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Accelerating towards a merchant model

Unleashing a commercially self-sustaining Carbon Capture & Storage Industry / An Integrated Approach

Reaping the benefits while dodging the risks and pitfalls

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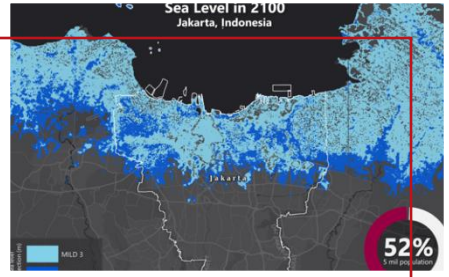
Intro: Why Capture & Store Carbon Dioxide?

CO2 is the biggest single contributor to global warming


LA


Dubai



Jakarta


Bangladesh


Wales


Fiji


Aberdeenshire

Hull

Merseyside

- Al Gore: *"We need to stop treating the skies like a sewer"*
- CCS is *"the single best near-term implement… all good climate outcomes lie down this path"*

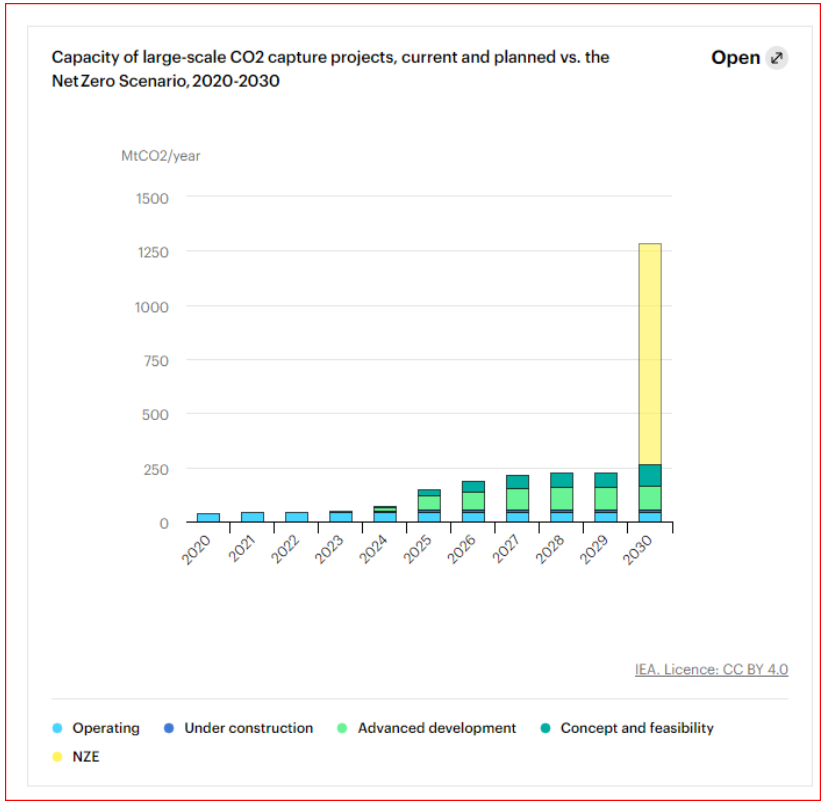
  - Wake Smith, Yale University, (Cambridge University Press)
- CCS is the *"obstinately unused"* tool for decarbonisation, and the only way for 'hard to abate' sectors like cement

  - Oliver Morton, Economist Editor, (Princeton University Press)

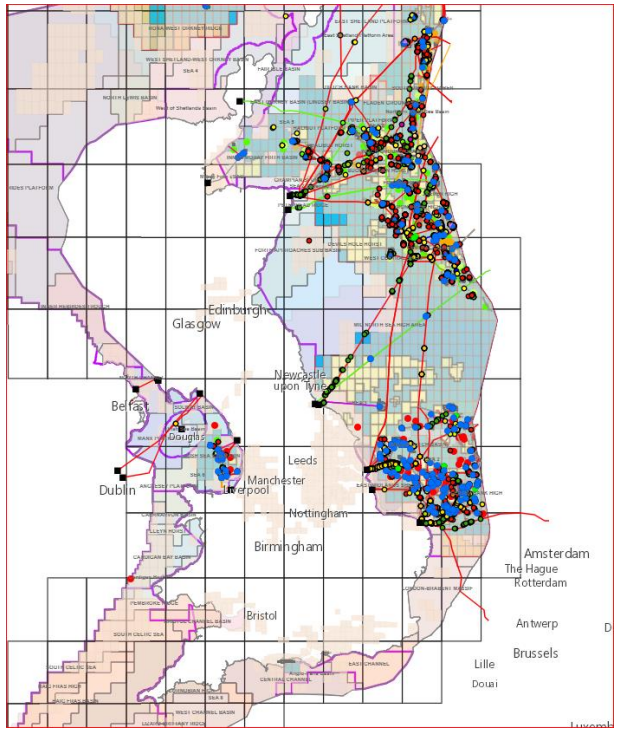
- **Latest EU Copernicus data (WEF Feb Session) shows unexpected acceleration in warming and related weather events. 2024 was:**
  - **1.6 degrees above 1850-1900 average**
  - **0.72 degrees above 2010-2020 average**
  - **0.12 degrees above 2023 average**

CCS is a UK Competitive Advantage

UK has an exceptional natural competitive lead to meet steep demand increases expected in CCS



Global CCS industry capacity is increasing. But to reach the IEA's Net Zero scenario, global demand must increase further and faster.
Source: International Energy Agency (IEA)

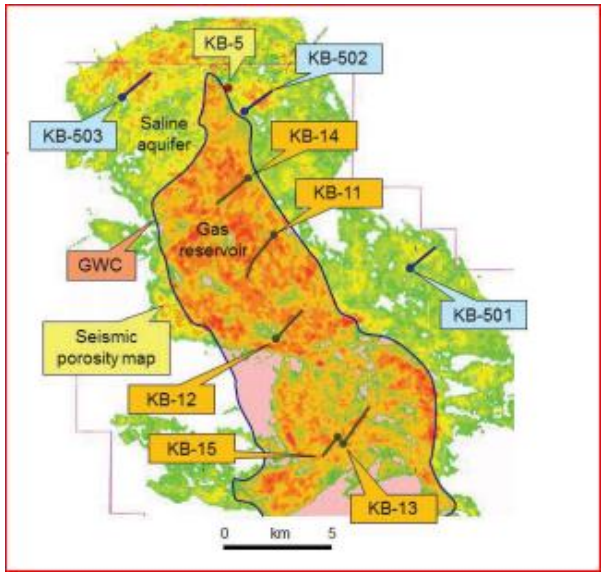


The UK has a mature offshore industry and substantial CO2 stores within close reach of major industrial centres
Source: North Sea Transition Authority (NSTA)

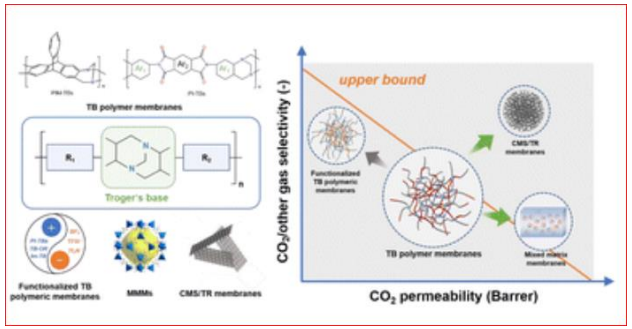
- ✓ Unique political commitment to CCUS
- ✓ Legal commitment to NetZero, long may it last
- ✓ 78Gt offshore CO2 stores, close to major emissions sources in UK and Europe and connected to Mid East
- ✓ Mature offshore and subsurface supply chains
- ✓ Advanced fuels and chemicals sector
- ✓ Mature offshore infrastructure and stable regulation with EU cooperation agreements
- ✓ Active capital markets

CCS is a new international market-place

CCS technologies have been in deployment for 20+ years in a range of economic contexts



Science Monitor image of CO2 store at Algeria, In Salah in depleted gas reservoir showing multiple injection wellheads



Polymeric membrane developments, Journal of Materials Chemistry A, used in Brazil Pre-Salt CO2 Capture and reinjection

In Salah in Algeria has been successfully injecting CO2 at the Krechba field since 2004 and monitoring seismic events

- No significant safety incidents, some limited geological deformation recorded, data available
- Lots of learning for underground CO2 storage around the world, c. 7.5Mt injected

Gorgon in Western Australia stores CO2 regularly from active gas production facilities, water problematic, c. 4Mt injected

- Costs have proved high; policy makers have struggled effectively to mandate ongoing capture at volume + issues with water

Northern Lights and predecessors storing in Norway's Sleipner field since 1996, no CO2 leakages in past 10 years nor related seismic activity, c. 20Mt injected

- Ships designed and 2 have left yards
- First contract to import CO2 from a factory in the Netherlands signed in 2022
- Brevik cement to start storing CO2 from June 2025

Brazil Pre-Salt now storing 10Mt/y, Total ~40Mt reinjected for EOR from 20% CO2 natural gas, from FPSOs and with potential future industrial CO2 emission storage

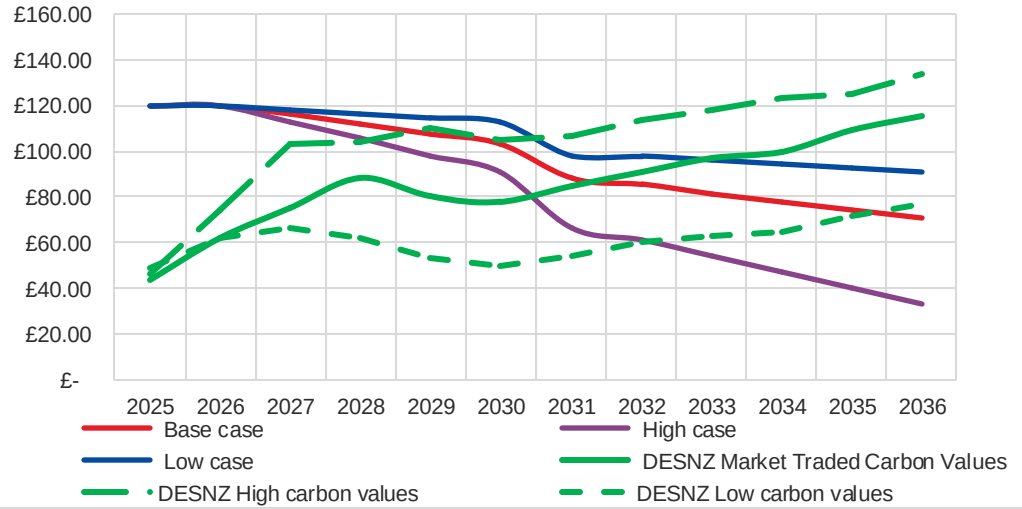
- Target 80Mt by 2025. First use alternating gas & water injection (Petrobras).
- Polymeric membrane separation.

"Creation of a global marketplace for CO2 capture, transport and storage is a critical step towards tackling the domestic costs of industrial decarbonisation"

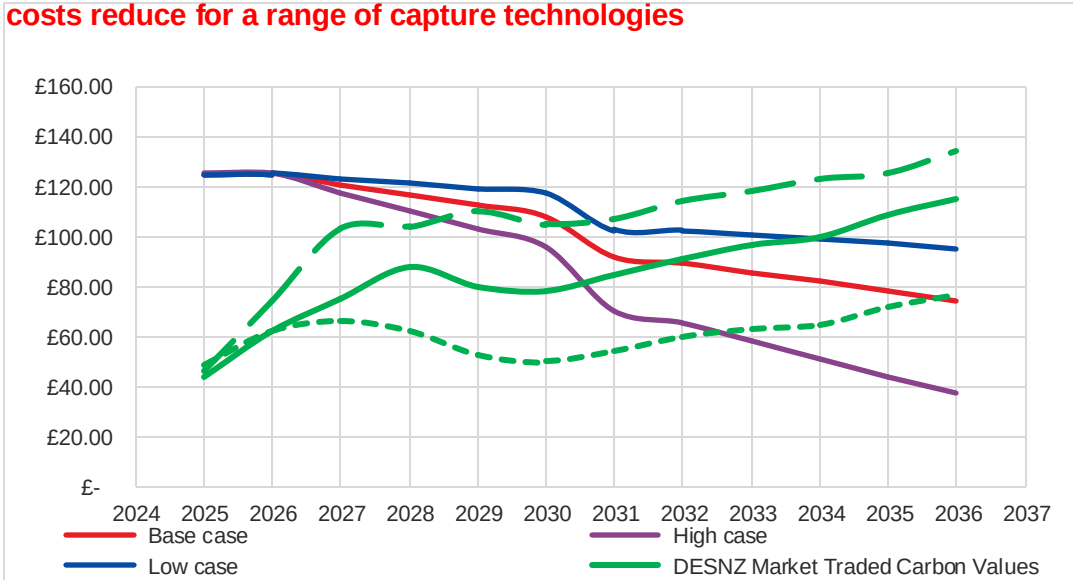
Northern Lights project celebrates the keel-laying of first Liquid CO2 carrying ship, April 23, 2 ships now launched and commissioned (China)

CCS costs and risks will reduce

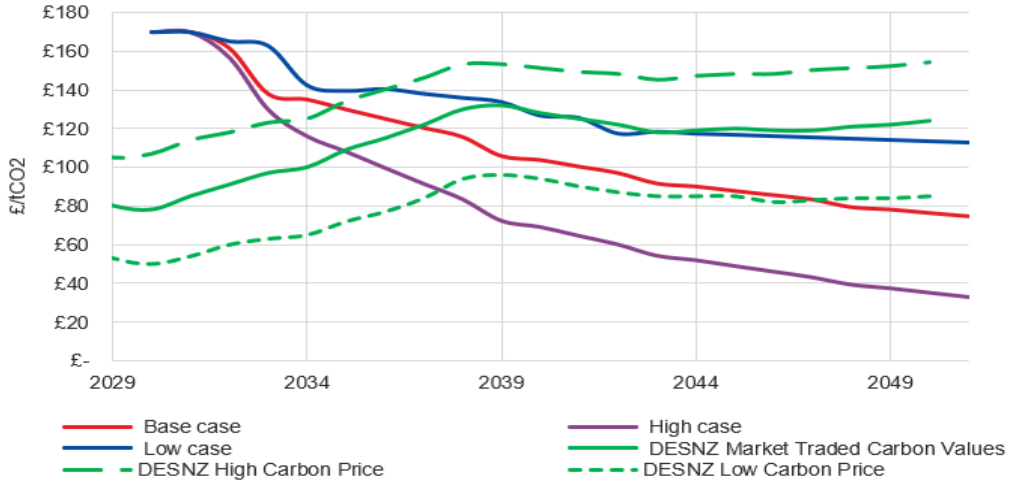
In Power + CCS we anticipate rapid cost reduction accelerating from 2030 when projects mature in the UK



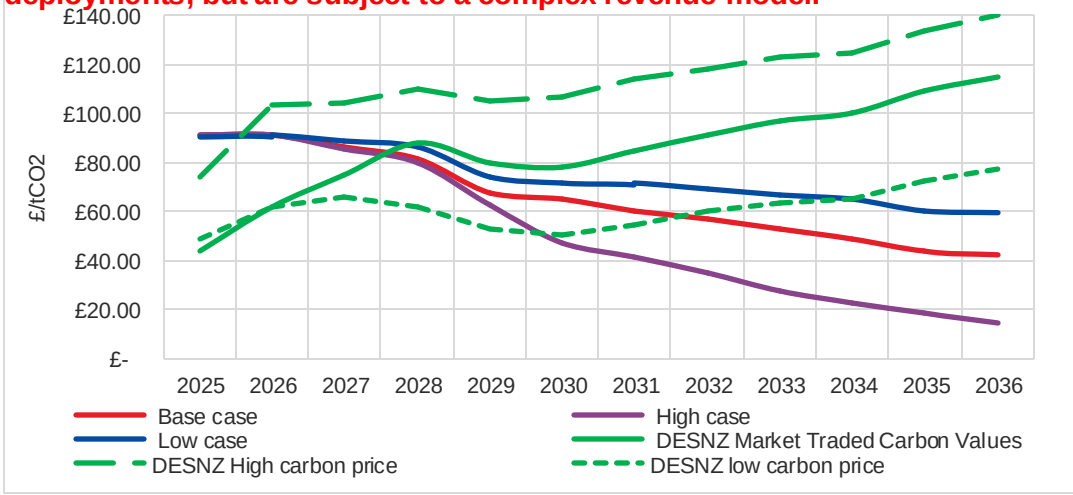
In Industrial CCS driven by cement, we expect widespread adoption to see costs reduce for a range of capture technologies



Waste to energy will benefit from economies of scale achieved in other CCS deployments



On average CCS costs are lower for CCS-enabled H2 than for other CCS deployments, but are subject to a complex revenue model.



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Power requirements for CCUS

A major operational cost; industrial heat can help and so can geothermal, other renewables. Industrial power must be cheap and clean

Capture

- Waste Heat re-use wherever possible; optimisation of waste heat in cement operations is increasingly competitive and protected technology
- Minimise ‘parasitic loads’
- Avoid process interruption
- Manage limited transmission network capacity

Storage

- MW requirement for compression and cooling may be considerable depending on volumes stored
- At stores, GEOTHERMAL is a key option to consider
- Offshore Wind PPAs may also be an option at a cost
- Low cost industrial power access essential
- Transmission (and distribution) network constraints to mitigate/avoid
- Avoid fossil power

(Below) Hanson Cement plant – HyNET Cluster

CCS and Geothermal Integration

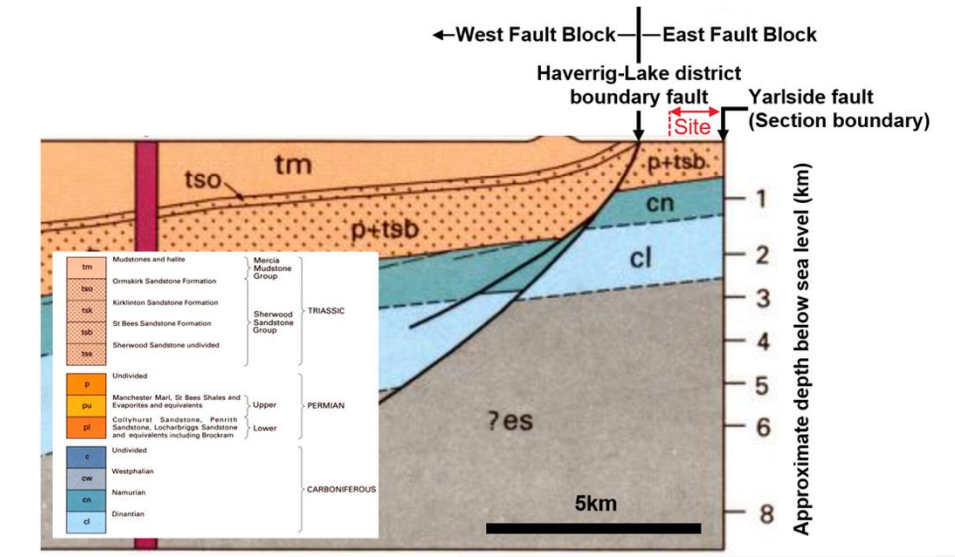
Initial Heat Output Findings

Geothermal Energy (Deeper)

- Multiple Options; 0.24 – 16 MW (Depth: 0.8 - 2km)
- Targeting deeper geology is possible, but uncertainty remains.

Geothermal Energy (with Heat Pumps) (Shallower)

- Surface Water; 0.92MW
- Closed Loop (385 boreholes); 6.3MW
- Open Loop (1 doublet); 0.6 - 1.2 MW
- Outputs are dependent on available space and flow



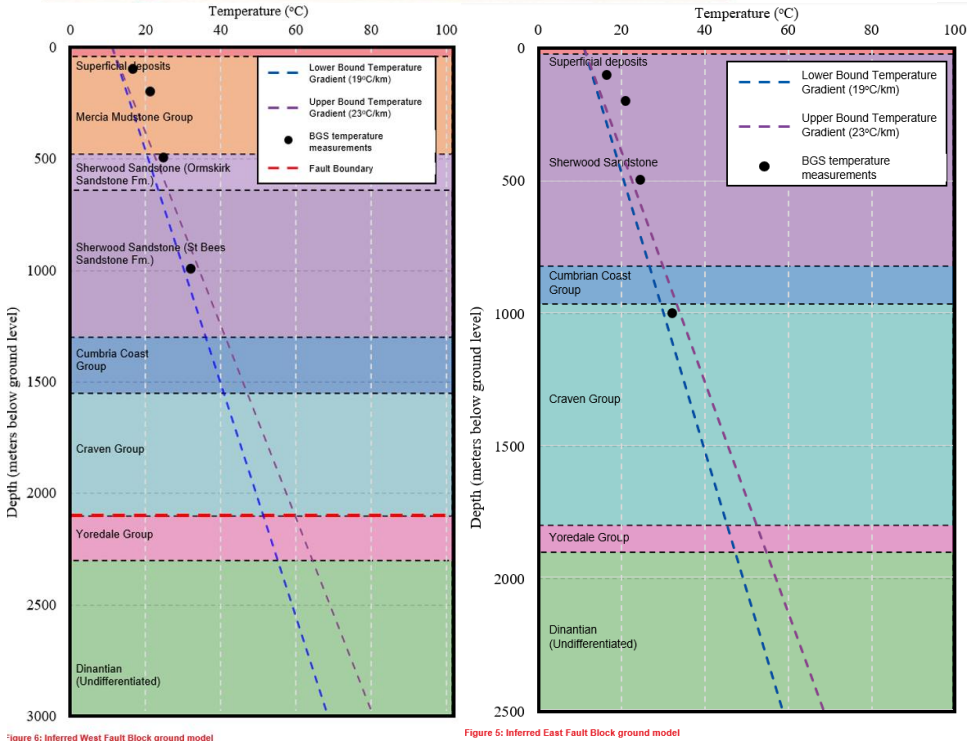


Figure 6: Inferred West Fault Block ground model

Figure 5: Inferred East Fault Block ground model

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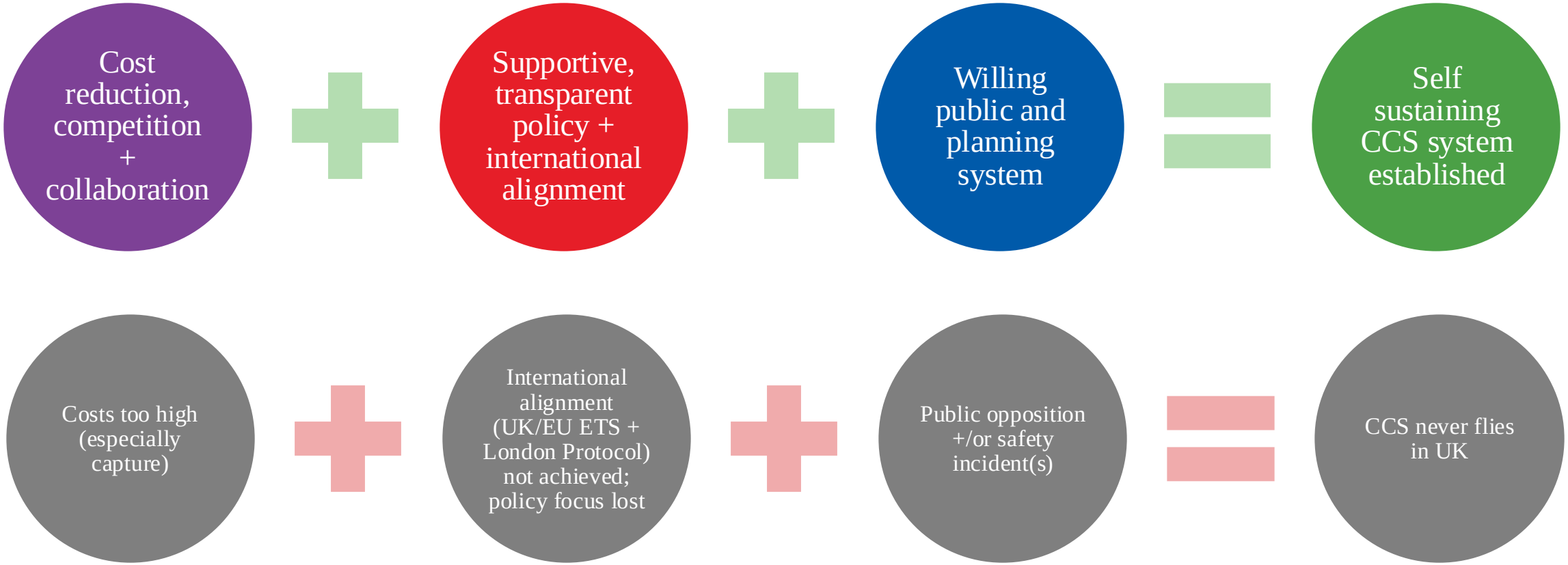
A self-sustaining system for CCS is within reach

What is necessary for CCS to be a self-sustaining industry? What risks and pitfalls must be avoided?



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To remove: key points

1.CCS is a UK competitive advantage

2.Importance of international market interconnection in CO2

3.Cost reduction trajectories

4.Importance of low cost clean power for CCS operations

5.Risks to UK CCS Roll out