Risk Analysis of Fortum's 560MW e net Power Plant Retrofit to Oxyfuel Combustion

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Agenda

- Joint development **Fortum / Babcock-Hitachi / Air Liquide** for **oxyfuel retrofit**, 90+% CO₂ capture

- Main Results from Risk Analysis

- Conclusion on Oxyfuel risk analysis
  - Safe, retrofit compatible, reliable, efficient
Oxyfuel Retrofit, a Joint Development

Fortum, Babcock-Hitachi and Air Liquide developed a concept for the oxyfuel retrofit of the Meri-Pori power plant:

- **Fortum**, among top EU utilities, committed to reducing its Carbon Footprint

- **Babcock-Hitachi**, a power plant & environment equipment manufacturer. It owns R&D test facilities for energy and environment technologies including Oxy-fuel combustion

- **Air Liquide**, a world leader in gases for industry, health & environment, has led strong developments in oxycombustion in the past 10 years including pilot plants, extensive engineering studies, laboratory tests, etc.
Proposed retrofitted plant by Fortum, BHK & AL

- Retrofit of Meri-Pori Power plant, Supercritical, 565MW e net
  - Very low emissions (NO$_x$, SO$_x$, Hg, Particulates)
  - Safe and reliable operation in both oxy- and air combustion modes
  - Efficiency drop ~ 7.8 points HHV, goal of 6 points for retrofit in 2020

- A risk analysis was required and lead by Fortum, as a validation step for this promising technology
Risk Analysis Methodology

Four fields of study:
- Safety (S), Environment (E), Costs (C) & (un)Availability of power (U);
- 4 levels of impact
- 4 levels of probability

<table>
<thead>
<tr>
<th>Maximum Impact</th>
<th>Probability</th>
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<tbody>
<tr>
<td>Mini of (C; U; S; E)</td>
<td>1</td>
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<tr>
<td>1</td>
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<td>2</td>
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Risk Criticality Table

1 - Critical
Critical risk that can't be tolerated/intolerable magnitude

2 - Significant magnitude

3 - Low/moderate magnitude

4 - Non critical/acceptable magnitude

Extensive involvement from all 3 companies:
- 3 days in the power plant site with technical manager,
- Led by Fortum risk analysis specialists, 7 experts from 3 companies

63 risks identified
Risk Analysis Main Results

- No critical risks or risks with significant magnitude (red & blue)
- 6 risks identified with a moderate magnitude
  - 4 [highest severity x lowest probability (extremely unlikely)]
  - 2 [moderate severity x moderate probability]
Moderate Risks #1 & 2 [ASU damage & Anoxia]

#1 Damaged ASU (due to HC ingress into liquid O₂)
- Major explosion: Extremely unlikely
  - only 3 Industry events in the past 50 years, over ~ 30 000 years operation from industrial gas companies (10⁻⁴ frequency of occurrence).
- In coal fired PP environment, explosion risk is reduced compared to petrochemical environment as hydrocarbons are under a solid form and not vapour

Sources:
EUROPEAN INDUSTRIAL GASES ASSOCIATION // COMPRESSED GAS ASSOCIATION
www.eiga.org
www.cga.net

#2 Release of inert gases leading to anoxia:
- Inherent risk to CCS
- Known preventing strategies (SO₂ detectors in FGD rooms, etc.)
Example of ASU located in challenging environment

- IGCC plant:
  - 9 Air Liquide references > 1500t/d in the past 15 years
Example of ASU located in challenging environment

Frequency rate of hydrocarbon incidents under $10^{-6}$ thanks to Air Liquide Design and Operational experience

Other risks (such as anoxia): frequency rate even lower
Moderate Risk # 3 [Boiler and/or Mill explosion/fire]

- **Known Risk of Boiler/Mill Explosion/Fire:**
  - **Case A:** Worse flame stability → All flame loss →
    - Accumulation of explosive mixture in furnace and enclosure + ignition energy
    - Boiler explosion
  - **Case B:** Rate of temperature rise too fast → Mill fire or explosion

Influence of $O_2$ on Temperature rise

Fundamental test result

$O_2$ vs Explosive Limit
**Moderate Risk # 3** [Boiler and/or Mill explosion/fire]

**Prevention of Boiler Explosion in Case A**

![Graph showing the prevention of boiler explosion in Case A.](image)

- **Case A**
  - Air
  - O₂=21%

- **Case B**
  - O₂=60%
  - O₂=80%
  - O₂=100%

The graph illustrates the temperature (Ts) over time (sec) for different oxygen concentrations (O₂) in air and flue gas + O₂ for both Case A and Case B.
Prevention of Boiler Explosion in Case A

**NR-LE Burner** to enhance flame stability

- Stable flame at low oxygen concentration of 10% assuming big deviation from normal oxygen setting of 21% (preliminary)

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**Test coal**
- Australian bituminous coal
- Fixed Carbon (FC): 55.2%, dry
- Volatile Matter (VM): 33.3%, dry
- Fuel Ratio (FC/VM): 1.66
- Fineness: 80% through 75μm sieve

**Coal specifications**
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**NR-LE**
- NOx reduction and load extension burner
- Pat. EP-P01312859, US-P07213522

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**Stable flame**
- Pry O2 = 21% (wet)
- Pry O2 = 10% (wet)

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**Diagram**
- Schematic of flame stabilization system
- Additional Air Injection Nozzle
- Secondary gas (O2 > 28vol% wet)
- Concentrated pulverized coal
- Venturi
- FSR: Flame Stabilizing Ring
- PCC*: Pulverized Coal Concentrator
- P'ry gas with coal (O2 ≤ 21vol% wet)
Moderate Risk # 3 [Boiler and/or Mill explosion/fire]

- Prevention of Mill Fire in Case B

![Diagram showing the relationship between time, Ts (K), and different oxygen concentrations (O2) in Case A and Case B.](#)
Moderate Risk # 3 [Boiler and/or Mill explosion/fire]

Prevention of Mill Fire in Case B

Emergency redundant shut down of oxygen & fuel

To avoid formation of abnormally high oxygen & fuel mixture
Moderate Risk # 4 [ Sulfuric Acid Corrosion (SO₃) ]

- Sulfuric acid corrosion (higher SO₃ content due to FG recirculation)
- Prevention of Corrosion
  - Gas Gas Cooler condenses sulfuric acid on ash particles, which is removed in EP (Proven design in actual plants for a decade)
  - Same system is applied to oxyfuel combustion

![Diagram of coal-fired power plant processes](image)

- **SO₃ Concentration**
  - Without Cooler
  - With Cooler

- **Corrosion rate**
  - Material: Carbon steel
  - H₂O: 30vol%

![Graph showing corrosion rate vs SO₃ concentration](image)
Other Modifications Without Risk Impact

- **Present Boiler, Mills, SCR, Air Heater, FGD and EP can be used** as they are (from test & simulation results)
  - Example for the boiler heat transfer sections:

- Smooth online changes between air mode and oxy mode are confirmed by combustion tests & dynamic simulations
Conclusions & Opportunities

- Oxyfuel is a real option for existing power plants today
  - It is Safe
  - It is Suitable for Retrofit
  - It will have similar reliability to air fired power plants
  - Oxyfuel is a nearly ZERO EMISSION process
Thank-you!

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