Greenhouse Gas Capture & Mitigation techniques for different industries

AIR LIQUIDE

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International Conference

CO₂ Summit: Technology and Opportunity

Vail, Colorado - June 6-10, 2010
Air Liquide – CO₂ capture activities

Clean Coal Power
- Oxy-Coal Combustion Process
  - Oxy-combustion development
  - Air Separation Unit (ASU) development
  - CO₂ Compression & Purification Unit (CPU) development

Steel Production
- Ultra Low CO₂ Steel Making (ULCOS)
- CO₂ capture from Blast Furnace

Summary
Air Liquide (AL), the world leader in gases for industry, health and environment:
- Present in 75 countries
- 43,000 employees
- Revenue €12 Billion (2009)
- > 60% of R&D budget for Sustainable Environment

AL involved in CO$_2$ capture developments for several industries:
- Power Plant
- Steel
- Hydrogen – poster

Worldwide CO$_2$ emissions – Breakdown by sector (excluding CO$_2$ emissions from land use)
Clean Coal Power
Three main routes for Clean Coal Power

Gasification (or pre-combustion)

Post-combustion

Oxy-combustion
What is Oxy-Coal Combustion?

Flue gas concentrated in CO₂

Air | Flue Gas after WFGD
---|---
N₂ | N₂
O₂ | H₂O

Oxygen + Coal → CO₂ + Nitrogen

Oxy-Coal Combustion
CO₂ capture from pulverized coal plants is possible with penalty of only ~6 percentage points in efficiency (HHV).

CO₂ capture from pulverized coal plants is possible with less than 50% increase in cost of electricity.
Clean Coal Development Roadmap

- Oxy-combustion development – Babcock & Wilcox
- Air Separation Unit (ASU) development for oxy-combustion
- CO₂ Compression & Purification Unit (CPU) development for CO₂ capture

Majority of Oxy-Combustion cost comes from ASU & CPU
Oxy-combustion development

Plant size (MWth)

Engg. Studies

Integration Studies

Engg. Study

Demonstration

CEDF: first oxy-combustion demo in the world at 30MW scale

SBS-I

SBS-II

2003 2005 2007 2009 2011 2013 2015

CEDF – Clean Energy Development Facility
SBS – Small boiler Simulator

DOE funded

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ASU optimized for Oxycombustion

- Cryogenic distillation for O₂ Production
  - More than 100 years of experience
- AL has built the world’s largest ASU
  - Sasol Train (4200 tpd O₂)
- ASU development specifically for oxy-combustion
  - Low purity Oxygen
  - No Nitrogen requirements

![Graph showing separation energy (kWh/ton) for different scenarios: Pure O₂ Year 2000, IGCC Year 2000, OXY LE, OXY XLE, Target 2015. Note: Dark blue represents integration gain. Reference line at -7.5% today, 2% lower in 2015 without integration, and 24% lower with integration. LE – Low Energy, XLE – Extra Low Energy.]

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CO₂ Purification Unit development

First Generation CO₂ CPU – Offer available
- Commercial test – CO₂ handling (LACQ, France)
  - Successfully started in 2010
- CPU in Callide, Australia (Startup in 2011)

Second generation CO₂ CPU in R&D to further reduce cost of capture
- Improvement in impurities management
- Improvement in heat integration
CPU optimization for CO$_2$ capture

**CO$_2$ Product Pressure = 175 bar**

- **No Purification**
- **Cold Box**
- **Cold Box and Distillation**

- **90% CO$_2$ Recovery**
- **95% CO$_2$ Recovery**
- **100% CO$_2$ Recovery**

Process studies to optimize CO$_2$ recovery and power consumption

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Callide, Australia

- A technological partnership with Callide Oxy-fuel Services, Australia
- Size: 100 MWth
- AL will provide 2 ASUs & CPU
- Near Zero Emission Plant

Enable cost reduction and performance improvement for large scale units

CPU demonstration based on the down-scale of large unit

Start up scheduled 2011
STEEL PRODUCTION
Steel Production - ULCOS

- 1 ton of steel from integrated steel plant emits almost 2 tons of CO$_2$ (>60% from Blast Furnace)

- Continuous growth in Steel demand
  - World-wide Steel Production in 2007 was >1.3 Billion tons
  - Projected 2015 ww Steel Production is 1.8 Billion tons

- Ultra Low CO$_2$ Steelmaking (ULCOS)
  - European consortium of Steel Companies and partners
  - 48 members from 15 EU countries

- ULCOS aims at reducing CO$_2$ emissions by 50%
Conventional Blast Furnace

Conventional Blast Furnace

Pellet/Sinter Plant

Iron Ore → Coke Plant

Coke Oven Off-gas can be used as fuel

Top gas contains about 50% N₂

Coal & Hot Air Blast

Coke Plant

Top gas (CO, N₂, CO₂, H₂)

Ash Removal

Pig Iron

Coal

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Top gas (CO, N₂, CO₂, H₂) from Sinter, pellets & Coke is used as fuel in the blast furnace. Gas cleaning system (PSA/VPSA) removes impurities, allowing for export gas.

Coal & Hot Air Blast, O₂ Blast, and Full Oxygen Blast are used to heat the furnace. Recycle gas CO, H₂ is used to reduce CO₂ emissions.

Pig Iron is produced from Ash Removal. CO/H₂ recycling and CO₂ separation for the reduction of CO₂ emissions in blast furnace (BF).
Air Liquide involved in CO₂ emission reduction from BF
- CO₂ Separation unit

LKAB’s experimental BF at MEFOS, Luleå Sweden
- Top Gas Recycle Blast Furnace (TGR BF)
- Full Oxygen Blast
- Max top gas flow rate: 2900 Nm³/h
- Recycle gas injection (CO/H₂)

Achievements
- CO₂ VPSA operated reliably as designed
  - Successful tests in Fall 2007 for seven weeks
  - upto 24% in carbon savings
- Reduction of the CO₂ emissions of up to 76% when assuming underground storage
- 88% of CO recovery

Next Step – Industrial size demo ULCOS II

1st world reference for CO₂ capture on top gas recycle BF Start up: Oct 2006
VPSA DESIGNED & BUILT BY AIR LIQUIDE
Air Liquide is evaluating opportunities for CO\textsubscript{2} capture in many different industrial sectors

**Power Plant – Clean coal oxy-combustion development**
- Optimized ASU with 20% reduced specific energy
- Optimized CO\textsubscript{2} CPU with flexible design for a range of feed and product specification
- Overall cost reduction with heat integration of ASU, CPU with steam cycles

**Steel Production – with reduced CO\textsubscript{2} emission**
- TGRBF at MEFOS, Sweden
- Successful VPSA operation for 7 weeks

**On-going efforts to identify Industrial Sized Demo Opportunities with industrial and government collaborations**
Acknowledgements

Babcock & Wilcox

TOTAL

Callide Oxy-fuel Services

ICCI

DOE

NETL

ULCOS
THANK YOU