The University Of Sheffield. Energy Institute

UKCCS RESEARCH COMMUNITY

CEA, 13th May 2026

CARBON CAPTURE AND STORAGE - ENSURING SUCCESSFUL UK DEPLOYMENT AND NATIONAL BENEFITS

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The UKCCSRC is supported by the EPSRC as part of the UKRI Energy Programme
but the contents are entirely the responsibility of the presenter

- After over two decades of discussions around CCS in the UK a number of projects have now made FID.
- This brings UK CCS to a time both of great promise and of great risk.
- It is essential for the future of CCS, in the UK and globally, that these projects are delivered more-or-less successfully and also that they lead to genuine improvements in subsequent phases of roll-out.

For Best Available Techniques (BAT) information for CCS
see https://ukccsrc.ac.uk/best-available-technology-bat-information-for-ccs/

Plus a range of CCS articles on LinkedIn

A series of UKCCSRC meetings in 2016 engaging with CCS stakeholders in the regions probably contributed to the development of the present CCS landscape based on clusters.

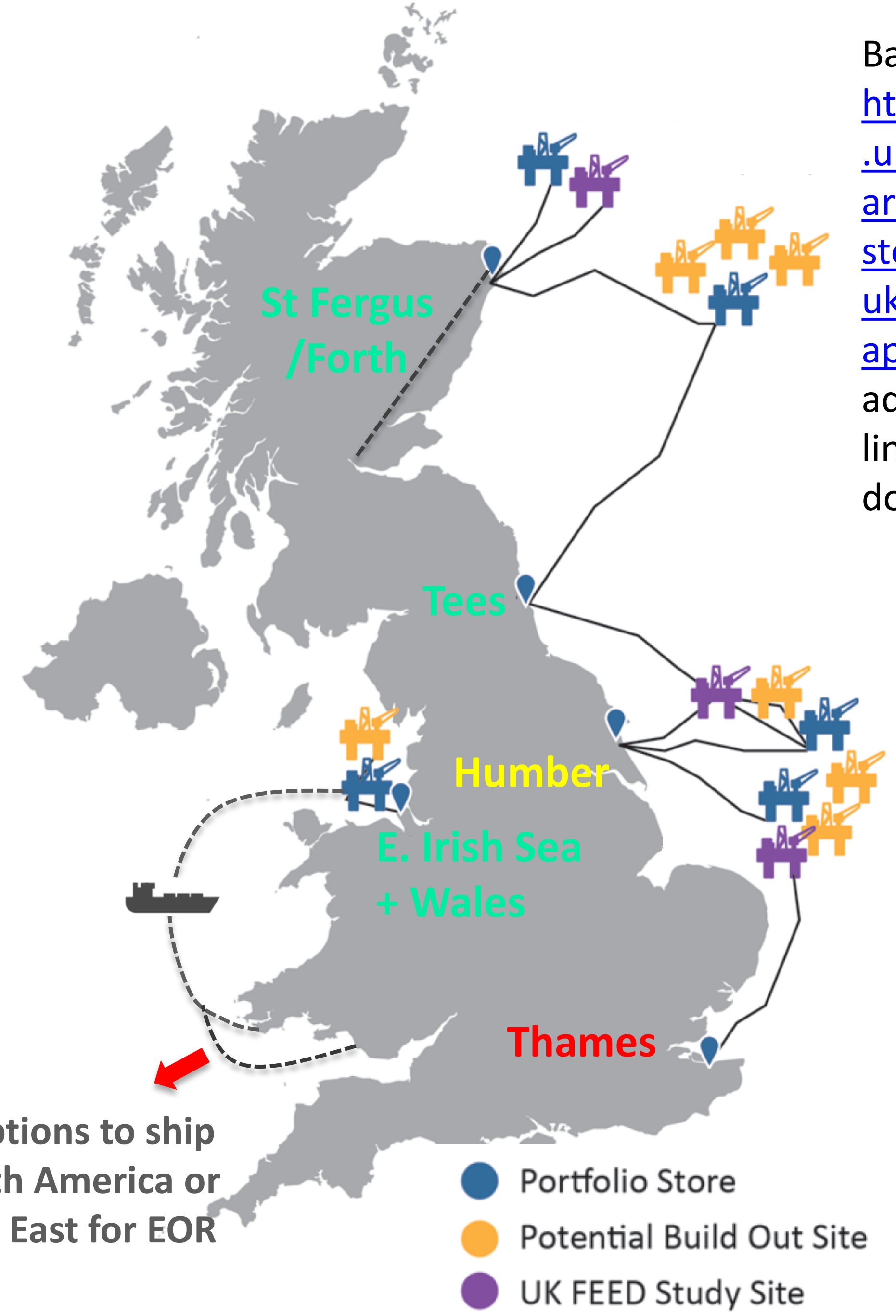
https://ukccsrc.ac.uk/delivering-cost-effective-ccs-in-the-2020s/

UK CCS RESEARCH CENTRE

Delivering Cost Effective CCS in the 2020s – a new start

A CHATHAM HOUSE RULE MEETING REPORT

March 2016



Also options to ship to North America or Middle East for EOR

Based on http://www.eti.co.uk/programmes/carbon-capture-storage/strategic-uk-ccs-storage-appraisal with added conceptual links shown dotted

4 October 2024

Major UK

£22bn for UK CCS

Chief

Chancellor

Secretary of State

Announcement

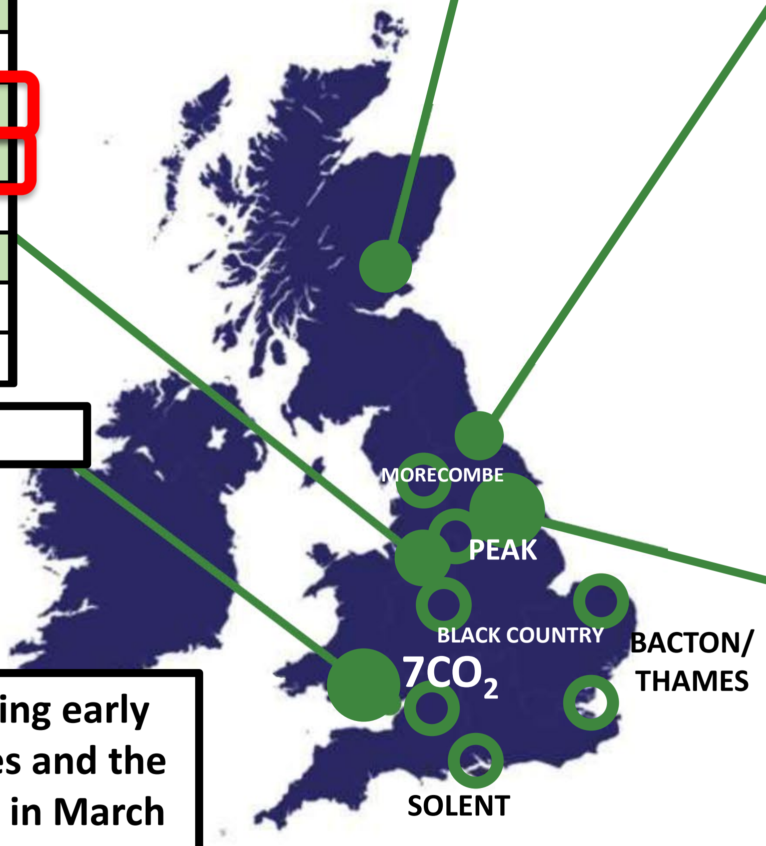
SCOTTISH CLUSTER	
8	Peterhead Carbon Capture Power Station
15	Acorn Hydrogen
16	Fife Hydrogen Hub
40	CO2 Extraction from St Fergus Gas at SAGE Terminal
41	Acorn Capture

HYNET	
7	Making Net Zero Possible – Grain
13	Project Cavendish
14	**HyNet Hydrogen Production Project (HPP)**
32	**Viridor Runcorn Industrial CCS**
33	Protos Biofuels
34	**Protos Energy Recovery Facility**
35	**Hanson Padeswood Cement Works CCS**
~~36~~	~~CF Fertilisers Ince Capture Plant~~
37	**Buxton Lime Net Zero**
38	**Carbon Dioxide Capture Unit - EssarOil UK**
39	Emerge CCS

TEESSIDE	
2	**Whitetail Clean Energy**
3	**Net Zero Teesside Power**
4	Alfanar CCGT Teesside
9	**H2NorthEast**
~~11~~	~~**bpH2Teesside**~~
28	**Norsea Carbon Capture**
~~29~~	~~**CF Fertilisers Billingham Ammonia CCS**~~
30	Teesside Green Energy Park Limited
17	STV 1+2 Energy from Waste Carbon Capture Project
18	STV 3 Energy from Waste Carbon Capture Project
19	**Tees Valley Energy Recovery Facility Project (TVERF)**
22	**Redcar Energy Centre**
26	**Teesside Hydrogen CO2 Capture**

SOUTH WALES

HUMBERSIDE	
1	VPI Humber Zero
5	**Keadby 3 Carbon Capture Power Station**
6	C.GEN Killingholme
10	Uniper Humber Hub Blue Project
12	**Hydrogen to Humber (H2H) Saltend**
27	Saint-Gobain Glass Carbon Capture Project
31	North Lincolnshire Green Energy Park
20	Altalto Immingham waste to jet fuel
21	Lighthouse Green Fuels
23	**Humber Zero - Phillips 66 Humber Refinery**
24	**Prax Lindsey Oil Refinery Carbon Capture Project**
25	**ZerCaL250**



Incomplete overview of UK CCS projects showing early clusters (solid green circles) and some later ones and the 41 CO_2 capture projects selected for evaluation in March 2022, with the 2 clusters and 8 projects selected for final negotiations in March 2023 highlighted in green.
Bold text = made interim cut of 20 in August 2022
Project type = Power/Blue hydrogen/Industry

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DESNZ has concluded its assessment of applications into the Track-1 expansion (T1x) of the HyNet CCUS cluster process. This follows Liverpool Bay Carbon Capture and Storage Limited's (LBCCS Ltd) financial close, which will establish the cluster's Transport and Storage network.

We are taking forward 6 projects into the negotiations phase:

T1x Project Negotiation List https://www.gov.uk/government/publications/hynet-track-1-expansion-selected-projects/hynet-expansion-project-negotiation-list

- Connah's Quay Low Carbon Power, Uniper
- Essar Energy Transition Industrial Carbon Capture (EET ICC), EET Fuels
- Hydrogen Production Plant 2 (HPP2), EET Hydrogen / Progressive Energy
- Ince Bioenergy with Carbon Capture and Storage (InBECCS), Evero Energy
- Parc Adfer Energy from Waste Industrial Carbon Capture Project, Enfinium Group Ltd
- Silver Birch, Climeworks UK Ltd

The Department for Energy Security and Net Zero (DESNZ) invites applications from carbon capture, usage and storage (CCUS) projects seeking to connect to the East Coast Cluster (ECC) Teesside network by 2032.

DESNZ will assess applications through the ECC Teesside Selection Process to identify projects that could connect to the network and make use of remaining capacity at the Endurance offshore site.

Key dates

https://www.gov.uk/government/publications/ccus-east-coast-cluster-updated-selection-process

- engagement session: week commencing 2 March 2026
- expression of interest deadline: 11.59pm on 10 March 2026
- application window closes: 11.59pm on 10 April 2026

DESNZ Cluster sequencing Phase-2: eligible projects (Power CCUS, Hydrogen, Industrial Carbon Capture and others), updated March 2023

https://www.gov.uk/government/publications/cluster-sequencing-phase-2-eligible-projects-power-ccus-hydrogen-and-icc/cluster-sequencing-phase-2-eligible-projects-power-ccus-hydrogen-and-icc

Key for project cluster

E: East Coast Cluster (Teesside and Humberside)

H: Hynet – NW Cluster

S: Scottish Cluster

Project selected in Track 1 (£22bn funding)

Amine post-combustion capture (PCC) projects (25 out of 41)

Industrial Carbon Capture (ICC)

- **E: STV 1+2 Energy from Waste Carbon Capture Project**
- **E: STV 3 Energy from Waste Carbon Capture Project**
- **E: Tees Valley Energy Recovery Facility Project (TVERF)**
- **E: Redcar Energy Centre**
- **E: Humber Zero - Phillips 66 Humber Refinery**
- **E: Prax Lindsey Oil Refinery Carbon Capture Project**
- **E: Teesside Hydrogen CO_2 Capture**
- **E: Saint-Gobain Glass Carbon Capture Project**
- **E: Norsea Carbon Capture**
- **E: Teesside Green Energy Park Limited**
- **E: North Lincolnshire Green Energy Park**
- **H: Viridor Runcorn Industrial CCS**
- **H: Protos Biofuels**
- **H: Protos Energy Recovery Facility**
- **H: Hanson Padeswood Cement CCS**
- **H: Carbon Dioxide Capture Unit - EssarOil UK**
- **H: Emerge CCS**
- **S: Acorn Capture**

Power CCUS

- **E: VPI Humber Zero**
- E: Whitetail Clean Energy
- **E: Net Zero Teesside Power**
- **E: Alfanar CCGT Teesside**
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- **S: Peterhead Carbon Capture Power Station**

Sustainable Aviation Fuel – different novel proprietary technologies

- E: Altalto Immingham waste to jet fuel
- E: Lighthouse Green Fuels

Lime kilns producing high-purity CO_2 – different novel proprietary technologies

- E: ZerCaL250 (Origen lime kiln)
- H: Buxton Lime Net Zero

~~**Ammonia production – established technology**~~

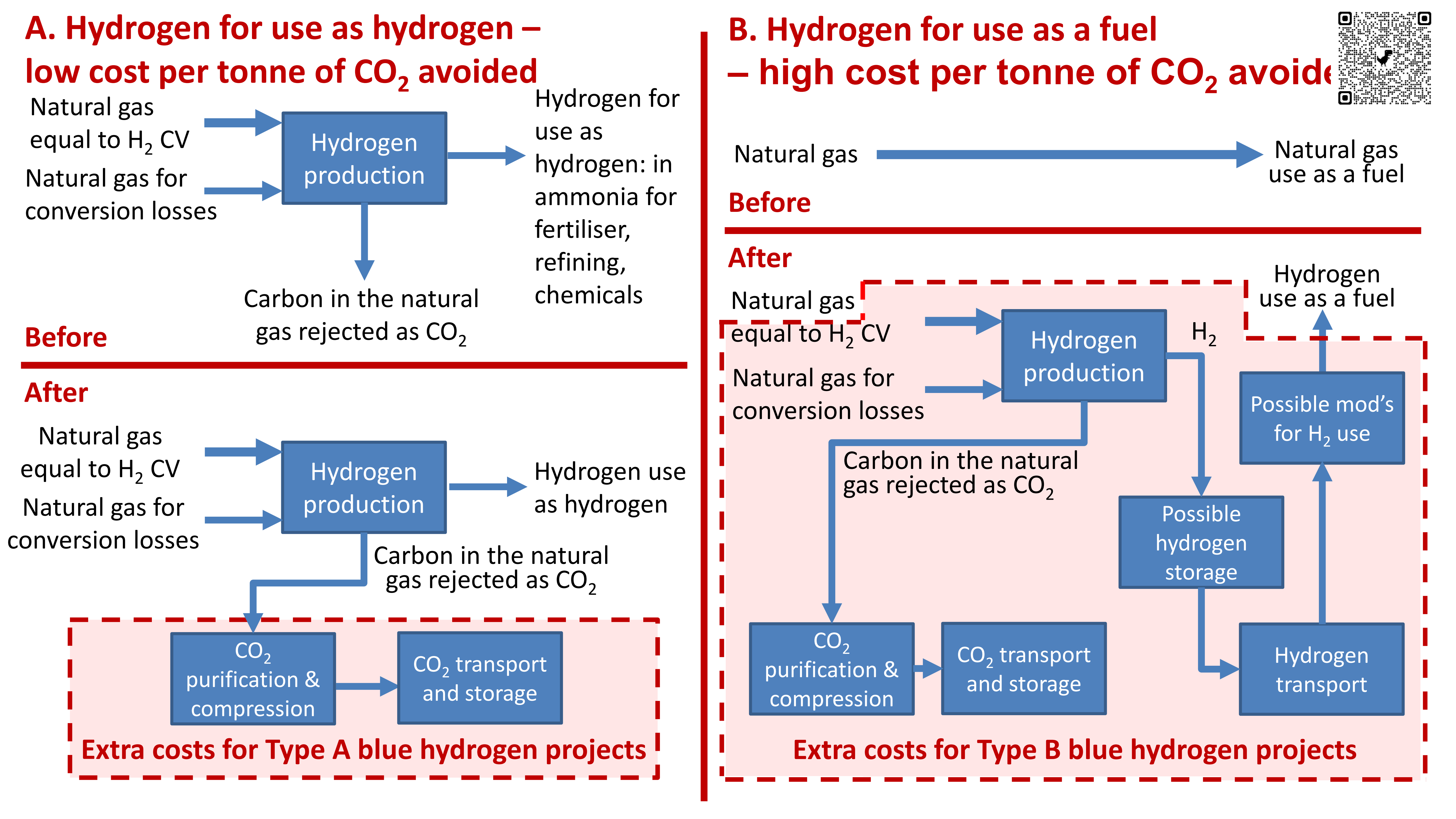
- ~~E: CF Fertilisers Billingham Ammonia CCS~~
- ~~H: CF Fertilisers Ince Capture Plant~~

Natural Gas Sweetening– established technology

- S: CO_2 Extraction from St Fergus Gas at SAGE Terminal

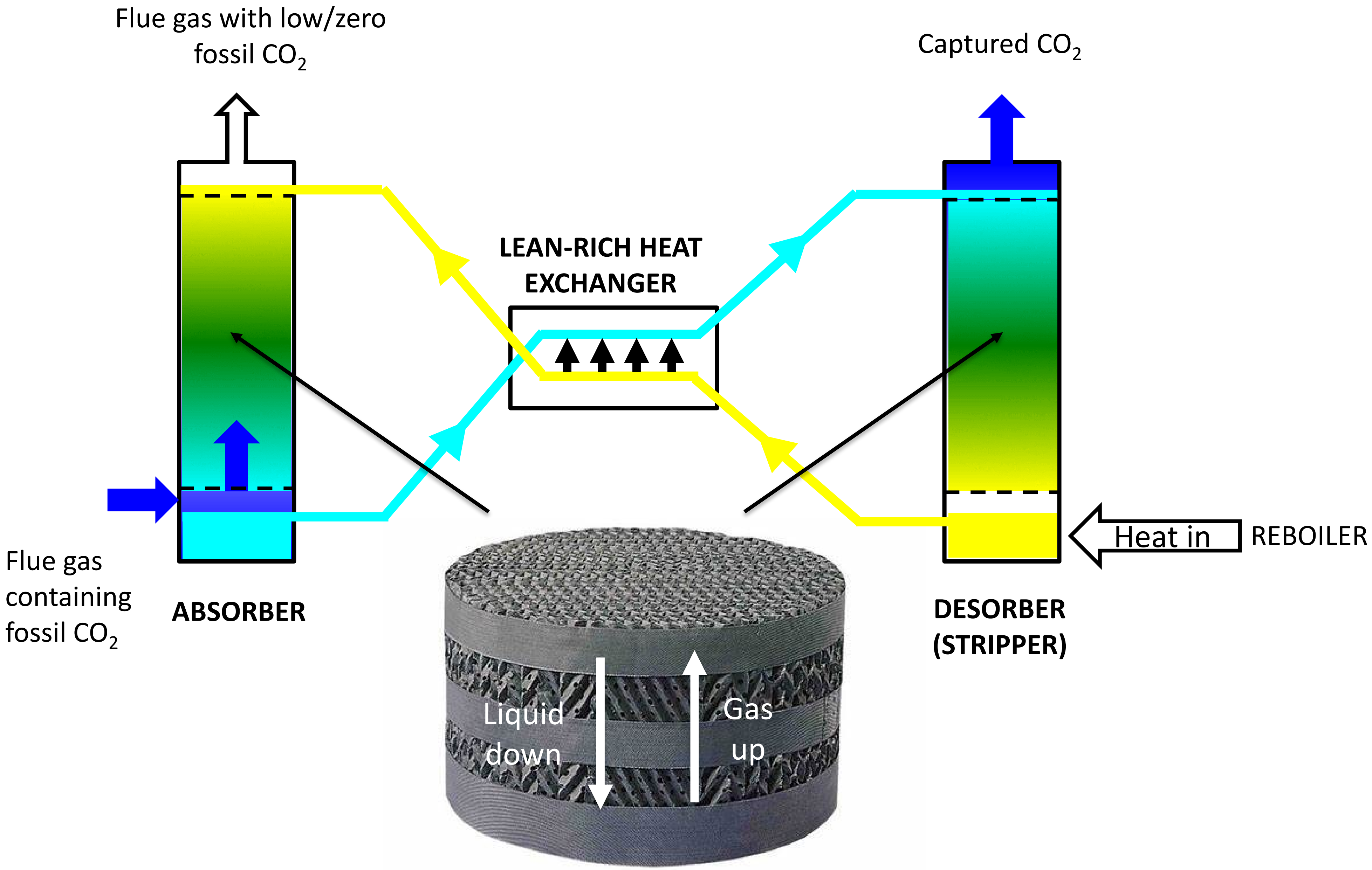
Hydrogen (pre-combustion capture?) – mix of established and novel proprietary technologies

- E: H2NorthEast
- E: Uniper Humber Hub Blue Project
- ~~E: bpH2Teesside~~
- E: Hydrogen to Humber (H2H) Saltend
- H: Project Cavendish
- H: HyNet Hydrogen Production Project (HPP)
- S: Acorn Hydrogen
- S: Fife Hydrogen Hub



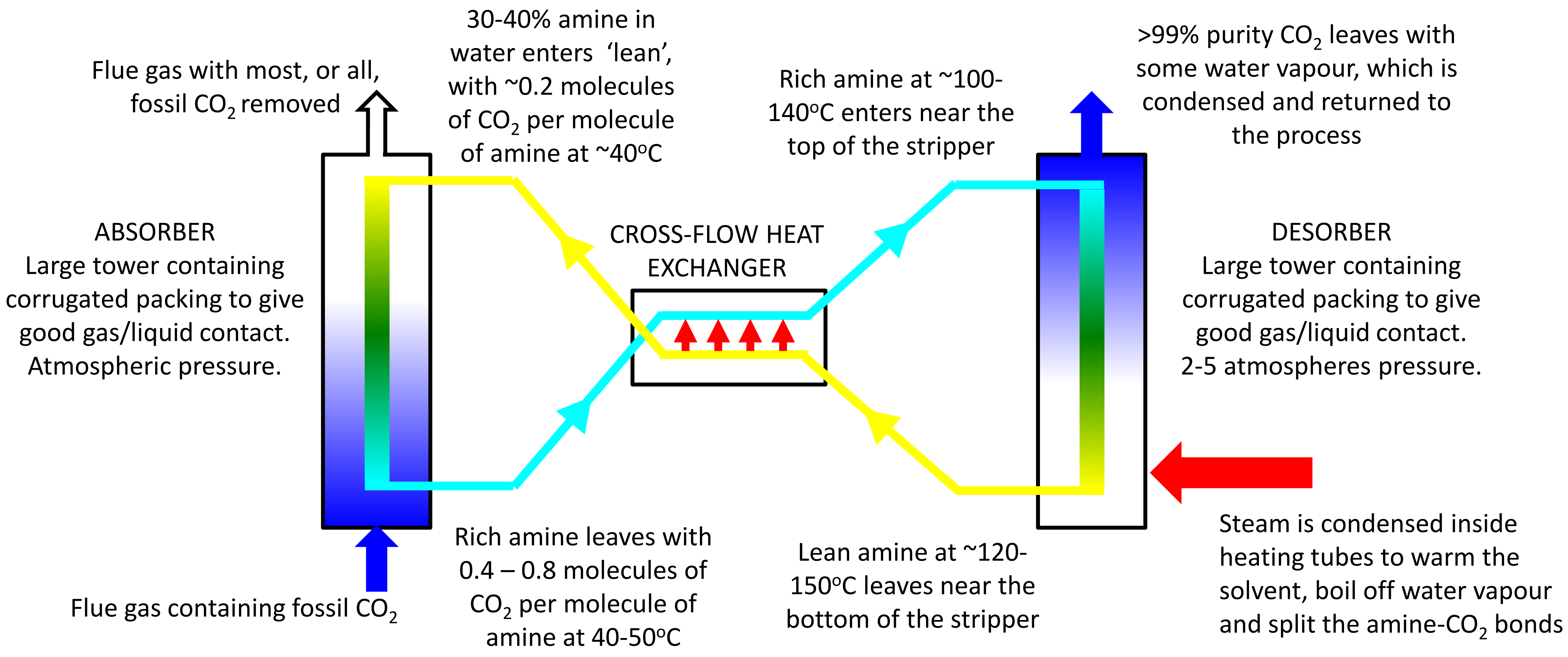
A. Hydrogen for use as hydrogen –
low cost per tonne of CO_2 avoided
Natural gas equal to H_2 CV
Natural gas for conversion losses
Hydrogen production
Hydrogen for use as hydrogen: in ammonia for fertiliser, refining, chemicals
Carbon in the natural gas rejected as CO_2
Before
After
Natural gas equal to H_2 CV
Natural gas for conversion losses
Hydrogen production
Hydrogen use as hydrogen
Carbon in the natural gas rejected as CO_2
CO_2 purification & compression
CO_2 transport and storage
Extra costs for Type A blue hydrogen projects
B. Hydrogen for use as a fuel
– high cost per tonne of CO_2 avoide
Natural gas
Natural gas use as a fuel
Before
After
Natural gas equal to H_2 CV
Natural gas for conversion losses
Hydrogen production
H_2
Hydrogen use as a fuel
Possible mod's for H_2 use
Carbon in the natural gas rejected as CO_2
Possible hydrogen storage
CO_2 purification & compression
CO_2 transport and storage
Hydrogen transport
Extra costs for Type B blue hydrogen projects

The basic principles of a post-combustion capture system



The basic principles of a post-combustion capture (PCC) system
Capable of up to 100% capture of added CO_2

- Numbers shown are typical ranges but they will vary between different amines/amine mixtures and depending on how the PCC system is designed and operated



More detailed PCC flow diagram with essential solvent reclaiming equipment

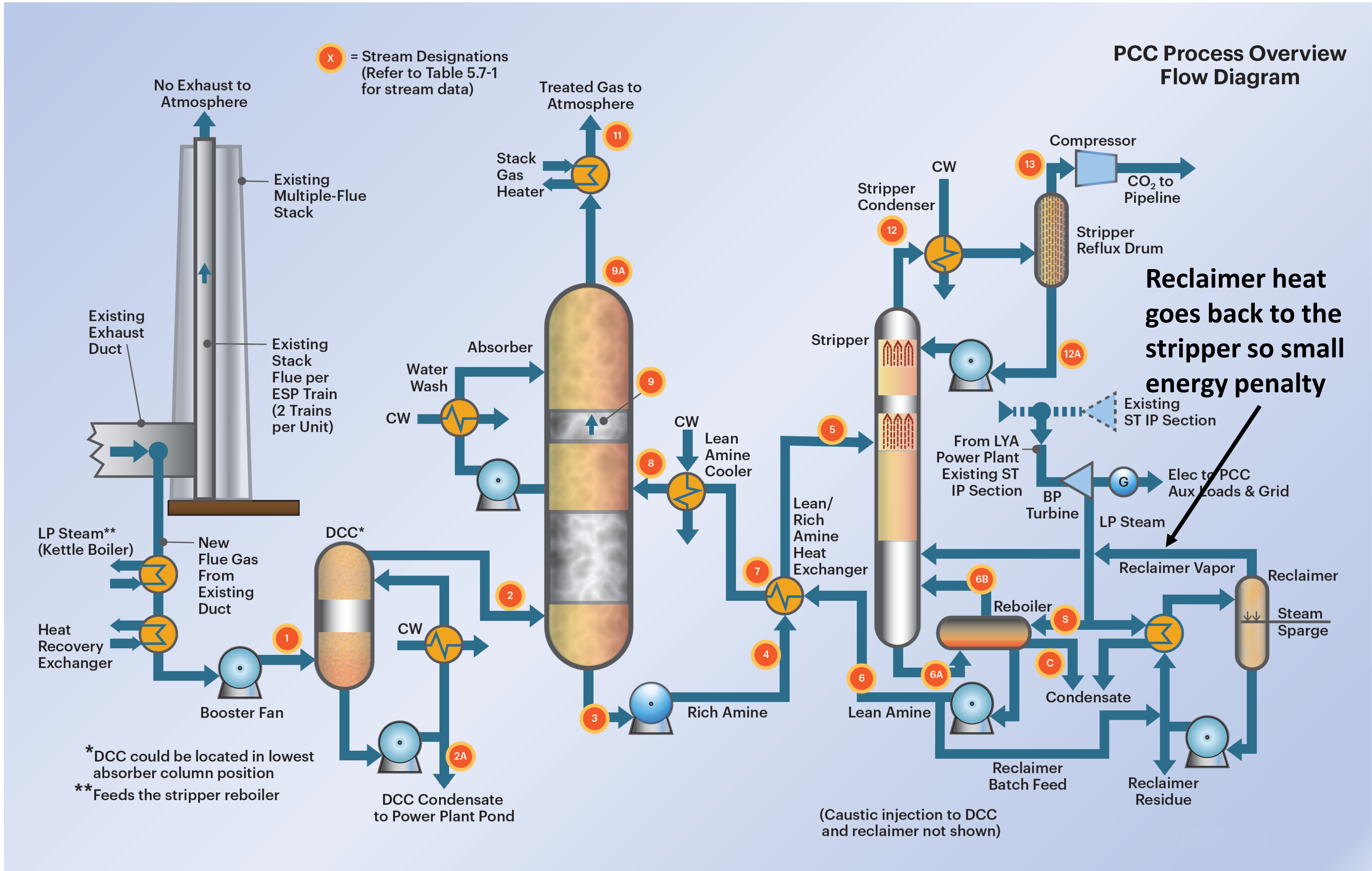
- This is a retrofit study for a brown coal power plant in Australia
- Bechtel (2018) for CO2CRC, Retrofitting an Australian Brown Coal Power Station with Post-Combustion Capture, https://ukccsrc.ac.uk/wp-content/uploads/2022/10/Retrofit-Main-Report-Final-Final-in-CO2CRC-webpage.pdf

- Some special features for this MEA plant are:

a) Continuous reclaimer, venting into desorber to recover thermal energy so high reclaiming rates

b) Typically will reclaim one inventory volume in a period of between one week to one month

c) Can reject >99% of MEA impurities in simple reclaimer with heat recovery – probably not possible with blends



World 1st: SaskPower, SK, Canada, 2014: Boundary Dam Unit 3 was rebuilt with PCC

A fully-integrated PCC system designed to capture ~90% of the Unit 3 CO_2, ~ 1MtCO_2/yr

Preston (2015) *Integrated Carbon Capture and Storage Project at Saskpower's Boundary Dam Power Station*, IEAGHG Report 2015-06. https://ieaghg.org/docs/General_Docs/Reports/2015-06.pdf

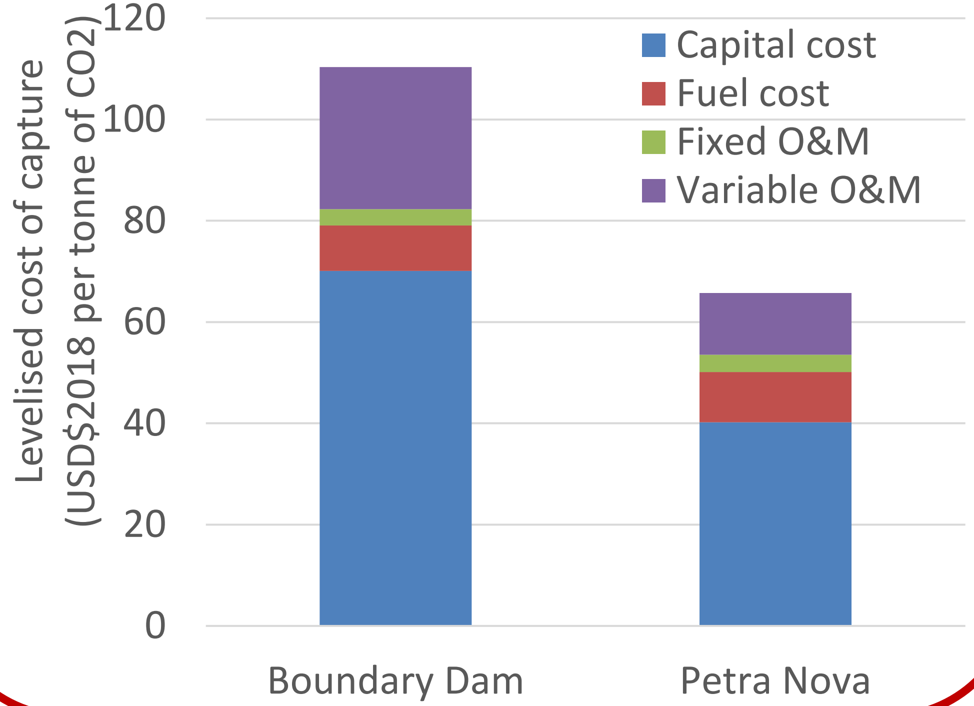
World 2nd: Petra Nova is a joint venture between NRG Energy and JX Nippon Oil & Gas

- Designed to capture ~1.6 $MtCO_2$/yr from NRG Energy's WA Parish generating station southwest of Houston, TX
- Became operational in early January 2017 - shut down in mid 2020 – reported to have restarted

Net Zero Teesside gas power plant with CCS – uses a new Shell Cansolv solvent

Reported capture costs for BD3 and Petra Nova – issues with solvent management

(GCCSI (2019) *Global Status of CCS Report: 2019.* https://www.globalccsinstitute.com/resources/publications-reports-research/global-status-of-ccs-report-2019/)



- 'Variable O&M' costs are likely to be predominantly for solvent management and replacement.
- Cost data normalised to 2017 values.
- Stated accuracy range for Boundary Dam and Petra Nova: -10% to +15%.
- Proprietary solvents reported as being used in these projects:

Boundary Dam 3: Cansolv DC-103
https://www.carboncapturejournal.com/news/saskpower-boundary-dam-project/2775.aspx?Category=allll

Petra Nova: MHI KS-1
http://www.mhi.co.jp/technology/review/pdf/e551/e551032.pdf

For Boundary Dam, which captures less than 1MtCO_2/yr, annual costs for solvent replacement alone were stated by the SaskPower chairman as $17.3M in 2015, $14.6M in 2016 (SaskPower, 2016) and reported to a government committee as $13.6M in 2017 (SaskPower, 2018), against initially-predicted costs of $5M. These solvent replacement costs would be consistent with the level of variable operation and maintenance (O&M) costs above.

SaskPower (2016) *A Word from the President on Smart Meters and Carbon Capture and Storage*, Blog on SaskPower web site, December 16, 2016.

SaskPower (2018) *Letter to Herb Cox, Chairman, Standing Committee on Crown and Central Agencies, Government of Saskatchewan*.
http://docs.legassembly.sk.ca/legdocs/Legislative%20Committees/CCA/Tableddocs/CCA%2061-28%20SaskPower%20Responses%20to%20questions%20raised%20at%20the%20June%2027,%202018%20meeting.pdf

Challenges

- Deployment **MUST** work more-or-less on time, on budget and with performance that stands up to scrutiny - any problems need to be fixed fast

- It may be impossible to permit some additional amine capture plants in clusters on the basis of permits awarded so far

Environment Agency

Research and analysis

The cumulative air quality impacts of net zero technologies - a case study of the Humber and Teesside industrial clusters: summary

Published 7 October 2025

- Costs need to come down

Opportunities

- Getting the above more-or-less right and learning by doing for real '2nd Generation' projects

- Combining DACCS with point-source capture to give the UK a relative cost advantage

Mobile phones – an example of how cost reduction is achieved once a technology starts to be deployed through incremental learning, innovation and development

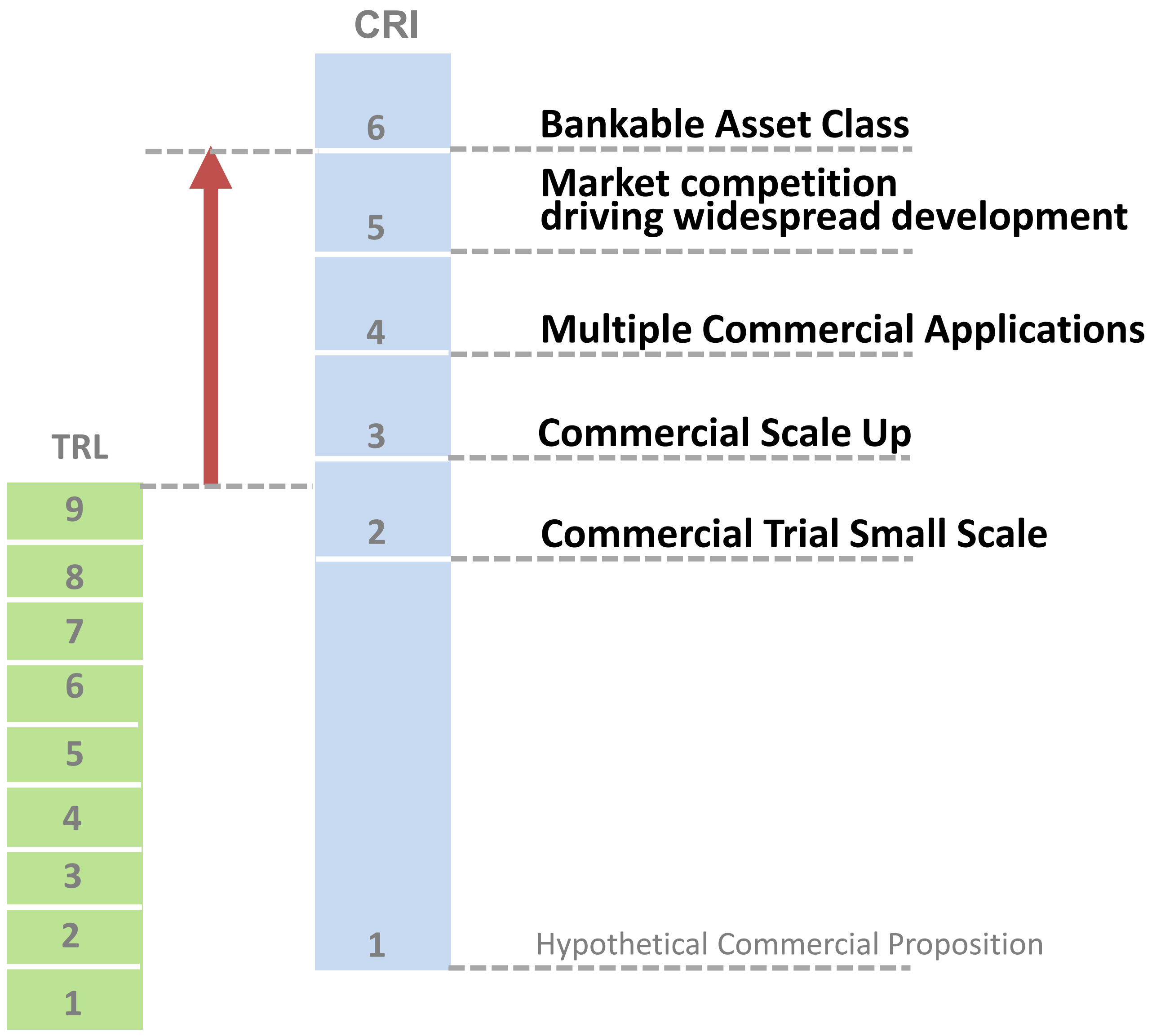
- Very few major changes in approach (i.e. really just one – the smartphone?) have been required to achieve a lot of improvements and even then the new models had many elements in common with previous examples
- Fundamental research on a very wide range of component technologies has been essential for making progress
- Even with a ‘throw away’ commodity like mobile phones, updates in service, via software and add-ons, are also important
- **The lifecycle time for each evolution in mobile phones is much shorter than for a CO_2 capture technology**

2050 is tomorrow!

https://slideplayer.com/slide/5274949/, Shona Simms, ‘How have mobile phones changed over time?’

Post- Combustion Capture is at TRL9 already - Commercial Readiness Index (CRI) for PCC now needs to be increased through incremental learning, innovation and development

- Examples of PCC are now at TRL 9, but that does not mean that research and innovation has ended on sub-systems for PCC
- This requires research at all TRLs, and research at all of the TRLs can get a fast track into commercial deployment, unlike completely new technologies that have to cross the ‘Valley of Death’ of piloting and first reference plants
- Open access is required for two-way information flow between deployment and research and innovation activities
- Applicable TRL1-9 research, including for upgrades in service, only stops when the last plants are closed!



Based on Bruce Adderley, Jeremy Carey, Jon Gibbins, Mathieu Lucquiaud and Richard Smith, “Post-Combustion Carbon Dioxide Capture Cost Reduction to 2030 and beyond”, Faraday Discussion on CCS, July 2016. http://pubs.rsc.org/en/Content/ArticleLanding/2016/FD/c6fd00046k#!divAbstract

High capture rates for net zero: experience from the COGENT project tests in China

Jon Gibbins[a,*], Lucas Joel[a], Aisha Ibrahim[a], Daniel Mullen[b], Abdulaziz Gheit[c], Muhammad Akram[c], Changyou Xia[d], Xi Liang[d], Qiang Jing[e], Weiming Zhao[e], Mathieu Lucquiaud[a]

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[b] SSE Thermal, Reading, United Kingdom

[c] Translational Energy Research Centre, The University of Sheffield, United Kingdom

[d] UK-China (Guangdong) CCUS Centre, 1 Tianfeng Road, Science City, Guangzhou 510520, China

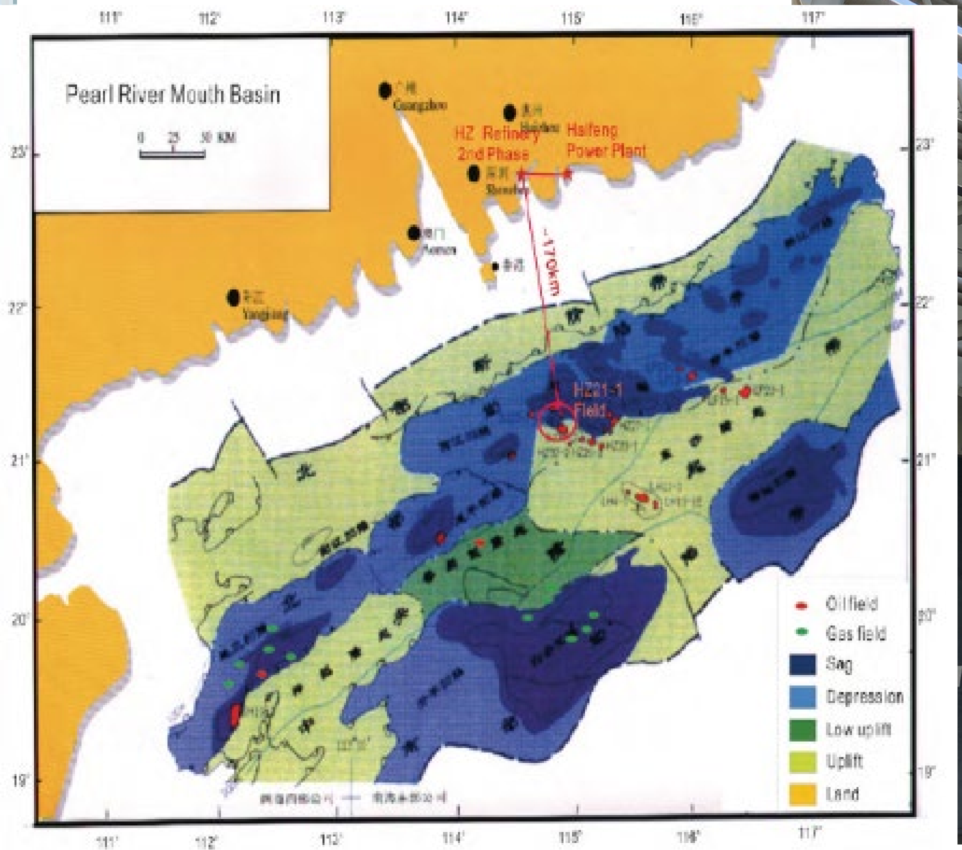
[e] Shenzhen Shenshan Special Cooperation Zone China Resources Power Co., Ltd, Shenzhen 518066, China

COGENT – Capture Operation with Greater Economy for Net-zero Targets

STRETCHER - System Tuning for Regenerator Efficiency and Target Capture with High Exit Rich

Based on projects funded by FCDO, DESNZ, building on previous UKCCSRC/EPSRC and University of Sheffield projects


China Resources Haifeng Power Plant


Pearl River Mouth Basin
Guangzhou
HZ Refinery 2nd Phase
Haifeng Power Plant
~170km
HZ21-1 Field
Oilfield
Gas field
Sag
Depression
Low uplift
Uplift
Land


Guangdong Carbon Capture Test Platform

A visit in August 2024 to discuss the theory behind high CO_2 capture rates with the Haifeng capture plant team, familiarize the GDCCUS/UKCCSRC team with the Haifeng pilot plant and plan the test campaign.

The once-through reboiler at Haifeng is an industry standard on commercial plants but is unusual for a pilot plant.

Principles for obtaining ultra-high capture rates:

1. **Produce the lowest possible lean loading without wasted energy** for a given desorber pressure (and hence temperature range) by operating at the **desorber inflection point**.

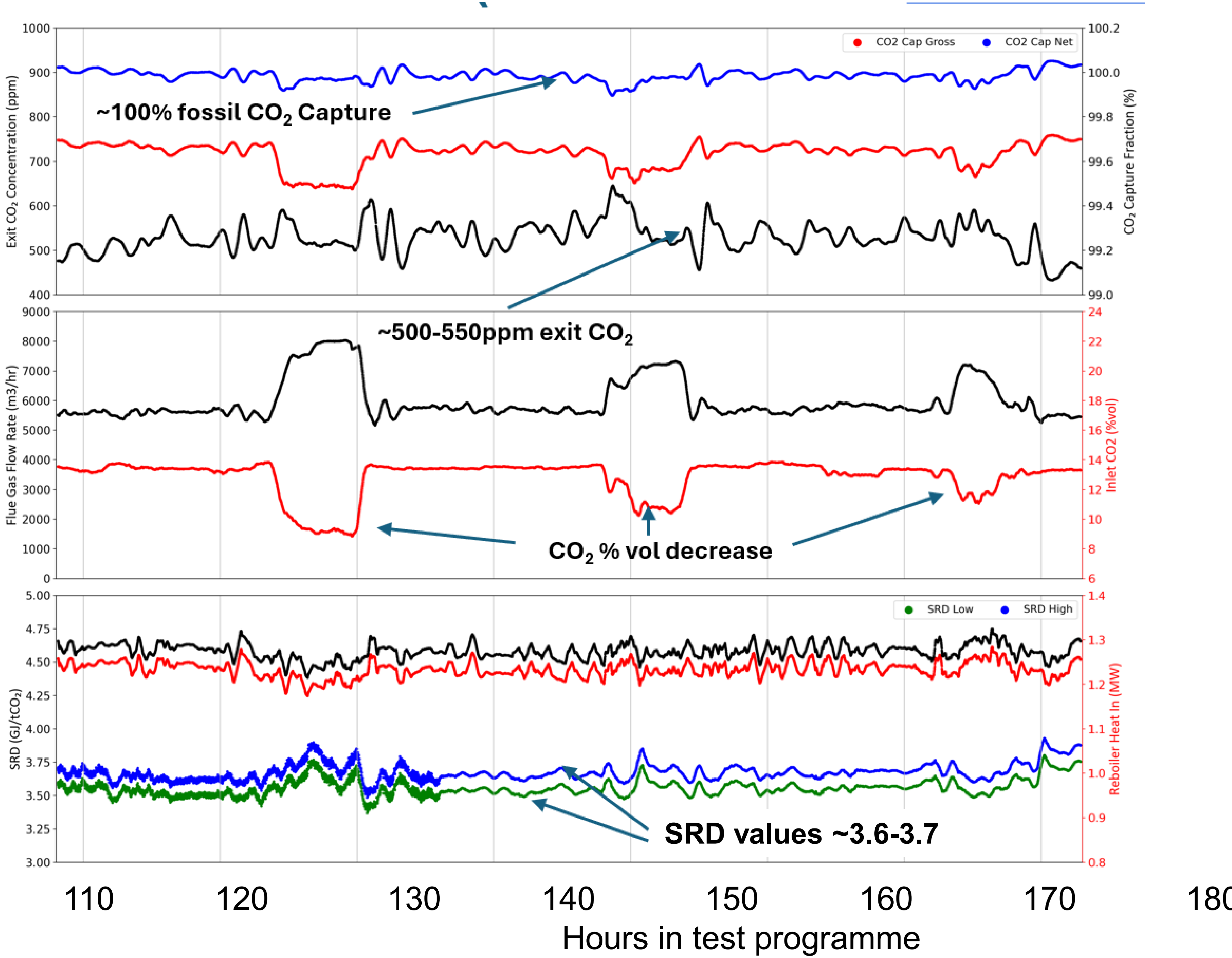
2. **Use the lean solvent flow rate that gives the optimum combination of capture rate and rich loading** – and hence specific reboiler duty – for that lean loading, given the **absorber corner** constraints.

3. Use **lean and rich solvent storage** to allow the desorber and absorber to be operated with the most rapid possible feedback and so be optimised independently in the short term, while obviously still also balancing in the long term.

In recent tests in December 2025 the desorber pressure was increased to 2.4 bara, giving a lower lean loading at the inflection point that allowed a capture rate of ~100% of the fossil CO_2 to be achieved with reasonable regeneration energy values.

The plant was operated under continuous control for a period of 75 hours.

Hope to establish test facilities for solvent management and emissions in the UK – these are what ultimately limit commercial performance.



CoDACCS - combining DACCS with point-source capture to give the UK a relative cost advantage

- DACCS can be done anywhere in the world for the same climate benefit and only makes sense at scale when there is effective global cooperation to tackle climate change
- So UK ‘vanilla DACCS’ will be competing with ‘vanilla DACCS’ in inherently-cheaper locations
- Something special to the UK is needed to give DACCS here a chance of being competitive:
  - Cheap electricity?
  - Cheap gas?
  - Cheap CO_2 transport and storage?
  - Cheap heat?
  - Access to existing CO_2 capture plants and CCS infrastructure – not unique, but globally in limited supply – probably the best we can do to bring down both OPEX and CAPEX
- Time-shared CoDACCS – use capture plant components and CCS infrastructure when not otherwise in use – particularly for power plants
- Parallel CoDACCS – use synergistic integration with an operating capture plant and CCS infrastructure
- Paper pre-print available
- Need to make business models and actual infrastructure CoDACCS-ready (in practice, at least not CoDACCS-impossible – **engineering not definitions**)
- Prioritise CoDACCS R,D & D **where it has the prospect of reducing costs**

A realistic set of targets for a UK CCS deployment programme supported by research and innovation

- Be a world-leading early user of CCS – and a supplier in some specialised areas building on strengths.

- Avoid showstoppers/serious setbacks in UK CCS deployment, e.g. analogues to Barendrecht, Hinckley Point C or limits on cluster growth due to amine-related emissions.

- Maintain continuity of CCS deployment to maximise UK content and retention of learning, i.e. steady expansion that re-employs teams with growing experience, not boom and bust.

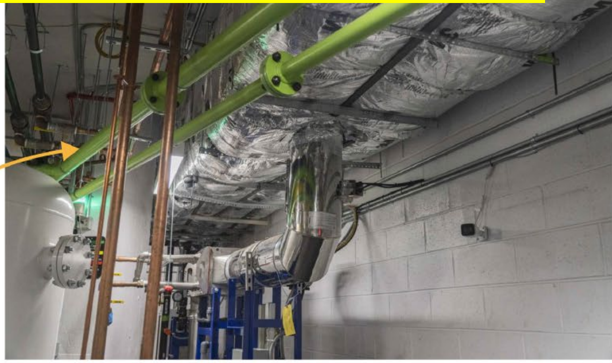
- Set examples, including this continuous improvement in the CCS infrastructure we build, that the rest of the world will want to follow (and in some cases pay us to help on) to also get to net zero, so that there is an actual climate benefit for the UK in doing this as well as some export potential.

- Get the best advantage we can from the UK's inherent geological and geographical advantages for CCS deployment to help deliver net zero (and eventually net negative) with the minimum cost (to consumers, taxpayers and industry) and the maximum benefits for jobs and broader UK economic activity – and to encourage the rest of the world to do the same.

This additional slide on very small scale carbon capture is provided for information only, with no form of recommendation. Published technical information appears to be very sparse.

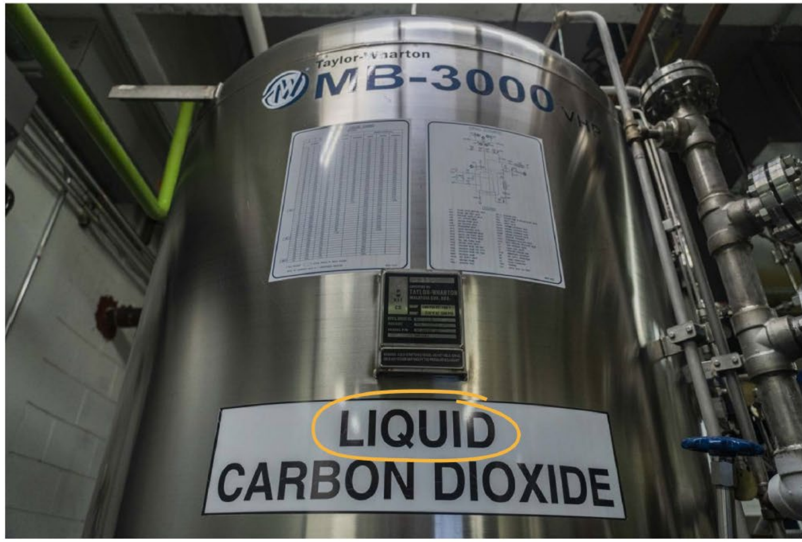
1. It starts with a building in Manhattan.

2. The boiler releases carbon dioxide.



3. Next is a complicated process involving lots of pipes.

Carbon dioxide is captured, liquefied, and stored.



CarbonQuest https://carbonquest.com/

4. The liquefied CO_2 is pumped outside the building.

Workers load it into a truck, ready for a journey.

5. Next stop: a concrete plant in Brooklyn.

NYT: A Huge City Polluter? Buildings. Here's a Surprising Fix.

March 10, 2023

https://www.nytimes.com/interactive/2023/03/10/climate/buildings-carbon-dioxide-emissions-climate.html

"The system currently captures about 60 percent of the carbon dioxide emitted by the Grand Tier's boilers …That reduces the building's overall emissions by about one-quarter, enough to meet the limits set by the new climate law. (The rest of the Grand Tier's emissions come from electricity consumption, which actually increased moderately to power CarbonQuest's compressors and cooling systems.)"