Carbon Capture Usage & Storage (CCUS): A Perspective

For IPHE H2 Initiative Steering Committee

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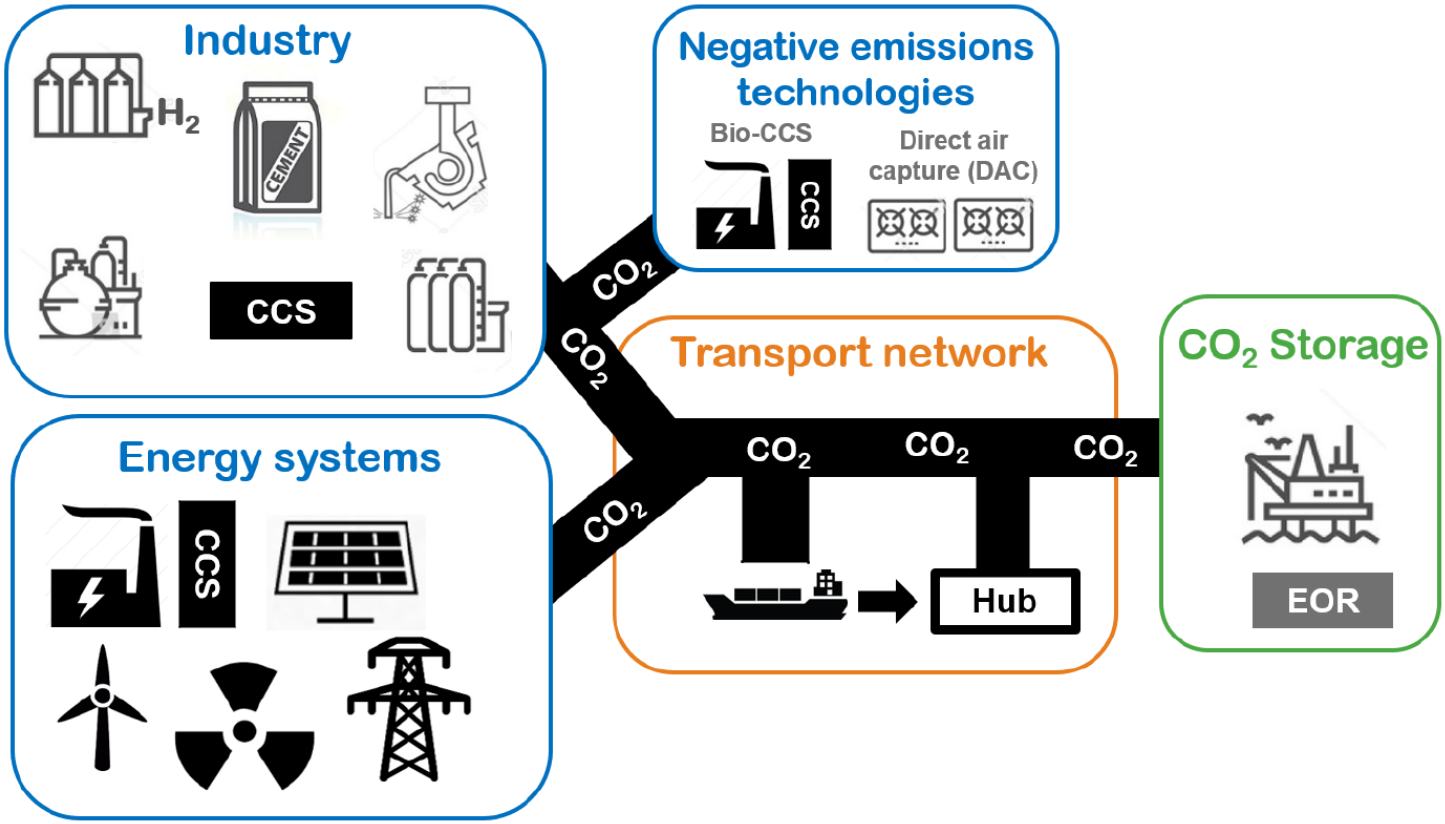
What is CCUS?

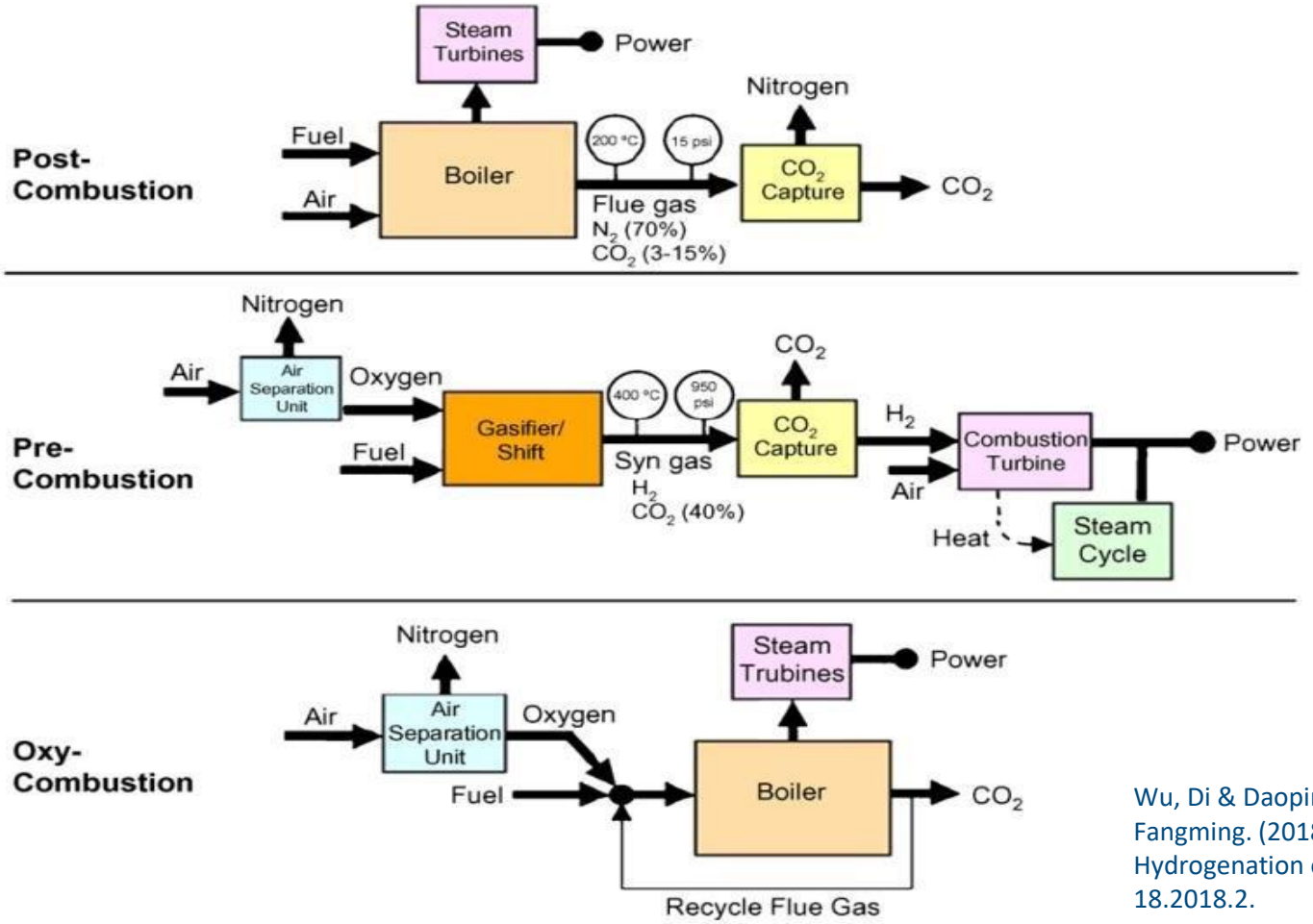
CCUS is the process of:

- Capturing carbon dioxide (CO_2) emissions from large-point sources (such as power stations and industrial facilities)
- Transporting CO_2 in pipelines or via ships to very deep subsurface rock formations, where it can be safely and permanently stored
- In some instances the CO_2 captured can be utilised
- There are a number of operational CCUS installations around the world, in a variety of applications

Stages of CCUS



Methods of Carbon Capture 1



Wu, Di & Daoping, He & Yao, Guodong & Jin, Fangming. (2018). Recent Advances in Fixation and Hydrogenation of Carbon Dioxide. 10.2991/aeecs-18.2018.2.

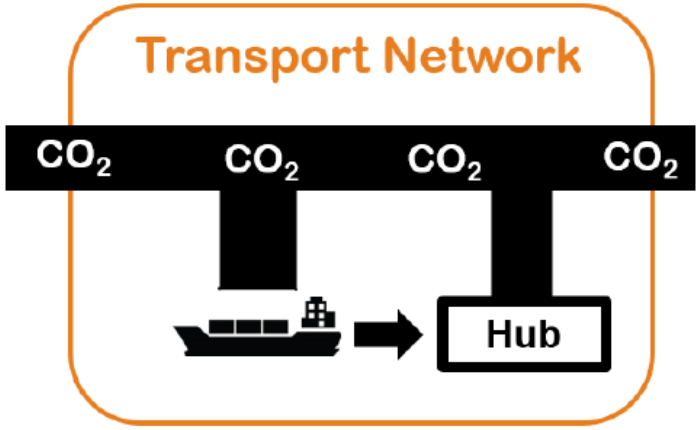
Methods of Carbon Capture 2

There are several different chemical processes which can be applied to separate carbon dioxide from flue or fuel gas

- A**b**sorption – liquid sorbent
- A**d**sorption – solid sorbent
- Chemical looping – metal oxides
- Membrane separation
- Hydrate-based separation
- Cryogenic distillation

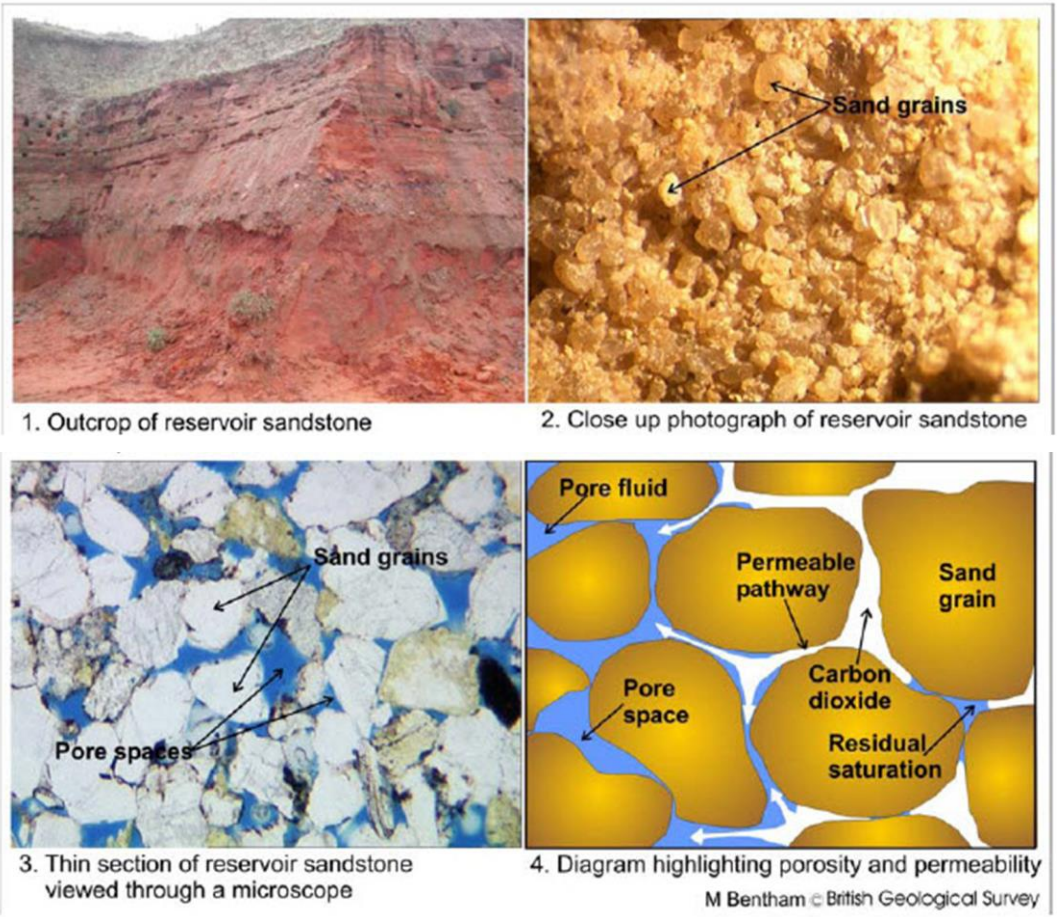
Methods - Transport

- Before transportation, the CO_2 rich gas will need to be processed or compressed
- Carbon dioxide transported in supercritical or liquid state is preferred
- Pipelines are most common method of transporting large quantities of CO_2
- Shipping is another option for long-distance transport – can be cost competitive with pipelines

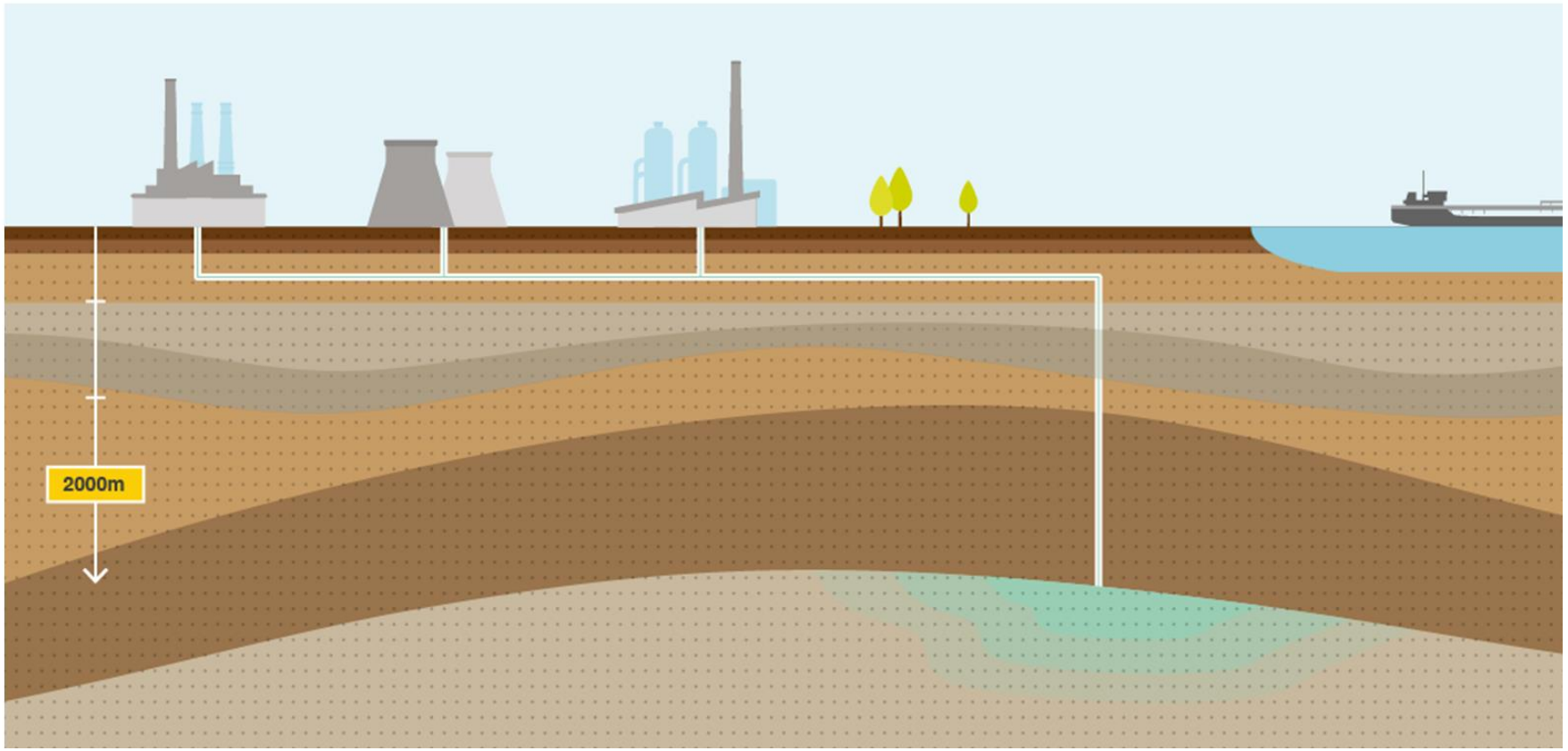


Methods - Storage

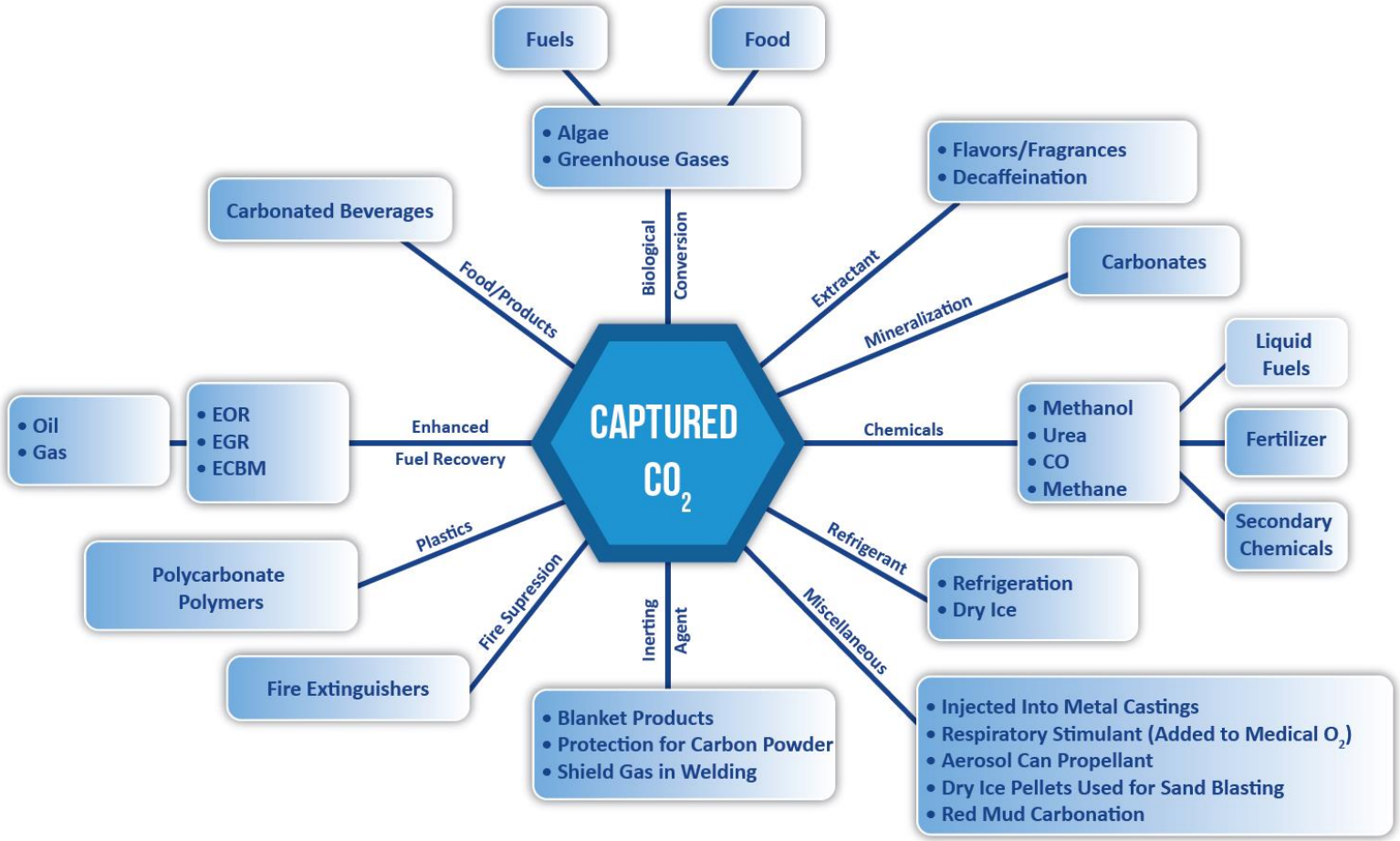
- CO_2 can be stored into geological formations such as deep saline aquifers which have no other practical use, and oil or gas reservoirs
- Geological storage is at present considered to be the most viable option for the storage of the large CO_2 quantities
- A typical geological storage site can hold several tens of million tonnes of CO_2



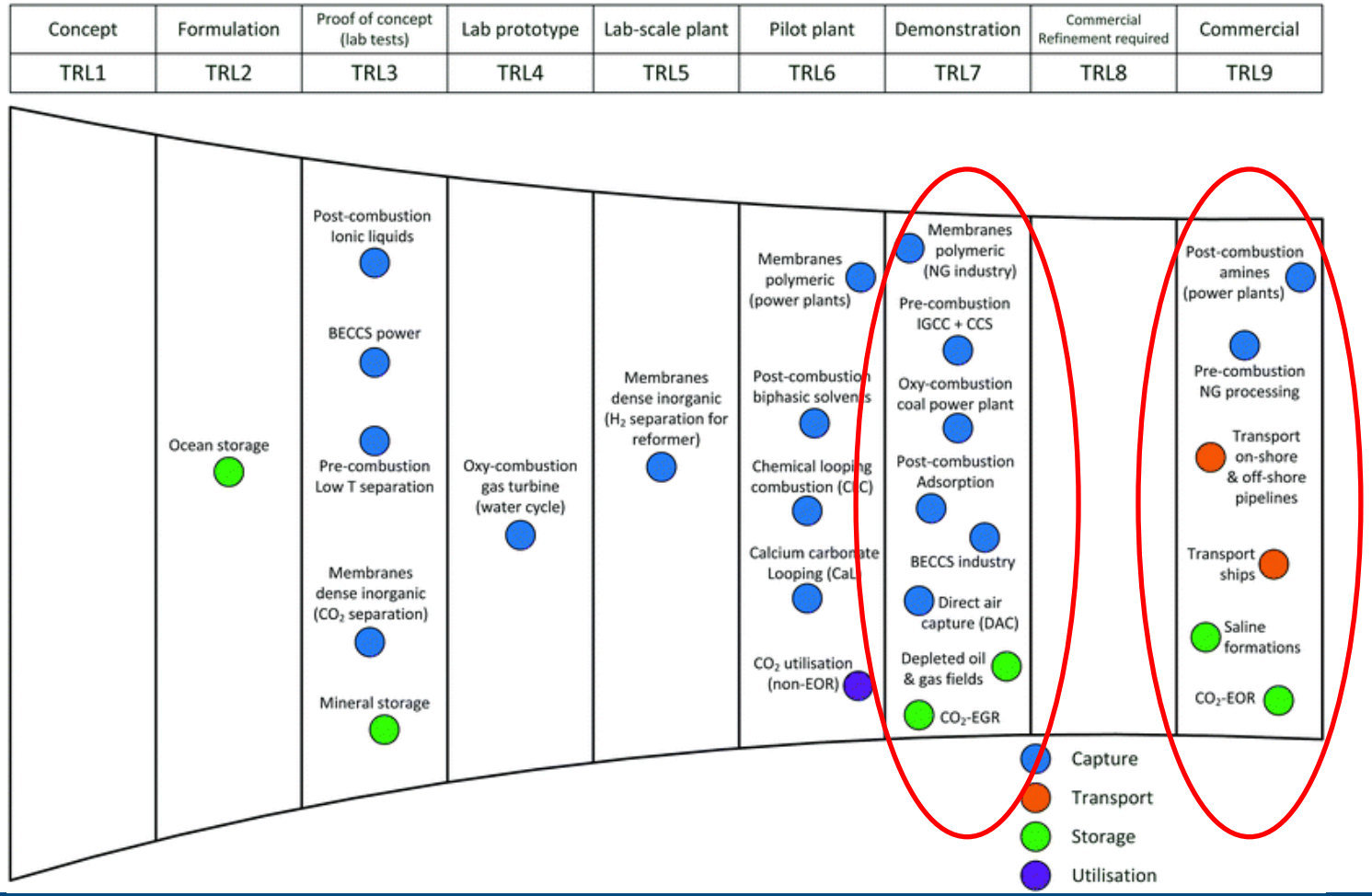
Methods - Storage



Methods - Utilisation



Technology Readiness Levels



Source: Bui *et al.*(2017). Energy & Environmental Science,DOI: 10.1039/c7ee02342a.

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Why do we need CCUS?

Growing consensus that CCUS is essential to meeting our 2050 'net zero' target. CCUS can also support industrial competitiveness through the development of, and UK leadership in, a globally significant technology.

Committee on Climate Change (CCC) recommends that 75-175 $MtCO_2$/yr CCUS is needed by 2050. Our latest analysis agrees broadly with this.

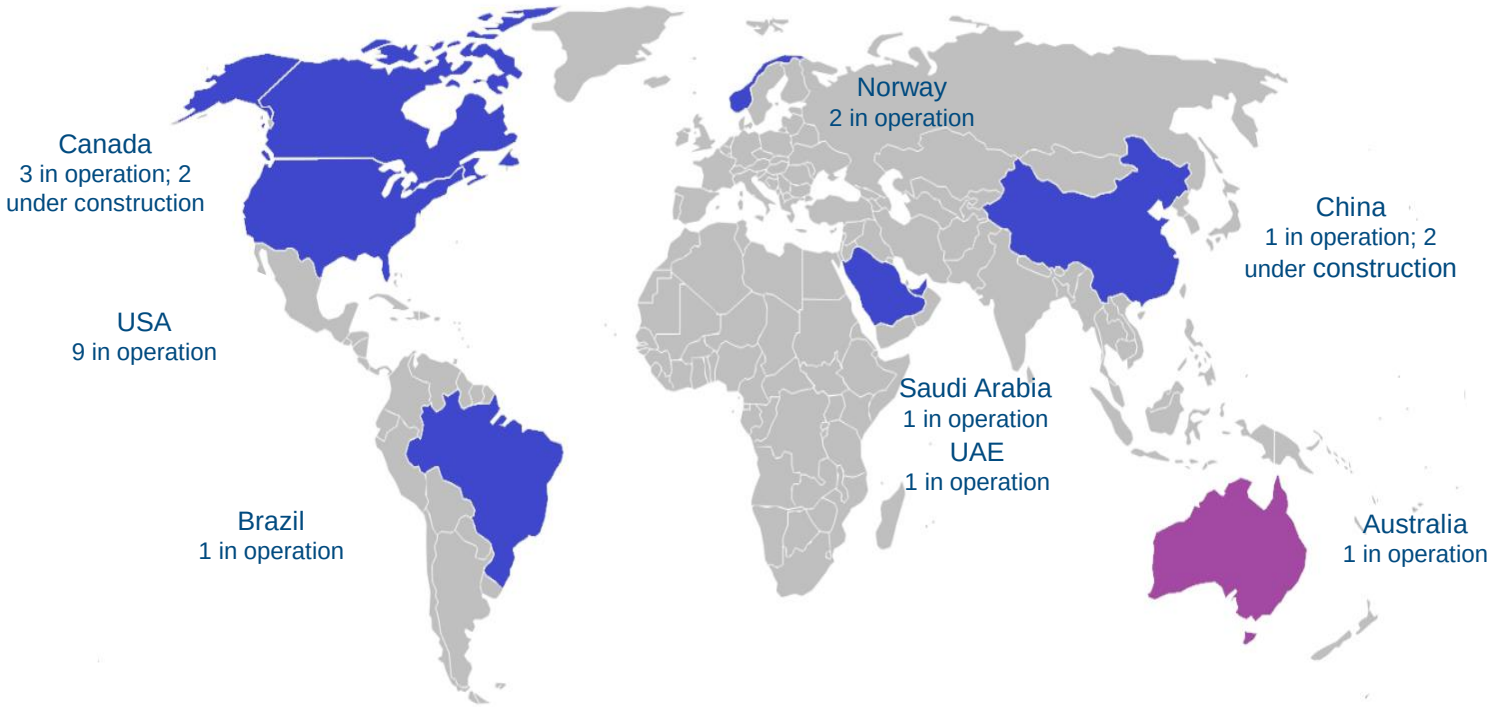
UK could capture up to £10bn/yr of c.£200bn/yr global CCUS market by 2050.

CCUS could support up to 6,000 well-paying jobs through the CCUS projects by 2050 and create up to an estimated 48,000 exported related jobs for UK business

CCUS could protect a share of the Energy Intensive Industries (EII) Sector, which overall accounts for 1.5m existing direct jobs.

Status of Global CCUS

The current projects that are operational or under construction have an annual CO2 capture capacity equivalent to removing 8 million cars from the road each year.



*in operation or construction as of September 2019 (GCCSI global database).

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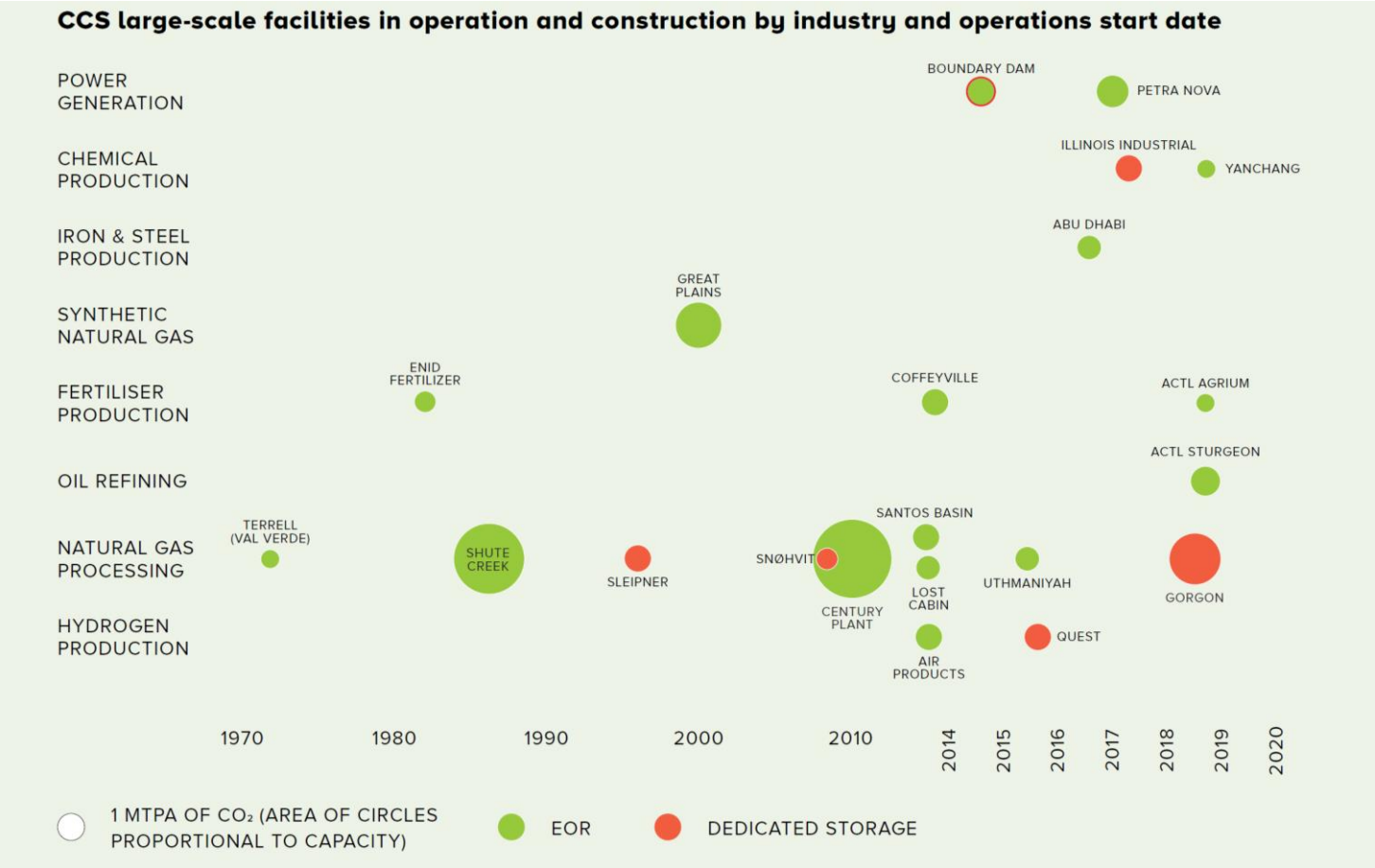
Context of CCUS deployment over time

CCUS has been deployed across a range of sectors globally.



Source: GCCSI 2017

My “Tourist” Pictures

Global Collaborations

- Achieving the Paris Agreement's goals will require a renewed focus on innovation and international collaboration.
- This is important at all levels:
  - Between governments
  - Between industrial partners
  - Between government and industry

CO2 Carbon Capture, Utilization & Storage
Accelerating CCUS Together
An initiative by the Clean Energy Ministerial

Mission Innovation
Accelerating the Clean Energy Revolution

iea International Energy Agency

carbon sequestration leadership forum

SET PLAN CEEC 2016

CCSA Carbon Capture & Storage Association

OGCI Oil and Gas Climate Initiative

Zep Zero emissions platform

UK CCUS – a brief history

2007
First UK CCS Demonstration comp. launched

2011
First UK CCS Demonstration competition ends due to lack of bidders

2012
Second UK CCS Commercialisation competition launched

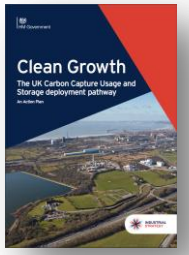
2015
£1bn funding withdrawn from CCS Commercialisation competition

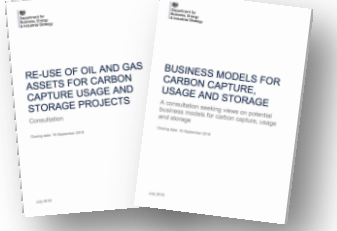
2016
White Rose and Peterhead CCS projects closed

2017
Clean Growth Strategy launched with Government's new approach to CCUS; moving focus away from full chain projects

2018
CCUS Cost Challenge Taskforce Report conducted

2018
CCUS Action Plan launched





2019
Consultations published setting out emerging thoughts on business models

2020
PM 10pp
£1bn

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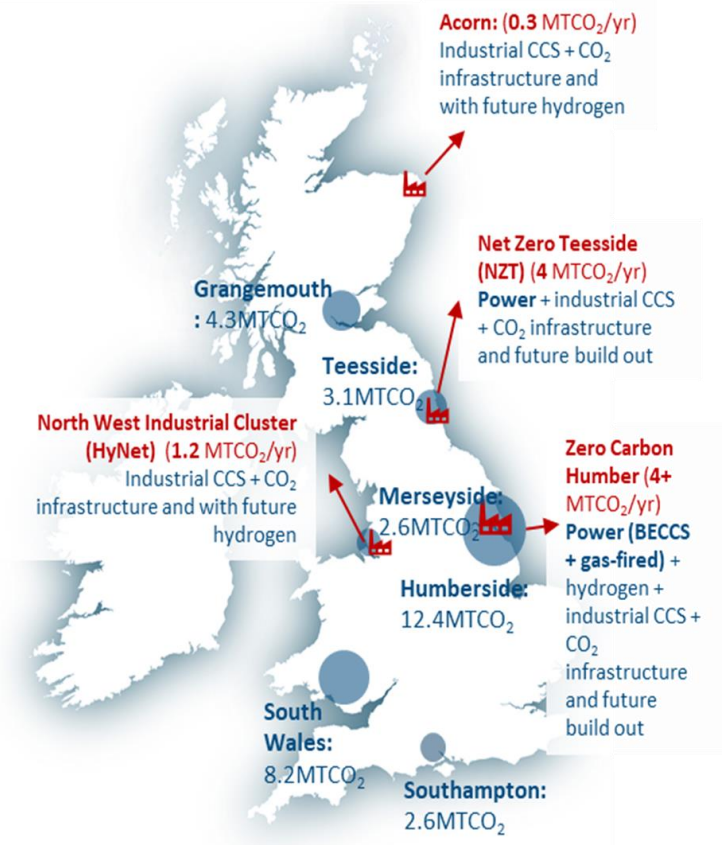
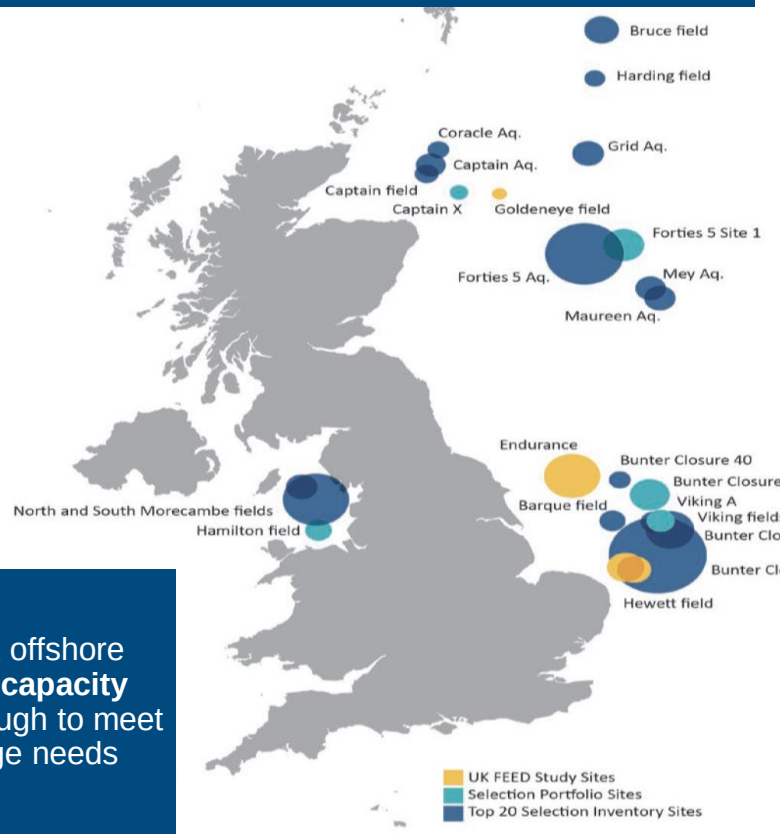
UK CCUS Policy Landscape

- CCUS will be essential to successfully tackling climate change and meeting the **UK's target to reach net zero emissions by 2050.** CCUS could form a key part of the **COP26 agenda**
- CCUS is likely to be play an important role in the Government's Industrial Clusters Mission, which sets out the ambition to **establish the world's first net-zero carbon industrial cluster by 2040**
- We are committed to deploying CCUS this decade, as reinforced by the **Ten Point Plan** and see an opportunity for the UK to become a global leader in CCUS and create new markets for UK businesses
- We have set **an ambition to capture 10MT/CO_2 per year by 2030** which is likely to be reaffirmed in an upcoming Energy White Paper. This requires collaboration with major industry actors including Equinor and deployment of key infrastructure at a number of North Sea Hubs
- A **CCS Infrastructure Fund of £1bn** to support deployment at four industrial clusters (with two operational by the mid 2020s). In 2021 we will execute a process for allocating funding and set out further details of a **revenue mechanism for industrial carbon capture and hydrogen projects**
- We will also put in place **new sustainable commercial models** to unlock investment in CCUS. In August 2020, we published our responses to two consultations to help achieve this – one on potential business models for CCUS projects and one on the re-use of oil and gas assets for CCUS. We will **finalise business models in 2022**

Proposed UK CCUS Clusters

At COP24 UK announced an Industrial Clusters Mission to establish the world's first net zero industrial cluster by 2040





Studies estimate UK offshore **geological storage capacity >70GT**, more than enough to meet the UK's CO_2 storage needs

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Accelerating CCUS Technologies (ACT) R&D Programme

- A growing number of countries all with a CCUS focus
- Norway, Netherlands, Germany, Romania, Turkey, Greece, Switzerland, Spain, UK, USA, France, Sweden, Finland, Denmark, Italy, Canada, India
- All working together in a framework that allows for national interests to be addressed within one programme

www.ACT-ccs.eu)

ACCELERATING CCUS: SUMMIT

28 NOVEMBER, EDINBURGH

International Energy Agency
Secure Sustainable Together

INDUSTRIAL STRATEGY

PROUD TO SUPPORT GREAT BRITAIN & NORTHERN IRELAND

World's first dedicated CCUS Summit

50 international leaders from:

- Governments (UK, USA, Japan, Norway)
- Energy companies (Exxon Mobil, Shell, BP)
- Institutions (IEA, IPCC)

Represents international agreement on the value of CCUS

Represents international agreement that a rapid scale up of CCUS investment is required

The Delegates agreed on key priorities for CCUS development, including:

- The 'hub and cluster' approach can drive down costs and reduce commercial risks.
- Identifying 'bankable' CO_2 storage sites will increase investor confidence
- Boosting early investment will require targeted policy measures
  e.g grant funding, subsidies or obligations
- Innovation in CO_2 usage (for production of chemicals, building materials, fuels, etc) can boost future demand for CO_2

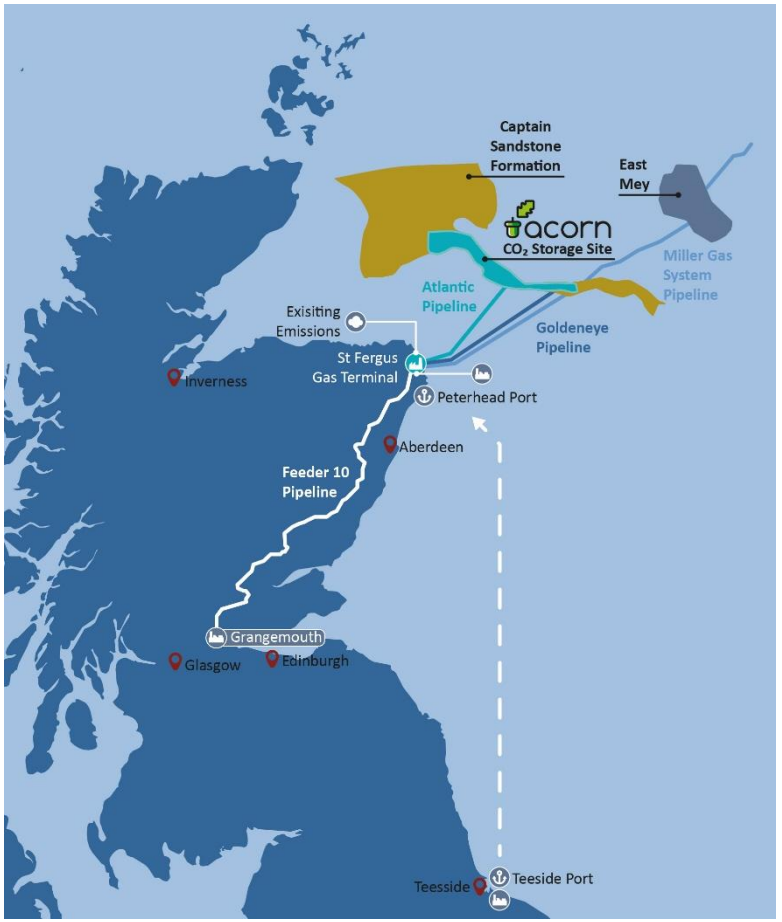
Case Studies

Acorn: Pale Blue Dot

Acorn is a low cost, low risk CCUS project, designed to be built quickly, taking advantage of existing oil and gas infrastructure and a well understood offshore oil and gas storage site in the north of Scotland

A 'Project of Common Interest', Acorn is a key cross-border infrastructure project, linking the energy system of EU countries

- Acorn can act as a catalyst for supporting growth and the creation of industrial opportunities in the North East of the UK
- The project aims to create of a major hydrogen hub at St Fergus, developing the port of Peterhead to be an international CO2 storage hub in the Central North Sea
- The gas pipelines Acorn aims to repurpose for CO_2 transport offer savings in the region of £750m compared to commissioning new pipes



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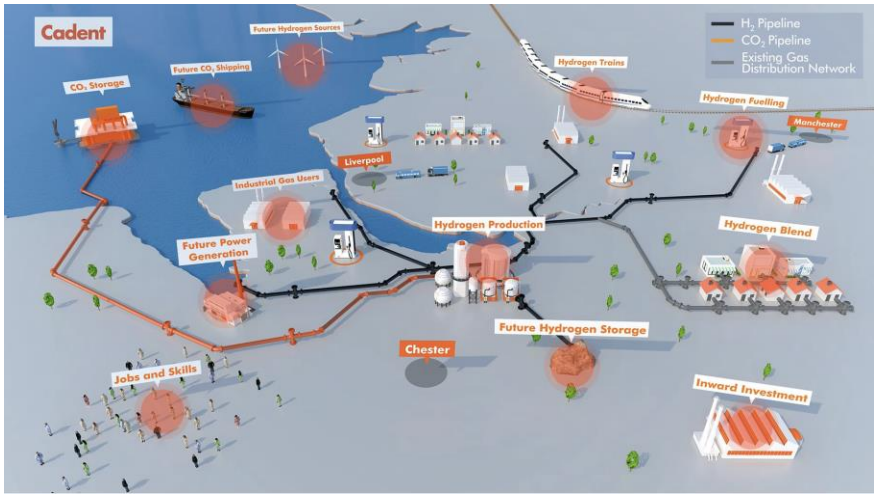
HyNet: Cadent

The HyNet project aims to produce and supply decarbonised hydrogen to industry and households in the North West of England, abating over 1.1MtCO_2 each year. Hydrogen can be produced from natural gas, with CO_2 captured as part of the same process. Hydrogen would then piped to energy intensive industries and households



Cadent's HyNet North West England project at a glance

- The project creates extendable CCUS and hydrogen infrastructure which is lower cost than other alternatives
- The project decarbonises energy intensive industry whilst also providing flexible power to the region
- The project focuses on using proven technologies along the hydrogen chain
- The project could support up to 5000 jobs from now to 2025
- Further extensions to the project which use and develop the same infrastructure will drive down total costs

Clean Gas Project: OGCI Climate Investments

The Oil and Gas Climate Initiative (OGCI) led Clean Gas Project ("CGP") aims to design a full scale, integrated gas fired power plant with CCUS. CGP hopes to unlock the decarbonisation of industries in the Teesside area and deliver up to 1.8 GW of clean, dispatchable low carbon electricity to UK consumers.

- A large combined cycle gas power plant with CCS will form the centre of the cluster
- CGP enables a full-chain CCUS project at scale in a key UK cluster
- OGCI - 10 Oil and Gas companies with previous CCUS and major project experience are behind the CGP development and execution
- The project will provide strategic CO_2 transport and storage infrastructure to enable wider decarbonisation of energy intensive industry
- The project also provides jobs and investment to regenerate and support long term competitiveness of industry in Teesside.

The Tees Valley. Image courtesy of Tees Valley Combined Authority

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Drax: BECCS Pilot Programme

Drax's biomass and coal-fired power plant is the UK's largest capacity power plant, generating over 11% of the country's renewable electricity. In May 2018, Drax announced they would invest £400,000 in a CCUS pilot project that will capture up to one tonne CO_2 per day, in partnership with C-Capture

- Drax will trial CCUS technology with biomass boilers in what would be Europe's first BECCS (Biomass with CCS) facility
- BECCS is a 'Negative Emission Technology' (NET). The IPCC and CCC view NETs as important for achieving global reductions in atmospheric carbon levels. By storing the carbon released in biomass combustion, BECCS can potentially achieve a net reduction in atmospheric carbon whilst also producing useful energy. This is dependent on a carbon efficient supply chain
- Technology partner C-Capture is developing new low cost, low energy chemical processes for CCUS which could make it easier to implement in the future
- Drax is exploring a number of innovative CO_2 utilisation schemes with UK-based project partners