Effective CO₂-capture technology development in Australia

Paul Feron | Senior Principal Research Scientist

8 August 2016

2016 NETL CO₂ Capture Technology Project Review Meeting
CCS drivers in Australia

- Export of fossil fuel products
- Electricity generation dominated by fossil fuels
Australia’s approach to CCS

- Policy position
- Understanding the CCS resource
- Demonstrating domestic LET capacities & capabilities
- Strategic partnering
- Building Australian skills and capacity
- Innovation
The Story So Far in Australia Key CCS Projects & Key Research Initiatives

Projects

- Gorgon LNG Project
- Callide Oxyfuel Project
- South West Hub Project
- CO2CRC Otway Project
- CarbonNet Project

Research & Exploration

- ANLEC R&D - accelerating deployment of CCS
- NGL - R&D facility established to advance carbon storage technologies
- Geoscience Australia - precompetitive exploration
- CCS RD&D - $25 million for research, development and demonstration activities

Slide provided by Commonwealth DoIIS
## Australian coal fired power stations

<table>
<thead>
<tr>
<th></th>
<th>Black coal</th>
<th>Brown coal</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average efficiency [% HHV]</strong></td>
<td>35.6</td>
<td>25.7</td>
</tr>
<tr>
<td><strong>CO₂ emission [tonne/MWh]</strong></td>
<td>0.9</td>
<td>1.3</td>
</tr>
<tr>
<td><strong>SO₂ concentration [g/m³]</strong></td>
<td>0.5 – 1.7</td>
<td>0.2 – 0.7</td>
</tr>
<tr>
<td><strong>NOₓ concentration [g/m³]</strong></td>
<td>0.4 – 1.5</td>
<td>0.2 – 0.4</td>
</tr>
<tr>
<td><strong>Particulate matter [mg/m³]</strong></td>
<td>10 – 100</td>
<td>10 – 60</td>
</tr>
<tr>
<td><strong>Flue gas temperature [°C]</strong></td>
<td>120</td>
<td>180</td>
</tr>
</tbody>
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*Data derived from CCSD – technology assessment report 62*
PCC technology requirements

- **Energy Efficient**
  - Towards zero energy penalty

- **Affordable**
  - Costs lower than other LET’s

- **Environmentally benign**
  - Zero harm to the environment
CSIRO’s PCC program

Learning by doing

Pilot plants

- AGL Loy Yang Power (2)
- Delta Electricity
- Stanwell
- China Huaneng (Beijing)
- China Huaneng (Changchun)

Learning by searching

Research & Development

- Amines
- Adsorbents
- Membranes
- Novel processes & equipment
- Environmental impacts
Piloting PCC Technologies in Australia

- Desk-top studies
- Establishment of capability and infrastructure
- Preparing for deployment
  - Next-generation PCC
- CCS demo’s

Timeline:
- 2007: Delta Electricity Munmorah
- 2008: Loy Yang
- 2009: Delta Electricity Vales Point
- 2010: Solid Sorbents
- 2011: AGL Loy Yang
- 2012: SPI Vales Point
- 2015: Solar Thermal

Other Projects:
- Tarong
- Loy Yang
- Piloting PCC Technologies in Australia
- Effective CO₂-capture technology development in Australia

Authors:
- Paul Feron
PICA Project

Project aims:

- 40% lower cost of CO\textsubscript{2} capture compared to the MEA base case
- Advanced packing materials, liquid absorbent and process
- To provide information on long-term performance and reliability of advanced liquid absorbents and equipment that have been developed in-house by both IHI Corporation and CSIRO independently in preparation of demonstration phase
- Supporting large-scale CCS as an affordable, secure and environmentally benign option for power generation

Approaches for reduction capture energy

- Development of amine formulations/new amines
- Process development
  - Novel process design
  - Innovative equipment
- Renewable energy integration
  - Solar thermal
  - Light swing absorbents
- Integration with Direct Carbon Injection Engine
- Absorption enthalpy conversion
Development of amine formulations/new amines

Formulations base on primary amines

- Selection of a first amine that reacts rapidly with CO\textsubscript{2} through the formation of a carbamate
- Selection of a second amine:
  - preferably with little or no carbamate formation and being a stronger base than the first amine
  - such that the enthalpy of protonation is large to maximise the temperature dependent pH change to aid thermal desorption of CO\textsubscript{2}
- Optimisation of the formulation composition to achieve acceptable physical properties
- Assessment of CO\textsubscript{2} absorption rates and reboiler duties

Designer amines and functionalised amines

- Focus on diamines with dual functionality
- Higher molecular efficiency
Solar thermal energy for absorbent regeneration

- Avoiding interface with existing steam cycle
- More effective in terms of CO₂-emission reduction
- Introduction of flexibility into the capture process

Pilot plant at Vales Point power station
- Integrated with existing PCC pilot plant
- 65 kWₜₘ solar array

Approaches for reduction capital costs

- Development of amine formulations/new amines
- Aqueous ammonia process development
- Packingless contactors: the rotating liquid sheet contactor
- Integrated removal of SO$_2$ and CO$_2$: CS-CAP
- Selective flue gas recirculation
- Solid sorbents
- Membrane assisted liquid absorbent regeneration
Rotating Liquid Sheet contactor

Basic principles
- Surface area of stabilized liquid sheet greater than that of resulting droplets.
- Rotating liquid surface proven experimentally to pump gas.
- Centrifugal + liquid pumping force creates interfacial area.

Advantages
- Higher gas velocities possible.
- Liquid entrainment significantly reduced.
- Suitable for viscous solvents.

Challenges
- Scale-up to commercial scale.
- Liquid residence time low.

Integrated Single Stream SO$_2$ and CO$_2$ Capture (CS-CAP)

Aqueous ammonia for PCC in Australia

- Indestructable liquid absorbent
- Chemical well-known to electricity industry
- Suited for “contaminated” feed gases
- Fertiliser by-product
- Product CO$_2$ at elevated pressure
- Technical feasibility demonstrated in pilot plant but no cost advantage
- Addressing challenges:
  - Mass transfer promotion, temperature increase
  - Vapour suppressors
  - Further integration of pretreatment and water wash
  - Process design

Li et al., Environ. Sci. Technol. 2015, 49, 10243−10252
Solid sorbent CO$_2$ Capture Unit at Vales Point power station

Objective

- to evaluate the stability of honeycomb CF composite monolithic adsorbents using the real flue gas at Vales Point Power Station
- to understand the effect of real flue gas characteristics on the operation and performance of the CO$_2$ capture unit

Results

- Excellent stability to real flue gas over 200 experiments
- CO$_2$ adsorption efficiency consistently over 98%
- CO$_2$ desorption efficiency between 90-95%
- Near complete removal of SO$_2$ and NO$_x$
- Could be pretreatment unit for amine based PCC

Thiruvengadachari et al. IJGGC 42 (2015) 415–423
Emission issues addressed via integrated risk-based approach

1. Formation of potentially harmful components
   - Absorbent degradation in absorber
   - Absorbent degradation in desorber

2. Emission analysis
   - Estimation of concentrations using process models
   - Actual measurements in pilot plants

3. Dispersion
   - Environmental chamber to investigate atmospheric degradation
   - Updating dispersion models with atmospheric chemistry
Managing environmental impacts of amine based PCC processes

- Absorbent type
- Process conditions
- Flue gas compounds

Absorber

- Pre-treatment
- Post-treatment
- CO₂ purification

Desorber

- Absorbent type
- Process conditions
- Amine-CO₂ reactions

Liquid absorbent quality

Reclaimer
- Filtration
- Purification
Outlook for PCC in Australia – Next steps

- Qualification of new liquid absorbents towards deployment
  - Formulations and designer amines
  - Optimisation of process design
- Development of $\text{SO}_2/\text{CO}_2$ process concepts
- Focus on process & equipment innovation
- Solar thermal integration demonstration
- Continued efforts in next-gen & break-through technologies
  - Adsorbents, membranes
  - Advanced liquid absorbent systems
Acknowledgements
Reference materials

- **Amine based post-combustion capture technology advancement for application in Chinese coal fired power stations**, Paul Feron et al., Energy Procedia 63 ( 2014 ) 1399 – 1406