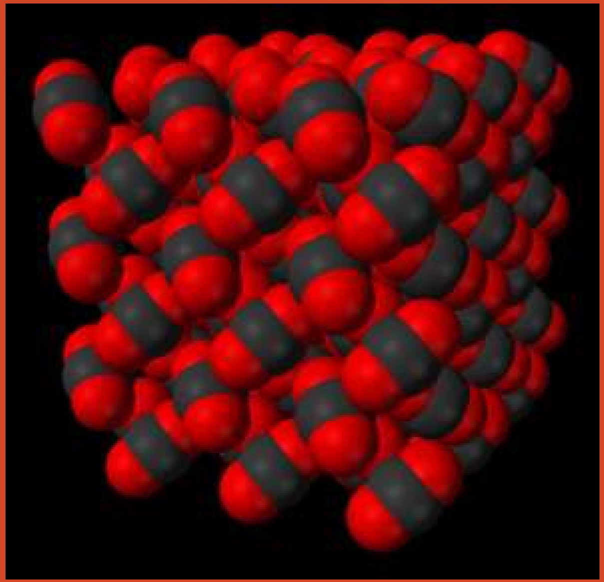
# Carbon Dioxide Utilisation as a Direct Air Capture Driver



Professor Peter Styring

*UK Centre for Carbon Dioxide Utilisation*

*The University of Sheffield, United Kingdom*

CDUK
UK Centre for Carbon Dioxide Utilisation

CO2Chem
An EPSRC Grand Challenge Network

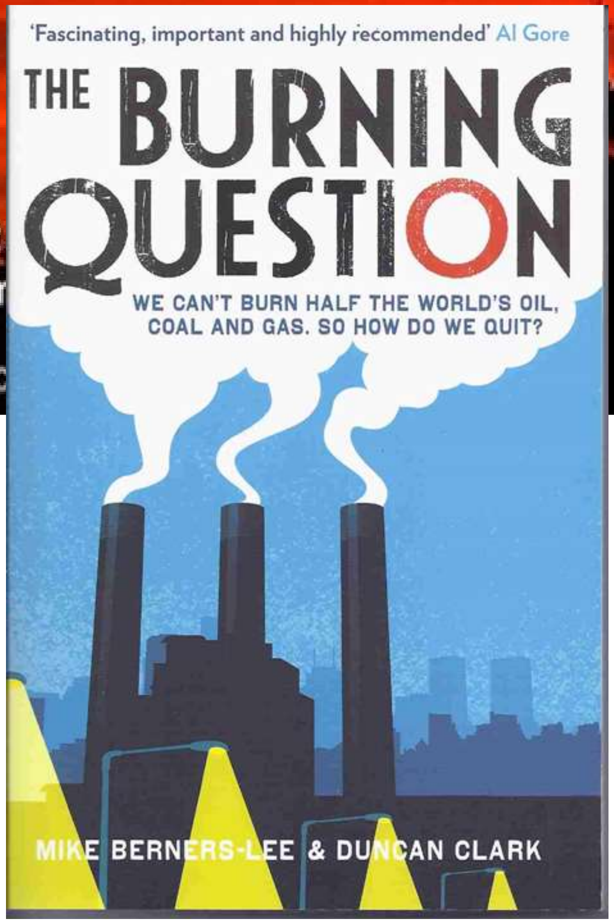
epic

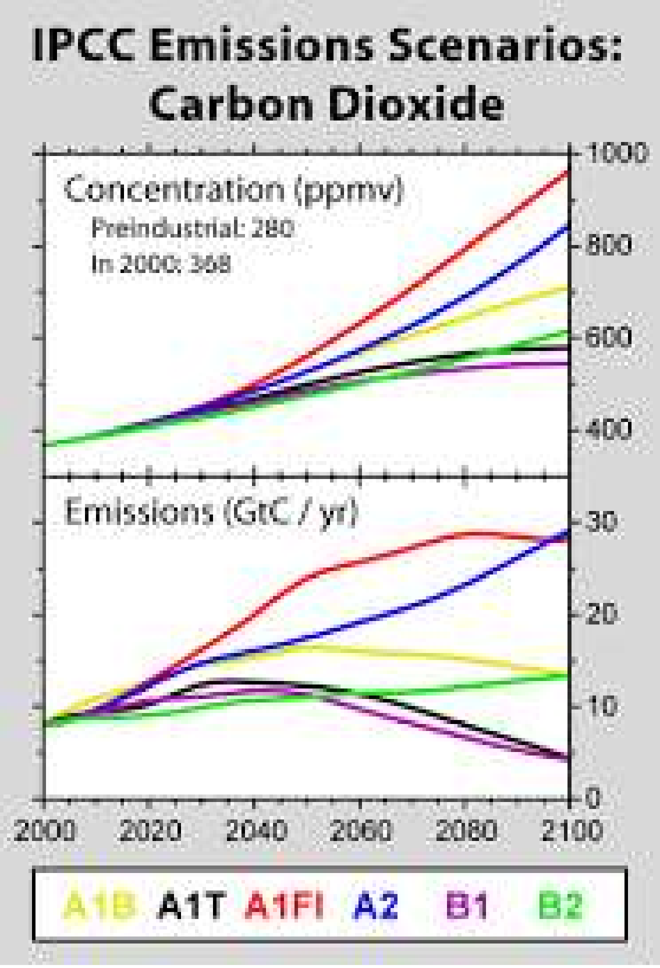
The University Of Sheffield.

# Summary

1. The Earth Wins
2. The $CO_2$ Trilemma
3. Capture Strategies
4. Direct Air Capture & Utilisation
5. Conclusions

# The Earth Wins?


The University Of Sheffield. | CDUK UK Centre for Carbon Dioxide Utilization | SCOT Smart CO2 Transformation | 4CU | CO2Chem An EPSRC Grand Challenge Network | EPSRC Engineering and Physical Sciences Research Council | European Commission | Seventh Framework Programme | BIS Department for Business Innovation & Skills | Department of Energy & Climate Change

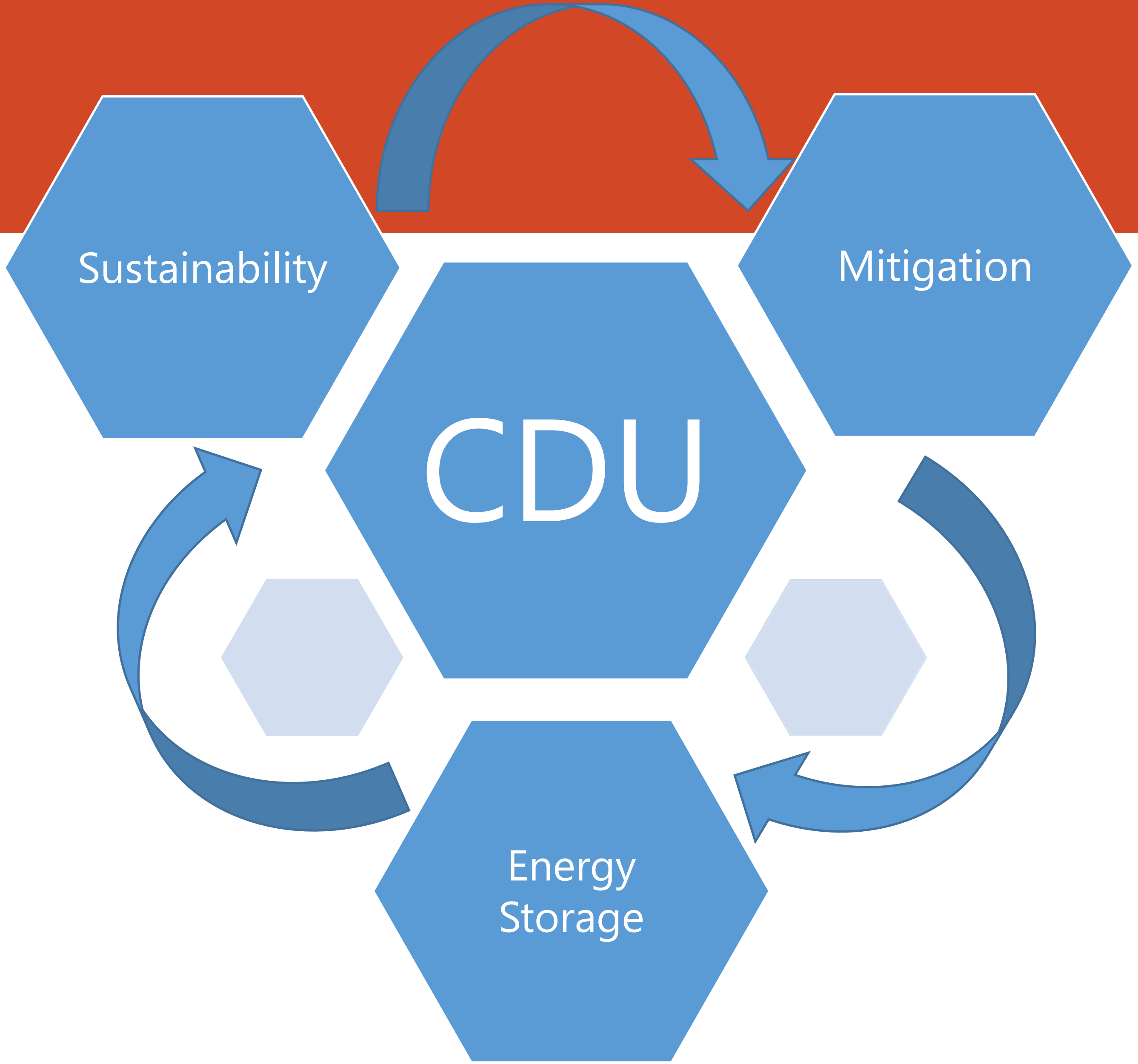
# The $CO_2$ Trilemma

**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)



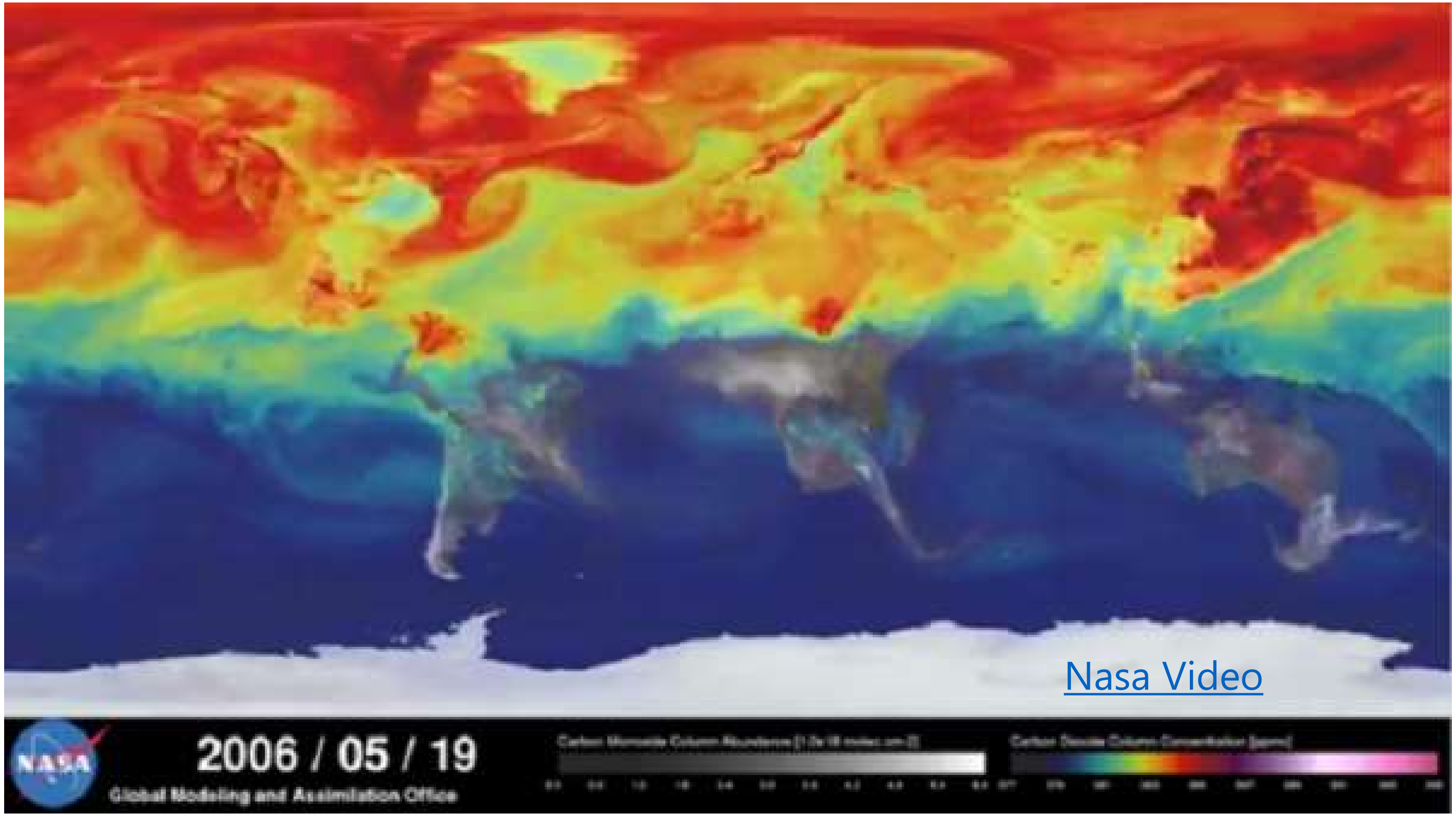
# CCS and CCU/CDU Capacity

"To date there have been occasional pilot scale demonstration plants but no commercial examples of adsorption processes for $CO_2$ 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".

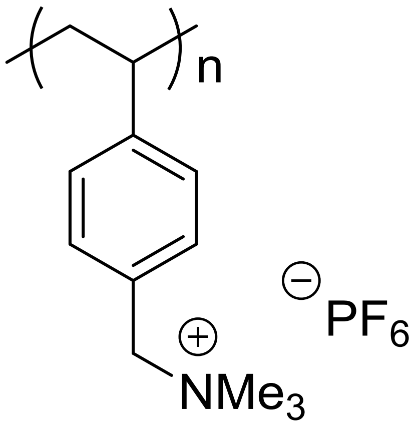
P.A. Webley, *Adsorption*, 2014, **20**, 225-231

# Atmospheric $CO_2$ patterns

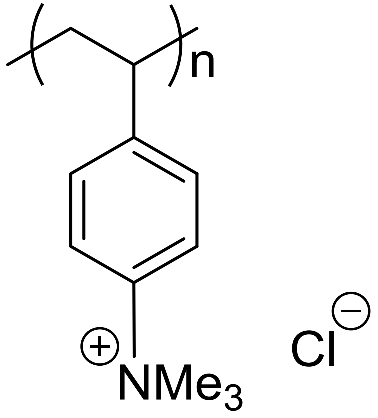



The University Of Sheffield.
CDUK
UK Centre for Carbon Dioxide Utilisation
SCOT
Smart $CO_2$ Transformation
4CU
CO2Chem
An EPSRC Grand Challenge Network
EPSRC
Engineering and Physical Sciences Research Council
European Commission
SEVENTH FRAMEWORK PROGRAMME
BIS
Department for Business Innovation & Skills
DEPARTMENT OF ENERGY & CLIMATE CHANGE

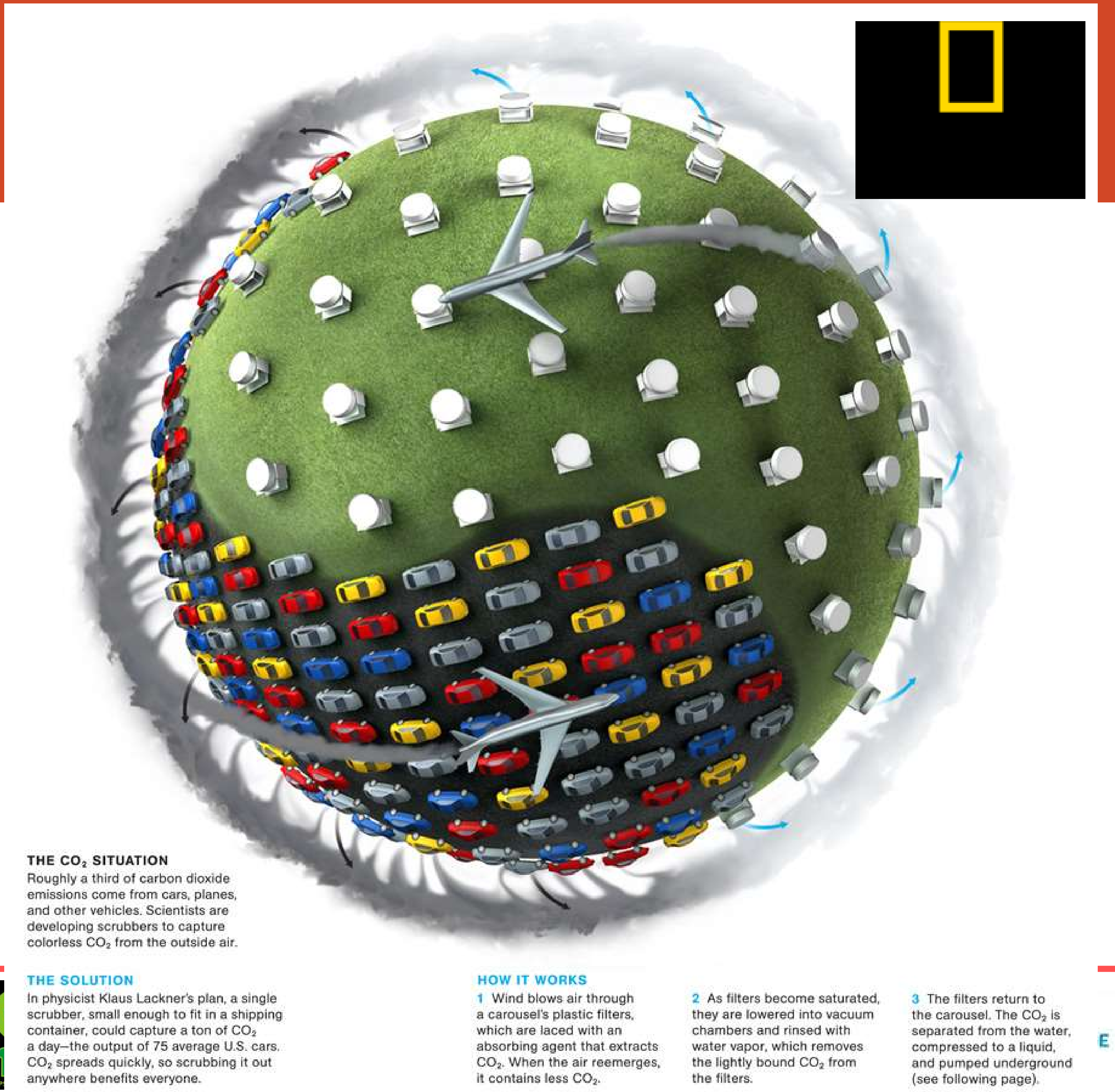
# Air Capture Materials



Styring



Lackner



# Capture-Conversion: Assessing Kinetics

The University Of Sheffield.
CDUK
UK Centre for Carbon Dioxide Utilization
SCOT
Smart CO2 Transformation
4CU
CO2Chem
An EPSRC Grand Challenge Network
EPSRC
Engineering and Physical Sciences Research Council
European Commission
SEVENTH FRAMEWORK PROGRAMME
BIS
Department for Business Innovation & Skills
DEPARTMENT OF ENERGY & CLIMATE CHANGE

# "$CO_2$ is unreactive"

**Reaction Kinetics**

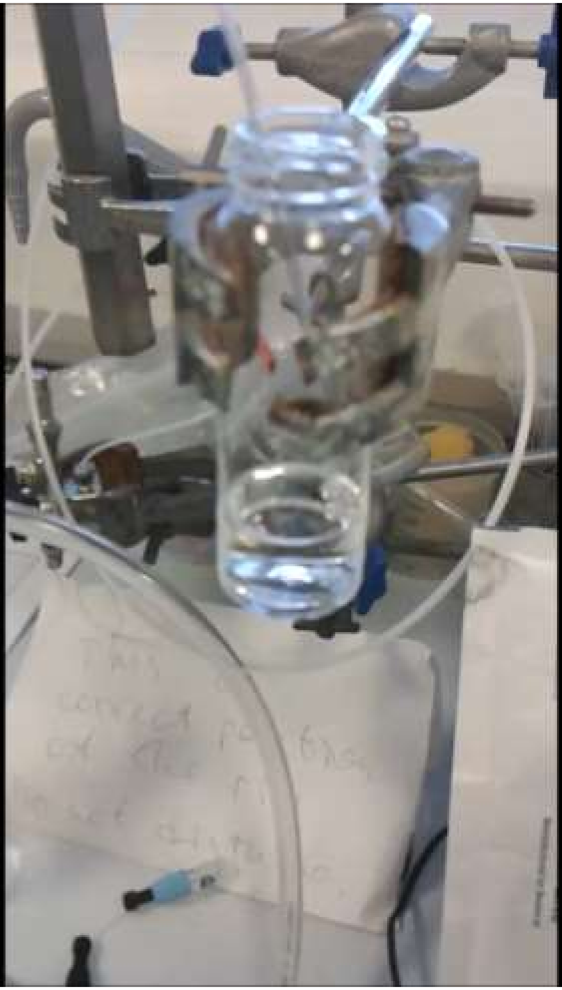
$dCO_2/dt = -k[CO_2]$

$[CO_2]_0 = 4 \times 10^2$ ppm air

$[CO_2]_0 = 10\text{-}15\%$ flue gas (*ca.* $10^5$ 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.

$CO_2$ **is** reactive

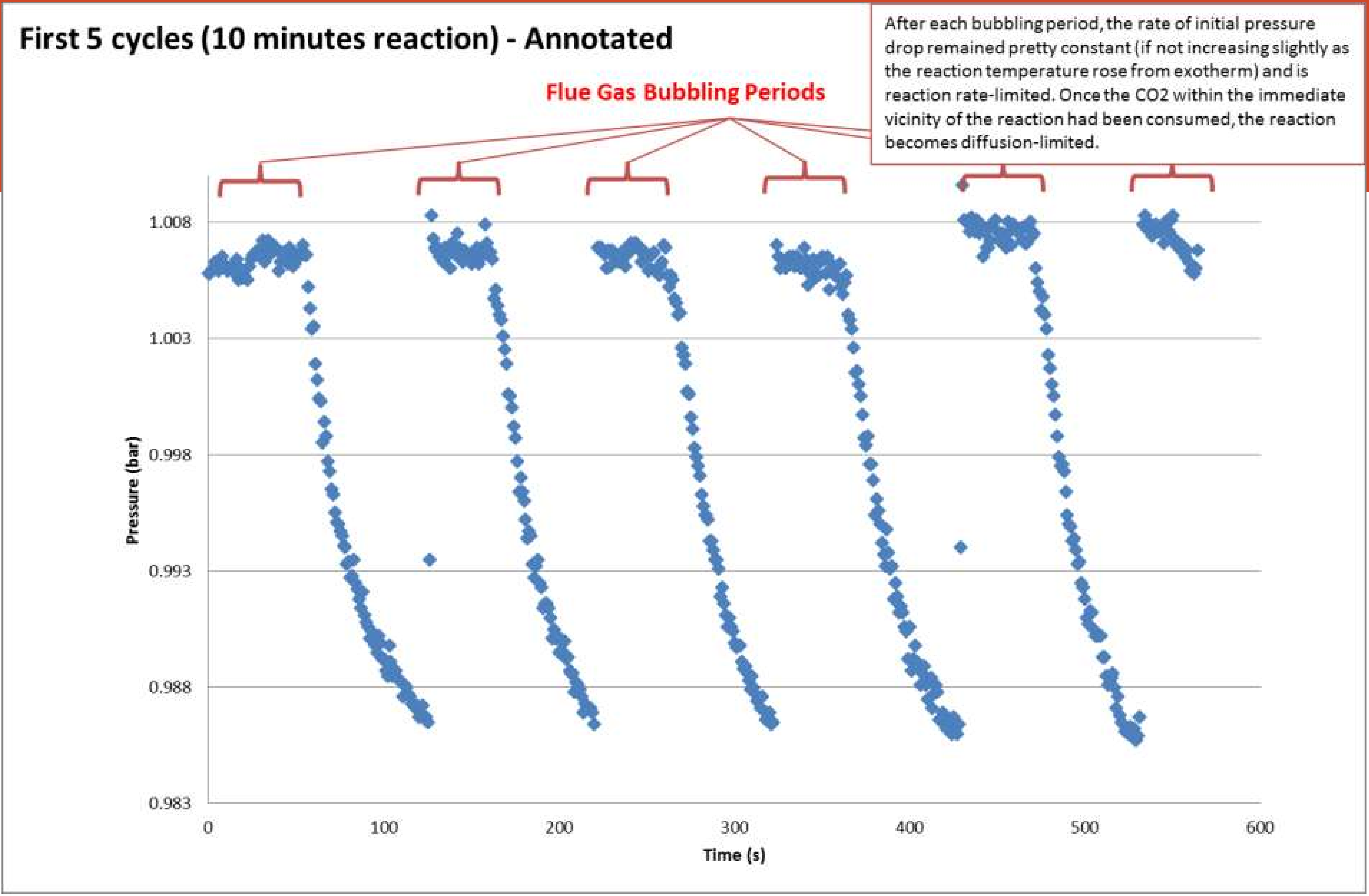
The concentration is less of an issue if the **rate constant** is high and the reaction is **first order** in $CO_2$. Alternatively, the **flow rate** could be increased.

Better to use high reactivity to produce a product rather than capture and add more energy to release the $CO_2$

# Kinetics

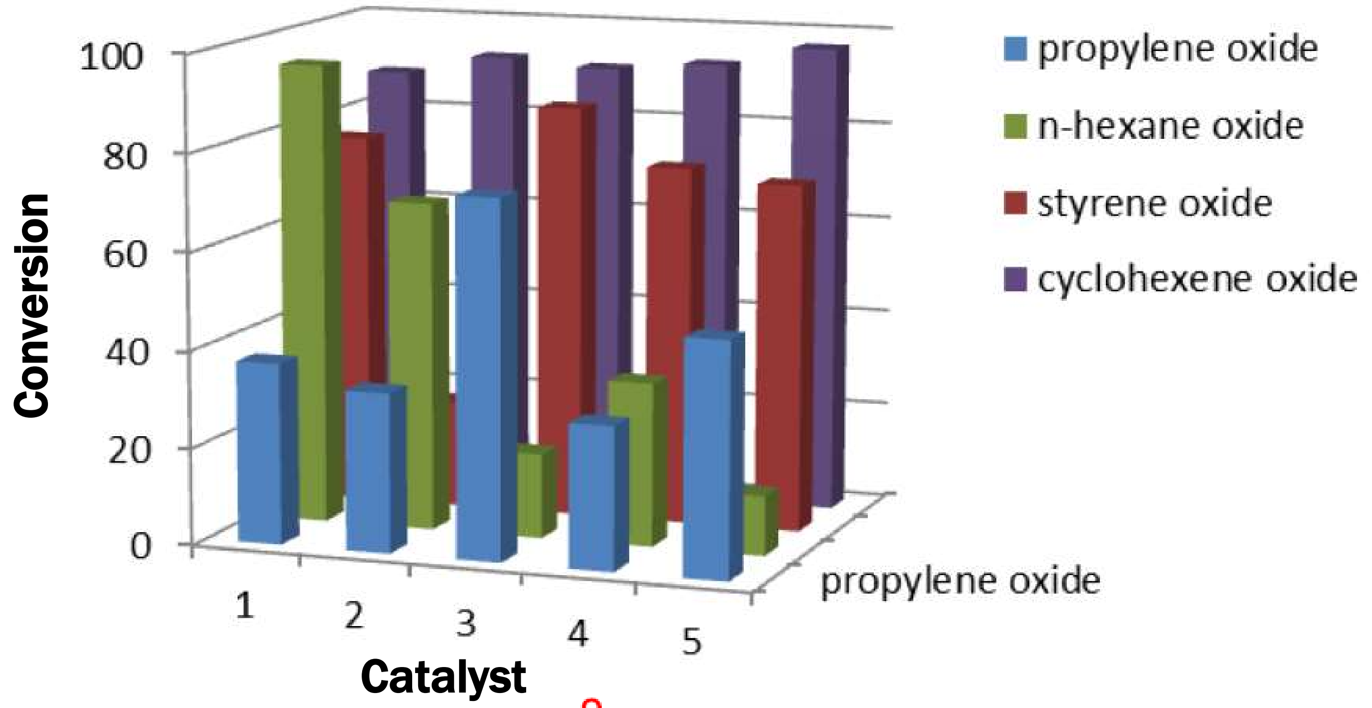
$CO_2$ sparging under kinetic control

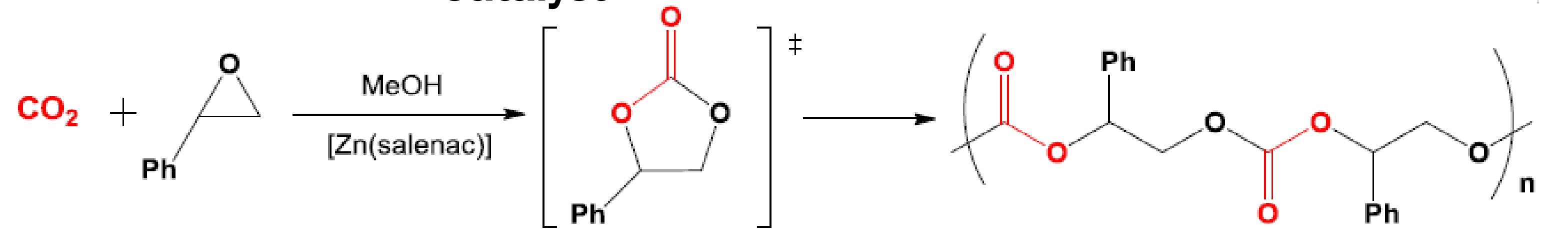
Static $CO_2$ atmosphere diffusion controlled




Dowson, Reed
and Styring (2015)

# Zn-Catalysed $CO_2$ Co-polymerisation Reactions




Affan, Dowson & Styring, 2015

# Capture-Free CDU

## Poly(methyl acrylate)

- 1.00 kg polymer sequesters 1.01 kg $CO_2$
- 65% atom sequestration from $CO_2$
- Produced from simulated flue gas (12.5% $CO_2$ in nitrogen)

EPSRC Engineering and Physical Sciences Research Council

# Conclusions

- We need to look at the $CO_2$ 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.

*$CO_2$ 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

Dr Grant Wilson

Dr George Dowson

Daniel Reed

Farah Bani Affan



The University Of Sheffield.

CDUK UK Centre for Carbon Dioxide Utilization

SCOT Smart CO2 Transformation

4CU

CO2Chem An EPSRC Grand Challenge Network

EPSRC Engineering and Physical Sciences Research Council

European Commission

Seventh Framework Programme

BIS Department for Business Innovation & Skills

Department of Energy & Climate Change