Concept of Vattenfall’s Oxyfuel-Demo-Plant

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### Agenda

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Vattenfall is dedicated to reduce its CO₂ emissions, aiming at a carbon neutral electricity portfolio by 2050.

Coal fired power plants have the greatest influence and reduction potential, with lignite at the best cost/delivery position.

Vattenfall sees the most effective method to lower the CO₂ emissions quickly, substantially and definitely in the CCS technology.

Vattenfall has worked on the CCS technology since 2002 and commissioned an Oxyfuel pilot plant (30 MWth.) in 2008.

We have gained many valuable practical experiences from this Oxyfuel pilot plant during the last 5 years.

➡️ Ready to scale up to a demo plant
## CCS Roadmap

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<th>Phase</th>
<th>Description</th>
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<td>Concept-studies</td>
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<td>Test rigs 0.1 - 0.5 MW&lt;sub&gt;th&lt;/sub&gt;</td>
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<td>Demo plant Jänschwalde 300 MW&lt;sub&gt;el&lt;/sub&gt;</td>
<td>- Verification and optimisation of component selection</td>
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<td>- Reducing risks</td>
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<td>- Proofing of economical viability</td>
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<td>Full scale plant 500 - 1.000 MW&lt;sub&gt;el&lt;/sub&gt;</td>
<td>- Economic and competitive power plant concept</td>
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*Years marked are indicative.*

2002: **Theoretical studies**
- Research
- Basic principles
- Combustion characteristics

2004: **2004**
- Demonstration of complete process chain
- Interaction of components
- Validation of test rig results
- Definition of scale-up criteria

2008: **2008**
- Verification and optimisation of component selection
- Reducing risks
- Proofing of economical viability

2015/2016: **2015/2016**
- Economic and competitive power plant concept

> 2020: **> 2020**

*Images not described.*
## Agenda

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CCS Demonstration Plant in Jänschwalde
**Oxyfuel:**
- Newly build single block at existing power plant site
  - Capacity: 250 MWe
  - Efficiency (net): 36 %
  - Separated CO₂: 1,34 Mio.t/a
  - Specific CO₂-emissions: 78 g/kWh

**Post combustion capture**
- Retrofitting of a part of an existing unit
  - Capacity: 50 MWe (equivalent to treated amount of flue gas)
  - Separated CO₂: 0,39 Mio.t/a
  - Specific CO₂-emissions: 107 g/kWh (related to treated amount of flue gas)
Demonstration Plant Jänschwalde - Capture in detail

- Lignite Dryer
- Machine House
- Post Combustion Capture (PCC)
- CO\(_2\)-Compression
- Air Separation Unit
- Oxyfuel-Boiler
- Desulfurization
- Cooling Tower
- Dedusting
Specifications of lignite drying plant (PFBD)

- Technology: pressurized fluidized bed drying (PFBD)
- 3 drying lines (103 t/h dry lignite)
- Operating pressure of dryers: 4 bar$_a$
- Throughput of raw lignite: up to 3 x 79 t/h
- Water content of raw lignite: $\varnothing$ 53.4 %
- Throughput of dry lignite: up to 3 x 44 t/h
- Water content of dry lignite: 6 - 12 Ma.-%
Oxyfuel boiler

• forced-circulation boiler
• parameters (state of the art):
  - live steam temp. 600 °C
  - live steam pressure 286 bar
  - live steam quantity 178 kg/s
  - re-heater steam temp. 610 °C
• specifics:
  - flue gas recirculation
  - gas pre-heater
  - DeNO\textsubscript{X} in 2\textsuperscript{nd} draught (optional)
  - CO\textsubscript{2} sealing gas system
  - CO\textsubscript{2}, O\textsubscript{2} alarm devices
  - Co-firing of residual gases from PFBD
## Air Separation Unit (ASU)

**Main data:**

- **Produced Oxygen**: 115,500 Nm³/h (GOX)
- **Oxygen purity**: 95% O₂
- **Main Air Compressor (MAC)**: 2 x 50%
- **Cryogenic part**: single line
- **Load range ASU**: 50 – 100%
- **Load range MAC**: 75 – 100%
- **Load change requirements**: 5%/min, O₂ 2%
- **Oxygen pressure battery limit boiler**: 1.2bar(a)  50mbar
- **O₂ Backup system (2x250m³ LOX)**: 60% load for 4hours
- **N₂ Backup system (1x250m³ LIN)**
- **Offered energy consumption**: ≈ 28 – 34 MWₑₜₐₚₜₖ

*50-75% - Oxygen blow-off / expected time 4% of annual hours*
Simplified block diagram CO₂-process

Raw gas (350 t/h)

FGC – Flue gas condenser
RGC – Raw gas compression (≈28 bar)
DC – Direct cooler / DeNOx*
CO₂S – CO₂-Separation
D/A – Dryer/Adsorber + Mercury adsorber
PC – Product compression (125 bar)

Vent gas (50 t/h)

Cooling water
Caustic soda*
Condensates (62 t/h)

CO₂-Product (175 t/h)

* depending on technical concept
## CO₂ processing unit (CPU)

### Main data:

- **Raw gas input**: 275,000 Nm³/h
- **CO₂-content in raw gas (wet)**: 45 - 58 Vol.-%
- **CO₂-content in product gas**: > 95 Vol.-%
- **Oxygen content in product CO₂**: < 0.8 Vol%  
- **Final pressure**: 125 bar
- **Recovery rate**: > 90%... 93 %*  
- **Load change requirements**: 5%/min
- **Load range GPU**: 50 – 100% **
- **Product compression unit**: combined compressor/pump
- **Offered energy consumption**: \( \approx 23 – 34 \text{ MW}_{el} \)

* depending on CO₂-content in raw gas
  
** 50-75% - by-pass / expected time 4% of annual hours
Oxyfuel - process flow sheet

- Optimization and layout for oxyfuel operation, air operation possible
- Flue gas recirculation after FGD (reduction of $SO_2$ content of flue gas)
- Oxygen mix as pre-mixd mode
## Operating figures

<table>
<thead>
<tr>
<th></th>
<th>Unit G Oxyfuel</th>
<th>Unit F with PCC (PCC: 50 MW behind boiler F2)</th>
<th>Unit F (conventional)</th>
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<tr>
<td><strong>mode of operation</strong></td>
<td>demo</td>
<td>base load</td>
<td>base load</td>
</tr>
<tr>
<td><strong>fuel</strong></td>
<td>dry lignite</td>
<td>raw lignite</td>
<td>raw lignite</td>
</tr>
<tr>
<td><strong>gross output capacity</strong></td>
<td>MW</td>
<td>250</td>
<td>519</td>
</tr>
<tr>
<td><strong>own consumption</strong></td>
<td>MW</td>
<td>83</td>
<td>37</td>
</tr>
<tr>
<td><strong>net output capacity</strong></td>
<td>MW</td>
<td>167</td>
<td>482</td>
</tr>
<tr>
<td><strong>efficiency (gross)</strong></td>
<td>%</td>
<td>53</td>
<td>39</td>
</tr>
<tr>
<td><strong>efficiency (net)</strong></td>
<td>%</td>
<td>36</td>
<td>35</td>
</tr>
<tr>
<td><strong>lignite demand (raw lignite)</strong></td>
<td>million t/a</td>
<td>1.5</td>
<td>4.1</td>
</tr>
<tr>
<td><strong>specific CO₂-emission</strong></td>
<td>g/kWh&lt;sub&gt;net&lt;/sub&gt;</td>
<td>78</td>
<td>933</td>
</tr>
<tr>
<td><strong>captured CO₂</strong></td>
<td>million t/a</td>
<td>1.3</td>
<td>0.4</td>
</tr>
<tr>
<td>(7,700 operating hours/a)</td>
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I. Brandenburg
Storage in deep saline aquifers (pipeline 50/140 km)

II. Altmark
EGR pilot project in cooperation with Gaz de France (pipeline 300 km)
Geology for storage

Geological profile

3-D model

Cap rock II

Indicator horizon

Cap rock I

Storage (Bunter)
CCS demonstration project Jänschwalde
Total investment: approx. 1.5 Mrd. €
from it: 1,2 bl. € Capture and 0,3 bl. € Transport & Storage
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• Applicable for demonstration projects applying for storage permit until 31. December 2016
• Limitation of storage volume: 1.3 million t CO₂ per project and annum; 4 million t per annum in general
• Opt-out clause for Federal States
• Financial security and other financial burdens: provisions from the first saved tonne of CO₂ (amount indetermined), security for post-operational treatment, levy for the municipalities (3 % of the certificate value for the CO₂ amount stored in respective year)
• Priority of other underground technologies (geothermal energy, natural gas storage) over the storage of CO₂
• Extensive rights of land owners

⇒ Insupportable conditions for a long-term investment
Why has Vattenfall cancelled this demo project?

- Boundary conditions for a 1.5 bl. € investment in a first-of-a-kind CCS industrial-scale demo plant were clear right from the start: proper regulatory and legal framework, EU co-funding, reliable market conditions (electricity and CO2 prices).
- Two out of these three conditions failed:
  - the business environment deteriorated due to the financial market meltdown and economic crises, resulting in a 50% loss on EEX revenue compared to 2008 baseload prices.
  - EU-wide transposition of the EU CCS Directive failed to deliver a stable and investment-friendly framework for an FID on such a scale.
- In Germany, political support for CCS faltered in the light of alternating energy concepts: first nuclear lifetime extension, then U-turn „Energiewende“ (Energy turn), with enforced nuclear phase-out, great expectations for renewable energies and little concern for coal/lignite.
- The German CCS law essentially falls short of delivering any investment certainty and incentive. Thus, Vattenfall had to cut the losses.
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Summary

• Vattenfall has gained many valuable practical experiences from the Oxyfuel pilot plant
• Vattenfall is technically ready to scale up for a demo plant
• CCS concept was worked out for a 300 MW Plant in Jänschwalde
• This concept was based on Oxyfuel and Postcombustion capture technology with pipeline transport and onshore storage in saline aquifers
• European funding was acquired, further funding possible
• Vattenfall had to cancel this demo project because of lacking political support in November 2011
• Boundary conditions of German CCS law prevent investment decisions for long-term CO2 storage

→ Vattenfall remains committed to build a coal fired power plant with CCS technology in the future, if public acceptance is existing
CCS Roadmap: skip the demo step!

Concept-studies

Test rigs 0,1 - 0,5 MW\textsubscript{th}

• theoretical studies

2002

2004

• Research
• Basic principles
• Combustion characteristics

Pilot plant 30 MW\textsubscript{th}

• Demonstration of complete process chain
• Interaction of components
• Validation of test rig results
• Definition of scale-up criteria

2008

Demo plant Jänschwalde 300 MW\textsubscript{el}

• Verification and optimisation of component selection
• Reducing risks
• Proofing of economical viability

2015/2016

Full scale plant 500 - 1.000 MW\textsubscript{el}

• Economic and competitive power plant concept

> 2020
Thank you for your attention!