Vattenfall’s Oxyfuel Pilot Plant

First Experiences from Commissioning and Operation

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Vattenfall Europe Generation, Germany
Decision process for the Oxyfuel Pilot Plant

2002
GAP Analysis
- Start of project
- Available components
- Known process steps
- Degree of development

2003
Technology Benchmark
- Evaluation of different steps of development
- Decision to develop Oxyfuel

2004
Feasibility Study
- Financial frame
- Comparing scales
- Possible sites
- Risks

2005
Decision for Oxyfuel Pilot Plant
- Building site: Lausitz area
- Scale: 30 MWth
- Complete process chain from ASU to CO_2^ processing
Design considerations for Oxyfuel Pilot Plant

• Basic purpose is to provide operating information to be able to later scale-up the technology to a 400-600 MW\textsubscript{th} demonstration power plant

• Realization a complete process of coal input and oxygen production up to separation of CO\textsubscript{2}

• Possible to operate on full load in air-firing mode and oxyfuel mode

• Designed to be able to operate on lignite and in a second phase on bituminous coal
Location of the Oxyfuel Pilot Plant

Power plant “Schwarze Pumpe”

Building site
**Time schedule of the project**

- **Planning**
- **Permission process**
- **Construction phase**
- **Commissioning**
- **Operation & test measurements**
View on the Oxyfuel Pilot Plant

- Boiler
- Electrostatic precipitator
- Flue gas desulphurization
- Flue gas condenser
- Air separation unit
- CO₂-plant
- Social and switchgear building

Webcam: www.Vattenfall.de/CCS
### Basic data

<table>
<thead>
<tr>
<th><strong>Boiler:</strong> dust fired</th>
<th>Combustion heat performance</th>
<th>30 MW&lt;sub&gt;th&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Steam production</td>
<td>40 t/h</td>
</tr>
<tr>
<td></td>
<td>Steam parameter</td>
<td>25 bar / 350 °C</td>
</tr>
<tr>
<td><strong>Coal:</strong> pulverized lignite (Lausitz)</td>
<td>LHV</td>
<td>21.000 kJ/kg</td>
</tr>
<tr>
<td></td>
<td>Moisture</td>
<td>10,5 %</td>
</tr>
<tr>
<td></td>
<td>Carbon content</td>
<td>56 %</td>
</tr>
<tr>
<td><strong>Media:</strong></td>
<td>Coal demand</td>
<td>5,2 t/h</td>
</tr>
<tr>
<td></td>
<td>Oxygen (purity &gt; 95%)</td>
<td>10 t/h</td>
</tr>
<tr>
<td></td>
<td>CO&lt;sub&gt;2&lt;/sub&gt; (liquid)</td>
<td>9 t/h</td>
</tr>
<tr>
<td><strong>Other:</strong></td>
<td>Required area</td>
<td>14.500 m²</td>
</tr>
<tr>
<td></td>
<td>CO&lt;sub&gt;2&lt;/sub&gt; capture rate</td>
<td>&gt; 90 %</td>
</tr>
<tr>
<td></td>
<td>Investment</td>
<td>70 Mio. €</td>
</tr>
</tbody>
</table>
System overview of Oxyfuel Pilot Plant

Furnace

2. Pass

DeNOx

3. Pass

Dry Ash

ESP

Fan 1

Hot Recirculation

Dry Ash

Fan 2

FGD

FG-Condenser

CO₂-Process

Steam-HEx

Oxygen

ASU

Air

Nitrogen

Sealgas <1,2 bar

Sealgas 6 bar

Cold Recirculation

Steam-HEx

Air

Sealgas

Nitrogen

Pulverised Coal

Pulverised Coal

Burner

Fan 1

Fan 2

Oxygen

Steam-HEx

Air

Sealgas

Nitrogen
Challenges

• 4 operating states
  - Air operation
  - Oxyfuel operation to atmosphere
  - Oxyfuel operation to CO2-process
  - CO$_2$ evaporation from on-site storage tanks
    (effortful in realization and regulation)
• 3 parallel I&C systems
  (ASU, conventional part, CO2-plant)
• Sulfur-rich flue gas recirculation
• Series connection of 5 fans/compressions
• FGD: external oxidation and high sulfur removal
• Flue gas condensation and high aerosol precipitation
• Fuel transport with air and/or flue gas
• More extensive safety requirements to media
  (CO$_2$, O$_2$, NH$_3$) and systems
**Status of the Oxyfuel Pilot Plant**

- Commissioning of all components and systems finished (Aug. 2008).
- Security and function test by technical authority (TÜV) finished (Sept. 2008).
- Optimization and verification of warranted characteristics finished.
- Functionality of the Oxyfuel process is verified in pilot scale.
- Until beginning of January 2009
  - > 700 hours of Oxyfuel operation
  - separation and liquefaction of > 800 t CO₂
- After first measurement campaigns in November 2008, start of the test program in January 2009.
Experiences with boiler

- Proven start burners (propane) having problems in Oxyfuel atmosphere due to high dust loads (Flame guards and installation situation had to be optimized)
- Authority demand: Individual burner examinations for all operating states
- Good flame stability in Oxidant at O₂ > 27%(w)
- 25 -30 % humidity in hot recirculation

- Supplying of pure O₂ and mixture in the burner possible
- Use of only a burner influences the burning behavior and the waste gas values
- Different burner swirls necessary for air and oxyfuel operation
### Requirements on flue gas scrubbing

<table>
<thead>
<tr>
<th>Component</th>
<th>Composition</th>
<th>Reduction from*</th>
<th>to*</th>
<th>Capture rate</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ESP</strong></td>
<td>Ash</td>
<td>11.200 mg/m³</td>
<td>&lt; 20 mg/m³</td>
<td>&gt; 99 %</td>
</tr>
<tr>
<td></td>
<td>SO₂</td>
<td>11.500 mg/m³</td>
<td>&lt; 100 mg/m³</td>
<td>&gt; 99 %</td>
</tr>
<tr>
<td></td>
<td>SO₃</td>
<td>50 mg/m³</td>
<td>&lt; 20 mg/m³</td>
<td>&gt; 50 %</td>
</tr>
<tr>
<td></td>
<td>Ash</td>
<td>20 mg/m³</td>
<td>&lt; 10 mg/m³</td>
<td>&gt; 50 %</td>
</tr>
<tr>
<td><strong>FGD</strong></td>
<td>H₂O</td>
<td>30 vol-%</td>
<td>4 vol-%</td>
<td>&gt; 85 %</td>
</tr>
<tr>
<td></td>
<td>SO₂</td>
<td>100 mg/m³</td>
<td>&lt; 20 mg/m³</td>
<td>&gt; 80 %</td>
</tr>
<tr>
<td></td>
<td>SO₃</td>
<td>20 mg/m³</td>
<td>&lt; 5 mg/m³</td>
<td>&gt; 75 %</td>
</tr>
<tr>
<td></td>
<td>Ash</td>
<td>10 mg/m³</td>
<td>&lt; 1 mg/m³</td>
<td>&gt; 90 %</td>
</tr>
</tbody>
</table>

**FG-Condenser**

All design data are fulfilled!

*All mg/m³ in Norm (dry)*
Simplified CO₂ Liquefaction Process

Vent-gas to Atmosphere
40 - 60 vol-% CO₂
20 - 150 °C

Flue gas
77 - 85 vol-% CO₂
20 - 40 °C
1.0 – 1.05 bara

Waste Water
20 - 40 °C
pH value: < 7

CO₂ Product
>99 vol-% CO₂
-30 - -20 °C
15 -17 bara
## Attainable CO₂ purities

<table>
<thead>
<tr>
<th>Composition CO₂, liquid</th>
<th>Oxyfuel pilot plant (Technical CO₂)</th>
<th>Comparison to Food quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>&gt; 99,7 %</td>
<td>&gt; 99,99 %</td>
</tr>
<tr>
<td>N₂+Ar+ O₂</td>
<td>&lt; 0,3 %</td>
<td>&lt; 30 ppm</td>
</tr>
<tr>
<td>H₂O</td>
<td>&lt; 50 ppm</td>
<td>&lt; 50 ppm</td>
</tr>
<tr>
<td>SO₂</td>
<td>&lt; 2,5 ppm</td>
<td>&lt; 1 ppm</td>
</tr>
<tr>
<td>SO₃</td>
<td>&lt; 0,5 ppm</td>
<td>-</td>
</tr>
<tr>
<td>CO</td>
<td>&lt; 10 ppm</td>
<td>&lt; 10 ppm</td>
</tr>
<tr>
<td>NO</td>
<td>&lt; 5 ppm</td>
<td>&lt; 2,5 ppm</td>
</tr>
<tr>
<td>NO₂</td>
<td>&lt; 15 ppm</td>
<td>&lt; 2,5 ppm</td>
</tr>
</tbody>
</table>
Transport concept for pilot phase

- Transport with trailers (22 ton $\text{CO}_2$)
- Max. 7 to 9 trailer per day
- Distance: approx. 350 km
- Storage in depleted gas field
Outlook on test program

- Variation of coal quality (moisture, sulphur content, particle size).
- Tests of special measurement technique for flue gas composition and CO₂ monitoring.
- Material tests for demo plants and 700°C technology under Oxyfuel atmosphere.
- Testing of different burners.
- Tests with bituminous coal.
- DeNOₓ tests at the boiler and for the vent gas stream from the CO₂ plant.
- Test of an integrated dry lignite ignition burner.
Summary

• Oxyfuel works in pilot scale, emission limits are kept.

• Successful integration of plant components from chemical engineering (ASU, CO2 plant).

• Gained experiences from permission process and implementation of secondary clauses for CCS power plants.

• CO$_2$ monitoring over the whole technology chain (capture – transport – storage) developed for the first time world wide.

• World-wide first application for participation in emission trading for a CCS plant.

• First steps towards full scale CCS plants is successfully done.
Vision of the next generation power unit

Concept 1
Oxyfuel boiler

Concept 2
Post combustion capture
Thank you for your attention!