O2)
- 48 ppmv, 7% O2 (70 mg/Nm3, 11% O2), the Netherlands
- 54 ppmv, 7% O2 (80 mg/Nm3, 11% O2), Austria and Switzerland
- Tax-system!
- New directive is under preparation – NOx emission limit most likely to be tightened (Germany expects 70 pmm (100 mg/Nm3) in year 2013)

- Raw gas typical 175 – 250 ppmv, 7% O2 (250-350 mg/Nm3) with modern combustion control
DeNOx

4 NO + 4 NH3 + O2 → 4 N2 + 6 H2O
6 NO2 + 8 NH3 → 7 N2 + 12 H2O

Stoichiometric consumption 1,5 kg 25% NH3/kg NOx (as NO2)
(or urea (NH2)2CO)
Dry/semi-dry FGT system

1. Furnace
2. Boiler
3. Reactor
4. Baghouse-filter
5. Activated carbon (HOK)
6. SCR-system
7. ID-Fan

- SNCR: \( \text{NH}_3 \) injection
- Lime/ Limemilk
- Bottom ash
- Boiler ash
- Solid residue
- Boiler ash
- Solid residue
Selective Non Catalytic Reduction (SNCR)

- Injection in the boiler at a temperature window at 1560°F – 1650°F (850-900°C)
- 2-3 nozzle layers
- 2- 2.5 times stoichiometric consumption
- Vendors guarantees easily 100 ppm NOx (150 mg/Nm3)
- 70-100 ppm NOx depending on inlet data and restrictions for ammonia slip (100-150 mg/Nm3)
- <70 ppm NOx (<100 mg/Nm3) considerable ammonia slip
- Typical ammonia slip limits 18 ppm (10 mg/Nm3) (Austria 9 mg/Nm3 (5 mg/Nm3))
Selective Catalytic Reduction (SCR)

- 430°F - 480°F (220-250°C)
- Close to stoichiometric consumption – low NH3 slip
- Active component V2O5
- By-effect – dioxin removal (oxidation)
- Clocking – ammoniumbisulphate, (SO2<10-12 ppm/20-40 mg/Nm3)
- Emission typically 15-70 ppmv NOx (20-50 mg/Nm3)
- 5 years guarantee (lifetime >10 years) if low SO2, K, Pb, As
NOx Reduction and NH$_3$ Slip

![Graph showing the relationship between DeNOx and NH3 slip as a function of NH3/NOx-ratio.](image)

- **DeNOx, %**
- **NH3 Slip, ppm**
- **NH3/NOx-ratio**

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Bettina Kamuk - European Experience for De-NOx removal from WTE process gas

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**SCR Systems**

- High dust (between superheater and economizer) – min 540°F (280°C) to prevent clocking, reduced lifetime, less efficient

- Traditional tail-end solutions, reheat to 430°F-480°F/220-250°C (gas/gas heat exchanger and drum steam)

- Low temperature tail-end solutions, reheat to 360°F-390°F/180-200°C, only with very low SO2 or with on-line high temperature regeneration (4-18 hours at > 540°F/280°C)
Air Pollution Control - SYSAV

- **Height 70-80 ft**
- **Width 45 ft**
### Cost

<table>
<thead>
<tr>
<th>Total Capital Cost (mill USD)</th>
<th>SCR 90 ppmvdv@7% O₂</th>
<th>SCR 50 ppmvdv@7% O₂</th>
<th>SNCR 90 ppmvdv@7% O₂</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8-9.5</td>
<td>8-9.5</td>
<td>1.8</td>
</tr>
</tbody>
</table>

### Annual Cost (mill USD)

- Capital cost, 5% 20 years  
  - SCR 90 ppmvdv@7% O₂  
    - 0.65-0.75  
  - SCR 50 ppmvdv@7% O₂  
    - 0.65-0.75  
  - SNCR 90 ppmvdv@7% O₂  
    - 0.14

- Extra maintenance  
  - SCR 90 ppmvdv@7% O₂  
    - 0.07  
  - SCR 50 ppmvdv@7% O₂  
    - 0.07  
  - SNCR 90 ppmvdv@7% O₂  
    - 0.07

- Consumables - NH₃  
  - SCR 90 ppmvdv@7% O₂  
    - 0.04  
  - SCR 50 ppmvdv@7% O₂  
    - 0.05  
  - SNCR 90 ppmvdv@7% O₂  
    - 0.06

- Consumables – additional electricity for ID-fan  
  - SCR 90 ppmvdv@7% O₂  
    - 0.06  
  - SCR 50 ppmvdv@7% O₂  
    - 0.06  
  - SNCR 90 ppmvdv@7% O₂  
    - 0.06

- Lost electricity revenue from steam use to reheating  
  - SCR 90 ppmvdv@7% O₂  
    - 0.20  
  - SCR 50 ppmvdv@7% O₂  
    - 0.20  
  - SNCR 90 ppmvdv@7% O₂  
    - 0.20

<table>
<thead>
<tr>
<th>Total Annual Cost (mill USD)</th>
<th>1-1.12</th>
<th>1-1.13</th>
<th>0.20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost pr. ton of waste (USD/t)</td>
<td>5.6-6.2</td>
<td>5.7-6.30</td>
<td>1.13</td>
</tr>
</tbody>
</table>

*Cost of electricity = 70 USD/MWh. Cost of NH₃ (100%) = 400 USD/tonne*
Global NOx Pollution

Institut für Umweltphysik
Power Production, Denmark

SNCR 135 ppm/200 mg/Nm³

WtE 17%

2020

Electricity and District Heating 83%

SCR 50 ppm/70 mg/Nm³

WtE 6%

2020

Electricity and District Heating 94%

Source: Danish EPA
Lessons Learned

- SNCR has a limit around 70-100 ppm (100-150 mg/Nm3) – otherwise high NH3 slip

- High dust SCR is risky - be aware of SO2 content

- Good operational experience with tail-end SCR

- Optimise energy consumption – use drum steam and control the SO2 correspondingly

- The choice is depending on emission limits!
Contact data

Bettina Kamuk
Market Director WtE
Ramboll
Teknikerbyen 31
DK-2830 Virum
e-mail: bkc@ramboll.dk
phone +45 45 98 86 26
cell +45 26 18 12 83
www.ramboll.dk