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Post-Combustion Capture (PCC) R&D and Pilot Plant Operation in Australia

IEA GHG 11th Post Combustion CO_2 Capture Network Meeting

Vienna, Austria, 20-21 May 2008

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Overview

- Clean Coal Technologies in Australia

- PCC in Australia
  - The Need
  - The Issues

- PCC programme at CSIRO
  - Pilot plant activities
  - Research activities

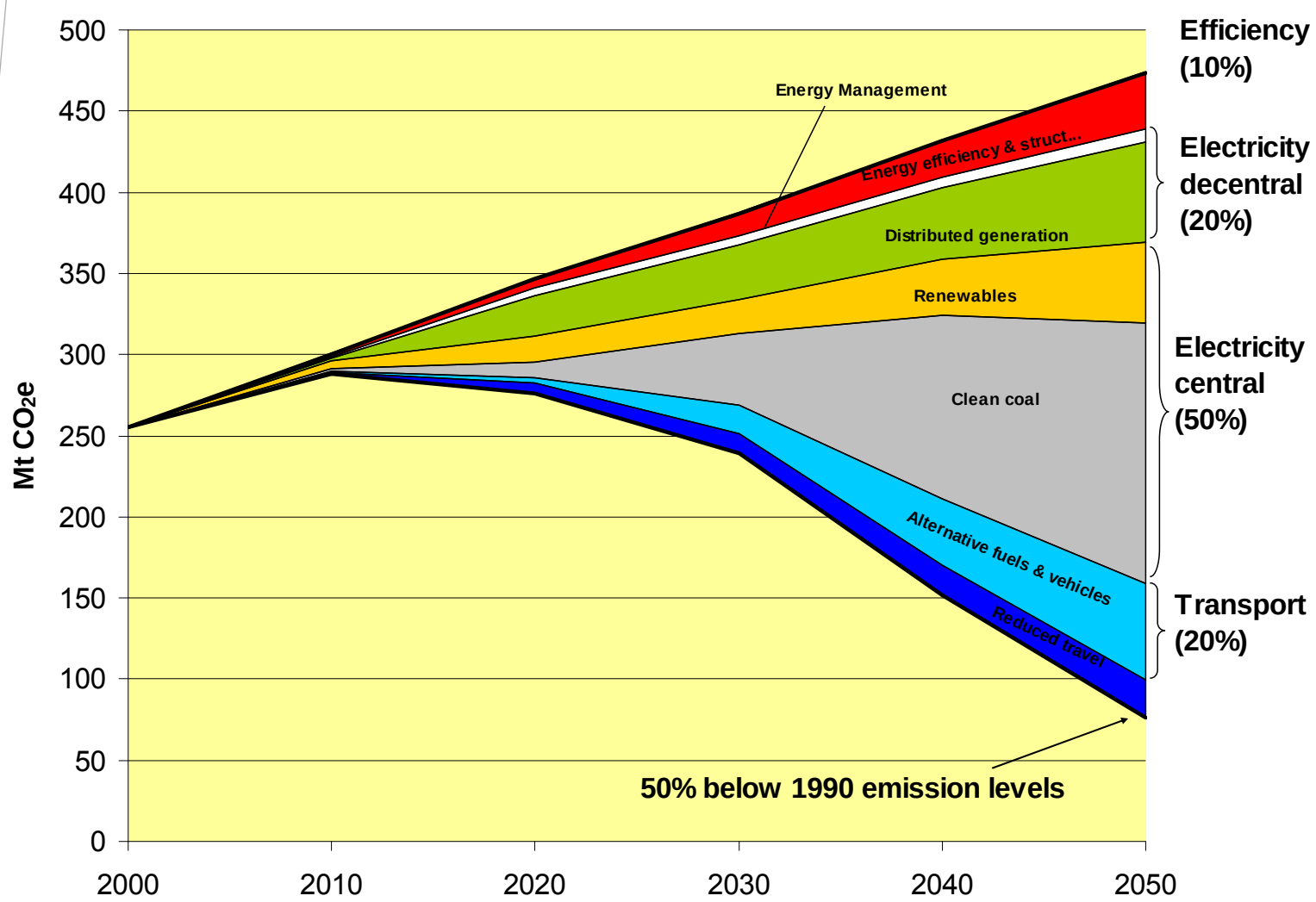
Australia's Greenhouse Gas Emissions

- Australia emitted 559 M tonnes CO_2 equiv. (2005)
- Australia has signed the Kyoto Protocol. Committed to the Kyoto target of a 108% increase over 1990 emissions (to 2012) – currently on track
- Australia's greenhouse gas intensity (per capita) at ~27 tonnes CO_2 – equiv. per capita is among the highest in the world
- Australia's greenhouse gas intensity (per $ of GDP) is 0.7 kg CO_2

Importance of Coal to Australia

- Black coal is Australia's largest commodity export and is worth $25 billion (AUD) per annum
- Australia is the world's largest exporter of coal
- Electricity generation accounts for ~35% of Australia's net GHG emissions
- Australia's electricity derives mainly from coal (57% black coal, 30% brown coal)

Emission reduction pathway for Australia



Source: Energy Futures, Paul Graham, CSIRO

Australian Research Organisations in CCT

- Cooperative Research Centre for Coal in Sustainable Development (CCSD)
- Centre for Low Emission Technologies (cLET)
- Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC)
- Australian Coal Association Research Program (ACARP)
- Energy Transformed Flagship of the Commonwealth Scientific and Industrial Research Organisation (ETF-CSIRO)

- *Until 2006 there was also a CRC for Clean Power from Lignite*

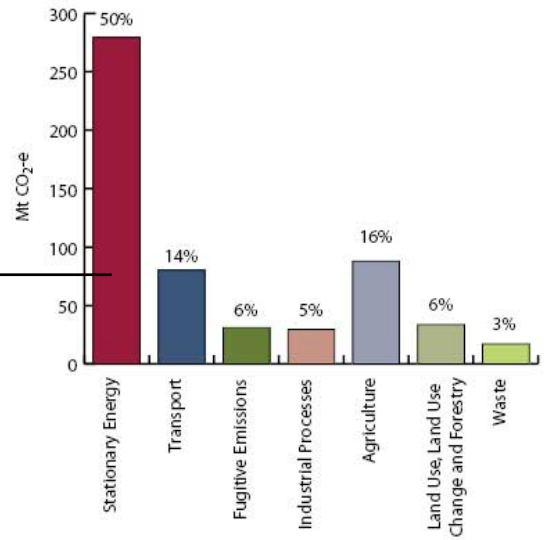
Clean Coal Technology Pilot and Demonstration Projects

1. IDGCC (HRL)
2. Monash Energy -Gasification/ GtL/ CSS
3. Stanwell IGCC/ CSS - *ZeroGen* Project
4. CS Energy Oxyfuel Project
5. International Power - Lignite Power Repowering, Drying and Capture
6. Gorgon
7. Zero Carbon - Fairview
8. CO2CRC Otway Basin Project
9. Kwinana Project
10. Latrobe Valley PCC Project
11. Moombah Carbon Storage
12. APP - Post Combustion Capture Project
13. APP - Enhanced Coal Bed Methane Project

The Need for PCC in Australia

- Potential for substantial impact on very high GHG intensity of nations with a heavy reliance on coal for power generation
- Offers ultimate long-term objective of near-zero CO_2-emissions
- Addresses the risk of having major stranded generation assets (if a high cost is applied to carbon emissions)
- PCC potentially offers cost competitive route to low GHG emission electricity from coal for existing and new power stations

80% of energy from burning coal



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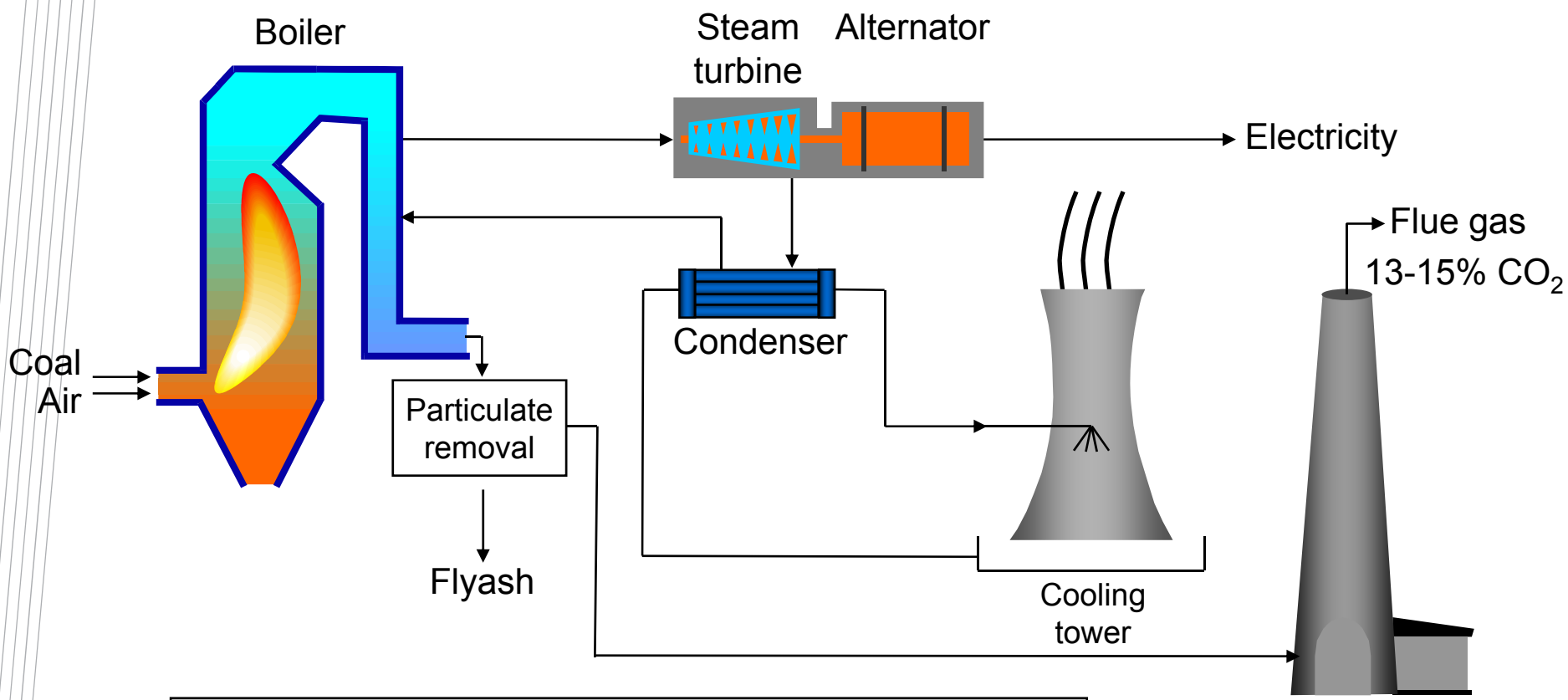
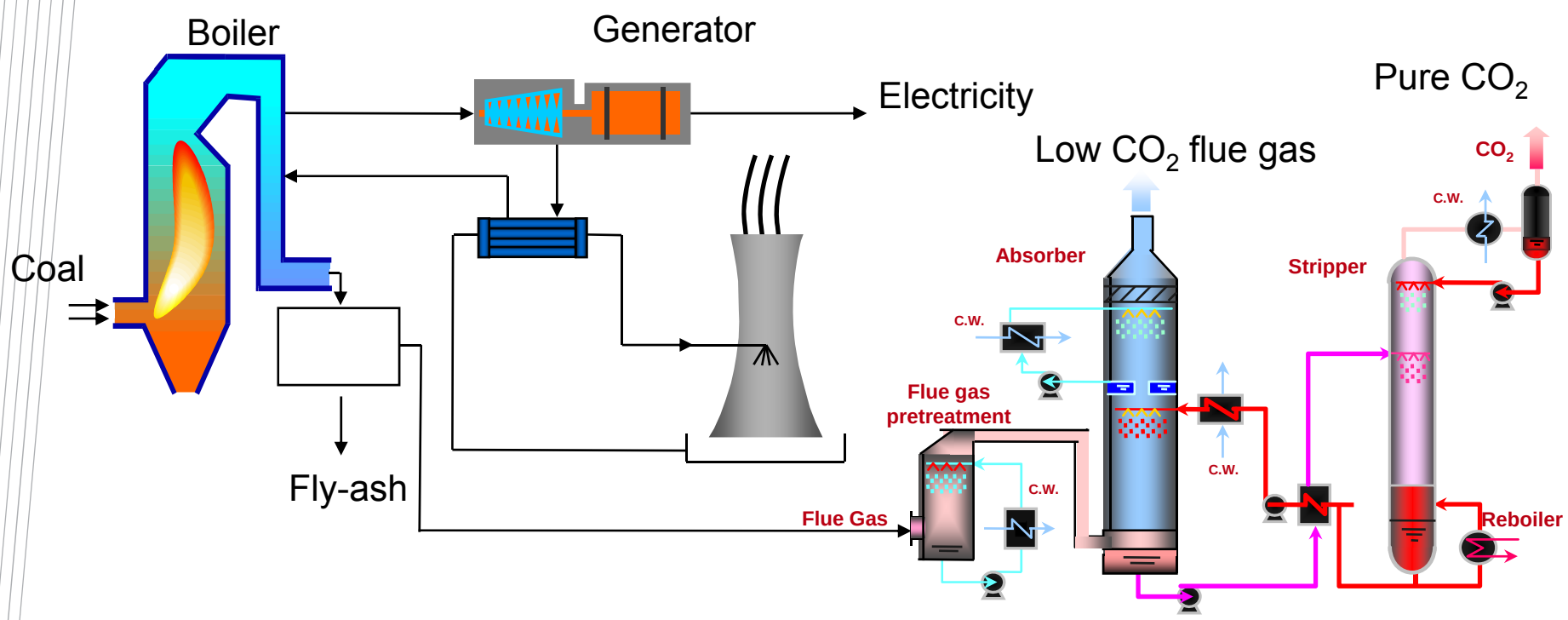
PF Power Plant



Coal Type	Thermal Efficiency (%)	CO_2 Emissions (kg/MWh)
Black	36 - 41	1000 - 800
Brown	28 - 32	1300 - 1100

PF Power Plant with Post Combustion Capture



Thermal efficiency 28 - 33%
CO_2 emissions <100 kg/MWh

PCC application in Australian coal fired power stations

- Generation capacity ~ 28 GW
- Electricity production 170 TWH/a
- Average generation efficiency
  - Black coal: 35.6% - 0.9 tonne CO_2/MWh
  - Brown coal: 25.7% - 1.3 tonne CO_2/MWh
- CO_2-emissions ~ 170 Mtonne CO_2/a from ~ 60 flue gas streams
- SO_2 levels:
  - Black coal: 200 - 600 ppm
  - Brown coal: 100 - 300 ppm
- NO_x levels:
  - Black coal: 300-700 ppm
  - Brown coal: 100-200 ppm
- Flue gas temperature
  - Black coal: 120 ^oC
  - Brown coal: 180 ^oC
- Cooling water: 1.5-3.0 m^3/MWh

Data used from CCSD – technology assessment report 62

Known issues with PCC

- High cost: around \$30/t CO_2 captured
- Electricity cost increase from \$30/MWh to \$50/MWh for an 85% reduction in GHG
- Loss of generation efficiency around 20-30% to capture 90% of CO_2
- Not demonstrated in integrated power plants scale
- Sensitive to O_2, SOx and other flue gas constituents
- Large increase in cooling water requirement

PCC programme at CSIRO

Integrated PCC R&D Programme

Pilot plant programme (Learning by doing)

- Hands-on experience for future operators
- Identification of operational issues and requirements
- Testing of existing and new technologies under real conditions

Lab research programme (Learning by searching)

- Support to pilot plant operation and interpretation of results
- Develop novel solvents and solvent systems which result in lower costs for capture
- Addressing Australian specifics (flue gases, water)

Confirmed Pilot Plants

Delta electricity

- APP support
- Munmorah Power Station
- Black coal
- Ammonia based
- No FGD/DeNox

CHINA HUANENG

- APP support
- Gaobeidian Power Station
- Black coal
- Amine based
- FGD/DeNox installed

LOY YANG power

Latrobe Valley Post Combustion Project

- ETIS support
- Loy Yang Power Station
- Lignite
- Amine based
- No FGD/DeNox

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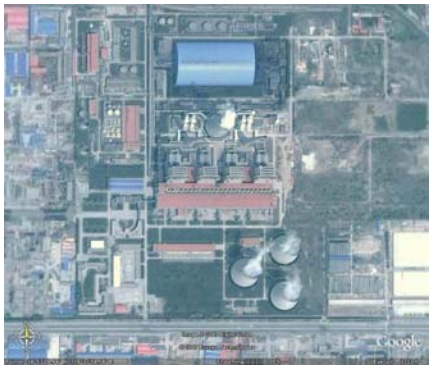
Pilot plant locations



Gaobeidian power station

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Latrobe Valley Post-Combustion Capture Project

Energy Technology Innovation Strategy

Project activities and actors

- New solvent development research – CSIRO/CO2CRC
- Membrane research 10 tpa – CO2CRC
- Adsorbent research at 100 tpa – CO2CRC
- Solvent testing in 1000 tpa test facility – CSIRO/Loy Yang Power
- Solvent testing in 10000 tpa demonstration plant – CO2CRC/International Power Hazelwood
- Process and energy integration studies - all
- Technical and economical studies - all

Scope of pilot plant experiments at LYP

- Technical and economical scale-up information about CO_2 capture plant based on operation on flue gas from brown coal combustion

- This includes determining the following interrelationships:
  - CO_2 capture energy consumption
  - CO_2 capture efficiency
  - Solvent CO_2 loading
  - Solvent and flue gas flow rates
  - Regeneration temperature and pressure
  - Absorption temperature
  - Solvent consumption and degradation rates
  - Fouling and corrosion
  - Effectiveness of the conditioning stage
  - Reagent loss rate both to acid gas and to release with flue gas
  - System water consumption

Loy Yang Power Station, Victoria

- The power station is capable of generating 2,200 megawatt.
- Loy Yang mine is the largest producing open cut brown coal mine in the southern hemisphere.
- Loy Yang Power supplies one third of Victoria's electrical energy needs.
- The Loy Yang open cut coal mine excavates approximately 30 million tonnes of brown coal each year.
- There are 168,000 million tonnes of accessible brown coal beneath the Latrobe Valley, or in excess of 1,300 years supply at current rates of usage.

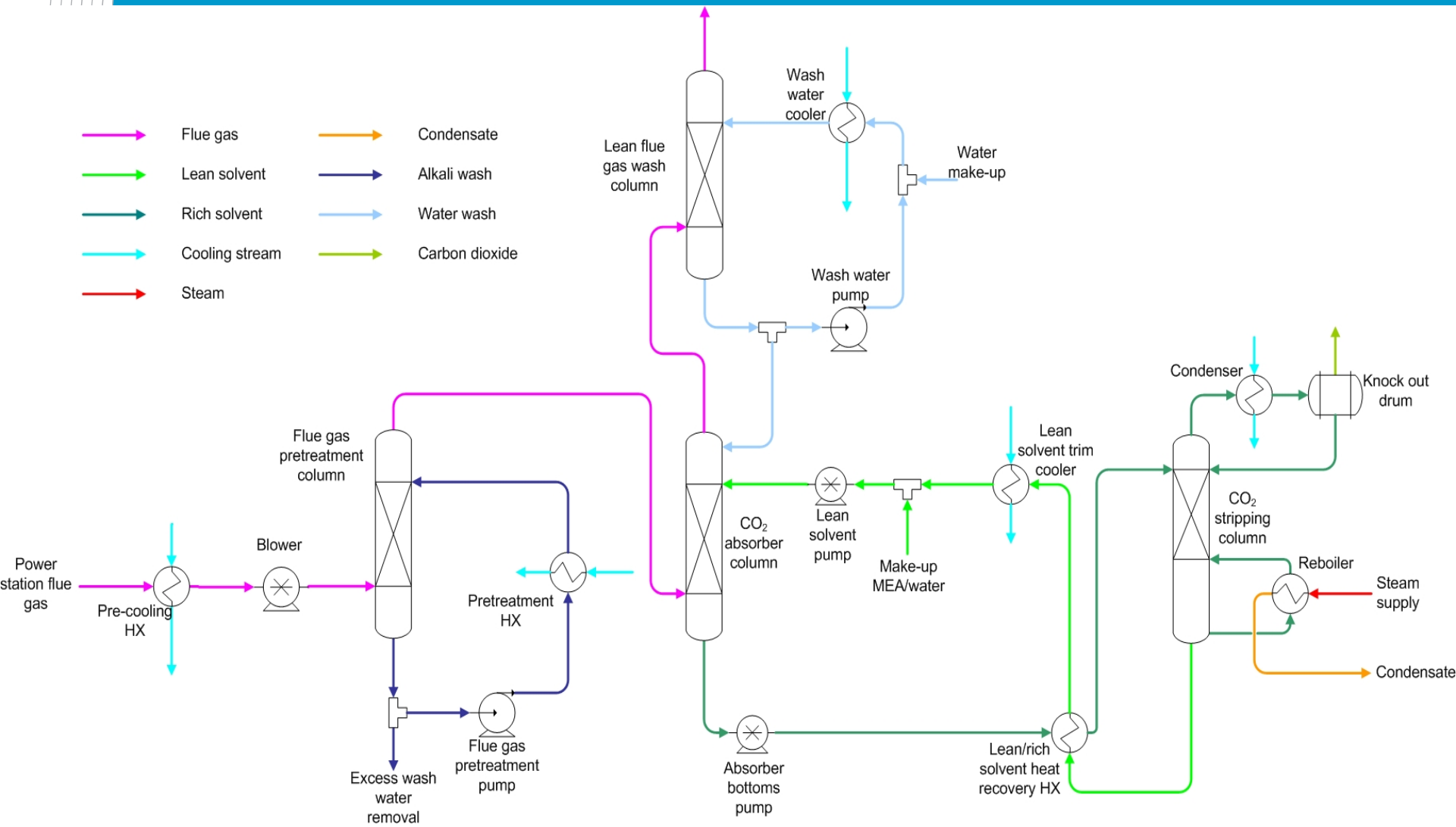
LYP Pilot plant design

- Use of two columns with a specified single column design CO_2 capacity of 100 kg/hr as a minimum (85% removal)
- Based on local flue gas composition (11% CO_2)
- Based on the use of MEA (30%)
- Operate with reboiler temperatures 100 - 120°C
- Operate with stripper pressures 1 - 2 bar
- Be able to determine thermal and electrical energy requirements of the pilot plant
- Be able to determine emissions to atmosphere and CO_2-product quality

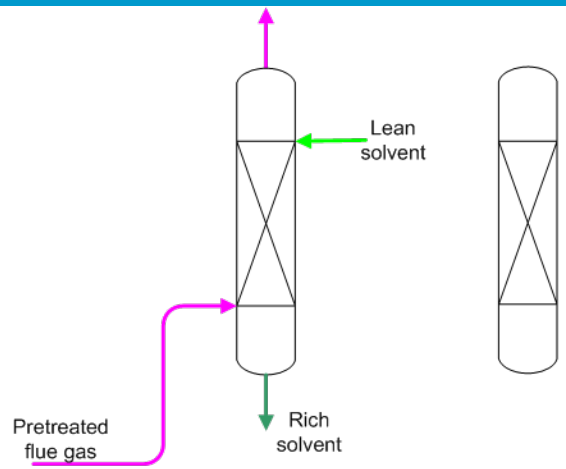
Pilot plant design process

- Process modelling based on Winsim and Aspen Plus providing heat and mass balance -> basis for design
- Sizing and costing of major equipment both internally and by external contractors
- Frame/skid design
- Detailed design including piping
- Process and Instrumentation
- Control logic

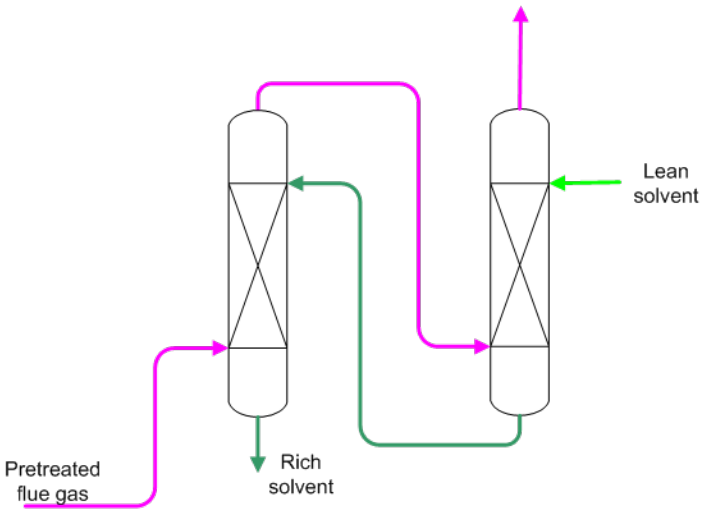
Simplified Pilot plant flow sheet



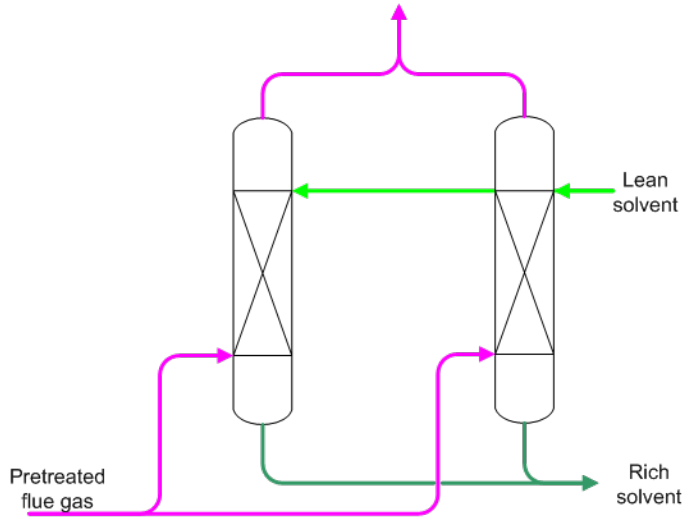
Two absorbers for added flexibility



Single column operation with other column on standby or changed out for new experiment



Series operation for higher packing heights



Parrallel operation for larger equivalent column diameter

Pilot Plant Gas Analysis

Gas analysis will be performed at 5 points throughout the pilot plants.

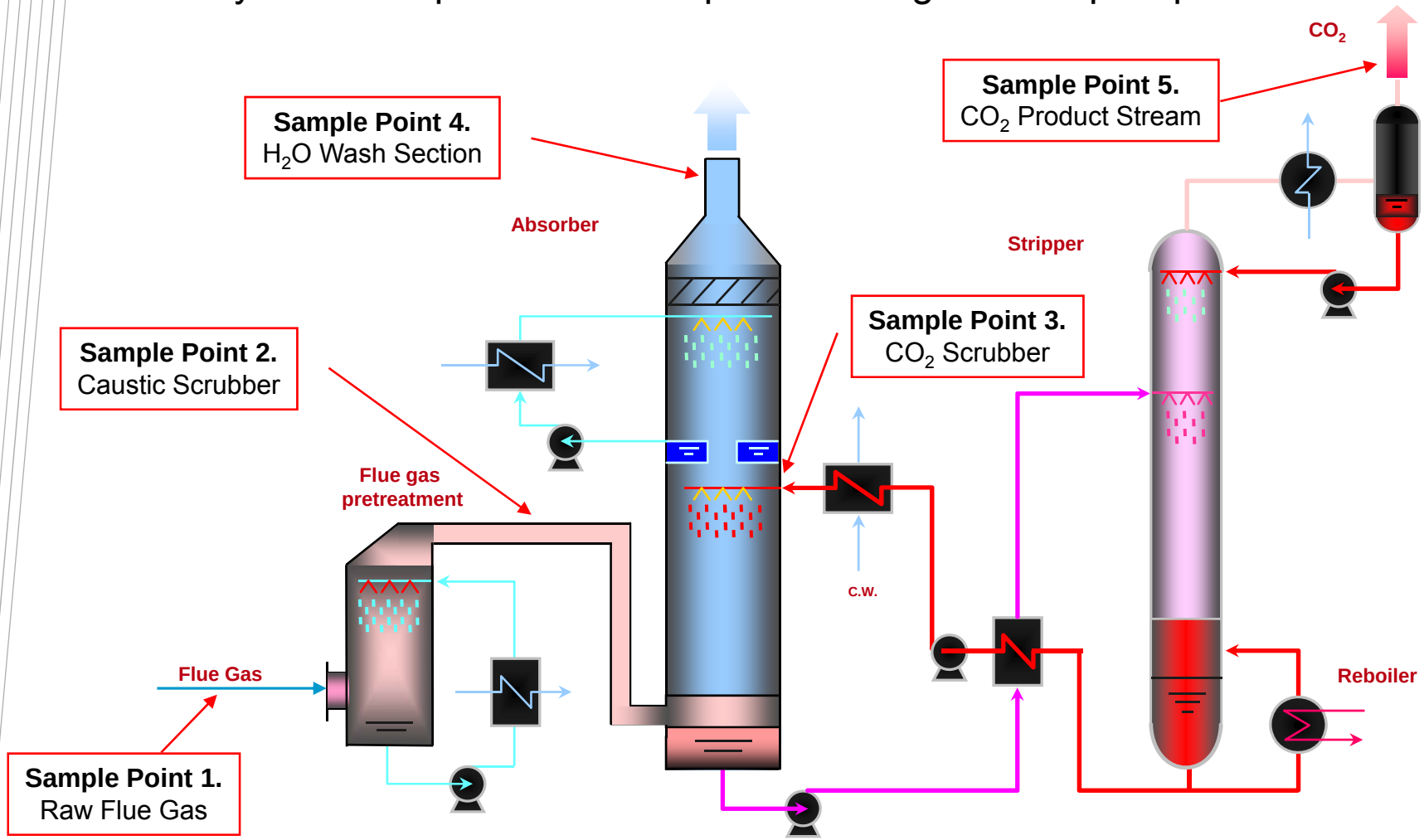


Diagram adapted from MHI.

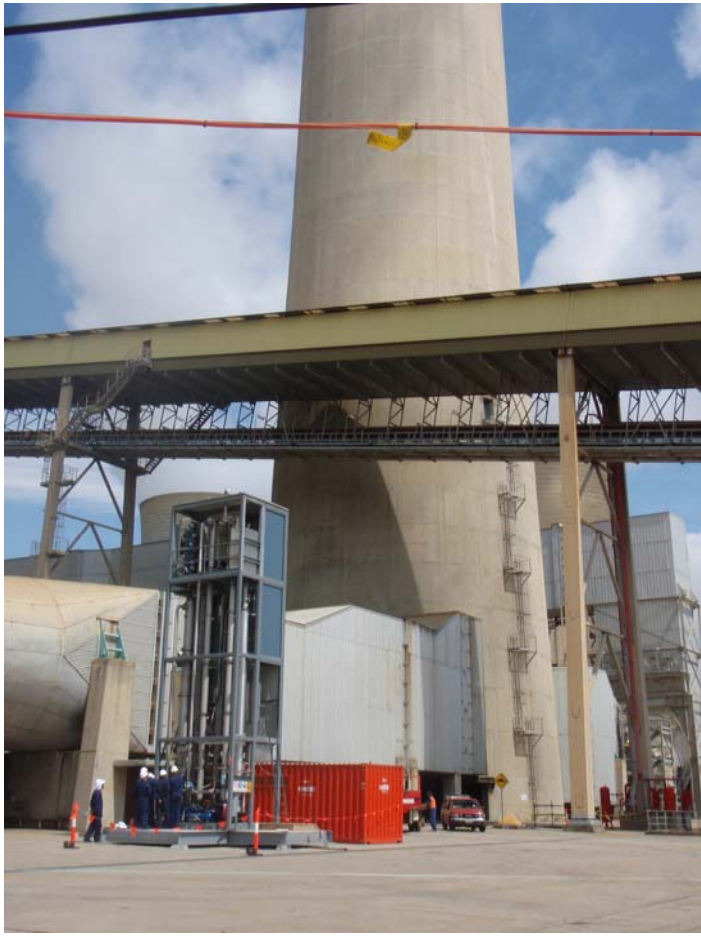
Loy Yang Pilot Plant Program

➢Collaboration Partners

- Loy Yang Power
- Victorian Government (Energy Technology Innovation Strategy - ETIS)

➢Project Milestones

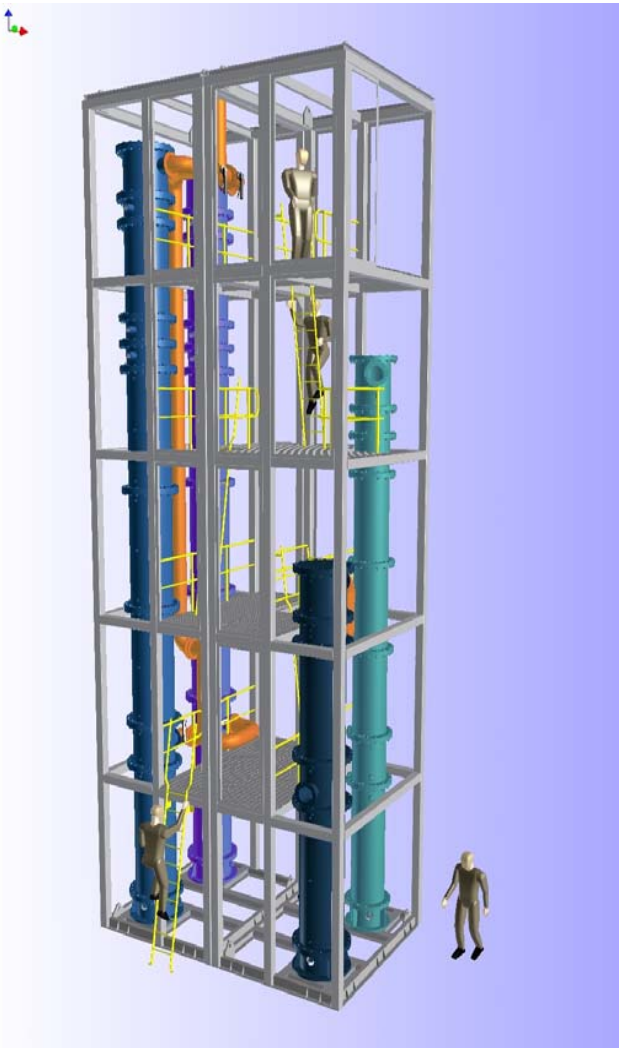
- Establishment of pilot plant on site Jan 2008
- Official opening 29 April 2008
- Pilot plant operational - May 2008
- Experimental program – Jun 2008 – Dec 2009



Munmorah Pilot Plant

- Collaboration Partners
  - DELTA Electricity
  - Department of Resources, Energy, & Tourism (Asia Pacific Partnership program)

- Project Milestones
  - Detailed design complete – Feb 2008
  - Construction complete – June 2008
  - Commissioning and experimental program – July 2008 – July 2010



Australian Government
Department of Industry, Tourism and Resources

Delta electricity

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Development Pathway for PCC

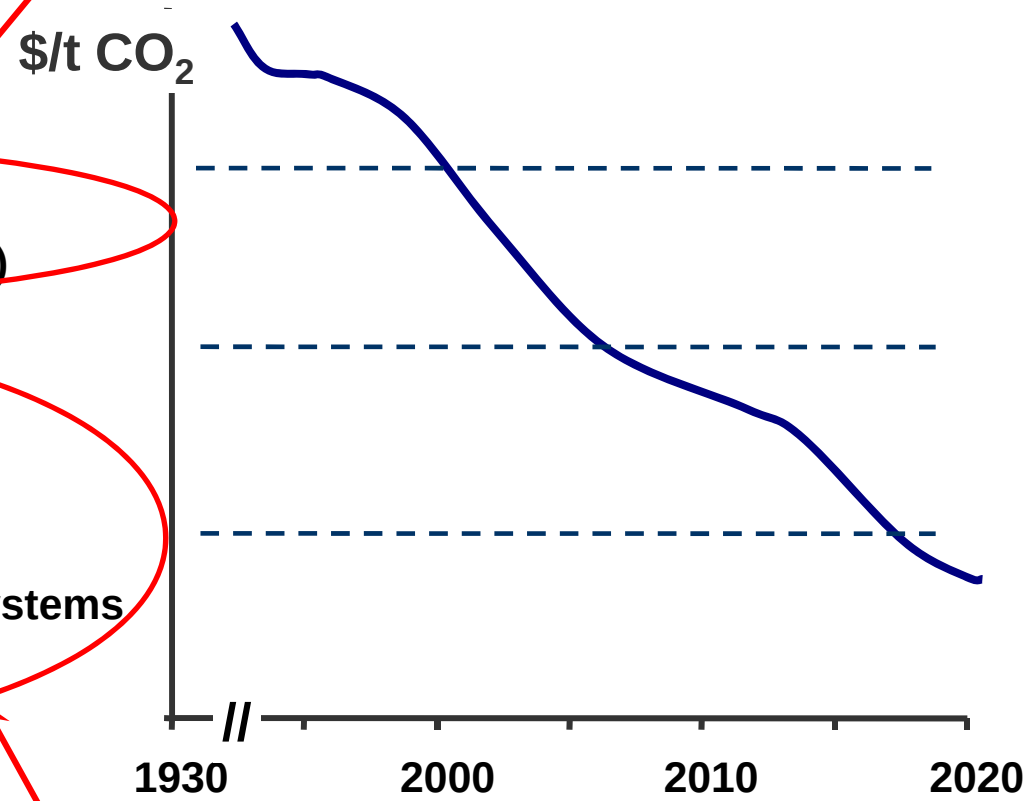
Current best technology

Generation I: **MEA (chemicals)**

Generation II: **Improved "MEA" (EOR, chemicals)**

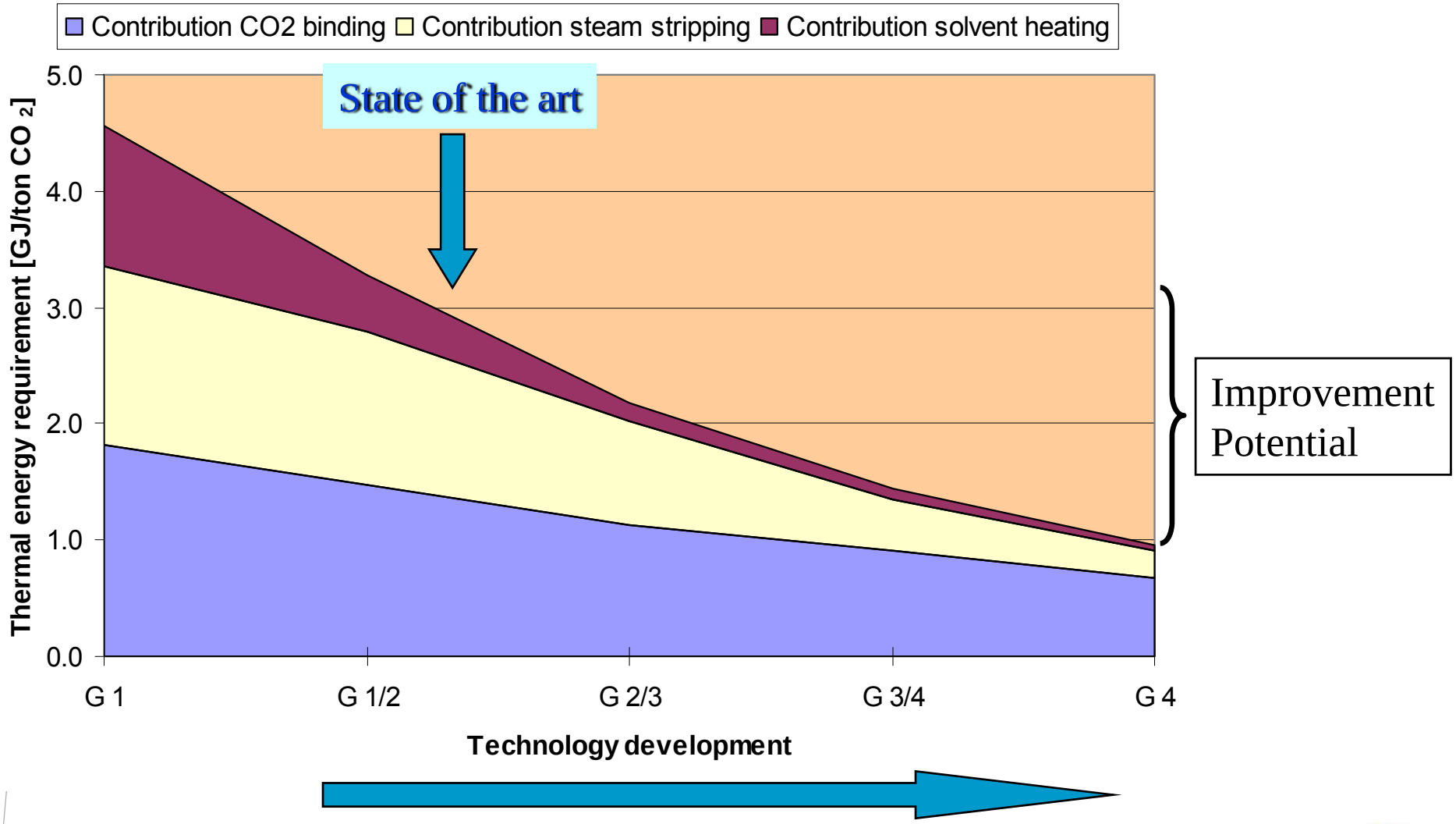
Generation III: **Novel solvents (PCC-CS)**

Generation IV: **Novel capture systems (PCC-CS)**

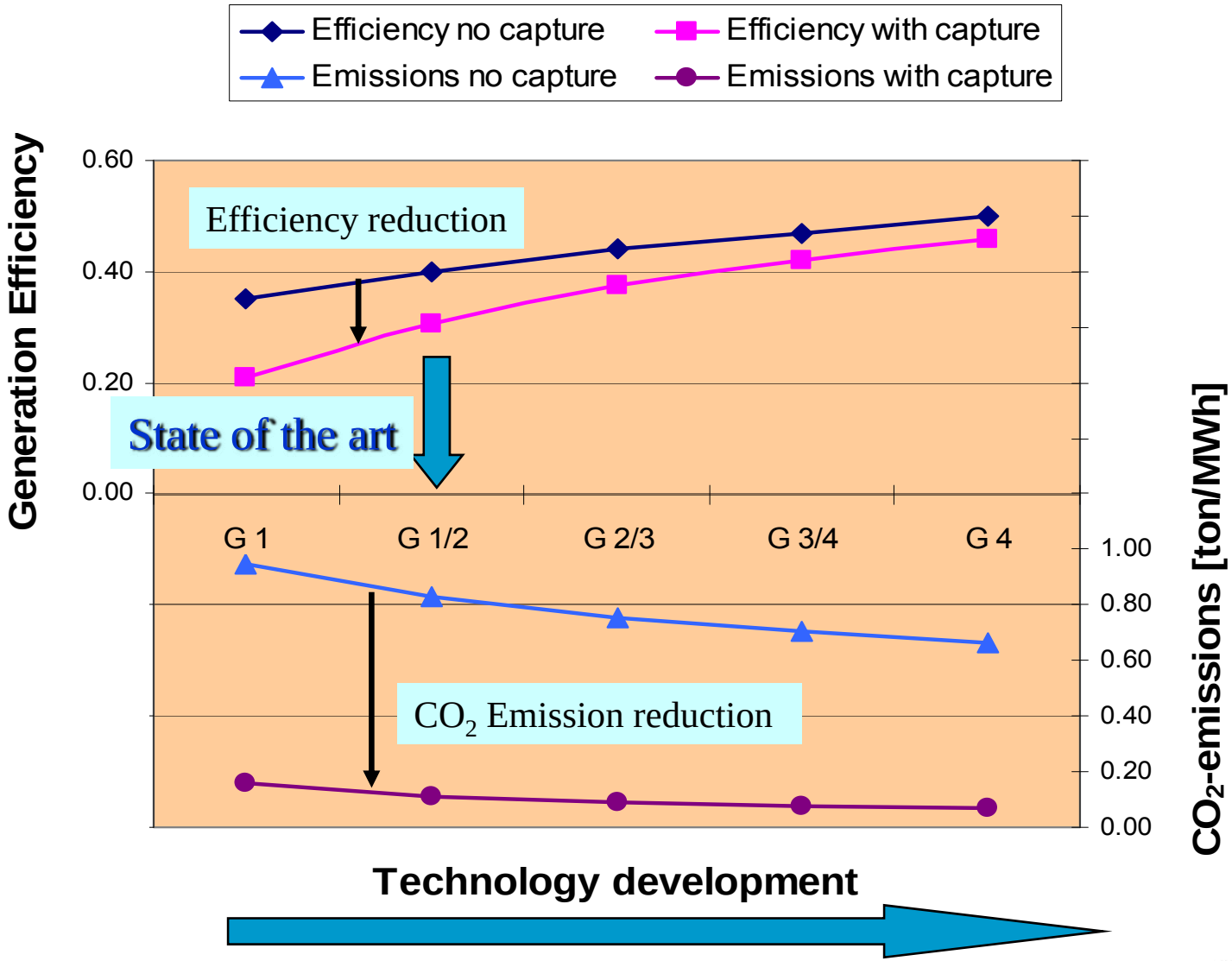


Focus of the lab research

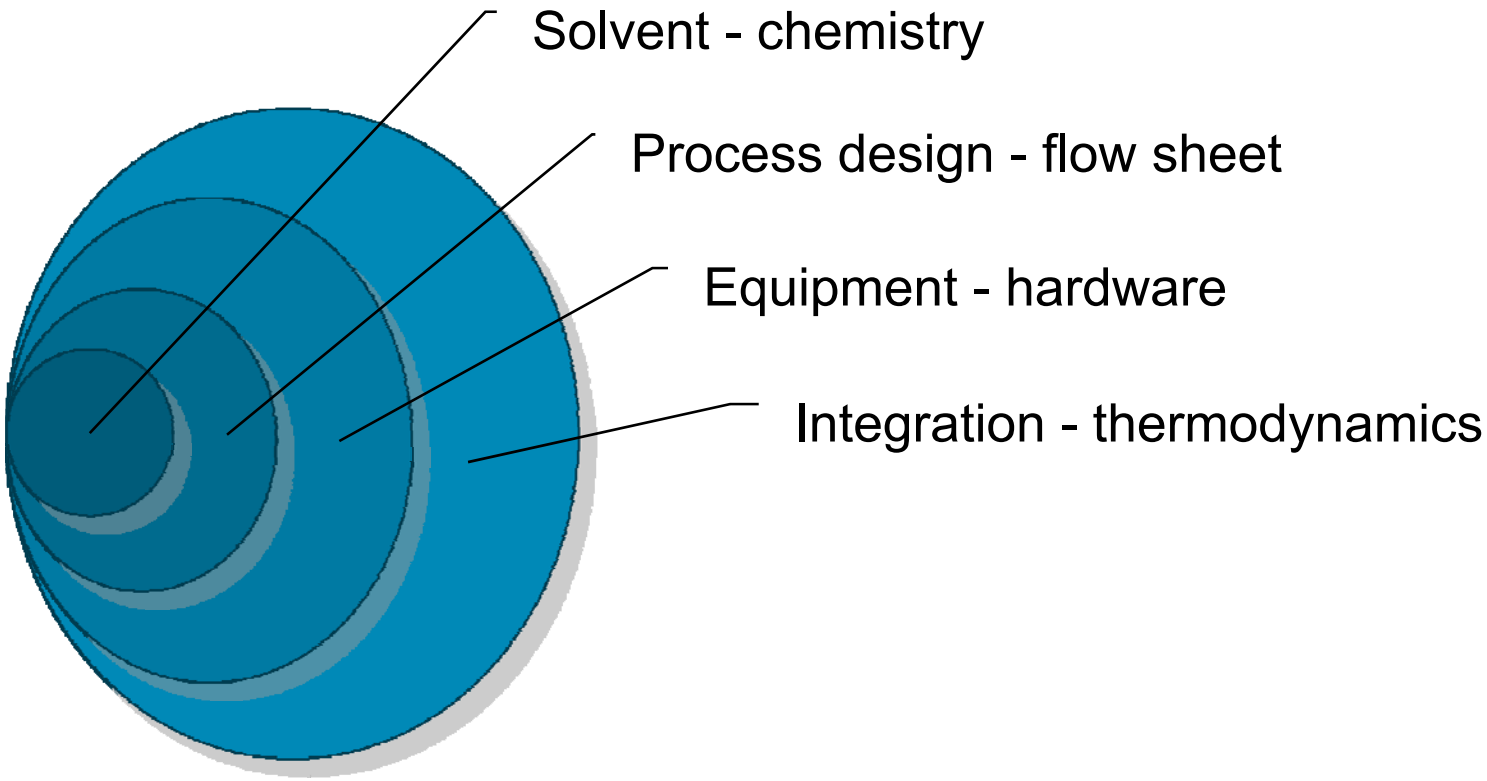
PCC Technology Development Scenario



Efficiency and CO_2 Emissions



Research: Solvent system development



A holistic approach is essential!

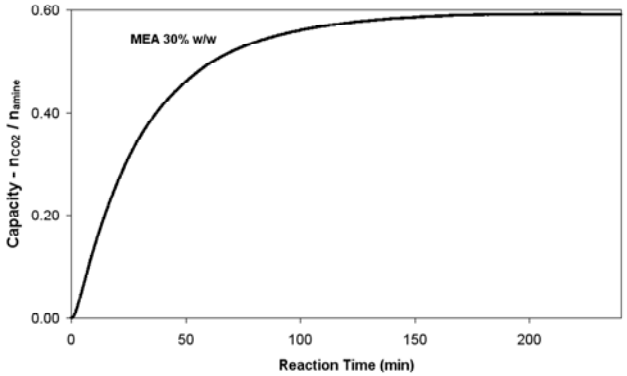
PCC Research programme overview

1. Solvent development focuses on new chemicals or chemical formulations for reversible binding of CO_2
2. Solvent process development involves the development of alternative processes, novel process flow sheets, inclusion of other separation processes such as membrane technology to improve the solvent process performance
3. Equipment development is particularly aimed at reducing the equipment sizes and the physical footprint of capture technology and hence reducing investment costs
4. Optimal power plant integration is required to have minimal impact of the capture process on the power plant, including the usual of solar energy

Solvent development programme

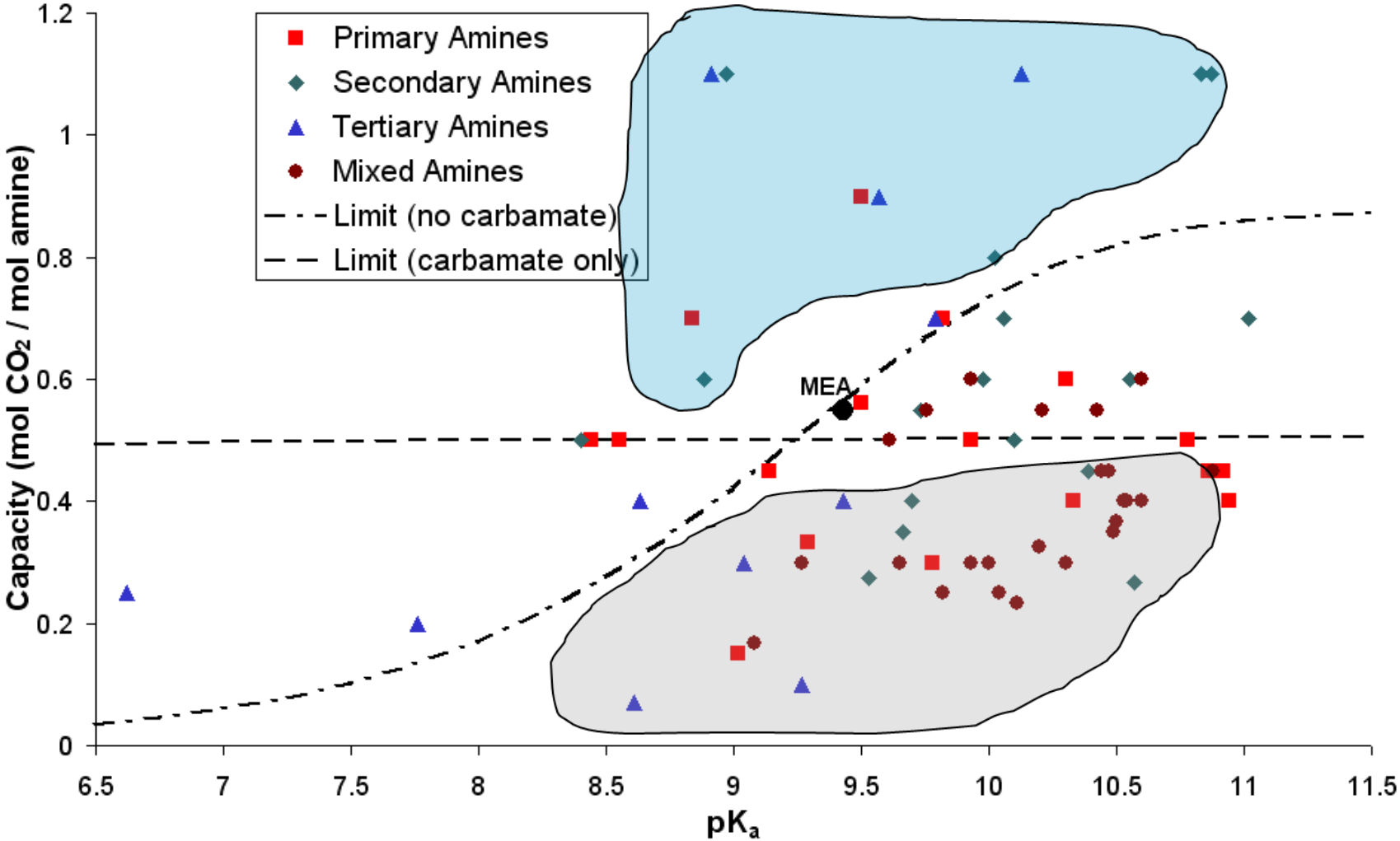
Screening of Capacity and Initial Rate

Gravimetric method used to measure CO_2 absorption and initial absorption rate on µL scale



Traditional absorption method used on the mL scale

Modelling + Screening



G III-IV - R&D Directions

- Advanced amines
  - Formulated mixtures, multiple amine groups
- Non-aqueous solvents
  - Ionic liquids
- Phase change solvents
  - Slurries, emulsions
- Modified process concepts
  - Intervolving, heat exchange integration in stripper, integration of compression, split flow
- Novel process components
  - Membrane contactors, heat pumps
- Robust solvents
  - Ammonia, carbonates
- Biomimetic approaches
  - Enzymes for solvent process improvements

CSIRO Energy Technology
Paul H.M. Feron
PCC Science Leader

Phone: +61 (0)2 4960 6022
Email: paul.feron@csiro.au
Web: www.csiro.au

www.csiro.au

Thank you

Contact Us
Phone: 1300 363 400 **or** +61 3 9545 2176
Email: Enquiries@csiro.au **Web:** www.csiro.au

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