Application of Clean Coal Technologies to New Zealand Coals

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CCT 2007, Sardinia

May 2007

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Conclusions

- Coal is a major indigenous energy source in NZ
- CCTs (including CCS) will be essential to ensure coal remains environmentally acceptable
- There is great potential for coal to play an important role in the transition to a H_2 economy in NZ
- Small Angle X-Ray Scattering (SAXS) can directly observe changes in coal pore structure as CO_2 is injected

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The New Zealand Situation

- Increased energy demand requires long term environmentally sustainable production of energy
- Dwindling gas reserves
- Well utilized hydro and geothermal reserves (~70% electricity supply)
- Developing wind resources
- Huge coal resource
- Draft Energy Strategy issued for comment

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Coal Resource

- More than 8 billion tonnes economically mineable coal reserves – will meet projected energy demands for centuries
- Coal offers secure and reliable energy supply
- Utilization MUST be environmentally acceptable – (CCTs)
- Bulk (70%) of the resource is low rank coal – very reactive, high ash fusion temperatures (well suited to atmospheric fluidised bed gasification)
- CRL Energy researching suitability of NZ coals to CCTs, including gasification

Coal Gasification

- Government has invested in a six year research programme "Hydrogen Energy for the Future of NZ"
- Aim is to demonstrate a small scale (<1 MW) coal to hydrogen to fuel cell to electricity package – specifically at 200 kW scale for distributed generation using atmospheric fluidized bed gasifier
- Concurrently develop the technology platform, knowledge and expertise to support the development of a hydrogen infrastructure in NZ
- Likely initial utilization of coal gasification in NZ will be to produce liquid and gas fuels

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Small Scale Gasifier Package

- Designed, constructed and demonstrated
- Routinely operated
- Good quality gas produced at 900ºC with moderate rates of steam injection
- Steam injection into the freeboard as well as the bed is beneficial in increasing H_2 production
- Increased rates of steam injection, increased bed temperatures and coal feed rates have had no significant impact on H_2 concentration

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Small Scale Gasifier cont'd

- Particulate removal carried out in two stages – initially by high efficiency cyclone (~95%) then a venturi scrubber
- Caustic sulphur scavenger is used to remove H_2S in a counter current flow scrubber to a level suitable for fuel cell use
- A water gas shift reactor has been designed to handle a slipstream of the gas (sufficient for 5kW electricity from the fuel cell)
- Shifted gas passed through a proprietary metal based membrane reactor to purify the H_2

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Results to Date

- The gasifier reliably generates a particulate free gas stream of around 15% hydrogen
- The H_2S scrubber has been trialled and proven
- The water gas shift reactor is currently being tested on bottled gas
- Concurrently the metal based membrane reactor is being set up and trialled (aiming for a gas stream of ~30% hydrogen)

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What next?

- Use the gasifier as a test bed for complimentary technologies (e.g. biomass co-gasification, new gas clean up technologies, oxygen enriched)
- Develop a pathway for NZ to transition/prepare for the implementation of a hydrogen economy – the subject of a new (February 2007) FRST research investment
- Initiate a research programme in a key enabling technology for CCTs – carbon capture and storage

The Role of Coal in a H_2 Economy in NZ

- Coal well placed to provide H_2 in the transition period to a renewable future

- Big demand for H_2 will occur when fuel cell vehicles become commercially viable – for NZ 2025 plus

- If NZ fleet is 90% fuel cell by 2050 it will require 1.2 to 1.75 million tonnes of H_2 – 10 to 15 million tonnes coal

- Prior to this H_2 applications will be in distributed generation applications and some larger scale electricity generation

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Coal in a NZ H_2 Economy

- Sufficient reserves of coal for 400 years at the 2050 demand
- Predicted new natural gas discoveries (NZ MED figures) will only meet one or two months supply of H_2 at 2050 demand
- H_2 from electricity (electrolysis) derived from renewables will meet one third of 2050 demand
- Estimate of costs (including CCS) of H_2 from coal for transport fleet significantly lower than renewable base
- Pathway via syngas for liquid fuels, chemicals, electricity then increasing H_2 for fuel cells

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Why Develop Direct Observation Method for CO_2 in Coal?

- Continued widespread use of coal at least through to 2050

- Need to stabilize levels of GHGs in atmosphere

- Major issues for CO_2 storage
  - Safe and Secure
  - Verifiable
  - Large enough to make an impact
  - Able to meet regulatory and legal requirements
  - **Well understood**

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Issues relating to CO_2 and Coal

- CO_2 dissolves in coal
- Coal swells in CO_2
- Pore structure of coals is variable (molecular to visible holes) – need to be able to access broad range of pore sizes (Angstroms -> microns)
- Need to carry out at elevated pressures

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Small Angle X-ray Scattering Analysis of Coal Structure

- SAXS provides pore size, size distribution, shape and surface morphology over broad length scales.

- SAXS is an in situ technique and can work with a variety of high pressure cells.

- SAXS has been used to follow changes in coal structure in gasification and solvent swelling.

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Preliminary Experiments
The US/NZ Bilateral Partnership for Climate Change Research

- Four NZ coals and three coals from the Argonne Premier Sample bank were selected
  - Ohai Subbituminous
  - Maramarua Subbituminous
  - Hawkdun Lignite
  - Mataura Lignite
  - Illinois No. 6 hvC Bituminous
  - Pittsburgh No. 8 hvA Bituminous
  - Upper Freeport mv Bituminous

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Implications for CO_2 Sequestration

- 3D network structure influences the impact of CO_2 on pore structure
  - Medium rank coals with well developed but flexible structure - may be susceptible to breakdown
  - Higher rank coals with well developed rigid structure - dissolve and hold CO_2
  - Lower rank coals with undeveloped structure -adsorb little but undergo little disruption

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Results - Summary

- SAXS allows for direct observation of changes in pore size and distribution with CO_2 uptake at sequestration pressures.

- The results are very reproducible.

- There is a significant rank dependence (3D network structure).

- Implications for CO_2 sequestration mechanisms.

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Future Activities

- Expand the coal set (NZ, US and international)
- Trial different temperatures, pressures and times
- Investigate different pore size ranges
- Correlate with available in-seam sequestration data
- Correlate with predictions from CO_2 sequestration models
- Correlate with traditional laboratory results
- Use these results in combination with other approaches to predict sequestration behaviour of selected coal seams.
- Direct observation with CO_2 injection into aquifers?

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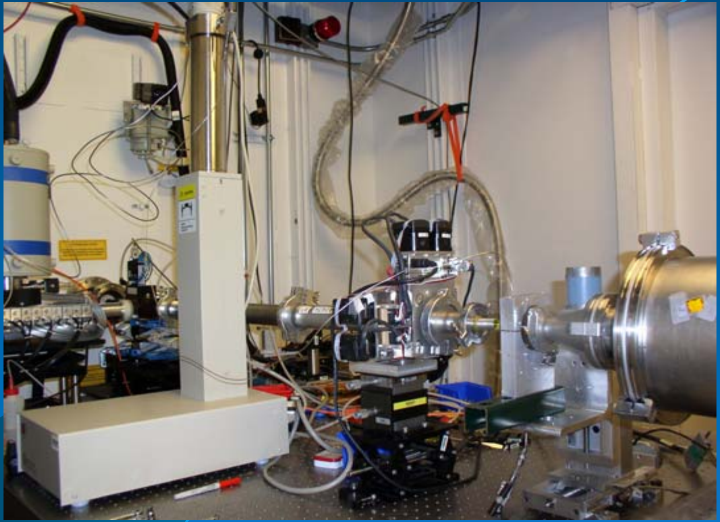
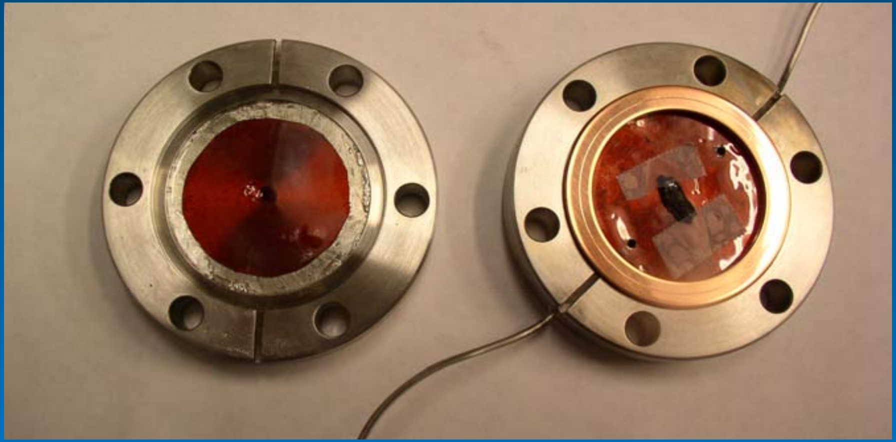
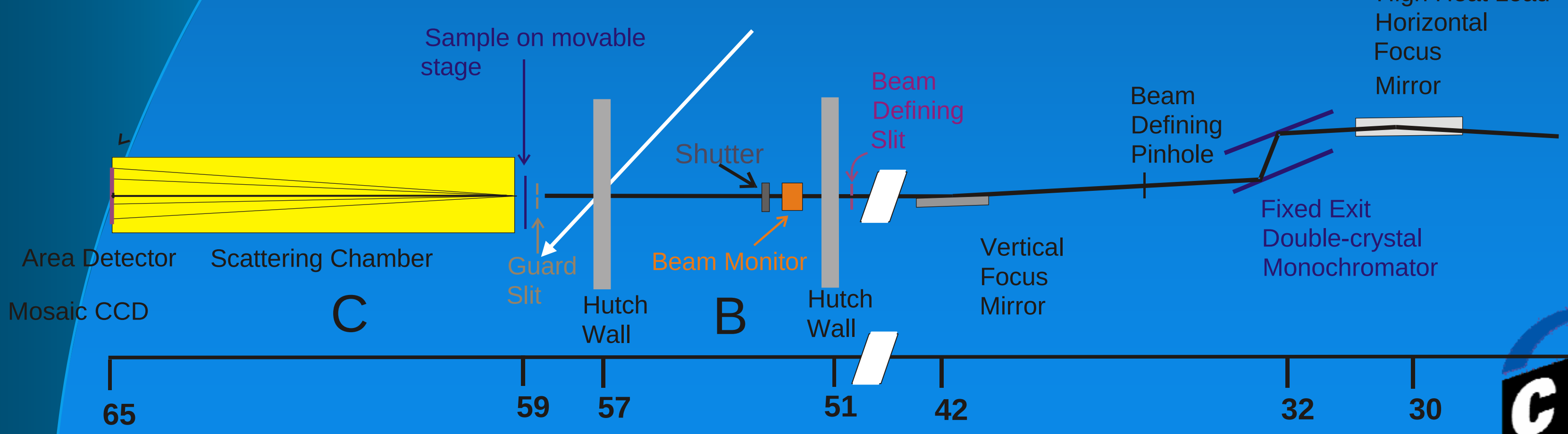
TR/ASAXS Instrument on the APS BESSRC ID-12-B&C Undulator Beamline





CO2 increased from 150 to 800 psi



High Heat Load Horizontal Focus Mirror

Sample on movable stage

Beam Defining Slit

Beam Defining Pinhole

Shutter

Area Detector

Scattering Chamber

Guard Slit

Beam Monitor

Vertical Focus Mirror

Fixed Exit Double-crystal Monochromator

Mosaic CCD

C

Hutch Wall

B

Hutch Wall

65 **59** **57** **51** **42** **32** **30**

Distance from source in meters

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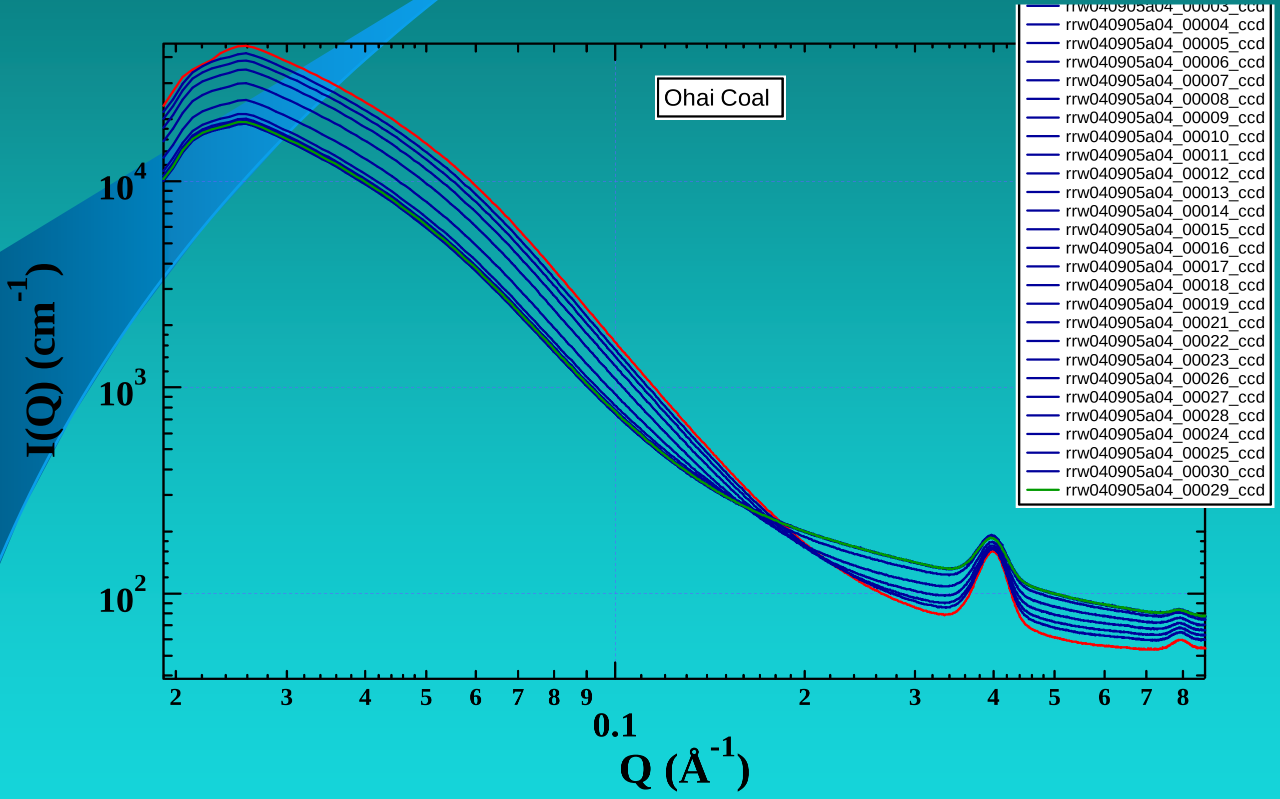
Ohai Subbituminous Coal

CO_2 increased from 150 to 800 psi



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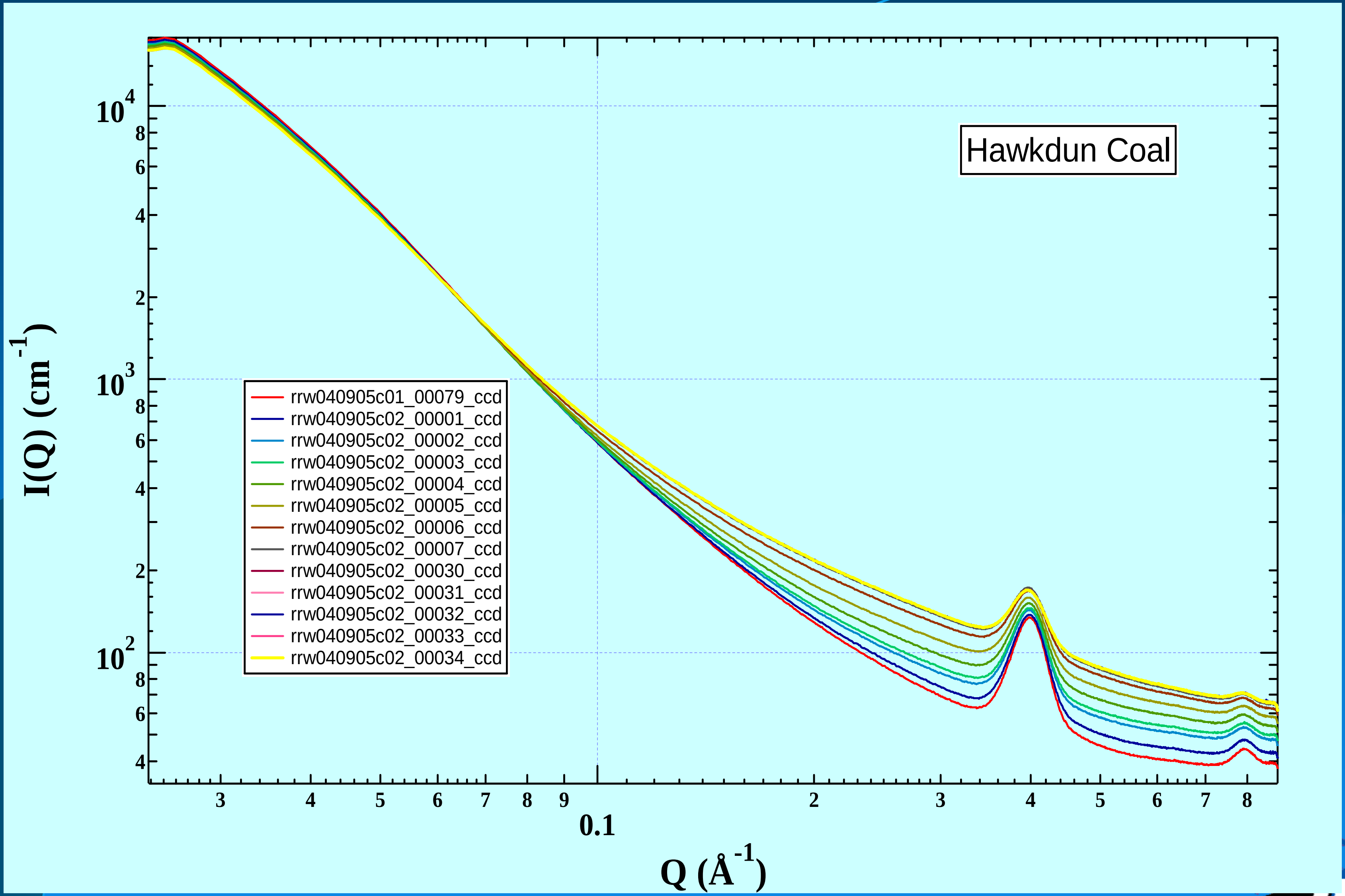

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