Future oxycombustion systems


*Air Liquide, *Contact persons
Agenda

- Introduction
- 2010 State-of-the-art plants
- Future oxycombustion systems
- Conclusion
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- **Introduction**

- 2010 State-of-the-art plants

- Future oxycombustion systems

- Conclusion
Air Liquide roadmap toward CO$_2$ capture

**Air Liquide is highly involved in oxy-coal technologies development**

- **AL is selected by DOE for the 1$^{st}$ full-scale oxyfuel plant**
  - **FutureGen 2.0 (200 MW$_{\text{e}}$)**

- **CPU pilot tested within the CIUDEN and O$_2$GEN projects**
  - in Spain (30 MW$_{\text{th}}$ boiler)

- **Joint studies with Vattenfall**
  - (1 GW lignite plant)
  - and B&W (700 MW sub-bituminous coal plant)

- **Near-commercial scale 30 MW$_{\text{th}}$ burner demonstration with B&W**

- **CPU pilot tested at Callide in Australia**
  - (100 MW$_{\text{th}}$ bituminous coal plant)
Further improvement of oxycombustion systems

- Air Separation Unit (ASU) and CO₂ Processing Unit (CPU) have a strong impact on oxyfuel process efficiency

- There are some development opportunities in the 2015-2020 timeframe
  - ASU & CPU specific energy consumption reduction
  - Oxyfuel process optimization

- Scope of the study has been:
  - Large-scale Oxy-PC power plant
  - High CO₂ purity (>99.9 %-vol) and high capture rates (>90%)
  - Focus on overall plant efficiency improvement (no OPEX/CAPEX trade-off)
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Air/Oxy reference plants: based on Vattenfall-Air Liquide 2010 study (1 GW gross)

ASU & CPU designs based on ‘2010 technology’ (Air Liquide commercial offer)

‘High efficiency’ plant design
- Steam data: 280 bar/600°C/620°C
- Pressurized steam lignite drier (+3-4 %-pts)
- Heat recovery below acid dew point (+1 %-pts)

Air-fired reference plant net LHV efficiency: 49.6%
Oxyfuel reference plant simplified process flow diagram:

- Oxyfuel plant net LHV efficiency: 41.9% \(\rightarrow\) Efficiency penalty of 7.7 \%-pts

HR: Heat Recovery
SDA: Semi-Dry Absorption
FGD: Flue-Gas Desulphurization
ASU: Air Seperation Unit
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Process simulation basis

- Steady-state simulation of the overall plant (Aspen Hysys software)
CPU heat integration

- Concept 1: CPU heat integration on dry CO$_2$ compression
  - Use of CO$_2$ compression heat for steam cycle condensate preheating
  - CPU steam consumption reduction

→ Plant net efficiency: +0.2 pt
Warm recycle

- Concept 2: Semi-Dry Absorption removal - Warm recycle
  - Alternative to SDA will avoid water injection quenching effect
    - Fully dry sulfur abatement technology
    - Low sulfur coal
  - Secondary recycle temperature increases
  - Heat recovery is increased by 40 MW\textsubscript{th}

→ Net efficiency: $+$0.5 pt
ASU & CPU development

- Concept 3: ASU ‘2015-2020’ design
  - Technology development
  - Advanced cycle design
  - Increased level of integration

  2020 target: 145 kWh/t (w/o int. credit) → + 0.7 pt

- Concept 4: CPU ‘2015-2020’ design
  - Advanced CO₂ membranes
  - REX on Ciuden and Callide pilots
  - Improvement of drying and compression

  2020 target at 90% capture: 120 kWh/t (w/o int. credit) → + 0.4 pt
Hot recycle & Oxygen preheating

**Concept 6: Hot recycle**
- Secondary recycling at boiler outlet
  - Reduced heat recovery
  - Increased boiler power
- Hot ESP technology

→ Net efficiency: + 0.2 pt

**Concept 7: Oxygen preheating**
- O₂ preheating at ~300°C against flue gas
  - Reduced heat recovery
  - Increased boiler power
- High temperature gas-gas heat exchanger

→ Net efficiency: + 0.2 pt
Influence of plant design

- No heat recovery below acid dew point
  - No acid corrosion risk
  - Efficiency reduction is higher for the air-fired plant (-0.7 pts) than for the oxyfuel plant (-0.2 pts)

→ **Without** heat recovery below acid dew point, air-oxy efficiency gap is reduced by **0.5 pt**

- Advanced steam cycle
  - Double reheat configuration
  - Ultra-Super Critical (USC) steam cycle

→ **With** advanced steam cycle, air-oxy efficiency gap is reduced by **0.1 pt**
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High improvement potential: **+2 pts** on net LHV efficiency

**ASU & CPU optimization** has strong impact on overall efficiency

Efficiency penalty can be reduced in the **5 pts range**
End of presentation
Thank you for your attention

Acknowledgments to Nicklas Simonsson, Vattenfall R&D AB
Design basis and boundary conditions

### Power plant design

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
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<tbody>
<tr>
<td>Main steam pressure</td>
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<tr>
<td>Main steam temp.</td>
<td>[°C]</td>
<td>600</td>
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<td>Reheat steam pressure</td>
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<td>Reheat steam temp.</td>
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<td>Final feed water pressure</td>
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<td>Final feed water temp.</td>
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<td>Condenser pressure</td>
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### Fuel specification

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<tr>
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<td>C</td>
<td>[%-wt]</td>
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<tr>
<td>H</td>
<td>[%-wt]</td>
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<tr>
<td>O</td>
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<td>S</td>
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<td>F</td>
<td>[ppm]</td>
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<td>Ash</td>
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<td>Moisture</td>
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### CO2 quality requirement

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<tr>
<td>CO₂</td>
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<tr>
<td>O₂</td>
<td>&lt; 10 ppmv</td>
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<tr>
<td>Ar</td>
<td>&lt; 0,1 %-%vol.</td>
<td></td>
</tr>
<tr>
<td>N₂</td>
<td>&lt; 0,1 %-%vol.</td>
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<tr>
<td>H₂O</td>
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</tr>
<tr>
<td>CO</td>
<td>&lt; 5 ppmv⁵</td>
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</tr>
<tr>
<td>NO</td>
<td>&lt; 5 ppmv³</td>
<td></td>
</tr>
<tr>
<td>NO₂</td>
<td>&lt; 5 ppmv⁵</td>
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</tr>
<tr>
<td>SO₂</td>
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<tr>
<td>SO₃</td>
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</tr>
<tr>
<td>HCl</td>
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</tr>
<tr>
<td>HF</td>
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<tr>
<td>NH₃</td>
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</tbody>
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Oxyfuel reference plant - ASU & CPU

- ASU & CPU designs based on ‘2010 technology’ (Air Liquide commercial offer)

**Air Separation Unit (ASU)**

- 15,300 TPD Oxygen (3-trains)
- Compression heat recovered for BFW heating
- Oxygen preheating at ~200°C, 96.5 %-v purity
- Specific consumption (w/o integ. credit): 160 kWh/t

**Cryocap™ CO₂ Processing Unit (CPU)**

- 16,000 TPD CO₂ (2-trains)
- CO₂ capture rate: 90%
- No heat integration
- 99,99 %-vol purity, 125 bars
- Specific consumption: 130 kWh/t