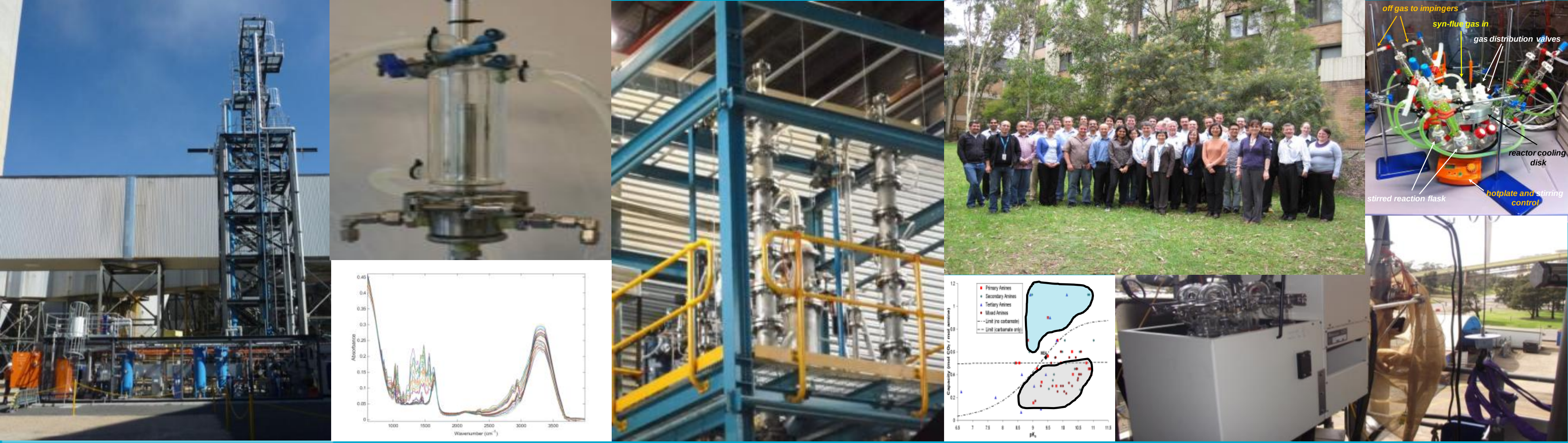


Effective CO_2-capture technology development in Australia

Paul Feron | Senior Principal Research Scientist

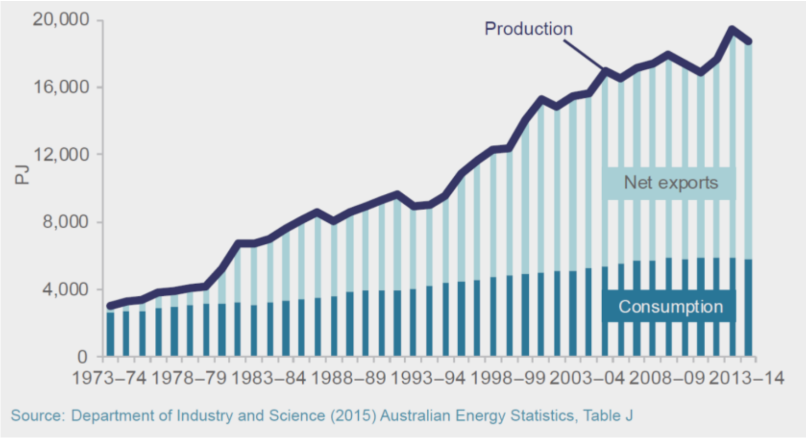
8 August 2016

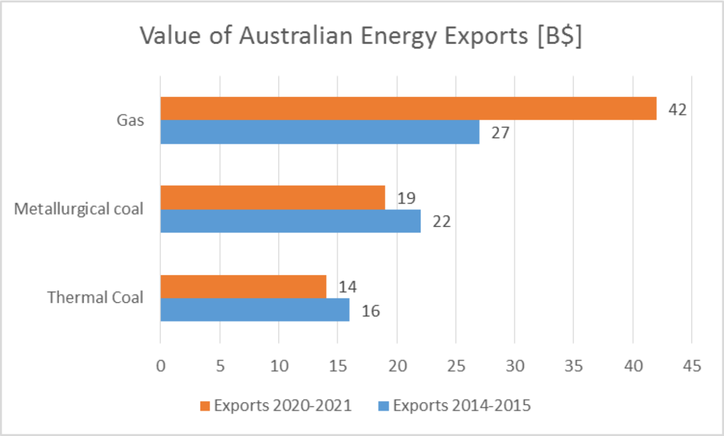
CSIRO ENERGY
www.csiro.au

2016 NETL CO_2 Capture Technology Project Review Meeting

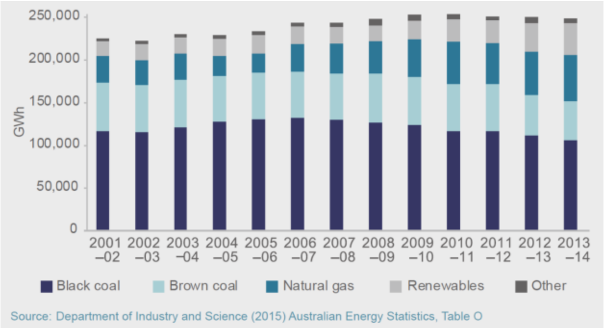
CCS drivers in Australia

- Export of fossil fuel products





- Electricity generation dominated by fossil fuels



Australia's approach to CCS

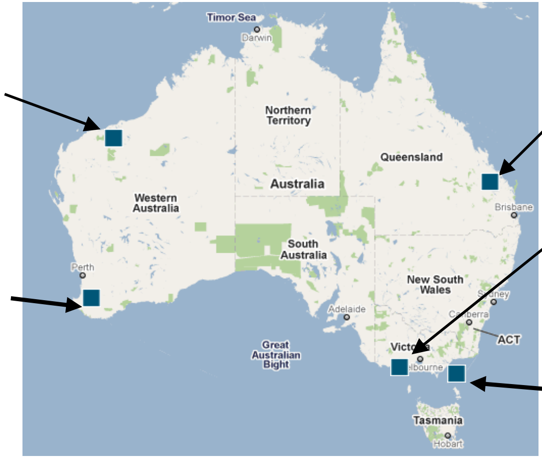
- Policy position
- Understanding the CCS resource
- Demonstrating domestic LET capacities & capabilities
- Strategic partnering
- Building Australian skills and capacity
- Innovation

The Story So Far in Australia Key CCS Projects & Key Research Initiatives

Projects

Gorgon LNG Project

South West Hub Project



Callide Oxyfuel Project

CO2CRC Otway Project

CarbonNet Project

Research & Exploration

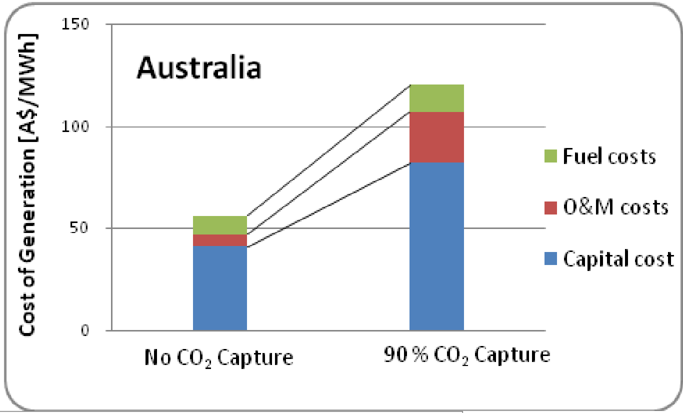
- **ANLEC R&D -** accelerating deployment of CCS
- **NGL -** R&D facility established to advance carbon storage technologies
- **Geoscience Australia -** precompetitive exploration
- **CCS RD&D -** $25 million for research, development and demonstration activities

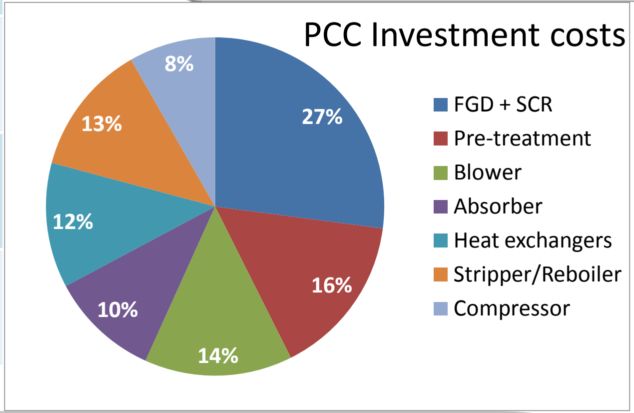
Slide provided by Commonwealth DoIIS

Australian coal fired power stations

	Black coal	Brown coal
Average efficiency [% HHV]	35.6	25.7
CO_2 emission [tonne/MWh]	0.9	1.3
SO_2 concentration [g/m^3]	0.5 – 1.7	0.2 – 0.7
NO_x concentration [g/m^3]	0.4 – 1.5	0.2 – 0.4
Particulate matter [mg/m^3]	10 – 100	10 – 60
Flue gas temperature [^oC]	120	180

Data derived from CCSD – technology assessment report 62

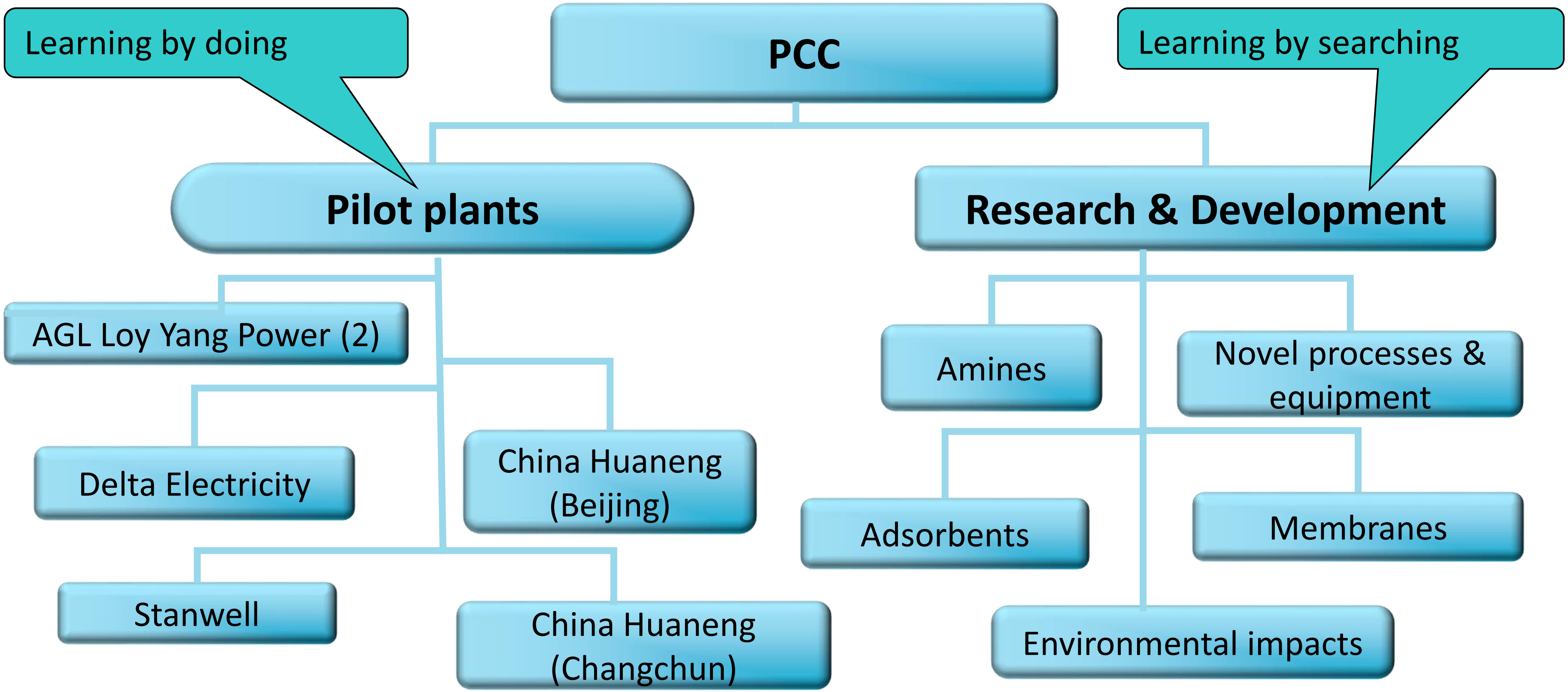




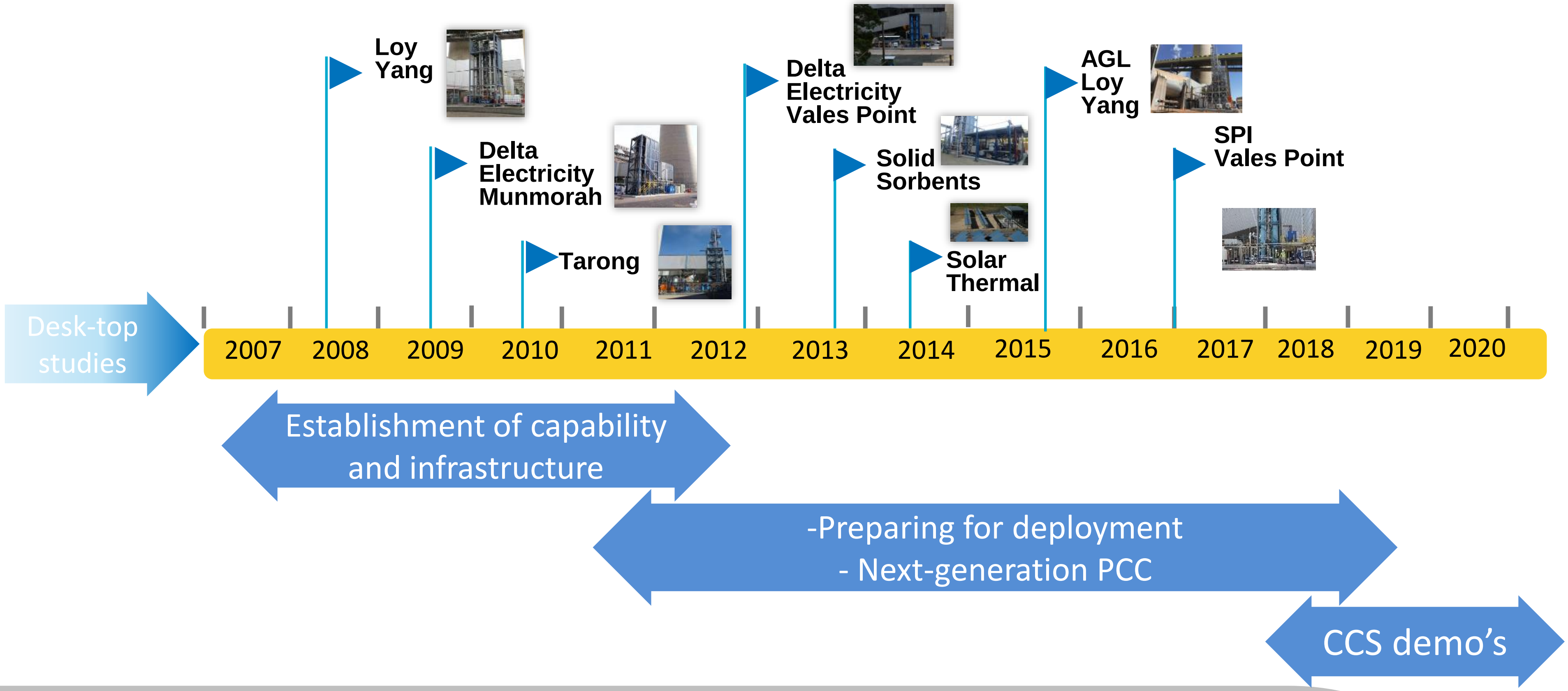
PCC technology requirements

- **Energy Efficient**
  - Towards zero energy penalty
- **Affordable**
  - Costs lower than other LET’s
- **Environmentally benign**
  - Zero harm to the environment

CSIRO's PCC program



Piloting PCC Technologies in Australia

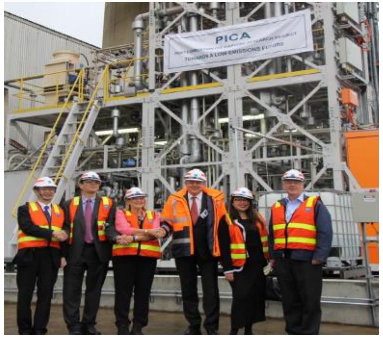


PICA Project

PCC
IHI
CSIRO
AGL

Project aims:

- 40% lower cost of CO_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




CCS in Australia: PICA project to improve CO2 capture efficiency

IHI
Realize your dreams

BROWN COAL INNOVATION AUSTRALIA

AGL

http://www.csiro.au/en/News/News-releases/2016/PICA-powers-up-to-improve-CO2-capture

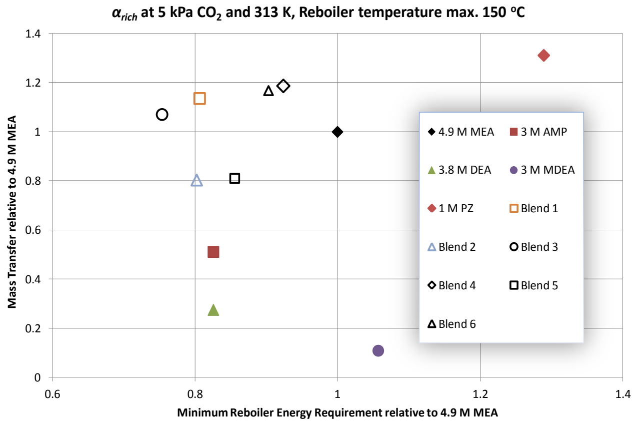
CSIRO

Approaches for reduction capture energy

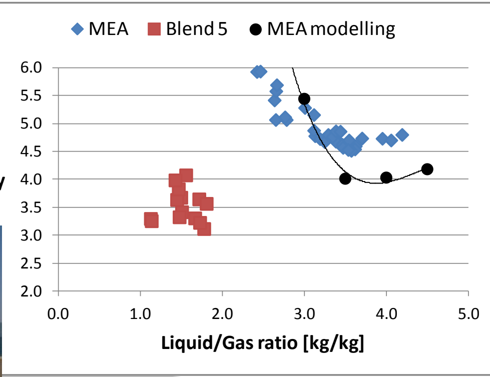
- Development of amine formulations/new amines
- Process development
  - Novel process design
  - Innovative equipment
- Renewable energy integration
  - Solar thermal
  - Light swing absorbents
- Integration with Direct Carbon Injection Engine
- Absorption enthalpy conversion

Development of amine formulations/new amines

- Formulations base on primary amines
  - Selection of a first amine that reacts rapidly with CO_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_2
  - Optimisation of the formulation composition to achieve acceptable physical properties
  - Assessment of CO_2 absorption rates and reboiler duties



- Designer amines and functionalised amines
  - Focus on diamines with dual functionality
  - Higher molecular efficiency

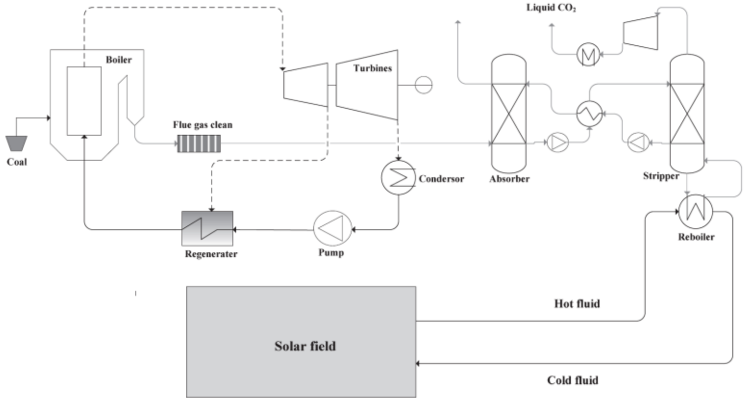


Solar thermal energy for absorbent regeneration

- Avoiding interface with existing steam cycle
- More effective in terms of CO_2-emission reduction
- Introduction of flexibility into the capture process

Pilot plant at Vales Point power station

- Integrated with existing PCC pilot plant
- 65 kW_{th} solar array



http://arena.gov.au/files/2015/08/3-A006-Final-Report-and-Lessons-Learnt.pdf

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

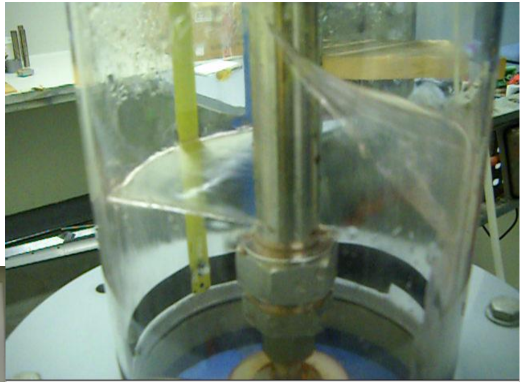
- Surface area of stabilized liquid sheet greater than that of resulting droplets.
- Rotating liquid surface proven experimentally to pump gas .
- Centrifugal + liquid pumping force creates interfacial area.

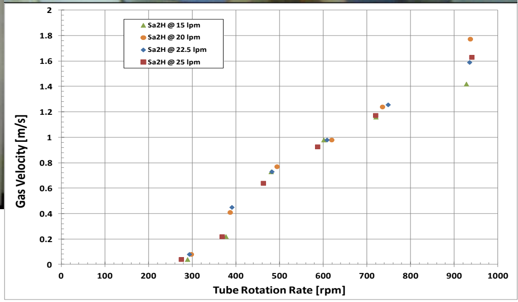
Advantages

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

Challenges

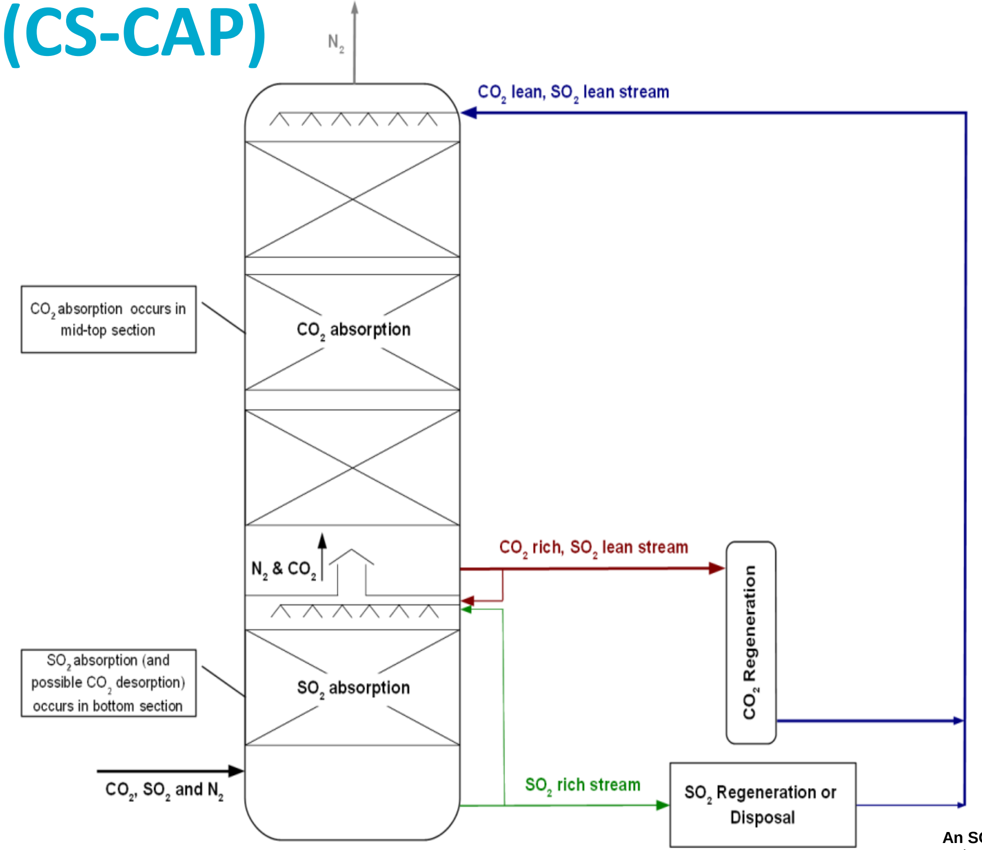
- Scale-up to commercial scale
- Liquid residence time low

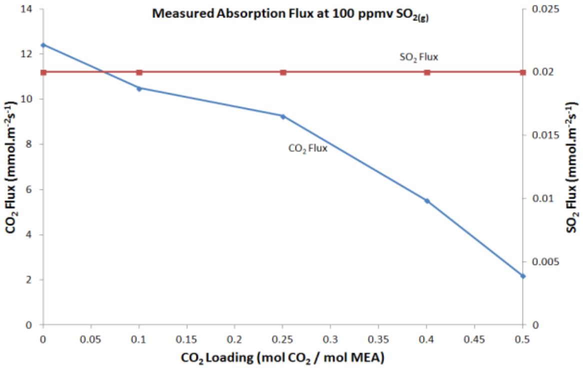


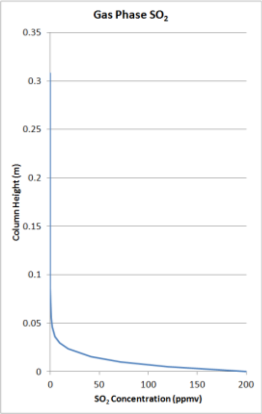


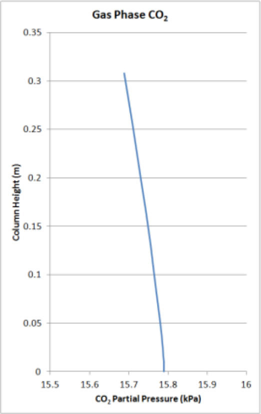
A novel type of gas-liquid contactor for post-combustion capture cost reduction, Leigh T. Wardhaugh, Andrew Allport, Christopher B. Sornordal, Paul Feron, Greenhouse Gas Sci Technol. 5:198–209 (2015)

Integrated Single Stream SO_2 and CO_2 Capture (CS-CAP)





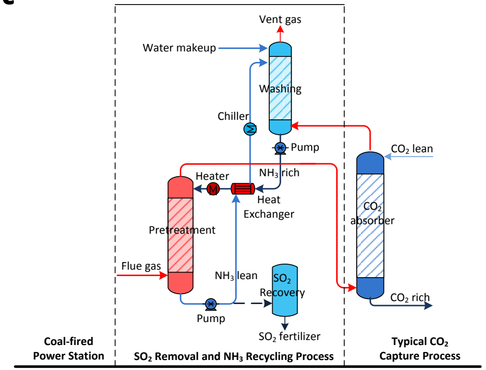




An SO_2 tolerant process for CO_2 capture, Yaser Beyad, Graeme Puxty, Steven Wei, Nan Yang, Dongyao Xu, Marcel Maeder, Robert Burns, Erik Meuleman, Paul Feron, International Journal of Greenhouse Gas Control 31 (2014) 205–213

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

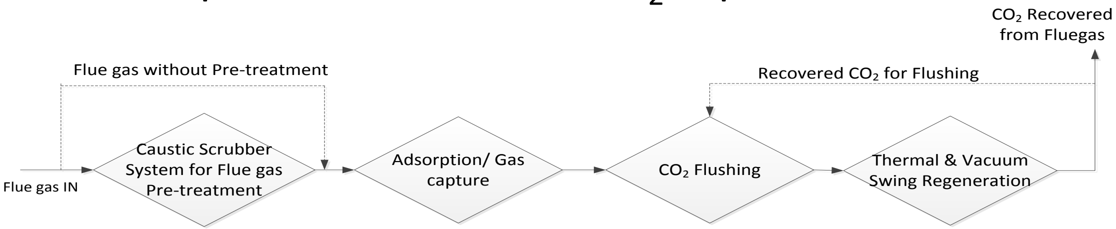


Li et al., Environ. Sci. Technol. 2015, 49, 10243−10252

Solid sorbent CO_2 Capture Unit at Vales Point power station

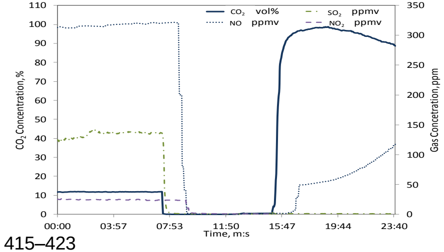
Objective

- 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



Thiruvenkatachari 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

Absorber

- Absorbent type
- Process conditions
- Flue gas compounds

Desorber

- Absorbent type
- Process conditions
- Amine-CO_2 reactions

Gas quality

- Pre-treatment
- Post-treatment
- CO_2 purification

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 SO_2/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

Australian Government
Department of Industry, Innovation and Science

Victoria
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NSW GOVERNMENT

Delta electricity

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iCap CO_2

HiPerCap CO_2

MONASH University

THE UNIVERSITY OF NEWCASTLE AUSTRALIA

The Rochelle Lab
The University of Texas at Austin
CO_2 Capture

Federation UNIVERSITY·AUSTRALIA

清華大學
Tsinghua University

Zhejiang University

CSIRO

Thank you

Energy

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CSIRO TV http://tv.csiro.au/#v=xbz189hynwj6

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