Greenhouse Gas Capture & Mitigation techniques for different industries

AIR LIQUIDE

Trapti Chaubey, Paul Terrien, Jean-Pierre Tranier, Rajeev Prabhakar & Aude Delebecque

International Conference

CO₂ Summit: Technology and Opportunity

Vail, Colorado - June 6-10, 2010
Agenda

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 CO₂ capture developments for several industries
- Power Plant
- Steel
- Hydrogen – poster

Worldwide CO₂ emissions – Breakdown by sector
(excluding CO₂ 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?

Oxygen + Coal \rightarrow CO_2 + Nitrogen

Flue gas concentrated in CO_2
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)

- 500
- 150
- 30
- 1

- 2003
- 2005
- 2007
- 2009
- 2011
- 2013
- 2015

Engg. Studies
Integration Studies
Engg. Study

CEDF: first oxy-combustion demo in the world at 30MW scale
Callide: Demo of entire oxy-combustion system

SBS-I
SBS-II

DOE funded

SBS – Small boiler Simulator
CEDF – Clean Energy Development Facility

Callide Oxyfuel Services

CO2 Summit: Technology & Opportunity
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 energy separation for different scenarios](Image)

- Pure O₂ Year 2000
- IGCC Year 2000
- OXY LE
- OXY XLE
- Target 2015

NOTE – Dark blue represents integration gain

Today 2015
- 20% w/o integration
- 17% w/ integration

170

LE – Low Energy, XLE – Extra Low Energy
**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)

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**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

Process studies to optimize CO$_2$ recovery and power consumption
Industrial Pilot: Callide, Australia

- 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

Iron Ore → Pellet/Sinter Plant

Coal → Coke Plant

Coal & Hot Air Blast

Coke Oven Off-gas can be used as fuel

Top gas (CO, N₂, CO₂, H₂)

Ash Removal

Pig Iron

Top gas contains about 50% N₂
Top Gas Recycle Blast Furnace

Sinter, pellets & Coke

Top gas
(CO, N₂, CO₂, H₂)

Gas cleaning system

Export gas

PSA/VPSA

Coal & Hot Air Blast
O₂ Blast

Full Oxygen Blast

Ash Removal

Recycle gas heater

Recycle Gas
CO, H₂

Enriched CO₂ gas

Pig Iron

CO/H₂ recycling and CO₂ separation for the reduction of CO₂ emissions in blast furnace (BF)
Industrial Pilot – MEFOS, Sweden

- 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