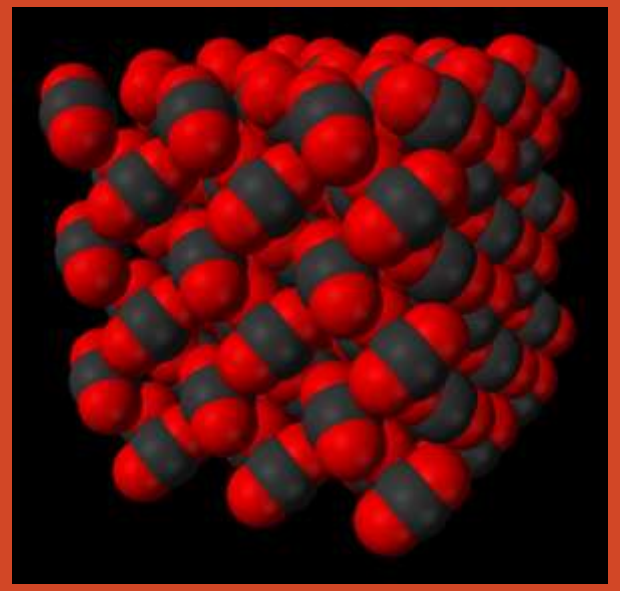
Carbon Dioxide: Myths and Magic?

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

The University Of Sheffield.

Summary

1. What is CDU/CCU?
2. Setting the Boundaries
3. The Functional Unit
4. Global Capacity
5. Conclusions: Separating Myth and Magic

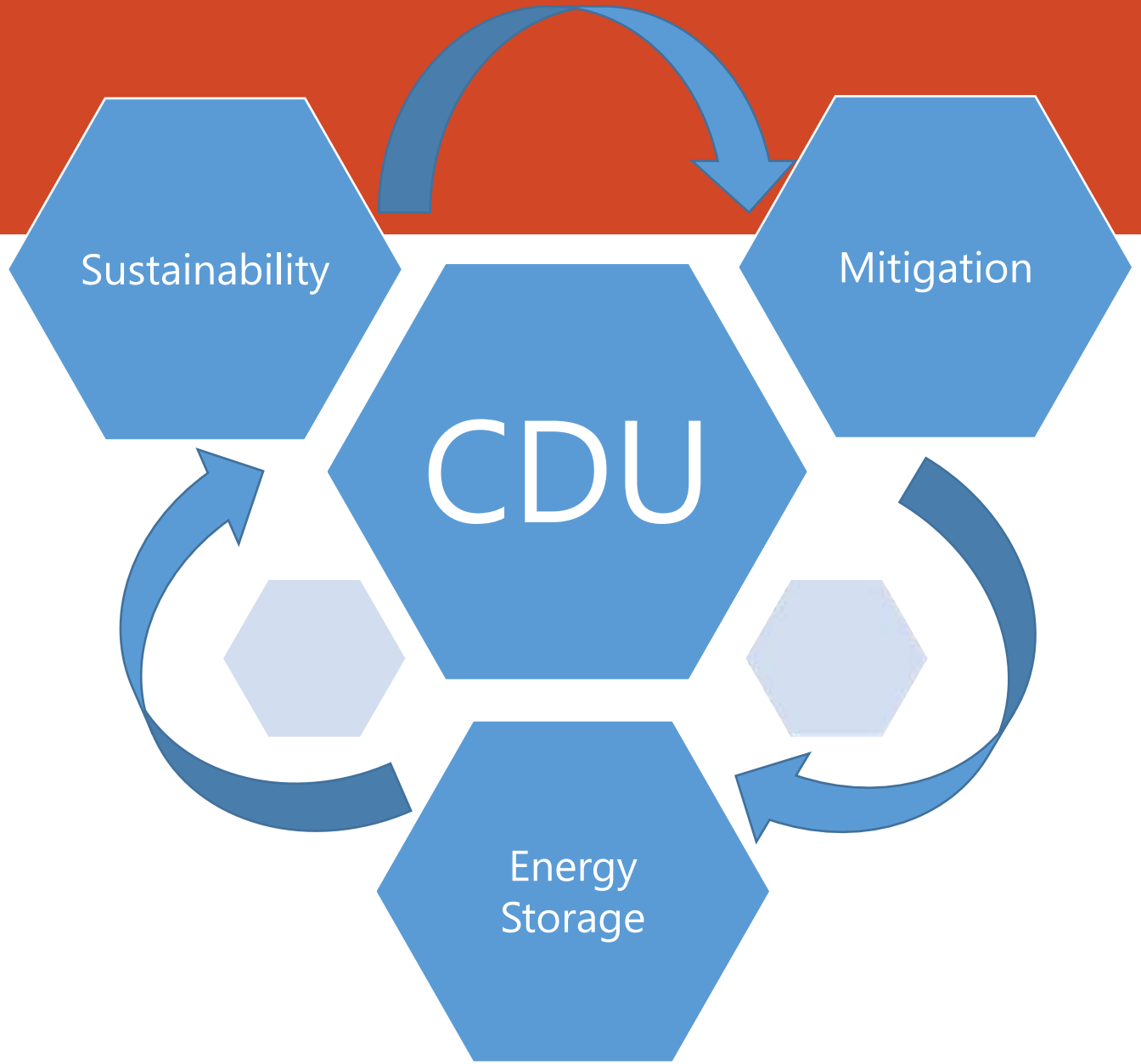
The CO_2 Trilemma

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)



What is CDU/CCU? Setting the boundaries

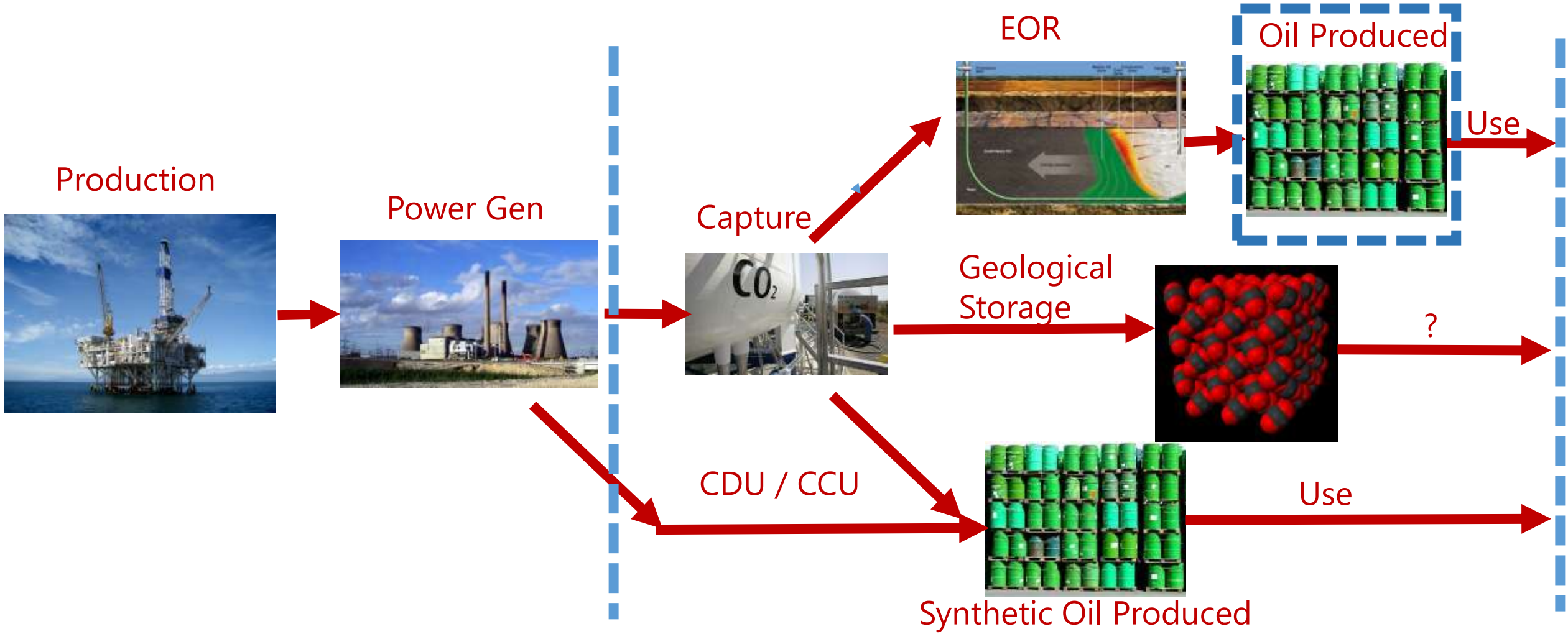
- **Carbon Dioxide Utilisation**: No separate capture step required
- **Carbon Capture & Utilisation**: Concentration and purification of CO_2 is required before reaction
- **Bonds** are broken and made: CO_2 goes in to a process, something else emerges
- Likely to provide a **net** CO_2 emissions reduction potential: carbon sequestration and avoidance
- There is an attractive **financial return** over the process
- The following are **not CDU/CCU**: CCS, EHR/EOR, technical use (e.g. decafination, solvent, *etc.* where there is no chemical change)

Styring's modification of Nyholm's Law

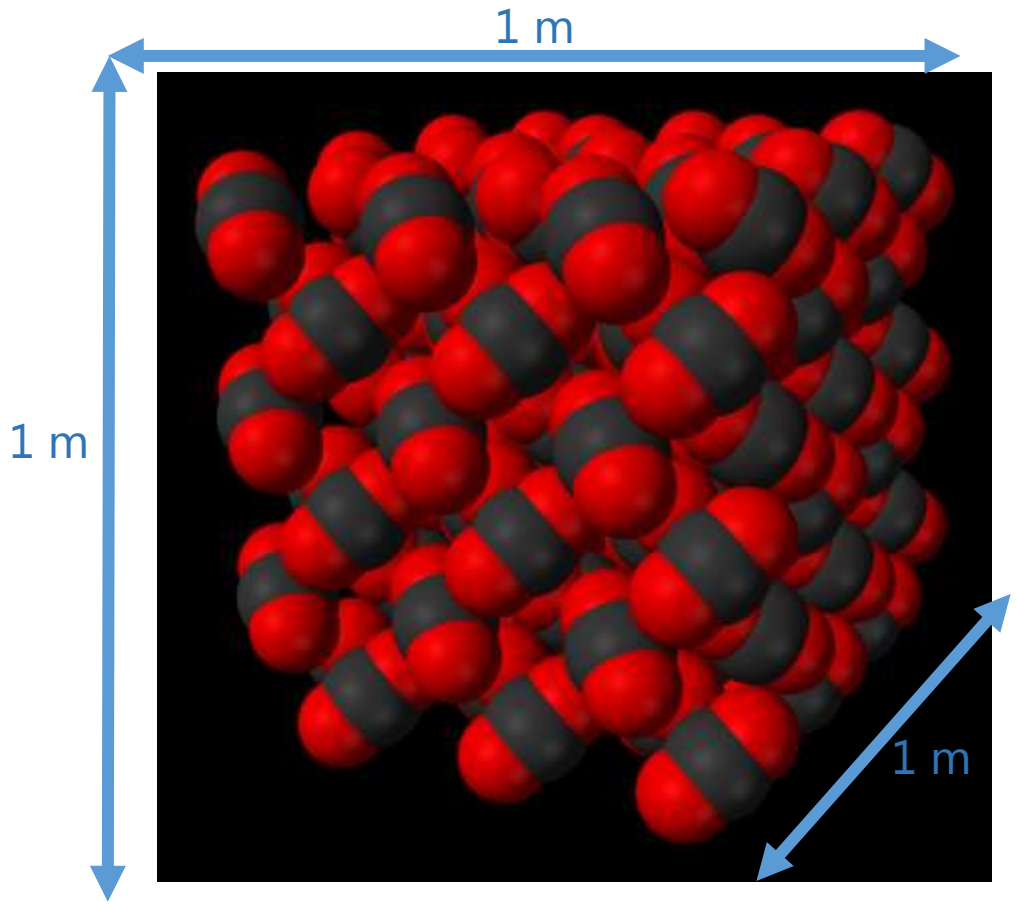
$$\frac{\text{Data}}{\text{Model}} = \frac{\text{Fact}}{\text{Fiction}}$$

MYTH - CO2 is unreactive…….

Boundaries


EOR
Oil Produced
Use
Production
Power Gen
Capture
CO_2
Geological Storage
?
CDU / CCU
Use
Synthetic Oil Produced

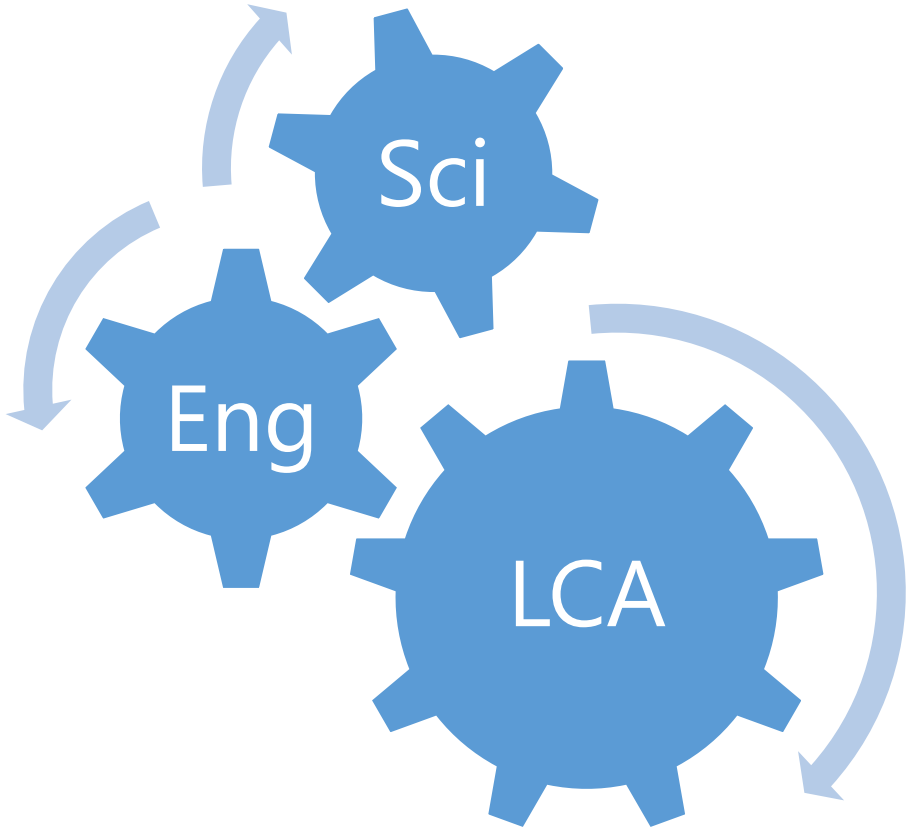
MYTH: CO_2 to Fuels will just cause more emissions
Functional Units are important

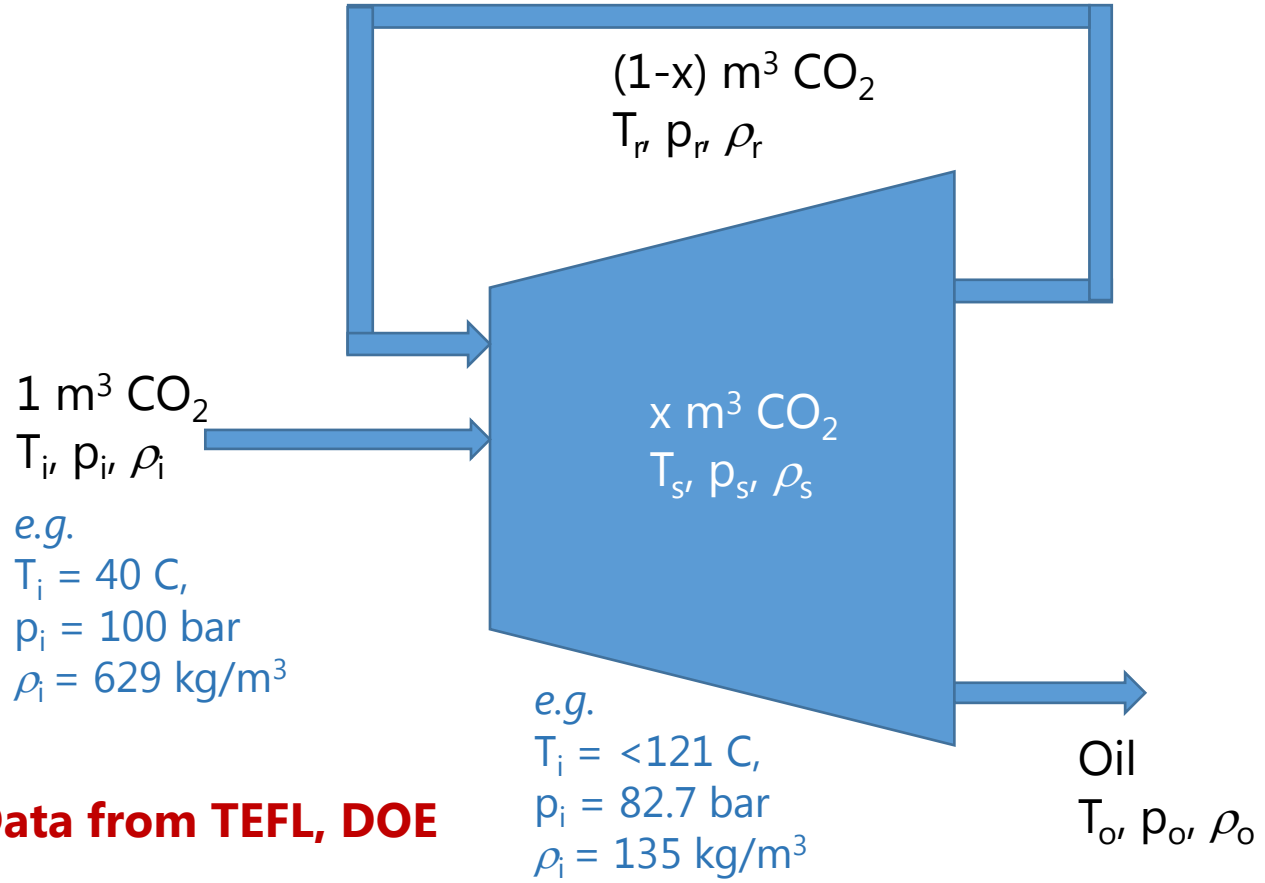


Armstrong & Styring, *Frontiers in Energy Research*, 2015, **3**, 8

- **CCS** sequesters 1 m^3 $scCO_2$ (469 kg)
  Net emissions - 469 kg CO_2
- **EOR (immiscible)** sequesters 1 m^3 $scCO_2$ (469 kg) and produces 1 m^3 (900 kg) crude oil.
  Product combustion emissions 3,051 kg CO_2
  Net emissions +2,582 kg CO_2
- **EOR (miscible)** sequesters 0.5 m^3 $scCO_2$ (234.5 kg) and produces 0.5 m^3 (450 kg) crude oil.
  Product combustion emissions 1,526 kg CO_2
  Net emissions +1,526 kg CO_2
- **CDU** sequesters 1 m^3 $scCO_2$ (469 kg) and produces 139 kg of synthetic oil.
  Product combustion emissions 469 kg CO_2
  Net emissions 0 kg CO_2

MAGIC: Can only work with knowledge of whole system





Data from TEFL, DOE

MYTH

CDU will never be able to operate at a capacity large enough to deal with CO_2 emissions

Global CCS Capacity

www.globalccsinstitute.com/projects/large-scale-ccs-projects

- **22** global projects in Operation (13) or Execute (9) phases in 2014.
- Total **42 Mt/yr** (up to 2016)
- Total to 2020 is **102 Mt/yr**
- DECC Scenario for UK by 2030 is **13 GWe/yr** or in terms of CO_2 **95 Mt/yr**

Type of plant	Number of projects	Type of capture	Storage method	Total CO2 Mt/annum	
Chemical Production	5	2 Industrial Separation 3 Pre-combustion	3 EOR	4.96	8-9
			2 Geological	3-4	
Coal to liquids	3	Pre-combustion	1 EOR	2.5	5.5
			1 Geological	1	
			1 Unspecified	2	
Fertiliser	4	Industrial Separation	3 EOR	2-2.6	4.5-5.1
			1 Geological	2.5	
H_2 Production	2	Industrial Separation	1 EOR	1	2
			1 Geological	1	
Iron and Steel	1	Industrial Separation	EOR		0.8
Natural gas processing	13	Pre-combustion	8 EOR	22.4	29.6-30.1
			5 Geological Storage	7.2 - 7.7	
Oil Refining	1	Pre-combustion	EOR		1.2
Power Generation	23	9 Post-combustion 10 Pre-combustion 4 Oxy	10 EOR	17.7	41.2
			11 Geological	19	
			2 unknown	4.5	
Synthetic Natural Gas	2	2 Pre-combustion	2 EOR		8.5
Unknown	1	Unknown	Geological		1
TOTAL	**55**				**102.3**

Current CDU Processes

Current CCS 27 Mt/yr
Current CDU 180 Mt/yr

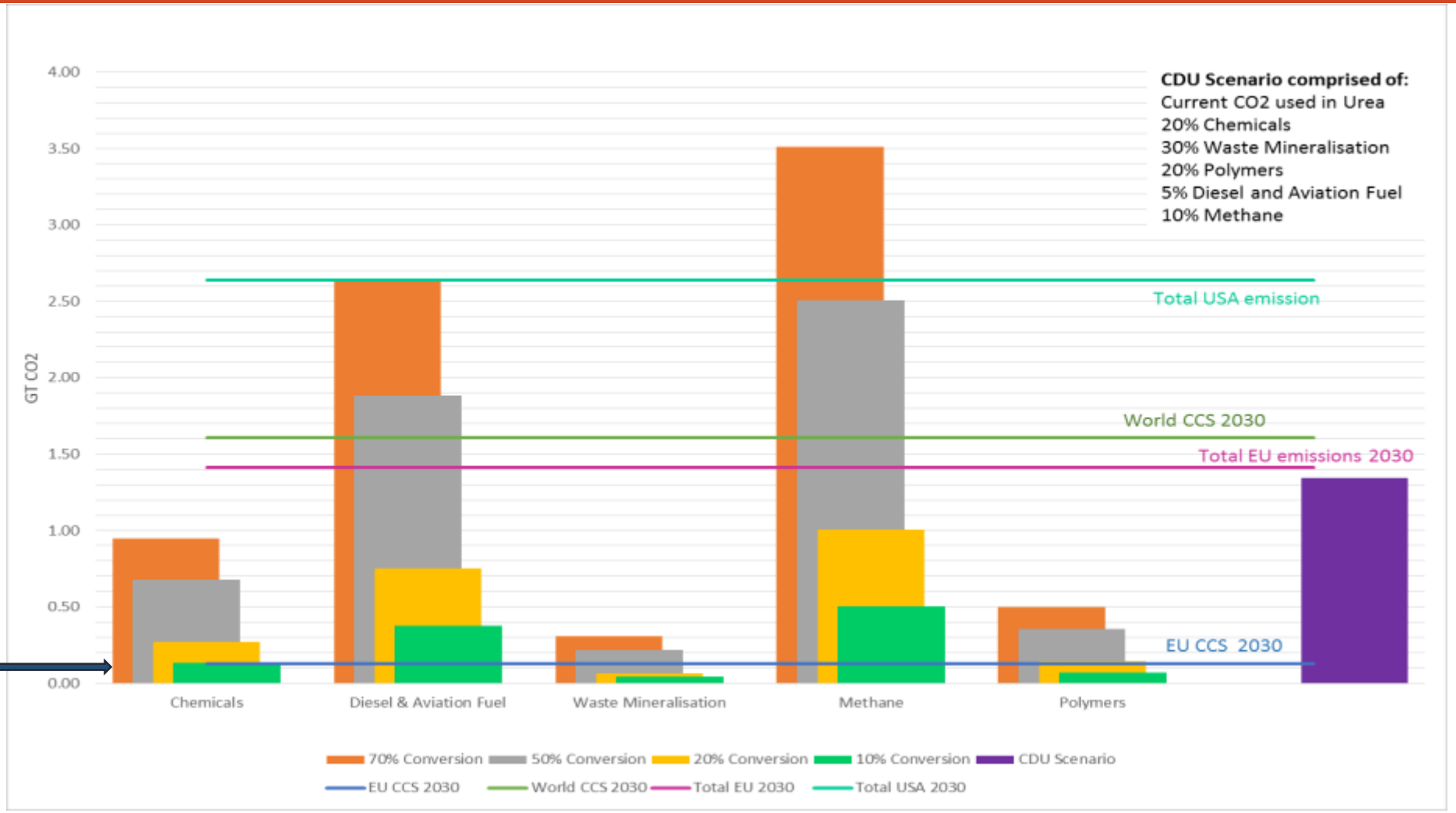
2016 CCS 56 Mt/yr
2016 CDU 256 Mt/yr

2020 CCS 102 Mt/yr

Compound	Actual production /Mt	CO_2 used/Mt	2016 Forecast/Mt	CO_2 needed/Mt
Urea	155	114	180	132
Methanol	50	8	60	10
DME	11.4	3	>20	>5
TMBE	30	1.5	40	3
Formaldehyde	21	3.5	25	5
Polycarbonates	4	0.01	5	1
Carbamates	5.3	0	>6	1
Polyurethanes	>8	0	10	0.5
Acrylates	2.5	0	3.0	1.5
Inorganic carbonates	200	ca.50	250	70
TOTAL		**180**	Aresta, *et al.* 2013	**256**

Carbon Dioxide Utilisation Potential

Armstrong & Styring, Frontiers in Energy Research, 2015, **3**, 8



Global CCS Capacity 2020

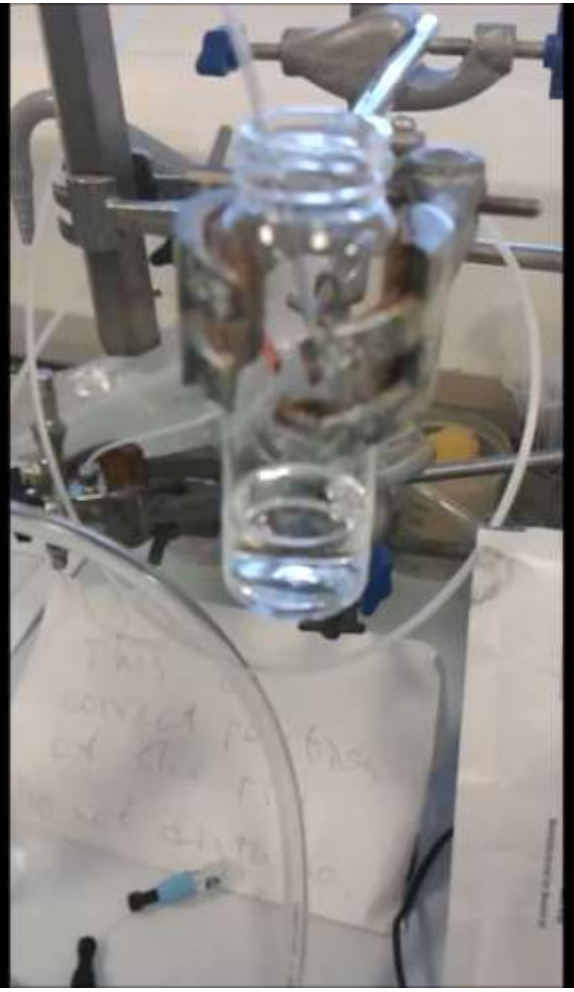
MYTH

- We should concentrate **only** on CCS as CDU/CCU as it can never match the capacity of CCS in dealing with global emissions
- Current global emissions are *ca.* 40 Gt/yr
- Current CCS capacity is *ca.* 27 Mt/yr (6.75×10^{-5} %)
- Current CDU capacity is *ca.* 180 Mt/yr (4.5×10^{-4} %) almost x7 more

In reality we need to be both

MAGIC

- Energy
- Process
- Hydrogen
- Reagents



- Profit
- Public Acceptance
- Scale
- The Carbon Cycle
- Direct Air Capture

Conclusions

- CDU / CCU has many associated myths: we need to be able to see through these
- LCA data are only as valid as the input data
- Many LCA studies are based on secondary data
- Studies need to be carried out with knowledge of scientific and engineering principles
- Conclusions must be made that are evidence based, even if it is through the collation of secondary data
- More real-life valedictory studies need to be carried out

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