Carbon Management Technology Conference
Houston, TX
July 2019

SOME OBSERVATIONS ON CCS FROM A UK ACADEMIC PERSPECTIVE

Jon Gibbins
Director, UK CCS Research Centre
Professor of CCS, University of Sheffield
www.ukccsrc.ac.uk
Email: j.gibbins@sheffield.ac.uk

About the UKCCSRC www.ukccsrc.ac.uk

The UK Carbon Capture and Storage Research Centre (UKCCSRC) is funded by the Engineering and Physical Sciences Research Council (EPSRC) to leads and coordinates a programme of underpinning research on all aspects of carbon capture and storage (CCS) in support of basic science and UK government efforts on energy and climate change.

It has over 280 academic members from more than 40 UK universities and research institutes.

The UKCCSRC welcomes experienced industry and overseas Associate members and links to all CCS stakeholders through its CCS Community Network.

https://ukccsrc.ac.uk/membership/associate-membership
https://ukccsrc.ac.uk/membership/ccs-community-network

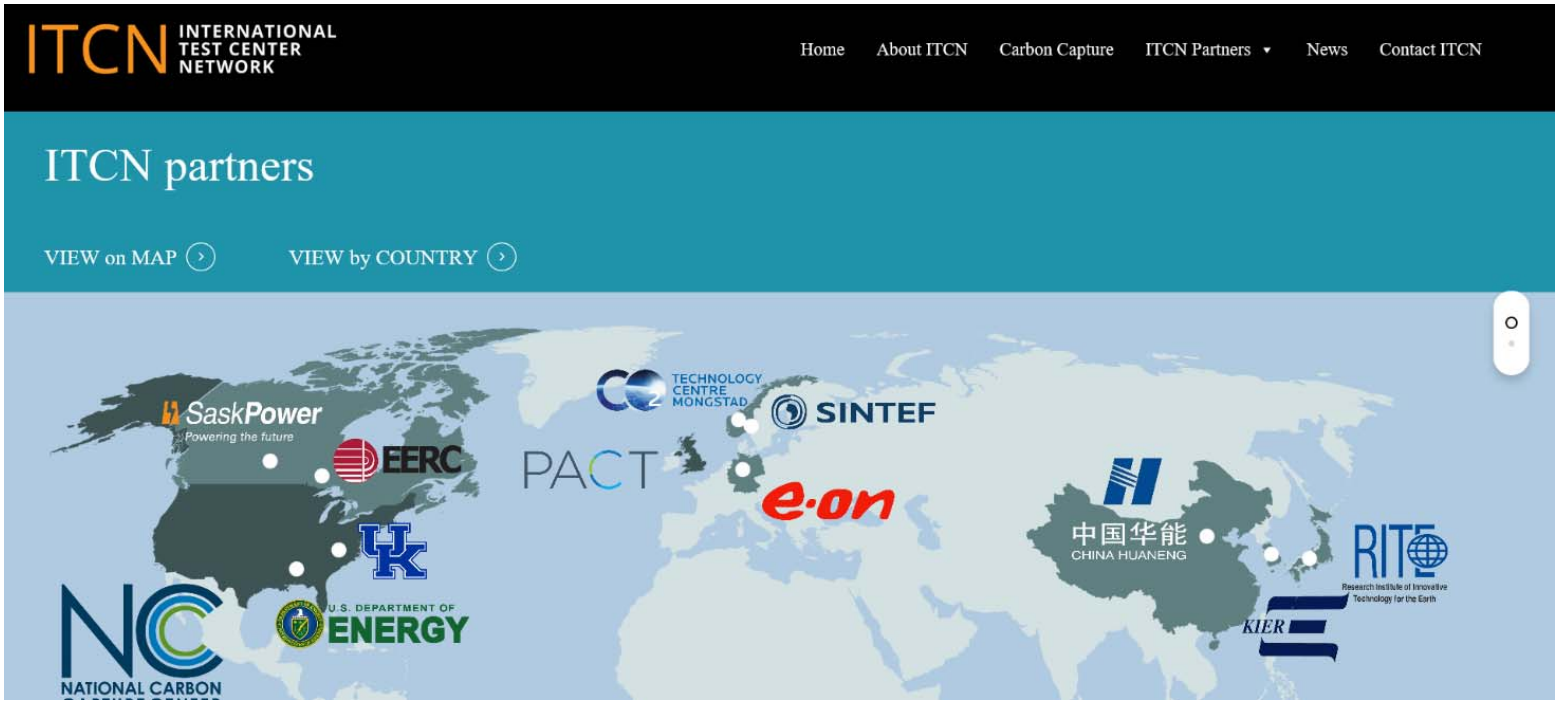
PACT: Pilot-Scale Advanced Capture Technology

A facility managed by the University of Sheffield

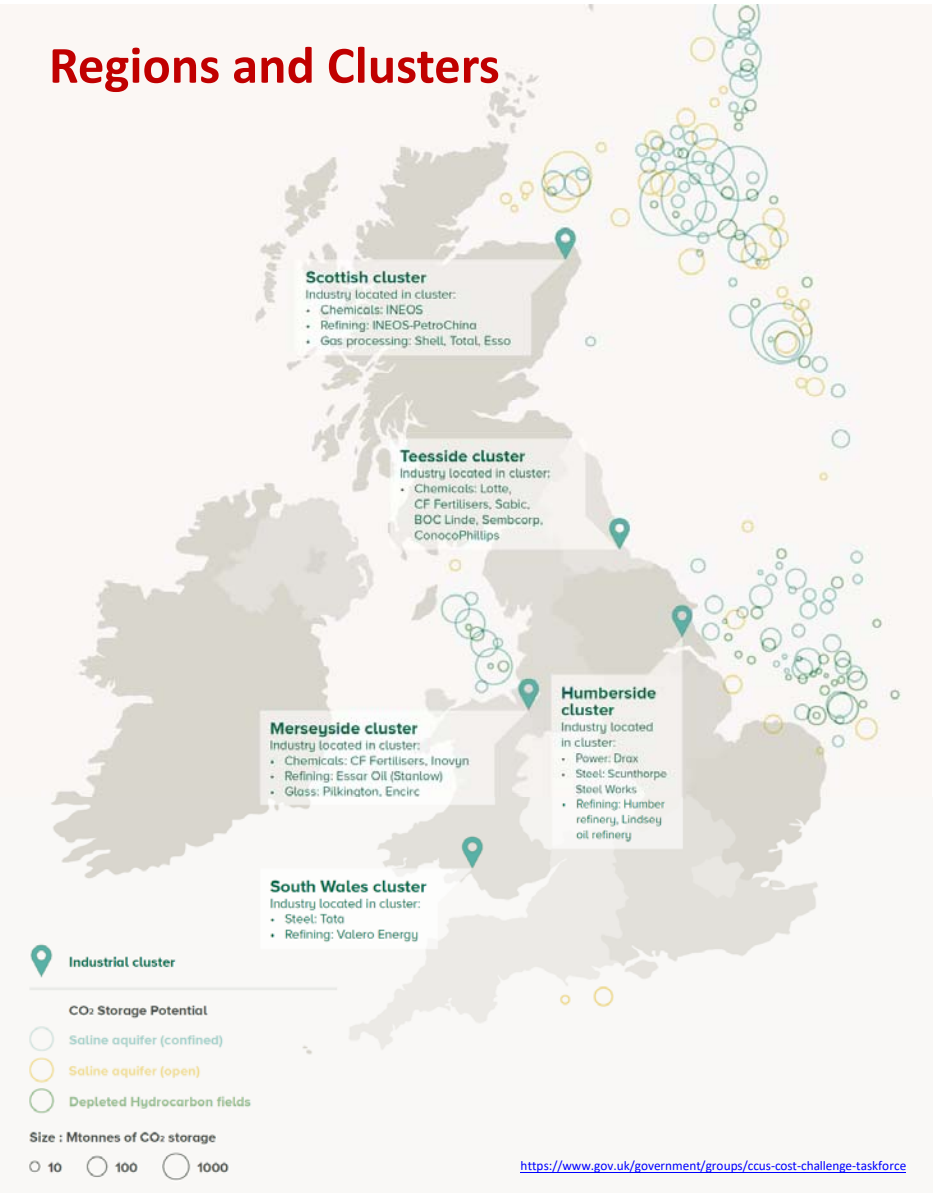
https://pact.group.shef.ac.uk/

PACT is coordinating the ITCN for 2 years

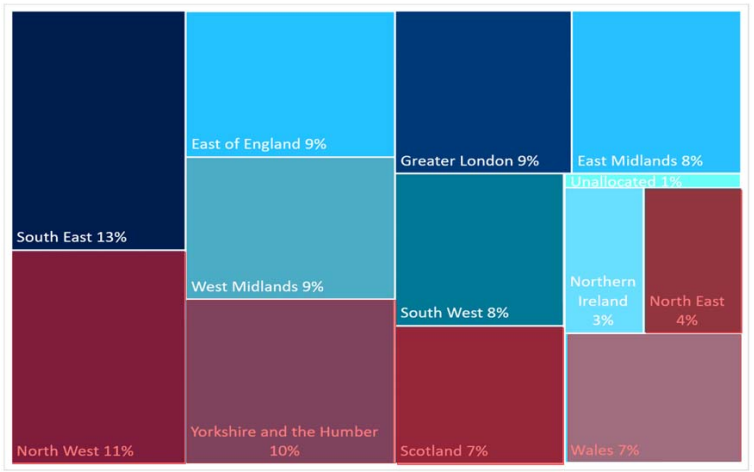
International Test Center Network https://itcn-global.org/

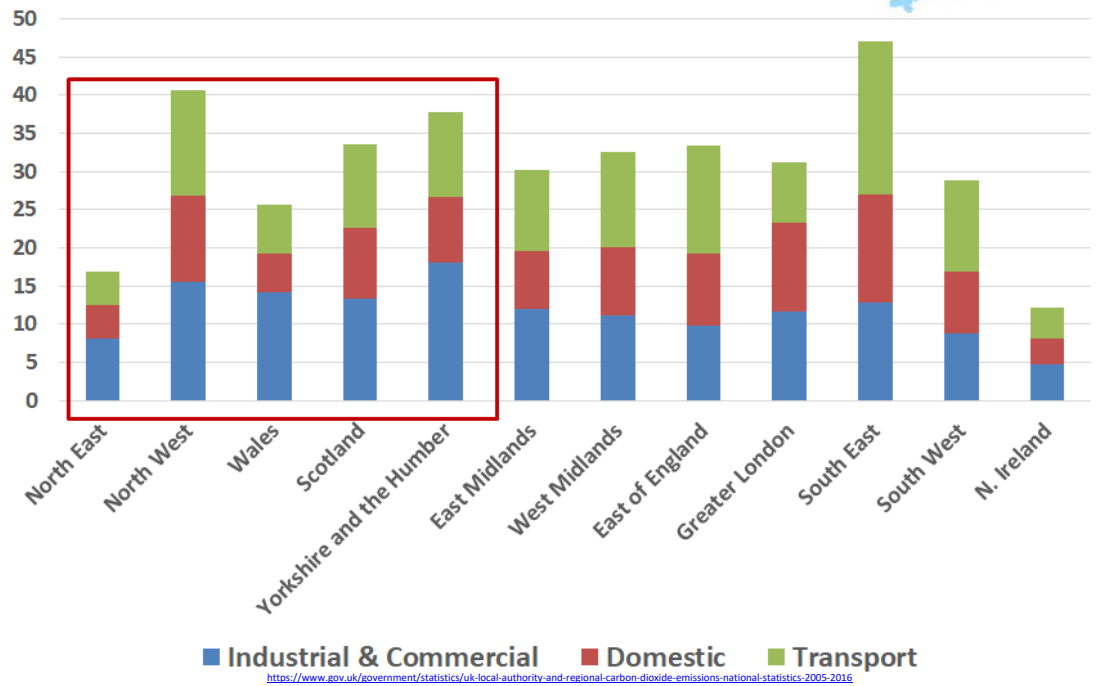


Regions and Clusters



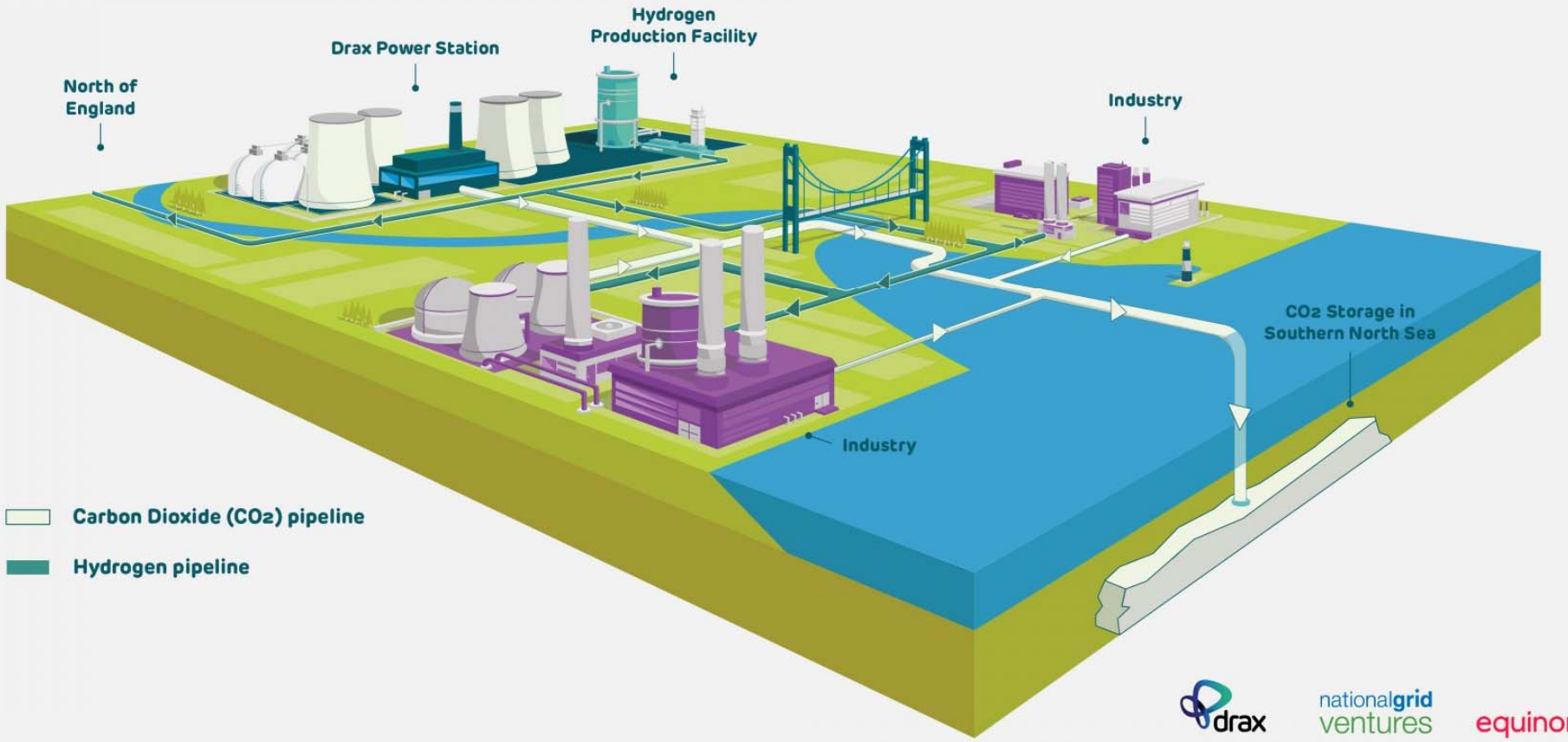
https://www.gov.uk/government/groups/ccus-cost-challenge-taskforce





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

WHAT A ZERO CARBON CLUSTER COULD LOOK LIKE IN THE HUMBER REGION



https://www.drax.com/press_release/energy-companies-announce-new-zero-carbon-uk-partnership-ccus-hydrogen-beccs-humber-equinor-national-grid/

HyNet North West

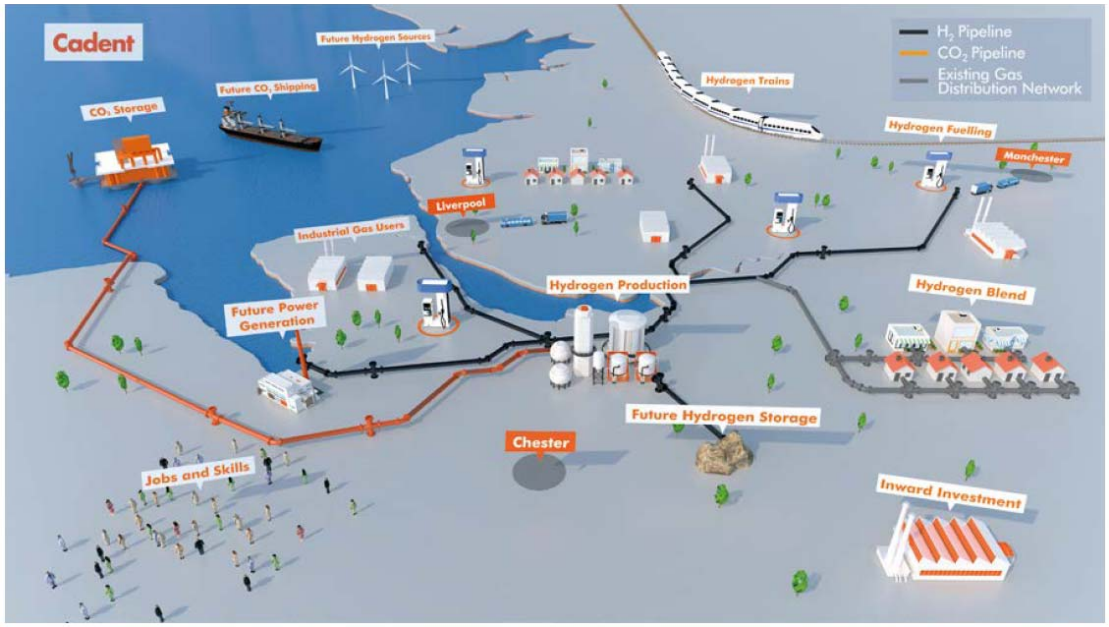
https://hynet.co.uk/

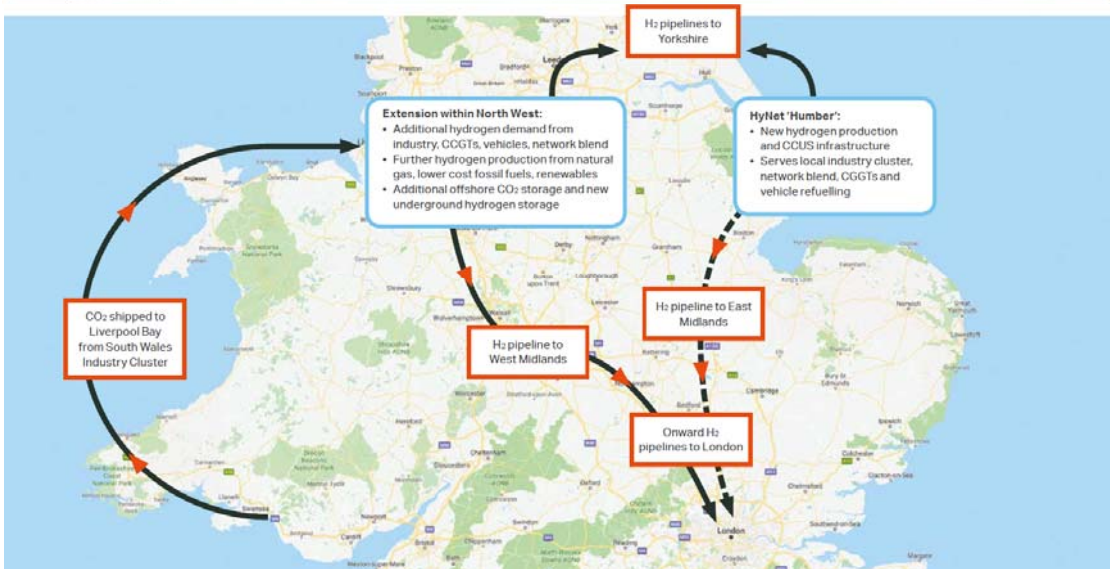
Table 2.2: HyNet Capex Data

Project Element[1]	Related Information	Average Unit Cost (£M)	Total Cost (£M)
Hydrogen Production and CO_2 Capture	HPCC plant comprises two ATRs, producing around 890 MW of hydrogen at pressure[2]	£256/unit	£513
Hydrogen Transport	Transport of 890 MW of hydrogen in new 109km onshore hydrogen pipeline from HPCC plant to industrial cluster and blend injection points	£1.65/km	£178
Hydrogen Compression and Injection to LTS	No compression required at HPCC plant, but additional equipment needed to inject hydrogen into the four LTS injection sites	£5/site	£20
Conversion of Industry to Hydrogen	Modifications to boilers, kilns and furnaces at 10 large industrial sites	£7.8/site	£78
CO_2 Transport	New 31km onshore pipeline from ATR plant to existing pipeline at Connah's Quay[3]	£2.03/km	£63
CO_2 Facilities	Modifications to existing Hamilton platform	n/a	£27
CO_2 Storage	Includes design, procurement, construction and commissioning of wells, licensing and permitting	n/a	£31
		TOTAL	£920

Notes:

1. The battery limit for CCUS costs is from the inlet to the CO_2 compressor at the HPCC plant
2. Includes costs of CO_2 compression
3. Also includes costs for modifications to existing gas pipelines which are repurposed for CO_2





‘South Wales’ + ‘HyNet’ form ‘West Coast cluster’

15Mt CO_2/yr injection capacity
1.5bt CO_2 storage - sufficient for 100 years
5Mt CO_2/yr from South Wales

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Developing a South Wales Cluster

nationalgrid

Progressive energy

RICE
Reducing Industrial Carbon Emissions
Lleihau Allyriadau Carbon Diwydiannol

FLEXIS

CARDIFF UNIVERSITY
PRIFYSGOL CAERDYDD
ABERYSTWYTH
BANGOR
University of South Wales Prifysgol De Cymru
Swansea University Prifysgol Abertawe

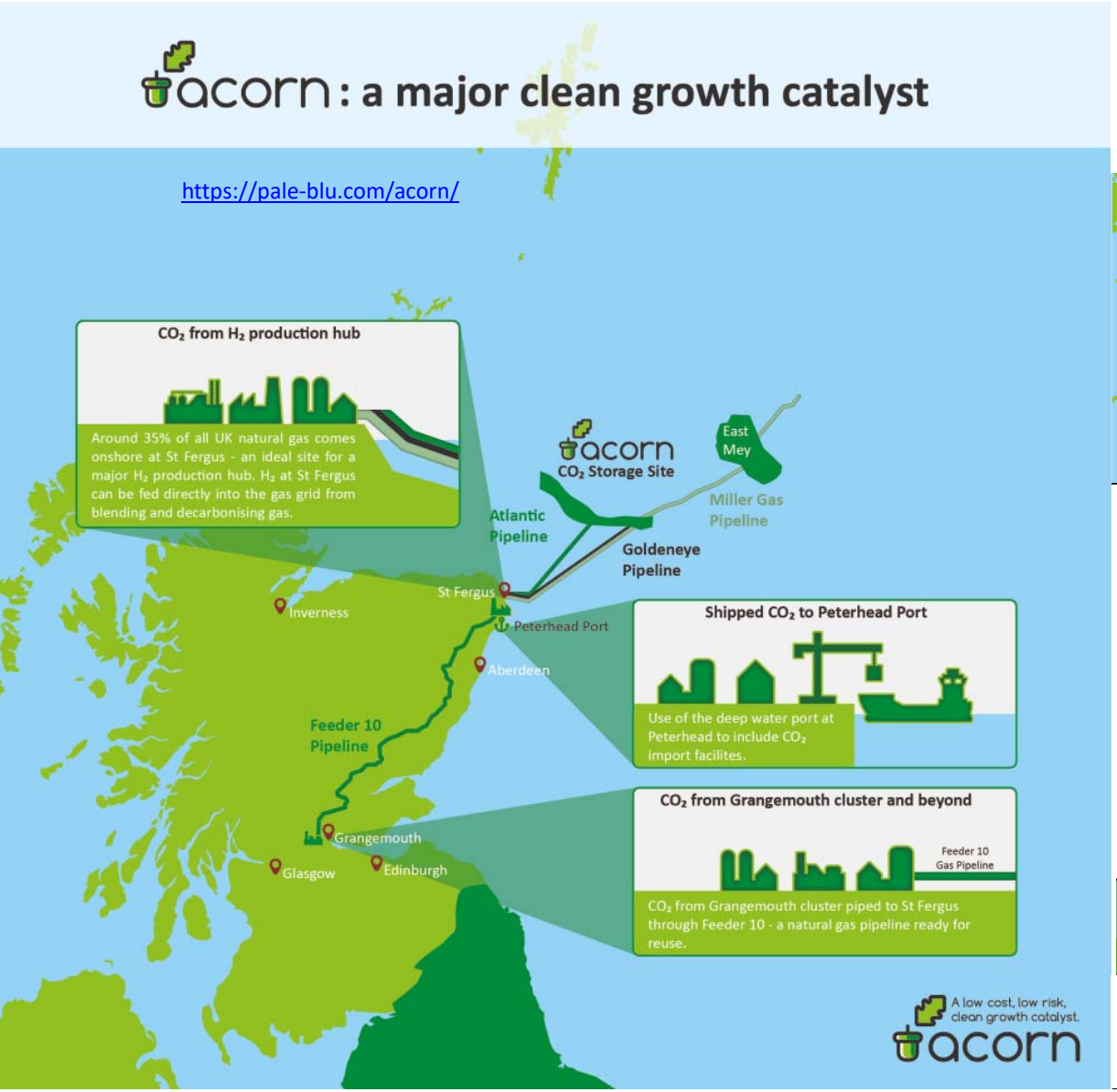
WALES&WEST UTILITIES
WESTERN POWER DISTRIBUTION
Dŵr Cymru Welsh Water
Cadent
UKCCS RESEARCH CENTRE
CO2 Chem

Credit: Chris Williams, Manager, Energy and CO_2 Research, Tata Steel

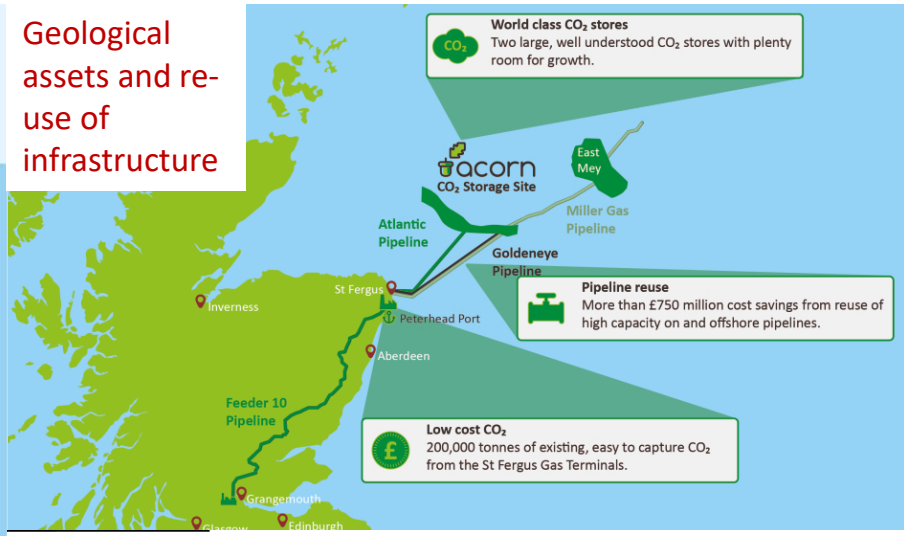
Thanks to Google Maps

acorn: a major clean growth catalyst

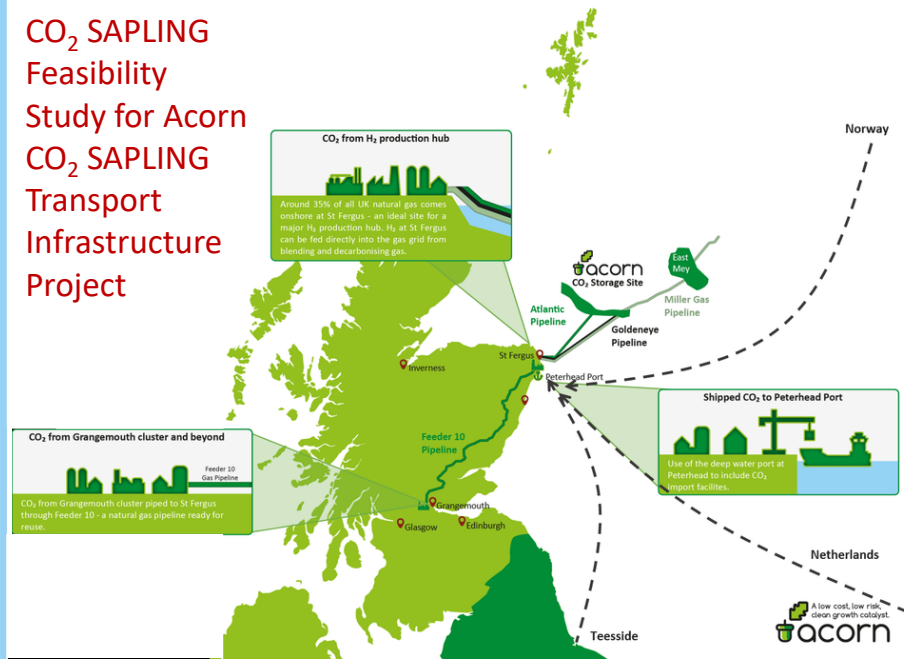
https://pale-blu.com/acorn/



Geological assets and re-use of infrastructure



CO_2 SAPLING Feasibility Study for Acorn CO_2 SAPLING Transport Infrastructure Project



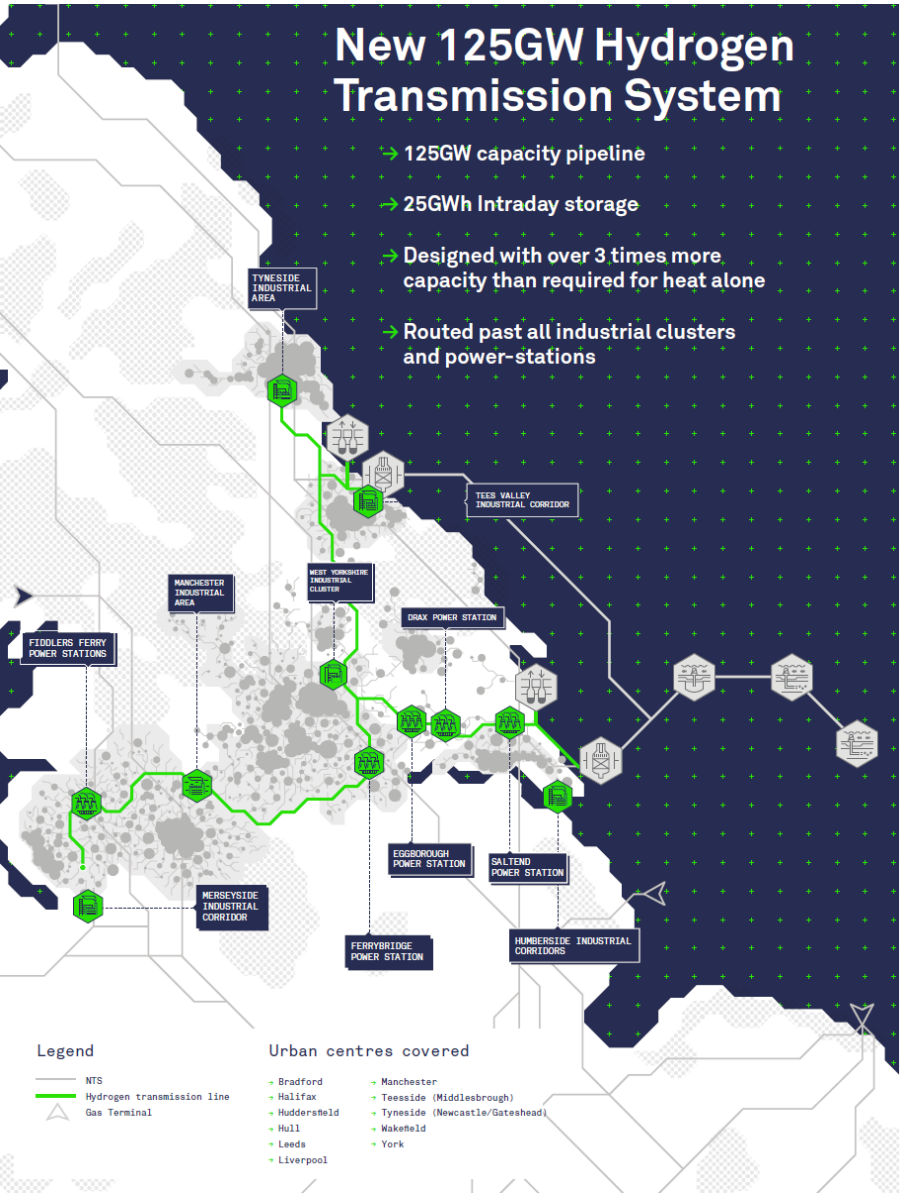
Teesside – Clean Gas Project

https://oilandgasclimateinitiative.com/climate-investments-announces-progression-of-the-uks-first-commercial-full-chain-carbon-capture-utilization-and-storage-project/

November 28, 2018, London, UK:
OGCI Climate Investments announced that it is entering into a strategic partnership with BP, ENI, Equinor, Occidental Petroleum, Shell and Total to progress the Clean Gas Project, the UK's first commercial full-chain Carbon Capture Utilization and Storage (CCUS) project in Teesside. The Clean Gas Project could form the heart of the Tees Valley CCUS Cluster that will deploy commercially viable, safe, environmentally responsible CCUS at scale. It will combine CO_2 capture from new efficient low-carbon power generation and local industrial emitters in Teesside.

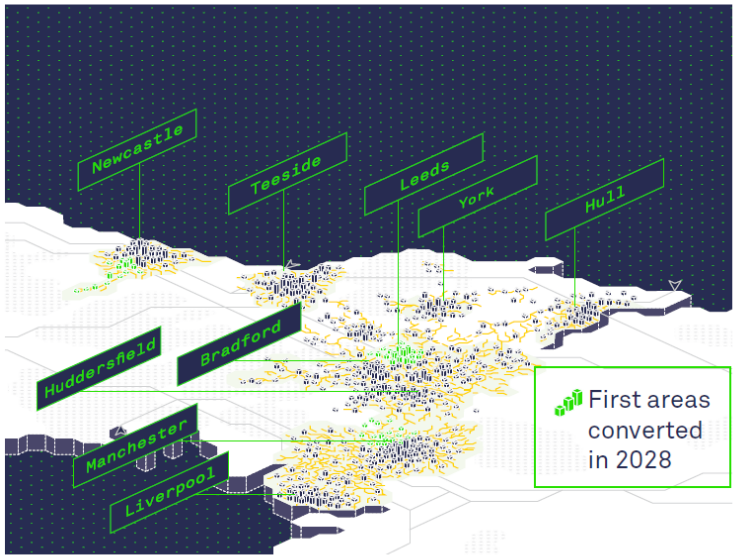
ETI gas power with CCS project

https://www.eti.co.uk/programmes/carbon-capture-storage/thermal-power-with-ccs



Conversion of The North of England

- Conversion 2028 – 2034
- Max time off gas 1-5 days
- Vulnerable customers less than 1 day off gas
- Supply and demand managed through engineering design.



↑ Conversion areas, 2028 year one position

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Key Technical Parameters

H_2 Facility

Hydrogen production
12.15 GW
(12,150 times larger than 1 MW)

Carbon capture and storage scaling
20 Mtpa
by 2035

H_2 Storage

Hydrogen storage
8,052 GWh ≡62,000
Australian mega batteries

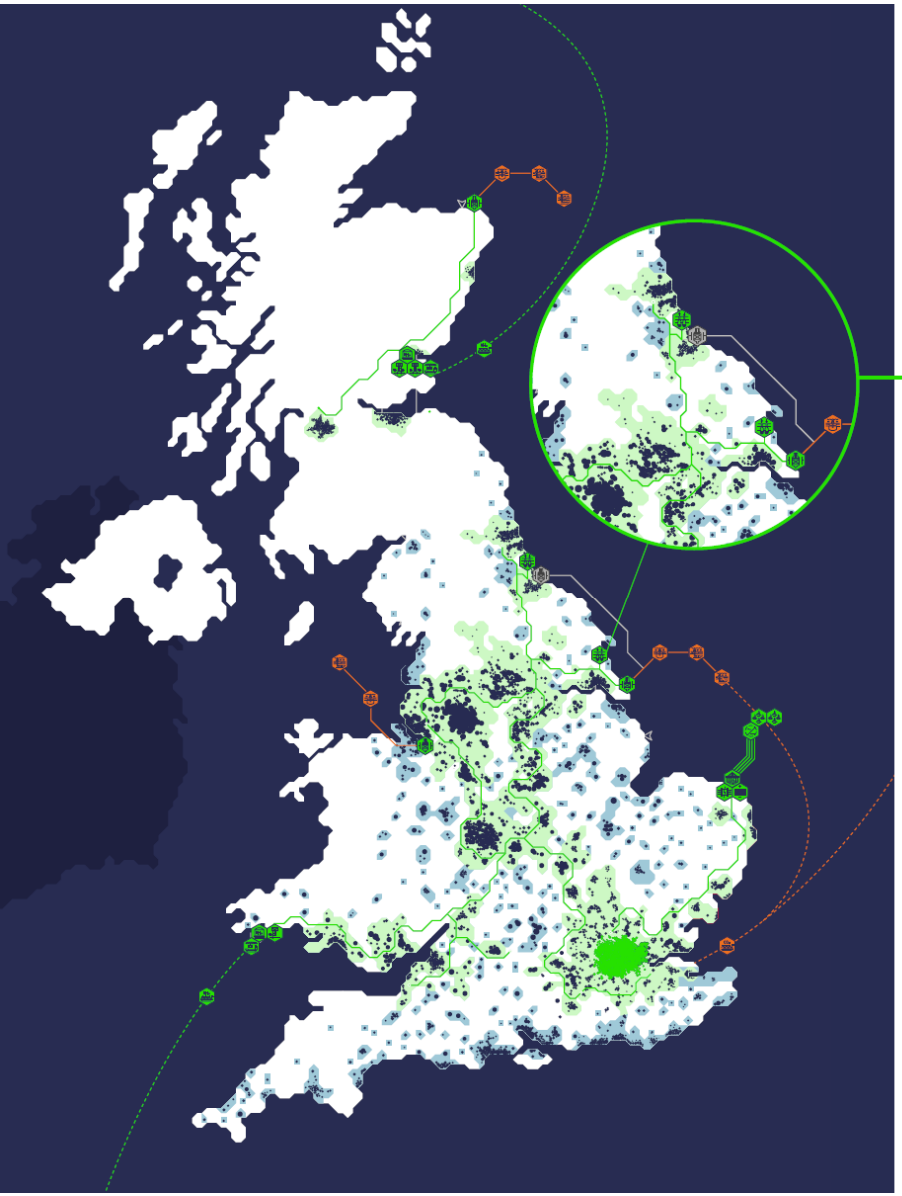
NTS

Hydrogen Transmission System
125 GW capacity + 25 GWh Intraday storage (≈200 Australian mega batteries)

Capital costs (£bn)

H_2 production	8.52
H_2 storage	1.99
CO_2 T&S	1.34
H_2 transport	3.43
Conversion	7.50
Total	22.78

https://www.northerngasnetworks.co.uk/wp-content/uploads/2018/11/H21-Meeting-UK-Climate-Change-Obligations.pdf



UK Hydrogen Conversion Position in 2050

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Phase 1
H21 NoE
Conversion 2028 - 2034
14% UK heat
30% Power (H21 XL) for North of England

Phase 2
H21 South Yorkshire & East/ West Midlands
2033-2038

Phase 3
H21 Scotland
2030-2032

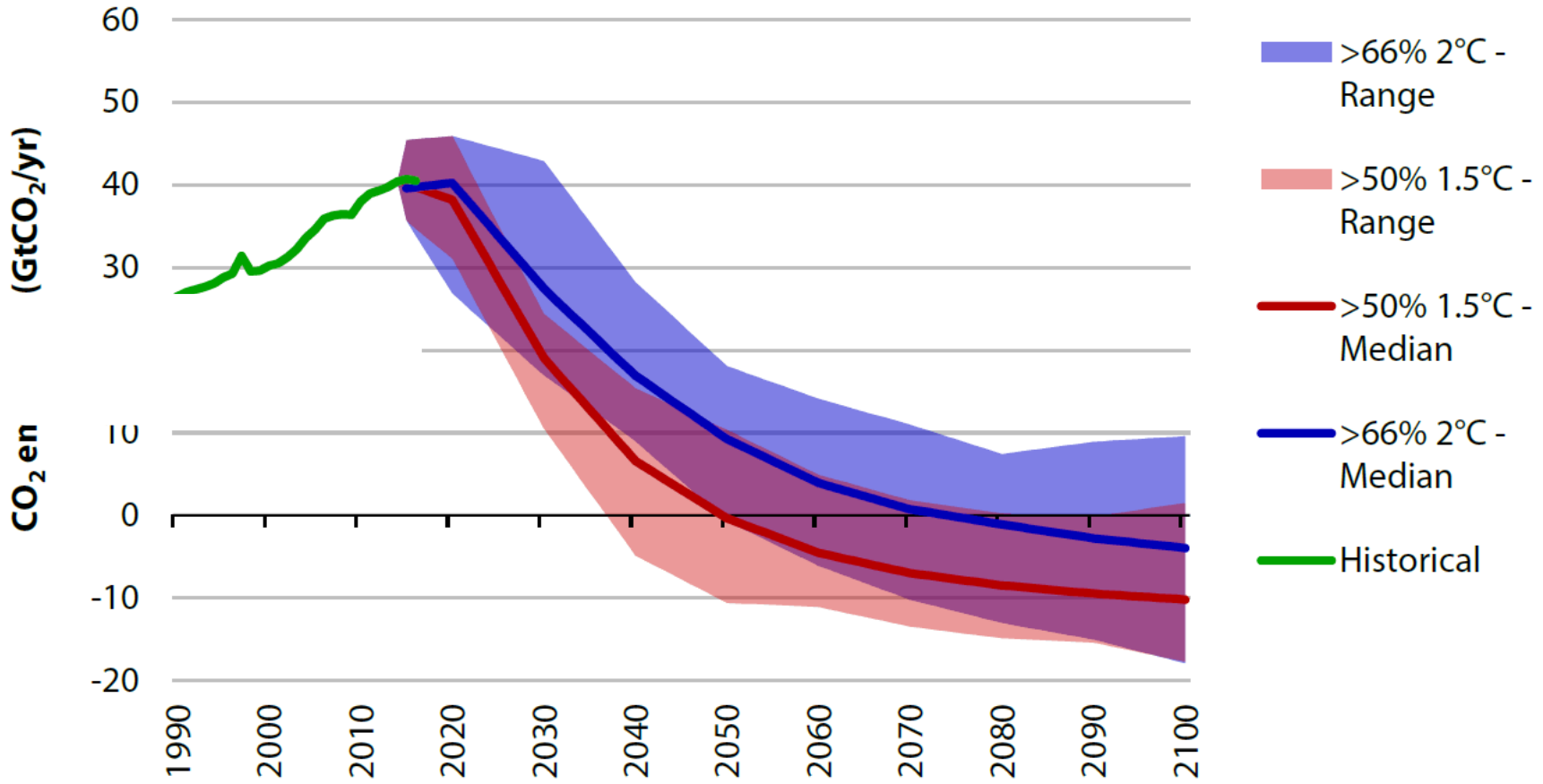
Phase 4
H21 South Wales & South West
2036-2037

Phase 5
H21 East Anglia & Home Counties
2040-2045

Phase 6
H21 London
2045-2050

https://www.northerngasnetworks.co.uk/wp-content/uploads/2018/11/H21-Meeting-UK-Climate-Change-Obligations.pdf

Q: How to get a return on achieving net zero?
A: MUST get the rest of the world to do the same.

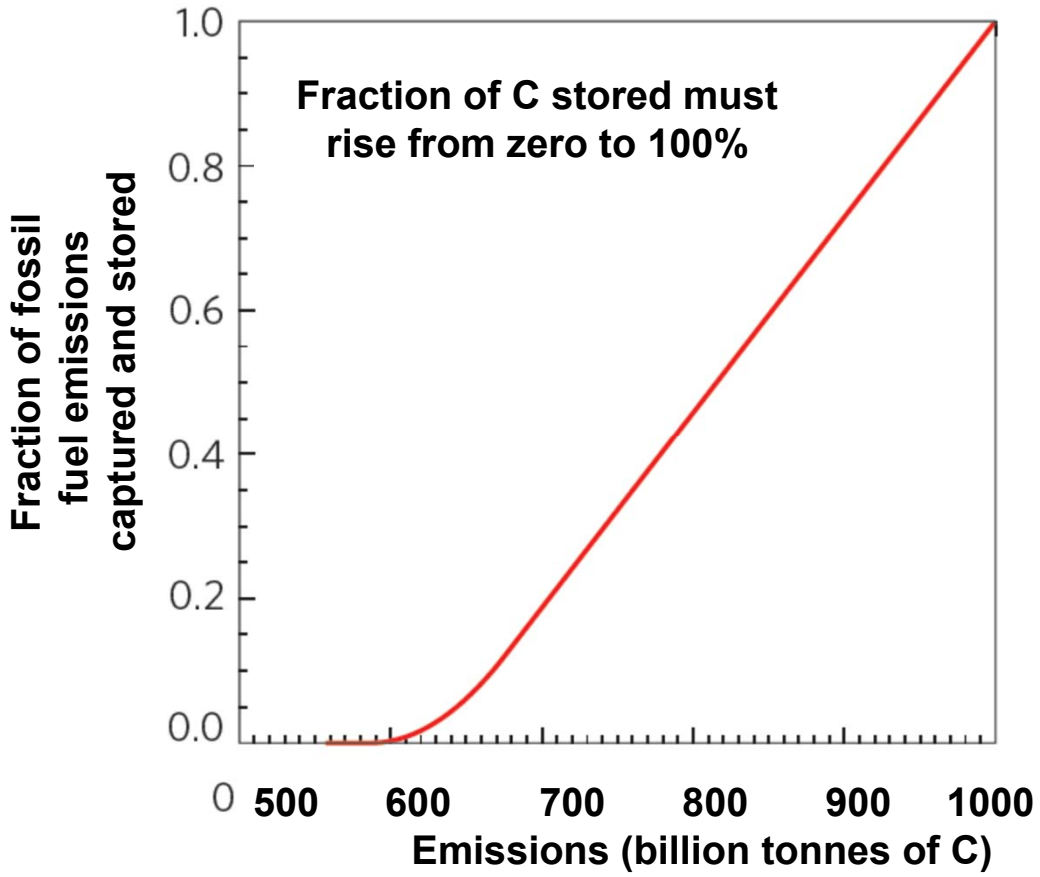


https://www.theccc.org.uk/publication/net-zero-the-uks-contribution-to-stopping-global-warming/

What does the whole world have to do?

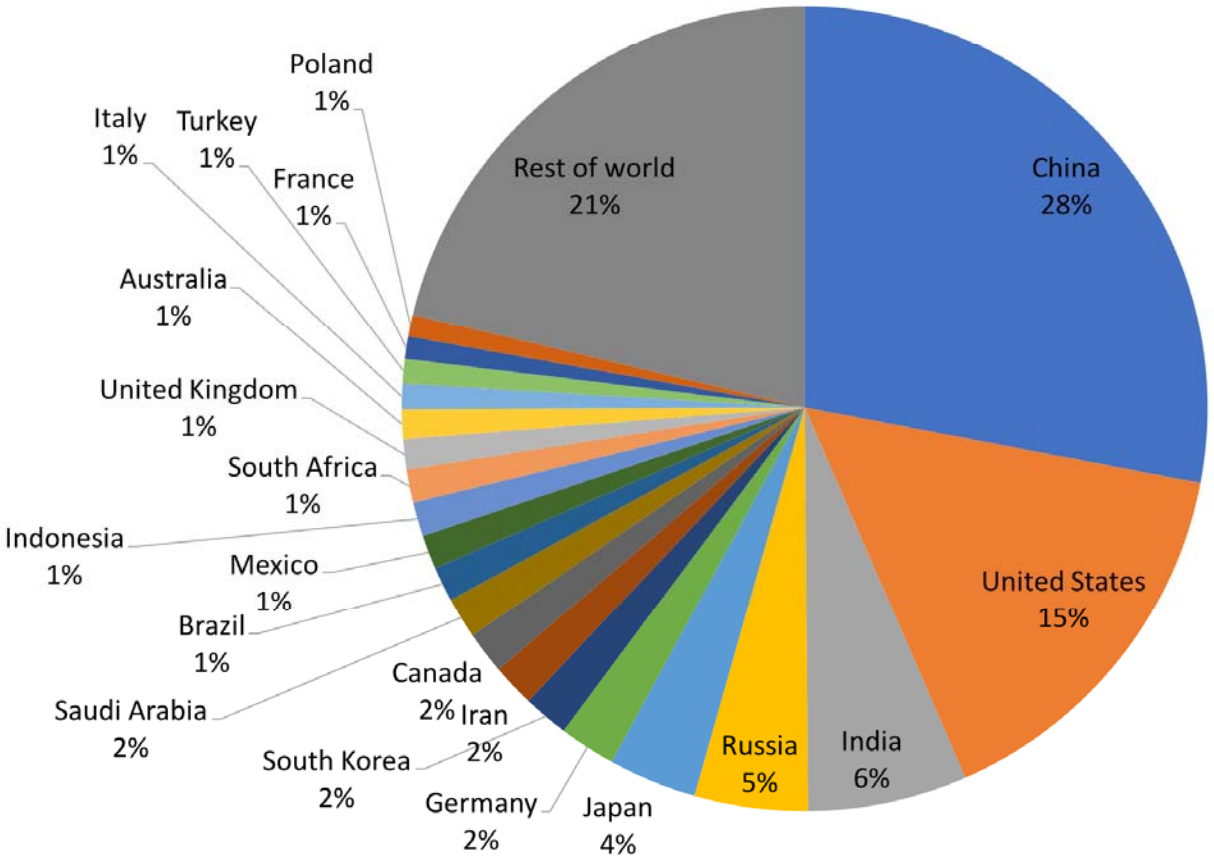
Deploying 100% CCS on fossil fuel use to limit cumulative emissions of CO_2 at a level where climate consequences are manageable is a sufficient measure to avoid dangerous climate change.

It is also in fact a necessary measure.



Myles R. Allen, David J. Frame & Charles F. Mason, The case for mandatory sequestration, Nature Geoscience 2, 813 - 814 (2009), doi:10.1038/ngeo709

Share of global carbon dioxide emissions from fuel combustion (2015)



Data: IEA
Image: Union of Concerned Scientists

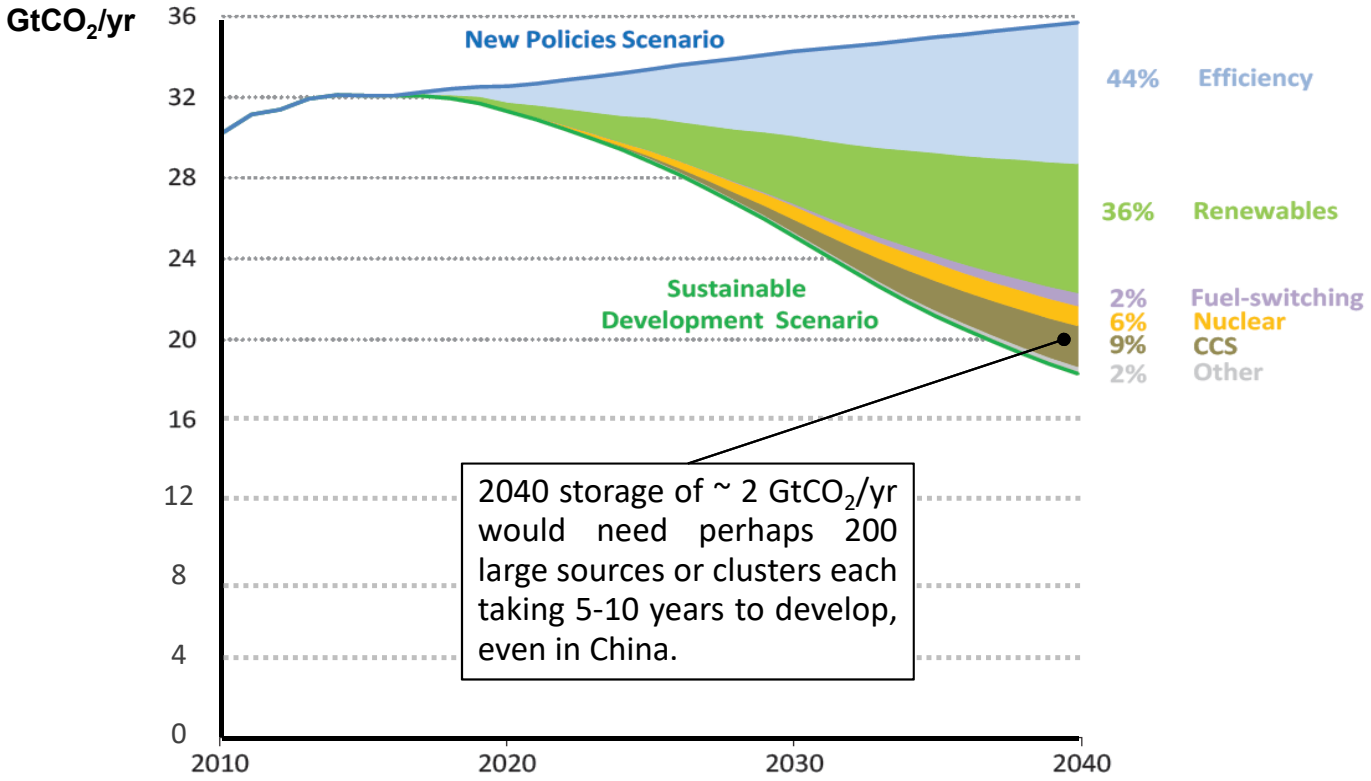
Spending on CCS deployment offers a much better return for public funding than any established technology

- CCS is absolutely essential but virtually undeveloped
- If a country, e.g. the UK, spends another £10bn on renewables or nuclear the rest of the world will hardly notice it, because these technologies are already well-known
- But £10bn on CCS would be widely noticed and would help build confidence in CCS as a key technical tool for resolving a very difficult political problem
- The return on CCS deployment costs can be further enhanced by better information sharing
- Particularly for post-combustion capture projects, CO_2 transport and CO_2 storage having open-access projects is particularly feasible
- Open-access PCC requires building plants that can use non-proprietary solvents, this also opens up scope for many other developments than just the solvent and avoids the 'Valley of Death' for innovation

CCS has a smaller role than renewables to 2040, but still a very significant increase from almost zero CCS now, and a crucial role after 2040

International Energy Agency (2017), World Energy Outlook 2017, OECD/IEA, Paris

New initiatives are needed to build the core of a CCS industry by 2030 that can be expanded rapidly in the 2030s after very low levels of activity (perhaps only 5-10 full-scale PCC plants globally?) in the 2020s



* http://www.globalccsinstitute.com/news/institute-updates/paris-climate-change-targets-cannot-be-met-without-ccs-cop23

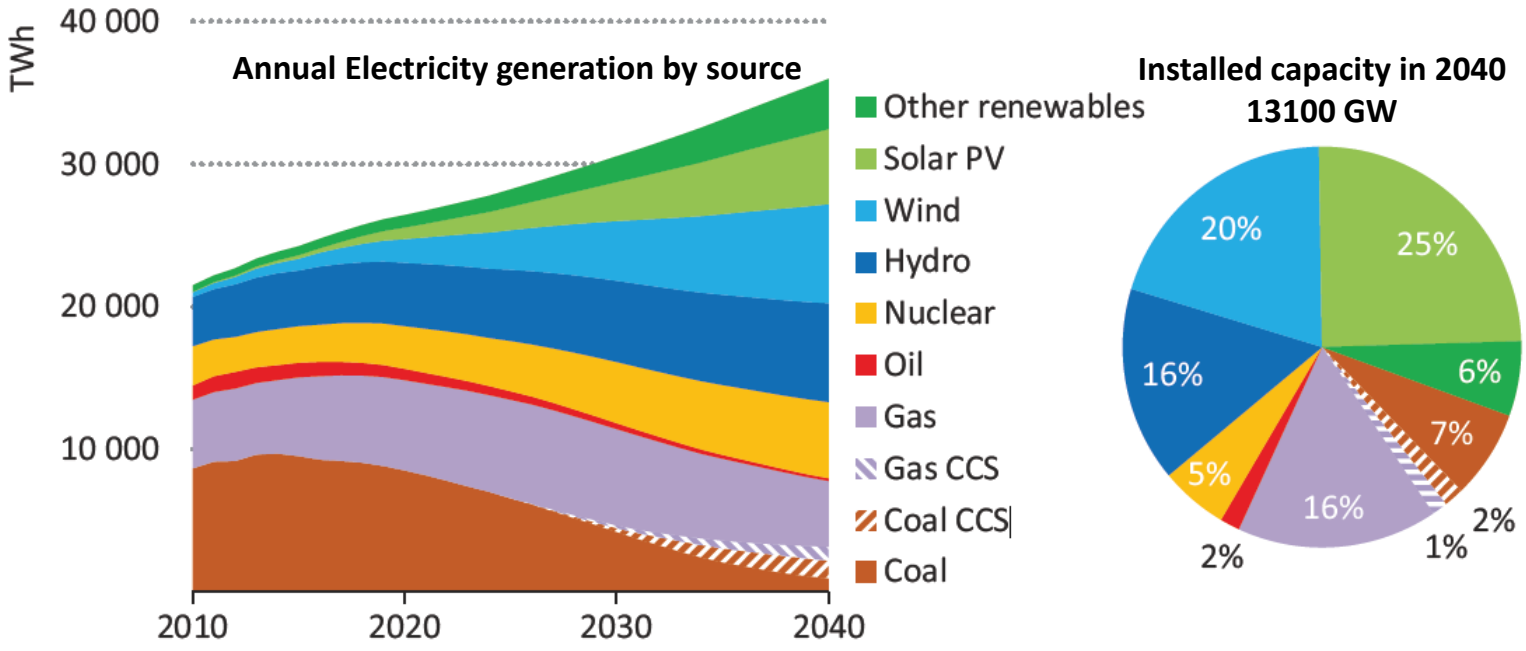
+ https://www.iea.org/publications/freepublications/publication/20-years-of-carbon-capture-and-storage.html

SDS power CCS is 'only' 6% of global electricity generation, but this is a major increase:

2040 power CCS capacity is x1000 - 375GW vs 360MW now*
(plus capture from industry)

- 210 GW of coal power capacity with CCS globally
- 150 GW of this is in China (~15% of current Chinese power plant capacity)[+]
- 165 GW of gas power capacity with CCS globally
- Most of the coal CCS likely to be post-combustion and retrofits to existing plants
- **This is still only ~500 generating units, but most will have to be built in the 2030s**
- **And then the pace has to pick up properly in the 2040s!**

International Energy Agency (2017), World Energy Outlook 2017, OECD/IEA, Paris



* Boundary Dam 3 120MW, Petra Nova 240MW

[+] https://www.iea.org/publications/insights/insightpublications/ThePotentialforEquippingChinasExistingCoalFleetwithCarbonCaptureandStorage.pdf

Global coal capacity without CCS in 2040 is still equivalent to nearly half of current capacity – but unabated coal power plants without CCS are run at very low load factors

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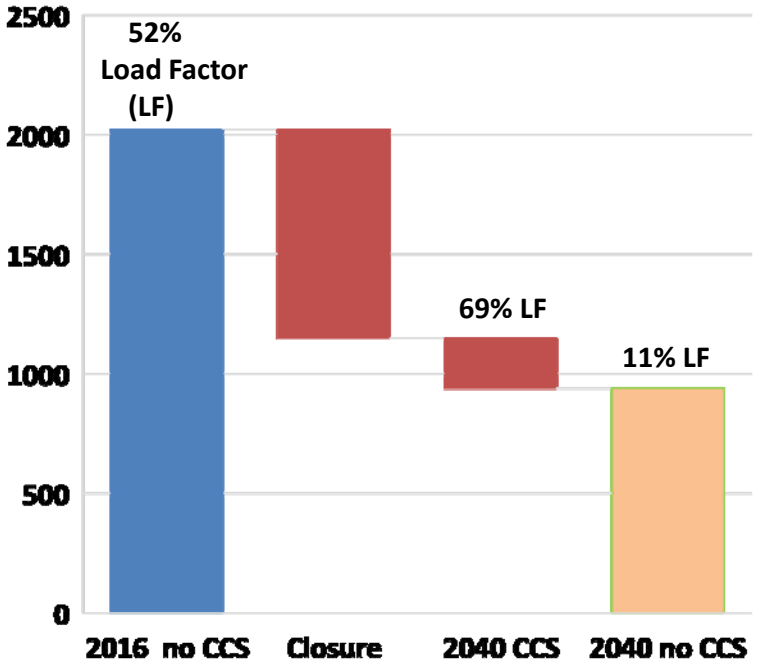
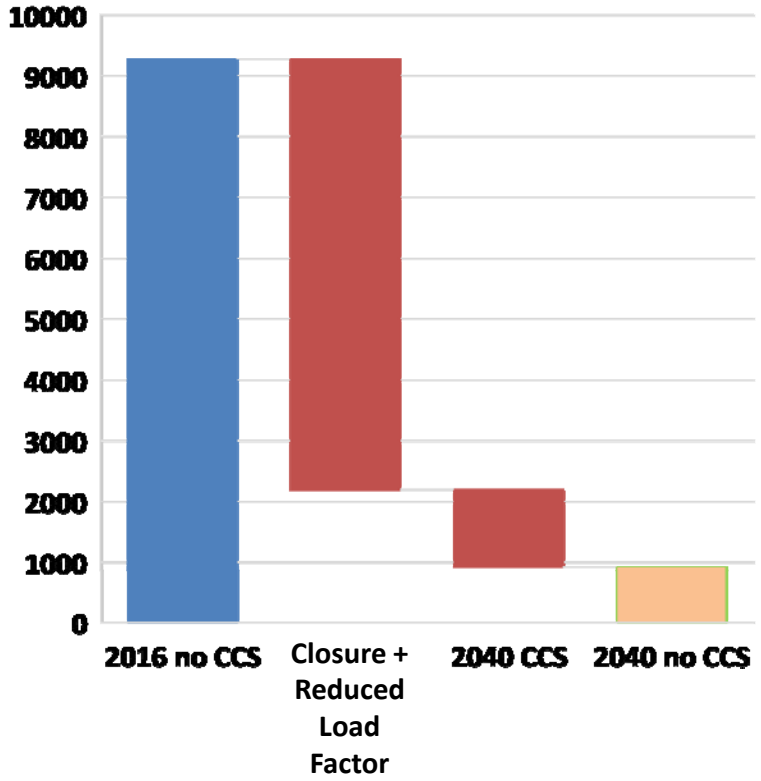
Changes in coal plant capacity (GW) and load factors by 2040



Changes in coal generation (TWh) by 2040, CCS plants >50% of total



International post-combustion capture retrofit workshop held in Sheffield, 9-12 April 2019 using open-access sources and experts involved with open-access plant design and pilot testing

CCUS specialists from the UK CCS Research Centre and the University of Sheffield's PACT facilities together with Bechtel (US), TNO (NL), Test Centre Mongstad (Norway) and the Universities of Edinburgh and Leeds held an international workshop on post-combustion capture (PCC) retrofit.

Together with application experts from China, Ireland, South Africa and Thailand, the workshop examined past open-access PCC studies* and potential future practical applications from across the world.

* For two studies on gas and coal power see https://ukccsrc.ac.uk/news-events/news/international-post-combustion-capture-retrofit-workshop and http://www.co2crc.com.au/publication-category/reports/

Franklin D. Roosevelt
December 17, 1940

In the present world situation of course there is absolutely no doubt in the mind of a very overwhelming number of Americans that the best immediate defense of the United States is the success of Great Britain in defending itself; and that, therefore, quite aside from our historic and current interest in the survival of democracy, in the world as a whole, it is equally important from a selfish point of view of American defense, that we should do everything to help the British Empire to defend itself.
……..

Suppose my neighbor's home catches fire, and I have a length of garden hose four or five hundred feet away. If he can take my garden hose and connect it up with his hydrant, I may help him to put out his fire. Now, what do I do? I don't say to him before that operation, "Neighbor, my garden hose cost me $15; you have to pay me $15 for it."

Guangdong UK/China CCUS Research Centre

Haifeng Pilot Plant opening, May 2019

Open-access MEA campaign in 2020

中英（广东）CCUS中心
UK-China (Guangdong) CCUS Centre

MEA法公开测试
Open Access MEA Testing Campaign

2020年，广东碳捕集测试平台（GCCT）将会开展为期一年的MEA法碳捕集技术测试。期待您的加入。
In 2020, a one-year Open Access MEA Testing Campaign will be held in the Guangdong Carbon Capture Test Platform (GCCT). We welcome your participation.

➢ **邀请对象 Who may apply?**

- 研究机构 Research institute
- 公司 Company
- 政府部门 Government department

➢ **项目运营方 Project operator :**

广州润碳科技有限公司
Guangzhou Reduce Carbon Technology Co., Ltd.

• **支持单位 Supported by :**

- 华润电力华南大区
China Resources Power South China Region
- 中英（广东）CCUS中心
UK-China (Guangdong) CCUS Centre
- 中国能源建设集团广东省电力设计研究院有限公司
China Energy Engineering Corporation Guangdong Electric Power Design Institute Co., Ltd.

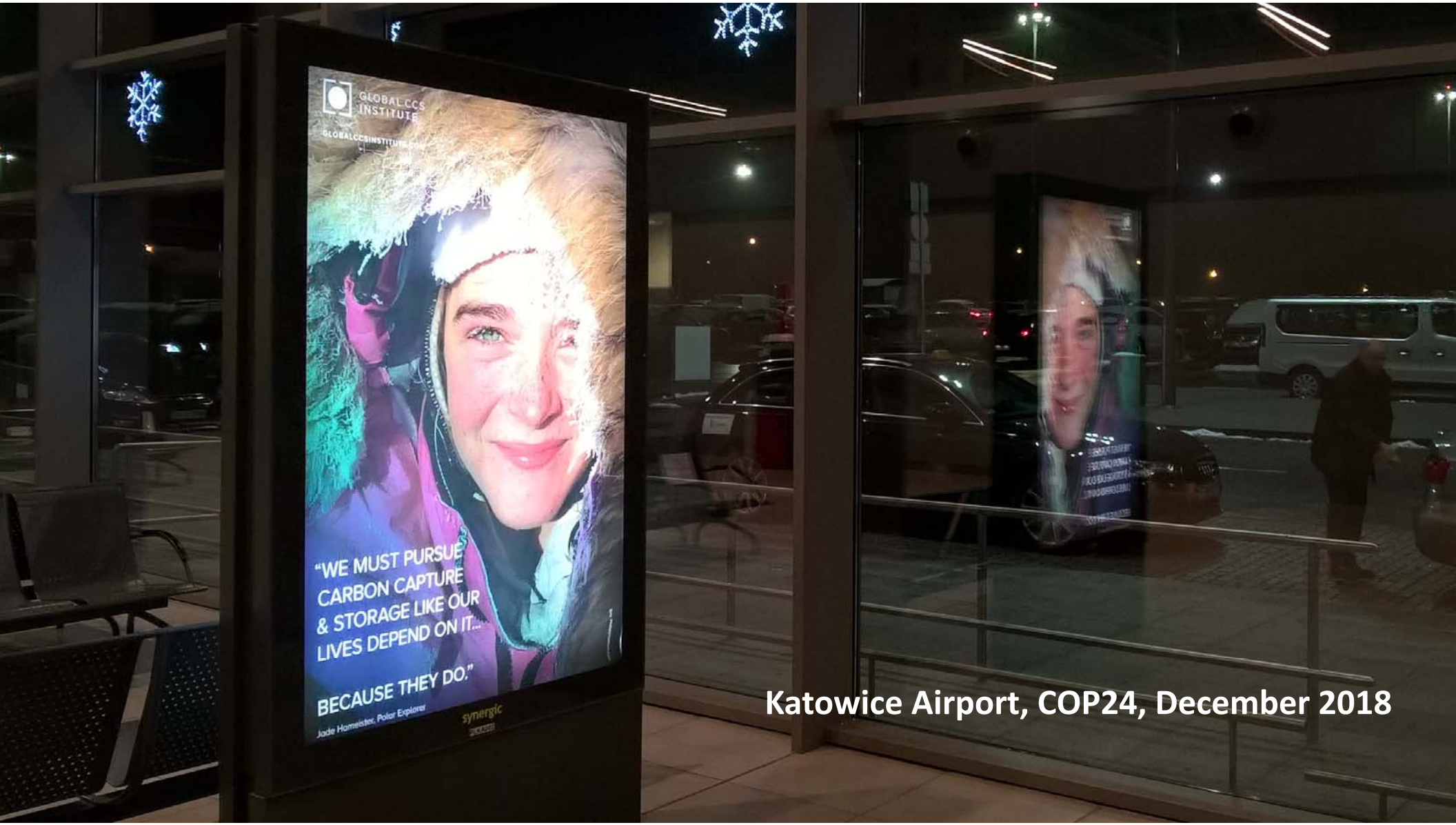
➢ **如何申请 How to apply :**

- 参与测试For testing purposes:
如有创新想法需要验证，请提交完整建议书至：general@gdccus.org
Please send a 2-page description of the proposed idea for testing to:
general@gdccus.org

- 交流学习 For study purposes：
各单位可派1-2名代表，参与2周的运营培训。请将个人简历、申请书发送至：
general@gdccus.org
One party could send 1-2 representatives for a 2-week training period during the campaign period. Please send CVs and covering letter to:
general@gdccus.org

*所有参与者须自理差旅、食宿费用。
All participants should cover their own transportation, accommodation and meal costs.


广东碳捕集测试平台（GCCT）



Katowice Airport, COP24, December 2018