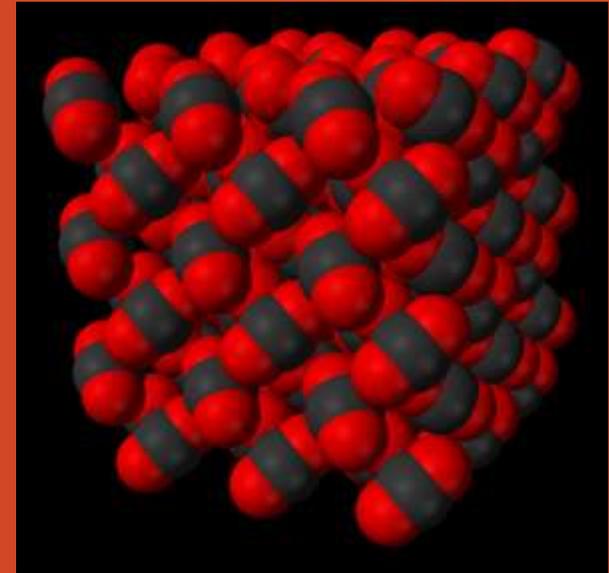


# Carbon Dioxide Utilisation as a Direct Air Capture Driver

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*UK Centre for Carbon Dioxide Utilisation*

*The University of Sheffield, United Kingdom*



epic



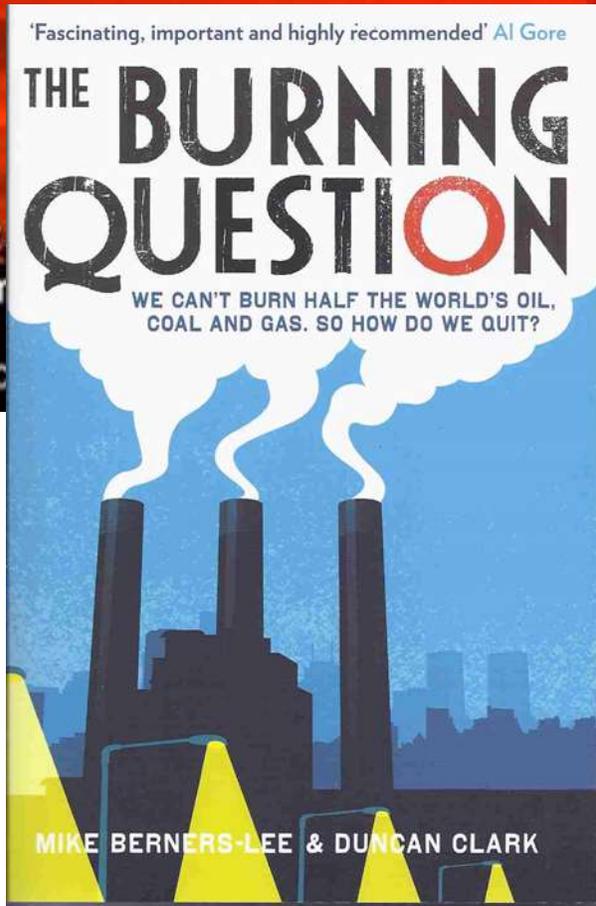
# Summary

1. The Earth Wins
2. The CO<sub>2</sub> Trilemma
3. Capture Strategies
4. Direct Air Capture & Utilisation
5. Conclusions

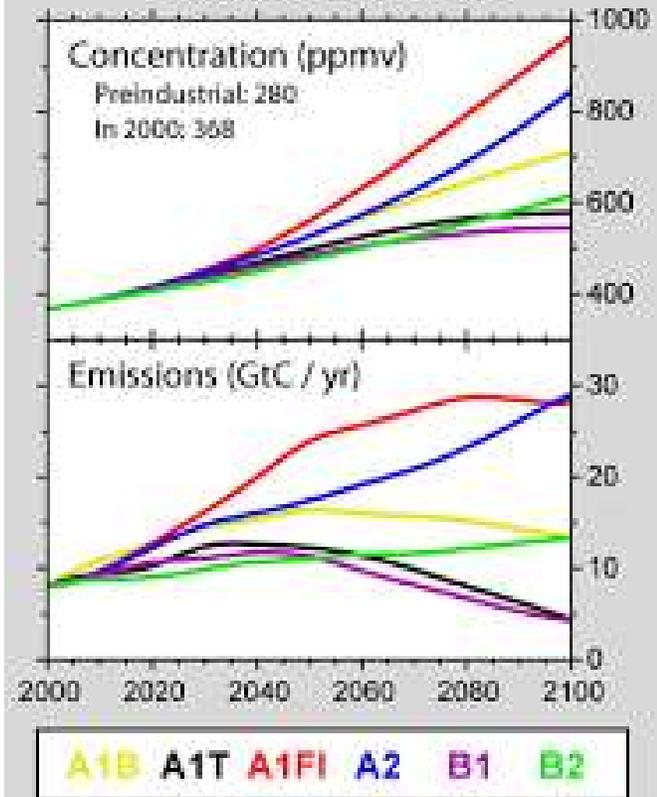


# The Earth Wins?

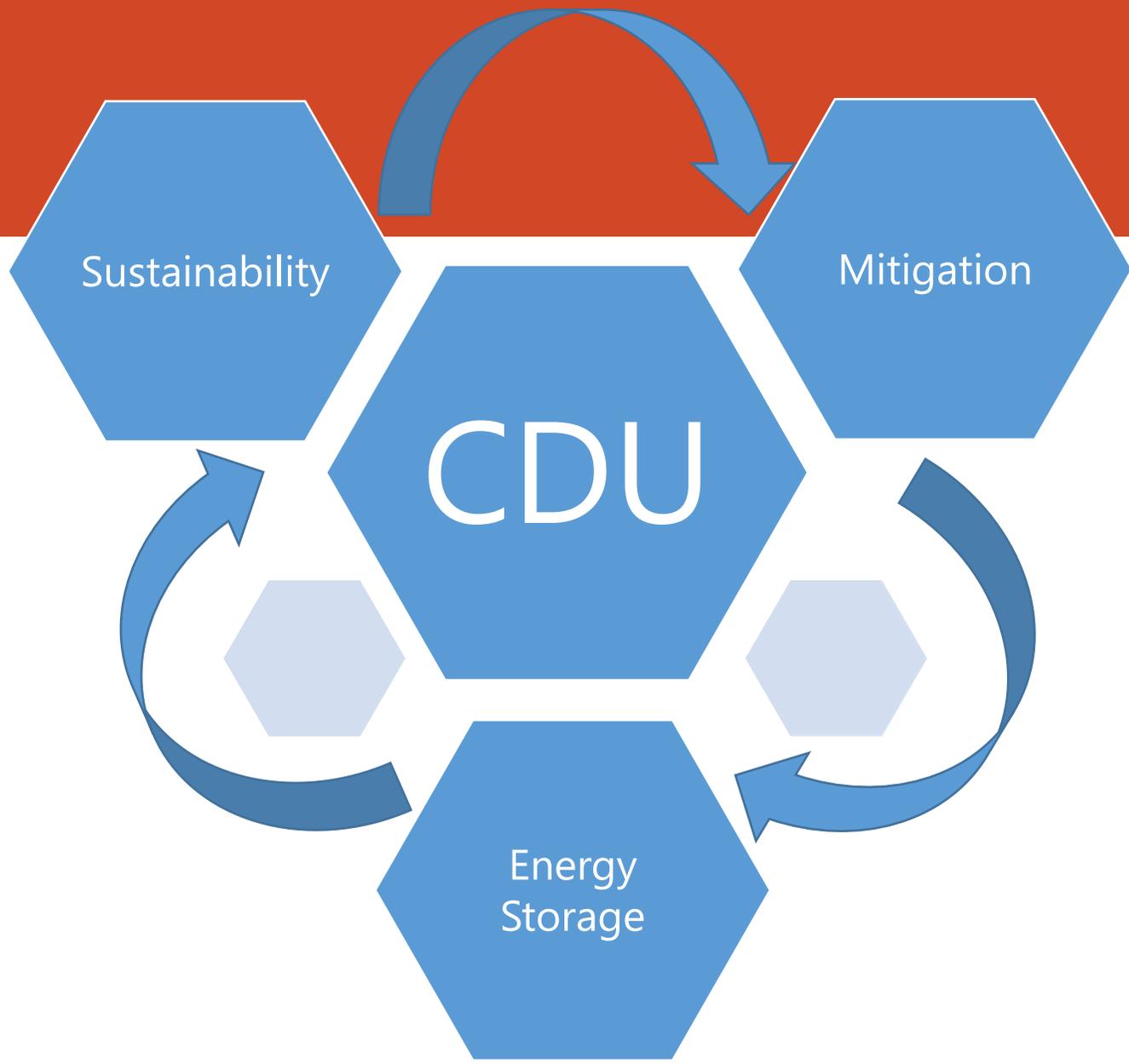
OFFICIAL SELECTION  
2013  
Helifilms presents  
a new film for giant  
dome & planetarium  
www.theearthwins.com



## IPCC Emissions Scenarios: Carbon Dioxide



# The CO<sub>2</sub> Trilemma



**Mitigation:** long-term and short-term carbon dioxide sequestration

**Sustainability:** carbon avoided, fossil product avoidance

**Energy Storage:** renewable electrical energy to chemical fuels and materials for long-term seasonal storage

**Carbon Cycle:** to manage emissions from synthetic fuels emissions (although remembering carbon avoided)

# CCS and CCU/CDU Capacity

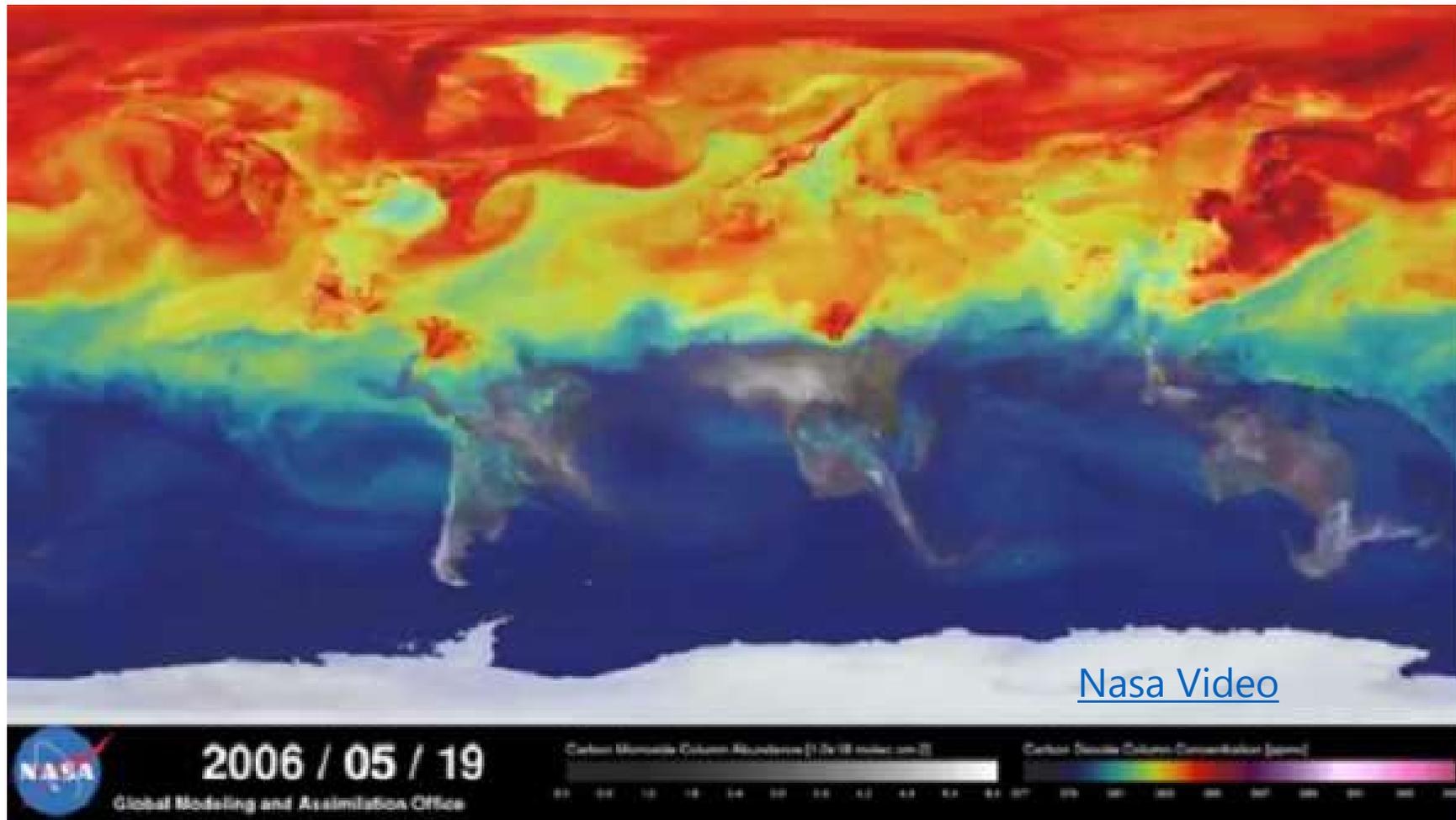
“To date there have been occasional pilot scale demonstration plants but no commercial examples of adsorption processes for CO<sub>2</sub> from low pressure flue gas streams”.

“The largest units in operation at the time of writing are at a 110 MW scale (SaskPower 2013) and significant additional work is needed to scale the technology to 500 MW and beyond”.

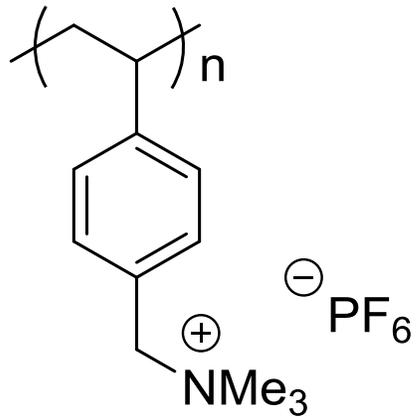
P.A. Webley, *Adsorption*, 2014, **20**, 225-231



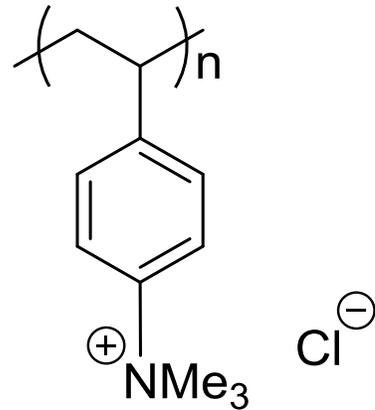
# Atmospheric CO<sub>2</sub> patterns



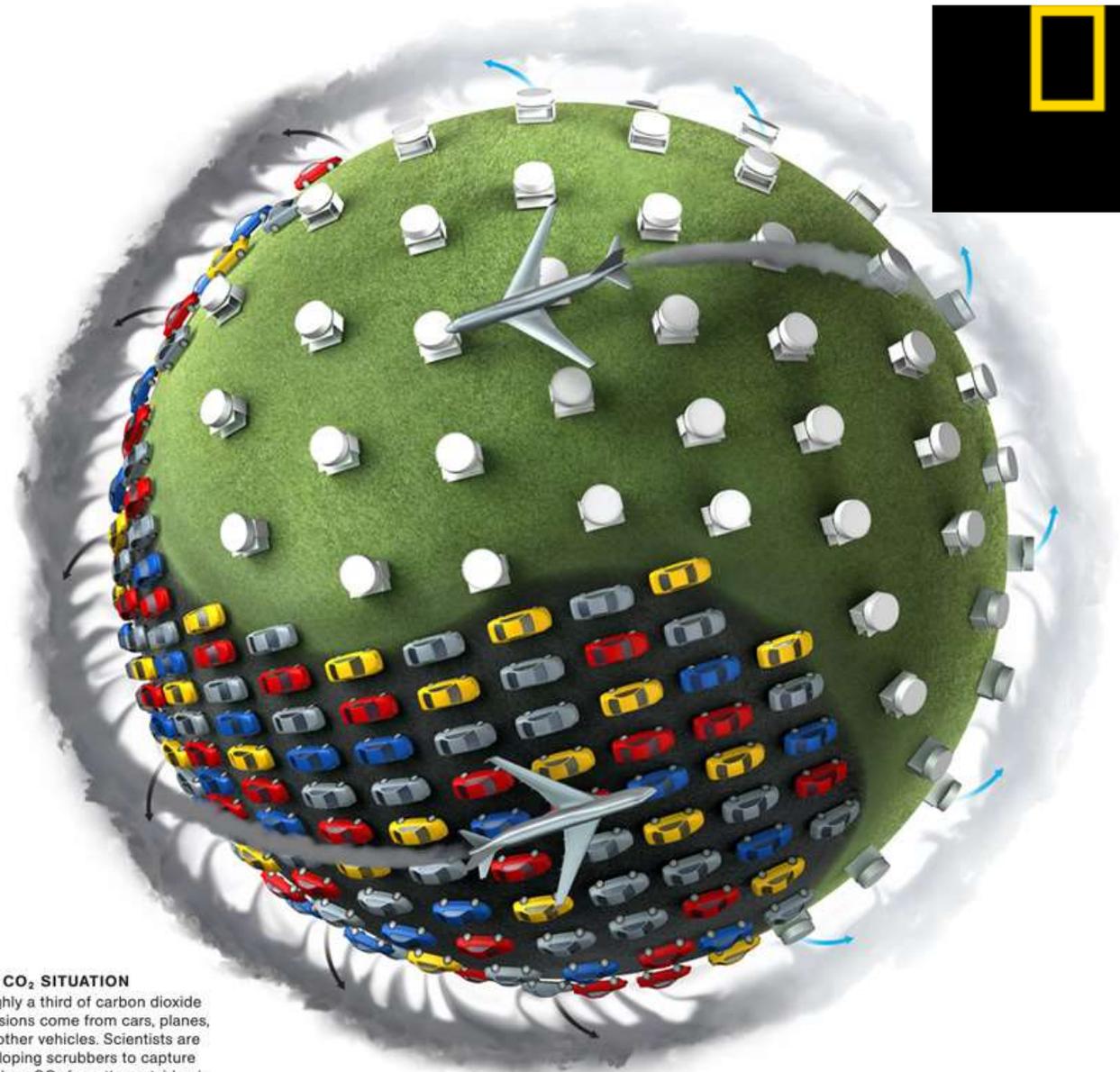
# Air Capture Materials



Styring



Lackner



## THE CO<sub>2</sub> SITUATION

Roughly a third of carbon dioxide emissions come from cars, planes, and other vehicles. Scientists are developing scrubbers to capture colorless CO<sub>2</sub> from the outside air.

## THE SOLUTION

In physicist Klaus Lackner's plan, a single scrubber, small enough to fit in a shipping container, could capture a ton of CO<sub>2</sub> a day—the output of 75 average U.S. cars. CO<sub>2</sub> spreads quickly, so scrubbing it out anywhere benefits everyone.

## HOW IT WORKS

**1** Wind blows air through a carousel's plastic filters, which are laced with an absorbing agent that extracts CO<sub>2</sub>. When the air reemerges, it contains less CO<sub>2</sub>.

**2** As filters become saturated, they are lowered into vacuum chambers and rinsed with water vapor, which removes the lightly bound CO<sub>2</sub> from the filters.

**3** The filters return to the carousel. The CO<sub>2</sub> is separated from the water, compressed to a liquid, and pumped underground (see following page).



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Smart CO<sub>2</sub> Transformation



# Capture-Conversion: Assessing Kinetics



# "CO<sub>2</sub> is unreactive"

## Reaction Kinetics

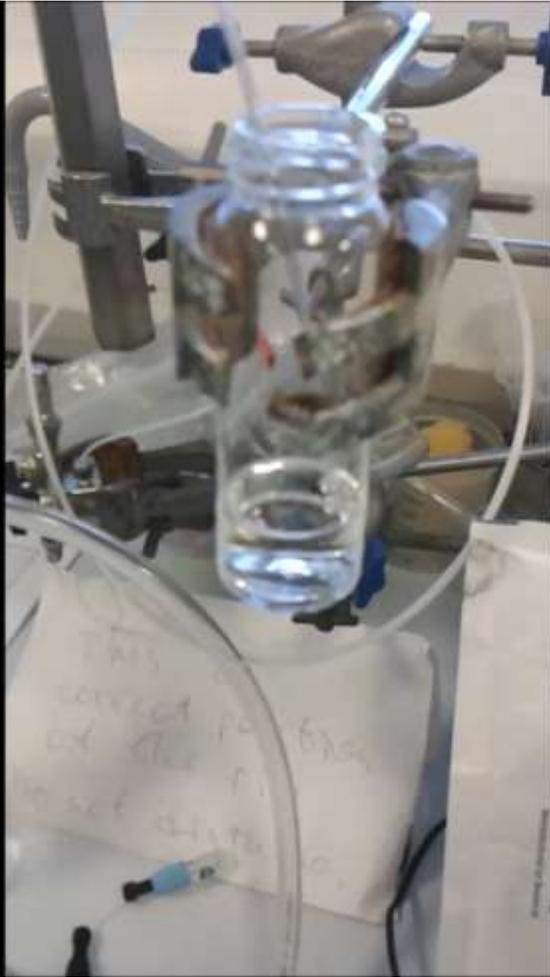
$$d\text{CO}_2/dt = -k[\text{CO}_2]$$

$$[\text{CO}_2]_0 = 4 \times 10^2 \text{ ppm air}$$

$$[\text{CO}_2]_0 = 10\text{-}15\% \text{ flue gas (ca. } 10^5 \text{ ppm)}$$

Mass transfer co-efficient?

Diffusion co-efficient?



## Adsorbent

MEA 30% aqueous (7 mol/kg)

Ionic Liquids 100%

Solids 100% but can be functionalised.  
Surface area a factor.

CO<sub>2</sub> **is** reactive

The concentration is less of an issue if the **rate constant** is high and the reaction is **first order** in CO<sub>2</sub>. Alternatively, the **flow rate** could be increased.

Better to use high reactivity to produce a product rather than capture and add more energy to release the CO<sub>2</sub>

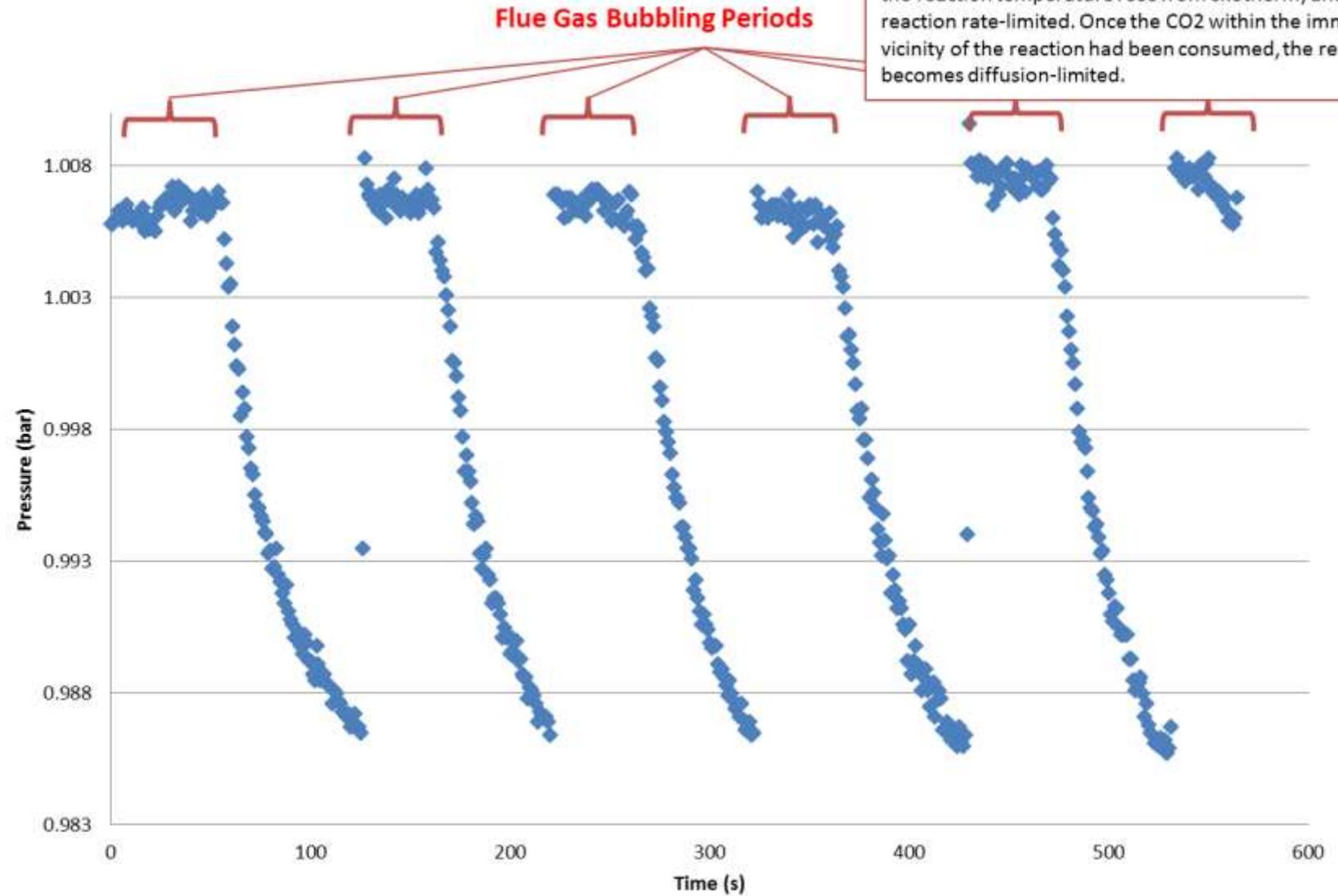
# Kinetics

CO<sub>2</sub> sparging under kinetic control

Static CO<sub>2</sub> atmosphere diffusion controlled

Dowson, Reed and Styring (2015)

## First 5 cycles (10 minutes reaction) - Annotated



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Smart CO<sub>2</sub> Transformation

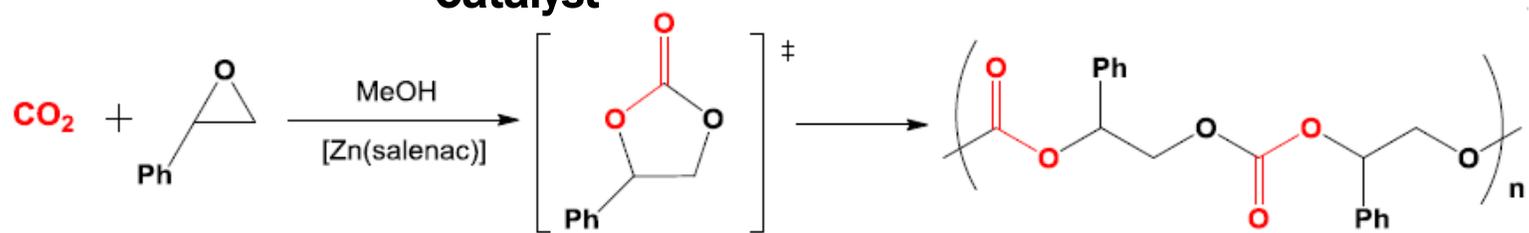
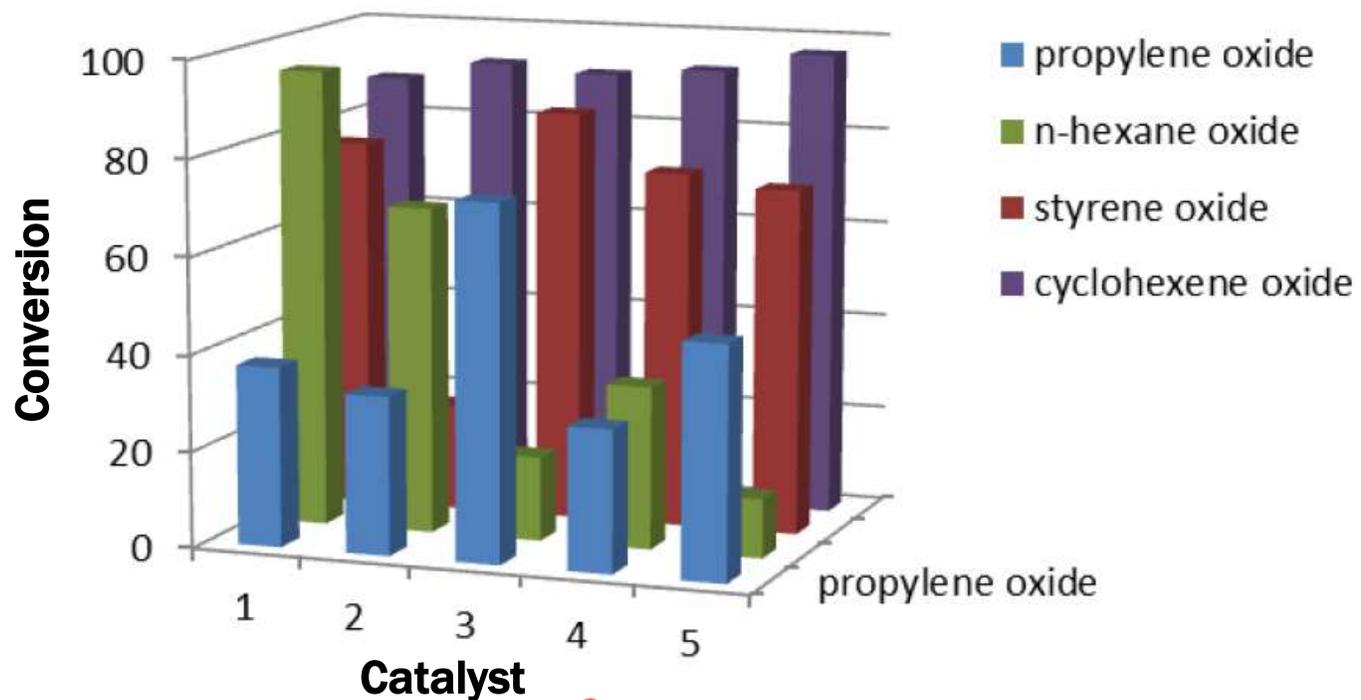


**EPSRC**

Engineering and Physical Sciences Research Council



# Zn-Catalysed CO<sub>2</sub> Co-polymerisation Reactions



Affan, Dowson & Styring, 2015

# Capture-Free CDU



## Poly(methyl acrylate)

- 1.00 kg polymer sequesters 1.01 kg CO<sub>2</sub>
- 65% atom sequestration from CO<sub>2</sub>
- Produced from simulated flue gas (12.5% CO<sub>2</sub> in nitrogen)

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# Conclusions

- We need to look at the CO<sub>2</sub> Trilemma, not just the individual aspects: **Direct Air Capture** is key
- Capture is the major economic burden: we need to look at “capture-free” processes from air
- We will continue to use hydrocarbon fuels in transport. To complete the carbon cycle and move towards a circular economy Direct Air Capture will be a necessity.
- Products with added-value will aid the economic argument.
- Catalyst/co-reactant activity will need to be high to counteract low concentrations

# Conclusions

CDU will provide much needed additional capacity, with profit, in the move towards a low carbon economy. Direct Air Capture will play a major role.

*CO<sub>2</sub> as a Resource, not a Waste*



(Click the arrow when in Slide Show mode)



# The Earth Wins?

# The Engineers and Scientists Fight Back!



# Acknowledgements

Katy Armstrong

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Daniel Reed

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