‘Rethinking CO_2: how can we put it to use’

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Importance of Carbon Capture

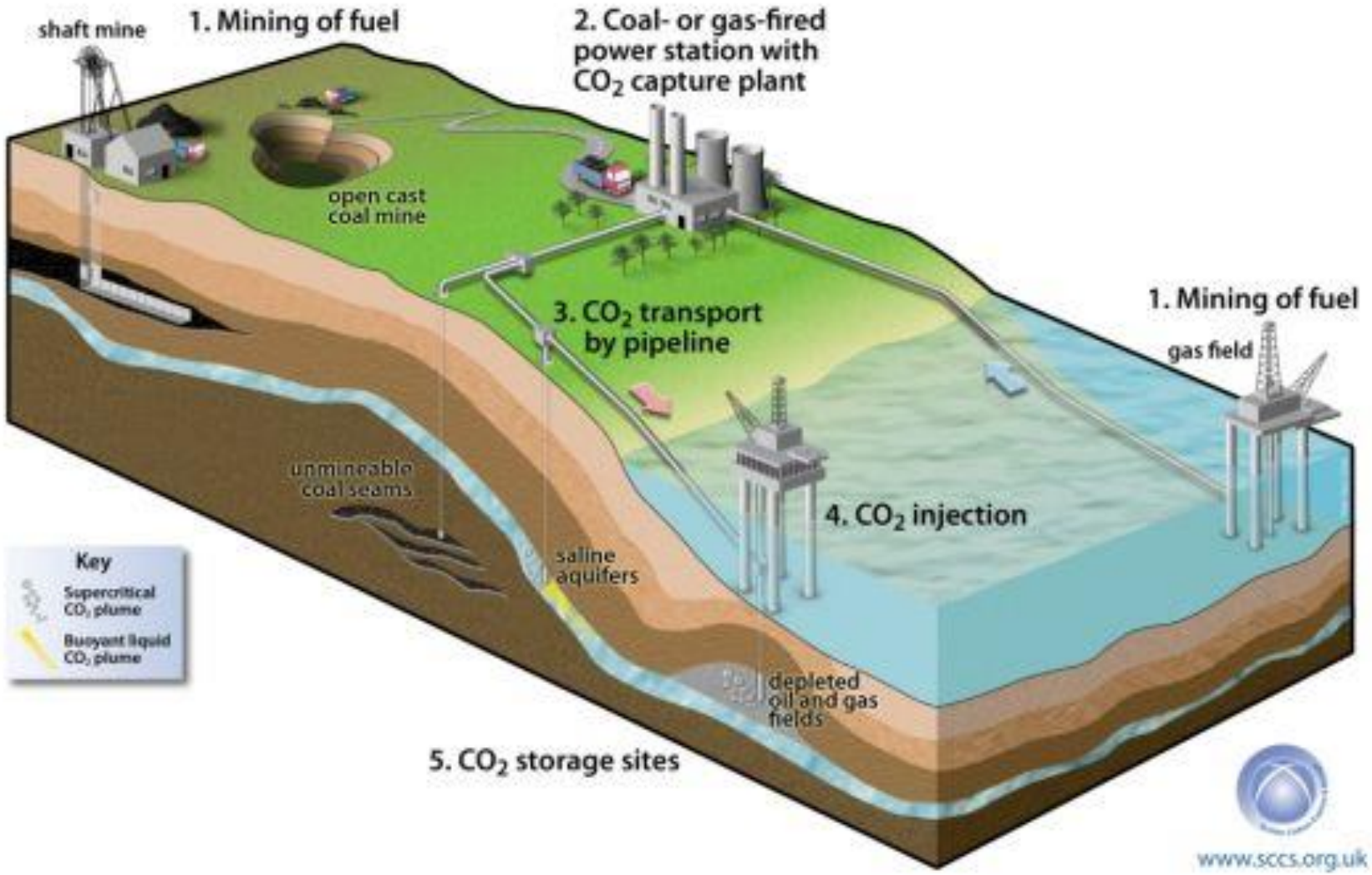
CCC (Fifth Carbon Budget, 2015) :

- *CCS is very important for reducing emissions across the economy.*
- *The cost of meeting the UK's 2050 emissions target would double in the absence of CCS deployment.*
- *Industrial CCS development and deployment on a large scale is required to decarbonise industry and meet the 2050 target.*

IEA (CCS roadmap, 2013):

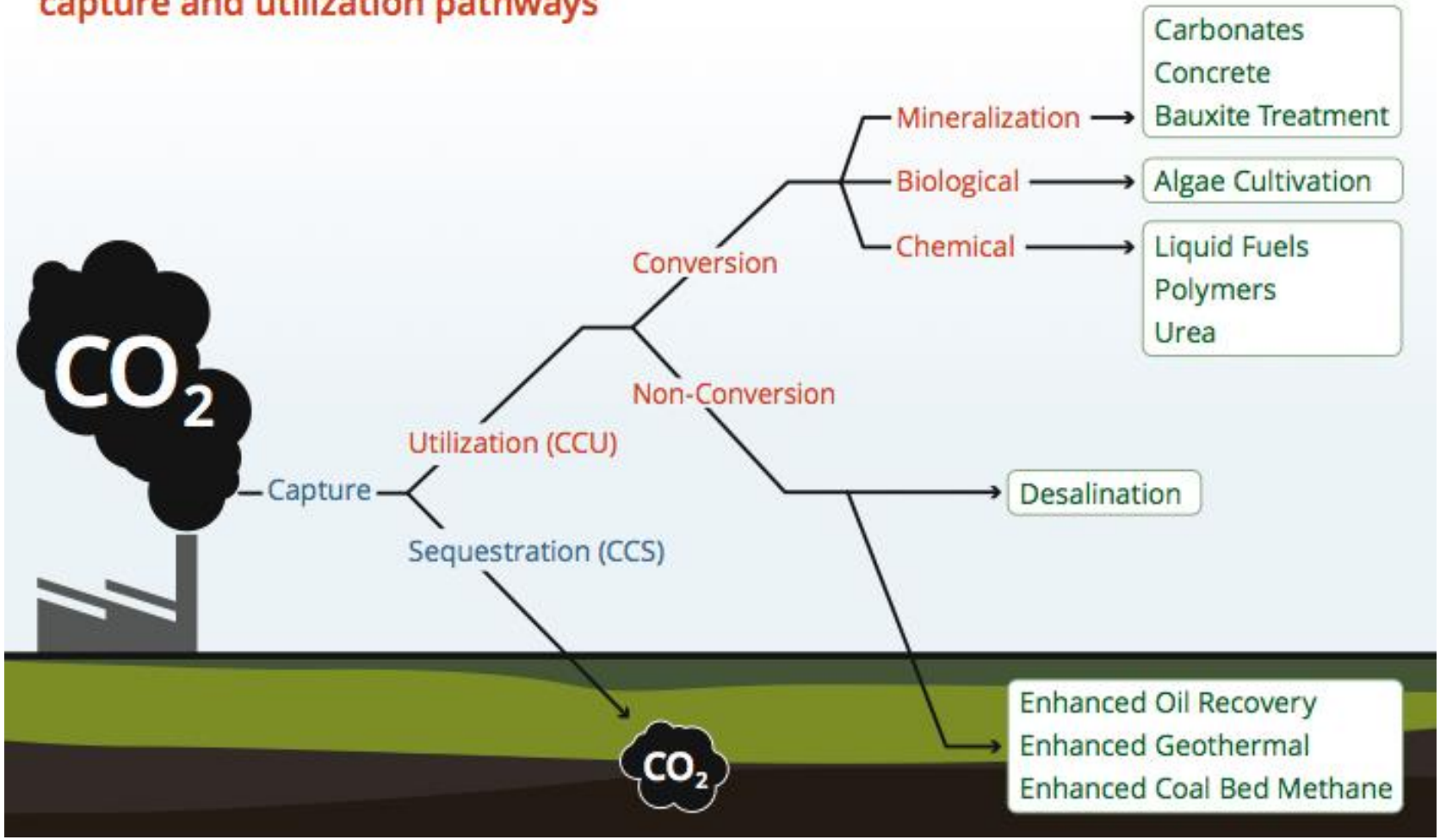
- *There is no climate friendly scenario in the long run without CCS.*

Carbon Capture and Storage

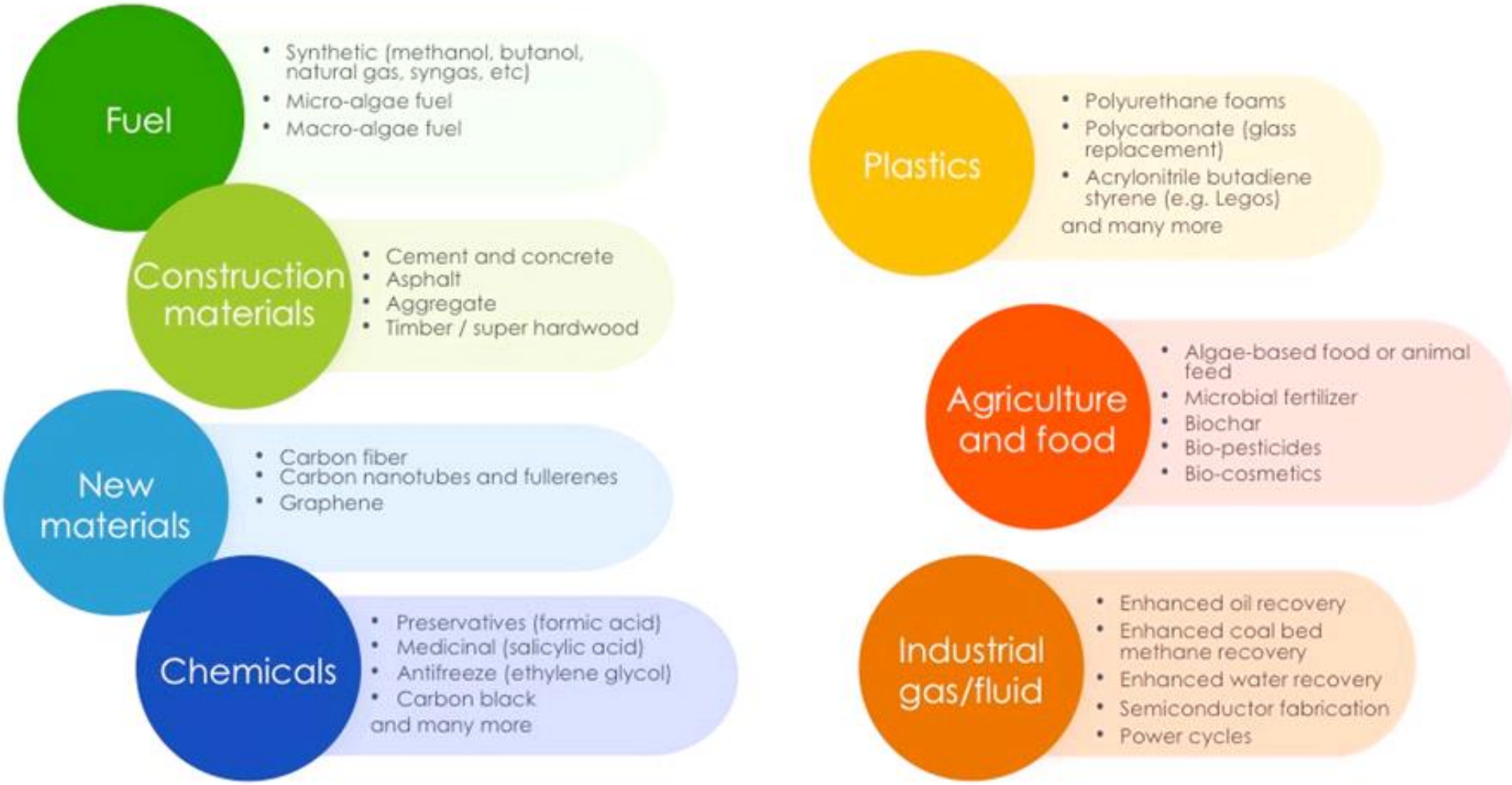


CCS and CCU

Figure 1. Paving the way — A selection of today's carbon capture and utilization pathways



…which have many potential uses



THE GLOBAL CO_2 INITIATIVE

The market for CCU products could be huge…

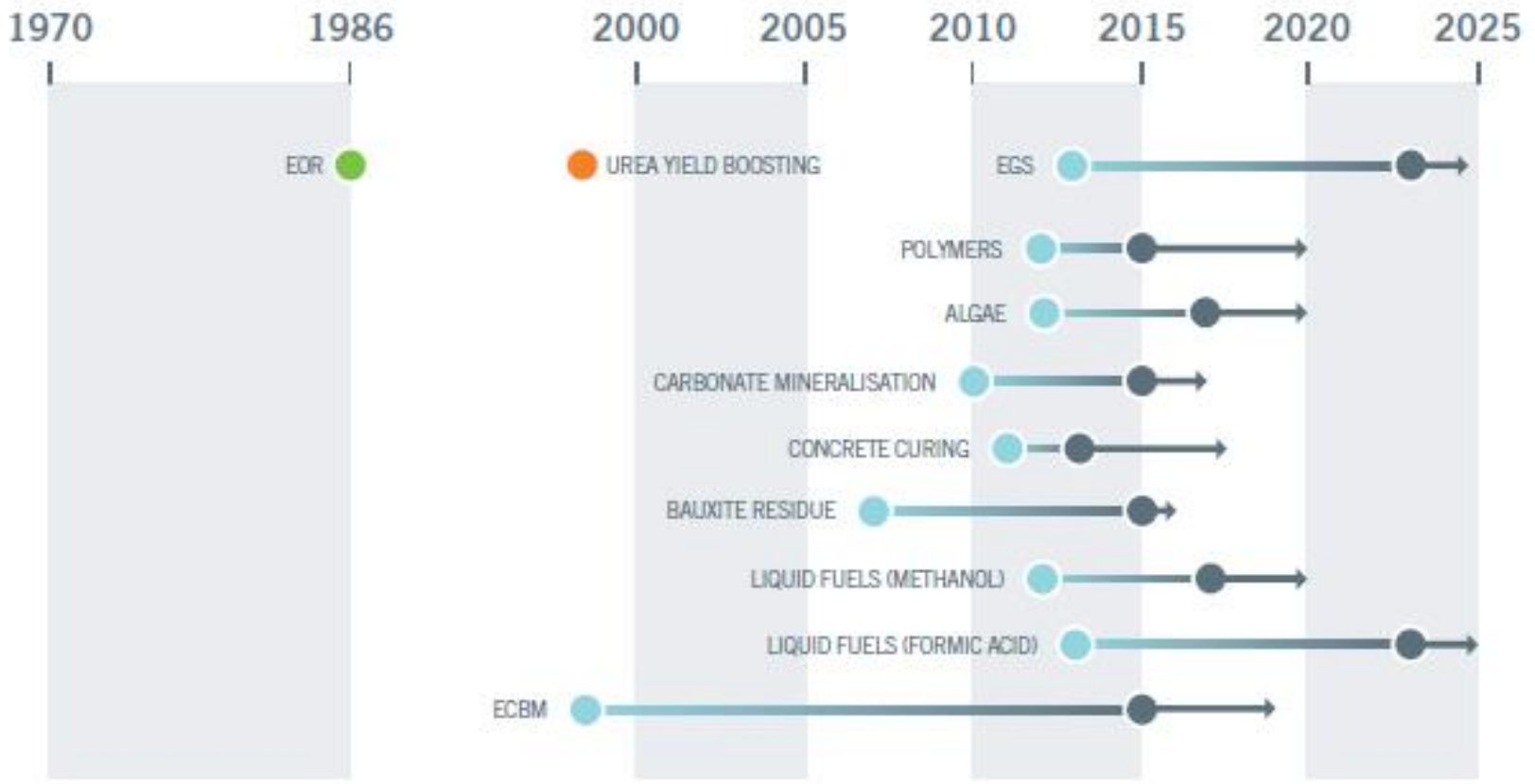
EXISTING USES	Current non-captive CO_2 demand (Mtpa)	Future potential non-captive CO_2 demand (Mtpa)
Enhanced Oil Recovery (EOR)	30< Demand < 300	30< Demand < 300
Fertilizer – Urea (Captive Use)	5 < Demand < 30	5 < Demand < 30

NEW USES	Future potential non-captive CO_2 demand (Mtpa)
Enhanced Coal Bed Methane Recovery (ECBM)	Demand >300
Enhanced geothermal systems – CO_2 as a working fluid	5< Demand <30
Polymer processing	5< Demand <30
Algal Bio-fixation	>300
Mineralisation	
Calcium carbonate & magnesium carbonate & Sodium Bicarbonate	>300
CO_2 Concrete Curing	30< Demand <300
Bauxite Residue Treatment ('Red Mud')	5 < Demand < 30
Liquid Fuels	
Renewable Methanol	>300
Formic Acid	>300

CCU product markets valued at up to $1 trillion p.a. globally by 2030

PARSONS BRINCKERHOFF

CCU technologies are close to commercialisation…



Note: The light blue circle represents the technology at demonstration scale, while the dark blue circle represents commercial operation of the technology based on claims from the respective proponents. Consequently, the predictions appear optimistic. The arrow extending from the dark blue circle indicates a more pragmatic timeframe to commercialisation.

Research Activity

- **Global CO_2 Initiative:** Investing up to $1bn over 10 years to commercialise CCU technology
- **X-Prize:** $20m innovation prize for development of commercial CO_2 conversion technologies
- **EC Horizon 2020:** funding for large scale CO_2 re-use
- **ULCOS:** European consortium investigating CCU in context of Ultra-low CO_2 steelmaking
- **CO_2 Chem:** UK / global Carbon Dioxide Utilisation Network (EPSRC funded)

Lack of policy context?

- Limited discussion of CCU by DECC / CCC / IPCC
- Focus on power sector > industrial decarbonisation
- Limited R&D funding for CCU in UK – e.g. £10m CCU out of £125m CCS R&D programme
- Lack of financial incentives to pursue CCU
- Recognition of CCU in EU ETS / carbon pricing?
- Fit with waste / recycling policy?

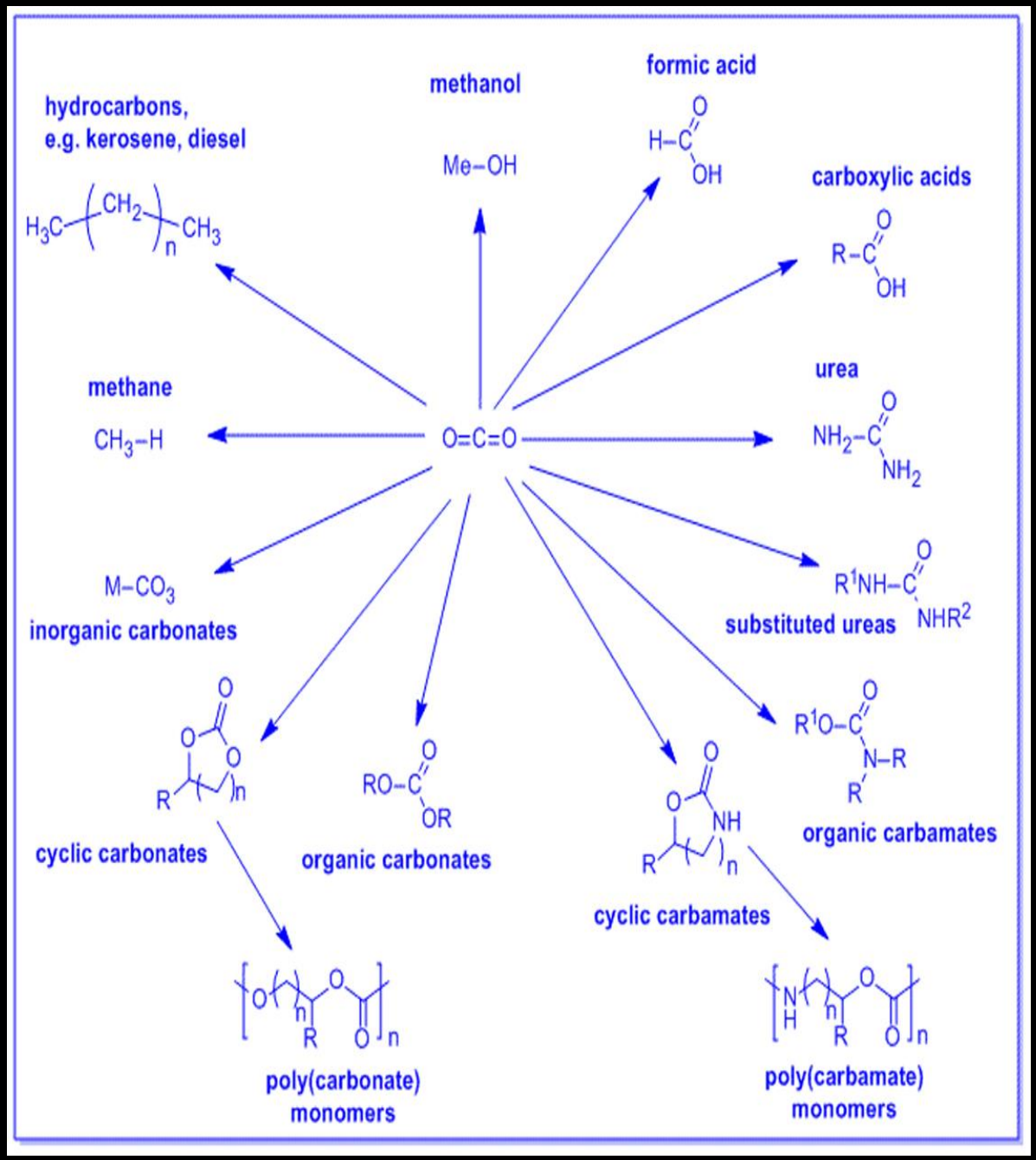
Questions

- What is true potential for CCU?
- Which CCU technologies have most promise?
- Is CCU commercially viable / at what cost?
- Is it a complement / alternative to CCS?
- Does it really result in CO_2 reduction?
- How should Government(s) support CCU technology development?
- Is the UK at risk of being left behind?

Professor Peter Styring

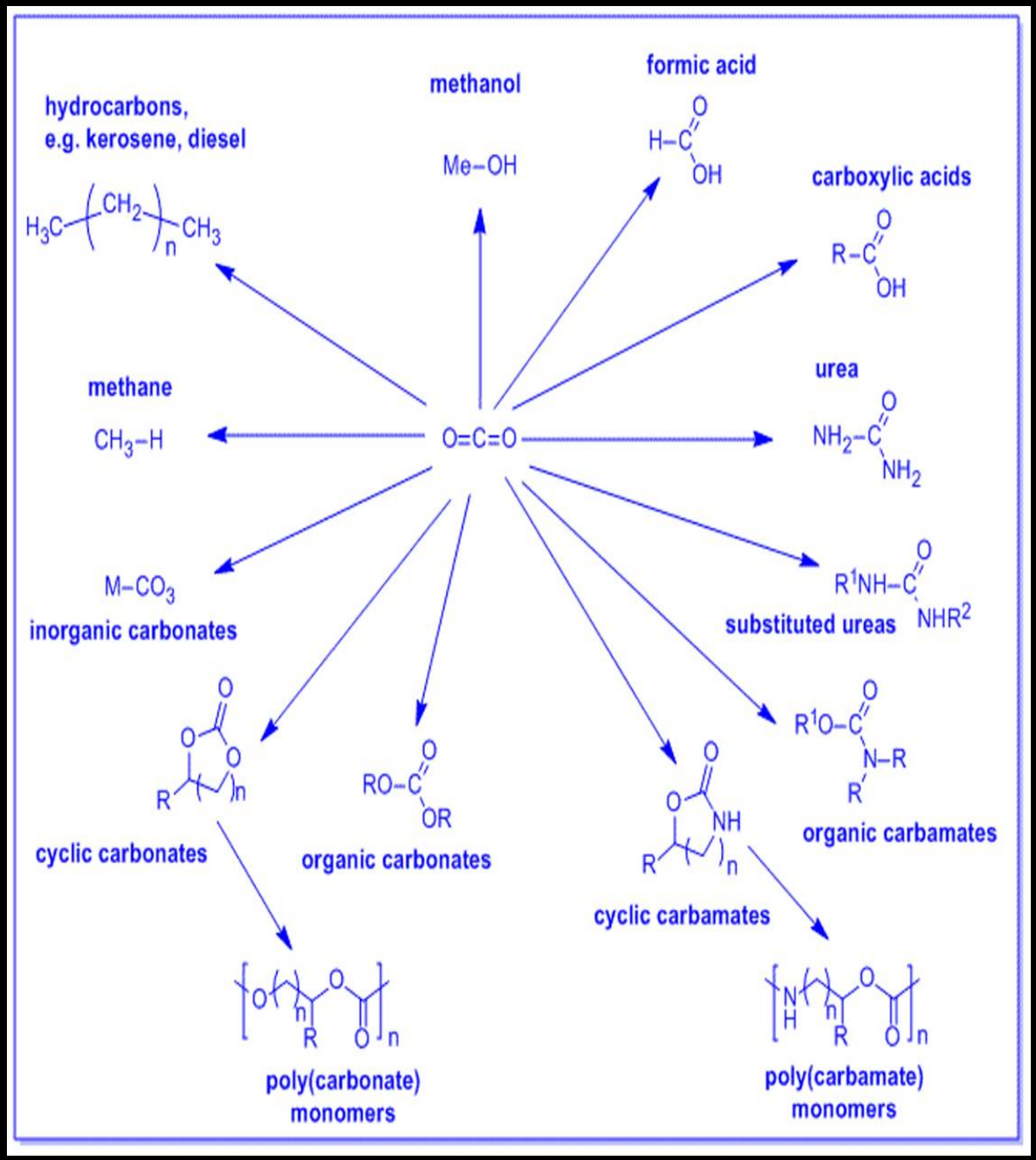
UK Centre for Carbon Dioxide Utilisation

The University of Sheffield


hydrocarbons,
e.g. kerosene, diesel
methanol
Me–OH
formic acid
carboxylic acids
methane
CH3–H
O=C=O
urea
M–CO3
inorganic carbonates
substituted ureas
cyclic carbonates
organic carbonates
cyclic carbamates
organic carbamates
poly(carbonate)
monomers
poly(carbamate)
monomers

thermodynamics

kinetics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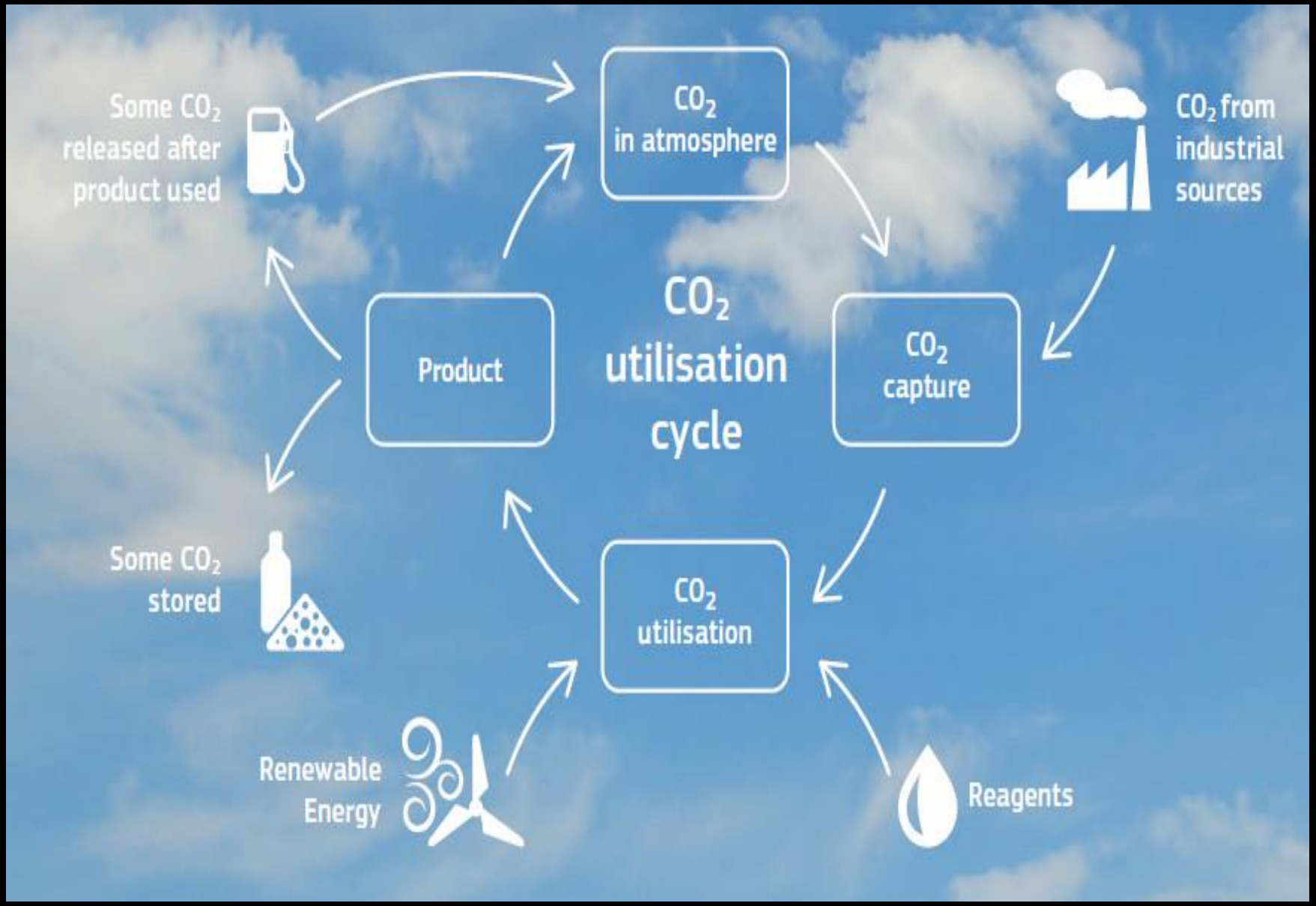
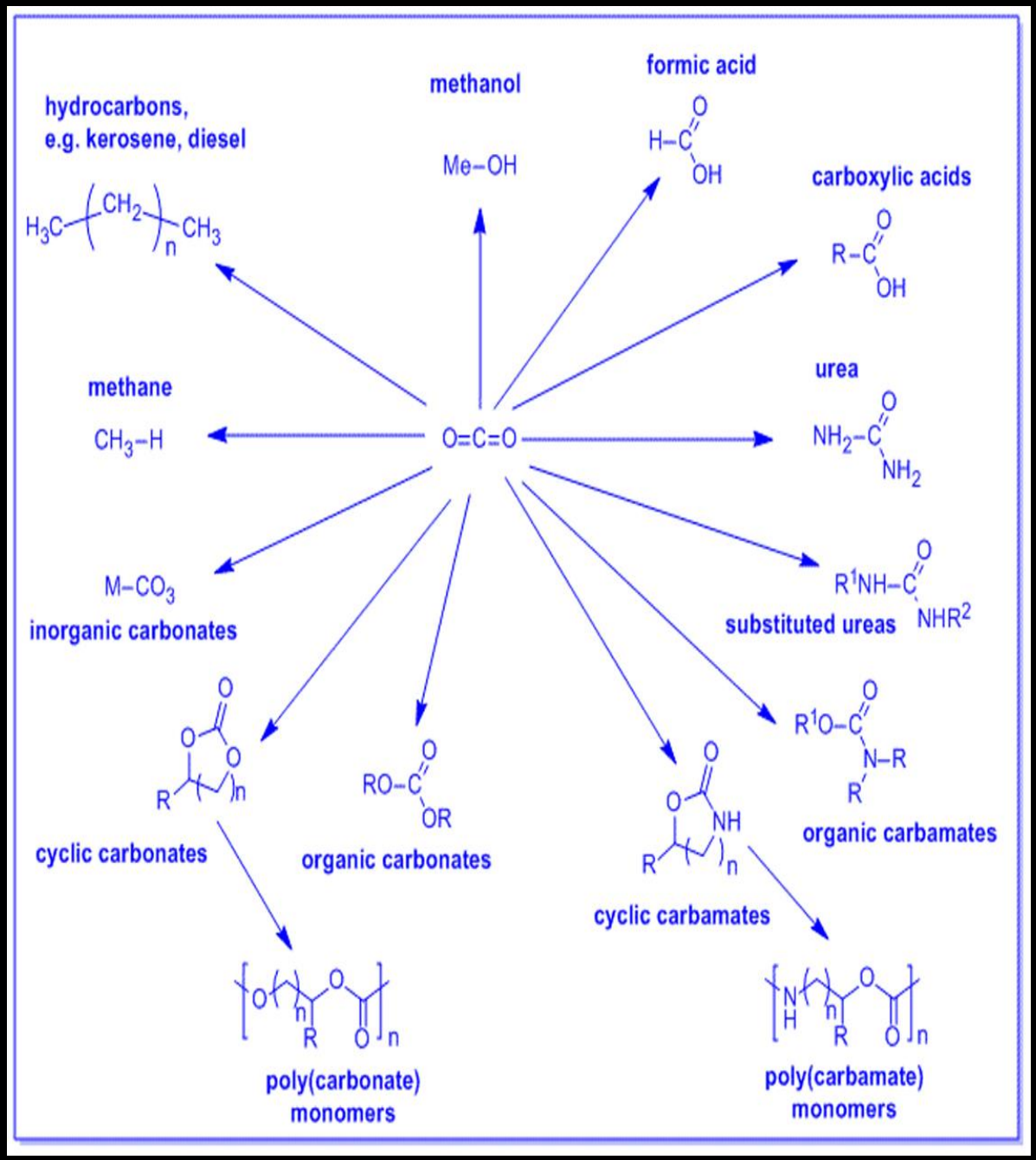
cyclic carbonates
organic carbonates
cyclic carbamates
organic carbamates
poly(carbonate)
monomers
poly(carbamate)
monomers


Some CO_2 released after product used
CO_2 in atmosphere
CO_2 from industrial sources
CO_2 utilisation cycle
Product
CO_2 capture
Some CO_2 stored
CO_2 utilisation
Renewable Energy
Reagents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monomers
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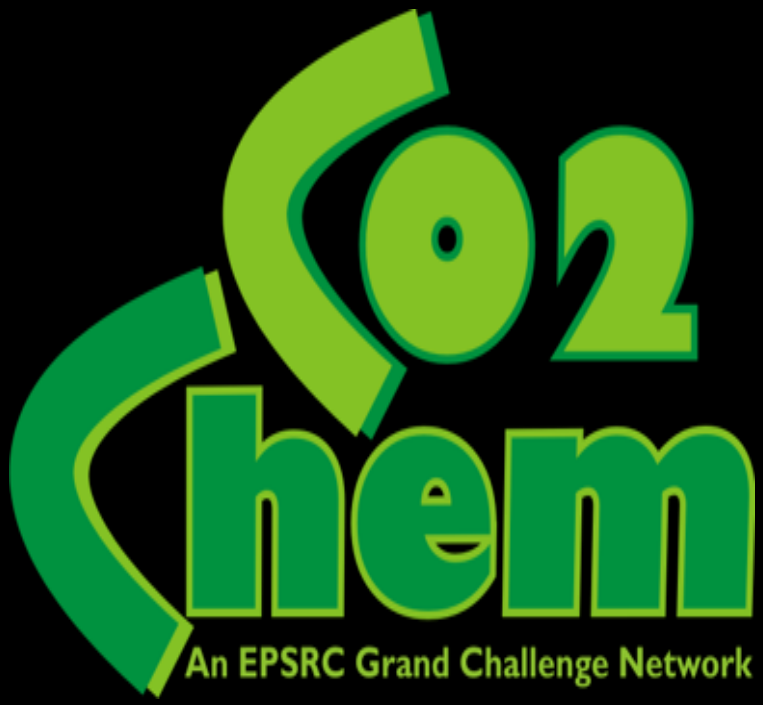
monomers


CDUK
UK Centre for Carbon Dioxide Utilisation


CO2
Chem
An EPSRC Grand Challenge Network


4CU
Foreseeing
a future
using CO_2


S
T
2
Smart CO2 Transformation


carbonNext

Manufactured Aggregates from CO_2 and Waste

Professor CD Hills

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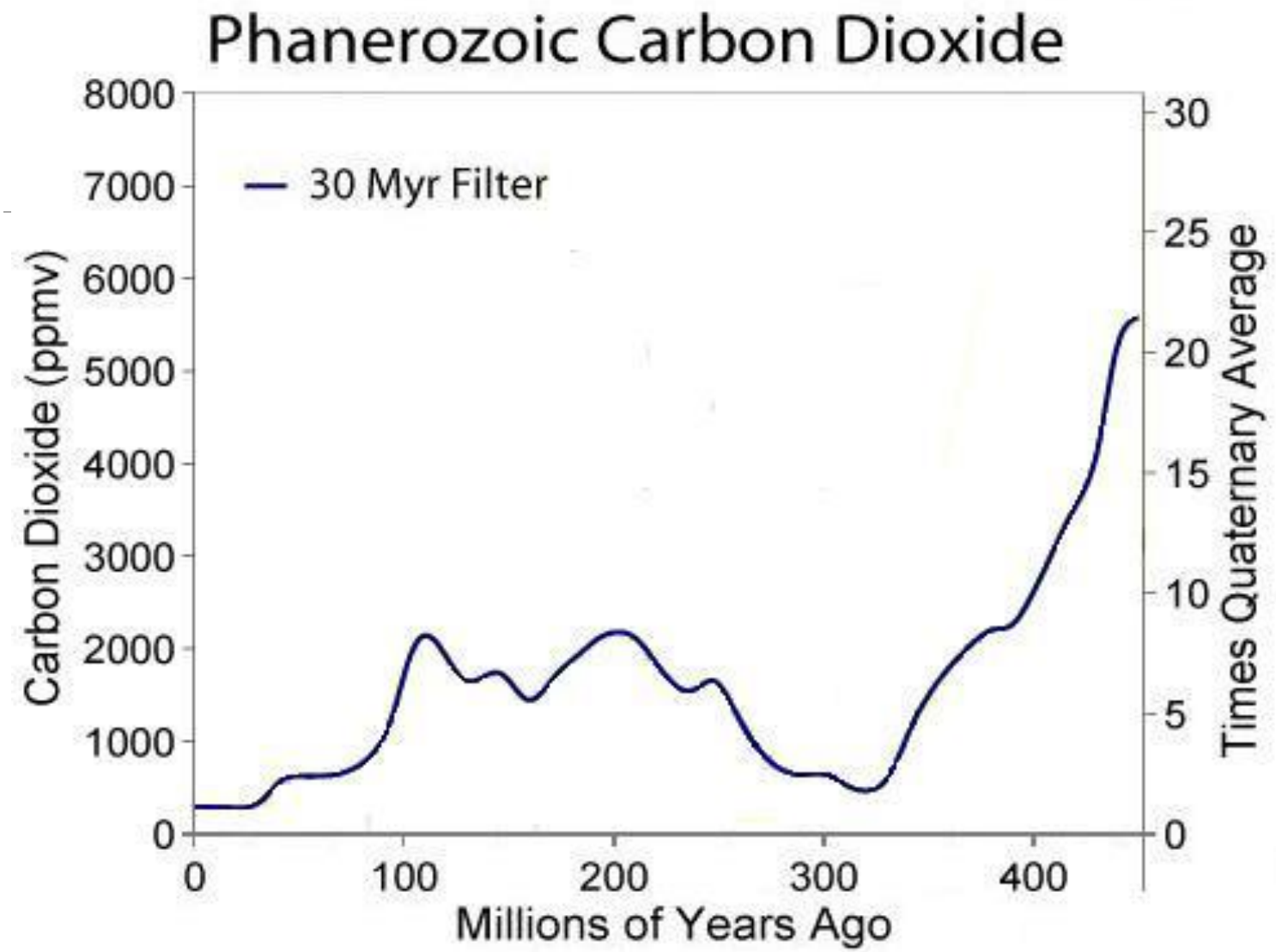


*After Royer (2006). Geochimica et Cosmochimica Acta **70** (23): 5665–75.*

Mineralisation of CO_2 in waste

Steel Wastewater Sludge

Quarry Fines

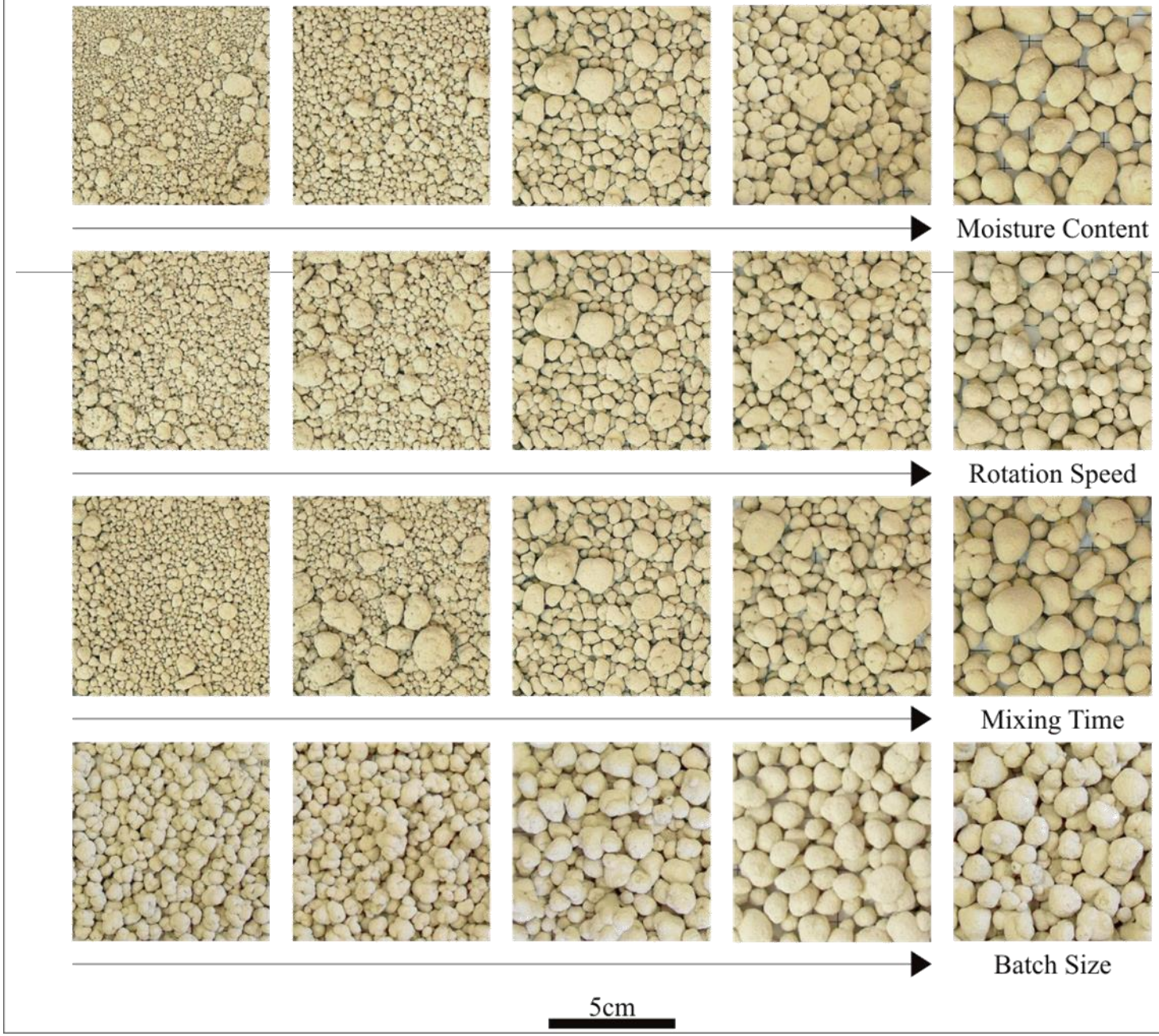
Bauxite

Paper Ash

Wood Ash

Metal Dust


5mm


Moisture Content
Rotation Speed
Mixing Time
Batch Size
5cm

Manufactured carbonated aggregates

- Approximately 250 Mtpa*of aggregates used in the UK (25 Gtpa world wide)
- Approximately 1 Gtpa of x7 CO_2 -reactive wastes are produced world wide
- Potential to mineralise x Mtpa of CO_2 in waste, whilst making useful products
- Market forces rule and so disposal will be the only option in some territories
- C8 has achieved 'end of waste' designation for aggregate use in construction blocks
- The aggregate meets European standards for light-weight aggregate and is 'fit for purpose'

- CO_2 can be used to stabilise/enhance soil geotechnical properties via carbonate ppt.

http://www.mineralproducts.org/documents/mpa_facts_at_a_glance_2014.pdf

Summary

- The mineralisation of CO_2 in products analogous to natural materials is a reality
- Carbonated aggregates are ‘fit for purpose’ and meet BS EN standards
- It is likely that ca >0.5 Mtpa aggregates manufactured in the UK by 2019
- New applications for carbonation are possible, including to high value materials

Key to extending the technology are:

- a level regulatory environment
- a price for the carbon mineralised, and
- lower cost methods to capture CO_2

Resources

Carbon8 Video

Samples of aggregate

Production concrete with carbonated aggregate

The world ‘famous’ bottle experiment