Greenhouse Gas Capture & Mitigation techniques for different industries

AIR LIQUIDE

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International Conference

CO_2 Summit: Technology and Opportunity

Vail, Colorado - June 6-10, 2010

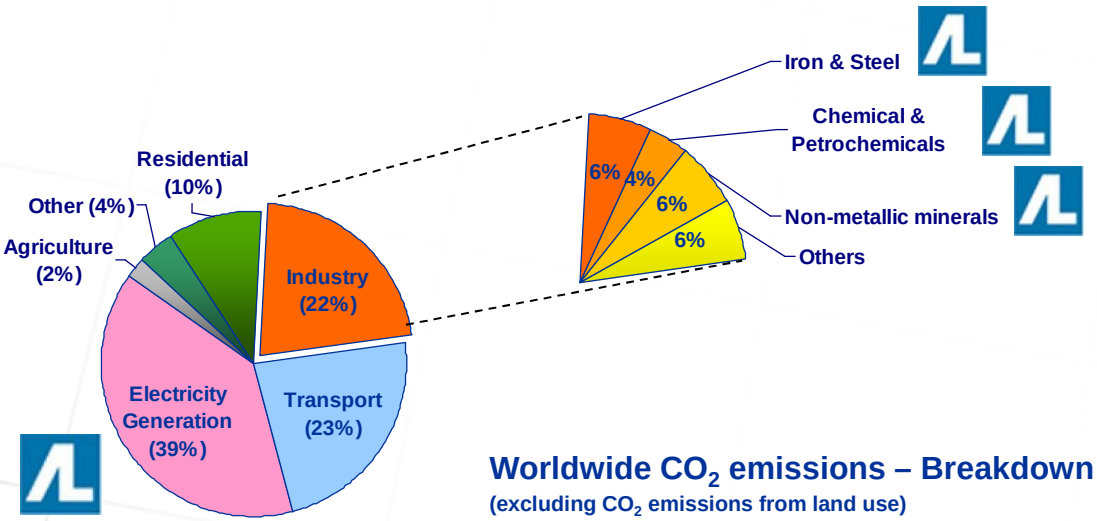
Agenda

- Air Liquide – CO_2 capture activities
- Clean Coal Power
  - Oxy-Coal Combustion Process
    - Oxy-combustion development
    - Air Separation Unit (ASU) development
    - CO_2 Compression & Purification Unit (CPU) development
- Steel Production
  - Ultra Low CO_2 Steel Making (ULCOS)
  - CO_2 capture from Blast Furnace
- Summary

Air Liquide

- 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

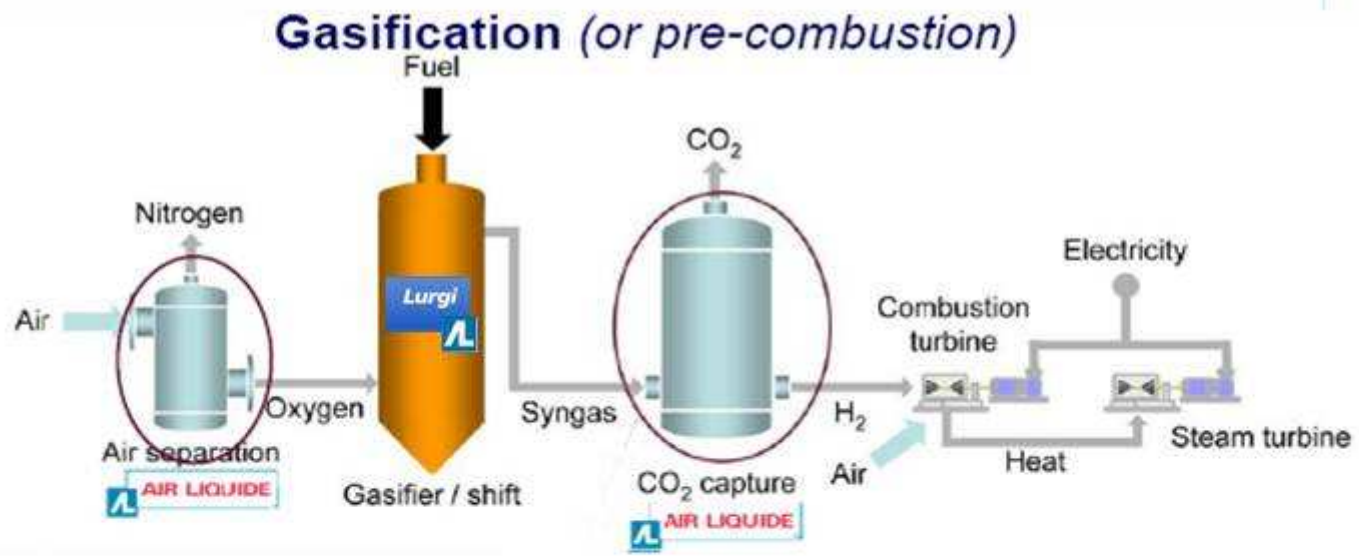
- AL involved in CO_2 capture developments for several industries
  - Power Plant
  - Steel
  - Hydrogen – poster

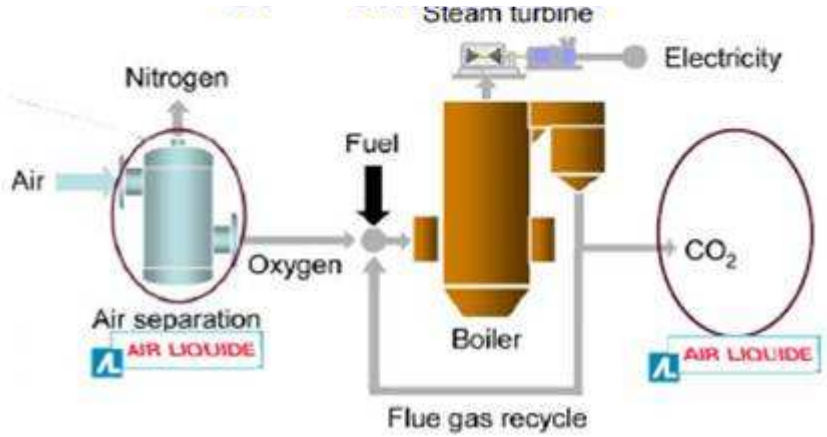


Worldwide CO_2 emissions – Breakdown by sector
(excluding CO_2 emissions from land use)

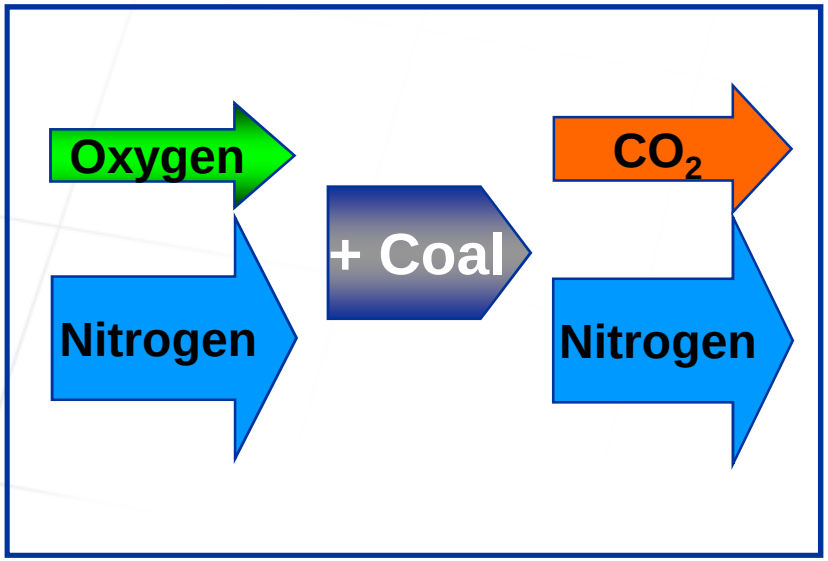
Clean Coal Power

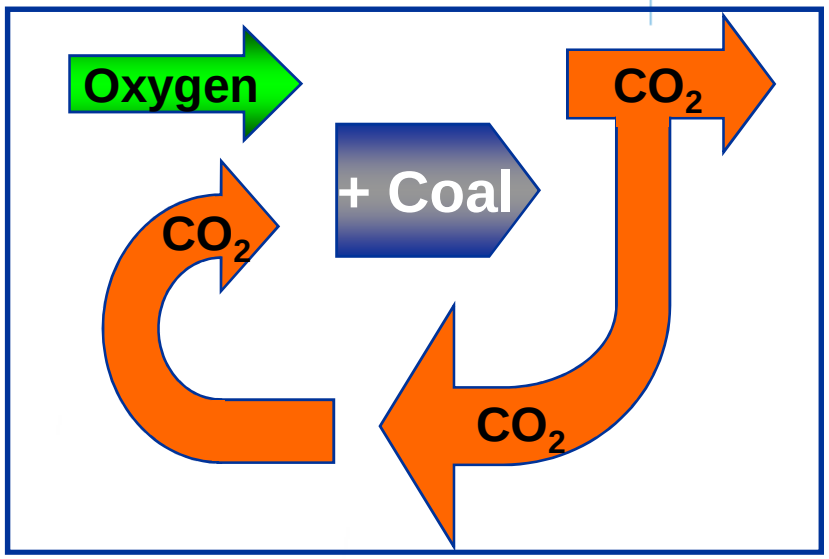
Three main routes for Clean Coal Power

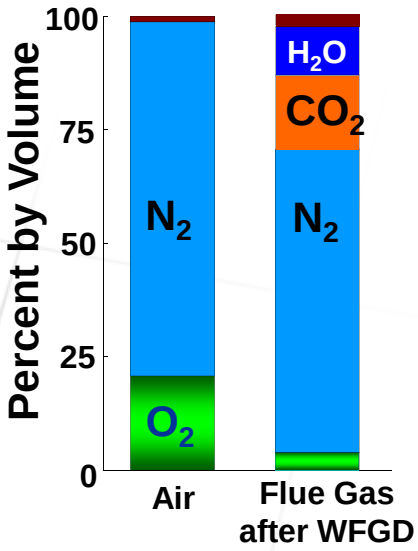


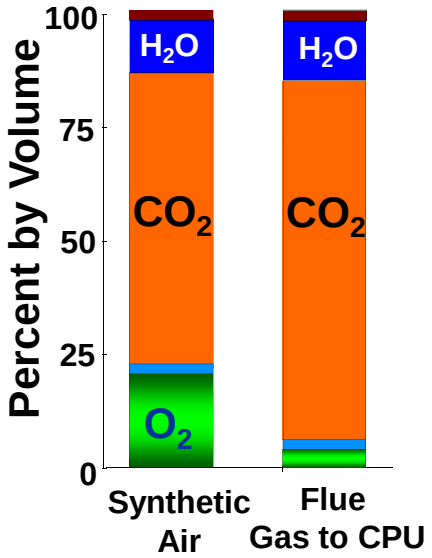


What is Oxy-Coal Combustion?



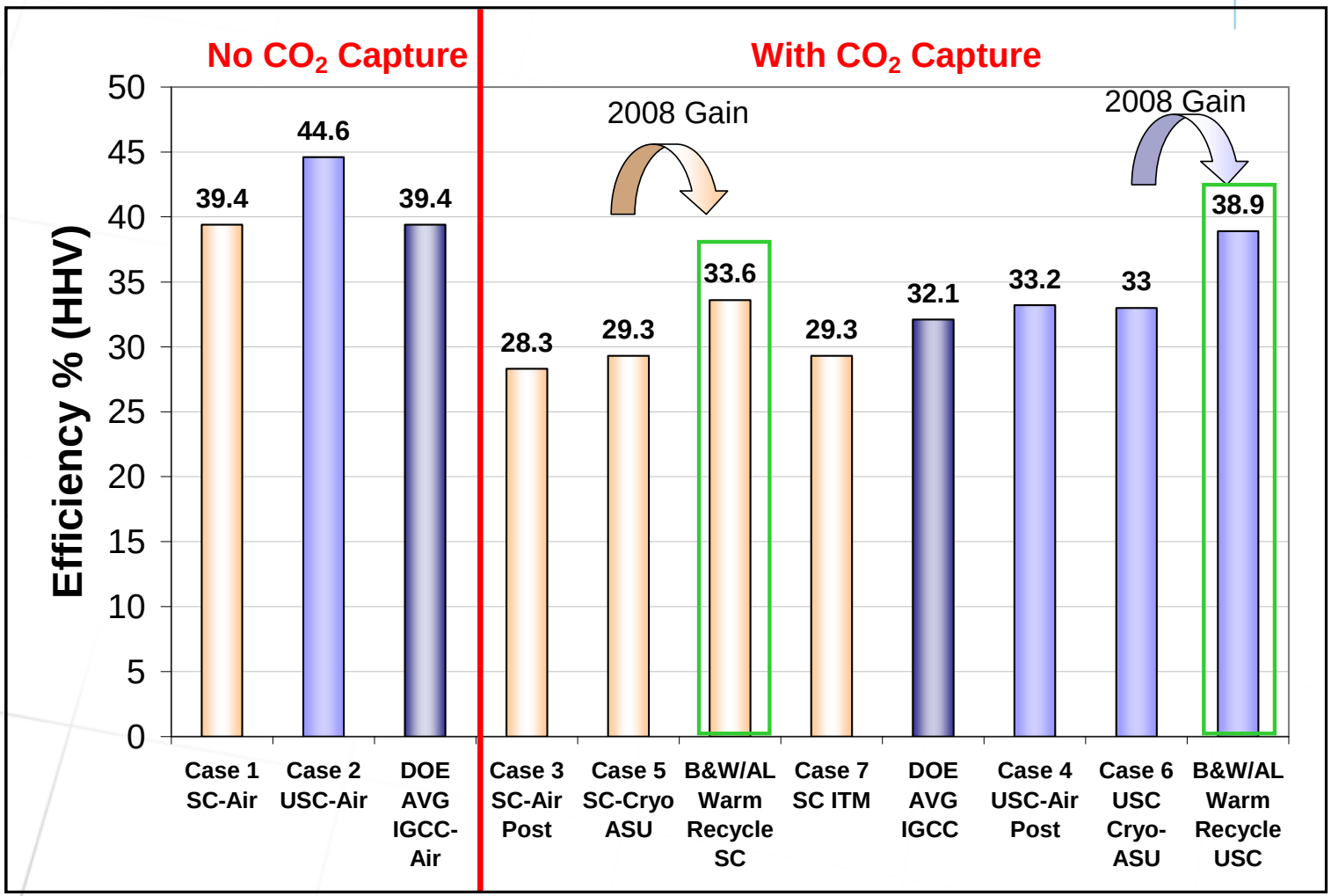






Flue gas concentrated in CO_2

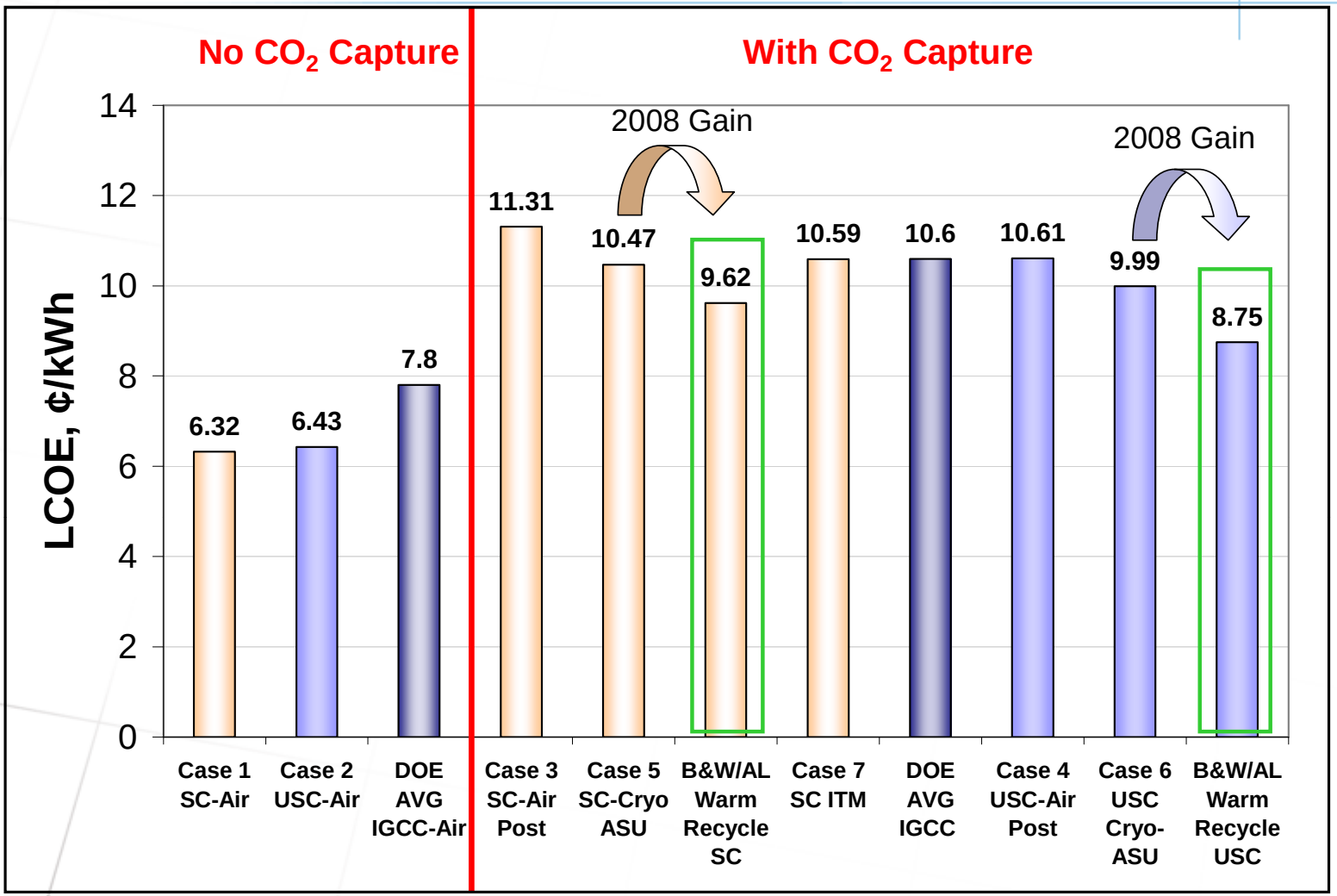
Plant Efficiency



References: DOE/NETL 2007 – 1291 "Pulverized Coal Oxy-combustion Power Plants" Rev.2, DOE/NTL 2007-1281 "Cost and Baseline for Fossil Energy Plants" Rev.1, and B&W/AL Integration Study

CO_2 capture from pulverized coal plants is possible with penalty of only ~6 percentage points in efficiency (HHV)

Levelized Cost of Electricity



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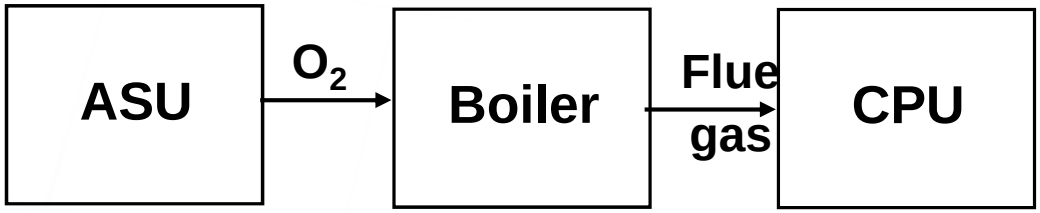
CO_2 capture from pulverized coal plants is possible with less than 50% increase in cost of electricity

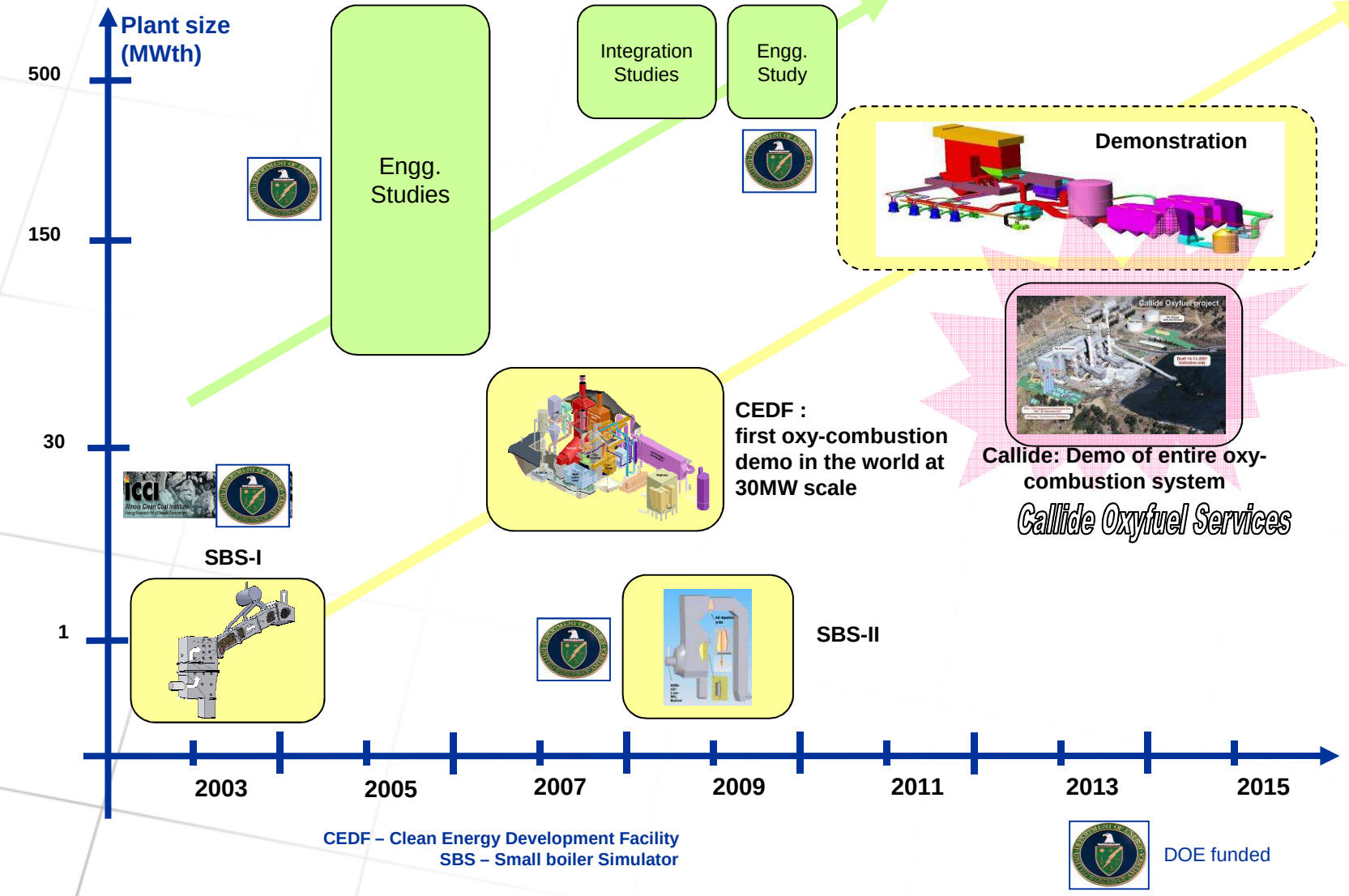
Clean Coal Development Roadmap



- Oxy-combustion development – Babcock & Wilcox
- Air Separation Unit (ASU) development for oxy-combustion
- CO_2 Compression & Purification Unit (CPU) development for CO_2 capture

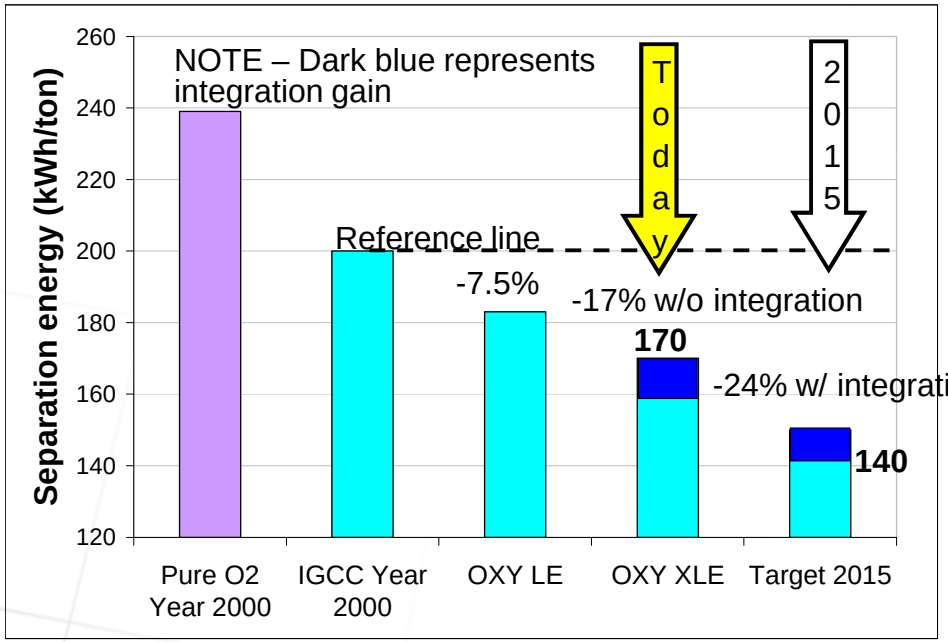
Majority of Oxy-Combustion cost comes from ASU & CPU

Oxy-combustion development



ASU optimized for Oxycombustion

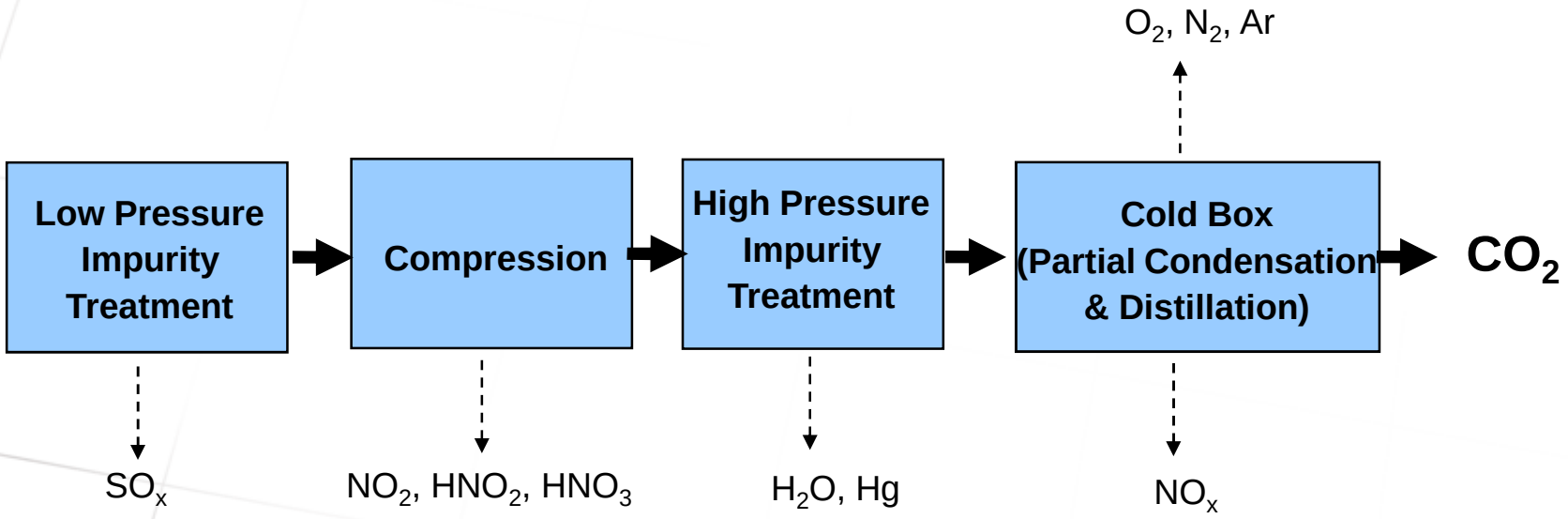
- Cryogenic distillation for O_2 Production
  - More than 100 years of experience
- AL has built the world's largest ASU
  - Sasol Train (4200 tpd O_2)
- ASU development specifically for oxy-combustion
  - Low purity Oxygen
  - No Nitrogen requirements



LE – Low Energy, XLE – Extra Low Energy

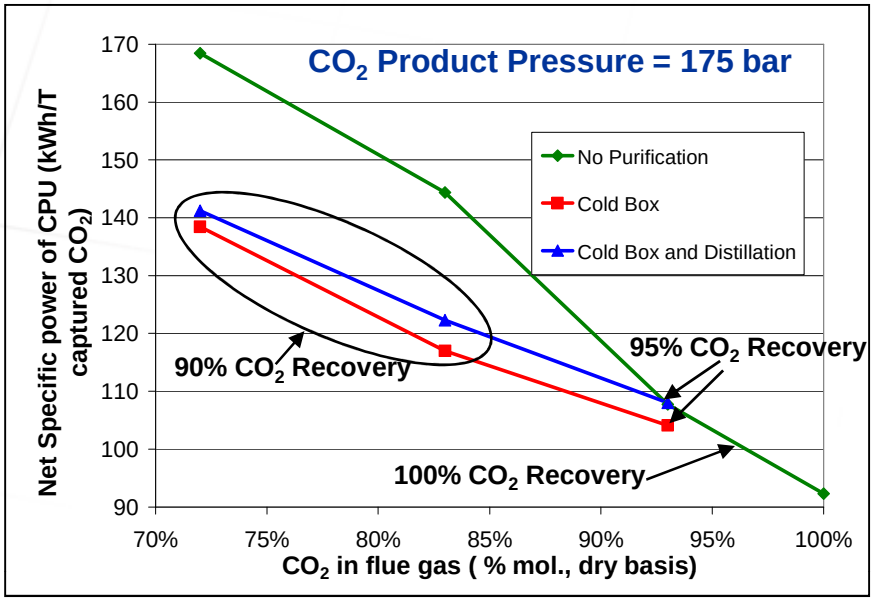
CO_2 Purification Unit development

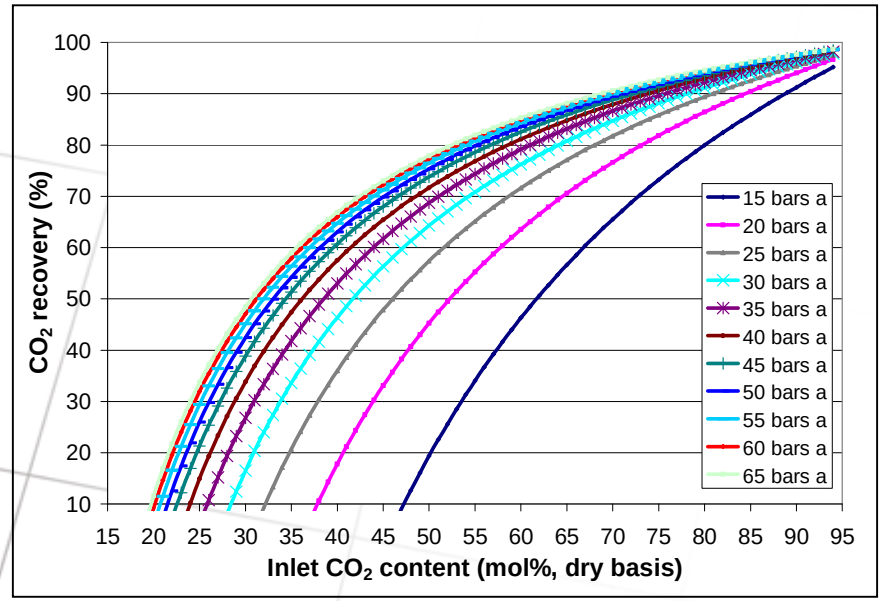
- First Generation CO_2 CPU – Offer available
  - Commercial test – CO_2 handling (LACQ, France)
    - Successfully started in 2010
  - CPU in Callide, Australia (Startup in 2011)



- Second generation CO_2 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

Callide Oxyfuel Project

- Enable cost reduction and performance improvement for large scale units
- CPU demonstration based on the down-scale of large unit

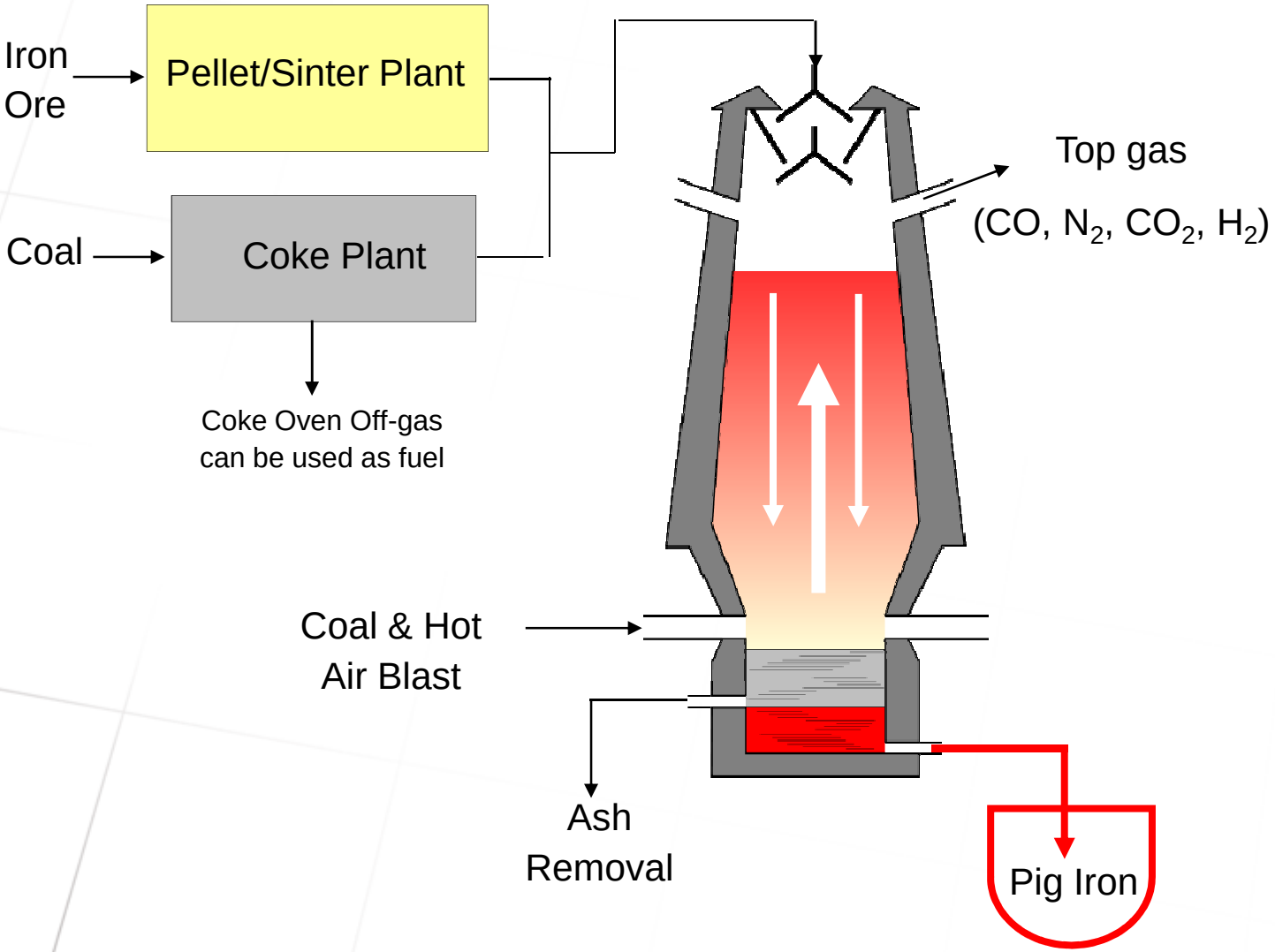
Start up scheduled 2011

STEEL PRODUCTION

Steel Production - ULCOS

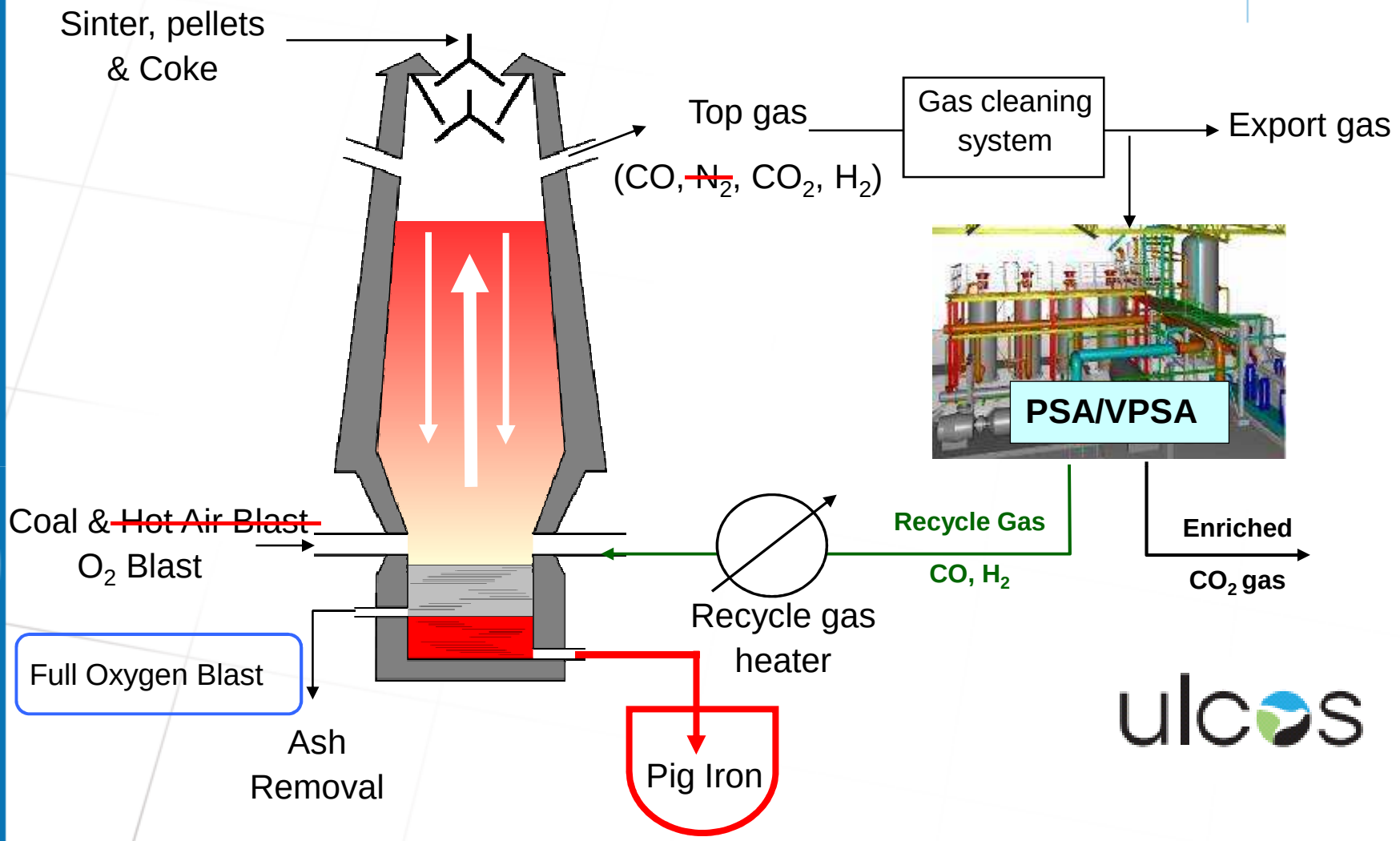
- 1 ton of steel from integrated steel plant emits almost 2 tons of CO_2 (>60% from Blast Furnace)
- Continuous growth in Steel demand
  - World-wide Steel Production in 2007 was >1.3 Billion tons
  - Projected 2015 ww Steel Production is 1.8 Billion tons
- Ultra Low CO_2 Steelmaking (ULCOS)
  - European consortium of Steel Companies and partners
  - 48 members from 15 EU countries
- ULCOS aims at reducing CO_2 emissions by 50%

Conventional Blast Furnace



Top gas contains about 50% N_2

Top Gas Recycle Blast Furnace



CO/H_2 recycling and CO_2 separation for the reduction of CO_2 emissions in blast furnace (BF)

Industrial Pilot – MEFOS, Sweden

- Air Liquide involved in CO_2 emission reduction from BF
  - CO_2 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 Nm^3/h
  - Recycle gas injection (CO/H_2)
- Achievements
  - CO_2 VPSA operated reliably as designed
    - Successful tests in Fall 2007 for seven weeks
  - upto 24% in carbon savings
    - Reduction of the CO_2 emissions of up to 76% when assuming underground storage
  - 88% of CO recovery
- Next Step – Industrial size demo ULCOS II

1st world reference for CO_2 capture on top gas recycle BF Start up: Oct 2006

VPSA DESIGNED & BUILT BY AIR LIQUIDE

Summary

- Air Liquide is evaluating opportunities for CO_2 capture in many different industrial sectors
- Power Plant – Clean coal oxy-combustion development
  - Optimized ASU with 20% reduced specific energy
  - Optimized CO_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_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