TECHNICAL INNOVATIONS IN NEW 500,000 T/YR WTE FACILITY IN THE CITY CENTER OF COPENHAGEN (AMAGER), DENMARK

Ole Poulsen, Ramboll
• Established i 1945
• Ramboll consulting group: approx. 9,000 employees
• Leading waste-to-energy consultant with >50 specialists within WtE
• Long track record of waste-to-energy plant projects – ongoing > 30 WtE projects.
• Independent consulting services
WASTE-TO-ENERGY PLANT REFERENCES

Denmark  
Avedøre, Copenhagen, Esbjerg, Frederikshavn, Glostrup, Hjørring, Hobro, Hørsholm, Kjellerup, Kolding, Koge, Nyborg, Nykøbing F., Næstved, Roskilde, Rønne, Skagen, Slagelse, Svendborg, Sønderborg, Thisted, Aalborg, Århus

Iceland  
Reykjavik

Faroe Islands  
Leirvik, Torshavn

Norway  
Bergen, Hamar, Kristiansand, Oslo, Tromsø, Trondheim, Tønsberg

Sweden  
Halmstad, Malmö, Stockholm, Uddevalla, Uppsala

Ireland  
South East Region

UK  
Buckinghamshire, Guernsey, Hertfordshire, Isle of Man, Lincolnshire, North London, North Wales, South Wales, Warrington

Canada  
BC Ministry of Environment, Dufferin, Durham/York, Environment Canada, Halton, Peel

US  
Atlanta, Frederick County (MD), Lancaster, Palm Beach, Salt Lake City, York

Bermuda

Germany  
Düsseldorf, Kiel

Netherlands  
Rotterdam

Hungary  
Budapest

Austria  
Vienna

Czech Republic  
Ostrava

Italy  
Brescia

Portugal  
Oporto

Spain  
Mallorca, Asturias, Gibraltar

Finland  
Vaasa

Lithuania  
Vilnius

Russia  
Moscow, Murmansk, St. Petersburg

Ukraine  
Kiev

China  
Guangzhou

Taiwan  
Kaohsiung

Hong Kong

Philippines  
Manila

Egypt  
Cairo

Mauritius
COPENHAGEN-AMAGER WTE PLANT

Capacity:
2 x 35 ton/h
PERFORMANCE GOALS

- World Class Architecture
- High Energy Efficiency
- Best Possible Environmental Standard
- High Level of Community Integration
- High Level of Public Acceptance

We want to show the world that it is actually possible to produce energy for the city ... and that it is possible to do this in the middle of the city... It is important that the waste-to-energy plant is integrated into the environment... the architecture should be a gift to the city!
World Class Architecture
VISUALISATION COPENHAGEN WTE
VISUALISATION COPENHAGEN WTE
VISUALISATION BOILER HALL
MEASURES TO INCREASE ENERGY EFFICIENCY

• Optimizing of boiler steam parameters

• Optimizing of district heating couplings
  • 2 water based DH networks
  • 1 steam based DH network

• Heat pumps

• Optimizing of technical concept and internal energy consumers
OPTIMIZING STEAM PARAMETERS

Expansion: Coal compared with waste

- Higher steam parameters => increased electricity (corrosion!)
- Backpressure vs. condensing (no heat)
- Optimizing of district heating couplings (increased electricity)
No strong tendency towards higher steam parameters...

~ 400 degreeC is often chosen, even for condensing plants.
STEAM PARAMETERS EVALUATED

Limits:
400-500°C
40-130 bar

400 C/130 bar:
Erosion of turbine blades due to moisture in turbine exhaust

500 C/40 bar:
Very high corrosion rates on superheaters

Optimal choice:
“somewhere” in between
RISK FOR CORROSION

a) Evaporator part:
   Higher live steam pressure =>
   High flue gas temperature and higher steam/wall temperatures

b) Superheater part:
   Higher live steam temperature =>
   Flue gas temperature <650 C and higher steam/wall temperatures
   (High temperature corrosion)
CORROSION DIAGRAM – EVAPORATOR PART
CORROSION – DIAGRAM SUPERHEATER PART

Super heater configuration 400°C/40bar and 480°C/70bar (with drum steam cooling)

- Negative heat transfer
- Transition zone
- Corrosion zone
- Small corrosion risk

Flue gas temperature (°C)

Steam/tube wall temperature (°C)
Furthermore there is a thermodynamic tendency to that the flue gas temperature before superheaters will increase with increasing steam parameters!

b) Superheater part:
Higher live steam temperature => Flue gas temperature < 650°C and higher steam/wall temperatures (High temperature corrosion)
Higher flue gas temperatures in front of superheaters results in a higher corrosion rate.
NPV CALCULATIONS

Effects considered:
- 20 year plan period
- Identical availability
- Investment in boiler
- Increased energy sales
- Increased O&M
RECOMMENDATIONS LIVE STEAM PRESSURE

T > 450 C (too high superheater corrosion)

Too high erosion of turbine blades due to moisture in turbine exhaust

P < 70 bar (efficiency gain at relatively low corrosion risk)

Recommendation: design for 440 C / 70 bar
CHANGE IN (GROSS) ELECTRICAL EFFICIENCY

Backpressure turbine, no flue gas condensation
Effect of live steam temperature and pressure on electrical efficiency

Efficiency change compared to 400° /40 bar,a

Eg: 400/40 → 440/70 =>
Plus ~2% electric efficiency:
## ENERGY EFFICIENCY

<table>
<thead>
<tr>
<th>Basis:</th>
<th>Production</th>
<th>Own consumption</th>
<th>Energy sales</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>El ( \eta_{el} ) (brutto)</td>
<td>Heat ( \eta_{vame} ) (brutto)</td>
<td>El ( \eta_{el} )</td>
</tr>
<tr>
<td>Steam data, 440°C / 70 bar,a</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wet FGT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Front-end SCR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flue gas condensation with heat pumps</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operation without heatpumps</td>
<td>27,2%</td>
<td>65,8%</td>
<td>~ 2,7%</td>
</tr>
<tr>
<td>Operation with heat pumps</td>
<td>24,8%</td>
<td>81,4%</td>
<td>~ 2,7%</td>
</tr>
</tbody>
</table>

Source: Rambøll basic design study
Best Environmental Standard
SCENARIOS FOR THE LCA STUDY

• Dry:
  • Reactor (bicarbonate)
  • Baghousefilter
  • Economiser

• Semi-dry:
  • Reactor (hydrated lime)
  • Baghousefilter
  • Economiser

• Semi-wet:
  • Reactor (hydrated lime)
  • Baghousefilter
  • Economiser
  • Wet alkaline scrubber

• Wet:
  • Electrofilter
  • Quench
  • Wet acidic scrubber
  • Wet alkaline scrubber (calcium carbonate)
  • Baghousefilter (activated carbon)
  • Waste water treatment

• De-NOx
  • SNCR (very low NOx)
  • SCR (tail-end)
  • SCR (front-end between ESP and Economiser)
LIFE CYCLE ANALYSIS
SCENARIOS WITH WET FGT ALTERNATIVES

PE (over plant life time)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Energy</th>
<th>Process</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1 (WET FGT with SNCR)</td>
<td>364,000</td>
<td>747,000</td>
<td>1,111,000</td>
</tr>
<tr>
<td>D3 (WET FGT with SNCR+AHP)</td>
<td>213,000</td>
<td>585,000</td>
<td>803,000</td>
</tr>
<tr>
<td>D9 (WET FGT with FRONT-END SCR)</td>
<td>585,000</td>
<td>585,000</td>
<td>1,170,000</td>
</tr>
<tr>
<td><strong>D11 (Chosen solution)</strong></td>
<td>213,000</td>
<td>213,000</td>
<td>426,000</td>
</tr>
</tbody>
</table>

Chosen solution: WET FGT with FRONT-END SCR+AHP

Beacon, Malmö, November 4, 2011
EXAMPLE OF ROBUSTNESS OF FGT SOLUTION

News 2011-11-02:
Potential danish NOx tax increase from 5 kr/kg to 50 kr/kg
PLANT LAYOUT – TECHNICAL CONCEPT
PLANT LAYOUT (WIND TUNNEL MODELS)

Chimney Config: D1
True wind dir = 240°
True wind Speed = 6m/s at 10m ref
PLANT LAYOUT (WIND TUNNEL MODELS)

Chimney Config: B4A
True wind dir = 240°
True wind Speed = 6m/s at 10m ref
RESULTS

• Created Innovative Ideas
• Lowest Possible Air Emissions and High Energy Efficiency
• Reduces CO₂ Emissions
• A Landmark for the City of Copenhagen
• An Example of a Modern “Next Generation” WTE Plants

=> A Strong Support from the Public and from the City Council
THANK YOU FOR YOUR ATTENTION!

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