Tests and Results of Vattenfall’s Oxyfuel Pilot Plant

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## Agenda

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Vattenfall’s Oxyfuel Pilot Plant

- Boiler
- ESP
- Air separation unit
- FGD
- CO2-Plant
- Social- and Switchgear building

- Germany
- Federal state of Brandenburg
- Schwarze Pumpe, location of the Oxyfuel pilot plant

Thermal capacity: 30 MWth
Capture rate: >90%
Investment: 80 Mio. €
Total costs: 150 Mio. €
Base data and industry partners

- Start up test operation Sept. 2008
- Until 17,000 operating hours in total, from it 13,200 in Oxyfuel mode, captured and liquefied CO₂ = 10,660 t
- CO₂ removal rate > 90 %
- High plant availability
- CO₂ quality sufficient for transport, storage and CCU

Thermal capacity: 30 MWth
Coal demand: 5.2 t/h
Oxygen demand: 10 t/h
CO₂ (liqu.) production: 9 t/h

Industry partner:

ALSTOM
SIEMENS
Linde
Babcock Borsig Steinmüller
Hitachi
Doosan
BABCOCK NOELL
TREMA
GEA
AIR PRODUCTS
VATTENFALL
General aims of Oxyfuel Pilot Plant in Schwarze Pumpe

- Practical proof of Oxyfuel technology in pilot scale (from coal input up to CO₂ output)
- Integration of new components from chemistry (ASU, CO₂)
- Complete approval procedure of a CCS power plant
- Compliance with necessary emission limits in all operating states
- Test of measuring equipment (for Air/Oxyfuel) and different materials
- Inject of “real Oxyfuel CO₂” in a geological CO₂ storage
- Collecting of experiences for operation and maintenance
- Develop of requirements and competitive equipment supply chain for a CCS demo plant
Specific plant features

Sep. start burner
on gas basis

30 MW burner performance
good scale-up possibility

Flue gas cooler
test inlet temperature in FGD

flexible
O₂
addition

Sulfur rich recirculation
Assessment SO₂-/ SO₃ enrichment
in boiler and recirculation
Test objectives for Air and Oxyfuel operation

- Optimization combustion behaviour (burner, \(O_2\) mix, OFA, emissions) and heat transfer behaviour
- Test of different burners for Air- and Oxyfuel- operation
- Test of sulphur rich (hot) flue gas recirculation
- Optimized interaction in combination of all components
- \(\text{CO}_2\) removal rate > 90 % reached
- Reduction of air ingress, maximization \(\text{CO}_2\) concentration
- \(\text{CO}_2\) purity > 99 % (Request for geological storage in project Ketzin)
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Effort for maximization of CO₂ purity

Integrate start burner in main burner

Coal-Input with dry flue gas

Seal gas systems to reduction air ingress

FGD with sep. Oxidation tank

Constructive measures to reduce air in-leakages

ASU High O₂ Purity > 99,5%
### Is effort worthwhile for maximization of CO₂ purity?

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<th>Component</th>
<th>Measure</th>
<th>Remarks</th>
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<tr>
<td>ASU</td>
<td>O₂ purity &gt; 99,5%</td>
<td>Standard ASU, higher operating costs</td>
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<tr>
<td>Boiler and ESP</td>
<td>Constructive measures for sealing</td>
<td>Proportional impact of air ingress in requirement openings is lower in big boilers</td>
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<td>Two flue gas fans</td>
<td>Reduction of under pressure</td>
<td>2nd. flue gas fan used as a „wet fan“, better optimization of both fans</td>
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<tr>
<td>Wet FGD</td>
<td>Separate oxidation tank</td>
<td>measure is effective, but more equipment/I&amp;C, reduce oxy-air (-12% inert gas) ➔ -1,5% FG</td>
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<td>Separate seal gas systems</td>
<td>Recirculation of cold flue gases for sealing and cooling equipment</td>
<td>To avoidance of 3% air-cooling streams: technical operational problems (humidity, corrosion) and higher maintenance effort</td>
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➤ Partly measures influence operating behavior disproportionately
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Hot vs. cold recirculation

**Hot recirculation:**
- Temperature: 170-190 °C
- Humidity: 28-29 %
- Sulfur: ~7,000 mg/m³

**Cold recirculation:**
- Temperature: 40-70 °C
- Humidity: 4-31 %
- Sulfur: 20-200 mg/m³

**But:** Difference of efficiency approx. 1% !!
Analysis of test heating surfaces after 10,000 operating hours
Result to material examinations

- Long-term material examinations due to changing operation parameters and more start ups and shut downs difficult (Pilot Plant).

- Results indicated by overlapping of all sorts of operating states (Air/Oxyfuel, coal quality, boiler cleaning)

- Assessment of the results for this reason very complex

- Indicators like abrasion (material loss) as well as local and areal corrosion of examined boiler pipes and material samples trends to result in:

**Selected materials can be used in conventional power plants and also in Oxyfuel plants**

➔ Influence of "sulphur richer flue gases" does not have any effects on additional material uses apparently
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Measurement concept

- Measurement concept
- Evaporator
- Measurement points:
  - pressure
  - temperature
  - flow
  - composition flue gas
  - sampling
- Conversion: oxyfuel/air
- Ash: lignite dust, fly ash
- Feed water: life steam, feed water, flue gas
- Recirculation gas: life steam, feed water, flue gas
- ESP: 1, 2, 3
Results for different loads in furnace

Heat transfer behavior of the evaporator

- Results were calculated by process model (Ebsilon software) and measurement results from testing.
- No significantly higher radiant heat transfer at evaporator in oxyfuel operation. Not general, because specific for burners and boilers.
Results for different heat exchanger

- Changed flue gas composition does not have significantly influence on heat transfer in the convective pass (boiler specific result) but for superheater.
- Significantly higher participation of gas heat exchanger in air operation because of a higher combustion air demand for preheating.
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CO₂ balance in Oxyfuel operation

100% C

Dry coal

100% CO₂

Absorbent CaCO₃ + 0,3% CO₂

Vapors - 0,9% CO₂

Ventgas - 7% CO₂

Wastewater - 0,02% CO₂

Condensate - 0,01% CO₂

CO₂-Cond. - 0,01% CO₂

2. path

3. path

Burner

Furnace

ESP

FGD

FGC

CPU

ASU

Air

Condensate

Ventgas

Wastewater

Absorbent

Vapors

ESPs

FGDs

FGCs

CPU

Air

Dry coal

Cold recirculation
Summary and outlook

• Goals of Oxyfuel Pilot Plant were accomplished completely, Oxyfuel works in pilot scale, all emissions are compliance to.

• CO₂ removal rates > 90 % were proved

• A sulphur rich recirculation is practicable after material examinations

• For Oxyfuel was proved, that a CO₂ purity > 99 % is possible. However, it depends on geological storage and economy, which CO₂ purity is necessary

• CCS chain was closed: Oxyfuel-CO₂ successfully stored in storage project CO2MAN (Ketzin)

• Further potentials for Oxyfuel technology are available

=> Ready to scale up to a demo plan
Thank you for your attention!