Electrical Swing Adsorption for CO_2 Capture

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Electrical Swing Adsorption for CO_2 Capture

Advanced Materials and Electric Swing Adsorption Process for CO_2 Capture

EU-Australian Cooperation, 7th Framework Project, ENERGY

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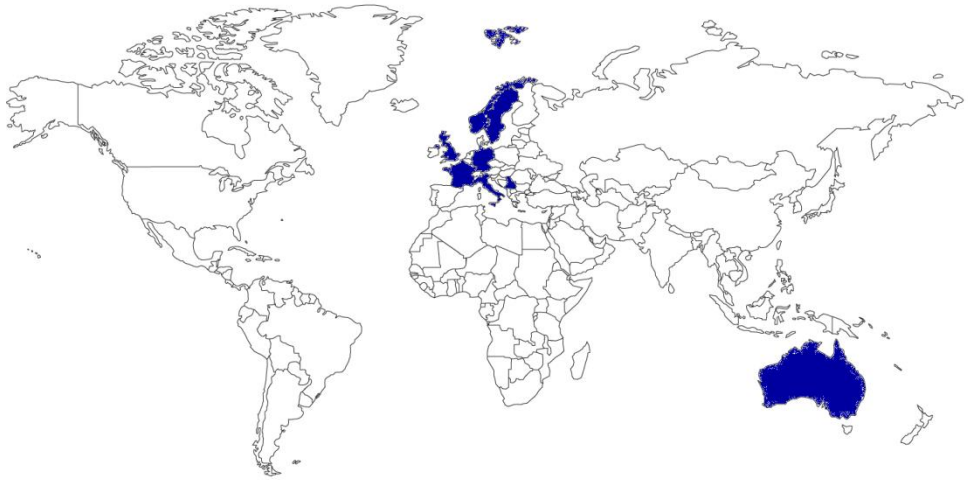
MATESA partners

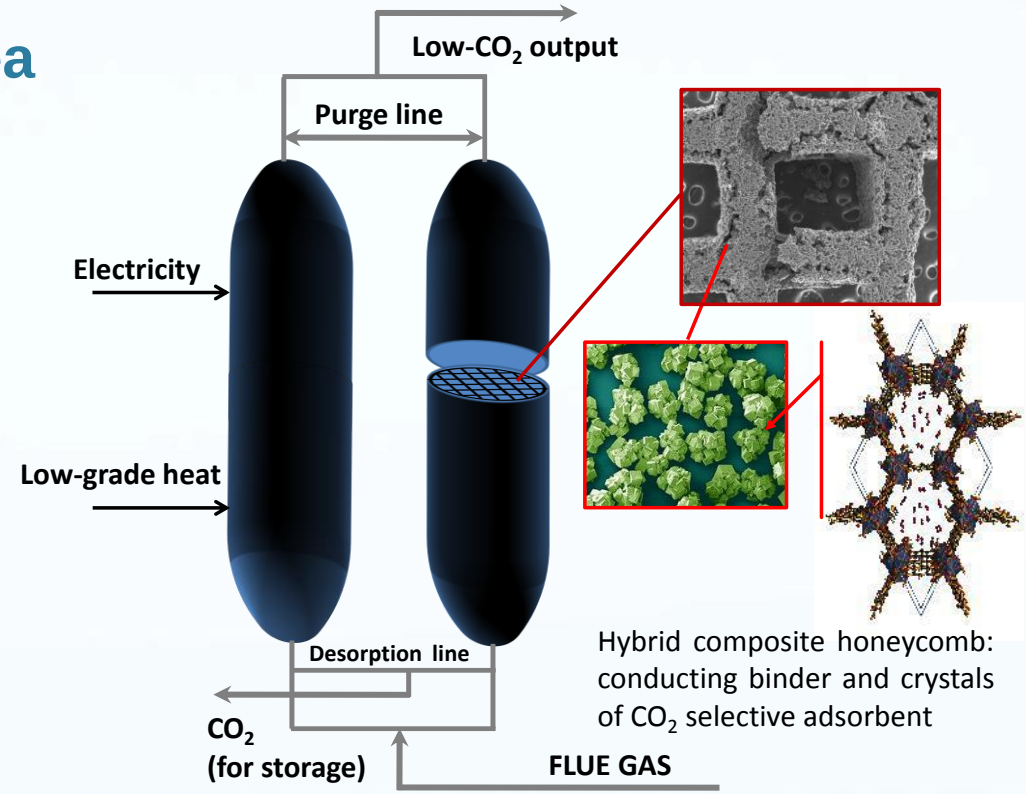
- The consortium is formed by: 5 universities (2 Australian), 2 R&D institutes, 3 SMEs and 2 large industries.

- SINTEF, Norway
- Politecnico di Milano, Italy
- University of Belgrade, Servia
- Cycleco, France
- Fraunhofer Institute, Germany
- Biokol, Sweden
- University of Torino, Italy
- Process Systems Enterprise, United Kingdom
- Corning SAS, France
- University of Melbourne
- Linde Engineering, Germany
- Monash University, Australia



web-page:
www.sintef.no/projectweb/MATESA

The main idea



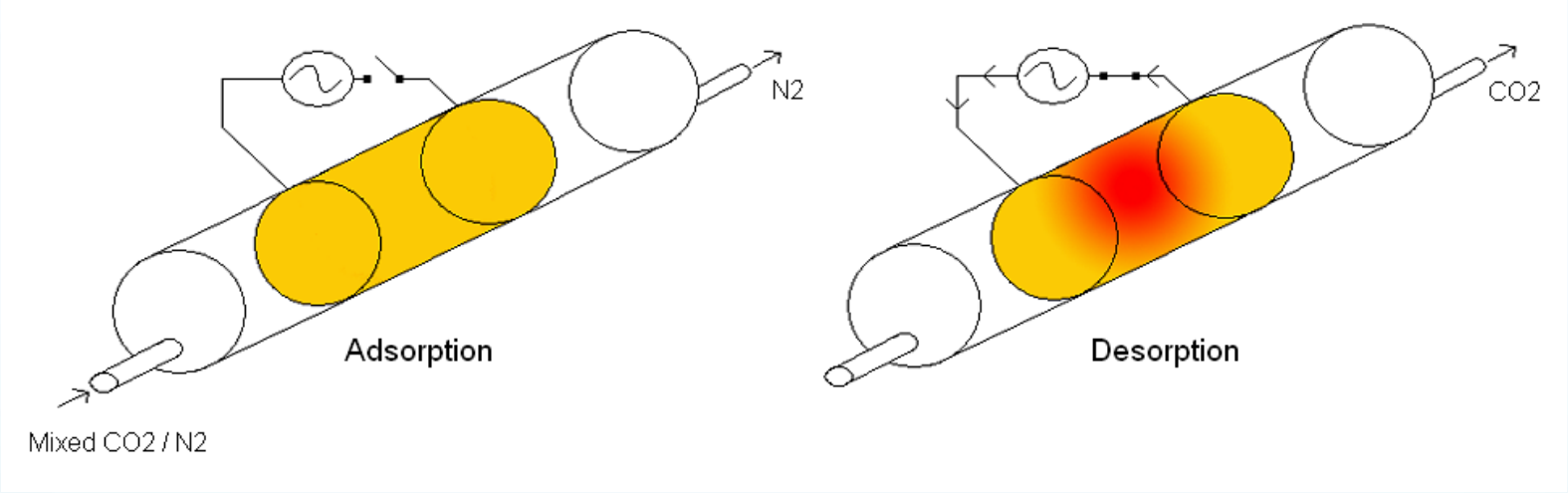
Hybrid composite honeycomb: conducting binder and crystals of CO_2 selective adsorbent

- Create a honeycomb material able to conduct electricity.
- Embed within this a material able to selectively adsorb CO_2.
- Use this material in an innovative Electric Swing Adsorption (ESA) process.
- Evaluate the integration of the ESA process into the power plant.
- Make a full life cycle assessment of the entire capture process.

ESA Concept

Electrical Swing Adsorption

- **A controlled (efficient), rapid, low cost regeneration process for conductive monolithic adsorbents**



Desorption is the key to an efficient adsorption process

Objectives of Australian Study

Develop active carbon monoliths from brown coal

Embed this with a highly CO_2 selective adsorbent material

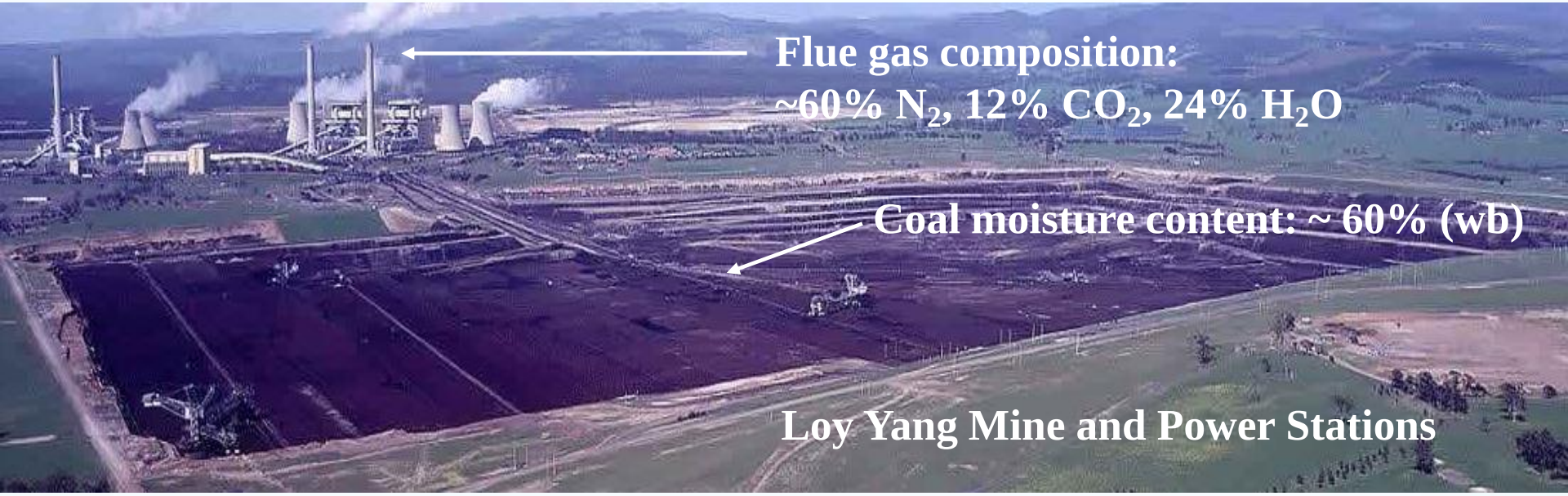
Evaluate performance at bench scale

Process modeling

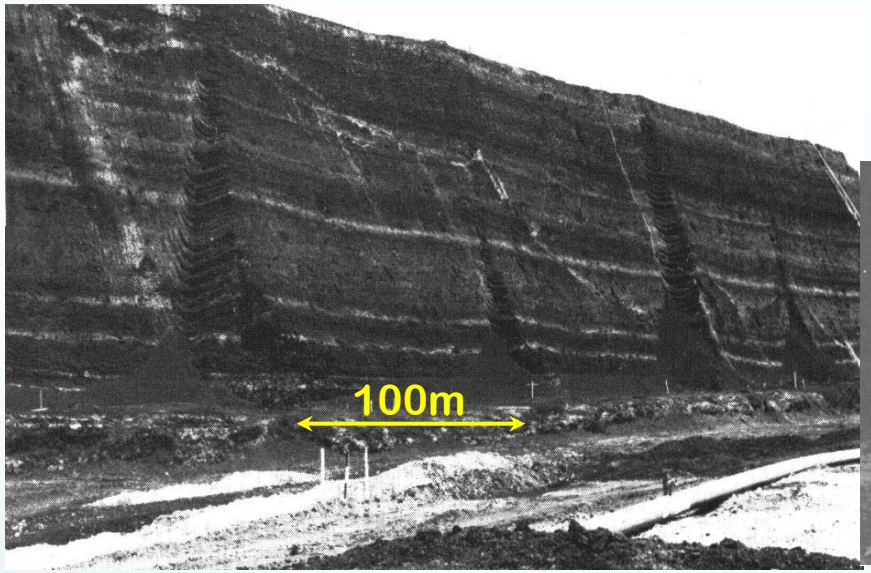
Life cycle analysis

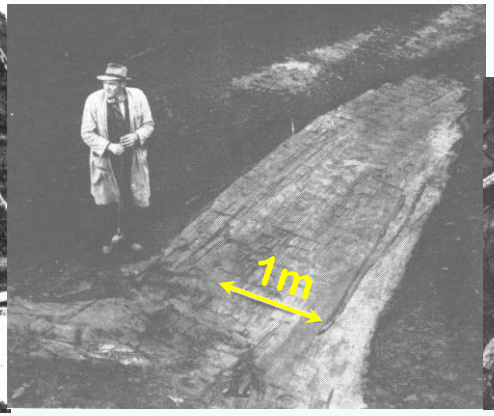
Victorian brown coal is a good carbon precursor
- it is very cheap
- it has very low inorganic content

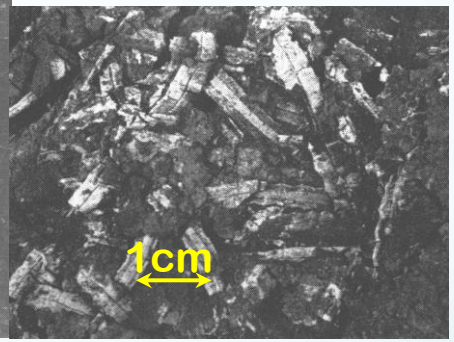
Latrobe Valley Coal Fields



Heterogeneity of Victorian Brown Coal (VBC)







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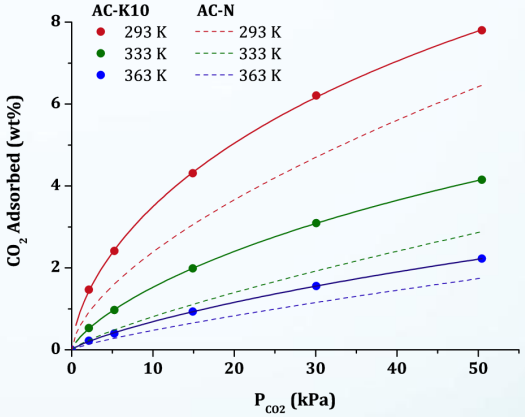

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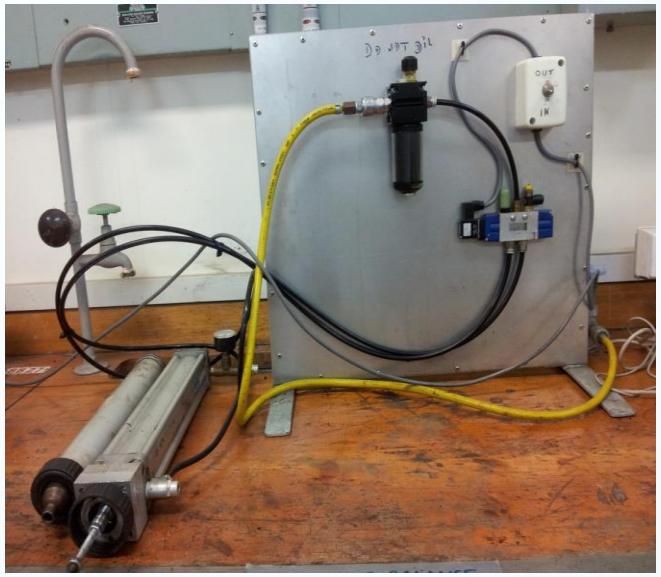
Dewatering by Densification



Strength Development on Drying

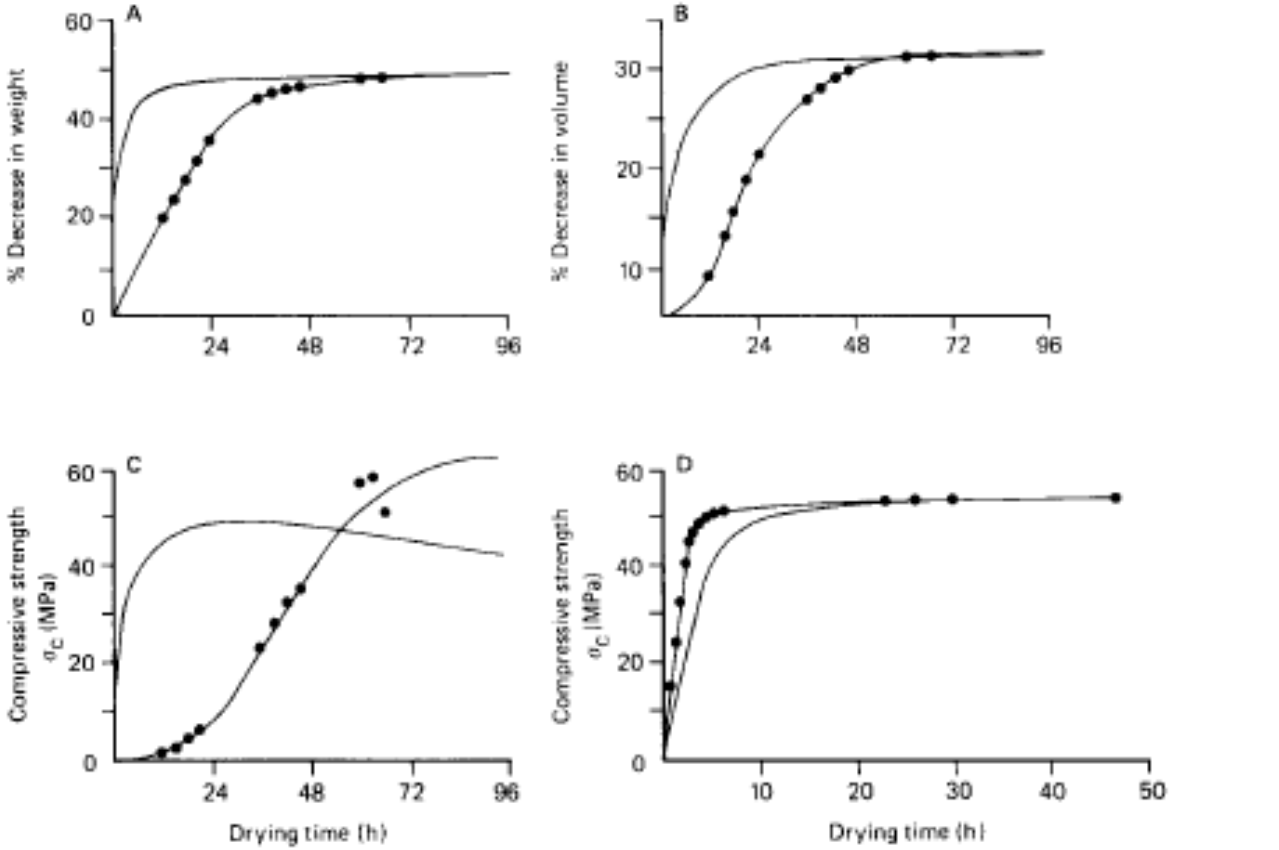


Fig. 3. Drying behaviour of densified brown coals in still (●-●) and in forced draught (—) conditions. A, B and C = Morwell coal (Narracan bore) containing 5% magnesite. D = Maddingley coal. (5 h kneading in each case, 55% relative humidity, 20°C; forced draught of 0.5 m/s). D — = 10 mm pellets; ●-● = 3 mm pellets, both under forced draught conditions.

Fuel Proc Tech 21, 208 (1989)

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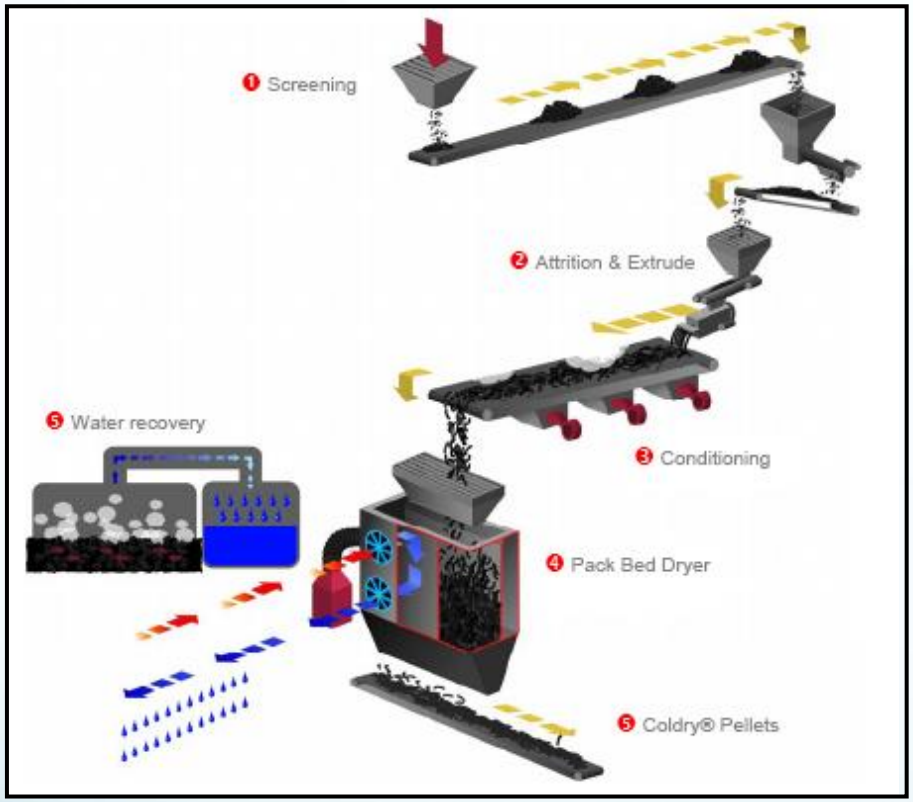
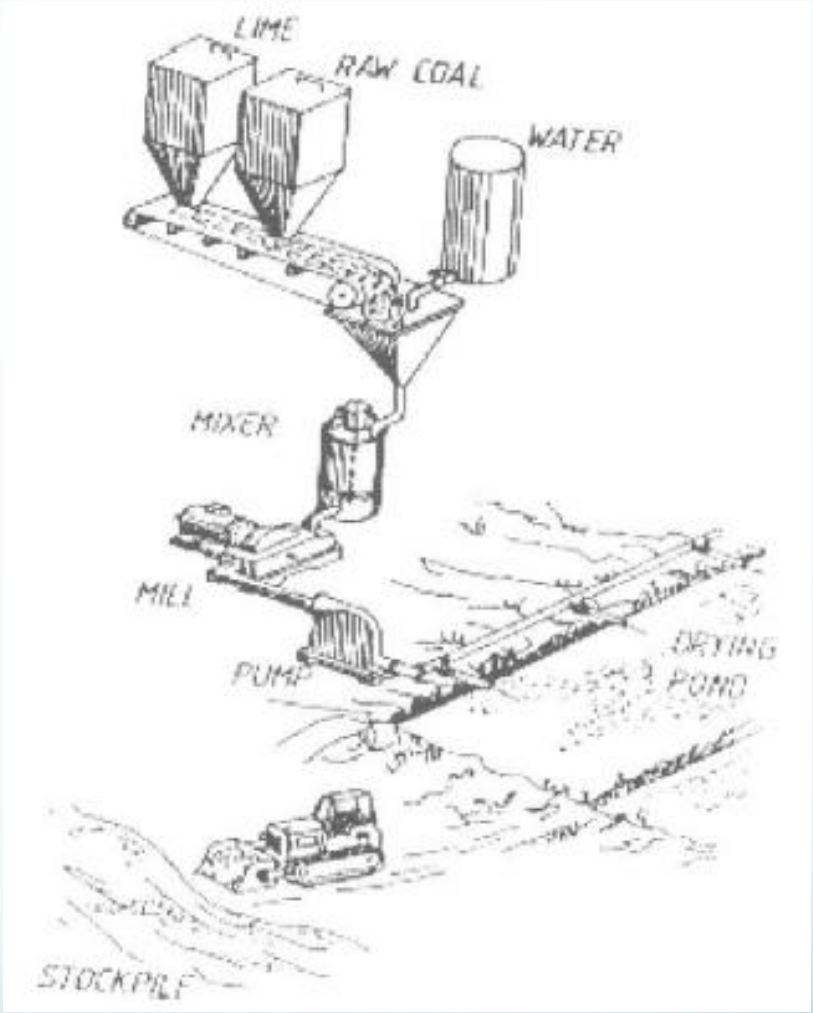
Coldry® Process*



* Environmental Coal Technologies Ltd
See: www.ectltd.com.au/coldry/the-coldry-process

Solar dried coal



Allardice et al, Ch 3, in: Advances in the Science of Victorian Brown Coal, Ed C-Z Li, Elsevier, 2004

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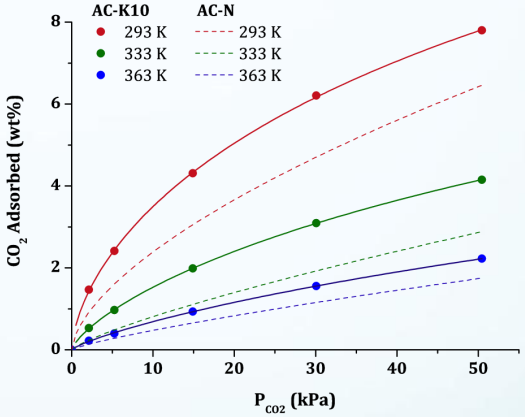

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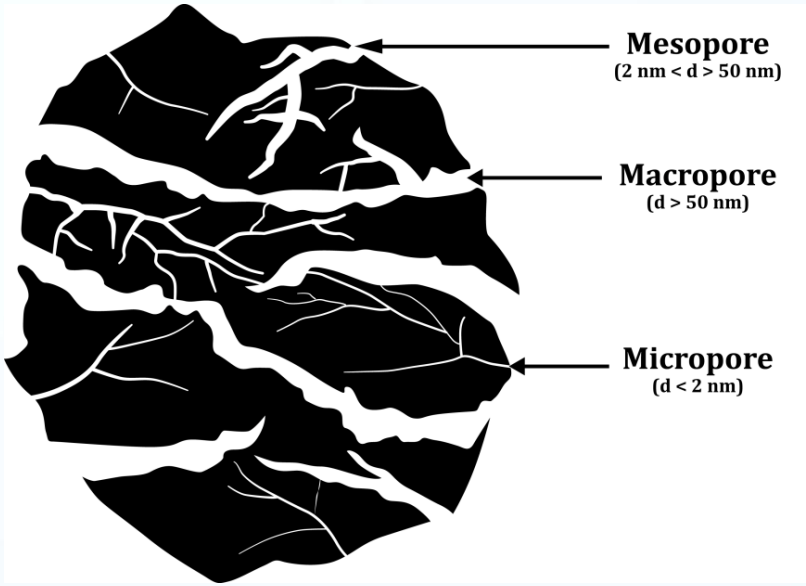
Active carbon powders from brown coal

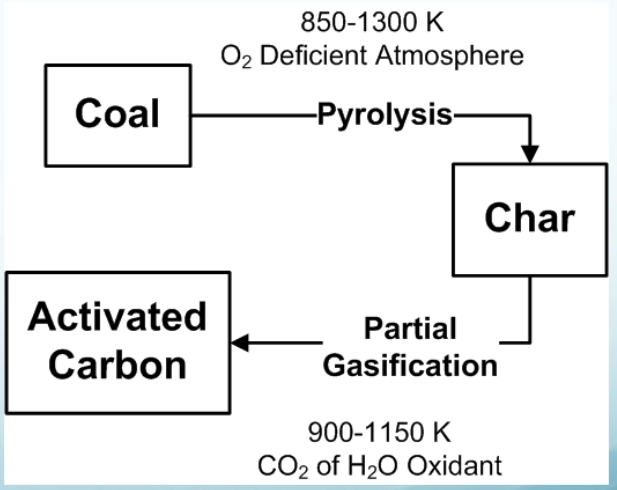
Activated Carbons (ACs)

- High Surface Area & Porosity (wide PSD)
- Water tolerant (usually)
- Precursors inexpensive & readily available
- Surface chemistry easy to tailor
- Adsorption of gases on ACs is non-selective



AC Production

- Prepared by one of two activation methods:
  - **Physical Activation:** Pyrolysis, followed by partial gasification.
    1. **Pyrolysis** – Volatile Matter Removal
    2. **Partial Gasification** – Pore Development
  - **Chemical Activation:** Uses catalysts in addition to pyrolysis & partial gasification.



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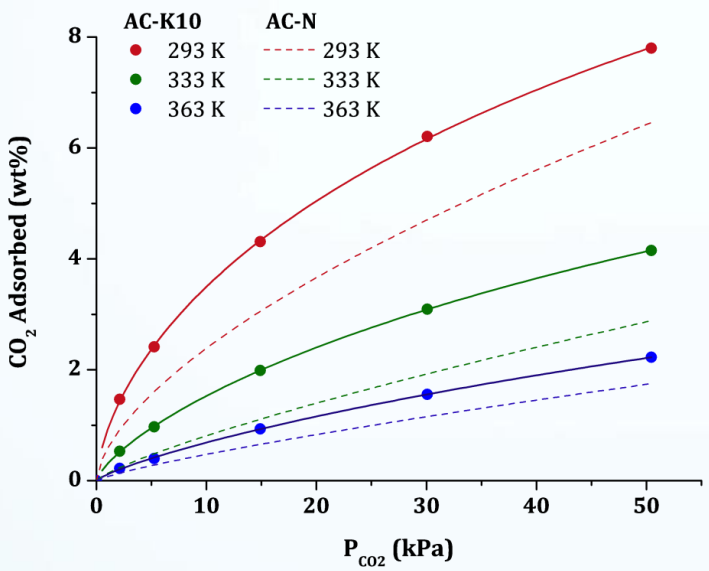
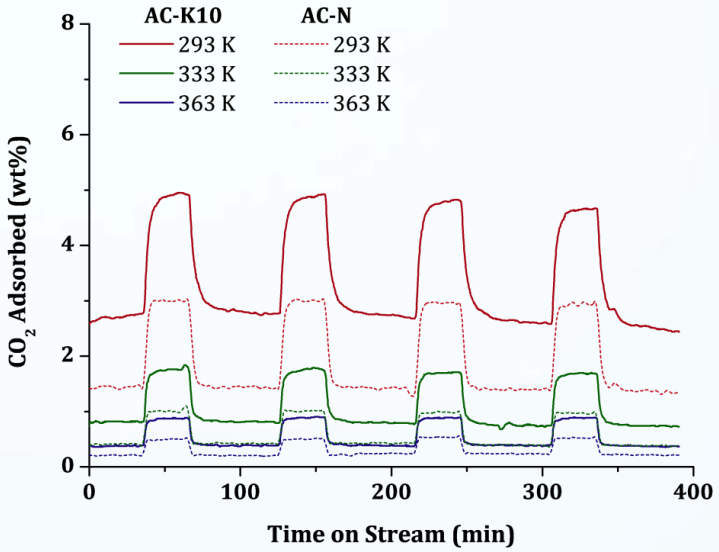
CO_2 adsorption of brown coal derived carbon

Adsorption Isotherm



Partial Pressure Swing (0.15 – 0.05 bar)



Sample Name	Yield (wt%)	Surface Area (m^2/g)		Pore Volume (cm^3/g)		True Density (g/cm^3)
		S_{DR}	S_{BET}	V_{micro}	V_{meso}	
AC-N	-	794.3	673.9	0.276	0.094	1.48
VBC	-	179.1	-	0.001	-	1.40
AC-K10	51.2	859.7	-	0.229	-	1.38

LA Ciddor et al, Proceedings of the Int Conf on Coal Science & Technology 2013, State College PA, Sept 29-Oct 3, 2013, 8pp.

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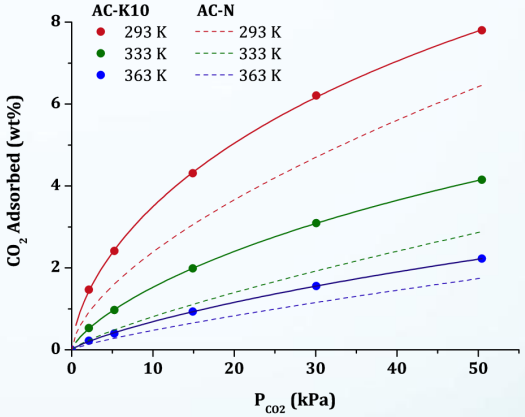
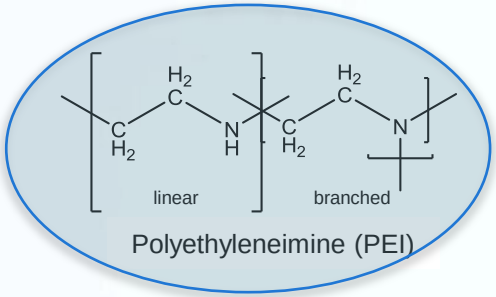
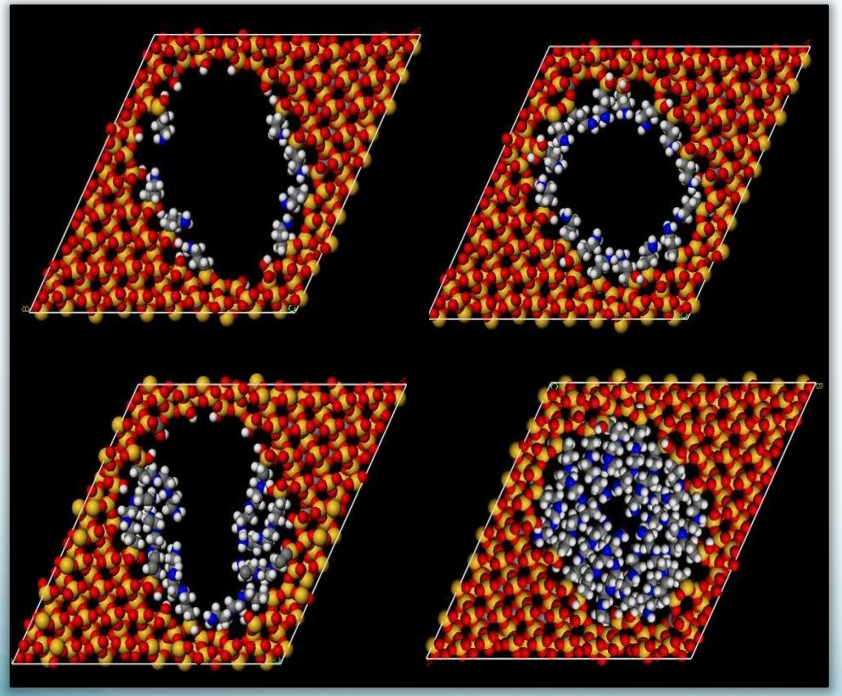
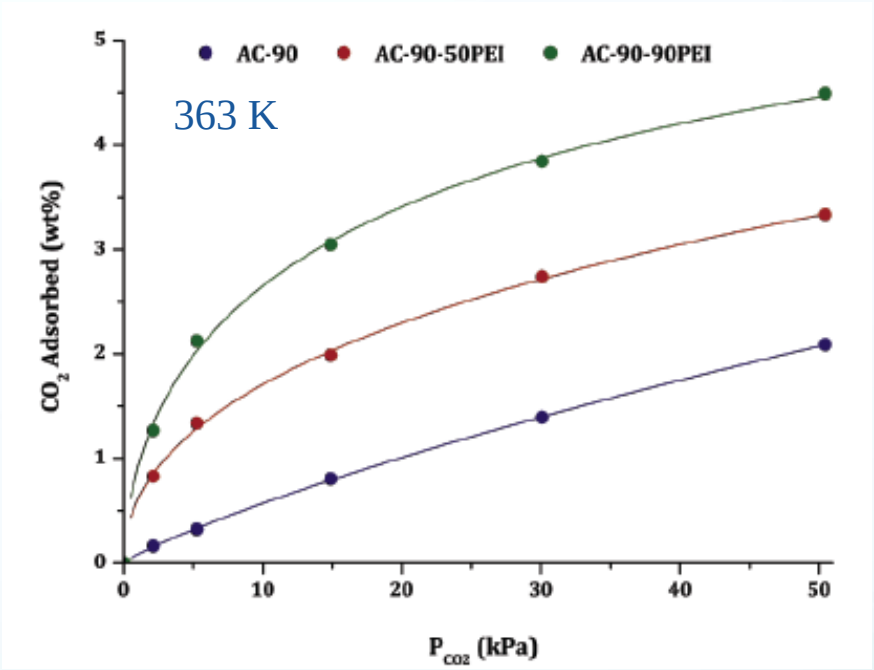


CO_2 adsorption on functionalised VBC carbons







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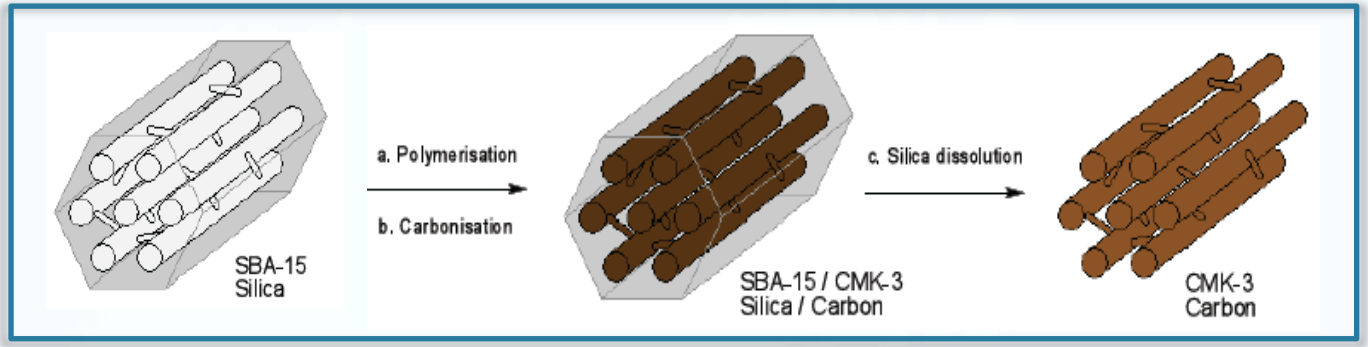
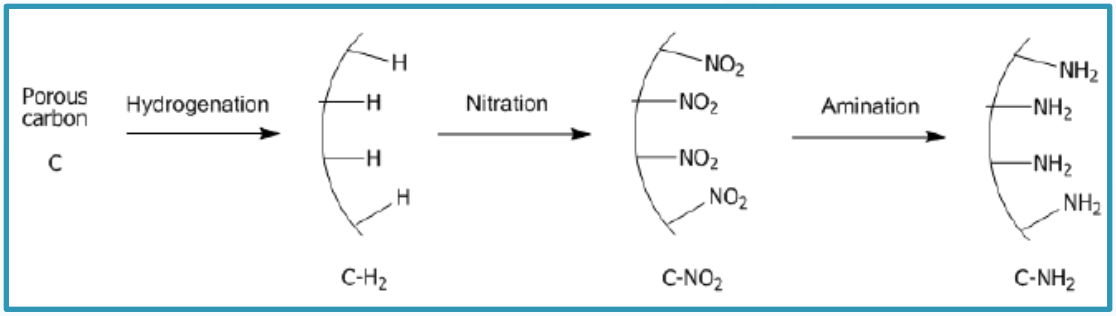
CO_2 adsorption on synthetic mesoporous carbons

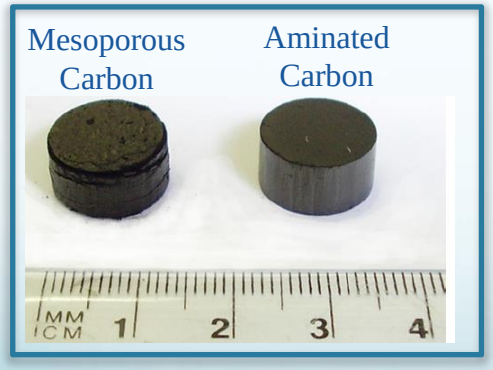
Mesoporous Carbon Synthesis



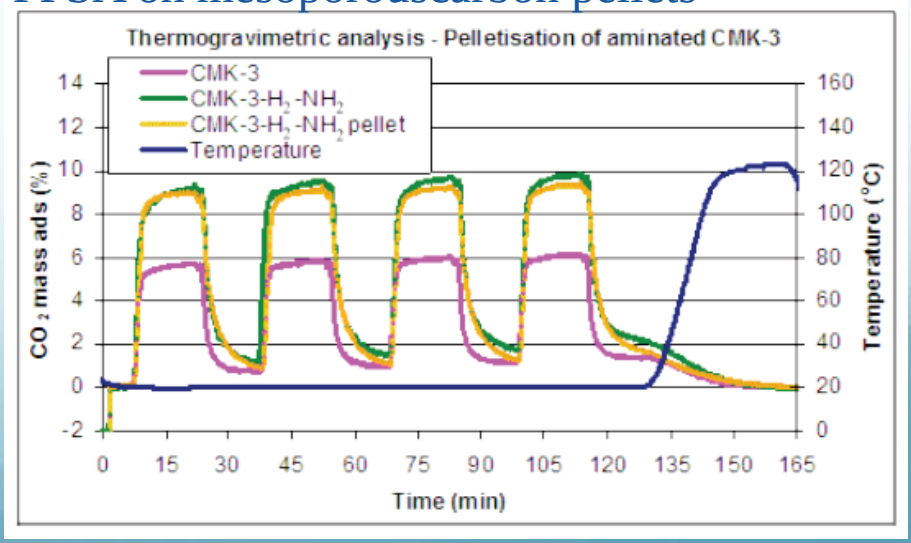
Amination procedure



Pellet products



PPSA on mesoporouscarbon pellets



S Delaney, PhD Thesis, 2009, Electrically Regenerable Carbon Adsorbents for CO_2 Capture

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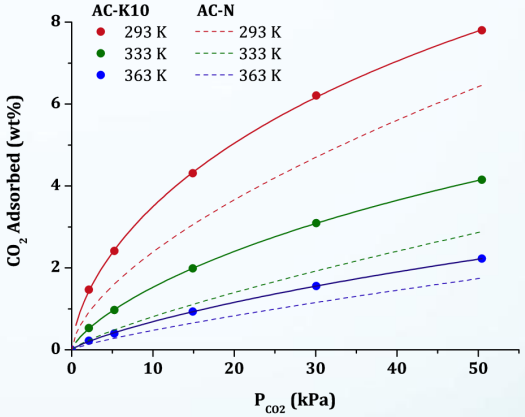
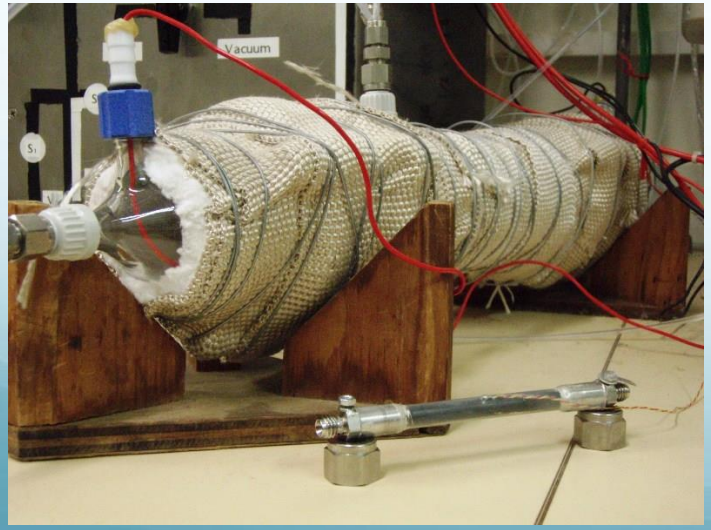


ESA Test Facilities – Mk 1



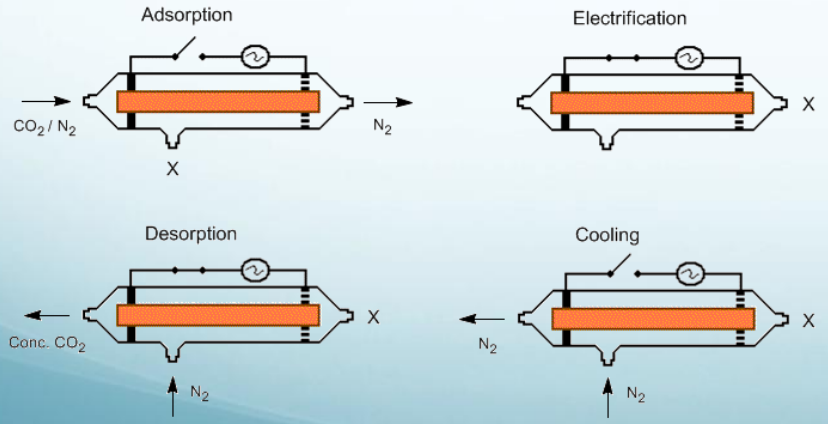
Electrically heated reactor units

- Monoliths acquired from Mast Carbon Pty Ltd, UK
- Thermocouple reading on external surface of monolith
- Sealed in glass vessel or with heat shrink wrap

ESA Investigation

Protocol

- Adsorption
  - Feed gas (15% CO_2 in N_2) at 80ml/min, 'breakthrough' at 35-40ml of CO_2 adsorbed
- Electrical Stimulation
  - Power requirements (10W)
  - ~65 sec to heat to 105°C (~5V, 2A)
- Desorption
  - Thermal evolution
  - Purge flow (4 – 8 ml/min), varied durations
- Cooling
  - High purge (cool) flow rates



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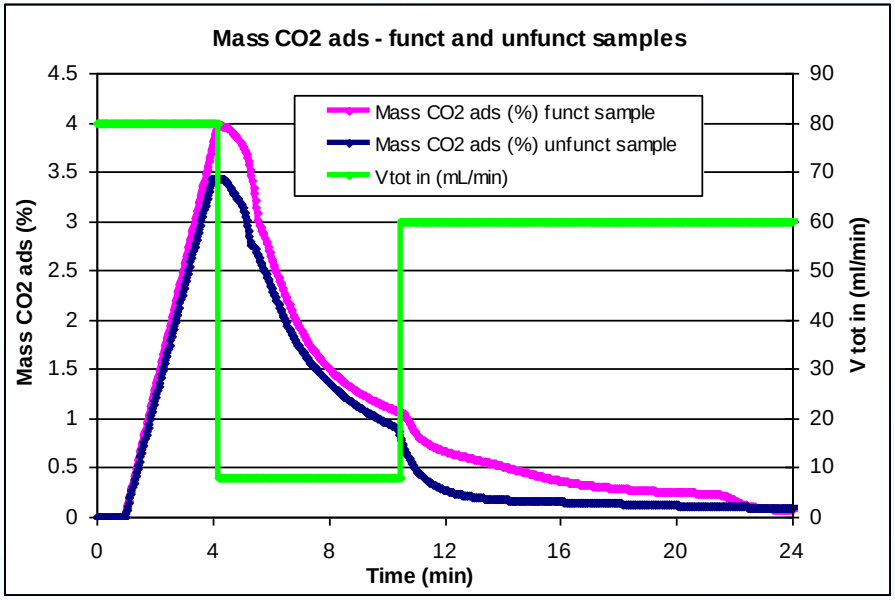

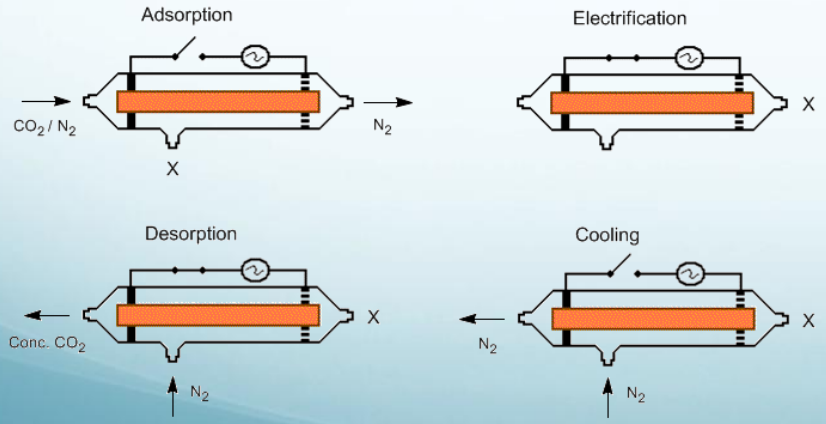

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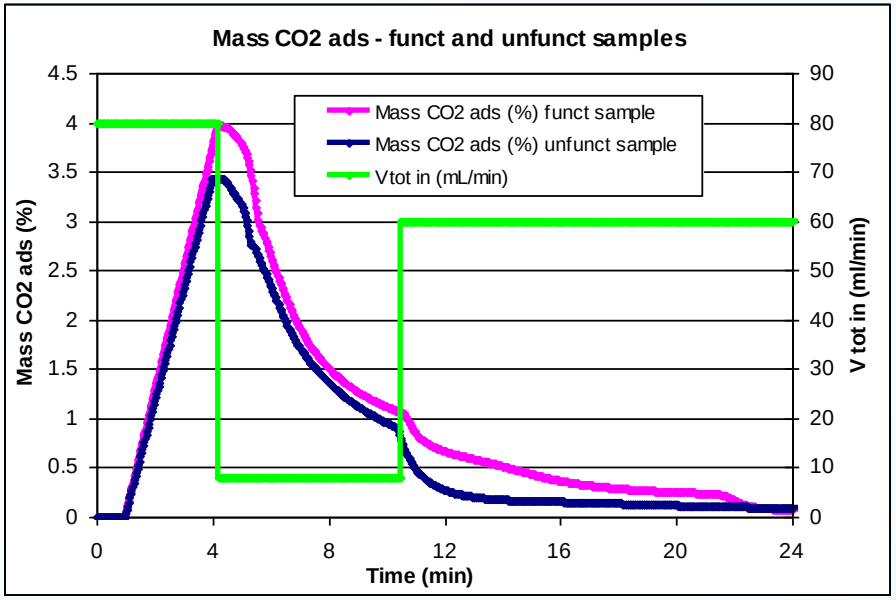

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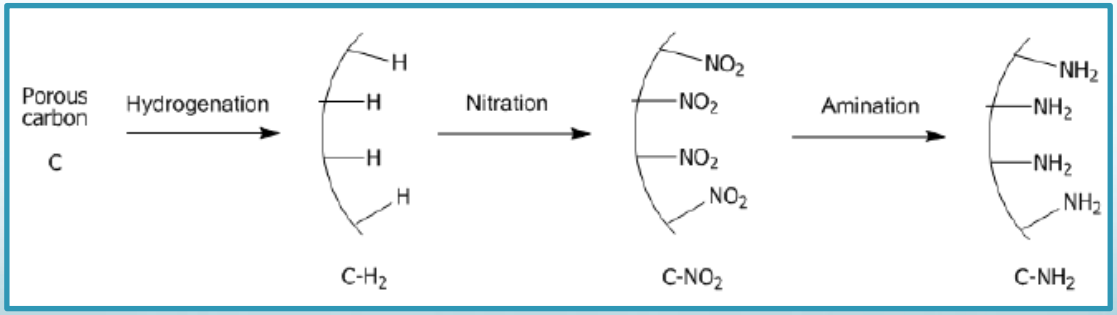

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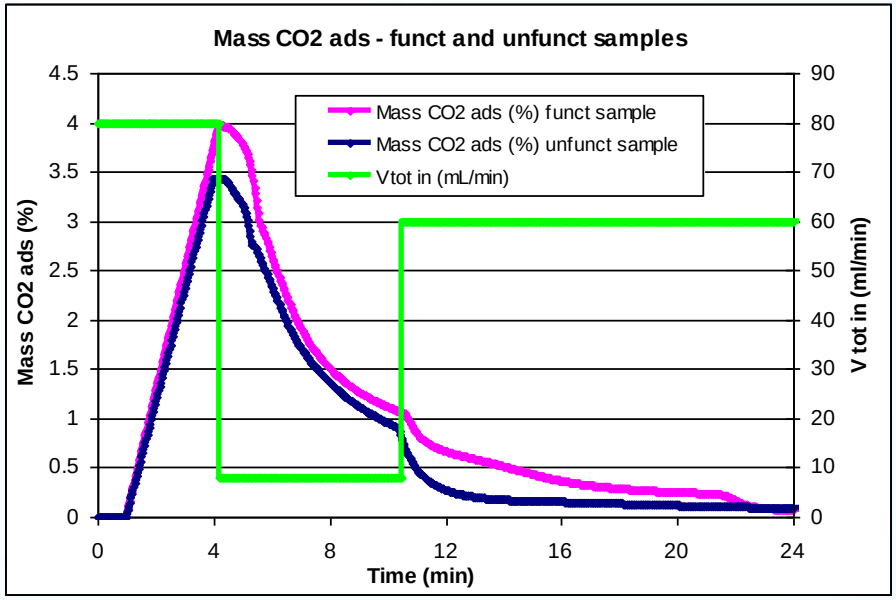
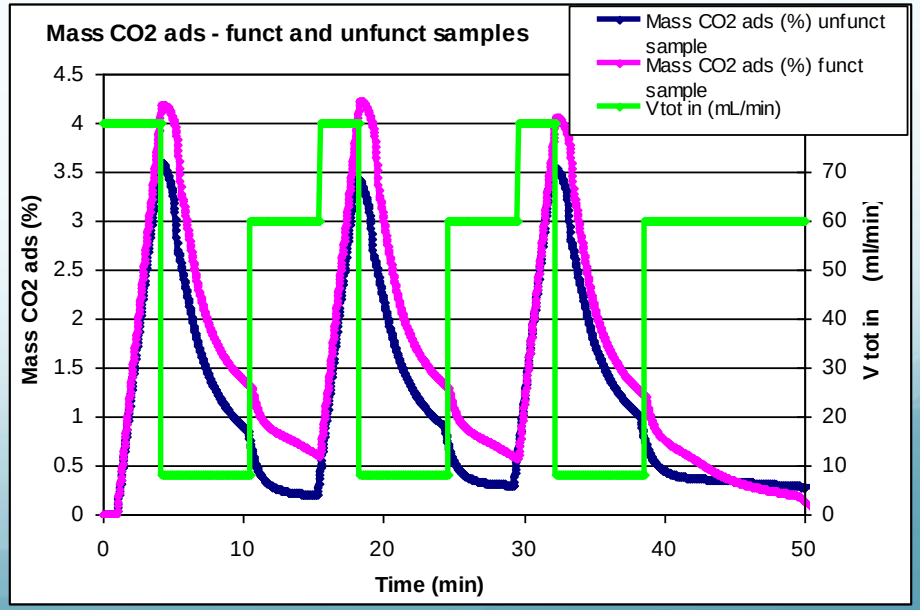
Functionalisation

- Improved CO_2 adsorption capacity
- Slower breakthrough time
- Working capacity slightly increased for functionalised sample

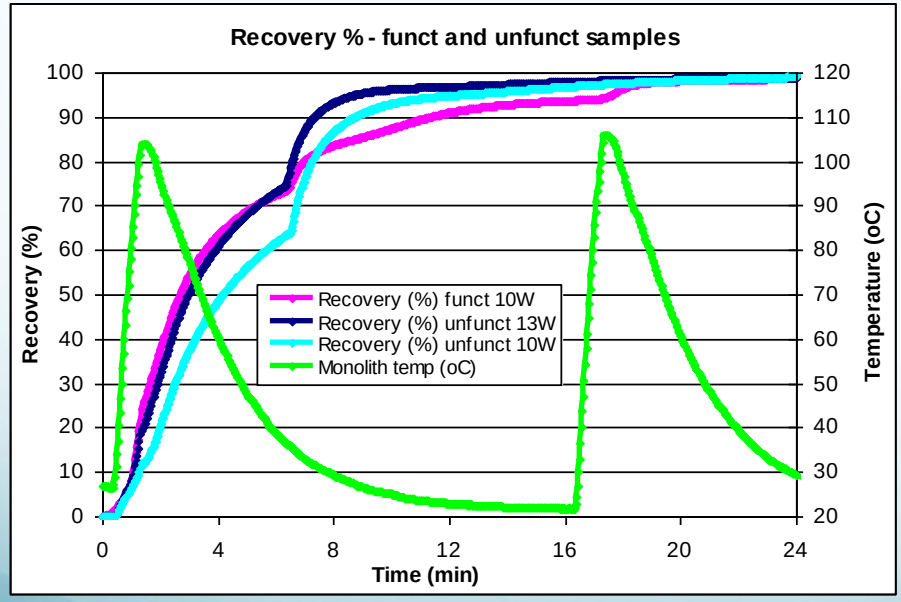


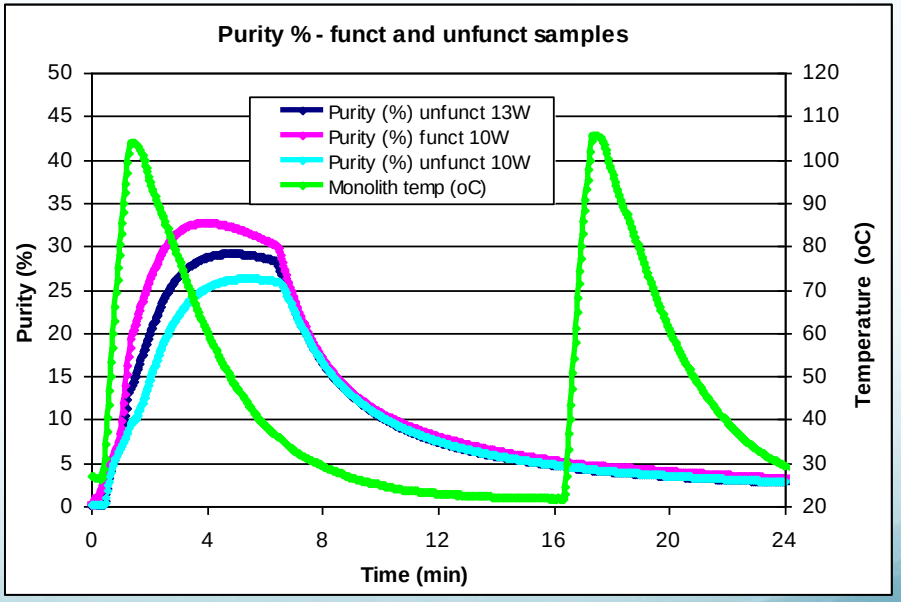


ESA test unit - Effect of functionalisation

Purity and Recovery of Desorbed CO_2

- Increased rate of recovery for functionalised sample.
- Electrical stimulation higher (~30%) to effect same temp increase
  - ~30% increase in resistivity for functionalised sample





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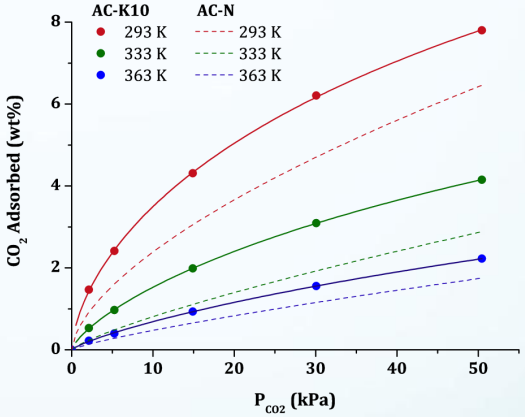
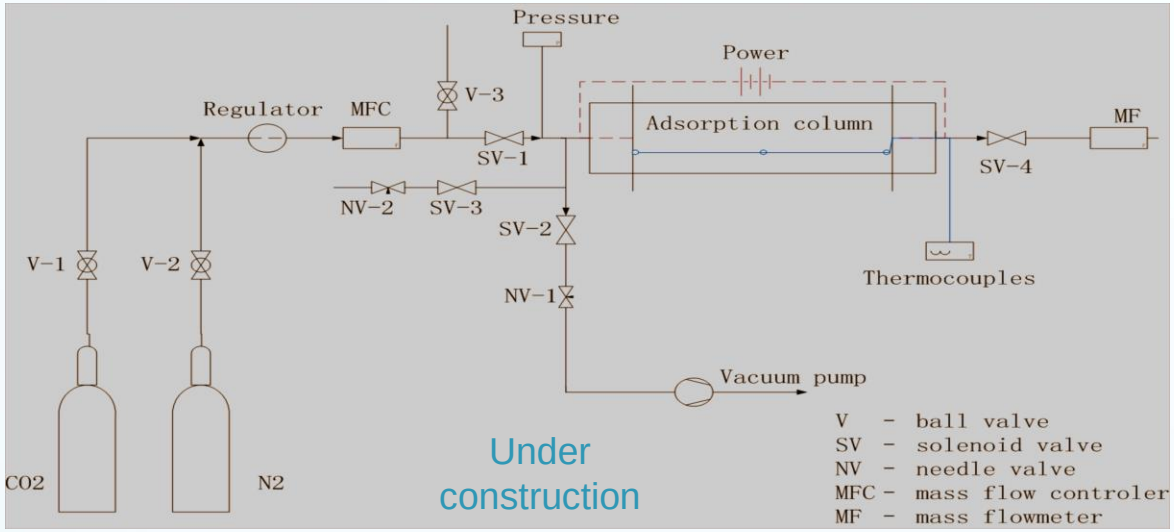


ESA Equipment – Mk 2 and 3

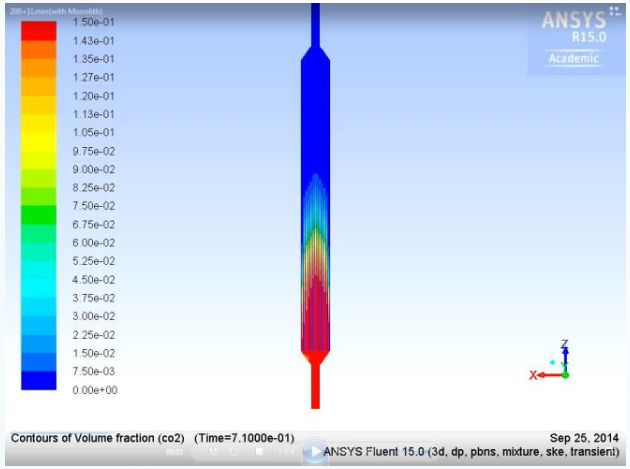
Bench scale testing



Under construction

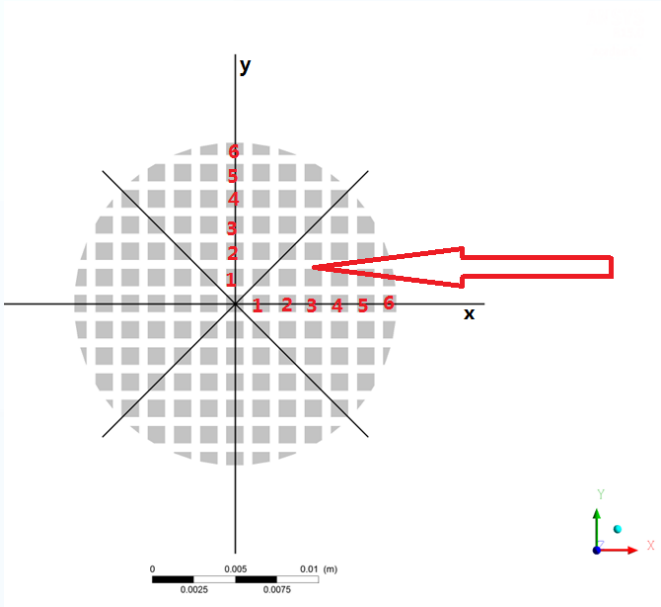
4-bed testing

Computational Fluid Dynamics



Dimension of Monolith

Diameter: 20mm
Length: 200mm
Wall: 0.525mm
Channel: 1.05mm
CPSI: 286
Open area: 42%



Due to symmetry, need to study the velocity of just 1/8 of monolith

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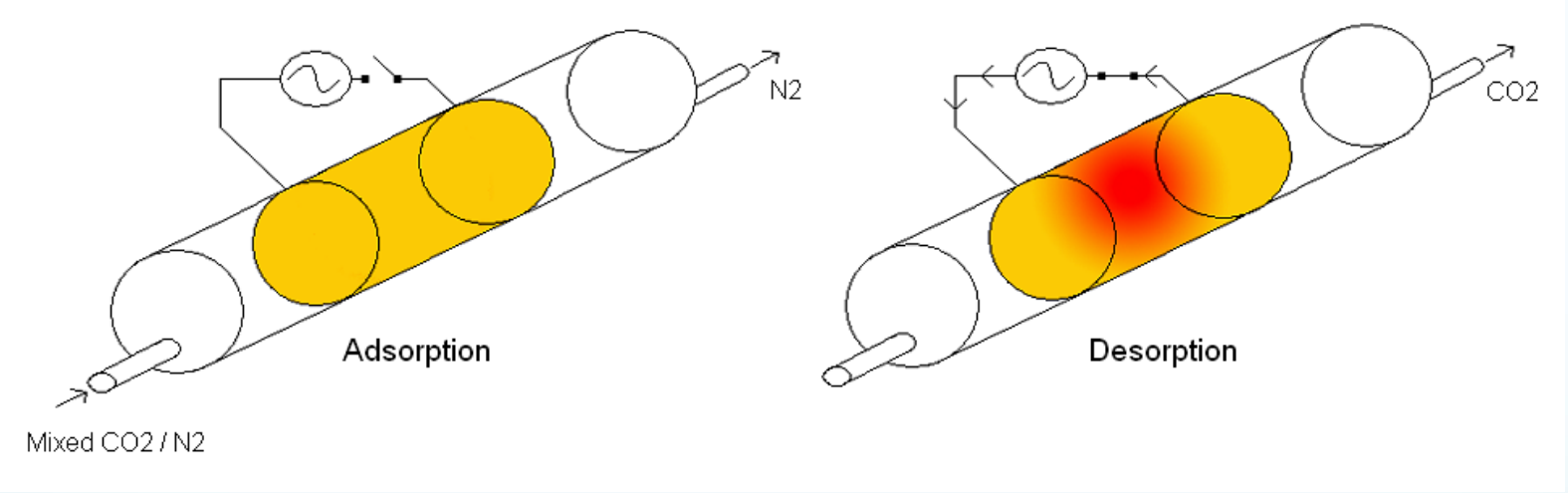
Electrical Swing Adsorption

- **A controlled (efficient), rapid, low cost regeneration process for conductive monolithic adsorbents**



Desorption is the key to an efficient adsorption process

Thank you!

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