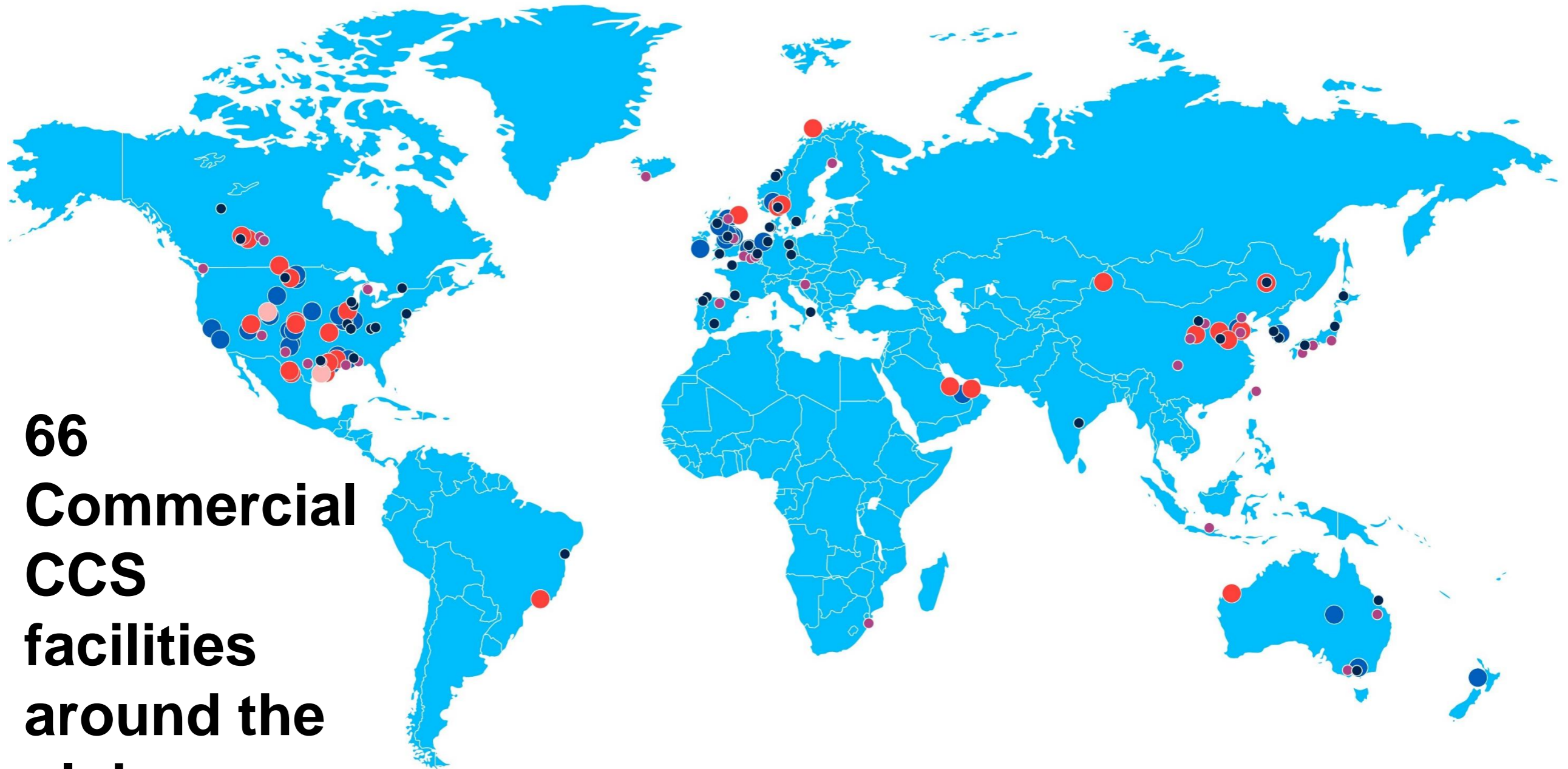


INFRASTRUCTURE

“The basic physical and organizational structures and facilities needed for the operation of a society or enterprise.”

Oxford Lexico English Dictionary

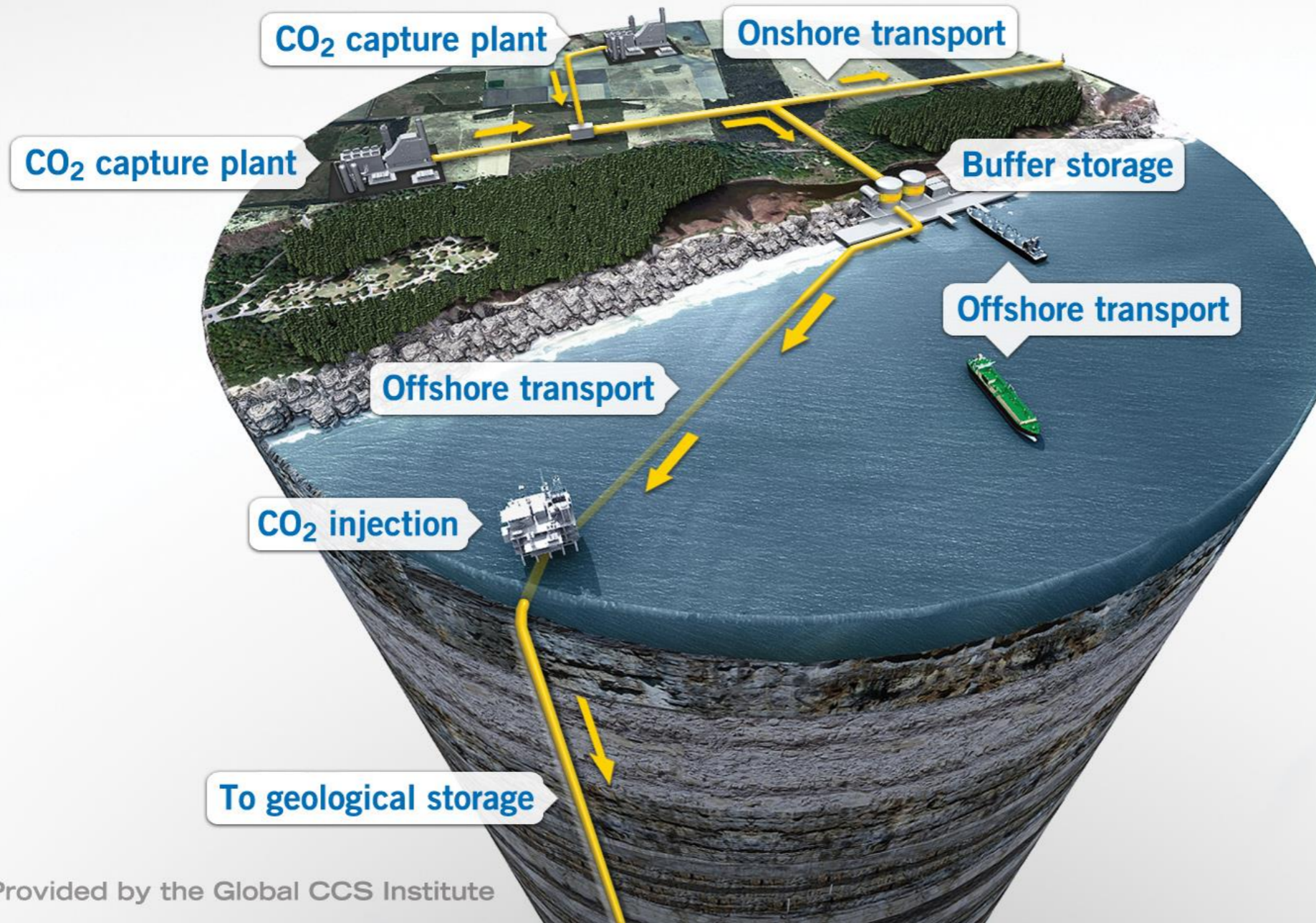
WORLD MAP OF CCS FACILITIES IN VARIOUS STAGES OF DEVELOPMENT



66
Commercial
CCS
facilities
around the
globe

THE LOOK OF CCS INFRASTRUCTURE

[TRANSPORT OVERVIEW]



Provided by the Global CCS Institute

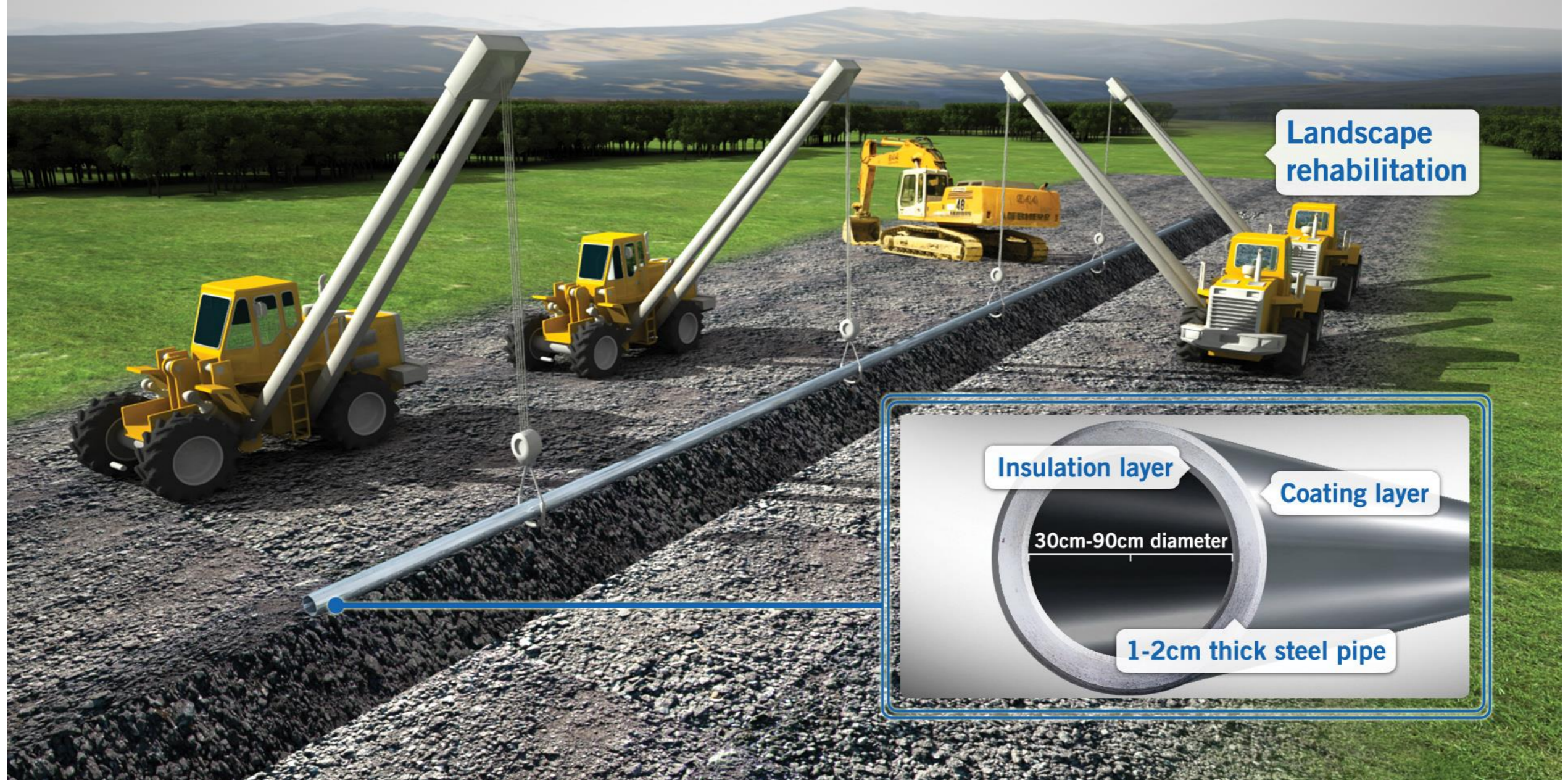


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INSTITUTE

THE LOOK OF CCS INFRASTRUCTURE

Provided by the Global CCS Institute

[ONSHORE TRANSPORT]



Landscape rehabilitation

Insulation layer

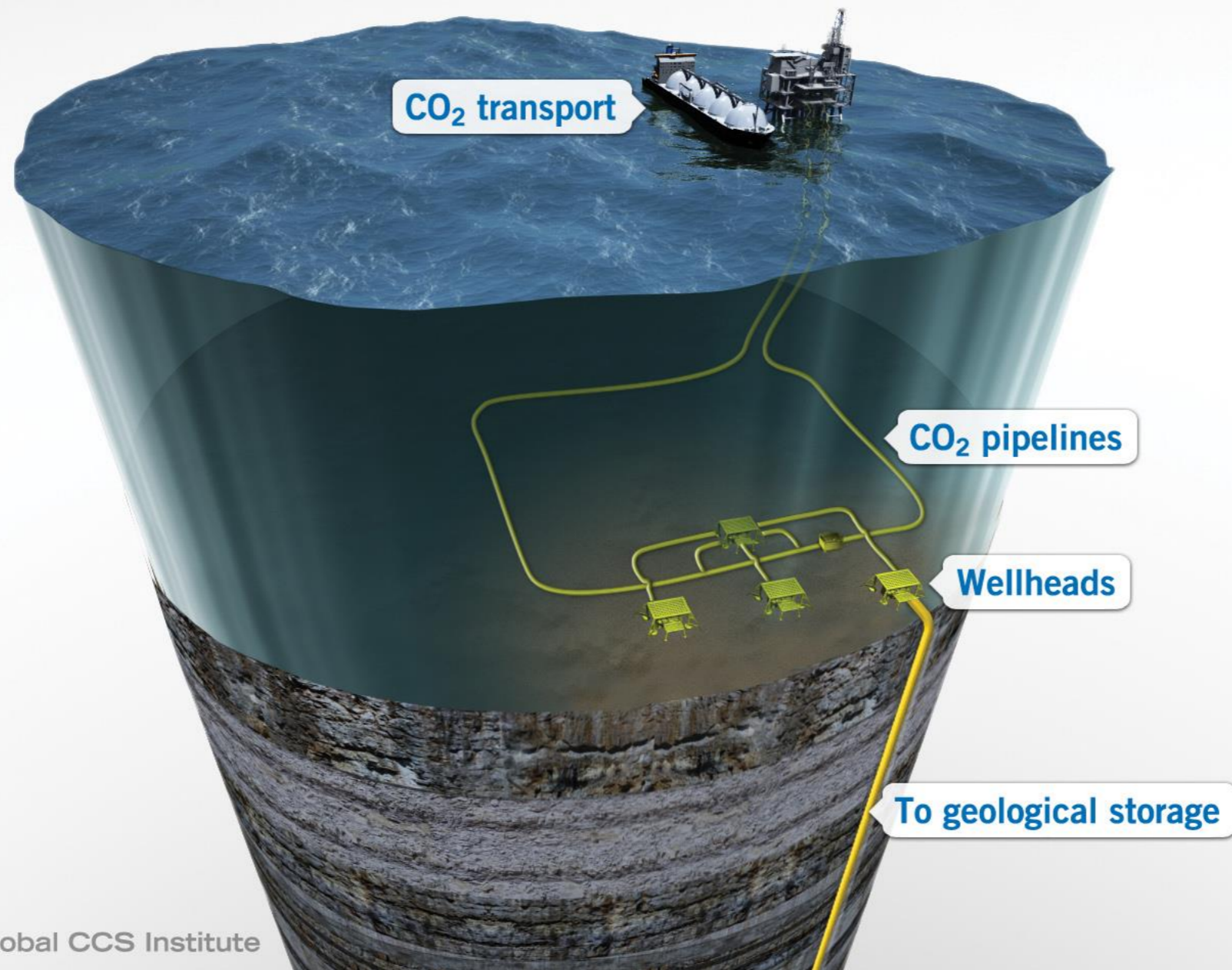
Coating layer

30cm-90cm diameter

1-2cm thick steel pipe

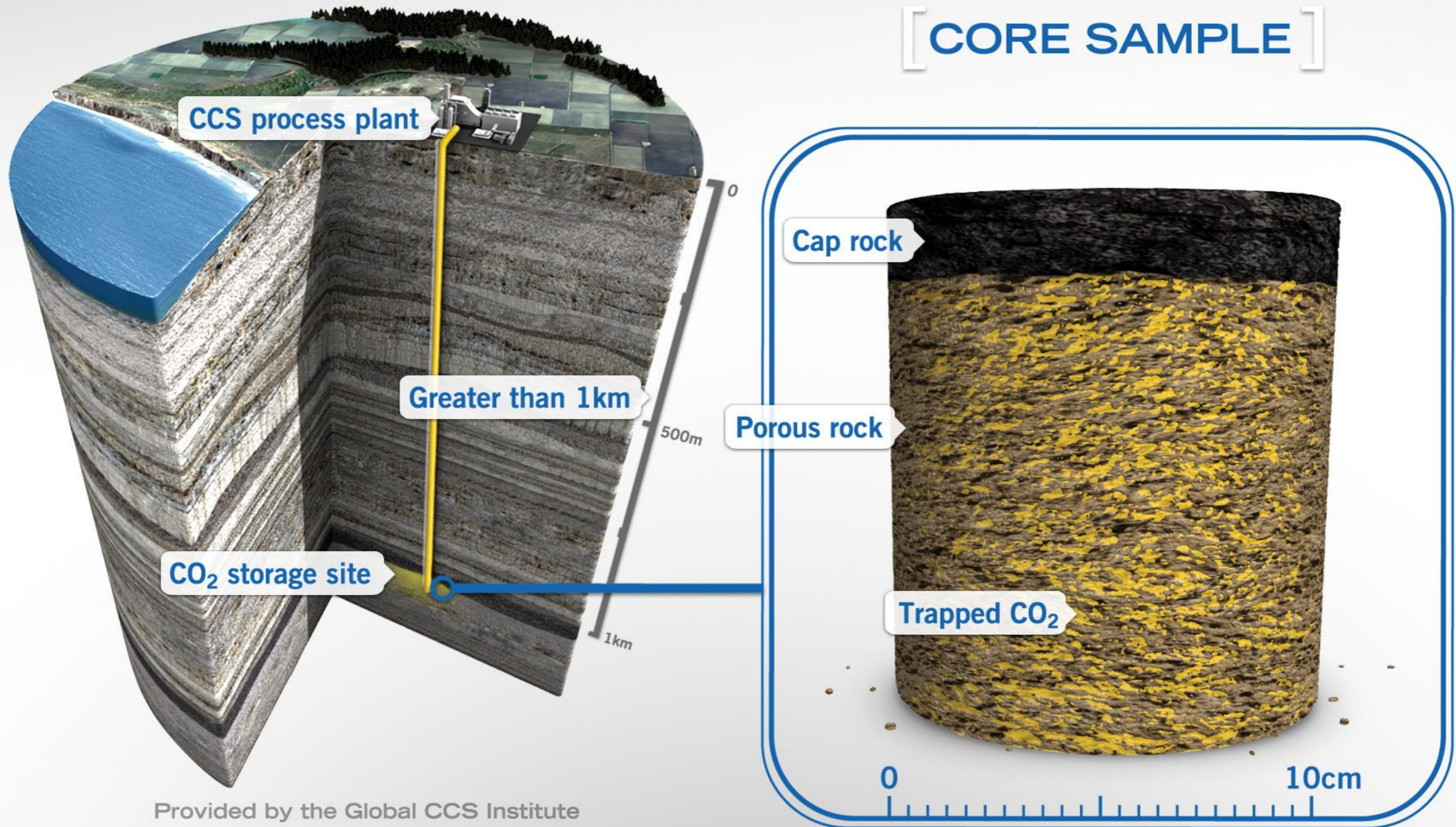
THE LOOK OF CCS INFRASTRUCTURE

[OFFSHORE TRANSPORT AND STORAGE]



Provided by the Global CCS Institute

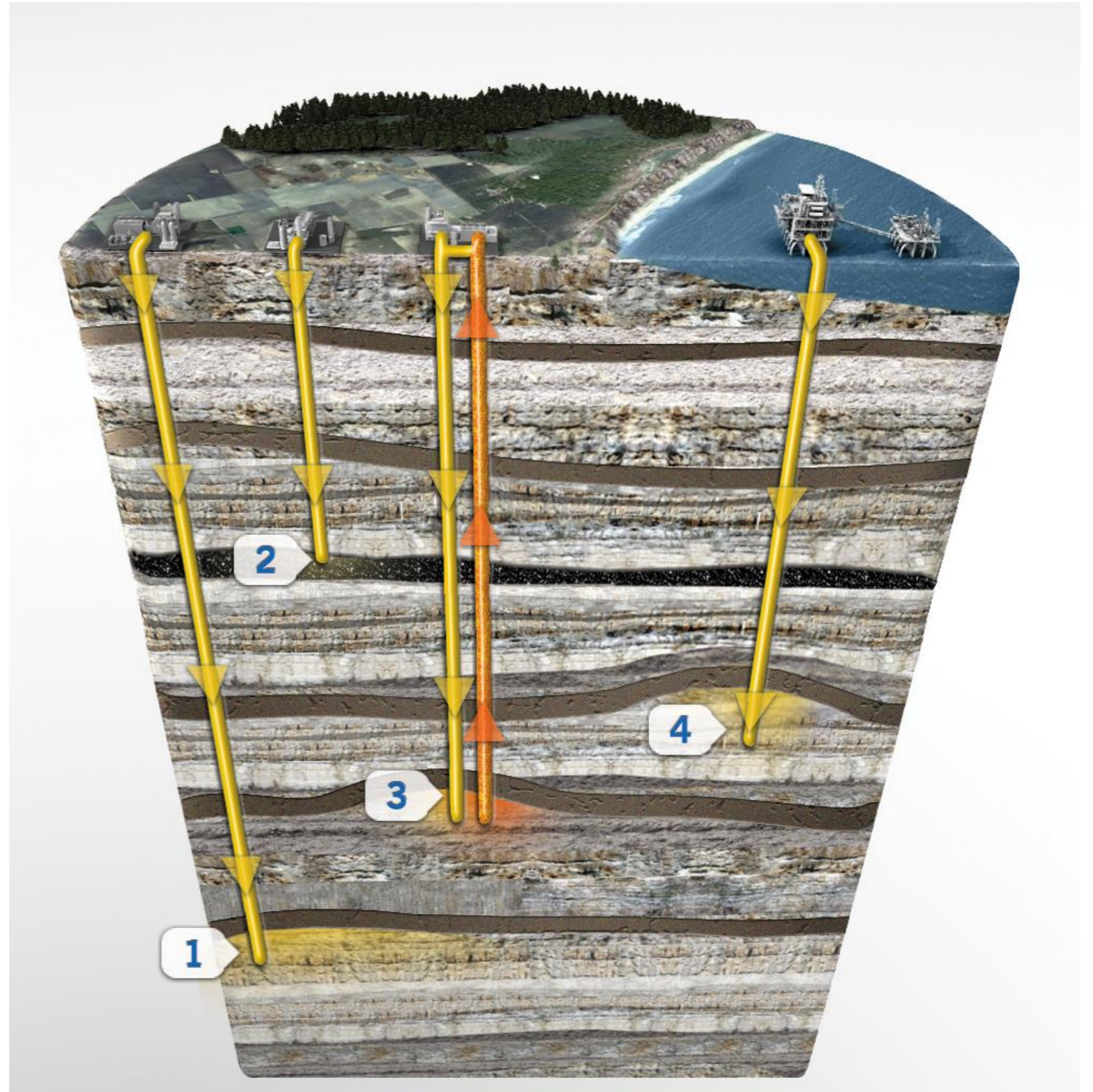
THE LOOK OF CCS INFRASTRUCTURE



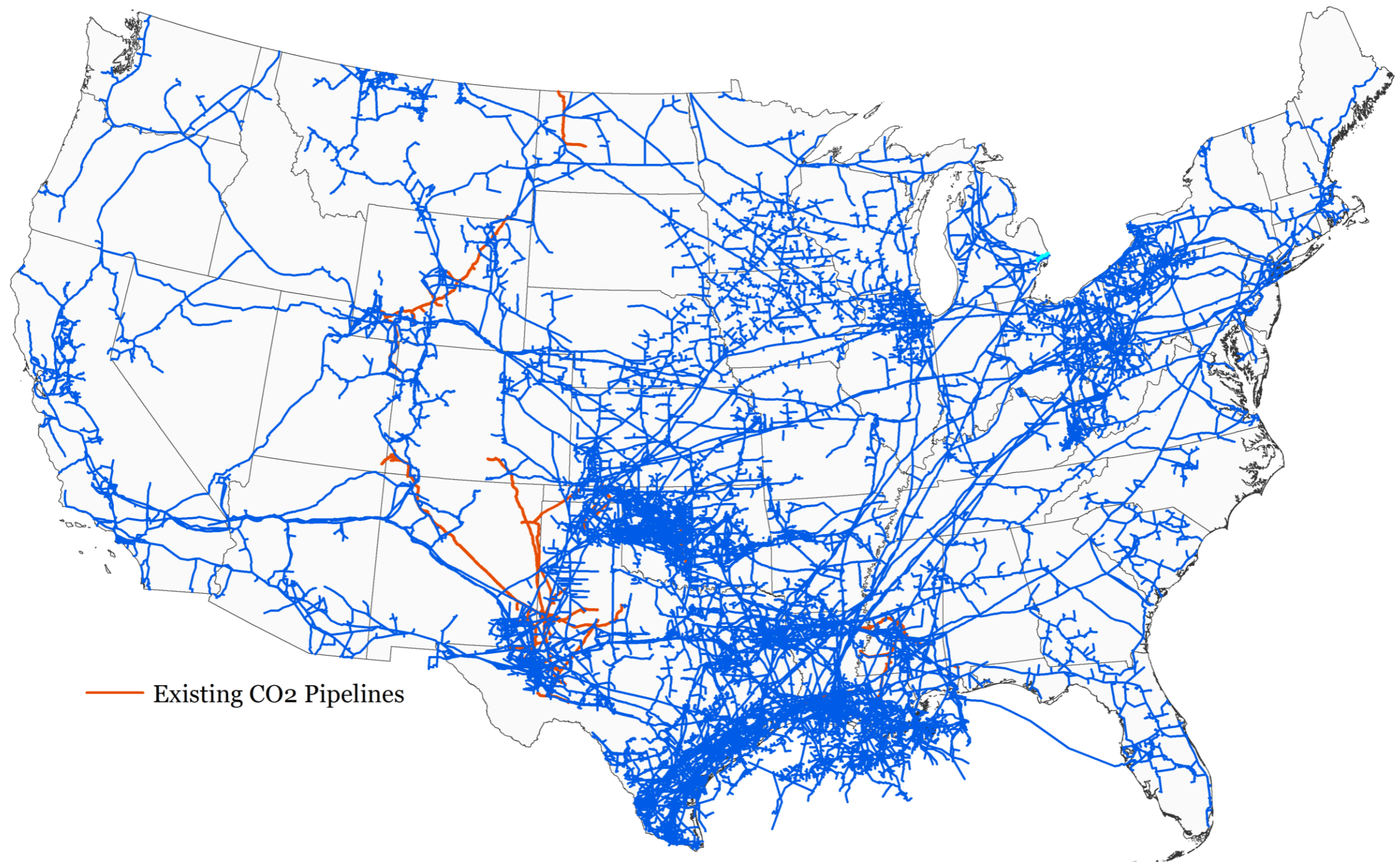
Provided by the Global CCS Institute

**CCS is
secure.**

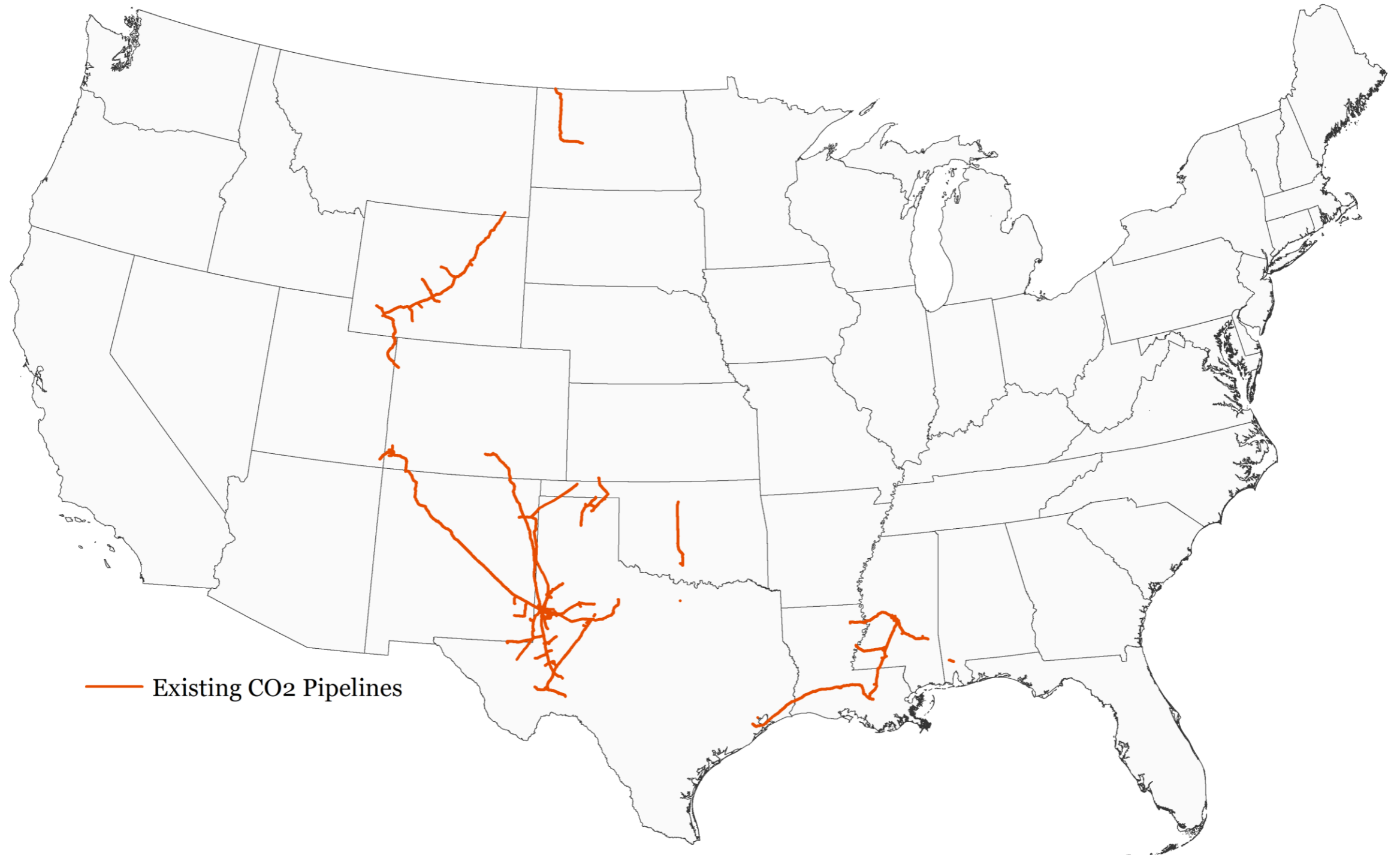
**220 million
tonnes of
CO2 stored
to date**



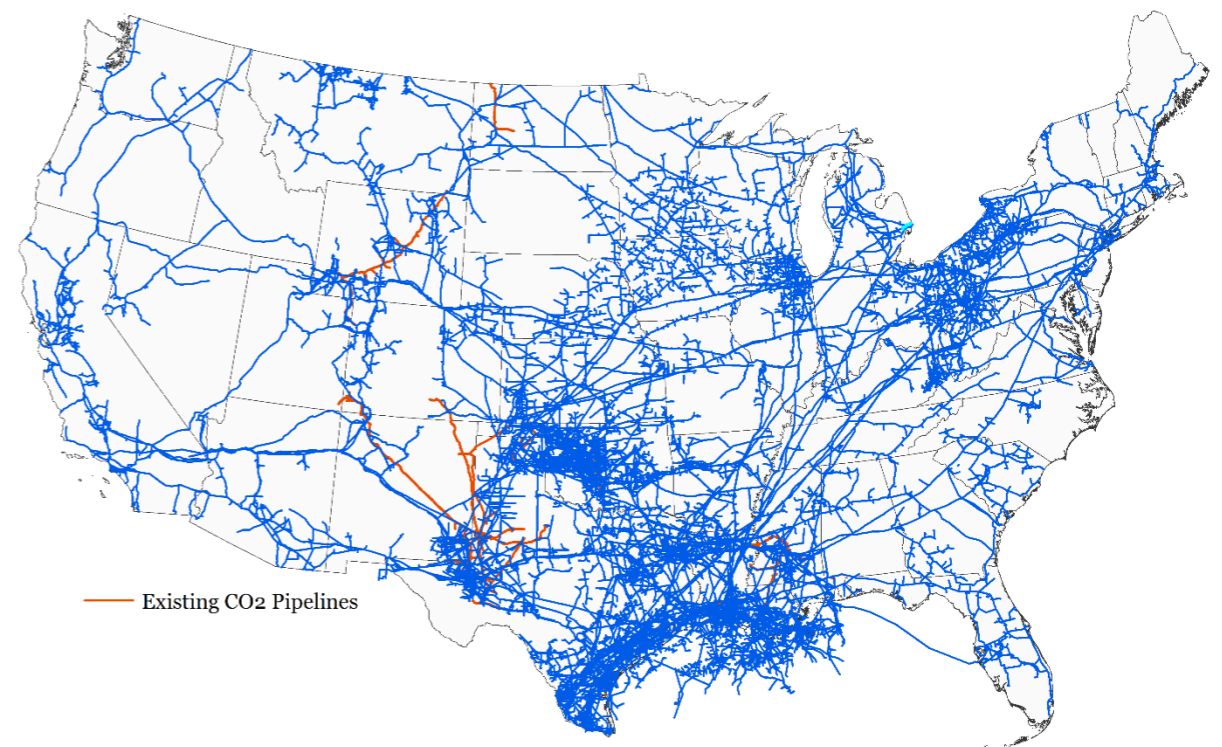
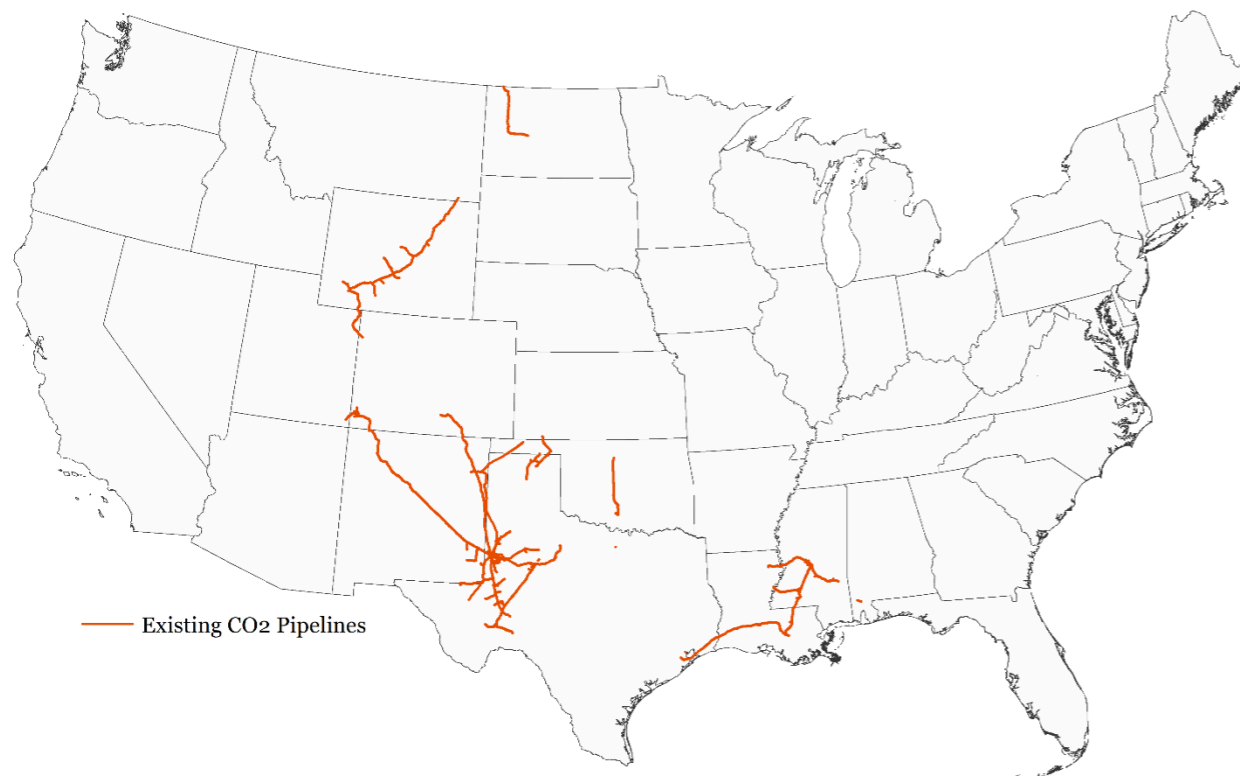
Natural Gas Infrastructure in the U.S.



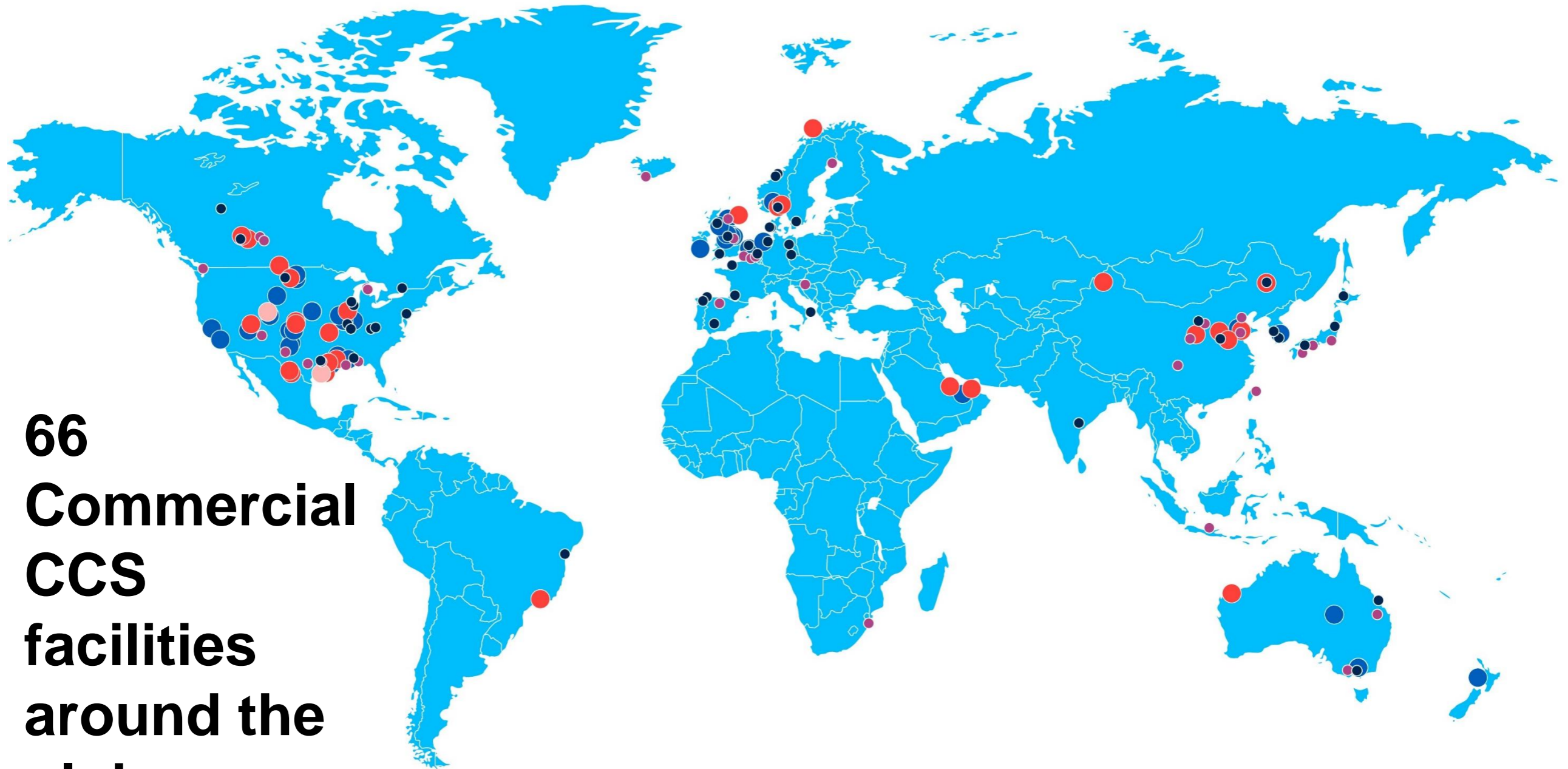
CO2 Pipelines in the U.S.



CO2 Pipelines in the U.S.



WORLD MAP OF CCS FACILITIES IN VARIOUS STAGES OF DEVELOPMENT



- COMMERCIAL CCS FACILITIES IN OPERATION & CONSTRUCTION
- COMMERCIAL CCS FACILITIES IN DEVELOPMENT
- OPERATION SUSPENDED

- PILOT & DEMONSTRATION FACILITIES IN OPERATION & DEVELOPMENT
- PILOT & DEMONSTRATION FACILITIES COMPLETED



Project Green Shoots

Midwest Carbon Capture Platform



What We Are Building

Navigator CO₂ Ventures is proposing to construct approximately 1,200 miles of new CO₂ pipeline spanning five states (Nebraska, Iowa, South Dakota, Minnesota, and Illinois) and sequestration facilities in Illinois with enough early capacity to sequester up to 8 million metric tonnes of carbon dioxide per year

- CO₂ will be sourced from different industrial sources based upon customer commitments
- Platform will be expandable to > 15 million metric tonnes of carbon dioxide per year

Project Timeline

- March 2021: Non-Binding Open Season Launch
- June 2021: Binding Open Season Launch
- 2H2021: Approximately 40 months of permitting & construction commences
- 4Q2024: Initial Phase Commissioning
- 1H2025: Full Commercial Service



Indicative Open Season Map





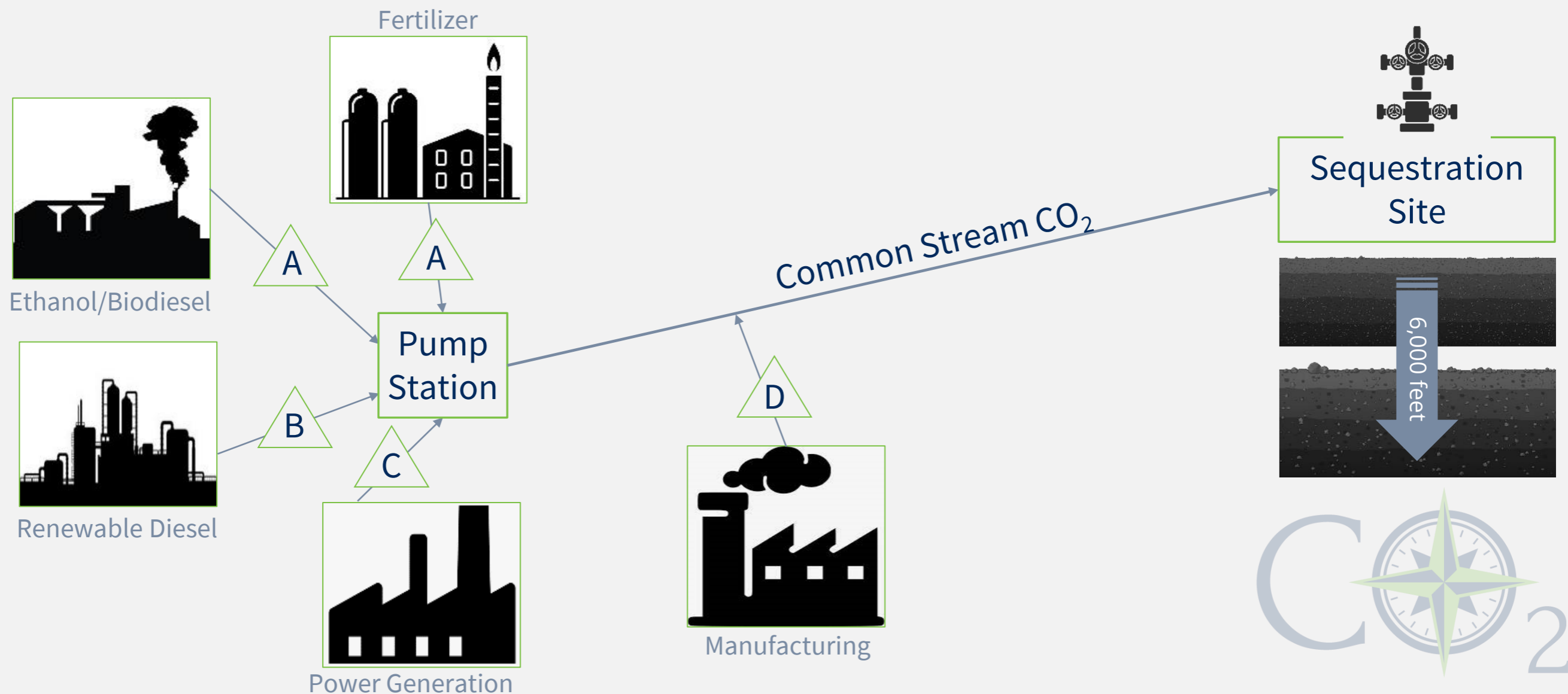
How We Are Commercializing CCS

- Pipeline will be offered to the market as a common carrier system consistent with FERC liquids principles
 - Shippers (versus pipeline or sponsor) will have contractual capacity rights
 - Transparent structure provides framework for new customer onramps and integration with other pipeline systems in the future
 - Fee for service model easy to understand and evaluate
- Navigator is conducting an open season process to solicit customer interest in firm capacity on the pipeline system
 - Rate grid: more capacity + longer term = lower rates
 - Project scale provides basis for attractive rate-setting
- Sequestration site(s) will be developed in parallel to accommodate open season customer responses
 - Fee for service
- Customer option for Navigator to construct and finance on-site carbon capture to minimize upfront emitter CAPEX



Why Pipelines Can Be Part of the Solution

- Pipelines represent an immensely scalable platform to aggregate and sequester carbon
- Emission sources often located at geographically disparate locations from practical carbon sequestration sites
- Engineered solutions for CO₂ capture and conditioning make pipeline systems agnostic to the emissions source
- Monitoring systems measure pressure differentials in tight distance intervals to help manage system integrity

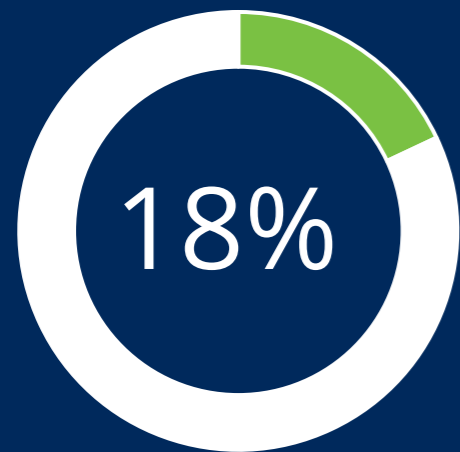


Project Benefits



1,000

The number of trucks per day it would take to transport **~8 million mT of CO₂ annually**



Project's potential to eliminate ~18% of emissions produced by Industrial Processes and Agriculture in the state of Iowa

First step in creating multi-industry carbon hub



Substantial Economic Benefits

- Dozens of permanent fulltime jobs
- Thousands of temporary jobs
- Millions in localized tax benefits



Source: 2019 Iowa Statewide Greenhouse Gas Emissions Inventory Report

About Us



Matt Vining, CEO

"Investing in CCS allows us to be a good steward of our midstream expertise while simultaneously addressing climate change and building a more sustainable future."

Founded in 2012, Navigator is a privately owned midstream infrastructure company with operations based in the US.

Since inception, Navigator has deployed over \$1.3 billion in capital and has safely constructed and operated more than 1,000 miles of pipeline.

The company employs 52 individuals and expects to double in size over the next 36 months. Our experienced management team has over 130 years of combined experience across multiple commodities.

Matt Vining, CEO, resides in Iowa and plans to establish offices in Iowa, Nebraska and Illinois.



Infrastructure for a Net-Zero Future: **Link to Geologic Storage**

Susan Hovorka
Gulf Coast Carbon Center
Bureau of Economic Geology
Jackson School of Geosciences
The University of Texas at Austin

*GCCSI Carbon Capture and Storage 101 Webinar #2
May 7, 2021*



BUREAU OF
ECONOMIC
GEOLOGY

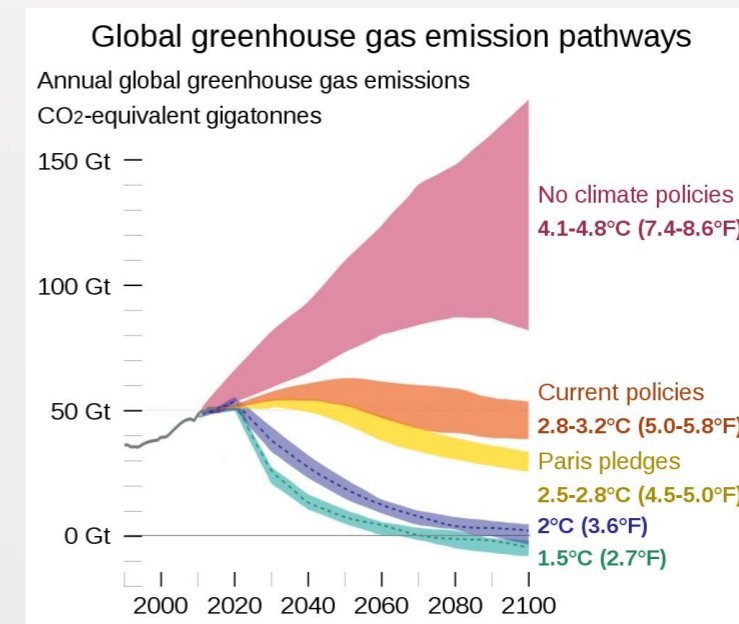


TEXAS Geosciences
The University of Texas at Austin
Jackson School of Geosciences



Role of Storage in CCS

- To attain very large volume atmospheric CO₂ reductions, large volume, permanent storage is needed.
 - Much of this need can be met by injection of CO₂ into Deep Saline Formations
 - Initiated and augmented by use and storage of CO₂ via EOR.



Ritchie and Roser (2017) - "CO₂ and Greenhouse Gas Emissions"

Mechanism of CO₂ Storage in Deep Saline Formations

Capture

Land surface

Underground

800 m

**Confining system
limits CO₂ rise**

brine

CO₂

Inje

Pore-scale trapping

Sand grain

CO₂

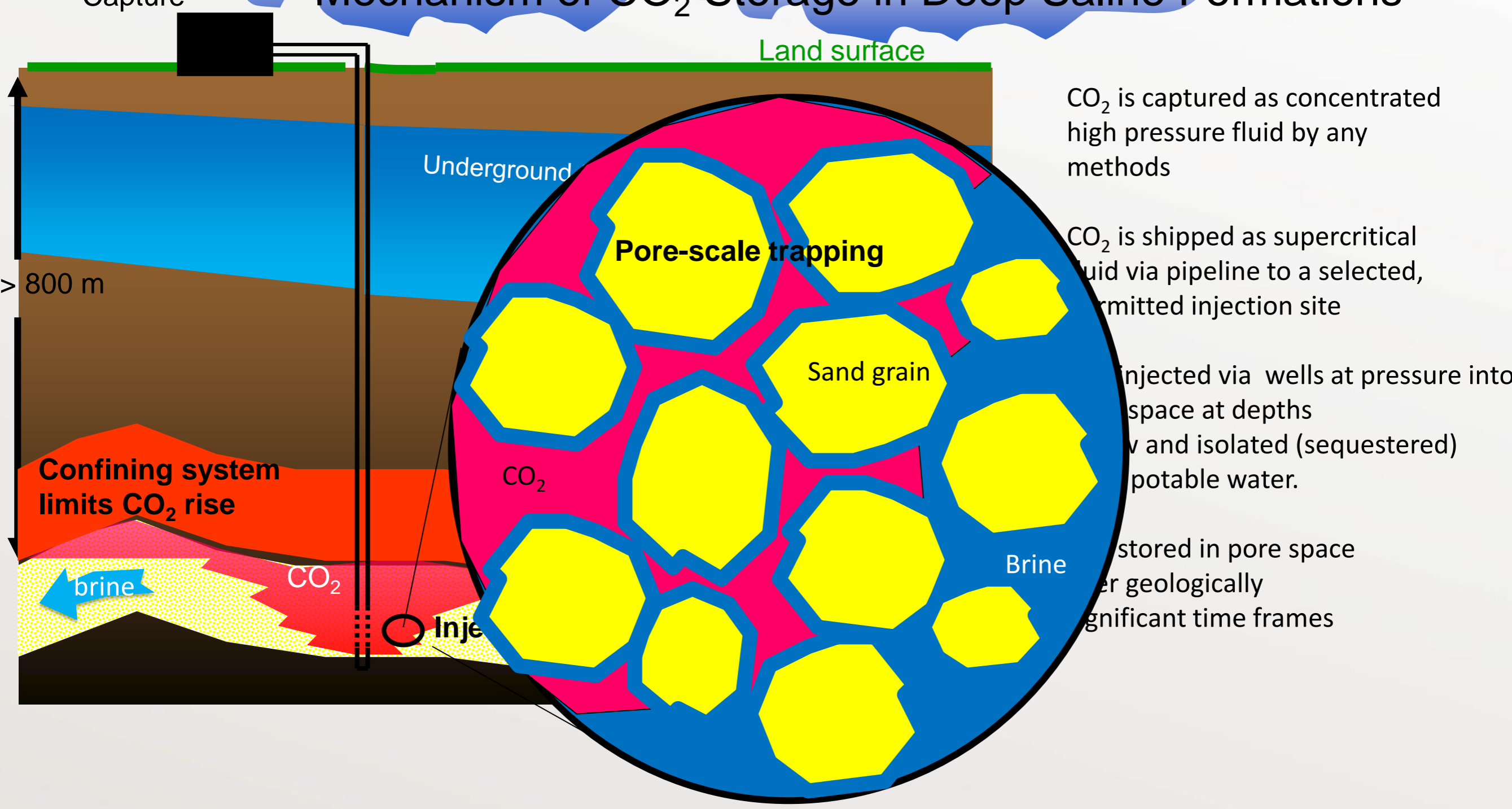
Brine

CO₂ is captured as concentrated high pressure fluid by any methods

CO₂ is shipped as supercritical fluid via pipeline to a selected, permitted injection site



Injected via wells at pressure into pore space at depths where it is slow and isolated (sequestered) from potable water.

CO₂ is stored in pore space for geologically significant time frames



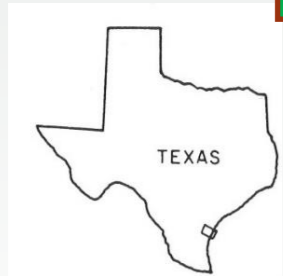
Multiple Stacked Storage Units

6000 ft
Below sea level

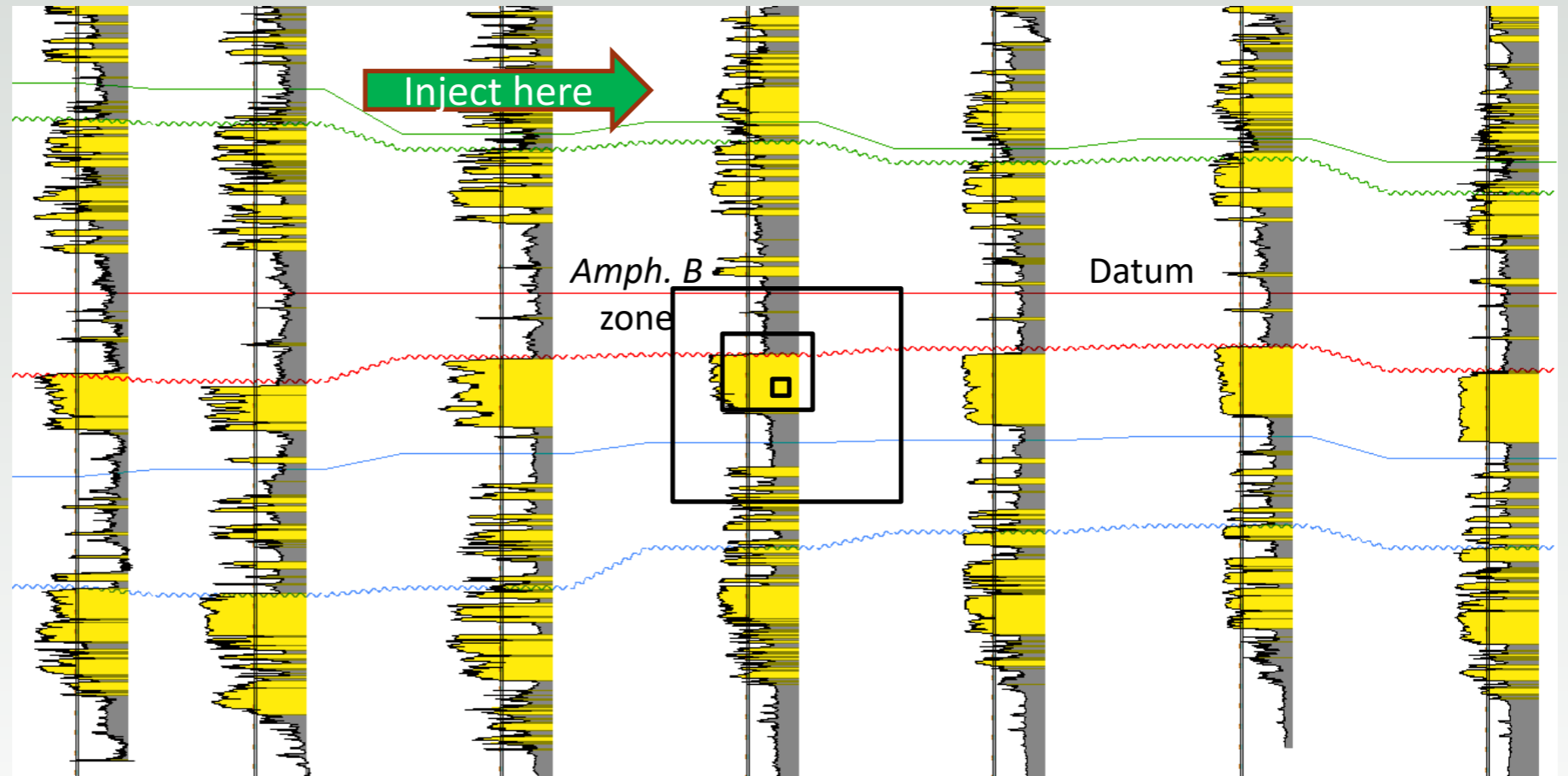
 Sandstone
Porosity indicator
 Mudrock

 Inject here

 Inject here



500 ft



7 miles

Tucker Hentz BEG

Rock Volume Occupied by CO₂



Porosity indicator

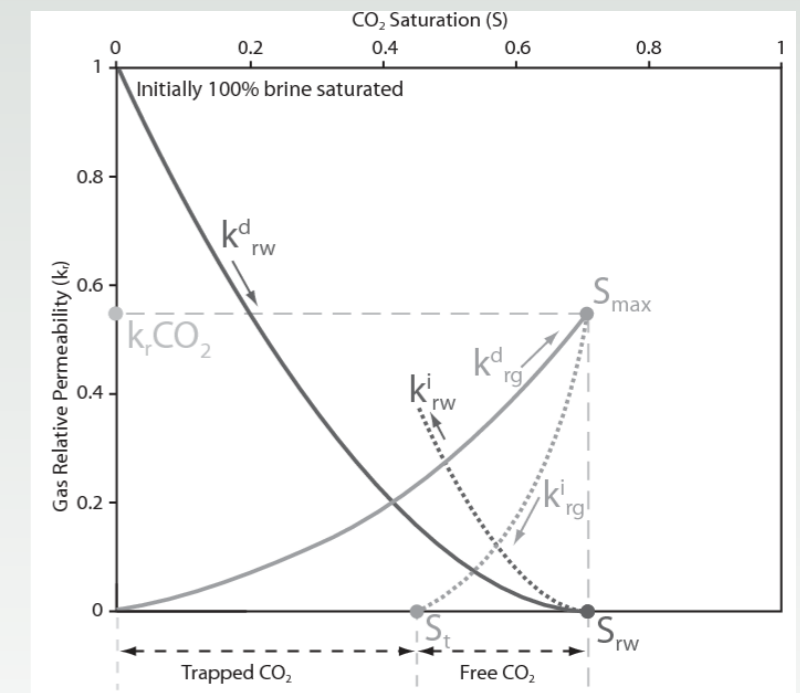
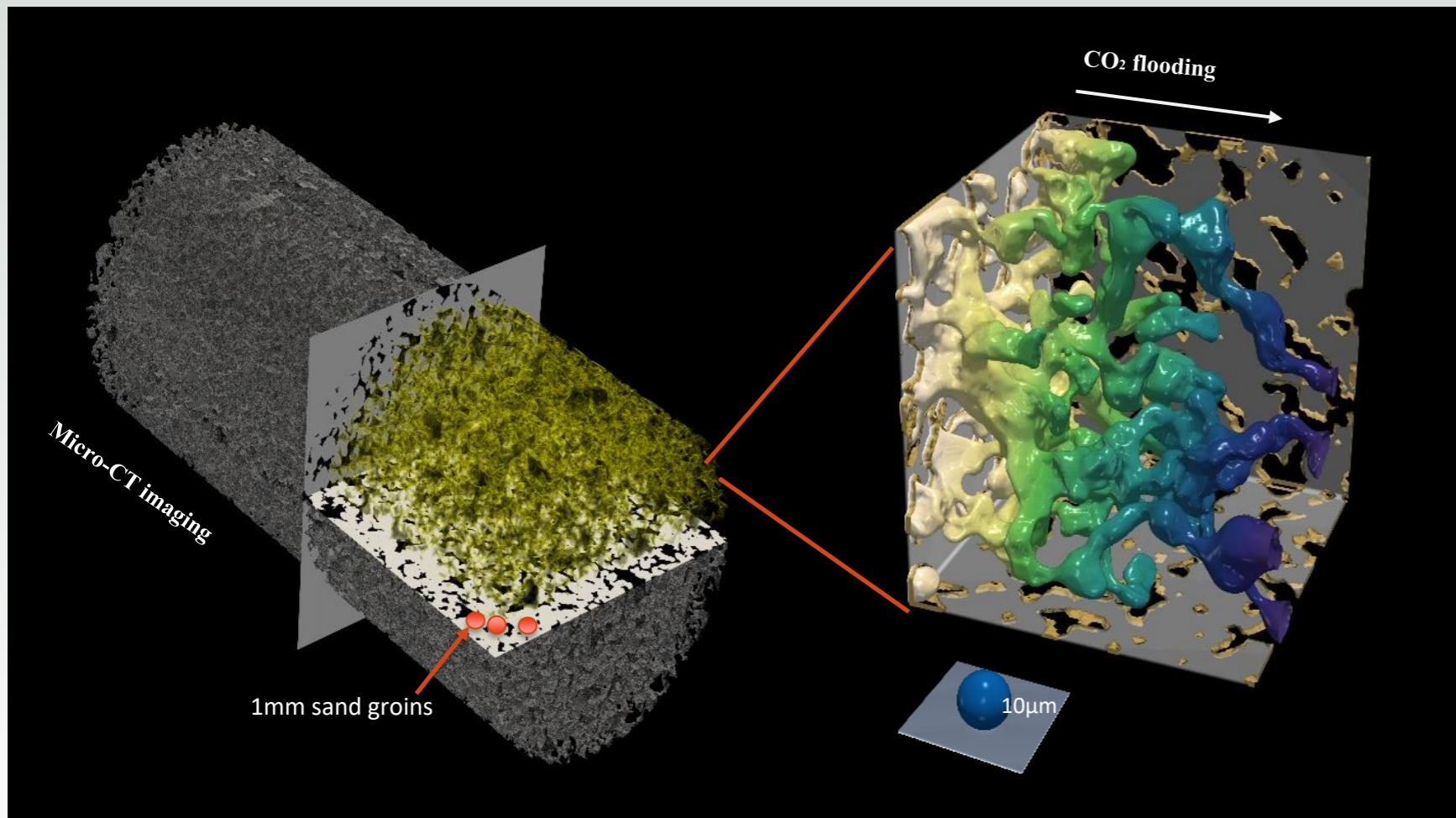
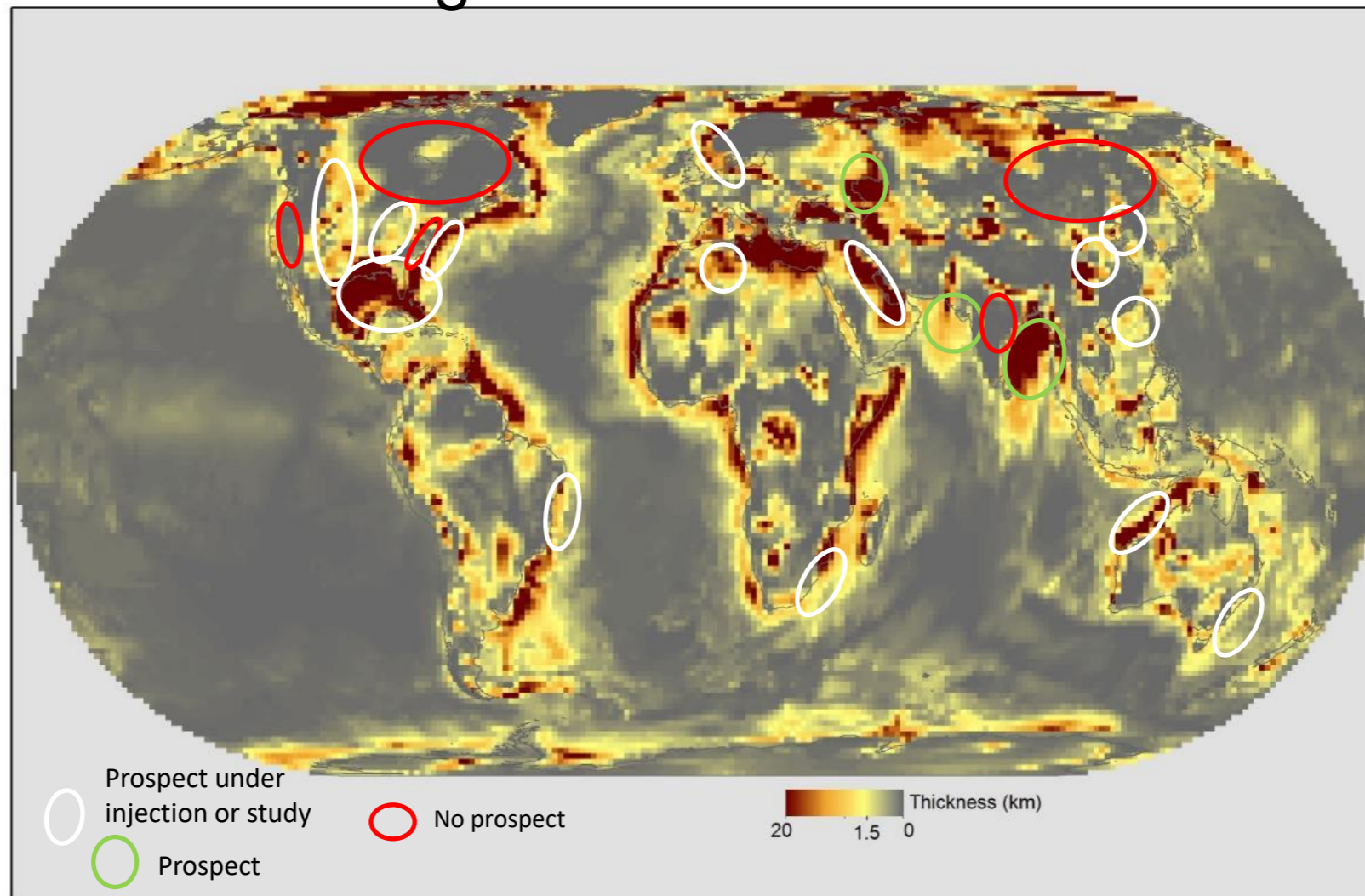


Fig. 1. An example. Burnside and Naylor 2014

Sahar Bakhshian BEG

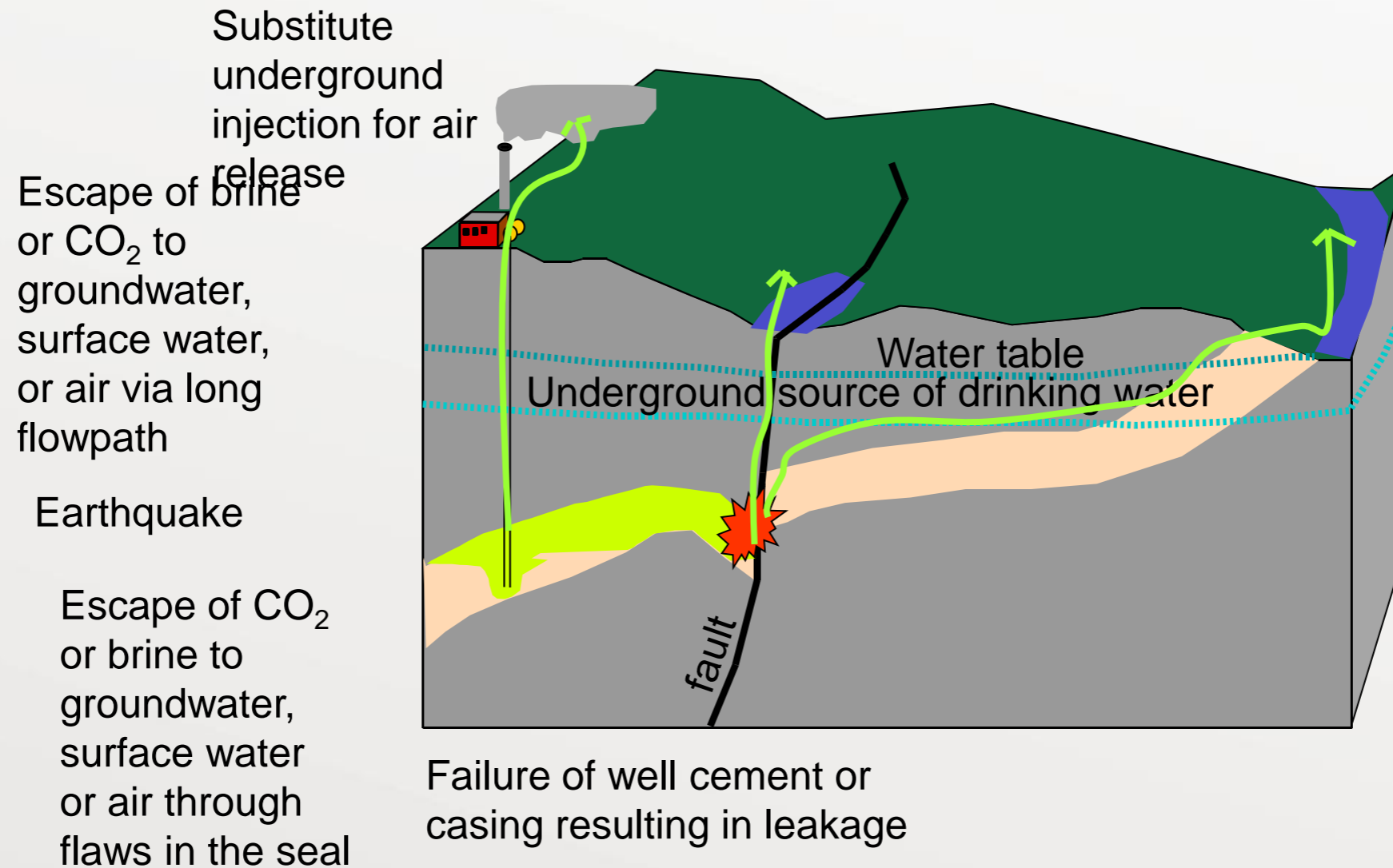
Storage Resource Distribution



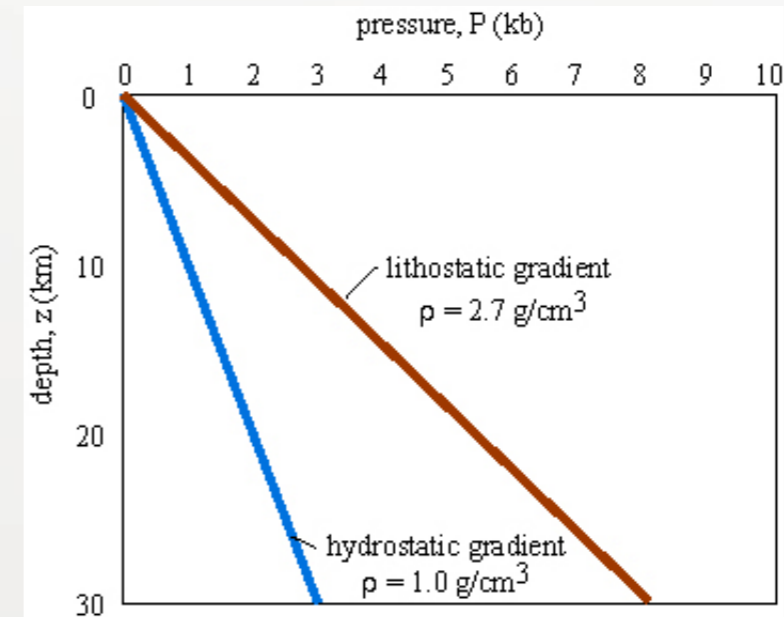
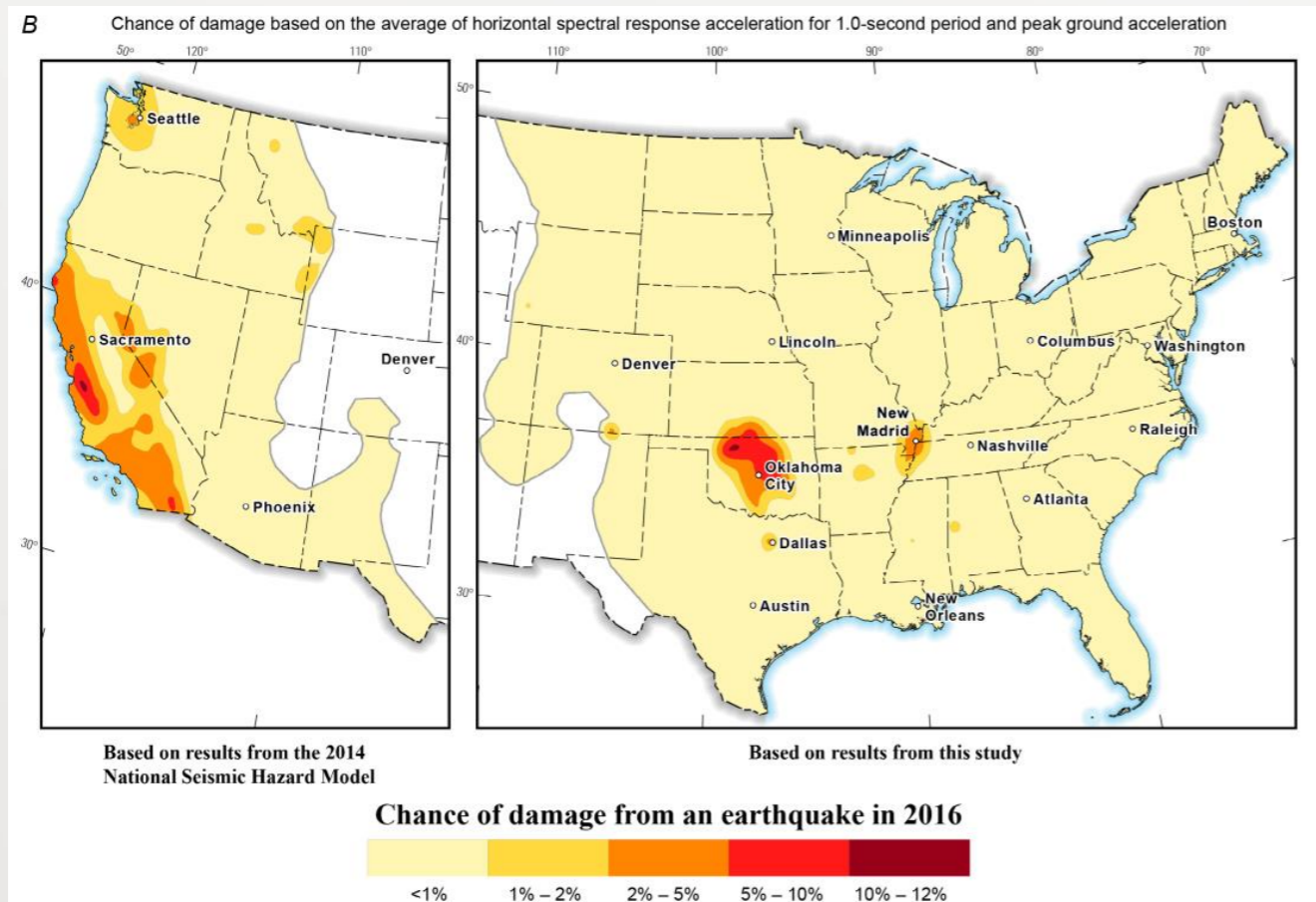
G. Laske and G. Masters, A Global Digital Map of Sediment Thickness, EOS Trans. AGU, 78, F483,
US capacity - 2,379 GT – 21,633 GT (NETL and USGS)

More info: <https://www.globalccsinstitute.com/resources/global-status-report/>

Risk assessment

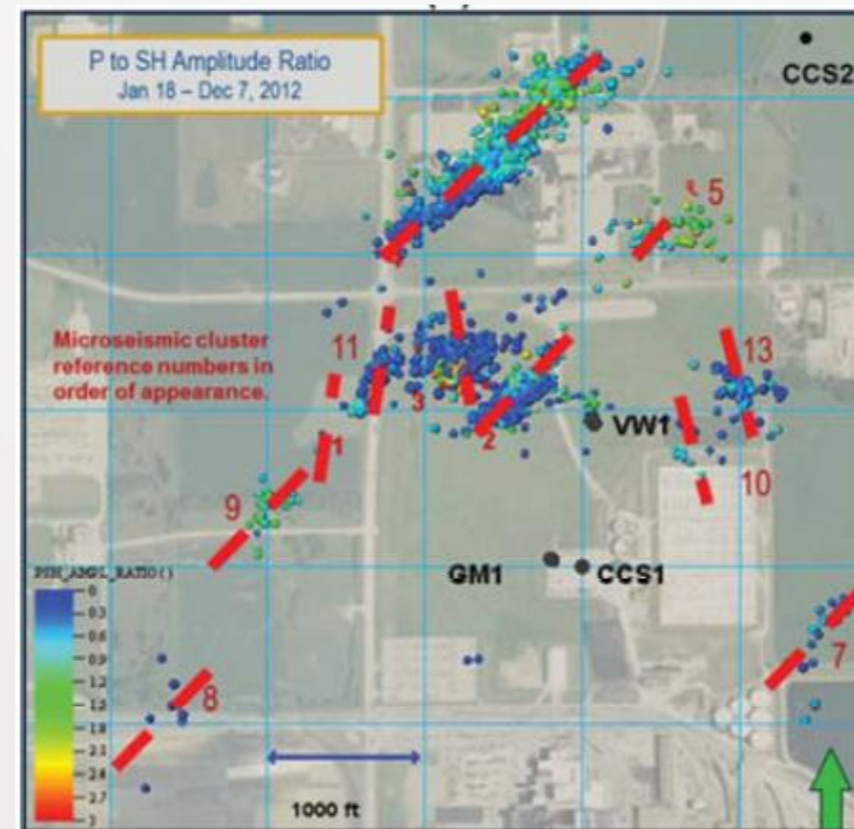
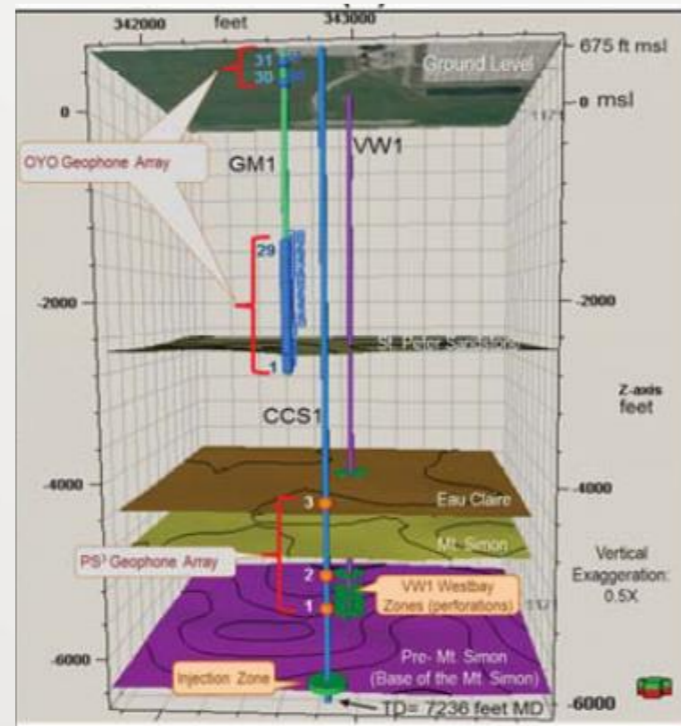


Induced Seismicity



USGS Pedersen, 2016 http://pubs.usgs.gov/of/2016/1035/ofr20161035ver1_1.pdf

Microseismicity for tracking pressure elevation



Illinois Basin Decatur Project, Lee et al, 2014

Leakage: likelihood is low x consequence is low = risk is low

- Available past practices
 - 80MMT stored at SACROC field, Scurry County TX
 - No detection of CO₂ in groundwater
 - 20 MMT stored at Sleipner field North Sea
 - No detection of loss by British Geologic survey
 - Well failure studies Kell 2011; Porse, Wade, Hovorka
 - <https://www.rrc.texas.gov/oil-and-gas/compliance-enforcement/blowouts-and-well-control/>
- Controlled release experiments
 - What would happen if CO₂ leaked to air, water, soil, ocean
 - Small but detectible impacts. No massive damage.

CO₂ Controlled Release Experiments



ZERT experiment:

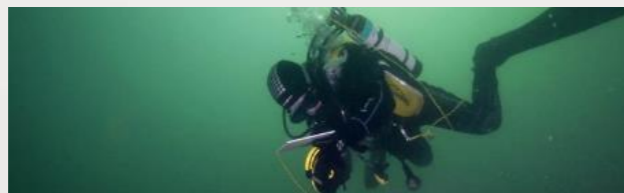
https://water.usgs.gov/nrp/proj.bib/Publications/2010/spangler_dobeck_etal_2010.pdf



Brackenridge and SECARB experiments
Changbing Yang -- BEG

Ginninderra

http://www.ieaghg.org/docs/General_Docs/1_Comb_Mon_EnvRes/3_GinnCRFSEC.pdf



http://www.pml.ac.uk/News/CCS_controlled_leak_results



<http://www.stemm-ccs.eu/>

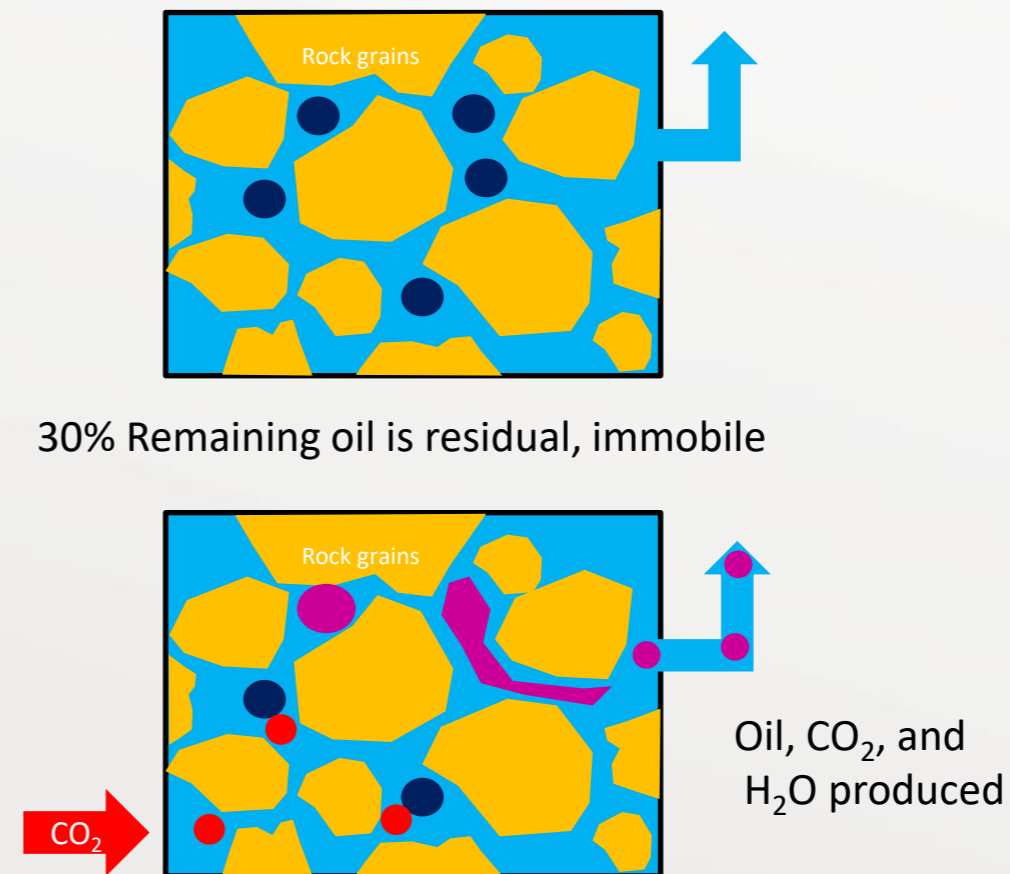
Use of CO₂ for enhanced oil recovery (EOR) process

Residual oil will not move to production wells

At reservoir pressure, CO₂ is miscible with oil

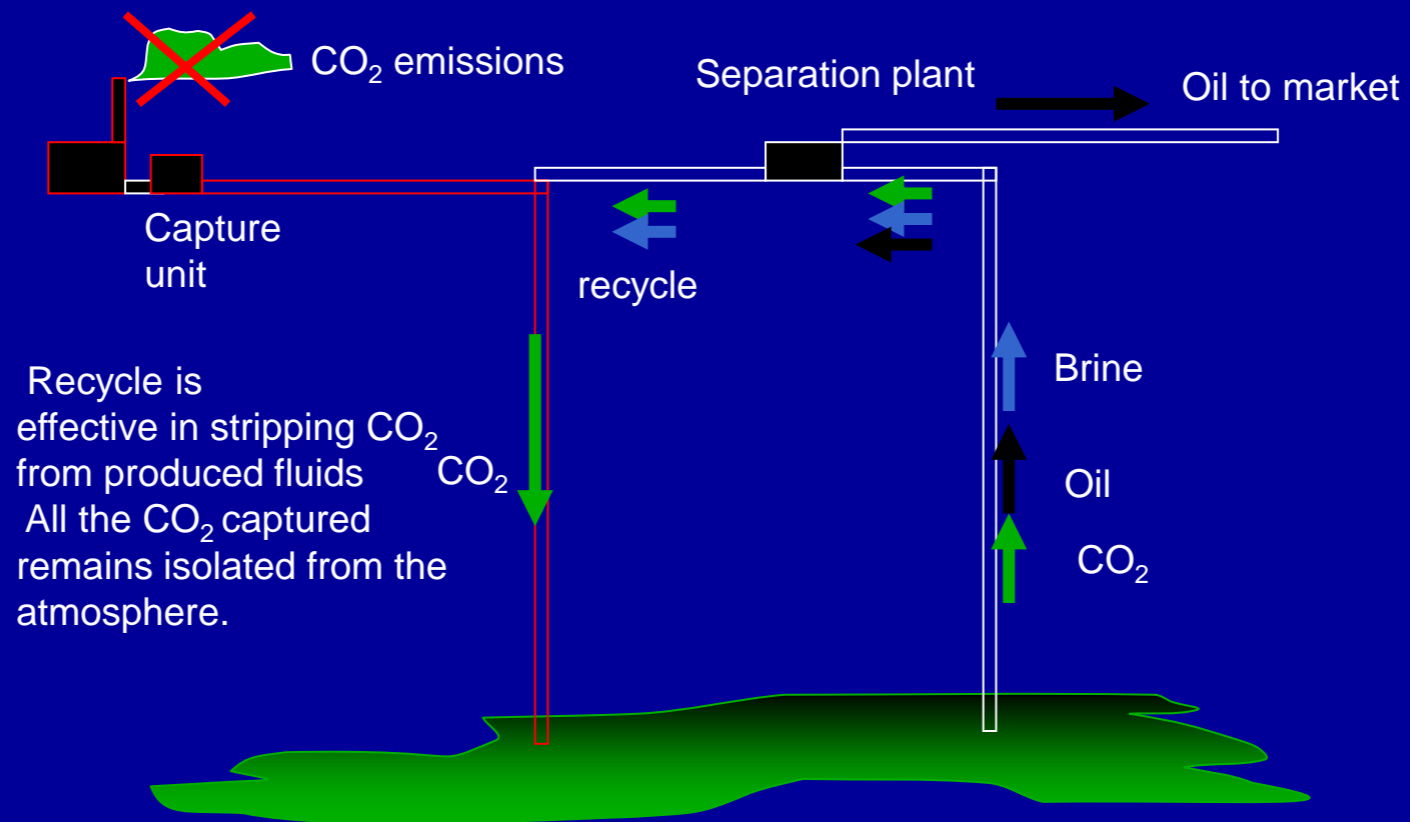
- Viscosity decrease
- Volume increase

Oil-CO₂ phase can migrate to production wells

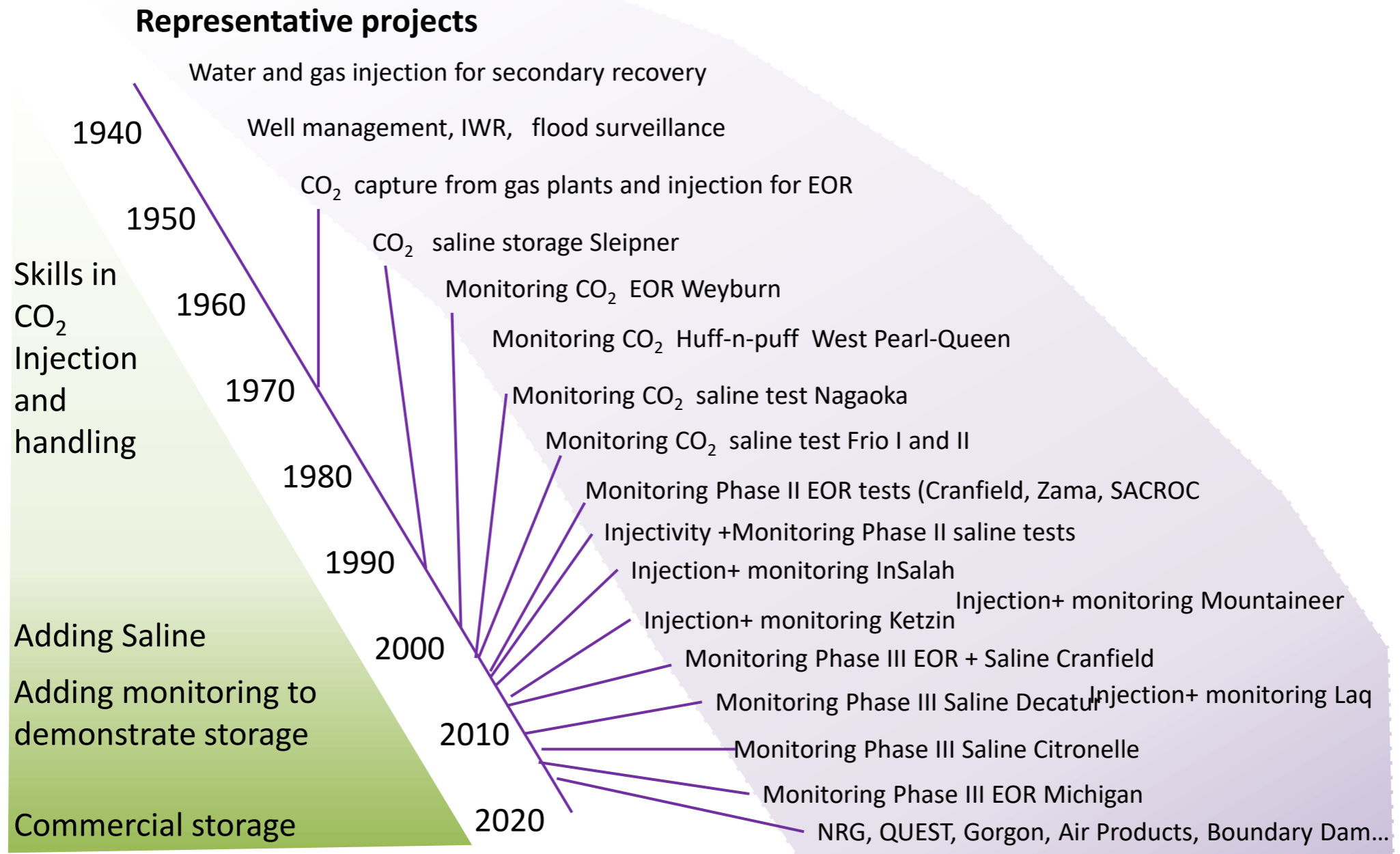


Note: Many other EOR techniques compete with CO₂

CO₂ EOR is a Closed Loop System



Safe and Effective Injection > 50 years



Conclusions

- Status of geologic storage in deep saline formations and via EOR: mature, successfully underway and ready for larger scale implementation
- Challenges: convincing key stakeholders this is true
- Capacity is large but unevenly distributed
- Failure is rare, consequences ordinary, and risk manageable

Questions?

Susan Hovorka

Susan.hovorka@beg.utexas.edu

www.gulfcoastcarbon.org



The Carbon Capture and Storage 101 Webinars, May 7 2021

CCS Infrastructure for a Net-Zero Future

Jean-Philippe Hiegel, Strategy & Market Director, Northern Lights JV



Northern Lights, part of a first commercial CCS chain involving multiple emitters



→ A flexible shipping solution

- Accommodating volumes from multiple emitters
- Allowing the decoupling of the emitter location from the storage



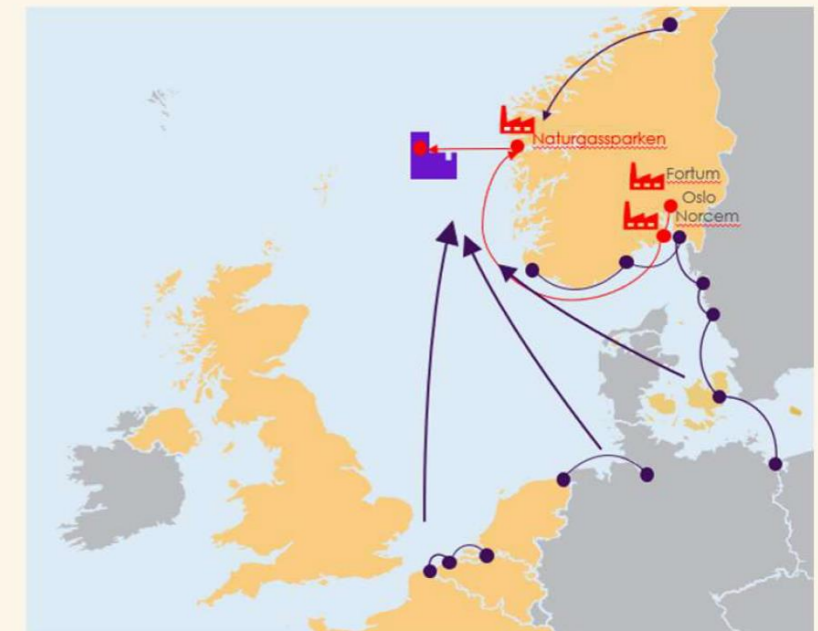
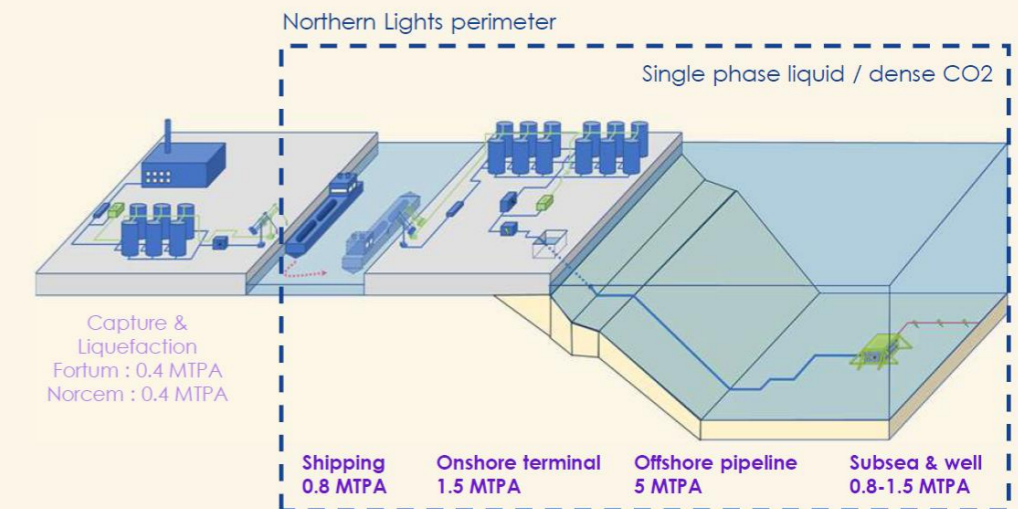
→ A phased development

- Phase 1 includes capacity to transport, inject and store up to 1.5 MTPA
- Phase 2 will increase capacity up to 5 MTPA



→ An incentive to launch a European CCS market

- Norwegian State subsidies during 13 years in exchange for up to 0.8 MTPA capacity reservation
- Future revenues to be sourced from marketing of available capacity



Permanent CO₂ geological storage, a return to the origins



→ Exploitation licence EL-001 “Aurora” awarded in January 2019

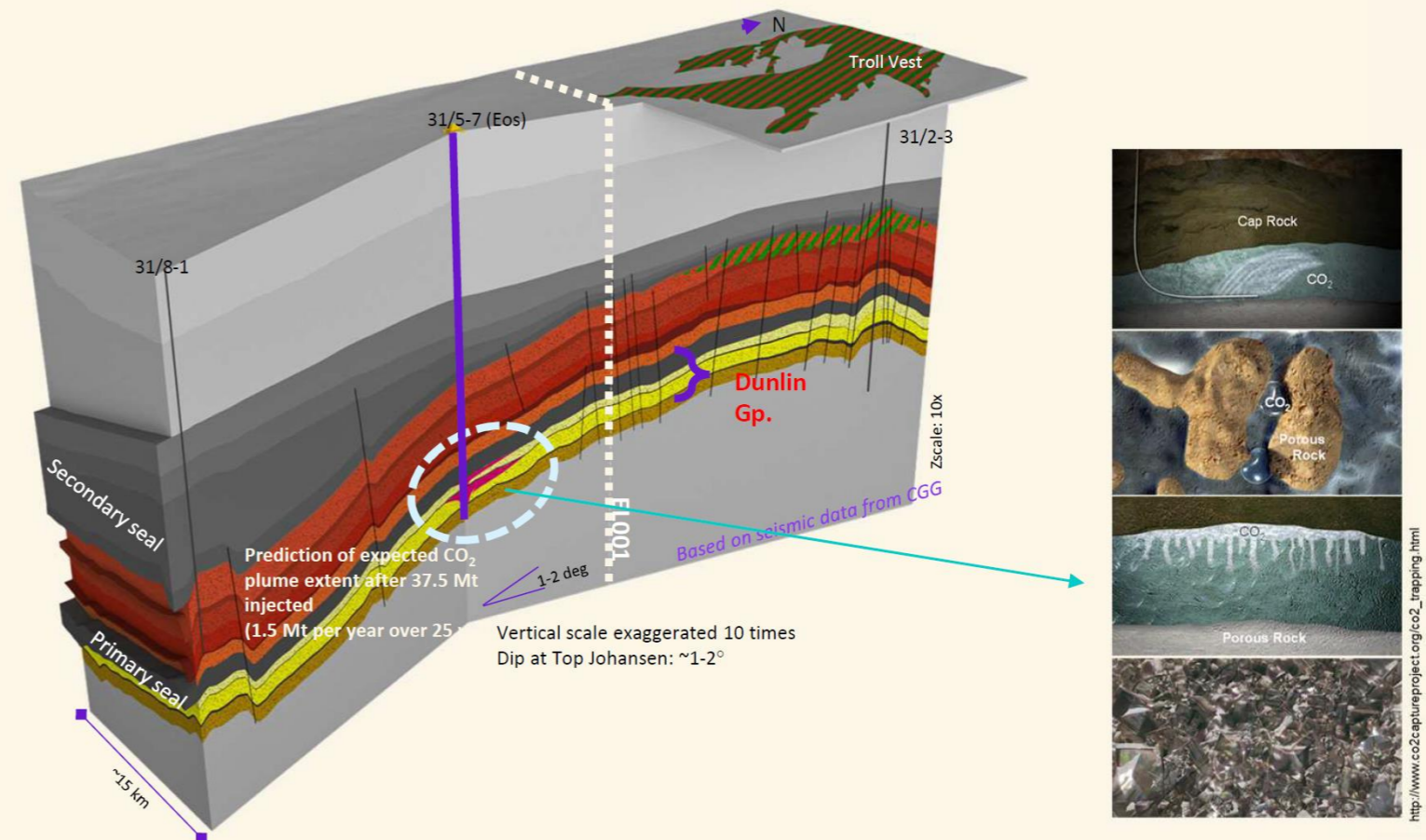
- Saline aquifer located south of Troll gas field, 2,800 meters below seabed in the Johansen formation
- Min 100 Mt expected capacity

→ “Eos” appraisal well drilled in March 2020

- High quality sandstones
- Sealing cap rock
- Hydrostatic pressure regime

→ A safe and well-known operation

- 25 yrs of expertise in CO₂ injection & storage (Sleipner since 1996, Snøhvit since 2008)
- Same natural conditions as O&G trapping for millions of years
- Monitoring and injection control



Structural trapping → Residual trapping → Dissolution & Mineral trapping

CCS, an essential technology to reach Europe carbon neutrality by 2050



→ A necessary tool to meet Paris Agreement's target

- IEA Sustainable Development Scenario <math><2^{\circ}\text{C}</math> requires CCS growth rate analog as the O&G industry at its beginning

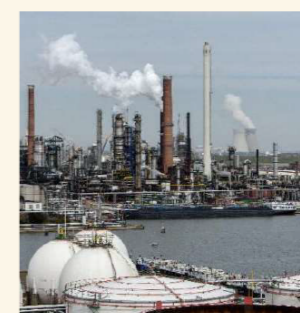
→ CCS at the core of the carbon neutrality virtuous circle

- Capturing and storing residual CO_2 emitted by hard-to-abate industries (cement, steel, refining & chemicals, etc.)
- Generating low carbon power from gas
- Enabling carbon removal ("negative emissions") through bioenergy with CCS (BECCS) and Direct Air Capture (DAC) with CCS

→ Fully part of the European climate-neutral ambition by 2050

- Objective at the heart of the European Green Deal and the first European Climate Law
- Embedded into Member States national strategies (Denmark Climate Act, Dutch Climate Agreement, Norway's Climate Plan, French Climate Law, ...)

CCS to grow *
x 20 by 2030
x 80 by 2040



* Source : IEA Sustainable Development Scenario <math><2^{\circ}\text{C}</math>

Northern Lights, part of a first commercial CCS chain involving multiple emitters



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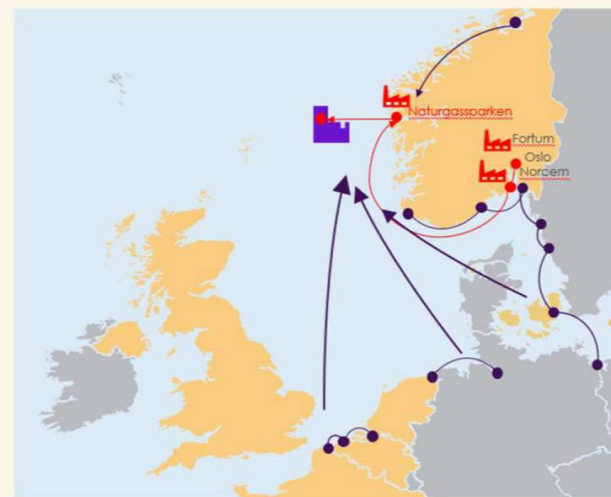
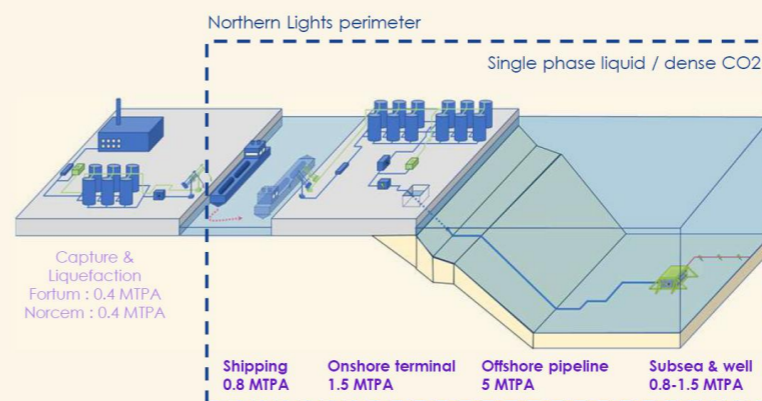
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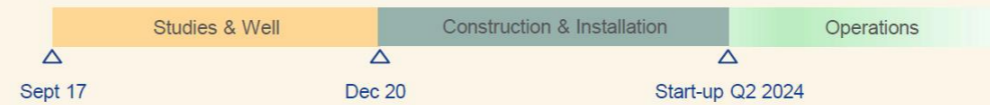
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The dawn of a new industry



→ Northern Lights, a frontrunner in Europe

- Phase 1 Final Investment Decision and Norwegian Parliament ratification in 2020
- Northern Lights JV incorporated in March 2021, first company worldwide to deliver CO₂ shipping and storage as a service
- Start of injection scheduled by mid 2024



→ Subsidies and carbon pricing as short-term enablers

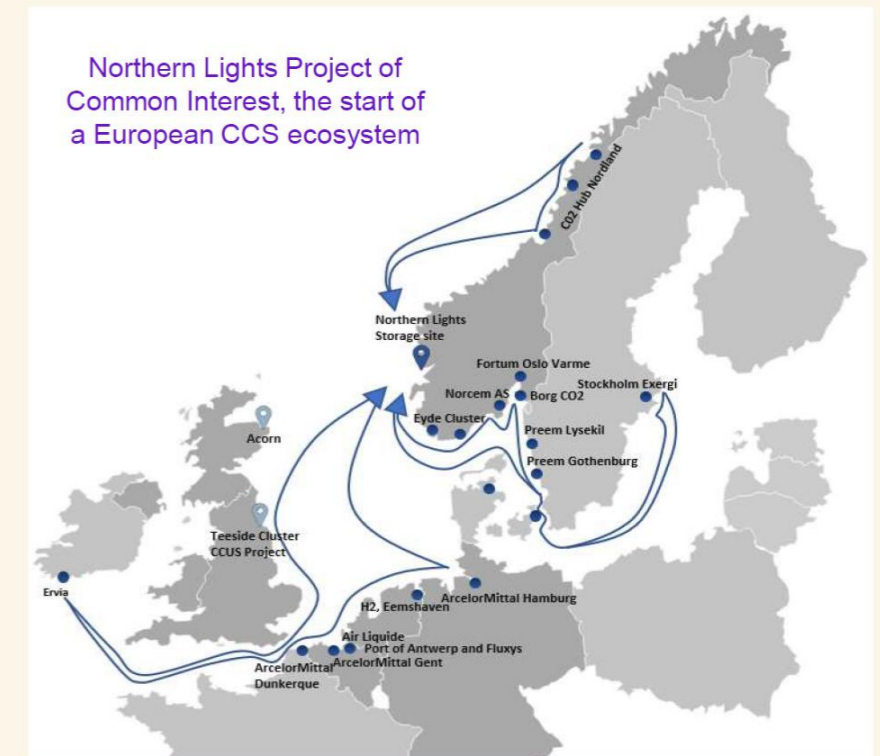
- Two pillars necessary to bridge the gap between the price to emit and the cost to decarbonize

Full chain cost
> 200 \$/t *
vs ETS ≈ 60 \$/t

* Before Norwegian State support

→ Next levers to create value

- EU/State policies linking CCS and emissions targets (storage certificates, fiscal incentives, etc.)
- Added value for zero carbon products





Northern Lights

norlights.com

CCS infrastructure in the UK

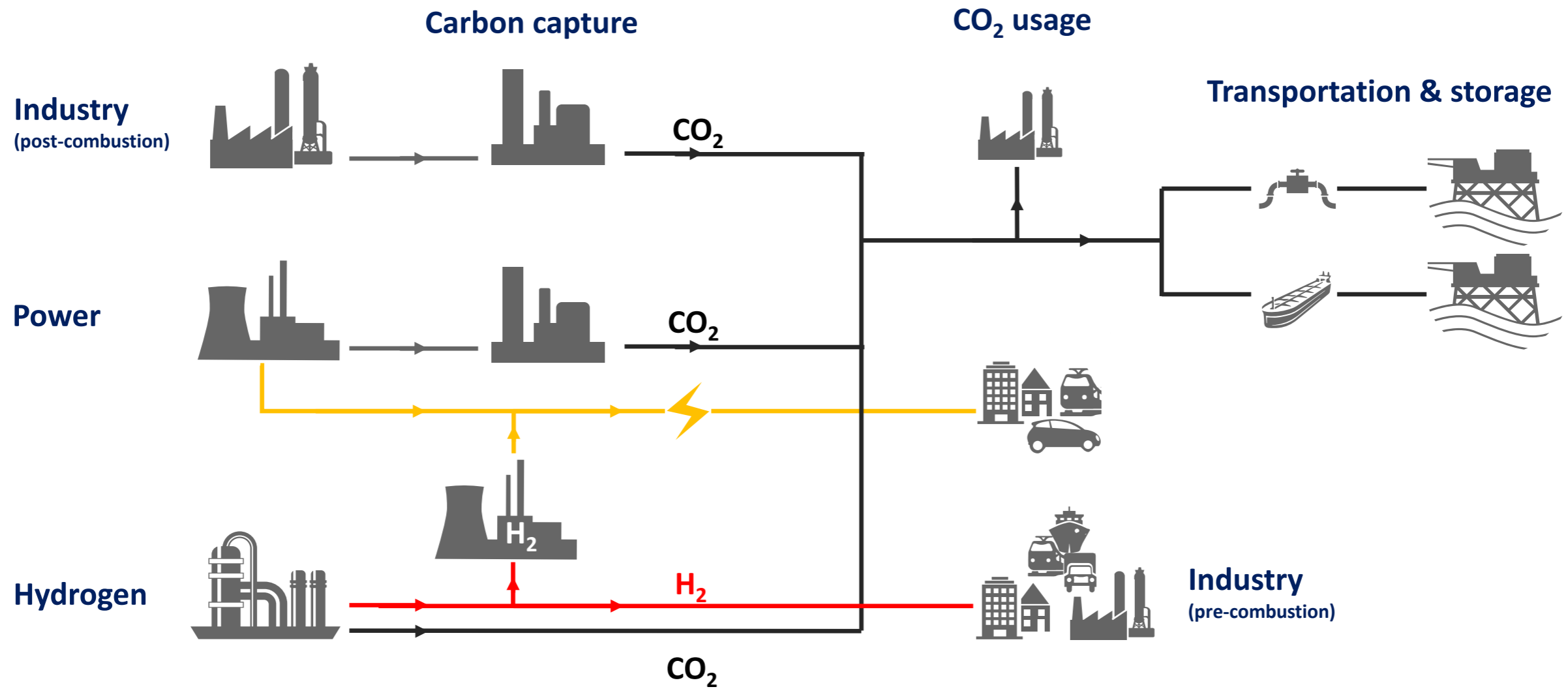
Ian Hunter

Commercial Manager

Net Zero Teesside & Northern Endurance Partnership













Key roles for CCS



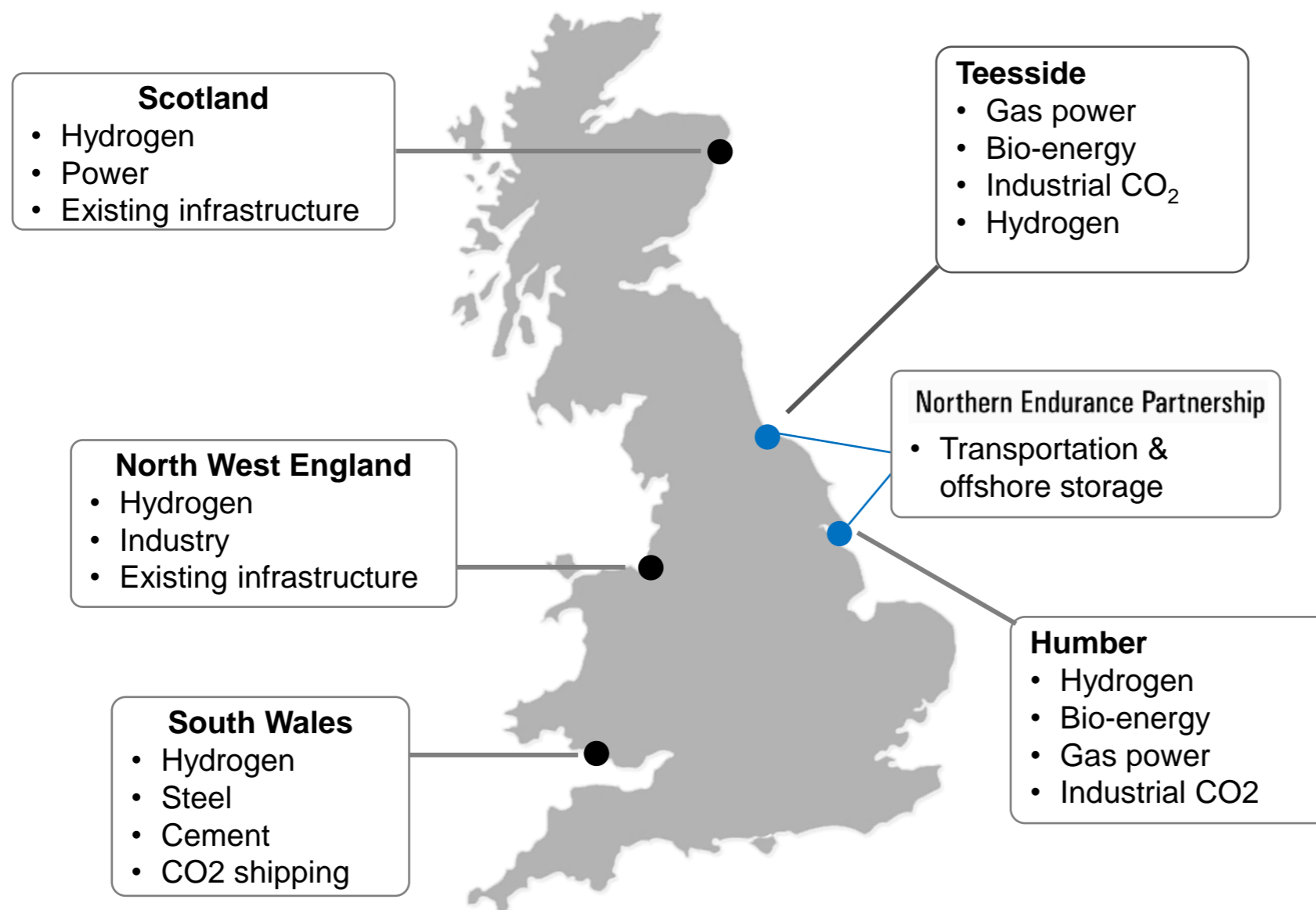
UK Government 10 point plan

- In 2019 UK put into law that the entire country would have Net Zero emissions by 2050
- In November 2020 UK government published its 10-point plan outlining key aims for the next decade
 - To develop four CCS clusters with two operating by the mid-2020s and two more by 2030
 - Capture 10 MtCO₂ a year by 2030
- December 2020, UK's 6th carbon budget update: CCS is essential to reach net zero:
 - >20mtpa by 2030
 - >100mtpa by 2050

The Ten Point Plan for a Green Industrial Revolution

- 
Point 1
Advancing Offshore Wind
- 
Point 2
Driving the Growth of Low Carbon Hydrogen
- 
Point 3
Delivering New and Advanced Nuclear Power
- 
Point 4
Accelerating the Shift to Zero Emission Vehicles
- 
Point 5
Green Public Transport, Cycling and Walking
- 
Point 6
Jet Zero and Green Ships
- 
Point 7
Greener Buildings
- 
Point 8
Investing in Carbon Capture, Usage and Storage
- 
Point 9
Protecting Our Natural Environment
- 
Point 10
Green Finance and Innovation

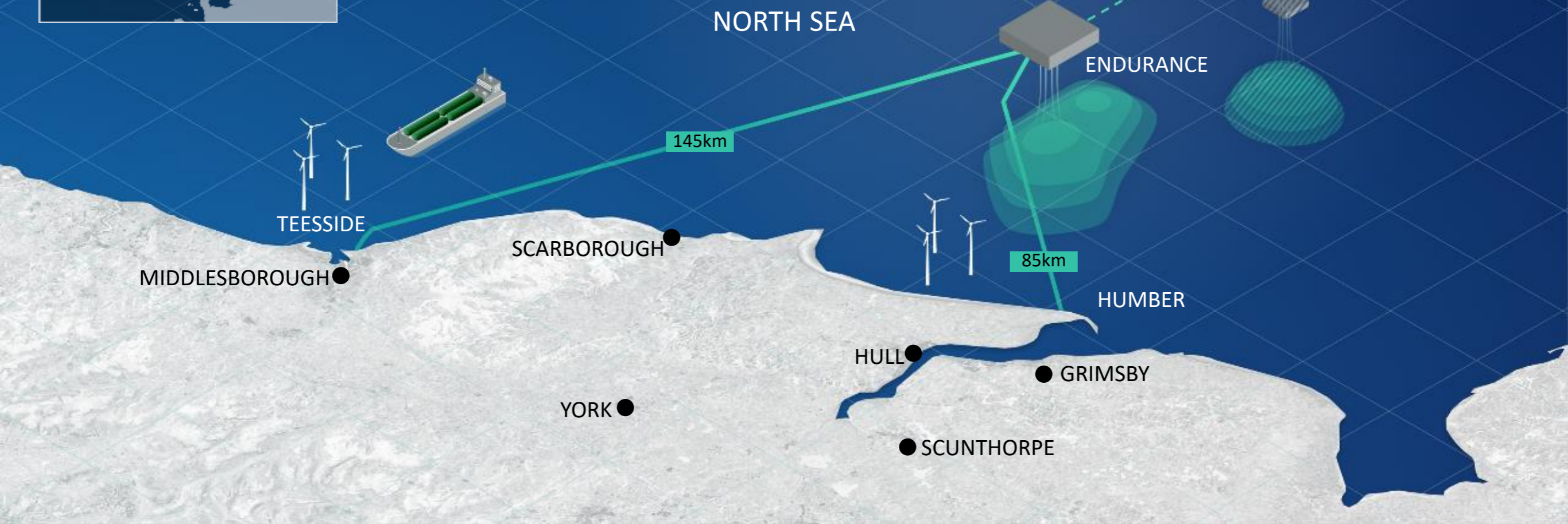
UK – Key CCS Clusters

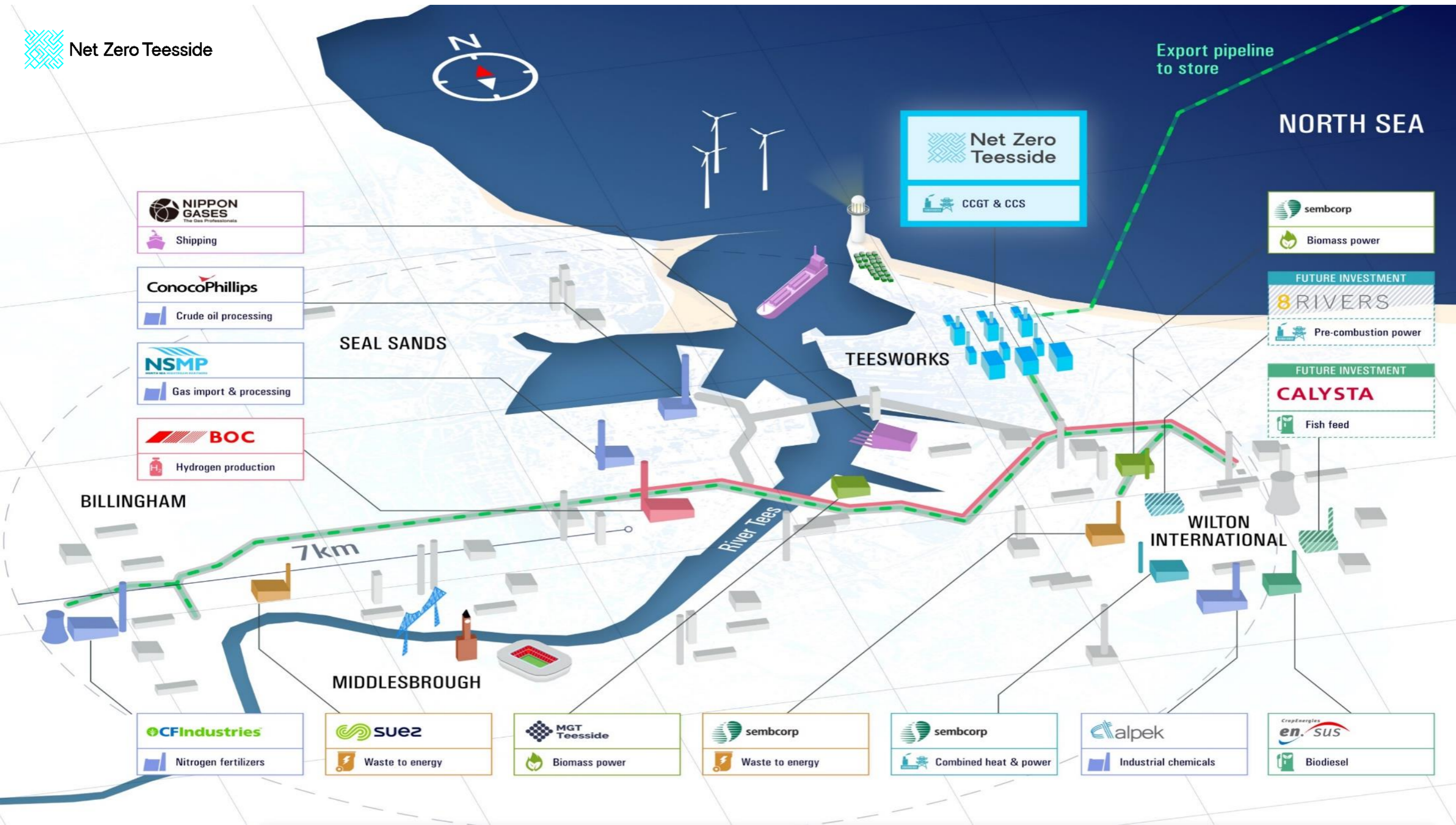


Teesside & Humber clusters



Net Zero Teesside & ZEROCARBON HUMBER
Northern Endurance Partnership





Business Models – “Split Chain” commercial structure

