Commonwealth Scientific and Industrial Research Organisation (CSIRO)

Australia’s national science agency

One of the largest & most diverse in the world

6500+ staff over 55 locations

Ranked in top 1% in 14 research fields

20+ spin-off companies in six years

160+ active licences of CSIRO innovation

Building national prosperity and wellbeing
CSIRO - Research Portfolios

- Energy Transformed
- Coal Technology
- Petroleum and Geothermal
- Climate Adaptation
- Minerals Down Under
- Water for a Healthy Country
- Food Futures
- Preventative Health
- Wealth from Oceans
- Future Manufacturing
- Sustainable Agriculture
- Light Metals
Energy - Coal - Australia

• Energy is central to all developed economies

• Predictions of future world energy use shows continued growth in coal use

• This is in part due to increasing world population and also the rapid development of a number of currently under-developed economies

• The heavy reliance on petroleum and coal has raised the issue of anthropogenic global warming change

• Coal plays a key role in Australia’s economy

• This talk will present a brief overview of research by CSIRO and CSIRO partners
Australian Electricity generation technology share (CPRS-5, 550ppm)

Source: CSIRO projection
CSIRO - Coal Technology

Focus is on innovative science and technology to address the challenges facing coal

Laboratories in NSW, Queensland and Victoria (200 scientists, $50m AUD pa)

- Quantification and mitigation of fugitives
- Gasification of coal and biomass (PEFR)
- Downstream gas processing for IGCC
- Post combustion capture of CO2 (amines, ammonia, adsorbents, ILs, enzymes - black and brown coal - lab and pilot-plants)
- Emissions limits for PCC - amines
- Coal in large scale diesel engines
- Enhanced coal bed methane (ECBM)
- CO2 storage in saline formations
  - Mineralisation
  - Direct carbon fuel cell
  - Coal to Liquids (direct)
  - Public attitudes to CCS

We work with many partners – Commonwealth and State Govs, ANLEC, CO2CRC, GCCSI, ACA, ACARP, industry, Universities and international research partners
Fugitive emissions of methane account for 6% of Australia’s GHG emissions.

Emissions arise from both surface and underground mines.

CSIRO is investigating pre-drainage at surface mines to mitigate methane emissions.

Emissions from spontaneous combustion not included in national inventories as no robust methods at present for their quantification. CSIRO is investigating methods for quantifying these emissions.
Underground Coal mining Ventilation Air Methane Control

VAMCAT can utilise methane from 1% and co-produce electricity

A 25kW pilot unit has been built and trialled under laboratory conditions

Field trials are scheduled for later in 2010

VAMCAT 25kWe Demonstration Unit at CSIRO, Queensland
Coal Gasification & IGCC Research Topics (Leader – David Harris)

To improve the understanding of coal performance in gasification technologies, supporting:
- Use of Australian coals in new technologies
- Implementation of advanced coal technologies in Australia
- Development of high efficiency IGCC-CCS systems

- High pressure, high temperature coal conversion measurements
  - Effects of reaction conditions and coal type
  - Development of coal test procedures
- Fundamental investigations of coal gasification reactions
  - mechanisms, kinetics, models
- Slag formation and flow
- Syngas cleaning & processing
- Gas separation (H₂/CO₂)
- Technology performance models

CSIRO PEFR at QCAT, Queensland
CO$_2$/char reaction rate and viscosity at ‘high’ temperature

Residence time (s)

Char conversion (%)

CRC252

CRC272

CRC281

1673 K
1573 K
1473 K
1373 K
1273 K

Semi anthracite
Bituminous
Sub bit, high vol

Viscosity Pa.s

Maximum for Slag Tappability

Slag Viscosity

25 Pa s is the accepted maximum viscosity at the slag tap for successful operation
Flux addition required if viscosity is too high
Improved shift reaction catalysts

- New ceria-based catalysts demonstrate much greater activity and stability than commercial reference catalysts up to 600°C
- Catalysts used in membrane reactor development
Catalytic membrane reactor

- Prototype planar proof-of-concept device
- Greater-than-equilibrium conversion achieved
- Pure H₂ product
- >70% H₂ recovery demonstrated

![Graph showing CO conversion vs. syngas feed rate and membrane area.](image-url)
Enabling technologies for coal-based H$_2$ energy systems (CSIRO, Queensland)

- Scale up facilities to investigate impacts of coal-derived impurities using simulated syngas
Direct injection coal engine
Leader - Louis Wibberley

- Efficiency of 54% HHV @ 67MW by low speed diesel engines
  - 97 MW engine available
- Coal should be able to achieve a fuel cycle efficiency of 50% (sent out basis)
- Coal has been used in diesel engines, mostly by injecting a coal water fuel
- Highly flexible and adaptable
  - easily cooled, rapid start, waste heat sufficient to energise CO₂ capture
- Conventional CWF are too viscous, too high in ash, and too coarse for DICE
  - needs <20um, <2-3% ash, at least 45% solids, and <500mPa.s
  - very low production cost needed for baseload
Challenge 1: reduce size of absorber
kinetics, packing

Challenge 2: reduce heat input
integration, cooling water

Challenge 3: Improve molecular efficiency
selectivity, binding energy, stability:
chemical, thermal, evaporation, pre-treatment

Conventional PF power plant with PCC
Leader – Paul Feron
Novel Solvents and Process Development

**Generation I**
Traditional capture solvents – MEA, $\text{K}_2\text{CO}_3$/promoter, …

**Generation II**
Modern capture solvents – MDEA/PZ, AMP/PZ, …

**Generation III**
Novel aqueous solvents – novel amines, promoters, …

**Generation IV**
Novel solvent systems – ionic liquids, enzymes, …
Establishing emissions limits for PCC

Smog chamber facility at Lucas Heights, NSW

Emission modelling

Transport of pollutants
CSIRO and partners PCC, Pilot Plants “Learning by doing”
Established PCC Pilot Plants - (CSIRO and partners)

- Latrobe Valley Post Combustion Project
  - ETIS support
  - Loy Yang Power Station
  - Lignite
  - Amine based
  - No FGD/DeNox

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

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

Pilot plants 1-3 kt pa
CSIRO is currently working on:

- Developing and using computer models to predict the fate of injected CO$_2$.
- Devising and applying methods to monitor the injected CO$_2$ to ensure it remains safe and secure.
- Examining movement of groundwater in the vicinity of potential storage sites.
- Investigating storage in deep uneconomic coal seams as an alternative geological target.
- Adapting and developing atmospheric technologies to determine whether CO$_2$ is leaking from stored locations underground.

CSIRO is a core research participant in the Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC)
Carbon dioxide modelling

CSIRO is developing computer models based on the technology and knowledge that have been used for decades by the petroleum industry to calculate and predict the movement and behaviour of injected CO$_2$.

(a) Carbon dioxide mass fraction 18 Sept: no cutaway.

(b) Carbon dioxide mass fraction 18 Sept: cutaway.
Cement plug reactions

Flow with reactions: 1000 years

Mineralised CO$_2$ (kg/m$^3$)
Determining the contribution of CO$_2$ storage in coal seams.

- Coal can adsorb carbon dioxide at liquid-like densities. Coal can store approximately twice as much carbon dioxide as methane.

- Adsorption of gases causes swelling of coal and injectivity declines.

- There is a huge planned expansion of CBM in Queensland.

- CSIRO is developing reservoir simulations for injectivity and to predict the long-term behaviour of CO$_2$ storage in coal.

- ECBM field trial planned for late 2010, in China, under Asia Pacific Partnership.
Subsurface monitoring

- CSIRO provides expertise and capabilities in monitoring and verification (M&V) technologies for the geological storage of carbon dioxide (CO$_2$).
  - Tracers
  - Surface geophysics
  - Downhole geophysics
  - Sensors
Atmospheric monitoring

1000s metres                  100s metres                 1 metre

Atmospheric module

Flux station

Soil CO₂ flux
Summary

• Concerns with climate change are posing significant challenges for coal

• CSIRO has focused all its coal research into a single program covering the entire coal value chain for
  • Coal production
  • Energy from coal
  • Capture and storage of CO2

• CSIRO has strong partnerships with government, industry, other research bodies and is seeking to consolidate and build on these relationships
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Thank you