CCUS and the North Sea

A Stepping Stone Towards Net Zero

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CCUS & the North Sea

A Steppingstone Towards Net-Zero

1

CCUS and the North Sea

Who are the big names?

Which countries are leading the pack?

Pioneering projects

2

Comparison With U.S. CCUS

Storage site selection and economics

Well containment risk

Compare, contrast and collaborate

3

Conclusions

What has the North Sea achieved?

What can be learnt from the U.S. to move forward?

North Sea

Making Waves With CCUS

- Country-level goals
- Projects and stakeholders
- Sleipner and Greensand
- Spatial challenges
- CCUS trailing renewables
- EU and country-level funding

Ambitious Goals Across Europe

Fit for 55 Sets Benchmark for Targeted GHG Cuts (and CCUS Capacity)

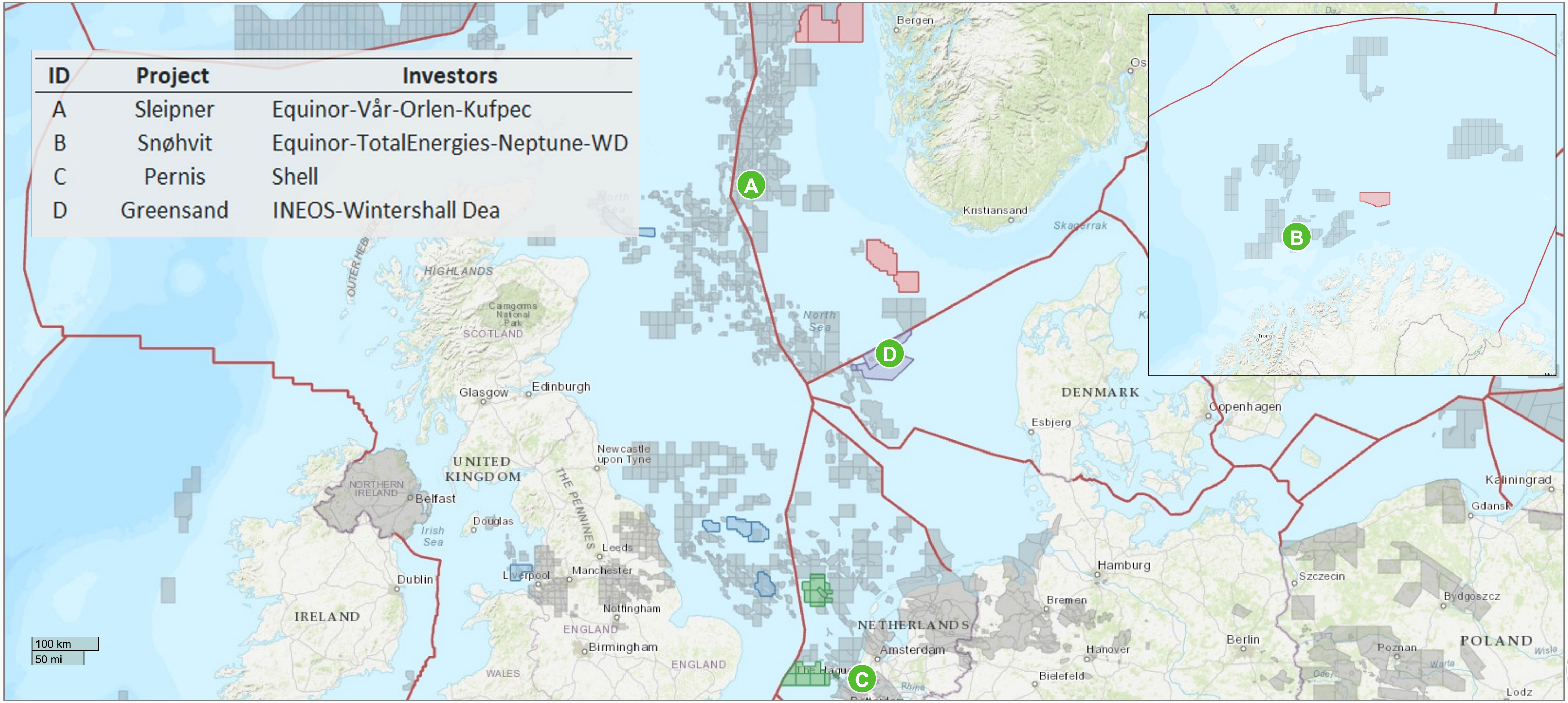
	2030	2050
Netherlands	49%	95%; net zero
UK	68% (20-30 mtpa)	Net zero emissions
Germany	65%	Carbon neutral (2045)
Norway	50-55%	90-95%
Denmark	70%	Carbon neutral
France	55%	Net zero emissions
Belgium	55%	80-95%, carbon neutral
EU	55% (50 mtpa)	Climate neutrality

Source | Enverus Global Scout

Equinor Leads the Charge

1.7 mtpa at Sleipner West & Snøhvit

ID	Project	Investors
A	Sleipner	Equinor-Vår-Orlen-Kufpec
B	Snøhvit	Equinor-TotalEnergies-Neptune-WD
C	Pernis	Shell
D	Greensand	INEOS-Wintershall Dea



Source | Enverus Global Scout

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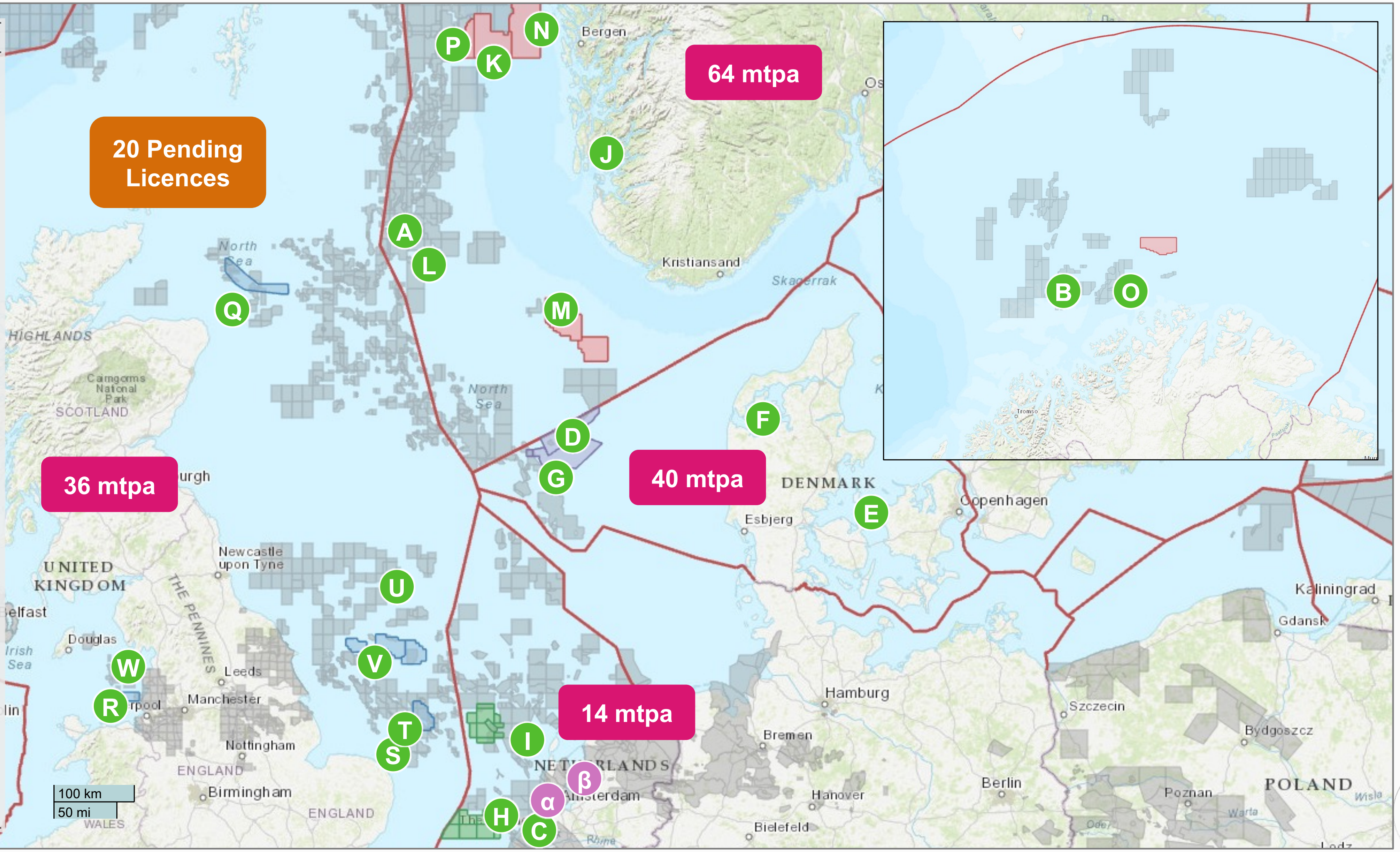
Who Will Follow?

150+ mtpa Storage Potential

ID	Project	Investors
A	Sleipner	Equinor-Vår-Orlen-Kufpec
B	Snøhvit	Equinor-TotalEnergies-Neptune-WD
C	Pernis	Shell
D	Greensand	INEOS-Wintershall Dea
E	Kalundborg	Ørsted
F	Norne	Capio Danmark
G	Bifrost	TotalEnergies-Noreco-Ørsted
H	Porthos	Shell-XOM
I	L10	Neptune-XOM-EBN-Tenaz
J	Errai	Horisont Energi, Neptune
K	Northern Lights	Shell, TotalEnergies, Equinor
L	Trudvang	Sval, Storegga, Neptune
M	Stella Maris	Altera
N	Smeaheia	Equinor
O	Polaris	Horisont Energi-Fertiberia
P	Luna	Wintershall Dea-CapeOmega
Q	Acorn	Storegga-Shell-Harbour-NSMP
R	Liverpool Bay	Eni
S	Bacton Thames	Eni
T	Viking	Harbour Energy
U	Medway	Oilex
V	NEP	BP-Equinor-TotalEnergies
W	Morecambe Hub	Spirit Energy
α	Aramis	TotalEnergies-Shell-Gasunie-EBN
β	Noordkaap	Neptune-CapeOmega-Vopak etc



Source | Enverus Global Scout

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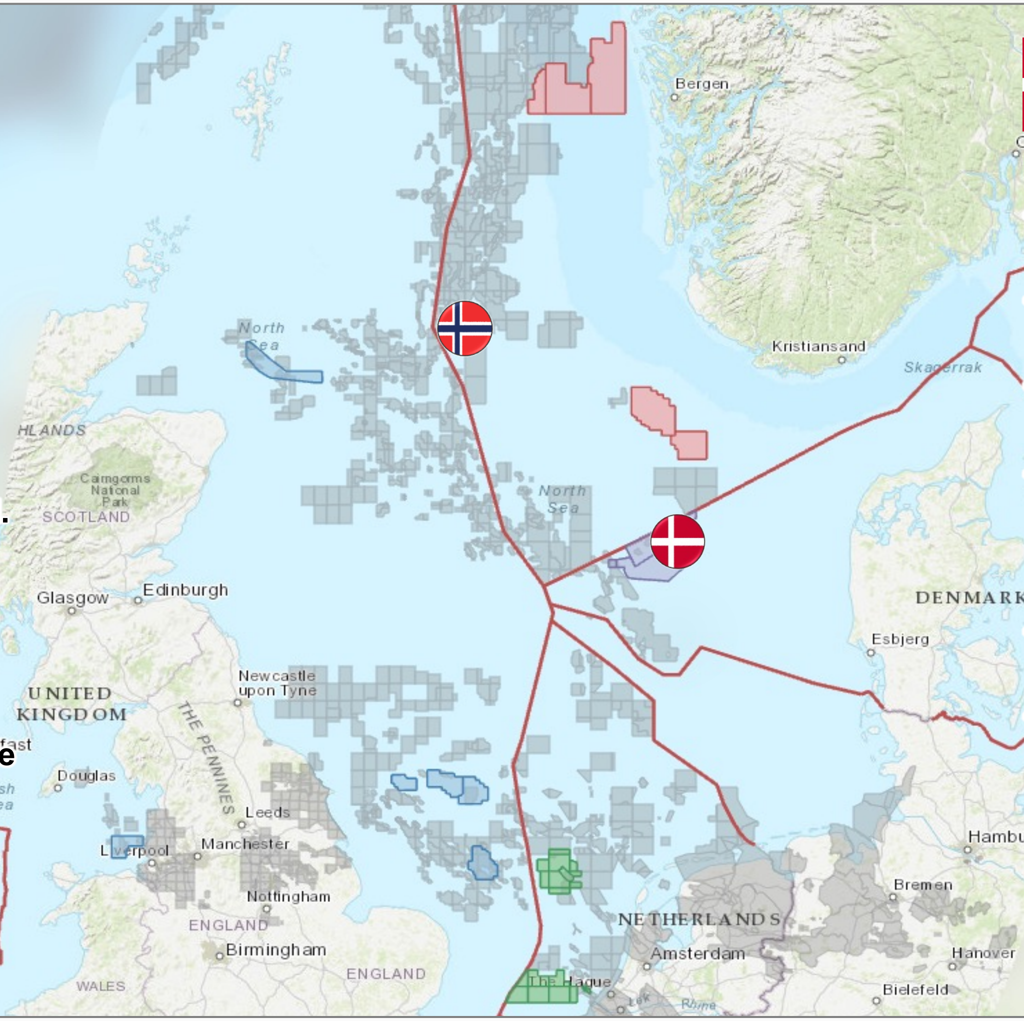
North Sea CCUS Pioneers

Project Sleipner

- Operated by Equinor
- Been in operation since 1996
- Successfully stored 20+ mt CO_2
- One of the longest-running and most significant CCUS initiatives in the world.
- Sleipner gas @9% CO_2 concentration
  - Reduced to 2.5% for export
- Utsira Fm - 200-250m sst; 600 Gt storage
- US$100 million investment
- $17 per tonne vs. $85+ per ETS credit



Project Greensand

- World's first cross-border offshore CCS
- INEOS, Wintershall Dea + 21 partners
- Ty Mbr sstr 1,800m below the seabed
- Pilot, 15kt @ Nini West ongoing
  - Ineos Oxide factory in Belgium
- 1.5 mtpa in 2025/6 (Nini West + Main)
- 8 mtpa in 2030 (Siri Fairway Expansion)

Source | Enverus Global Scout

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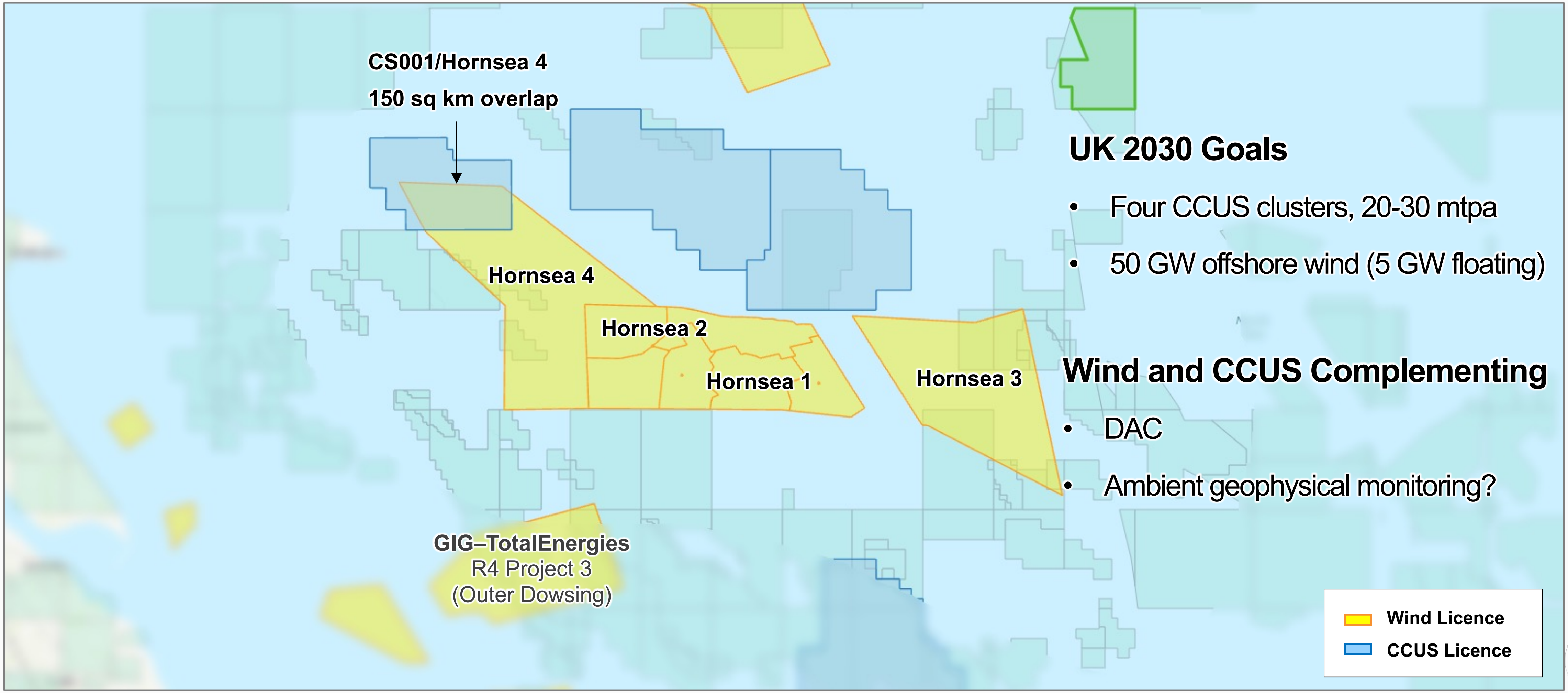
CCUS Clashing With Offshore Wind

NEP CCS Overlapping Ørsted's Hornsea 4



UK 2030 Goals

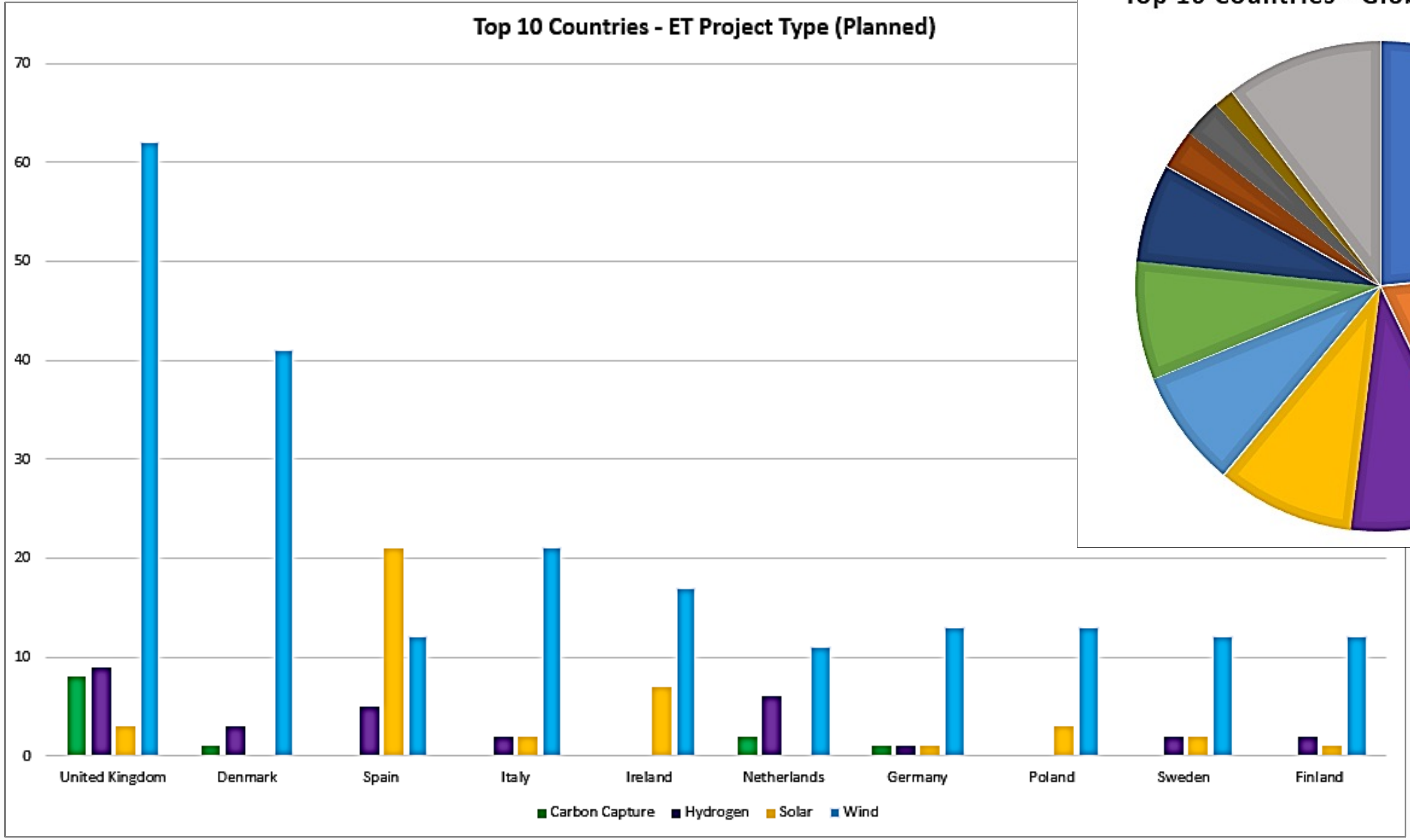
- Four CCUS clusters, 20-30 mtpa
- 50 GW offshore wind (5 GW floating)

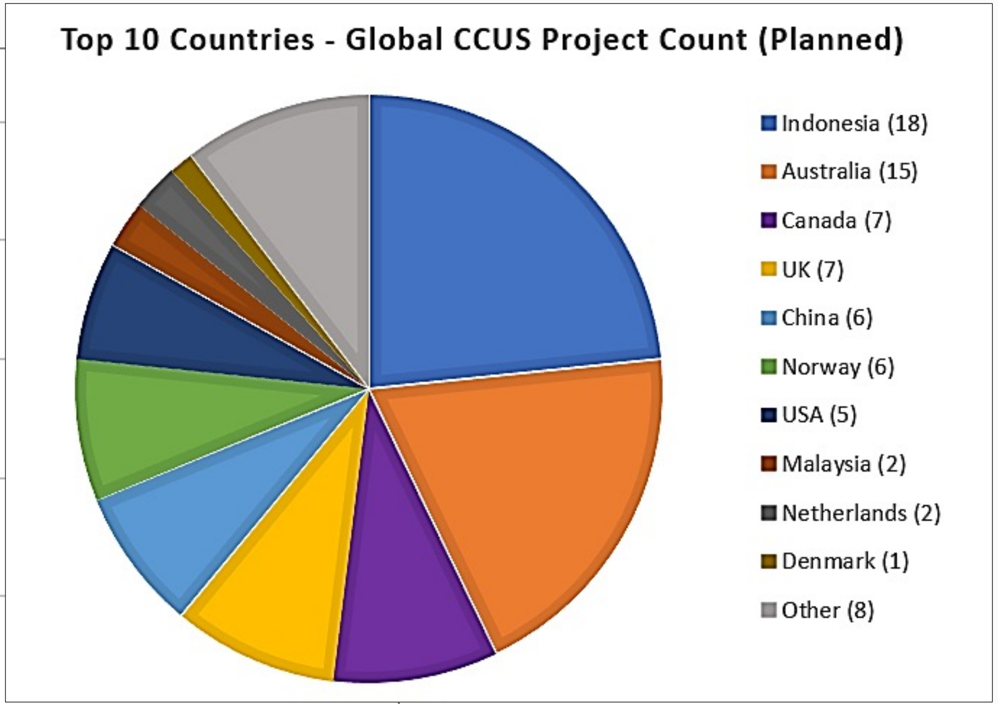
Wind and CCUS Complementing

- DAC
- Ambient geophysical monitoring?

Source | BP

CCUS Lags Renewables Power





Data captured by
Enverus Global Scout
since February 2022.

Source | Enverus Global Scout

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EU and State Funding For CCUS

€150 Billion May Not Be Enough for a 4 Btpa, Multitrillion € Challenge

EU Support

Innovation fund

- €10 Bn during 2020-2030

Horizon EU

- €95.5 Bn, runs until 2027

State aid

- Jan 2023 – €1.1 Bn Danish CCUS support
- Apr 2023 – €450 Mn Italian green hydrogen

Supports demonstration projects (e.g., PCIs)

- € 5.2 Bn Hy2Use

Regulatory framework

Country Level

Netherlands

- SDE++
- €4.6 Bn, 3,500 projects - €2.1 Bn for Porthos

UK

- Spring 2023 budget
- £20 Bn for CCUS rollout
- 20-30 mtpa of CO_2 by 2030

Norway – Investment in macroscale demo projects

- Northern Lights - $1.2 Bn
- DAC - considering €177/t reverse tax subsidy

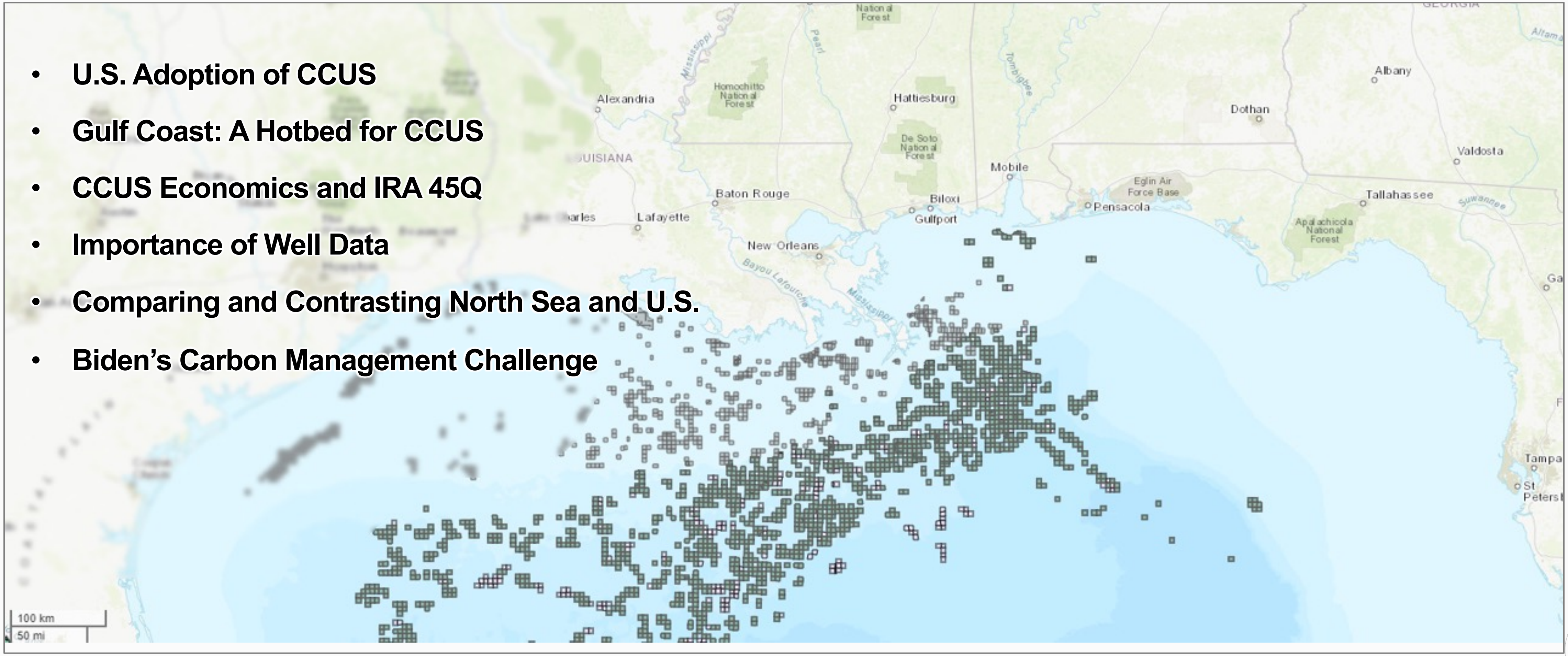
Denmark

- €330 Mn CCUS subsidy pool

Source | Enverus Global Scout

U.S.A.

A CCUS Benchmark



- U.S. Adoption of CCUS
- Gulf Coast: A Hotbed for CCUS
- CCUS Economics and IRA 45Q
- Importance of Well Data
- Comparing and Contrasting North Sea and U.S.
- Biden's Carbon Management Challenge

Source | Enverus Global Scout

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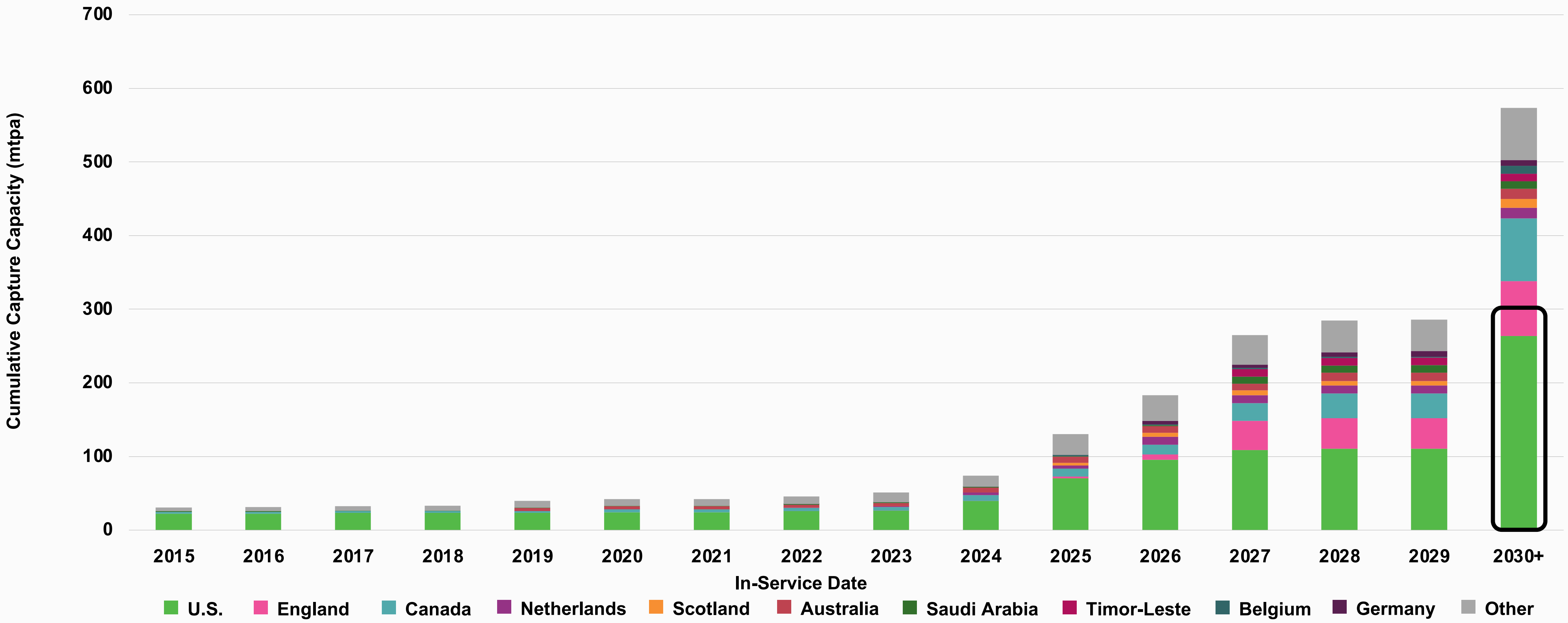
CCUS Adoption Supports Decarbonization Goals

U.S. Accounts for Nearly Half of Planned and Operational Capture Projects

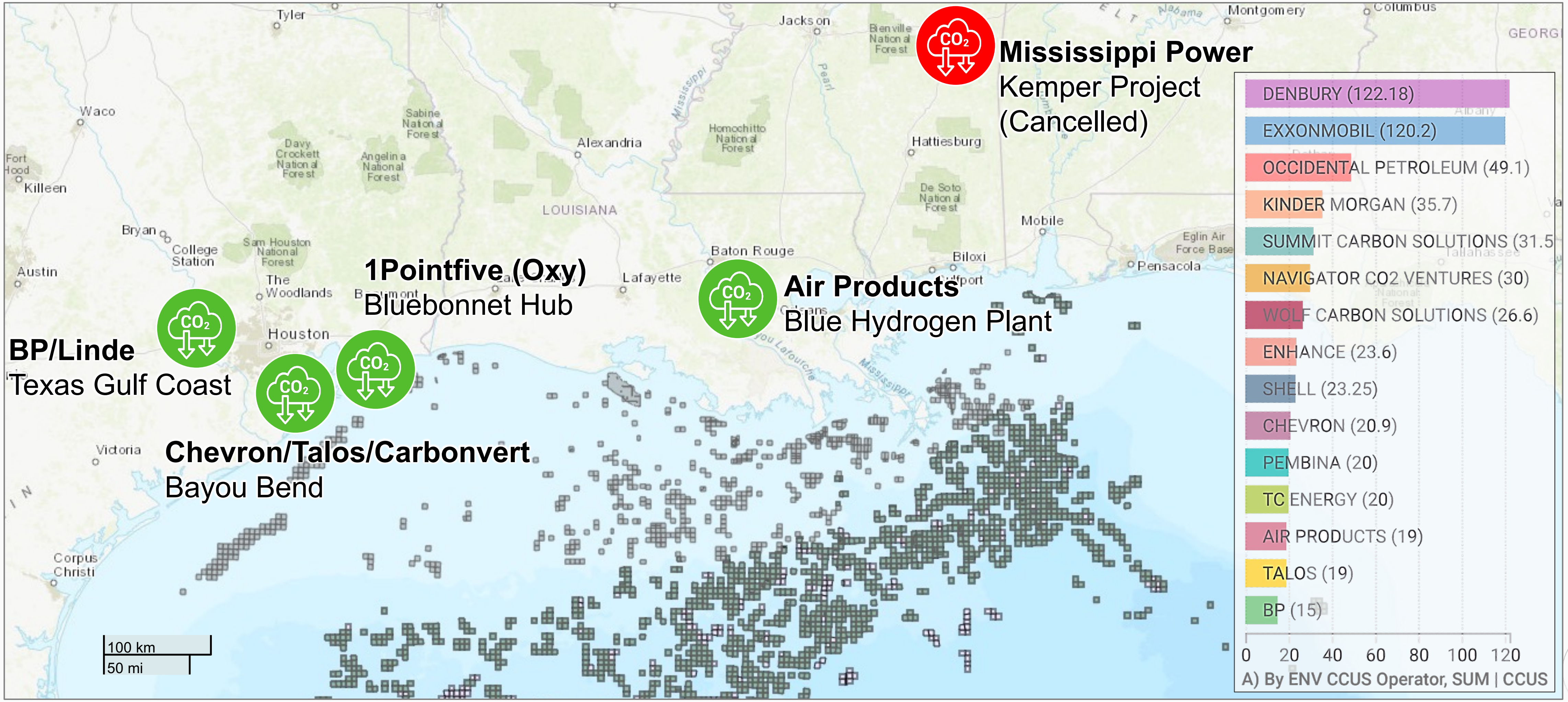


Note | Figure reflects operational and planned projects disclosed up to the end of September 2022. Projects with unknown in-service dates are included in the 2030+ bucket.

Source | Enverus Intelligence® | Research

U.S. Gulf Coast

A Hotbed for CCUS



Source | Enverus Global Scout

45Q Enabling CCS

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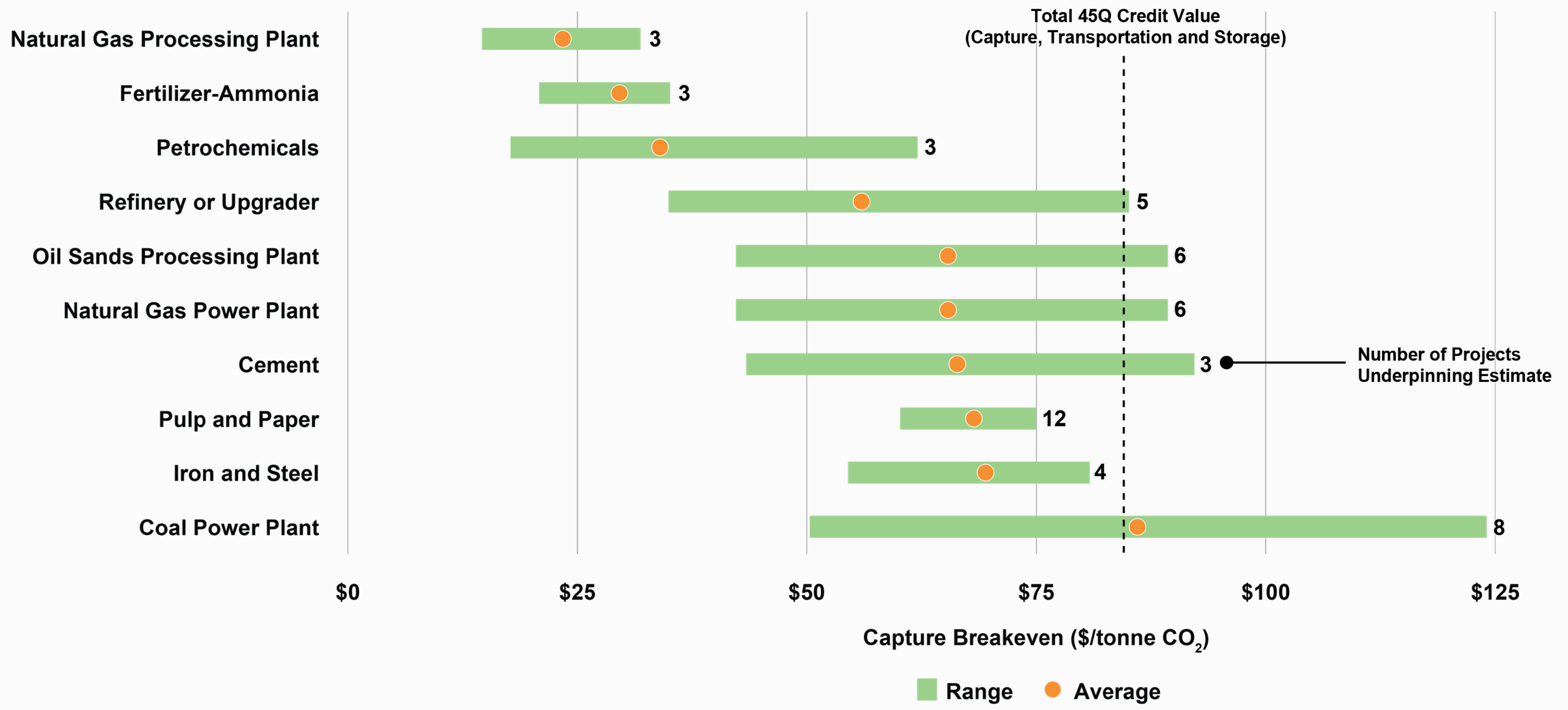
$15-$125/T Cost Range Offset by Up to $85/T Credit



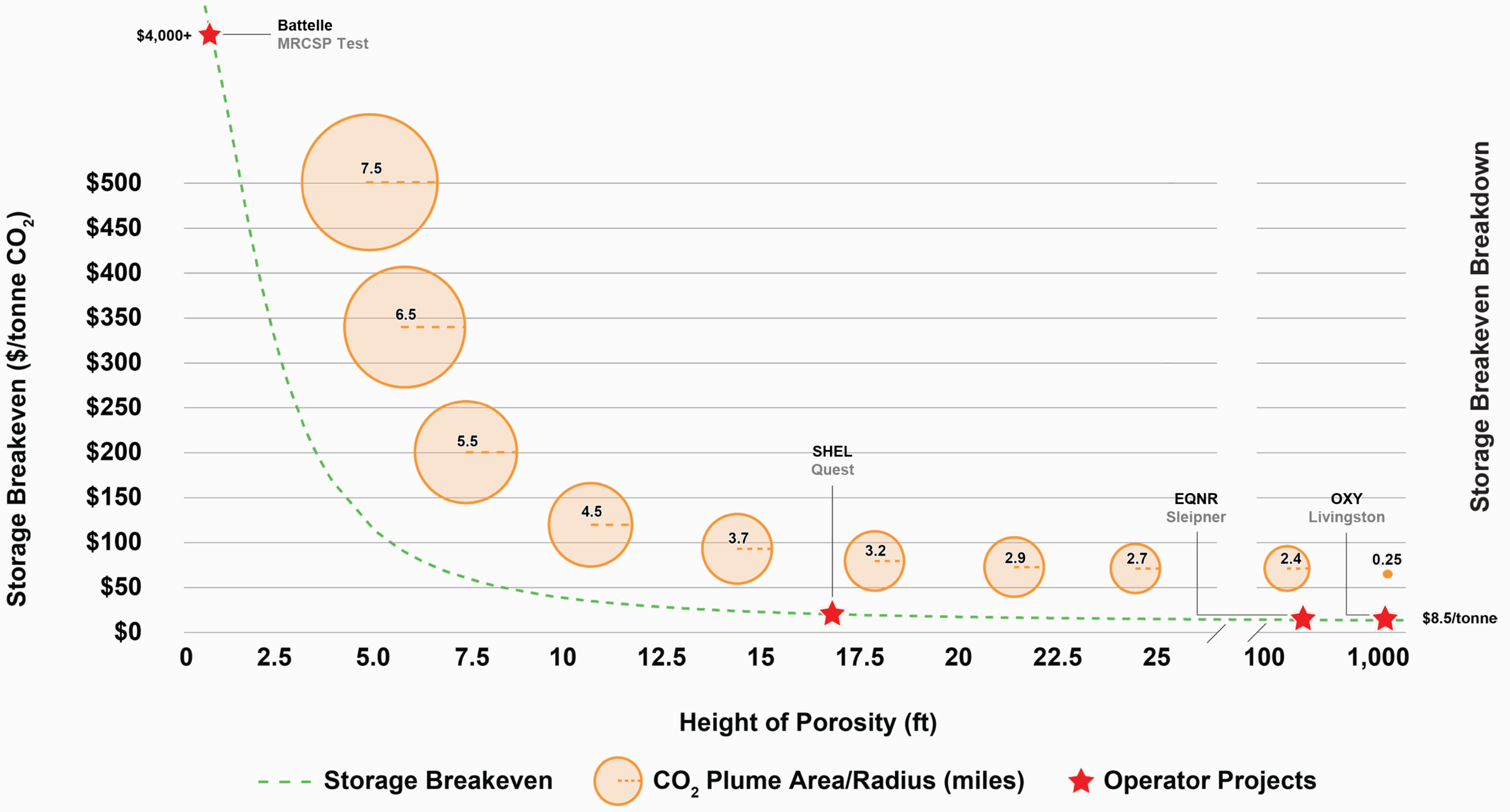
- 45Q tax credit
- DOE funding
- State-level incentives:
- Federal loan guarantees (Title XVII)
- CarbonSAFE
- Also: CCUS Innovation Center and NEORI

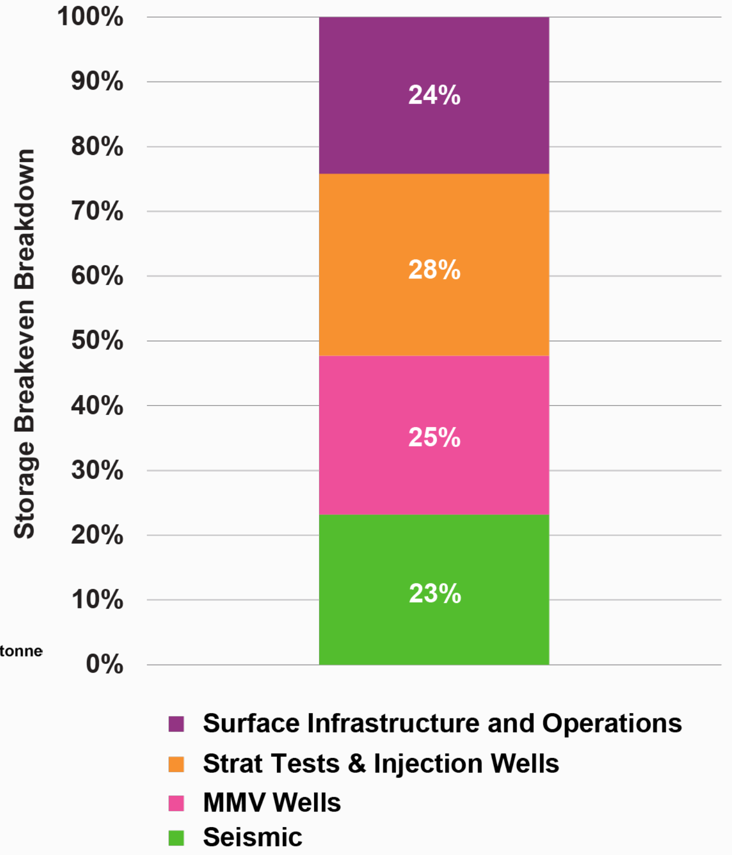
Note | Carbon capture breakevens are reported in $/tonne CO2 for a 1 mtpa facility over a 25-year project life using a 10% discount rate. Each sector range represents capital and operating costs scaled from an aggregate of active projects and engineering cost estimates for various technologies around the world. Operating costs were calculated using $70/MWh for electricity and $3/Mcf for natural gas.

Source | Enverus Intelligence® | Research, IEAGHG, NETL, U.S. DOE, Alberta government

Making CO_2 Storage Affordable

Porosity and Reservoir Thickness Are the Key Drivers



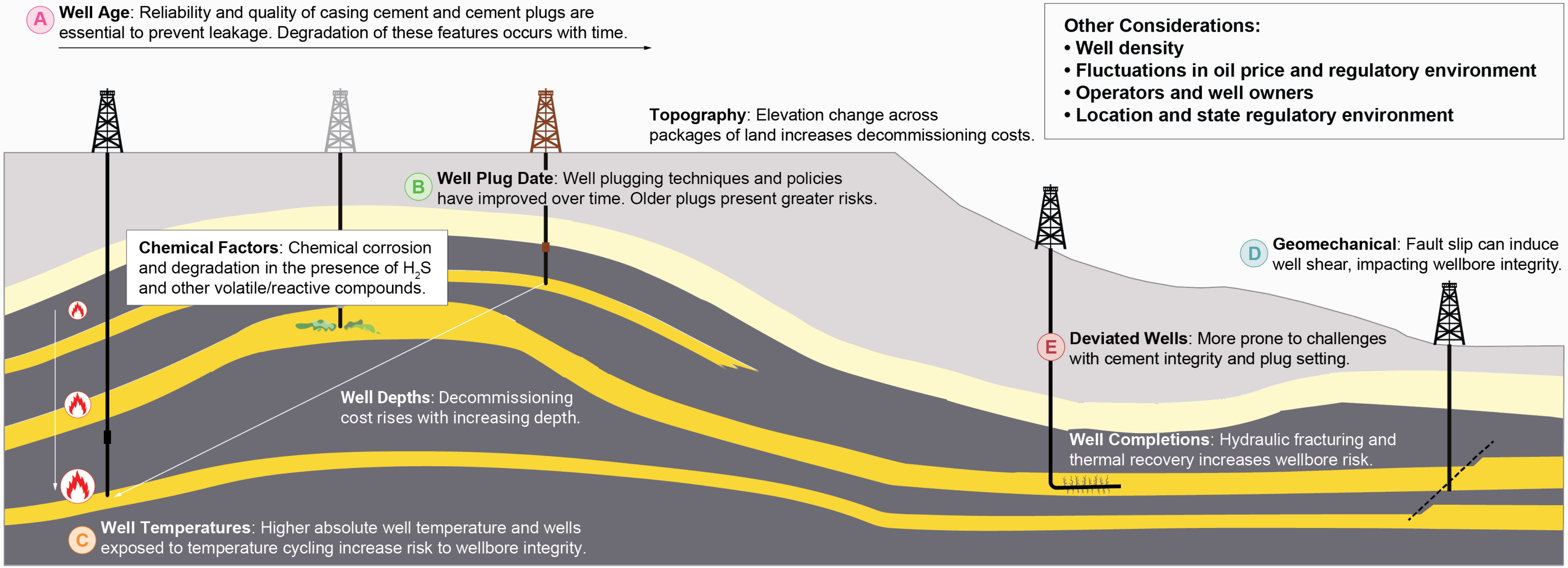


Note | Carbon storage breakevens are reported in $/tonne CO_2 for 1 mtpa injection at a 7,000-ft depth over a 25-year injection life using a 10% discount rate. Height of porosity is defined by reservoir thickness multiplied by porosity.

Source | Enverus Intelligence® | Research, FE/NETL CO_2 Saline Storage Cost Model, U.S. DOE

Not All Wells Pose the Same Containment Risk

Highest Risk Comes From Older Deviated Wells in Hot Reservoirs Near Faults



Source | Source | Enverus Intelligence® | Research, Modified from van Oont 2022 – EVO Energy Consulting, Enverus Core

Gulf Coast vs. North Sea

Some Overlaps, Some Differences

<table>
<tr><th>U.S. Gulf Coast</th><th>North Sea</th></tr>
<tr><td colspan="2">Concentration of petrochemical and refining industries</td></tr>
<tr><td colspan="2">Extensive O&G infrastructure (less dense in northern Norway)</td></tr>
<tr><td colspan="2">Supportive government policies & incentives (n.b. UK, Norway)</td></tr>
<tr><td>Federal government pays</td><td>ETS + EU/gov’t development funding</td></tr>
<tr><td>Largely onshore</td><td>Mainly offshore potential</td></tr>
<tr><td>Significant CCUS investment already</td><td>Only Norway has large-scale carbon storage</td></tr>
</table>

Source | Enverus Global Scout

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Europe-U.S. Co-operation

European Countries Sign Up to COP28 Carbon Management Challenge

- **UK, Norway, Denmark & EU**
  - Joined by Australia, Canada, Egypt, Japan, KSA and UAE
- **Four “Pillars of Action"**
  1. Decarbonising energy
  2. Ending deforestation
  3. Tackling non-CO_2 GHG
  4. Accelerating CCUS and CDR technologies

Source | Enverus Global Scout

Summary and Conclusions

Where We Are Now? Where Are We Going?

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Summary

1 All Elements of CCS Value Chain Are 'Mature'

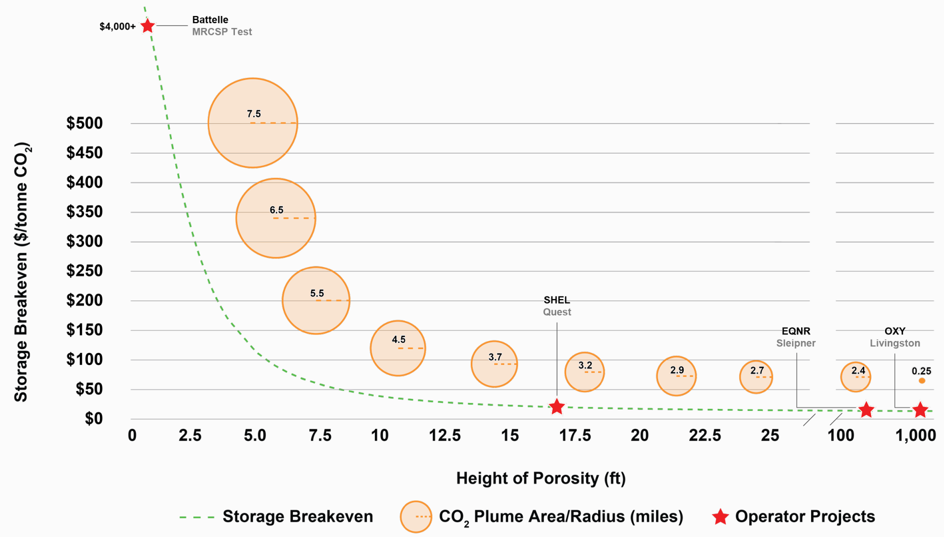
- Has not been done at many sites, few analogues
- Have been in commercial operation for decades

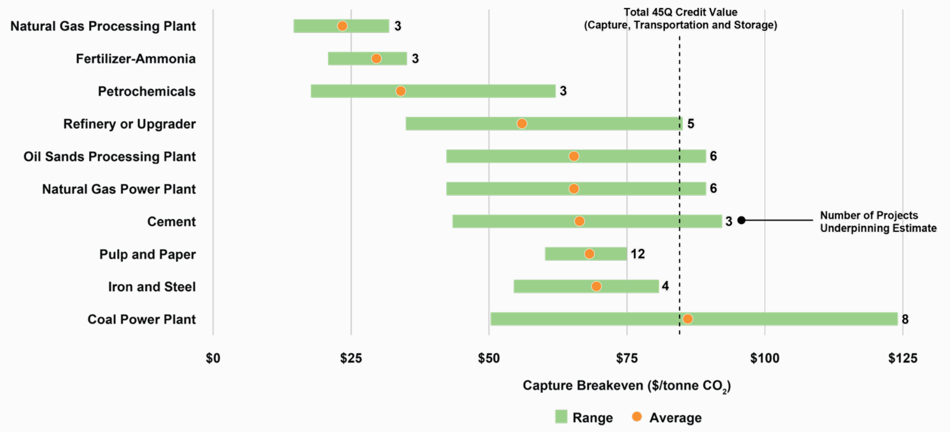
2 Key Factors

- Geological storage resource
- Differential CO_2 capture costs
- Scale of capture facilities
- Transport infrastructure
- Cost of energy and capital

3 Cost Reductions Achieved by "Learning by Doing"

- Improved CCS technologies have reduced costs over past 10-15 years
- Competition between vendors
- Larger developments benefiting from economies of scale
- New tech and commercial synergies





Conclusions

1 Challenges Across Value Chain

- Biggest uncertainty is subsurface
- Natural gas CO_2 is “easy”; can we process other CO_2 economically?
- Will industry guarantee long-term emissions for CCUS?
- CCUS has to work at €80/$85

2 Strong Policies Needed

- No market otherwise and no other way to execute
- Explore different solutions
- Balance development benefits of collaboration with cost gains from competition
- Successfully regulate and mix CCUS and renewables

3 Differential CCS Landscape Emerging?

- Europe reducing emissions
- U.S. finding new industry – less urgency on emissions

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Questions