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Making CCUS Happen

Making CCUS happen: public imperatives, business models and capital injections

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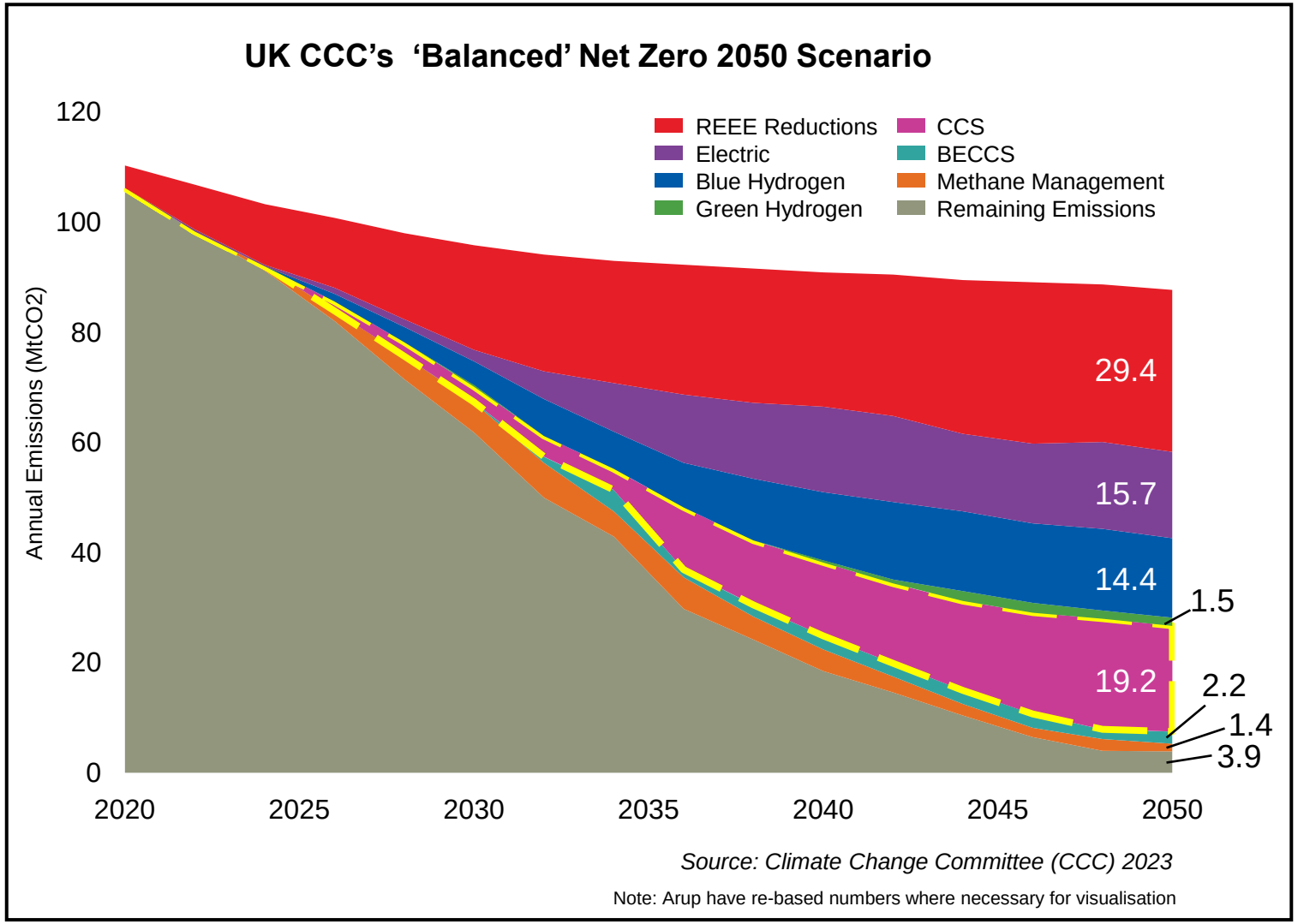
Talk structure

1. CCS is Critical to Net Zero
2. Some expert views
3. CO2 storage is understood
4. Why not at scale?
5. Business models
6. Full chain CCS
7. An infrastructure system
8. Supply chains
9. Local solutions
10. Conclusions

Critical to meeting global commitments

CCS is central to every future vision of net zero



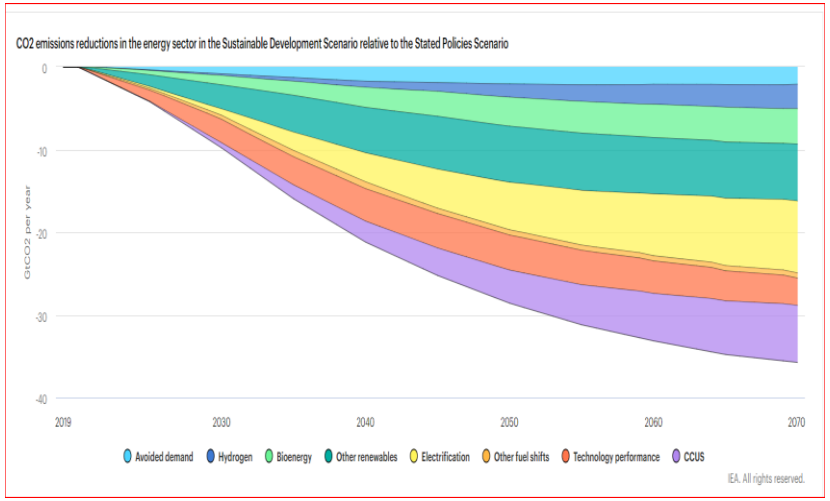
Source: Climate Change Committee (CCC) 2023

Note: Arup have re-based numbers where necessary for visualisation

CCS provides 19.2% to the reduction of overall emissions in the UK by 2050 according to the Parliamentary Committee on Climate Change.

CCS provides over 20% of carbon savings in the International Energy Agency (IEA)'s global Net Zero scenario, rising to 7 gigatonnes stored annually by 2070.

IEA's 'Stated Policies' scenario



Source: IEA 2022

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Experts point to CCUS

Under-used; under-communicated and the best near-term solution

- 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)

- CCS is ‘one of the only technologies capable of reducing the amount of CO2 in the atmosphere, rather than just slowing accumulation’ – and –
- ‘Energy interests have technical expertise in implementing large infrastructure projects combined with the experience and funding to run public campaigns on controversial issues’

  - David Reiner, Cambridge University

(Below) Hanson Cement plant – HyNET Cluster

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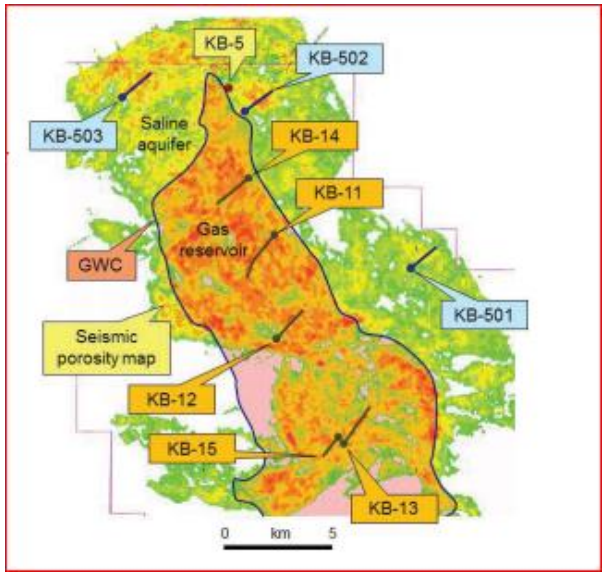
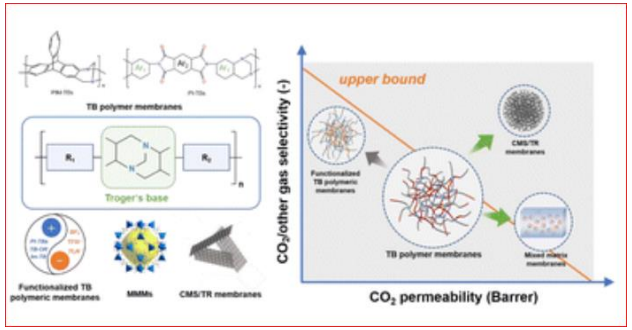
A known technology set

CCS has been in deployment for 20+ years, lessons have been learnt



Science Monitor image of CO2 store at In Salah in depleted gas reservoir showing multiple injection wellheads and seismic porosity illustration



Polymeric membrane developments, Journal of Materials Chemistry A

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

- No significant safety incidents, some geological deformation
- 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

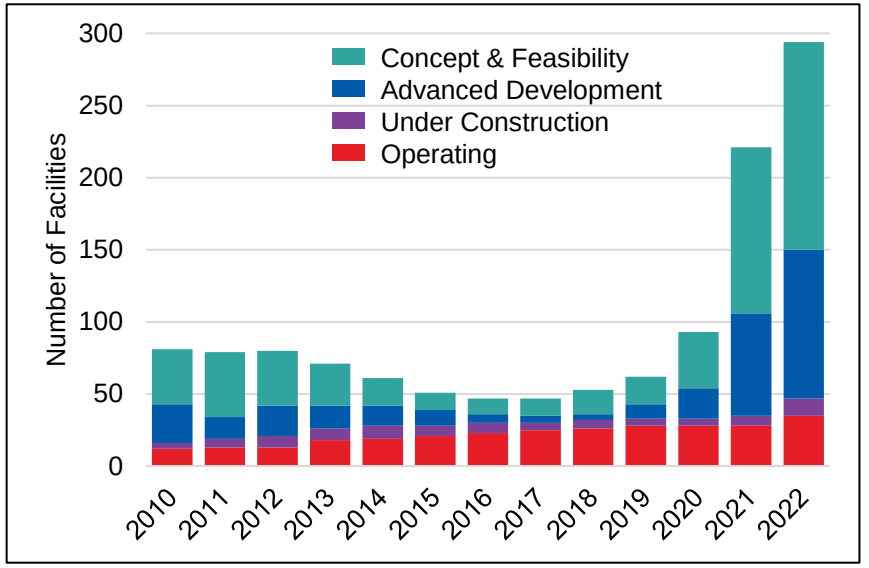
Northern Lights and predecessors storing in Sleipner field since 1996, no CO2 leakages in past 10 years nor related seismic activity, c. 20Mt injected

- Import via ship planned
- First contract to import CO2 from a factory in the Netherlands signed in 2022

Brazil Pre-Salt now storing 10Mt/y, ~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.

Evolution of the global CO2 capture project pipeline, 2010-2022 (Source data: IEA)



Northern Lights project celebrates the keel-laying of first Liquid CO2 carrying ship, April 23

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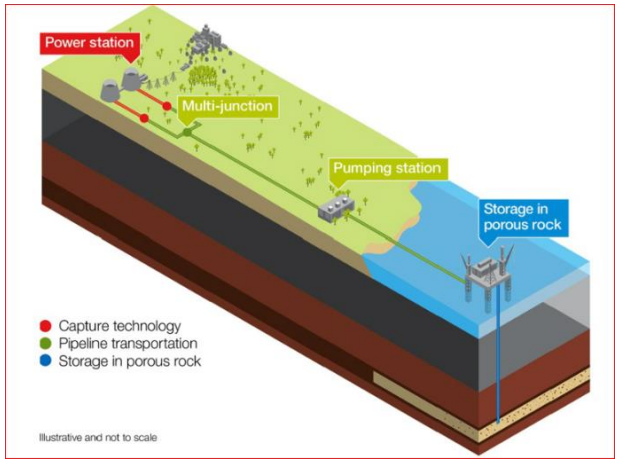
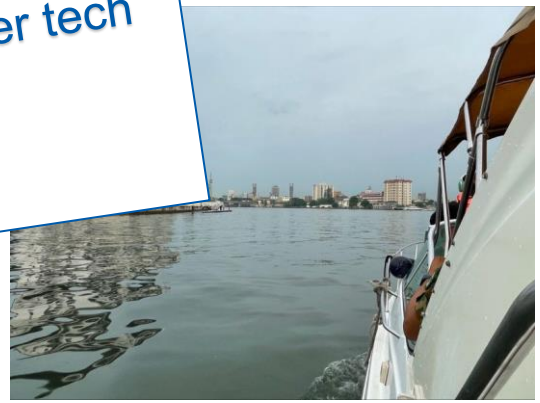
Why isn't CCS at scale yet?

After all, CCS is a proven technology for permanently removing warming gases from our atmosphere



Why hasn't CO2 ...

- Challenging integration with emitter tech (intermittency)
- Lack of viable CO2 transport infrastructure



- Pre-Salt
- Quest Alberta

Why have governments ... cancelled ... globally

- Lack of consistent policy landscape
- Weak economic fundamentals

- White Rose
- 20% of all globally announced CCS projects have been cancelled – says Brazilian regulator

Why are some govts with reserves only just starting ... to think ...

- Growth imperative to fight poverty
- No investment available for massive shift of trajectory right now

- US
- Nigeria

Business models are in testing

Different jurisdictions with different politics and economics are finding different ways through the problem

US: Large tax credits via boosted 45Q under IRA

- Willing and socially-minded government (not for long?) providing strong signals to store CO2
- Boosted 45Q Tax credits include $85/tonne industrial & power emissions, $60/tonne EOR, $180/t direct air capture & store and $160/t direct air capture & utilisation.
- Some odd effects so far: Occidental acquisition of CarbonEngineering (DAC) for EOR; Datacentre CCS

UK: Pay as you go model for CCS as a utility

- Familiarity with regulated utility model
- Requirement to protect taxpayer from risk/burden, use of ‘RAB’ (Regulated Asset Base) business model
- Imminent financing should demonstrate T&S networks as regulated assets are investment grade assets
- Slowly but surely approaching FID later in 2024

South-East Asia: EOR, gas sweetening is initial basis for CCS

- Rising seawater (Jakarta is moving)
- Depleting reserves (in some areas)
- Indonesia, Malaysia pressing ahead, Singapore seeking hub status, Brunei considering first steps, Thailand intends to move
- Initial focus on CO2-rich gas and EOR: business model is via hydrocarbon production

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Full Chain CCS is still being worked out

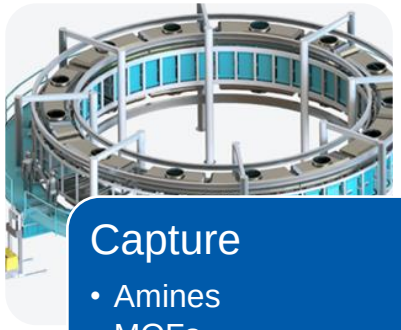
Investable CCS infrastructure must consider the full value chain from capture to storage

- Flue type?
- Purity required?
- Volume? Variability?
- Asset management
- Incentives

- Pipeline/ port availability
- Volume
- CO2 specifications & impurities
- Planning considerations
- Storage / flexibility risks (buffering)

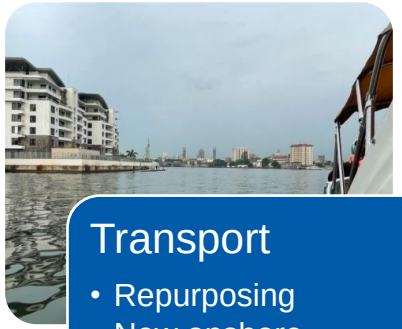
- Commercial models & access to markets
- Whole life emissions impacts
- Incentives/penalties

- Reservoir geology
- Subsurface access and infrastructure
- Store capacity/ reliability risk
- CO2 plume behaviour and monitoring
- Incentives or credits



Capture

- Amines
- MOFs
- Pyrolysis
- Filtration
- Other

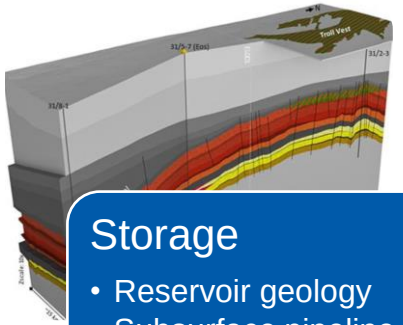


Transport

- Repurposing
- New onshore
- New offshore
- Shipped solutions

Use

- Use cases (from elemental C to gaseous CO2: building materials, car manufacture, horticulture)

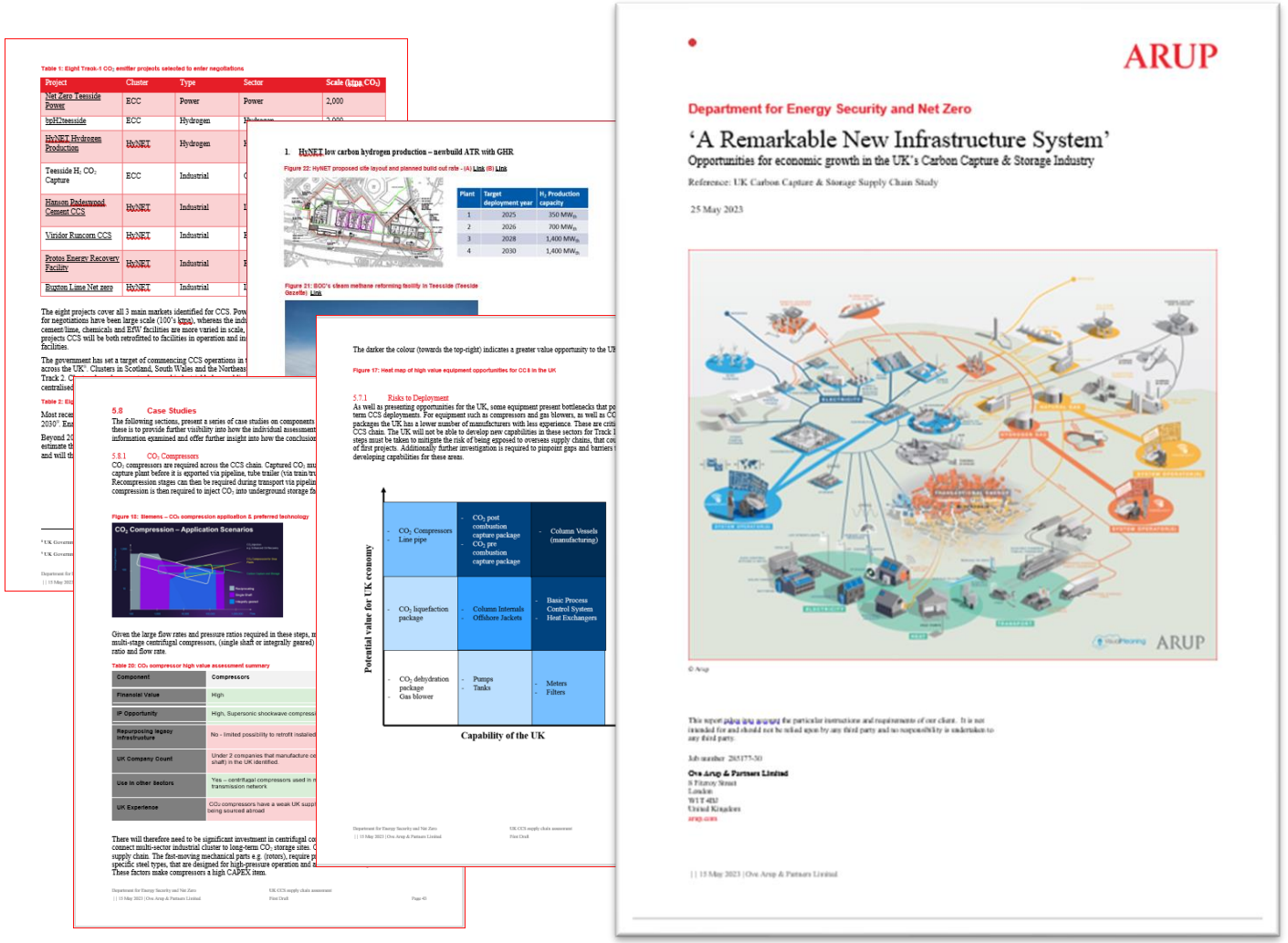


Storage

- Reservoir geology
- Subsurface pipeline constraints
- Plume behaviour

A whole new infrastructure system to develop

A ‘Remarkable New Infrastructure System’ to build, operate and regulate



Key Findings of ‘High Value Items’ CCS Supply Chain Taxonomy & Analysis for UK government, June 2023

- Construction & management services, engineering design constrained and high value, government interventions recommended
- Column vessels and heat exchangers can be a success story, with support and enablement
- Process controls, including controls interfaces and dashboards, as well as connected linear monitoring and controls is a key area requiring growth and investment
- CCS-as-a-service provisions are emerging, supporting companies without planned CO2 infrastructure to de-carbonise, these would benefit from further support and profile raising

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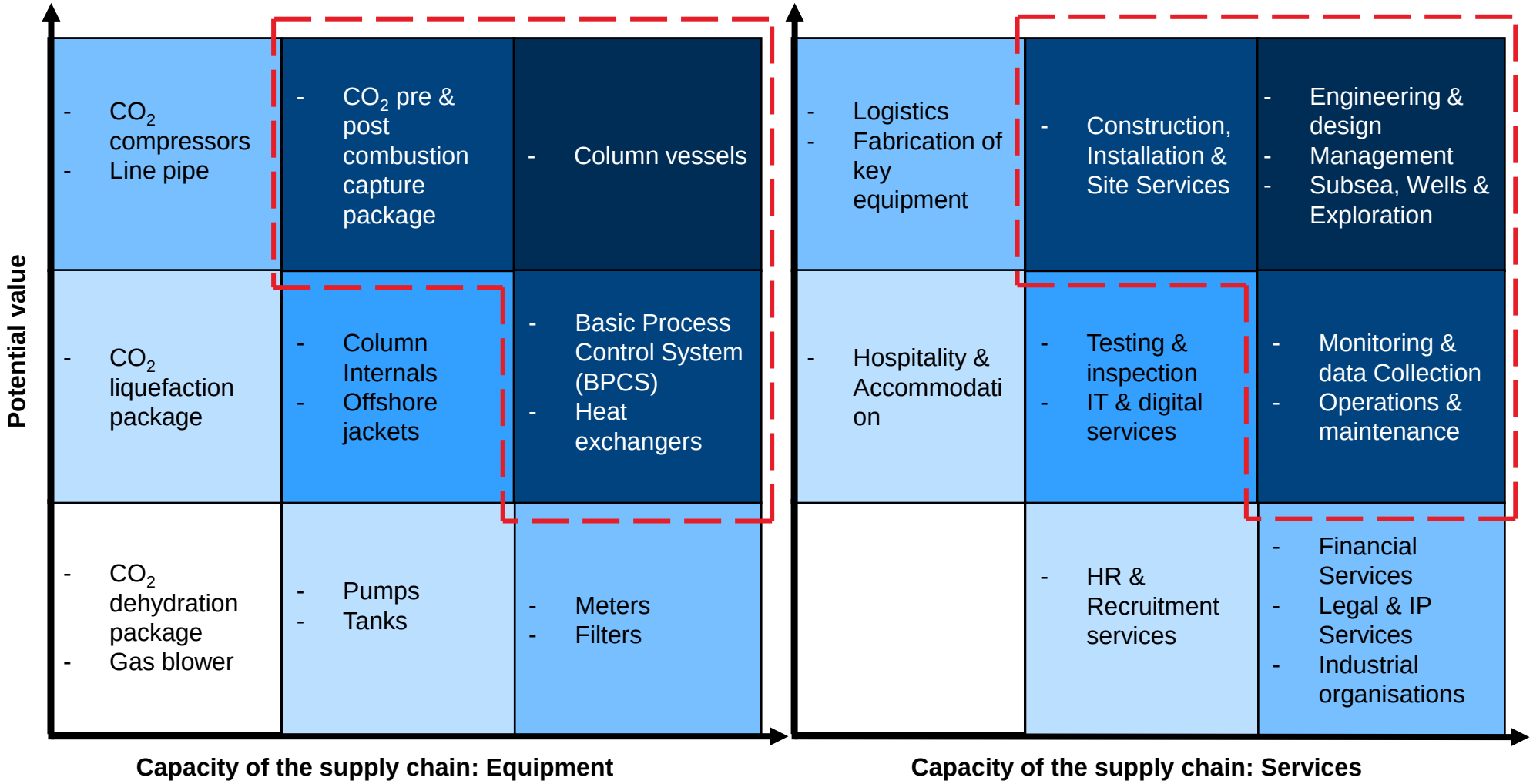
Economic opportunity via the supply chain?

Column vessels and EPC services likely to prove both high value and constrained in CCS supply chain



- For countries to benefit from CCUS supply chain development, governments must invest to add capacity and competitive specialisations
- Currently, supply chains tied to O&G, and often at capacity or close

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Some examples of key next steps

Just a few examples of key hurdles to overcome: different in each jurisdiction, but with common themes

Brunei: Revenue model

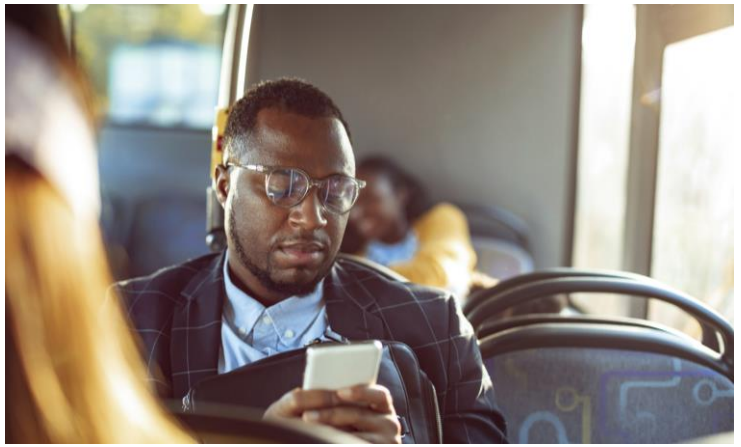
Develop an economic model for CCS which can produce revenue and employment for local companies

UK: Financing of T&S networks

Achieve investment grade financing of CO2 Transport & Storage (T&S) systems

US: Post-IRA sustainability

45Q projects must mature to self-sustainability, based on ?a carbon price?



Nigeria: Public acceptance

Navigate a social transition through economic hardship; and move from distressed extractors to willing injectors

Conclusions: Critical Levers for CCS

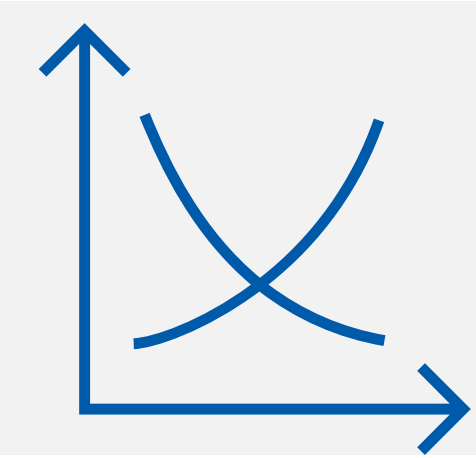
Strongest levers which can have most immediate global impact

Carbon price

- Above $100/t in EUR, USD or GBP suddenly pushes many projects into the black
- CCS costs are still more often at 120-180/t, so needs to stay at that level or above

Predictable govt mechanisms

- Capital, revenue, tax credits, carbon price,and/ or RAB model as utility
- Public & climate impetus behind the policy ideal, public acceptance managed



A market for H2

- Tradable commodity moving around the world
- Different classes/prices of H2 depending on production method
- CO2 as a by-product of H2 production

A market for CO2 (storage)

- Centralised markets, trading infrastructure
- Regulations for import/export
- Hubs for direct injection by CO2 source type

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