Alstom Development of Oxyfuel PC and CFB Power Plants

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3rd Oxy-Combustion Workshop
Yokohama, Japan
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Improvement Measures for Fossil Power Plants Regarding CO2 Mitigation

1. Efficiency Increase

2. CO2 Capture & Storage
"The pathway to zero emissions can best be achieved by addressing the issues of improved energy efficiency of fossil fuel power plants together with the development, adoption and effective integration of CO2 capture technologies. These routes are not mutually exclusive, and it is essential that carbon dioxide capture plant is based on the best available and appropriate underlying technology"...........IEA
Oxy-fuel Firing

- Complementary with conventional boiler and steam power plant technology, including efforts towards ultra-supercritical conditions (for efficiency improvement), as well as environmental control developments.

- Applicable for new and retrofit plants.
Oxy-combustion opportunities and challenges

**Opportunities**

- Low technological risk option
- Large power plant size possible
- Repowering and Retrofit possible
- All boiler technologies adaptable
- Fuel flexible
- Steam Cycle increases possible
- Potential boiler size reduction
- Advanced O2 supply

**Challenges**

**Cost**
- Cryogenic oxygen
- CO2 Quality
- CO2 compression
- Heat flow optimisation
- Integration

**Time**
- On time Development

**Technology**
- Scale-up validation
- Adaptation to installed base
- Innovation
# CO₂ Product Quality Discrepancies

Table: Tolerances for the various contaminants of CO₂

<table>
<thead>
<tr>
<th>Component</th>
<th>Tolerance</th>
<th>Limiting factor:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>low</td>
<td>high</td>
</tr>
<tr>
<td>CO₂ [%]</td>
<td>&gt; 90</td>
<td></td>
</tr>
<tr>
<td>H₂ [%]</td>
<td>&lt; 4</td>
<td></td>
</tr>
<tr>
<td>N₂ [%]</td>
<td>&lt; 4</td>
<td></td>
</tr>
<tr>
<td>Ar [%]</td>
<td>&lt; 4</td>
<td></td>
</tr>
<tr>
<td>CH₄ [%]</td>
<td>&lt; 4</td>
<td></td>
</tr>
<tr>
<td>O₂ [ppm]</td>
<td>&lt; 10</td>
<td></td>
</tr>
<tr>
<td>H₂O [ppm]</td>
<td>&lt; 10</td>
<td></td>
</tr>
<tr>
<td>CO [ppm]</td>
<td>&lt; 100</td>
<td></td>
</tr>
<tr>
<td>NOₓ [ppm]</td>
<td>&lt; 100</td>
<td></td>
</tr>
<tr>
<td>SOₓ [ppm]</td>
<td>&lt; 100</td>
<td></td>
</tr>
<tr>
<td>H₂S [ppm]</td>
<td>&lt; 100</td>
<td></td>
</tr>
<tr>
<td>Particulates [mg/Nm³]</td>
<td>&lt; 0.1</td>
<td></td>
</tr>
</tbody>
</table>

Alstom compilation from published reference data
Oxy-PC Power Plant -
CO2 product quality impact on ASU, APC, and GPU equipment

IEAGHG Int. Oxy-Combustion Network, Yokohama, Japan, 5-6, March, 2008
Oxy-CFB Concept

- Potential for Reduced recycle FGR and resultant smaller boiler & APC
- Market segmentation as with air-fired CFB’s (low quality fuels)
Going Down The Experience Curve for Oxy Combustion CO2 Capture

Energy requirements [KWh / TCO2]

- ENCAP studies
- Large Demos
- Chemical looping
- Process Optimisation
- Integration & Process Improvt
- Scale economy
- Process Innovation

CO2 €/T

2000 2010 2020 2030

lower
Oxy-Fuel Power Plant with Advanced O2 Production Technology

Breakthroughs will improve oxy-firing performance and economics
What is the status of developments?
Oxy-combustion: Chemical Looping Combustion (CLC)

CLC features
- 100% CO2 Capture
- No Air Separation Unit
- Lowest Cost CO2 Capture
- High Net Plant Efficiency
Long term products: Oxy-fired PC, Oxy-fired CFB and Chemical Looping

- **Oxy-fired PC**
  - Lab scale tests (500kWt)
  - Demonstration scale tests (30MWe)
  - Utility scale tests (250MWe)
  - Commercialization

- **Oxy-fired CFB**
  - Pilot scale (3MWt)
  - Demonstration Scale tests (10-40MWe)
  - Utility scale tests (>150MWe)
  - Commercialization

- **Chemical Looping**
  - Lab scale tests (10-100 kWt)
  - Pilot scale (1-3 MWt)
  - Demonstration scale tests 10-20 MWe
  - Utility scale 50-100MWe

Source: ALSTOM analysis
IEAGHG Int. Oxy-Combustion Network, Yokohama, Japan, 5-6, March, 2008
30 MWth Oxyfuel Steam Generator – Vattenfall
Schwarze Pumpe Site (Erection Status)

Source: Vattenfall

Jan. 2008

Boiler House
Air Separation Unit
ESP
FGD
FGC
CO2-Compression
Control Building

Source: Vattenfall

Jan. 2008
30 MWth Oxyfuel Steam Generator – Process
30 MWth Oxyfuel Steam Generator – Boiler Design

IEAGHG Int. Oxy-Combustion Network, Yokohama, Japan, 5-6, March, 2008
30 MWth Oxyfuel Steam Generator – Boiler Manufacturing
30 MWth Oxyfuel Steam Generator – Burner for Indirect Firing Systems

Niederaussem-K: 8 x 90 MWth

OxPP: 1 x 30 MWth

ROW Wesseling K5: 4 x 25 MWth

HKW Senftenberg: 2 x 19 MWth
Niederaussem-K : 8 x 90 MW_th

- Since 2003 in operation
- Start up / Support firing system for a 1000 MW_{el} unit
- T-fired
- 8 burners installed
- Fuel : Dried Lignite ; 19.5 .. 21.7 MJ/kg
- Furnace Width : 23160 mm
- Furnace Depth : 23160 mm
- Oil gun
30 MWth Oxyfuel Steam Generator – Burner Operation Modes

**Green:** Air  
Brown: Fuel

**Blue:** RFG + O2  
Brown: Fuel

**Yellow:** RFG  
Violet: O2  
Brown: Fuel

Air operation  
Oxyfuel operation  
Oxyfuel operation

(premixed oxygen)  
(direct oxygen injection)
Conclusions

• New coal fired power plants shall be designed for Highest Efficiency to minimize CO2 and other emissions.

• Oxy-combustion is Complementary with conventional boiler and steam power plant technology, including efforts towards ultra-supercritical conditions (for Efficiency), and Environmental control developments.

• Cost Attractive Options are needed and should be actively supported, particularly, breakthroughs like Chemical Looping & Adv. Oxygen.

• Scale-up and Validation is needed.

• The Schwarze Pumpe project is an important and significant demonstration. Start-up is expected this year.
Today we provide the cleanest air solutions

- For New Plants
- For the Installed Base