



A Global Perspective on the Status of Carbon Capture

John Gale

General Manager

IEA Greenhouse Gas R&D Programme

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Post Combustion Capture

- Significant progress in reducing energy of regeneration for amine based process
 - Now 2.0-2.3 MJ/Kg CO₂, Cansolv 201 solvent, +others
 - Down from 4-4.5MJ/Kg in 1990
- Significant number of vendors testing or tested at 10MW - 100,000t scale
 - TCM – Cansolv, Aker, Carbon Clean Solutions,
 - Shand – Hitachi
 - Shanghai – Huaneng Group
 - Tomakomai – MHI
- Many more at 1-2MW scale - NCC

PCC Developments



Boundary Dam 3, Canada



- Refit of existing coal fired unit
- Operational for 1 year
- CanSolv amine based PCC technology
- **110MWe**
- 95% capture
- CO₂ sold for EOR

NRG Parish, USA



- Refit of existing coal fired unit
- Operational in late 2016
- MHI amine based PCC technology
- **250 MW slip stream**
- 90% capture
- CO₂ sold for EOR

Post Combustion Capture



- **Boundary Dam 3 Operational Achievements**

- March 2016 - a 90% reliability factor had been achieved for the first quarter of 2016
- July 2016 – 1 millionth tonne of CO₂ had been captured

- **Cost reduction from learning by doing**

- 30% CAPEX, 25% OPEX

- **A word from the wise!**

“A capture technology must be piloted at a scale that allows for reasonable engineering scale up to a commercial size”



Oxy Combustion

- Alstom/GE
 - 35MWth test facility at Schwarze Pumpe, Germany
 - Engineering design for White Rose 426MWe (gross) – now cancelled
- B&W
 - 30MWth Burner tests, Ohio, USA
 - Engineering design for FutureGen 2.0 159MWe project – now cancelled
- HUST, China
 - 35MWth test facility in Wuhan, China
 - Lead to a 200MWe FEED design



Callide Oxy Fuel Project

Key technical achievements

- 10,200 hours oxy-firing operation and 5,600 hours of CO₂ capture plant operation
- A boiler turn-down to 50% Load Factor was demonstrated
- > 95% capture of SO_x, NO_x, particulates and trace metals
- A high purity of CO₂ product (> 99.9%) was produced



“The project was successful and that the technology is ready to move to the full commercial scale.”

Supercritical CO₂ Cycles



- IEAGHG techno economic study has evaluated technology options
 - SCOC-CC, S-Graz, NET Power and CES.
- Cycle efficiencies , 49% to 55%
 - NGCC/CCS base case 52% efficiency
- LCOE of base-load plants were 84-95 €/MWh,
- The cost of CO₂ emission avoidance was 68-106 €/t CO₂ avoided.
- The base case was 90% capture
 - Could go to 98% without increasing the cost/t of CO₂ avoided,
 - Or essentially 100% if lower purity CO₂ was acceptable.

Supercritical CO₂ Cycles (2)



Other points

- The cycles could be net producers of water
- Cycles could have advantages at compact sites

Route to commercial deployment

- NET Power is constructing a 50MW power plant
- Toshiba has developed turbine component
- Testing begins in 2017
- If successful will allow scale up to 295MWe



Pre-combustion capture

- Rectisol and Selexol capture technologies are commercially proven
 - Rectisol process in operation at Dakota Gasification facility since 2000
 - Selexol process to be demonstrated at Kemper County in late 2016
 - No cost overruns on capture component
- Osaki CoolGen Project - IGFC
 - Project is planned in three steps.
 - 166 MW oxygen-blown IGCC to operate in 2017-18
 - Add an amine based capture test facility , 2019 on
 - Add MCFC – 47-49% cycle efficiency

Industry CCS



- CCS now deployed in:
 - Natural gas upgrading – mostly amine based technology (Sleipner, Snohvit, Gorgon ...)
 - Game changer – Membrane technology for Lula project, offshore Brazil
 - Hydrogen refining/upgrading
 - Quest – solvent based technology
 - Air Products, PSA technology
 - Steel sector
 - Emirates Steel – Amine based capture

Summary



- Post combustion capture is the technology leader
 - Demonstrated at scale in power sector and industry
 - Cost reduction potential from learning by doing
 - Competitive situation with a large number of vendors, can help drive down costs
- Oxygen combustion technology awaits full scale demonstration, as does IGCC based capture
- Supercritical CO₂ cycles show considerable promise
 - Needs to be operationally proven then scaled up
- IGCC/MCFC not on radar at present
- Other novel options are being tested but are not close to the power sector market deployment yet
 - Some niche applications in industry



What Next?

- Next projects on horizon
 - Fluor to demonstrate at ROAD in 2018?
 - Capture at bio-CCS power plant in Japan in 2018?
- Monitor cost reduction and technology developments
 - Which capture options moving up TRL levels?
 - Which options can we get techno-economic estimates on?
 - Chemical looping – 20MW facility built in France in 2018/19?
- Options and costs of 99-100% capture
 - Higher capture rates important to reduce residual emissions from CCS in future
 - Higher capture process rates or combination with biomass firing?