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Managing the Energy Transition towards 2050: Carbon Capture and Storage… Challenges and Opportunities







Geoff Maitland FREng FIChemE

Imperial College London

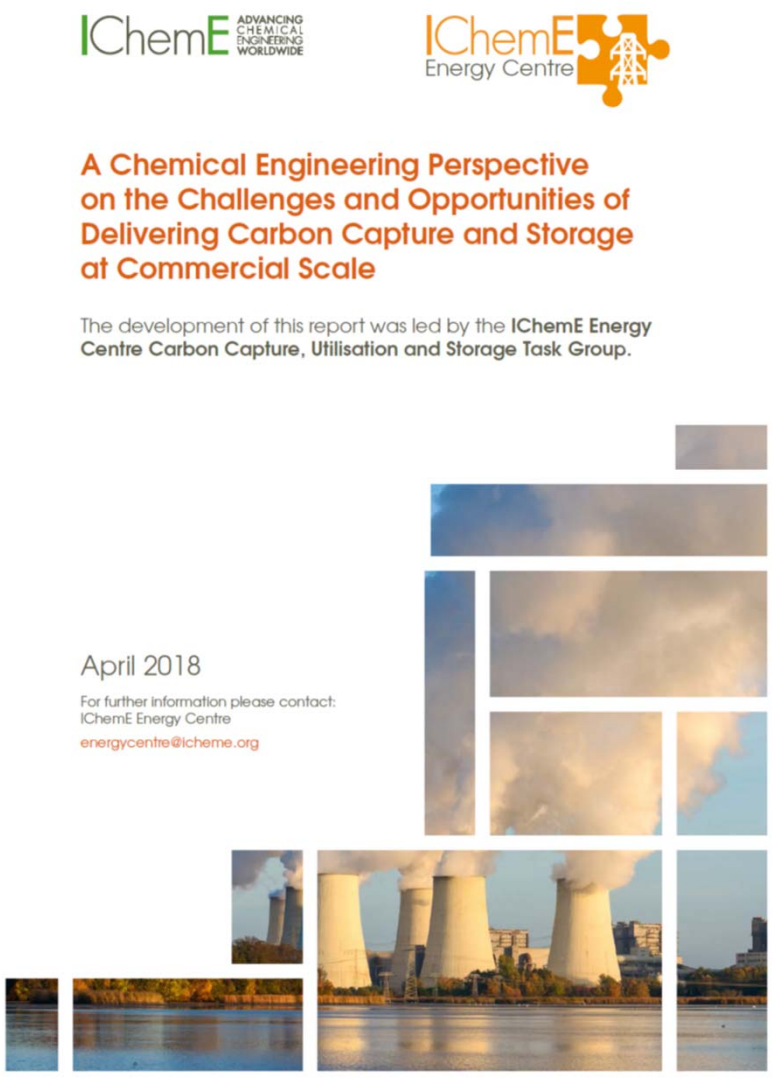
Past President IChemE

Founding Director, Qatar Carbonates and Carbon Storage Research Centre

CCS Green Paper

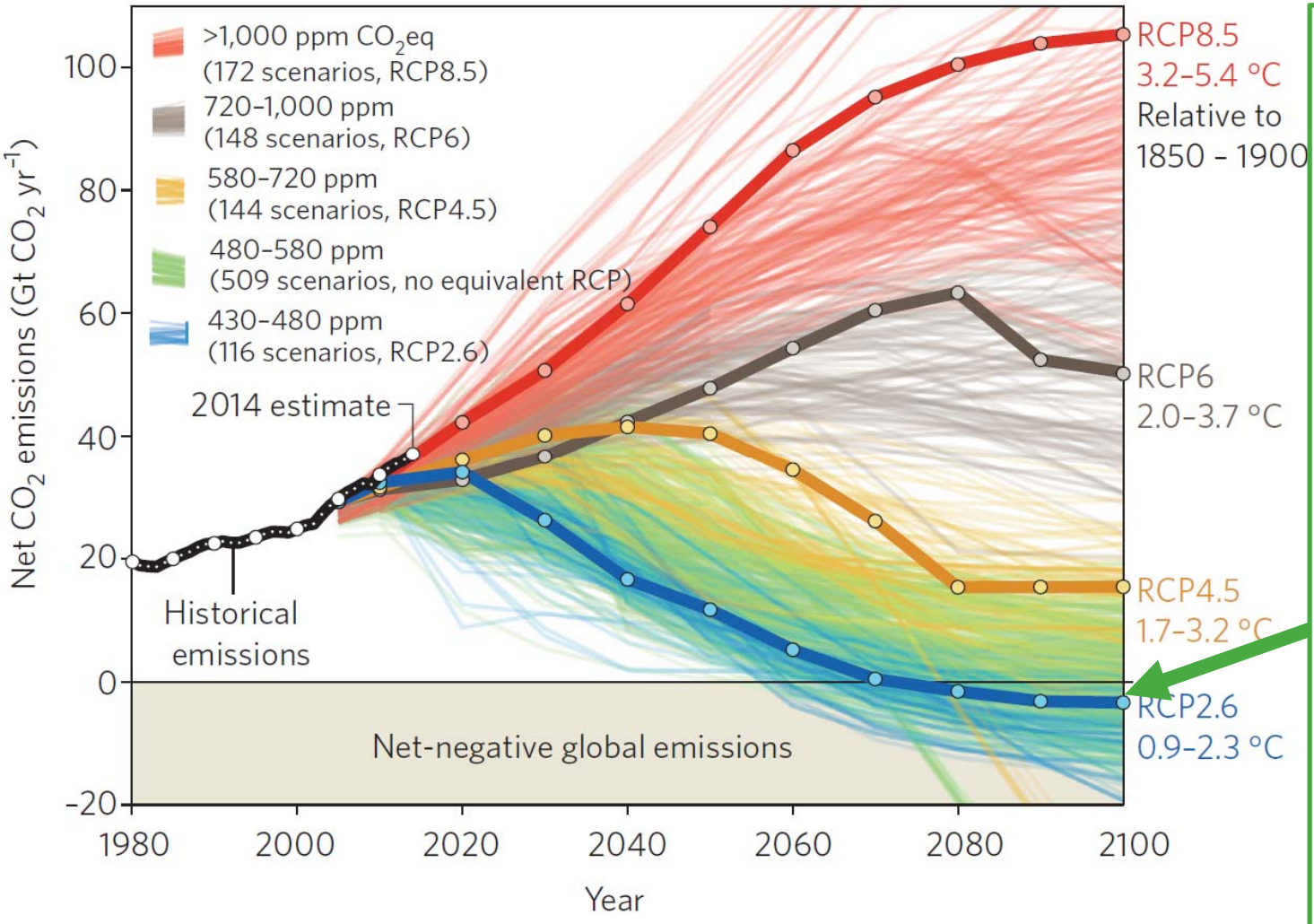
Launched 11th April 2018

27 Task Force Members from:
Australia
India
South Africa
UK
USA



The Task Force was strongly supported by Jacob Ohrvik-Stott, Policy Officer, and Alana Collis, Manager, IChemE Energy Centre.

Meeting the 2°C IPCC & 1.5°C COP21 targets



- Mitigation costs 138% more without CCS
- Without CCS, <50% of IAM models solve the problem
- Most feasible solutions use BioEnergy + CCS (BECCS) - a key negative emissions technology
- CCUS needs to remove ~20% of target CO_2 – 800Gt total or 10Gt pa by 2050

CCS = Carbon capture & storage
IAM = integrated assessment models

IPCC Fifth Assessment Synthesis Report November 2014, Fuss, S., et al. (2014). Nature Climate Change, 4(10), 850–853

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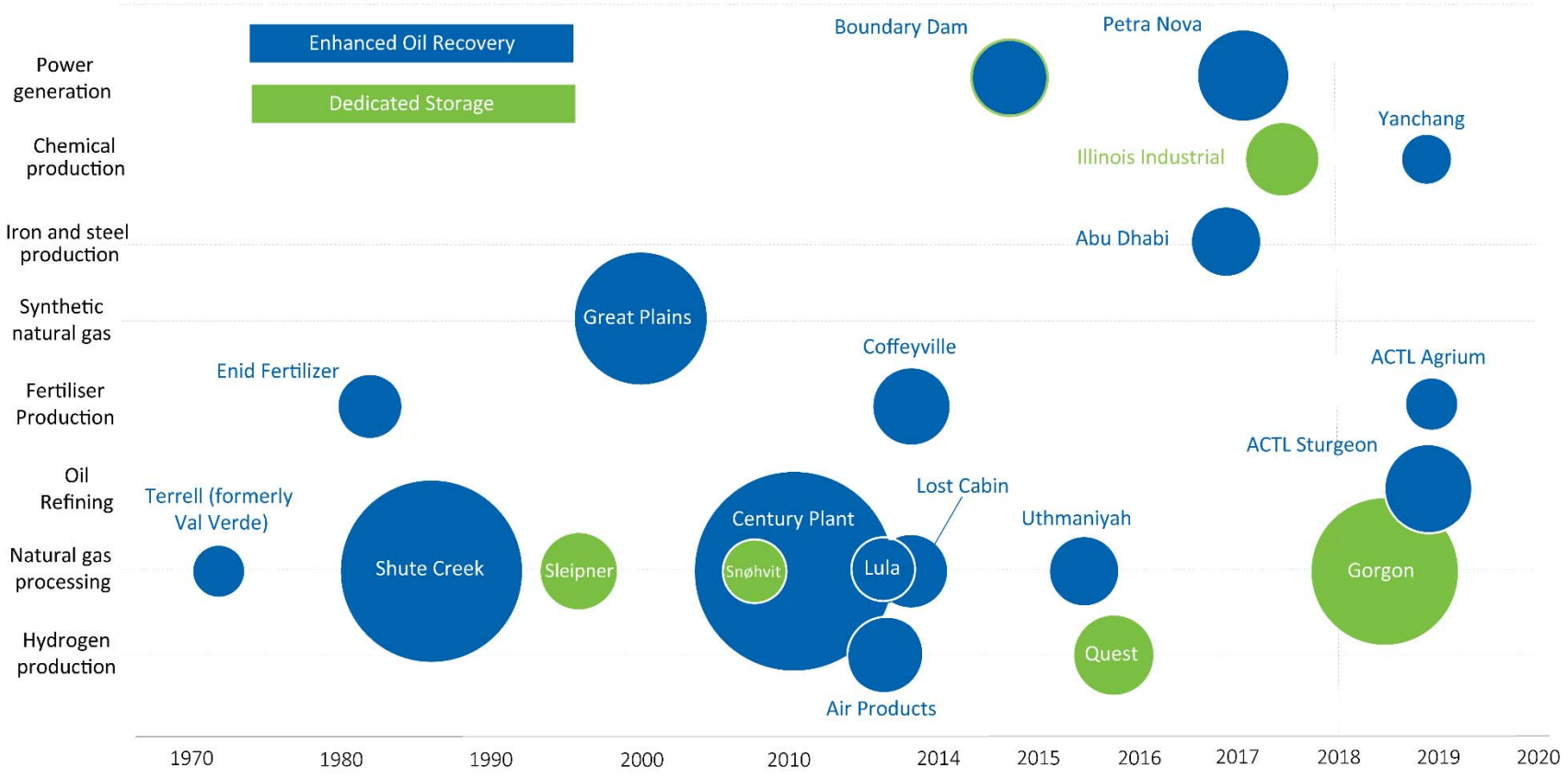
Large-scale CCS Projects



Actual and planned start dates for large-scale CCS facilities in operation or under construction

= 1Mtpa of CO_2 (area of circles proportional to capacity)

Diagram courtesy of Global CCS Institute

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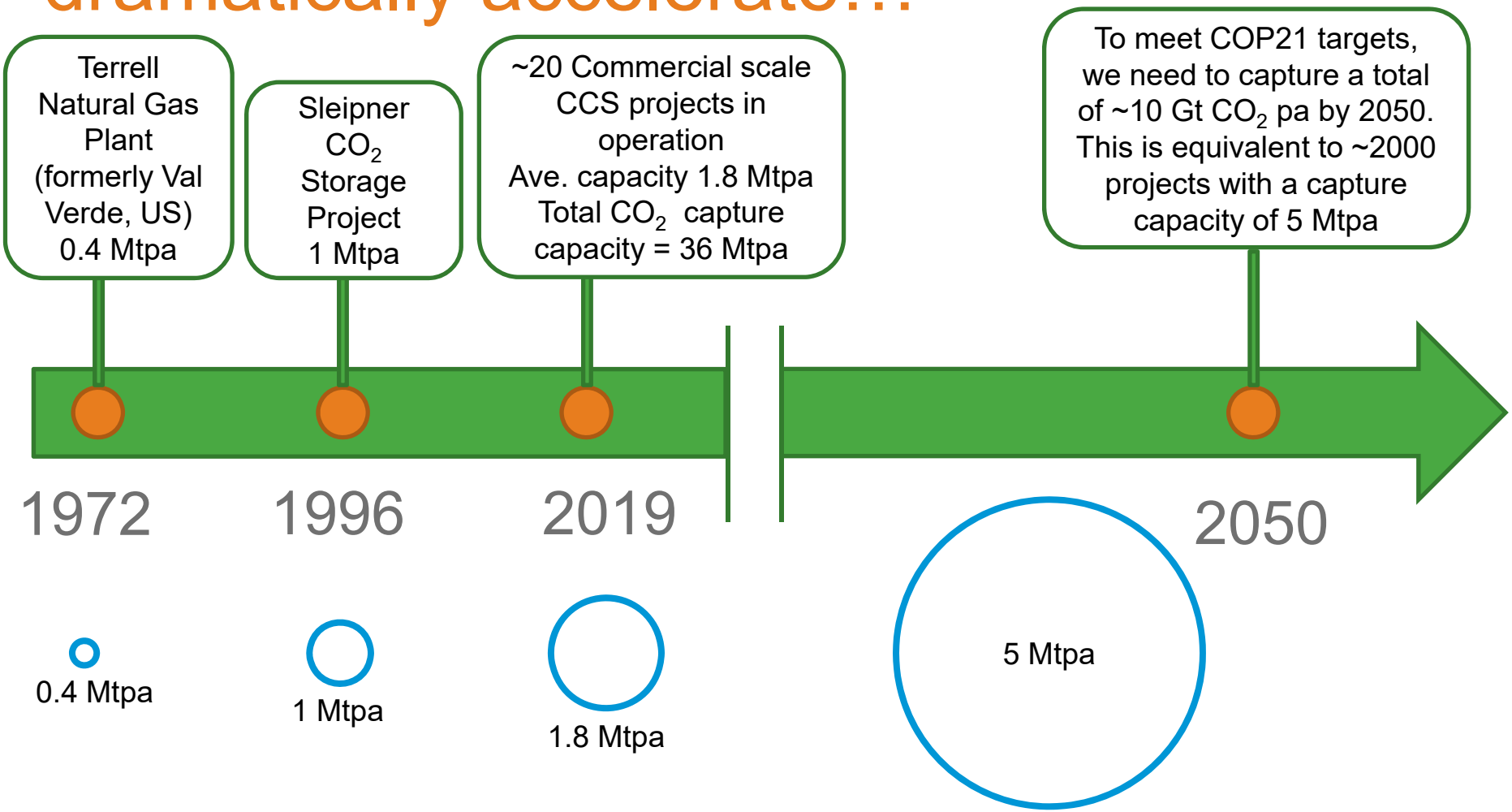
Large-scale CCS growth needs to dramatically accelerate…



GCSSI database http://www.globalccsinstitute.com/projects
Committee on Climate Change (2016). UK climate action following the Paris Agreement. London, UK.

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Making CCS a commercial reality

- The barriers are not technical.
- We need a combination of the following:
  1) Provide a monetisation route (e.g. EOR, CO_2 pricing);
  2) Target other sectors as well as Power
     - Industrial Processes, Hydrogen Production
  3) Multi-plant large-scale deployment
     - taking advantage of economies of scale
     - cost reduction and efficiency improvements through learnings – and 1st to nth plant improvements.
  4) A systems engineering approach to CCS
  5) Supportive policy framework
  6) New business models for sharing risk

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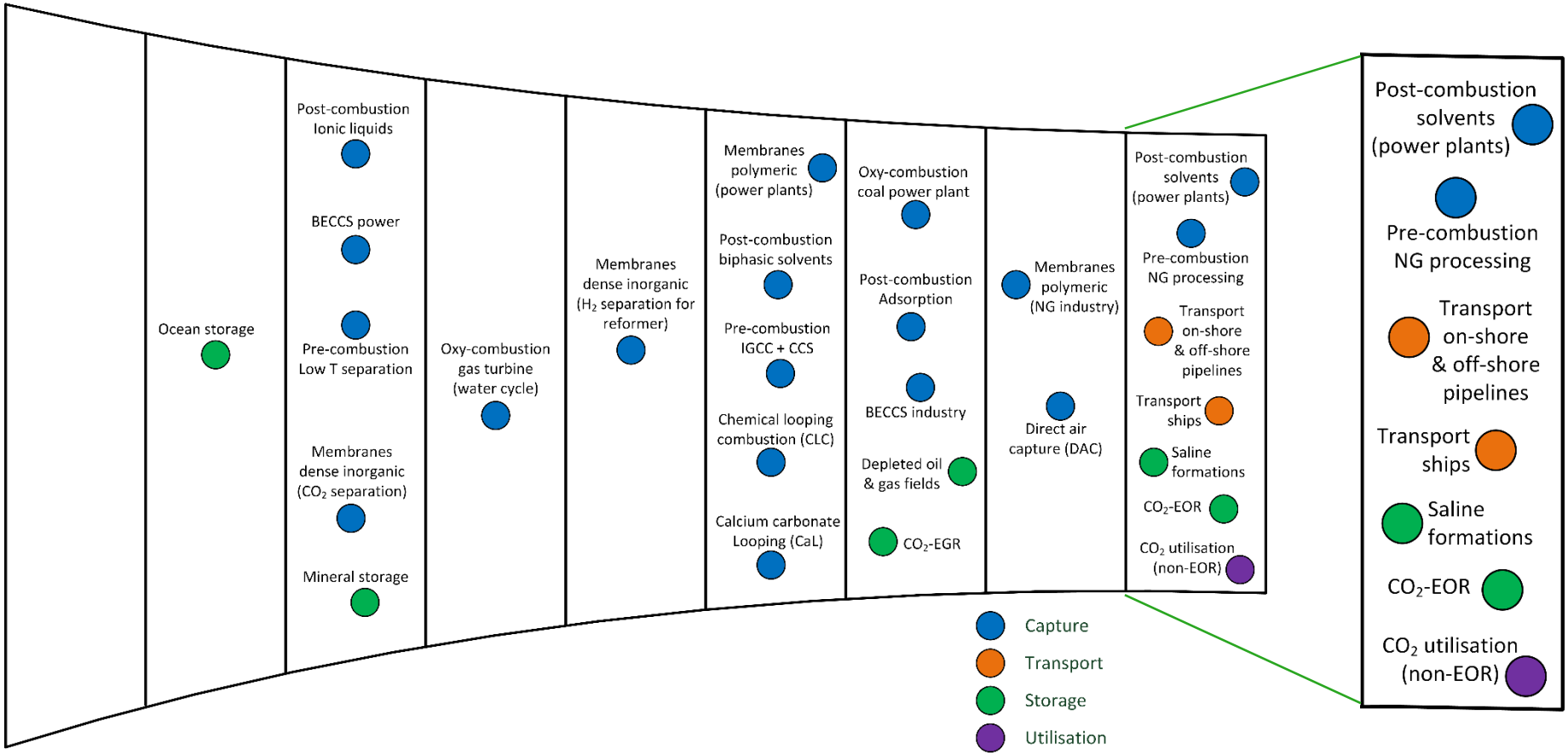
CCS technologies are mature and deployable

Concept	Formulation	Proof of concept (lab tests)	Lab prototype	Lab-scale plant	Pilot plant	Demonstration	Commercial Refinement required	Commercial
TRL1	TRL2	TRL3	TRL4	TRL5	TRL6	TRL7	TRL8	TRL9



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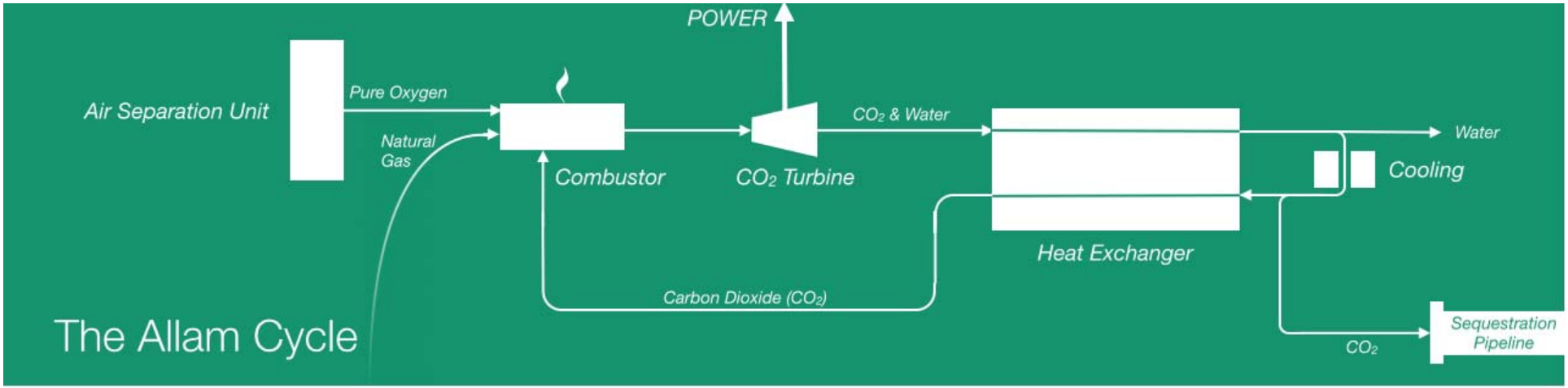
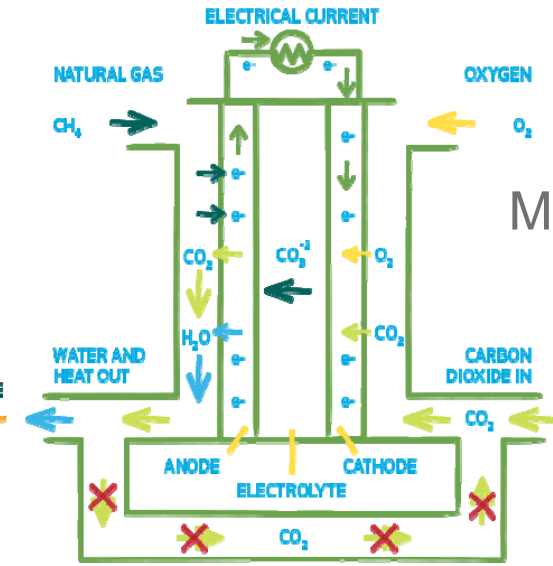
New technology is coming through…



NetPower



Molten Carbonate Fuel Cells
ExxonMobil - Cosia

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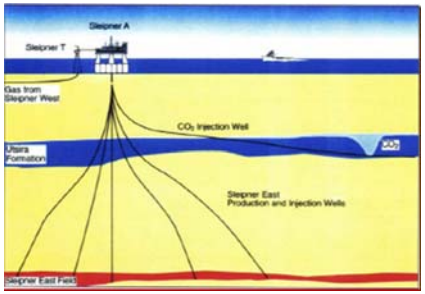
Routes to monetise stored CO_2

- CCS adds cost (so called ‘energy penalty’)
  - ~$50 per te CO_2 depending on source and technology used
- Costs can be recouped by monetising CO_2 by
  - Revenue generation through EOR or EGR (PetraNova)
  - A carbon price or other financial incentive
    - Carbon tax (Sleipner, Norway)
    - Carbon trading
    - Carbon tax credits, such as 45Q in US



- However, these are not currently available options in many countries/regions

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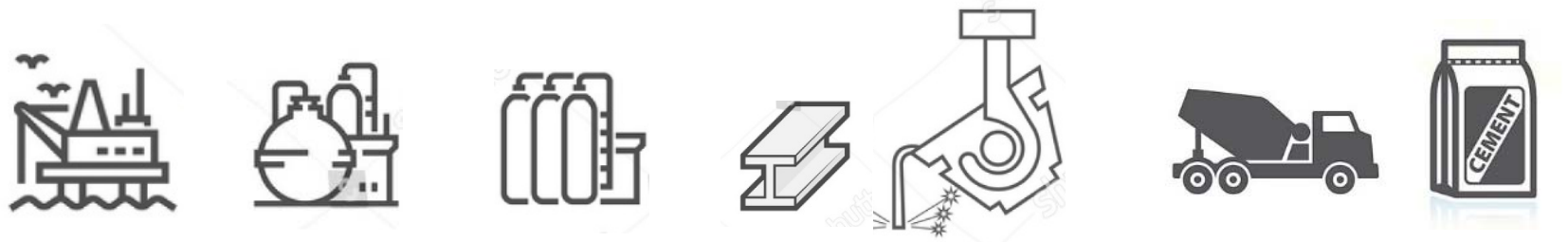
Mitigating direct industrial emissions

- Industrial emissions represent over 20% of the total anthropogenic CO_2 release globally.
- CCS is the most cost effective option for industrial decarbonisation and the only option where CO_2 is a by-product e.g. cement manufacture.
- CCS combined with process efficiency optimisation – for both existing and new build plants – should be a priority for industry…and for Chemical Engineers!

Recommendation: decarbonise this sector in UK by 2030.



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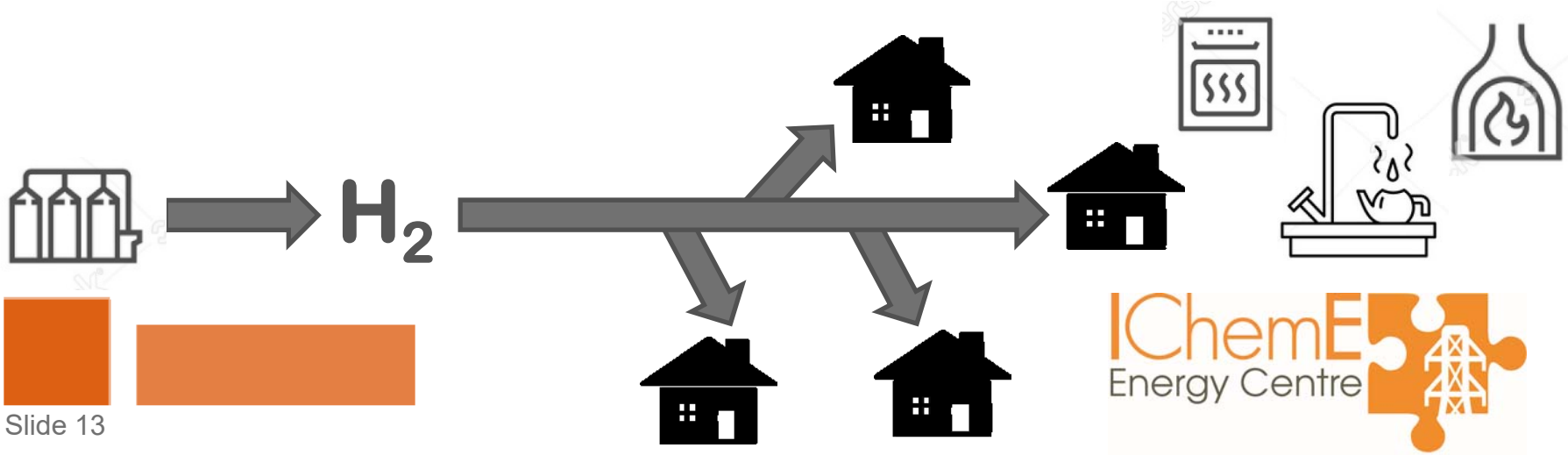
Decarbonising heating networks with CCS

- Hydrogen is now seen as a leading contender for the decarbonisation of heating.
- CCS is required for the removal of CO_2 during the production of hydrogen from fossil fuel, e.g. steam methane reforming (SMR) of natural gas, or syngas from oil and heavy hydrocarbons.
- This process could deliver low-carbon hydrogen at the volumes and cost required globally…also for decarbonised transport.
- UK examples: H21 Leeds City Gate Hydrogen Project; Cadent Liverpool-Manchester Hydrogen Cluster



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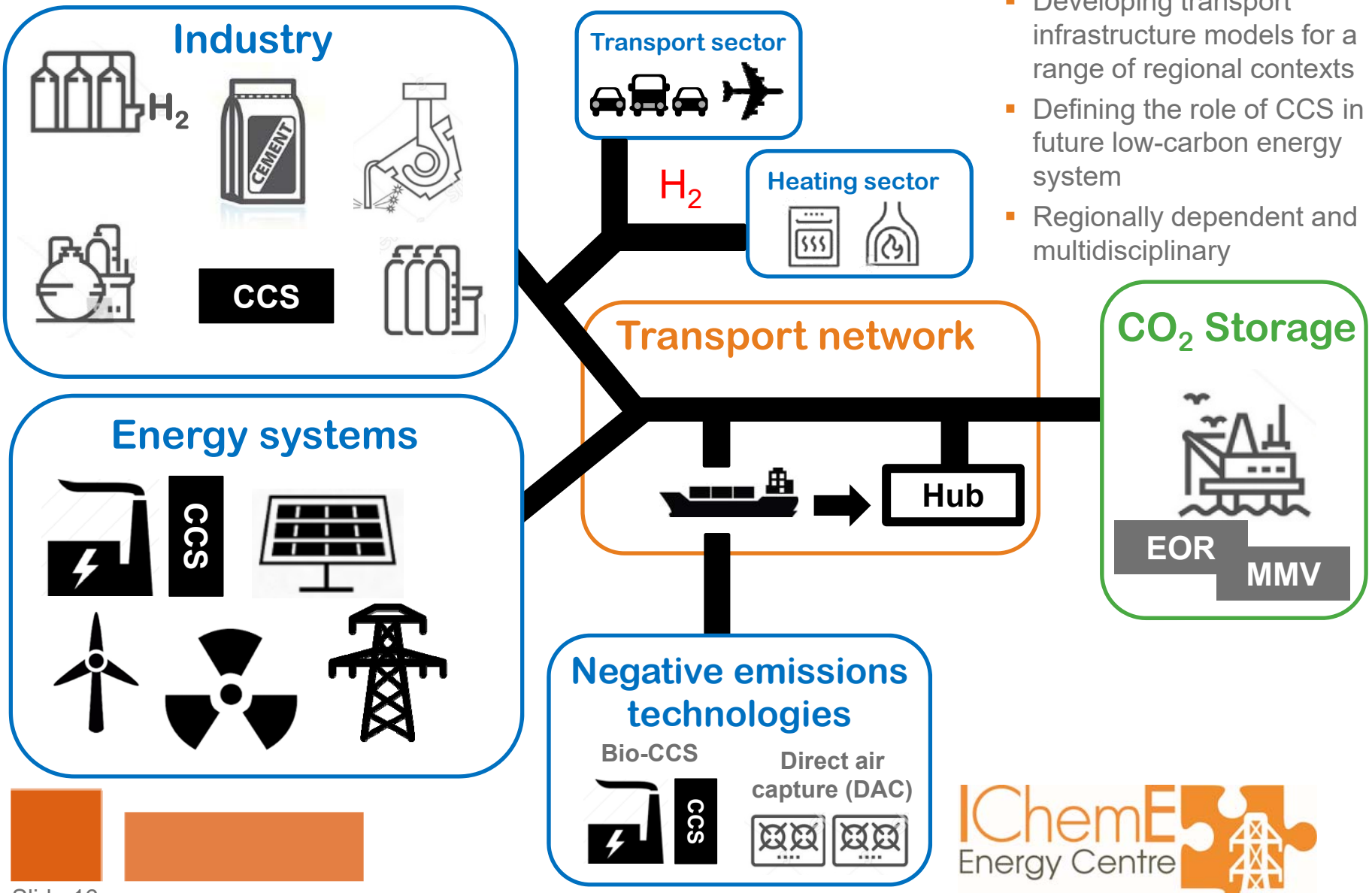
A systems approach to CCS

- Optimise costs and benefits across the full value chain
- Developing transport infrastructure models for a range of regional contexts
- Defining the role of CCS in future low-carbon energy system
- Regionally dependent and multidisciplinary



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A supportive policy environment

- Stable, enabling policy frameworks
  - Establish effective carbon pricing
    - Regional and international; minimise ‘carbon leakage’
    - Sector specific, as in Norway
  - Incentives and regulations that encourage investment in CCS
    - Contracts for Difference for Power; for (gas) Heating?
    - Industrial capture contracts
    - Tax credits for sequestration
    - International tradable permits

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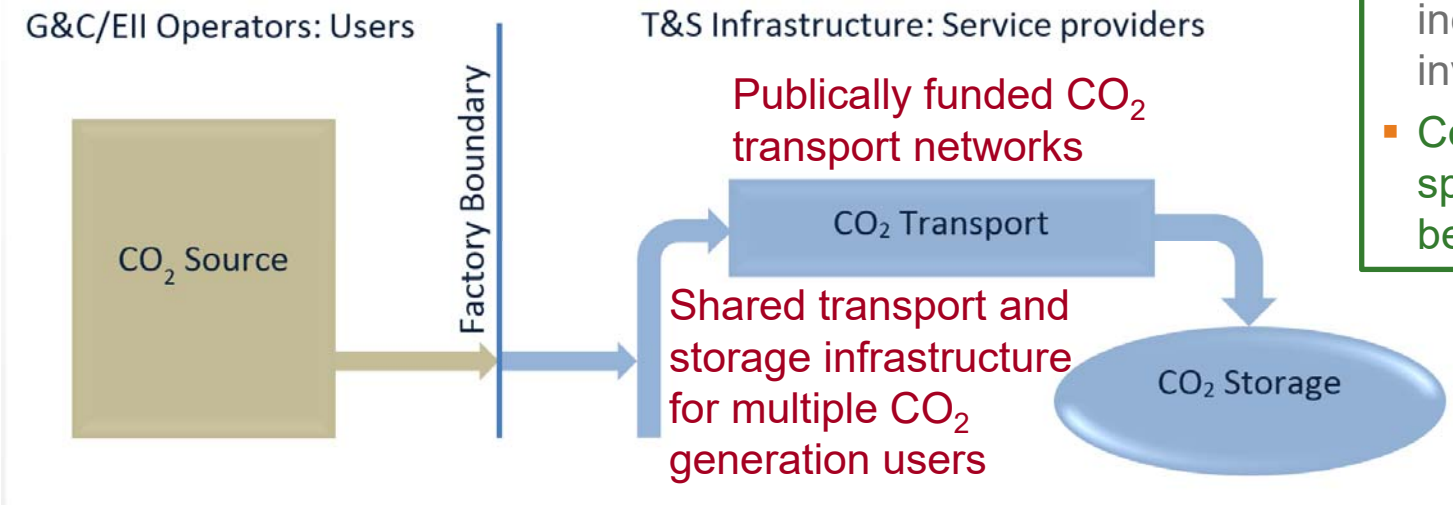
Fostering supportive market conditions – New Business Models

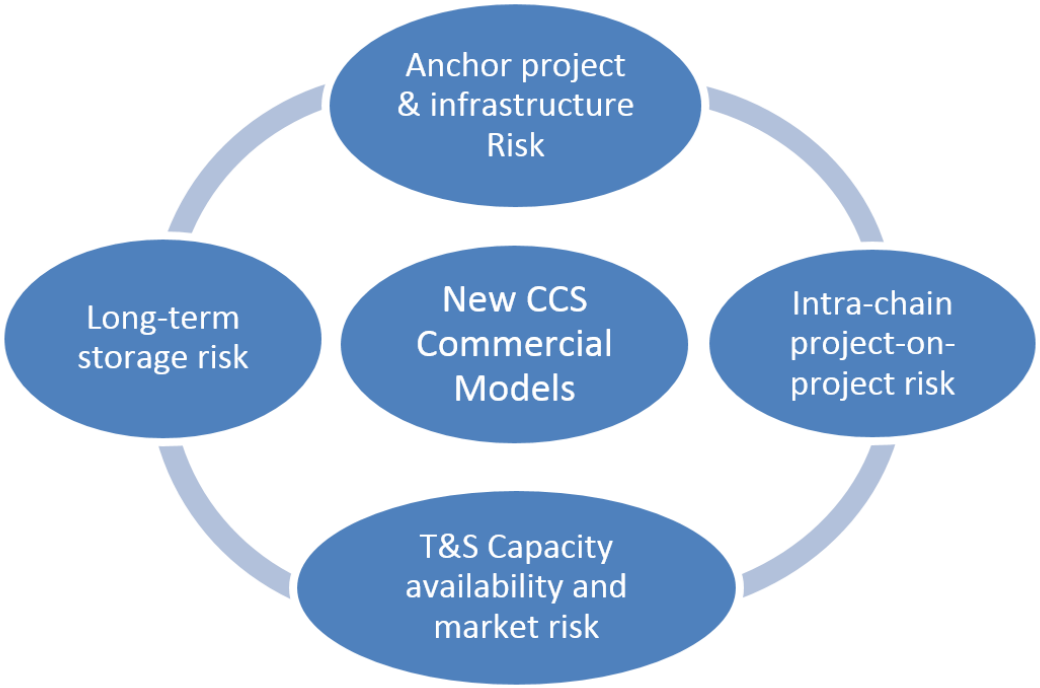
- Supportive policy frameworks that incentivise long-term investment
- Commercial models that spread risks equitably between stakeholders



Publically funded CO_2 transport networks

Shared transport and storage infrastructure for multiple CO_2 generation users

Governments taking on long-term storage risks and liabilities



Sharing risks and costs between public and private sector

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HM Government

An independent assessment of the UK's Clean Growth Strategy - From ambition to action Committee on Climate Change, January 2018

Committee on Climate Change

- **2008 UK Climate Change Act – Carbon Reduction Budgets**
- The Clean Growth Strategy - three illustrative pathways to 2050, one of which excludes carbon capture and storage (CCS).
- CCC: the Government should not plan to meet the 2050 target without CCS.
- A 'no CCS' pathway to even the existing 2050 target is highly challenging and likely to be much more costly to achieve.
- Furthermore, deeper reductions requiring the deployment of CCS will be needed to meet the aims of the Paris Agreement, whether by 2050 or subsequently.
- Although the Strategy states an ambition to deploy carbon capture use and storage (CCUS) in the 2030s, the level of detail and funding (which was directed at innovation only) are not commensurate with what will be needed.
- **The Government should set out plans in 2018 that kick-start a UK CCS industry in the 2020s.**

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CCUS Cost Challenge Taskforce report July 2018

Four key messages for UK Government:

1. Need to recognise the CCUS opportunity and the **urgency of acting now** in order to deliver CCUS at scale, at lowest cost.
   - **Project lead times are long**, and time is limited if we are to deliver CCUS on the required scale by 2050, (>100 million te CO_2 pa)
   - **Can be achieved with joint industry and Government vision and partnerships**
     - First projects becoming operational from the mid-2020s and an industry pipeline of financeable projects.
2. **CCUS can unlock value** across the economy to enable low carbon industrial products, decarbonised electricity and gas, a hydrogen economy, greenhouse gas removal, and new industries based around utilising CO_2.
3. **Need viable business models** to move the technology to a sustainable commercial footing.
4. **CCUS can already be deployed at a competitive cost**.
   - Project concepts being proposed are **comparable in cost with other first of a kind** low carbon technologies.
   - **Focus on deploying CCUS in clusters**, with the cluster stakeholders identifying how the value of CCUS can best be secured to benefit their local economies and needs.

https://www.gov.uk/government/groups/ccus-cost-challenge-taskforce

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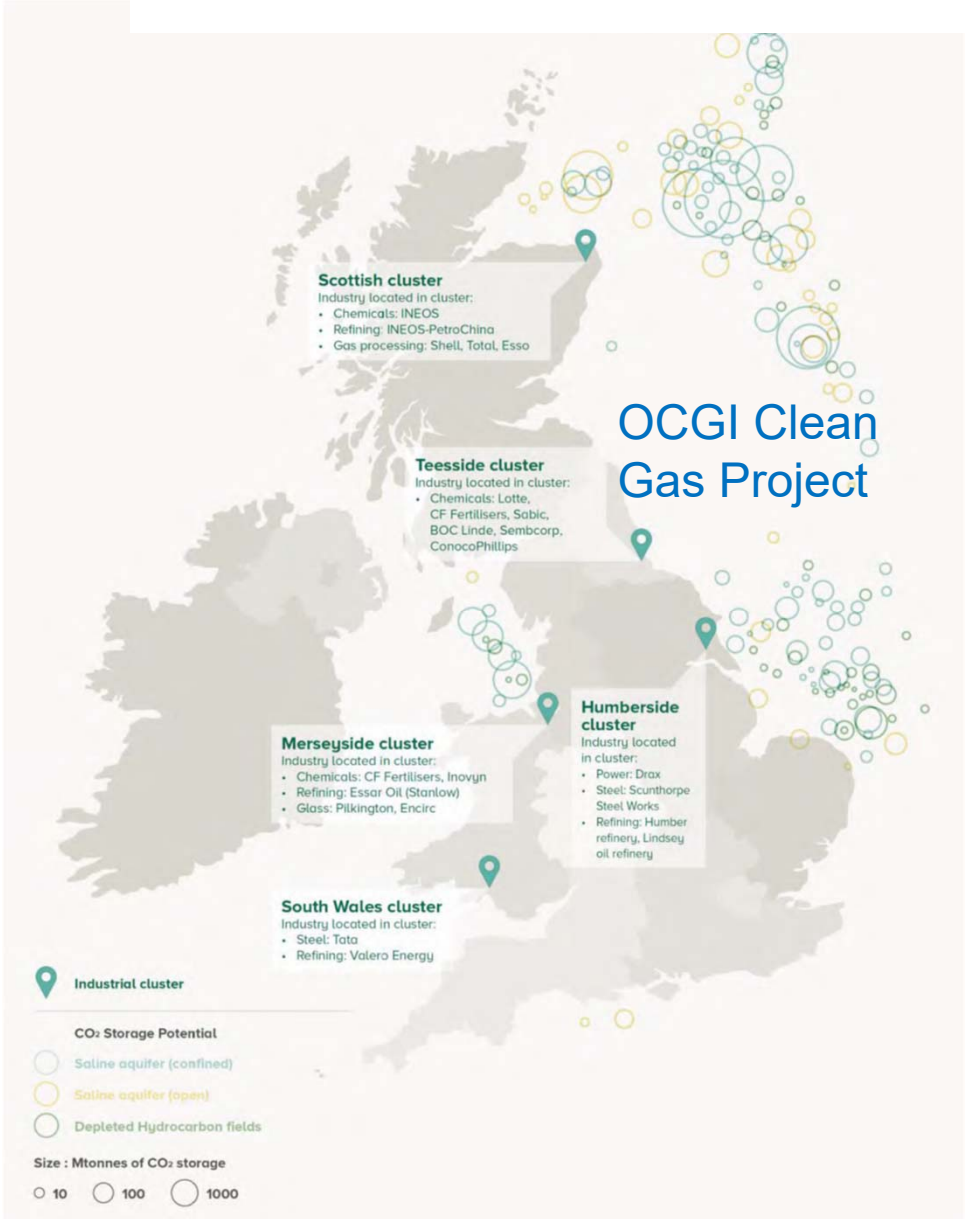
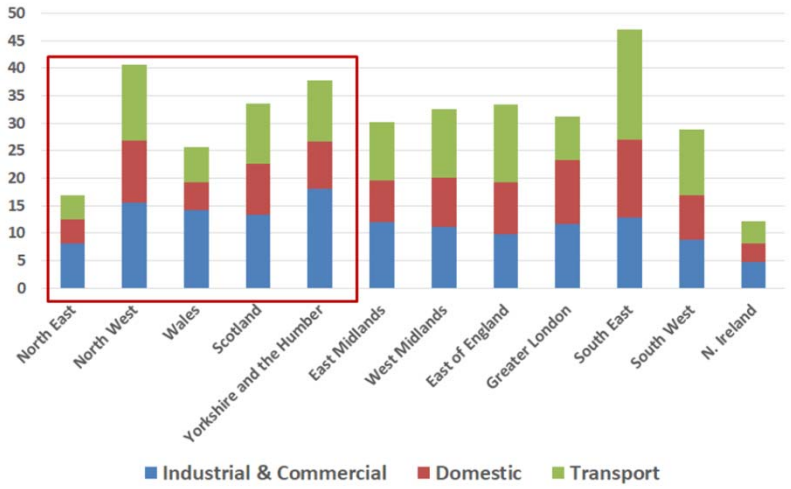
Regions and Clusters



OCGI Clean Gas Project

https://www.gov.uk/government/groups/ccus-cost-challenge-taskforce

Mt CO_2 pa



https://www.gov.uk/government/statistics/uk-local-authority-and-regional-carbon-dioxide-emissions-national-statistics-2005-2016

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UK Government funding to deliver on CCUS announced at COP 24 Katowice, December 2018

- Claire Perry, Minister of State for Energy and Clean Growth, announced £170M funding for an Industrial Clusters mission under the Industrial Strategy with the objective '…establish the world's first net-zero carbon industrial cluster by 2040 and at least one low-carbon cluster by 2030'.
- Critically for CCUS, 'in at least one cluster, by 2030, the low-carbon infrastructure needed to support industrial decarbonisation will be in place and operational.'

https://www.gov.uk/government/news/world-first-carbon-net-zero-hub-of-heavy-industry-to-help-uk-seize-global-economic-opportunities-of-clean-growth

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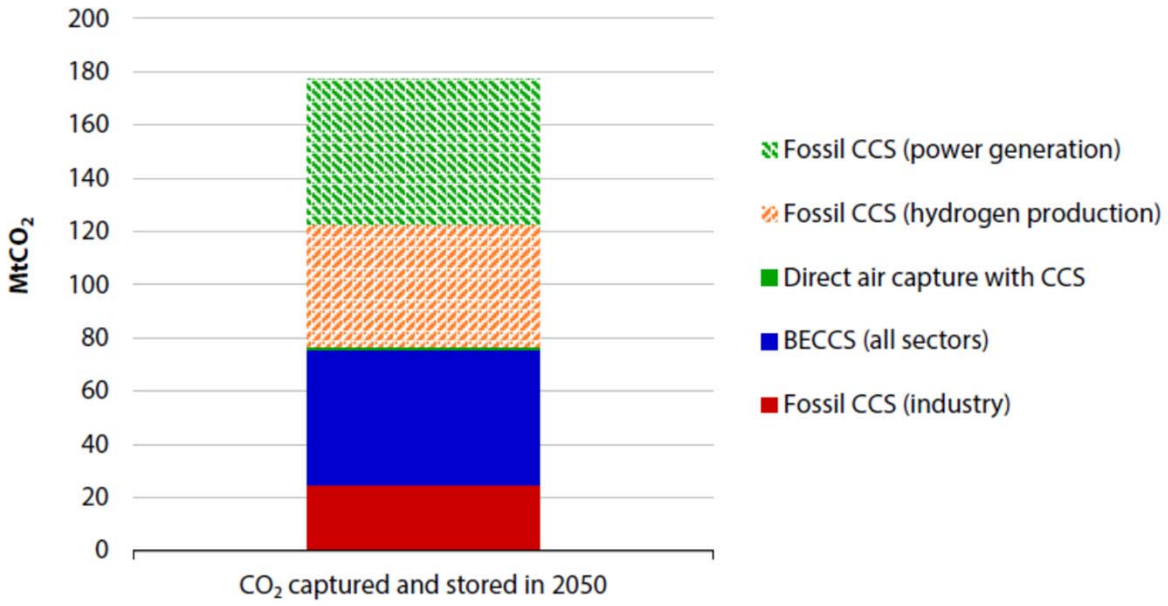
Committee on Climate Change Net Zero report, May 2019

https://www.theccc.org.uk/publication/net-zero-the-uks-contribution-to-stopping-global-warming/

- **CCS is a necessity not an option**
- CCS in industry, with bioenergy (for 'negative emissions'), and very likely for hydrogen and electricity production.
- The scenarios involve aggregate annual capture and storage of 75-175 $MtCO_2$ in 2050, requiring
  - a major CO_2 transport and storage infrastructure
  - servicing at least five clusters
  - some CO_2 transported by ships or road vehicles.



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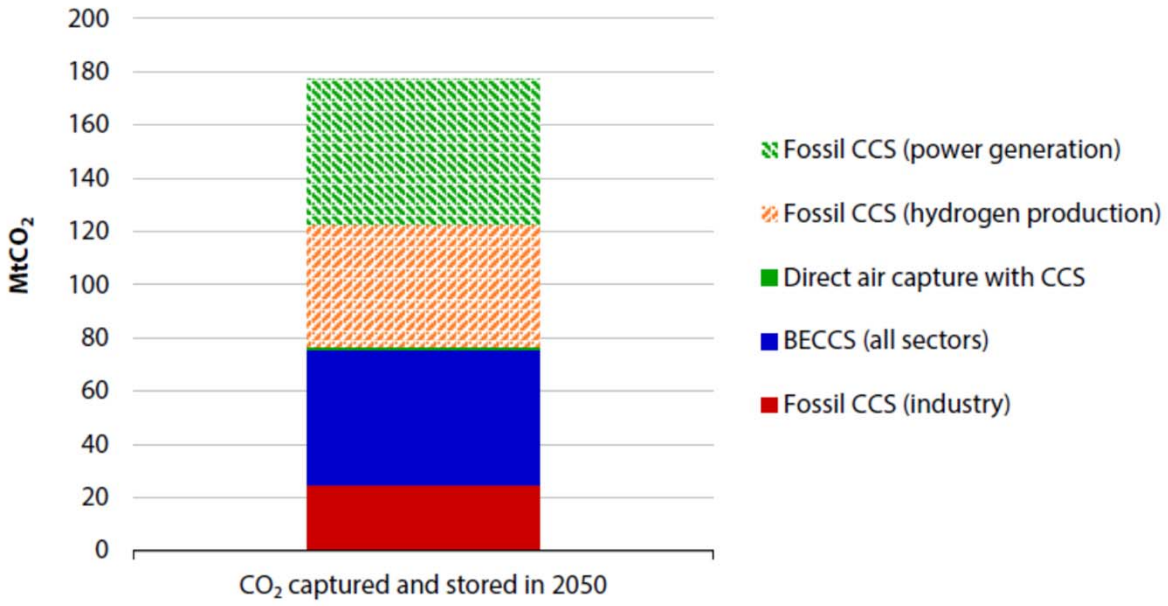

12th June 2019 UK Government commits to net zero emissions by 2050

2008 Climate Change Act amended - UK the first G7 country to legislate for net zero emissions.

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Further UK Government Actions…

- UK CCUS Deployment Action Pathway: Action Plan
- Review of delivery and investment models for CCUS

  Business models to overcome barriers to
  - deploying carbon dioxide capture in the industrial sector
  - deploying carbon dioxide capture in the power sector
  - establishing the infrastructure required to transport and store CO_2
- Test the development of CCUS industrial decarbonisation clusters
  - Work with the Teesside, Merseyside and Grangemouth to test the potential for development of CCUS industrial decarbonisation clusters.
- Established CCUS Council
- International collaboration on CCUS
  - MoU with Norway, Mission Innovation…

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Summary…

- CC(U)S essential to meet IPPC zero-carbon target
- Widescale global deployment requires a collective technological-government-business approach:
- There are some encouraging large-scale projects but as yet no integrated CCS Systems producing a range of ‘green products’ from fossil fuels
  …power/heat/chemicals/materials
- The UK is having a third attempt at CCS with a more integrated approach and is committed to achieving its share of a zero-carbon target by 2050
- Green shoots, but a long way to go and a lot to do…

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