Experience from Vattenfall’s pilot plant in Schwarze Pumpe

Large scale testing of oxyfuel technology

Hanasaari, Espoo, 2010.11.11
Stina Rydberg
Agenda

• Vattenfall at a glance
• Short on Vattenfall’s efforts on CCS
• Schwarze Pumpe’s role in Vattenfall’s CCS-activities
• Schwarze Pumpe chronicle
• Pilot plant overview
• Tests in Schwarze Pumpe
• Lessons learned
• Summary
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  - MSc Chemical Engineering
  - R&D engineer, working with CO₂ capture technology development
  - CCS Project Communication
  - Working for Vattenfall with CCS since 2004
  - Vattenfall Power Consultant AB in Gothenburg
Vattenfall at a glance

- Europe’s fifth largest generator of electricity and the largest producer of heat
- Net sales 2009: MEUR 19,840 (SEK 205,407 million)
- Operations in Sweden, Finland, Denmark, Germany, Poland, the Netherlands, Belgium and the UK
- Core markets: Sweden, Germany and the Netherlands
- Electricity: generation, distribution and sales
- Heat: production, distribution and sales
- Gas: production and sales
- Mining and sales of lignite
- Energy trading in electricity, gas and coal
- Consulting and contracting operations in the energy sector
- 40,000 employees
- Vattenfall AB is wholly owned by the Swedish state
Our markets and main energy sources

- Wind
- Nuclear
- Gas
- Biomass
- Coal
- Hydro

Core markets
## Roadmap to realisation – Vattenfall’s project and forecast for scale-up

<table>
<thead>
<tr>
<th>Year</th>
<th>2001</th>
<th>2004</th>
<th>2008</th>
<th>2015</th>
<th>2020</th>
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<tbody>
<tr>
<td><strong>Conceptual investigations</strong></td>
<td>Theoretical studies</td>
<td>Research</td>
<td>Demonstration of the process chain</td>
<td>Verification and optimization of the component choice, the process and reduction of risks</td>
<td>Competitive on the market at that time</td>
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<tr>
<td></td>
<td></td>
<td>Basic principles</td>
<td>Interaction of components</td>
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<td>No subsidies</td>
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<td></td>
<td></td>
<td>Combustion characteristics</td>
<td>Validation of basic principles and scale-up criteria</td>
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<td></td>
<td>Long term characteristics</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>Non-commercial</td>
<td></td>
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<tr>
<td><strong>Test rig</strong></td>
<td>0.1 – 0.5 MW&lt;sub&gt;th&lt;/sub&gt;</td>
<td>€ 70 million</td>
<td></td>
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<td></td>
<td>&lt; €3 million</td>
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<tr>
<td><strong>Pilot plant</strong></td>
<td>30 MW&lt;sub&gt;th&lt;/sub&gt;</td>
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<td></td>
<td>€ 70 million</td>
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<tr>
<td><strong>Demonstration plant</strong></td>
<td>300 – 700 MW&lt;sub&gt;th&lt;/sub&gt;</td>
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<tr>
<td></td>
<td>&gt; € 1,5 billion</td>
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<tr>
<td><strong>Commercial concept:</strong></td>
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<td></td>
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<td></td>
<td>~ 1000 MW&lt;sub&gt;th&lt;/sub&gt;</td>
</tr>
</tbody>
</table>

- **2001:** Test rig
  - 0.1 – 0.5 MW<sub>th</sub>
  - < €3 million

- **2004:** Pilot plant
  - 30 MW<sub>th</sub>
  - € 70 million

- **2008:** Demonstration plant
  - 300 – 700 MW<sub>th</sub>
  - > € 1,5 billion

- **2015:** Commercial concept: ~ 1000 MW<sub>th</sub>
  - Competitive on the market at that time
  - No subsidies
Roadmap to realisation – Vattenfall’s project and forecast for scale-up

2001
• Theoretical studies

2004
• Research
  • Basic principles
  • Combustion characteristics

2008
• Demonstration of the process chain
  • Interaction of components
  • Validation of basic principles and scale-up criteria
  • Long term characteristics
  • Non-commercial

2013
• Verification and optimization of the component choice, the process and reduction of risks
  • Must be commercially viable incl. subsidies

2020
• Competitive on the market at that time
  • No subsidies

Test rig
0.1 – 0.5 MWth
< €3 million

Pilot plant
30 MWth
€ 70 million

Demonstration plant
300 – 700 MWth
> € 1.5 billion

Commercial concept:
~ 1000 MWth
The Oxyfuel pilot plant

- Furnace
- ESP
- FGD
- FGC
- ASU
- Control room
- CO₂ plant
Schwarze Pumpe Oxyfuel pilot plant overview

1. Pulverised Coal
2. Burner
3. Furnace
4. 2. Pass
5. Catalyst
6. 3. Pass
7. ESP
8. Ash
9. Cold Recirculation
10. Sealgas <1.2 bar
11. Steam-HEx
12. Air
13. Steam-HEx
14. Nitrogen
15. Sealgas 6 bar
16. Hot Recirculation
17. Vent gas
18. Ash
19. Oxygen
20. ASU
21. Nitrogen
## Basic data of the plant

<table>
<thead>
<tr>
<th>Boiler: Indirect dust fired</th>
<th>Thermal power</th>
<th>30 MW&lt;sub&gt;th&lt;/sub&gt;</th>
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<tbody>
<tr>
<td></td>
<td>Steam production</td>
<td>40 t/h</td>
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<td></td>
<td>Steam parameters</td>
<td>25 bar / 350 °C</td>
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<tr>
<td>Fuel: pulverized lignite (Lausitz)</td>
<td>LHV</td>
<td>21 MJ/kg</td>
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<td></td>
<td>Moisture</td>
<td>10,5 %</td>
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<tr>
<td></td>
<td>Coal demand</td>
<td>5.2 t/h</td>
</tr>
<tr>
<td>Media: Oxygen (purity &gt; 95%)</td>
<td>8.5 t/h</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CO&lt;sub&gt;2&lt;/sub&gt; (liquid)</td>
<td>9 t/h</td>
</tr>
<tr>
<td>Other: Required area</td>
<td>14.500 m&lt;sup&gt;2&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Investment</td>
<td>~ € 70 million</td>
</tr>
</tbody>
</table>
Tests in Schwarze Pumpe

• First test period will last for three years, 2009 – 2011
• Combustion only with Lignite, tests with Bituminous coal may start 2012
• Different firing modes:
  - Variations of O₂ concentration in oxidant
  - Variations in O₂ supply in the burner
  - Variations in recycle rate
Tests in Schwarze Pumpe: Main objectives

- The different components in Oxyfuel environment, i.e. ASU, Boiler, ESP, FGD, FGC, CO₂ compression
- How the different components act together in operation
- Optimise flue gas recycle
- Find burner settings (swirl numbers, oxygen injection and mixing) optimal for oxyfuel firing
- Material and corrosion issues
- Emissions formation, behaviour, removal (SOx, NOx, CO, HF, HCl)
- Combustion efficiency
- Ash formation and composition
- Heat flux and transfer
- Operational experience: Start-up, shut-down, transition air->oxyfuel
Lessons learned

• **Burner and boiler:** Three different burners, which are somewhat different, have been tested. Oxyfuel operation at this scale is possible. Emissions limits are kept.

• **ASU:** Black box. Start-up and shut-down takes time, but it works. Operation with lower oxygen purity will be tested next year.

• **ESP:** ESP is a good choice for fly ash separation. Dust is easily charged and separated.

• **FGD:** More SO2 than in air firing, but possible to meet reduction with a FGD in two parts, i.e. separate oxidation tank.

• **FGC:** Design chosen is good for full load operation, however not the best choice at part load. Temperature can be lowered to desired value.

• **CO₂ compression:** High purity CO2 at desired pressure and temperature (22 bar, -28°C) achieved. A second technology for CO2 purification and compression will be tested, start later this year.
CO₂ transport and storage

- CO₂ produced in Schwarze Pumpe was supposed to be transported to Altmark for storage
- CO₂ in liquid phase, 22 bar, -28 °C
- Transport in trucks
- 9 ton/hour -> 216 ton/day at full load
- 7-9 trucks per day at full load
- Distance: 350 km
CO₂ storage in Altmark

- Cooperation with Gaz de France for EGR – Enhanced Gas Recovery
- For Vattenfall the purpose is to draw important conclusions about on-shore CO₂ injection and CO₂ storage potential in Altmark
- Technically ready, but postponed due to political blockings
Summary

• Full plant operation of oxyfuel is possible
• Emission limits are kept
• CO2 quality reached
• Important lessons learned on all parts of the oxyfuel chain
• Important operational experience obtained
• Largest difficulties met for the transport and storage

For demo scale:
• Capture technology ready for larger scale
• Political support and local acceptance for transport and storage are the largest challenges
Questions?

Thanks for listening!

Please visit our webpage: www.vattenfall.com/ccs

If you have further questions: stina.rydberg@vattenfall.com

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