CCS: Challenges in Large-scale Carbon Storage

Zach Liu, PE, PG, CFA (Harvestone Low Carbon Partners, ex-Wood)
Meisong Yan, PE (WE Resources Consulting)
Feb 14, 2024

Acknowledgement

Harvestone Low Carbon Partners.
Wood Plc.

Contributors:

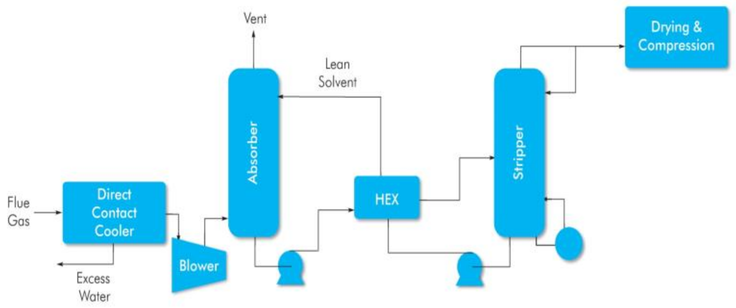
- Lauri Hardwick (Wood)
- Sri KV (Wood)
- Suzanne Ferguson (Wood)
- Stephen Stoke (Wood)

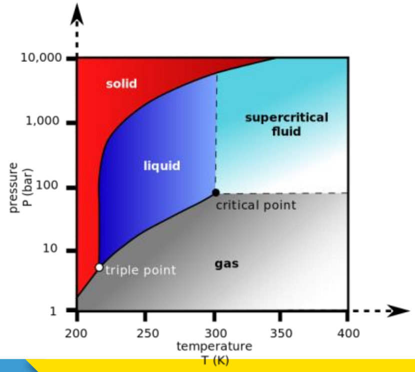
Agenda

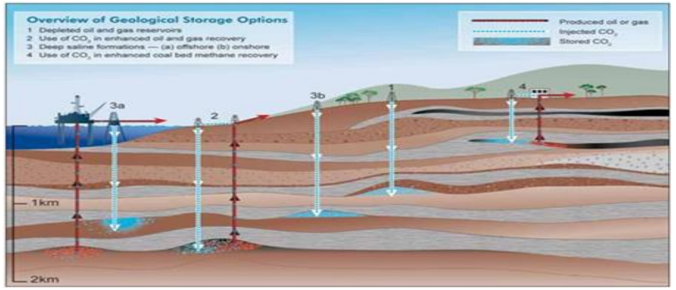
- Review of worldwide CCS projects status.
- 4 challenges to large-scale CCS projects
    1) Cost.
    2) Transportation and storage infrastructure.
    3) Perceived risks from stakeholders.
    4) Competition with other decarbonization technologies.
- Blue Flint CCS Injection (small scale, near site CCS example)
- Q&A

Complex CCUS Value Chain

From Capture to Transportation and Storage







Carbon Capture → **Transportation** → **Storage**

Carbon Capture

- Pre/Post/Oxy -combustion
- Physical, Chemical and Hybrid solvents
- Licensed technologies
- Novel technologies and Technology development (R&D)
- Technology independent
- Permitting

Transportation

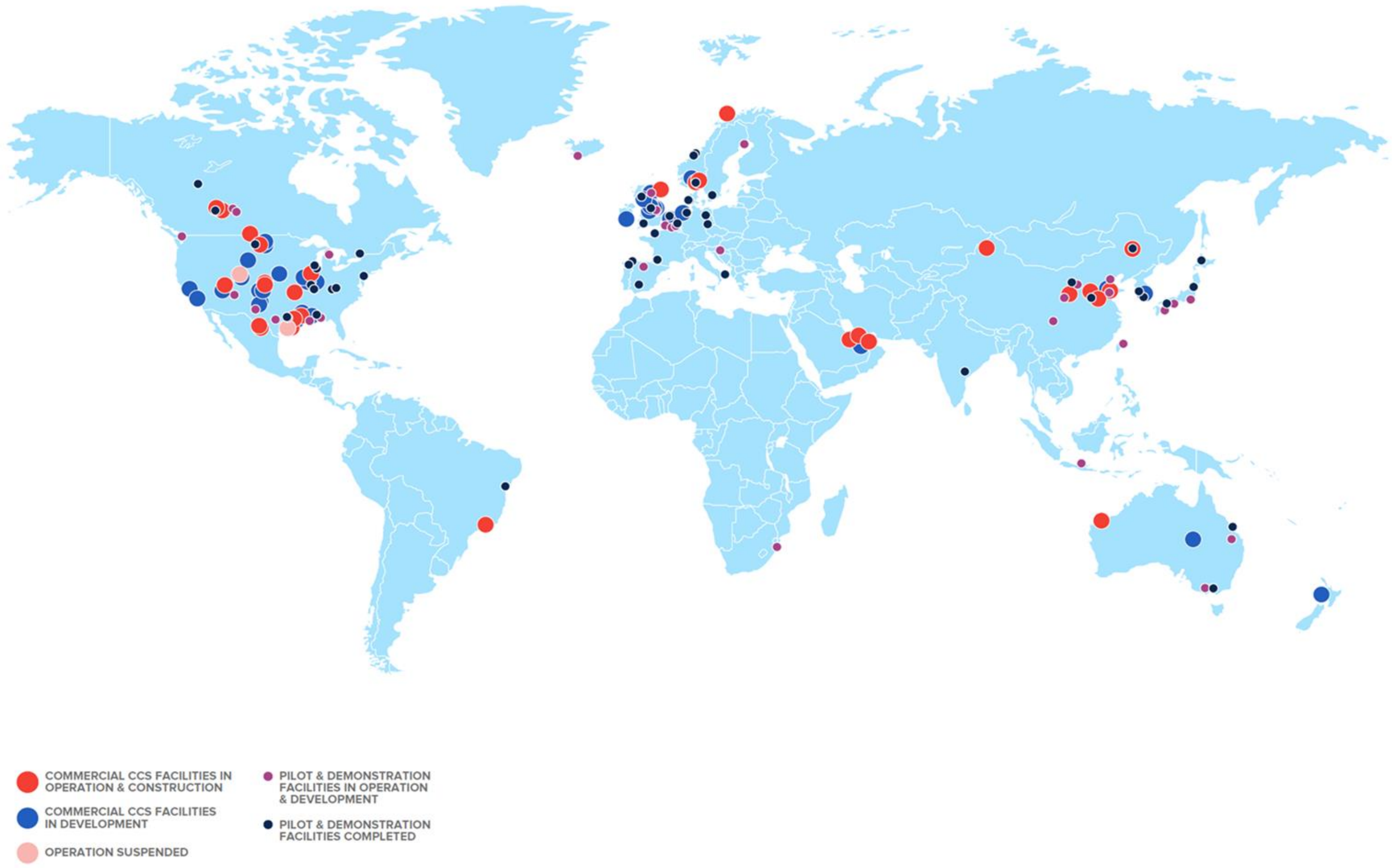
- Ports / Marine
- Pipeline
- Ship
- Road Tankers
- Pipeline route analysis
- Materials and corrosion
- Dynamic behavior

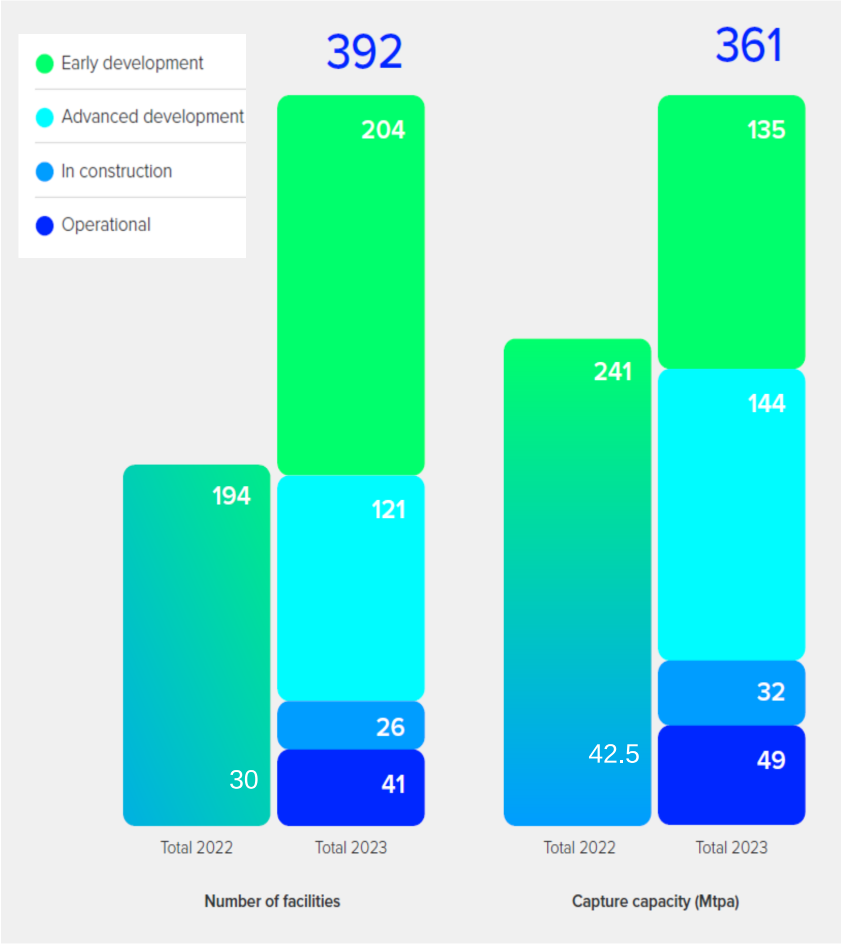
Storage

- Class VI and Class II Permitting
- Drilling and Completion
- Reservoir Modeling and Simulation
- Geomodelling
- Techno-economics (45Q/LCFS/VCM)
- CO2 facilities design and modeling
- CO_2 Wells design and modeling,
- MMV/MRV (Monitor Measurement Verification)
- Geology/Geophysics
- Petrophysics/Geomechanics
- CO_2 EOR

From development to decommissioning

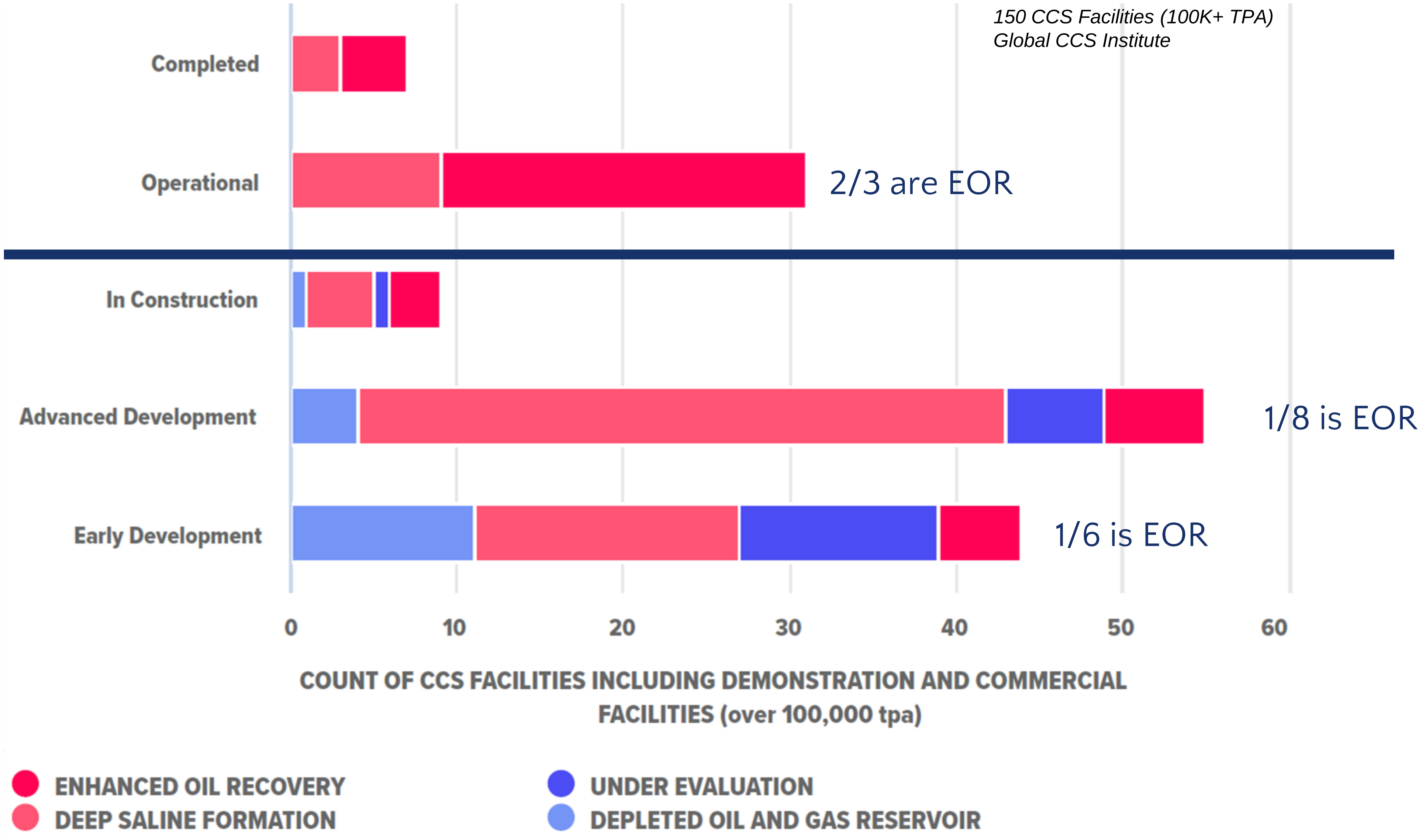
World CCUS Project Status 2022-2023



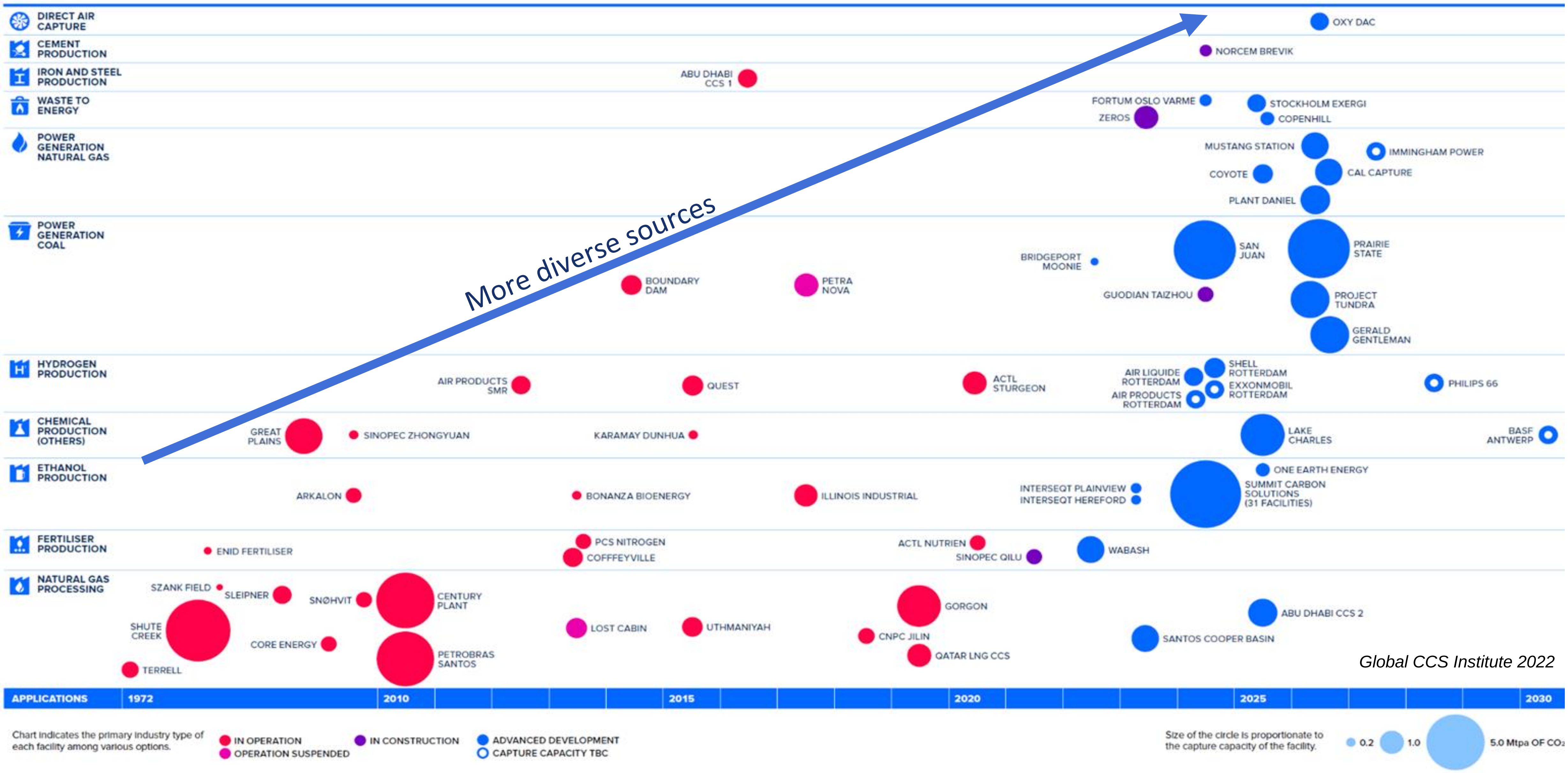


Global CCS Institute

2022 CCUS Projects by Type

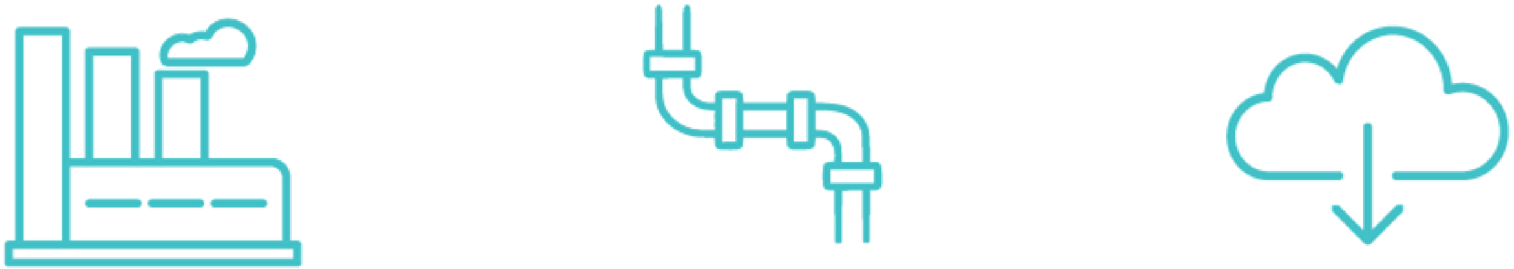


Global CCS Project by Sector and Scale



CCS is Critical for Paris Agreement Goal

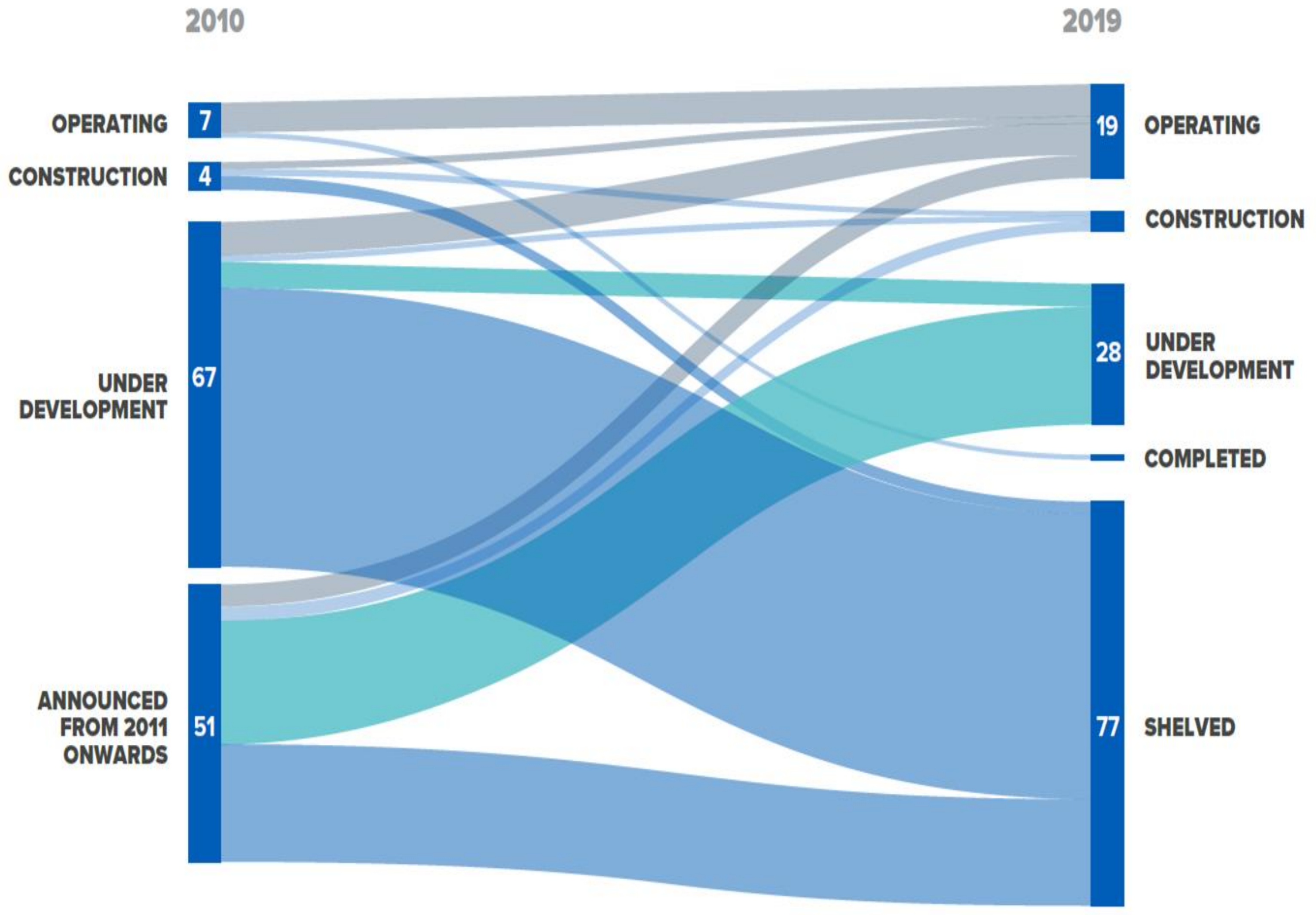
- Currently 2023:
  - 0.05 Gt/yr (in operation)
  - 0.36 $GtCO_2$/yr (including early development)
- 2030: 0.8 $GtCO_2$/yr in operation (16 times increase from 2023)
- 2050: 2.8 $GtCO_2$/yr in operation (56 times increase from 2023)



	CAPTURE FACILITIES	PIPELINES	STORAGE SITES
TOTAL IN 2050	MORE THAN 2,000	200,000 KM	400
ANNUAL BUILD RATE TO 2050	70 - 100	5,200 - 7,200 KM	10 - 30

iea

2010-2019 CCS Project Pipeline



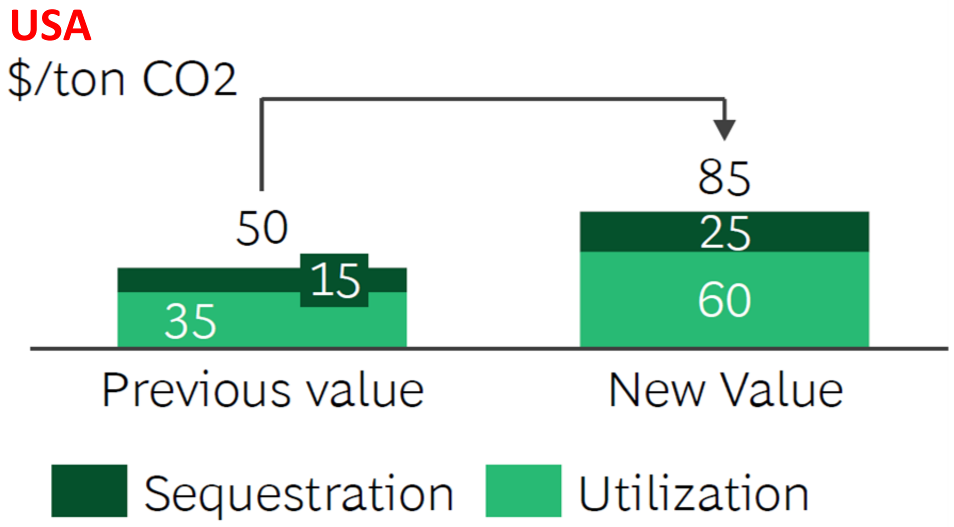
[1] As of February 2020.

Global CCS Institute

- Project: 129->52
- Operating: 7->19
- Boom and bust cycle?

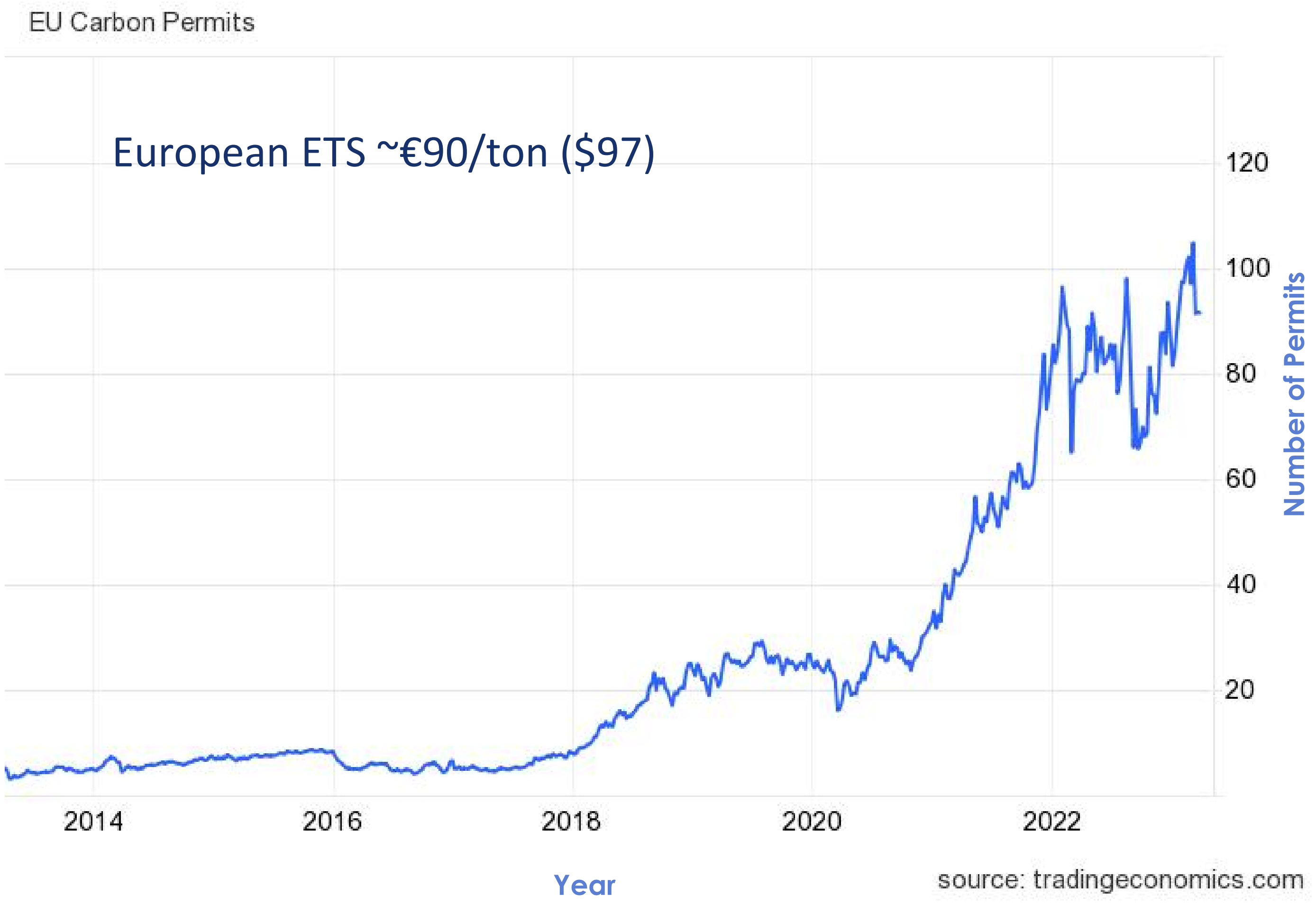
Challenge #1: Economics...improving but still tough

Carbon capture, utilization and storage (CCUS)

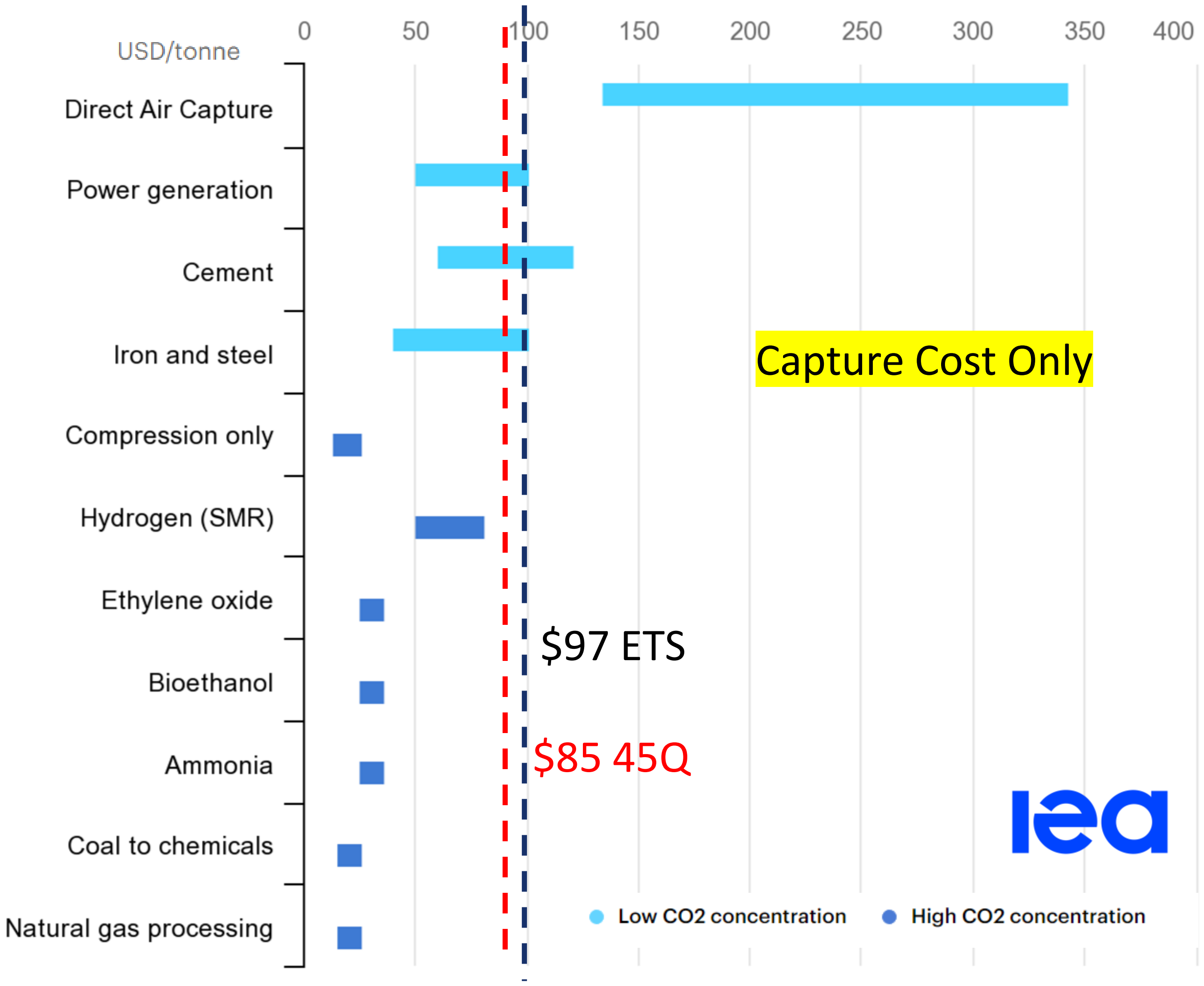


BCG report

Expansion of existing 45Q credit to $85/ton for permanent geological sequestration of CO2, or $60/ton for utilization of CO2 (incl. enhanced oil recovery)



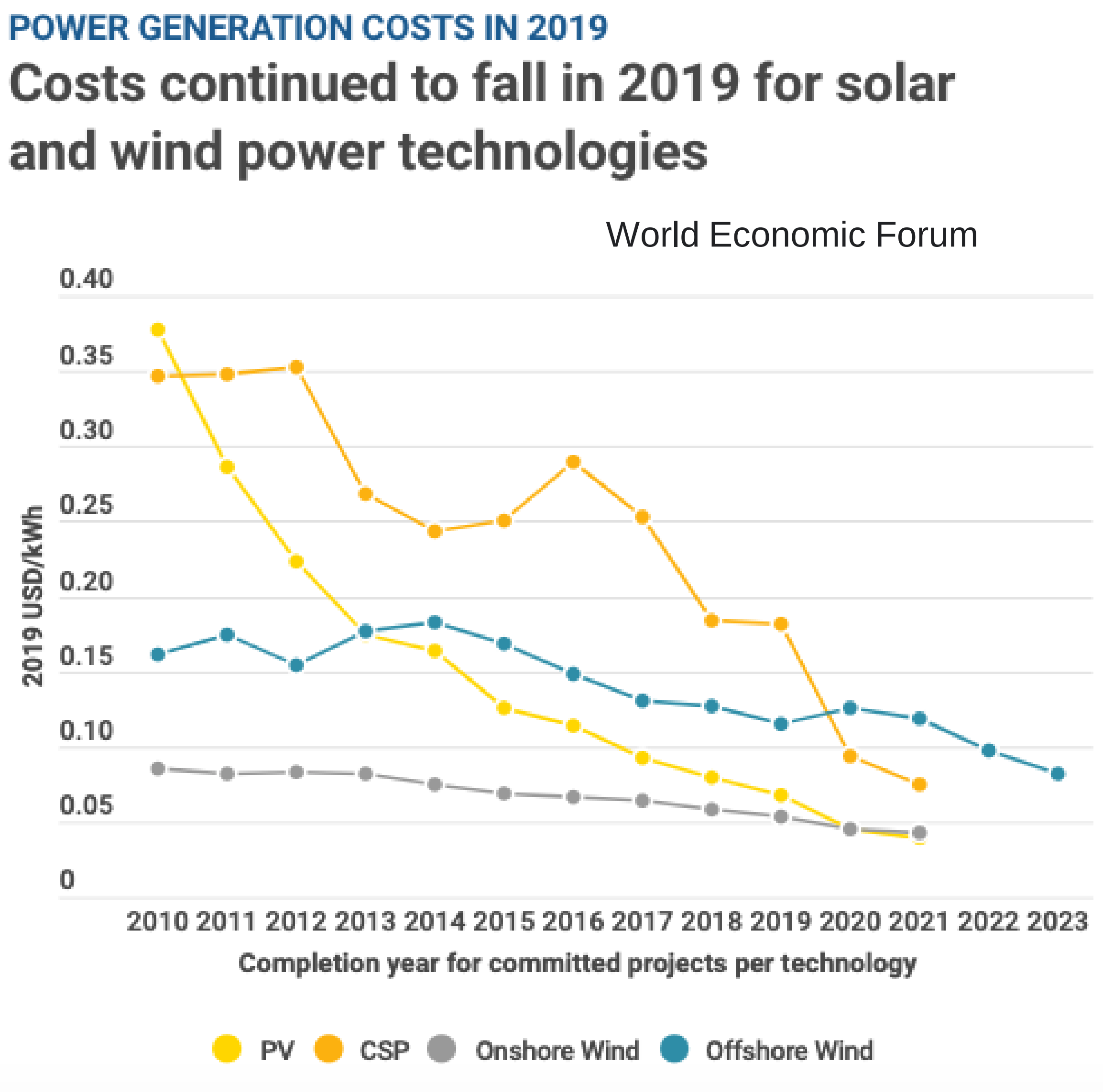
Challenge #1: Economics…tough but improving



- Low concentration CO_2 is challenging.
- High concentration CO_2 with capture cost below ~$50 is economical.
- LCFS/SAF?
- EOR?

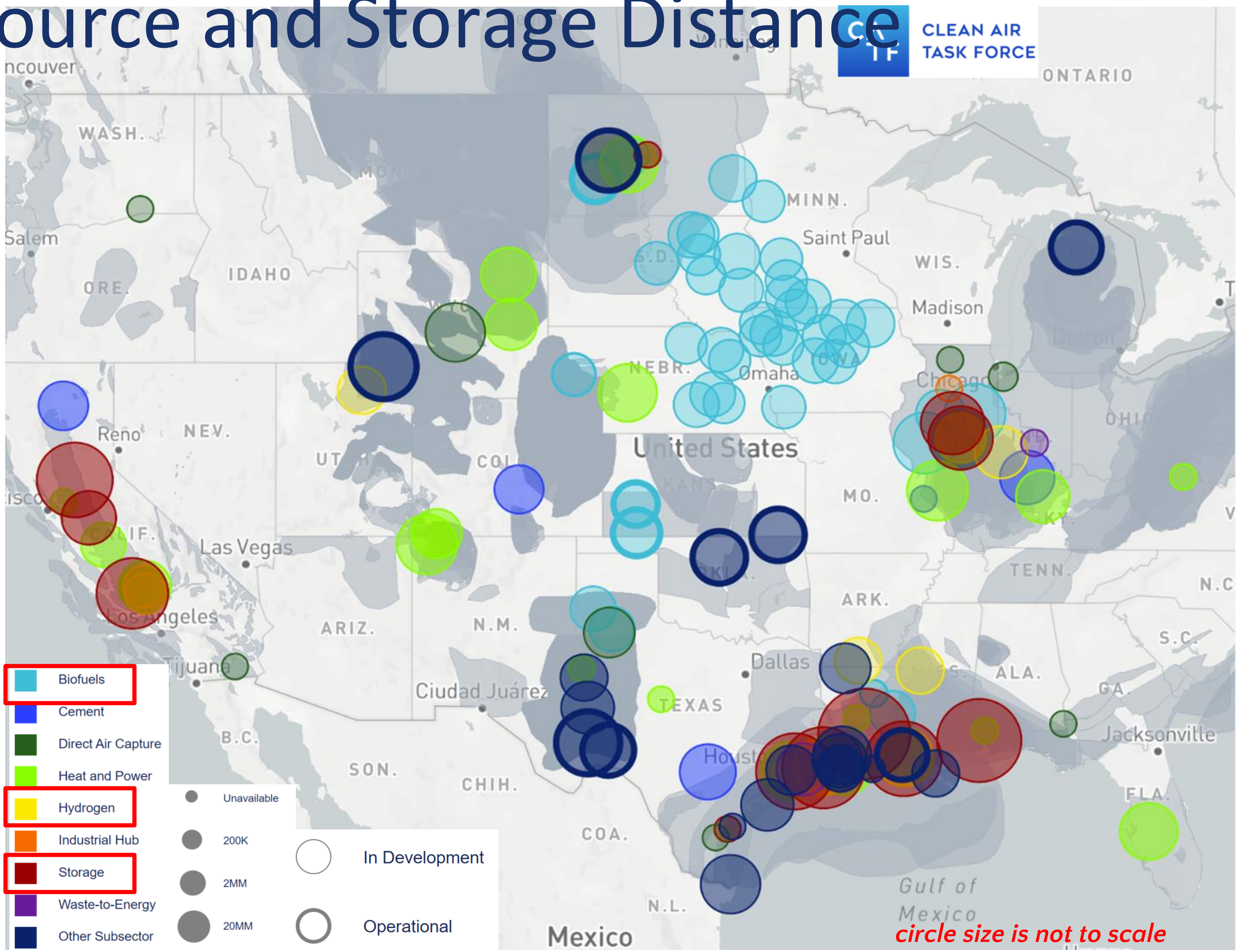
CCS Cost Reduction: Solar PV and Wind Analogy

- Solar PV dropped 80%.
- Onshore wind dropped 50%
- Opportunity: CCS capture cost reduction of 50% in 10 years?
  - "Blue Oil" (Captured CO_2 EOR).
  - Capture technology.
  - CO_2 pipeline network.
  - Economy of scale.



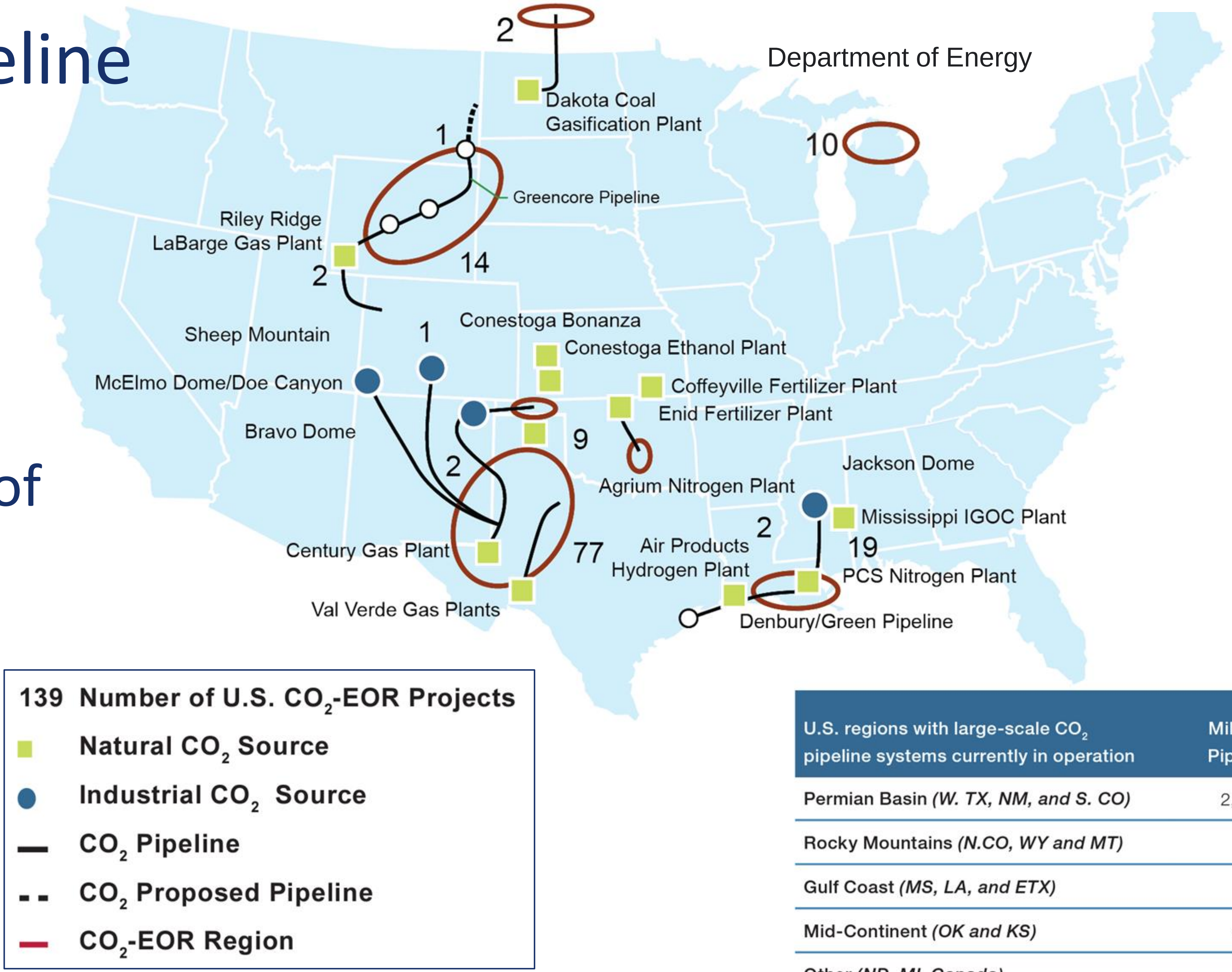
Challenge #2: Source and Storage Distance

- Scattered low-cost **small** **CO_2 sources.**
- Isolated low-cost **large** CO_2 **storage site.**
- Long pipeline route challenges.
  - Sizing.
  - Permitting.
  - Cost.



Current CO_2 Pipeline

- Only ~5000 miles.
- Driven by EOR.
- Very few CO_2 pipelines outside of US.

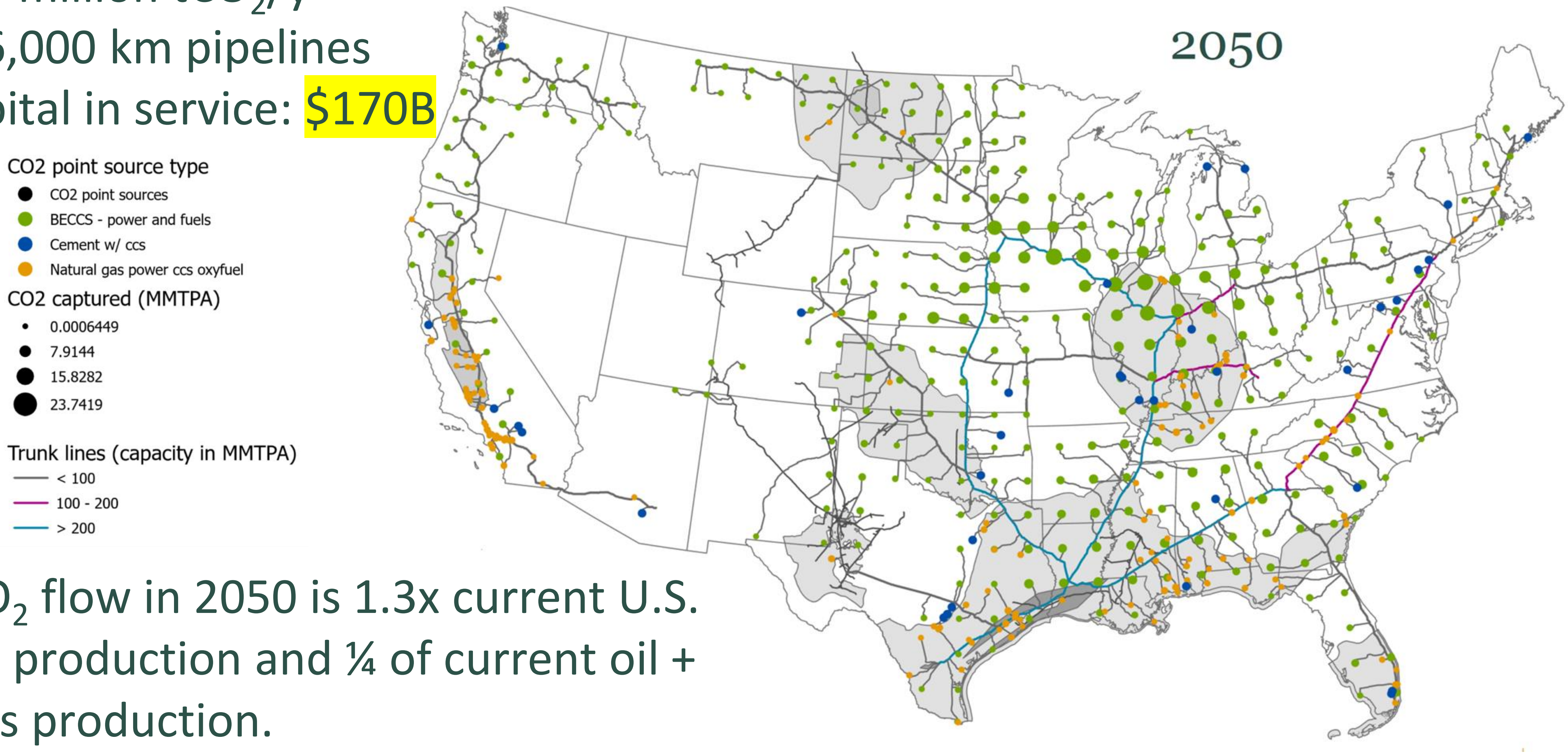


Department of Energy

U.S. regions with large-scale CO_2 pipeline systems currently in operation	Miles of Pipeline
Permian Basin *(W. TX, NM, and S. CO)*	2,320
Rocky Mountains *(N.CO, WY and MT)*	810
Gulf Coast *(MS, LA, and ETX)*	740
Mid-Continent *(OK and KS)*	480
Other *(ND, MI, Canada)*	215

Hypothetical US CO_2 Pipeline Network

929 million tCO_2/y
106,000 km pipelines
Capital in service: $170B

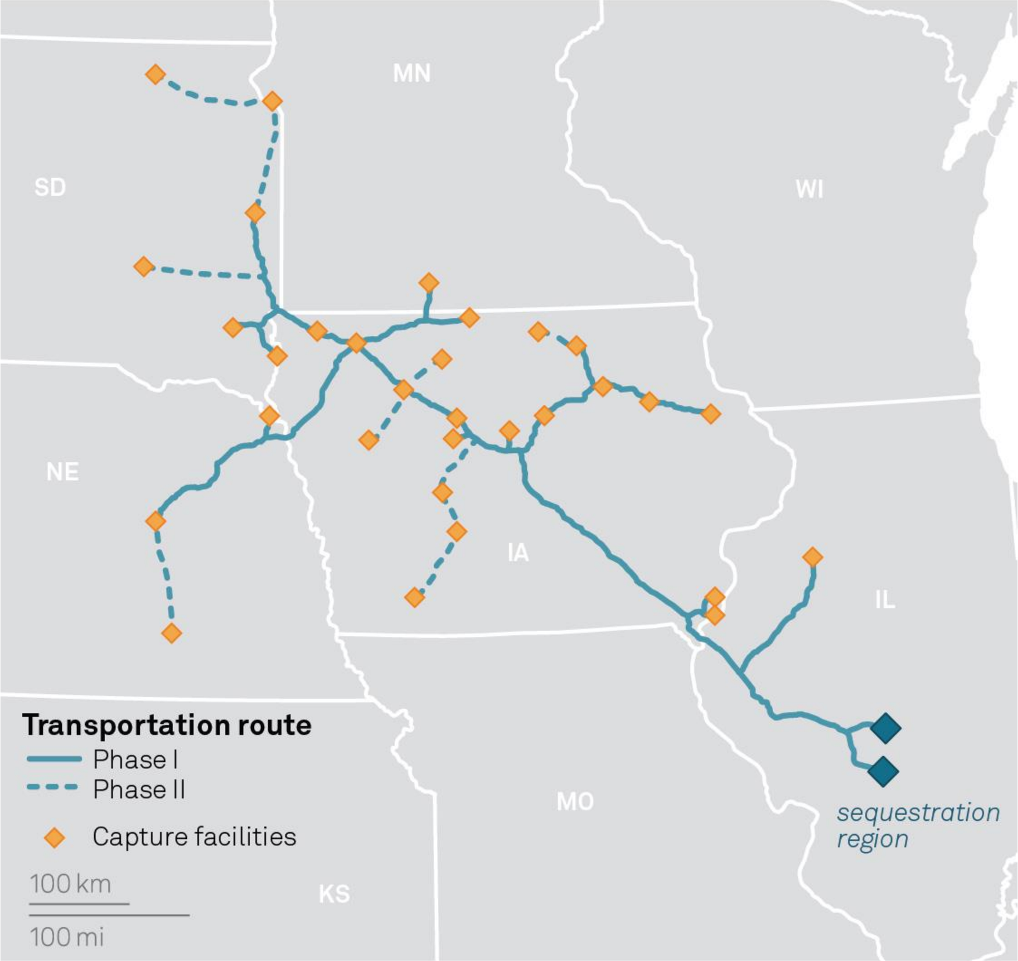


CO_2 flow in 2050 is 1.3x current U.S. oil production and ¼ of current oil + gas production.

Princeton University: Netzero America Report

Challenge #3: Public Perception of Risk

Navigator CO_2 Ventures cancels its Heartland Greenway pipeline project, impacting over 30 ethanol facilities



Source: Navigator CO_2, S&P Global Commodity Insights

ENVIRONMENT

Fatal Risk from Stored CO2 Leakage Appears Remote

Experience with natural seeps in Italy suggests that any CO2 leaking from proposed underground storage is unlikely to kill

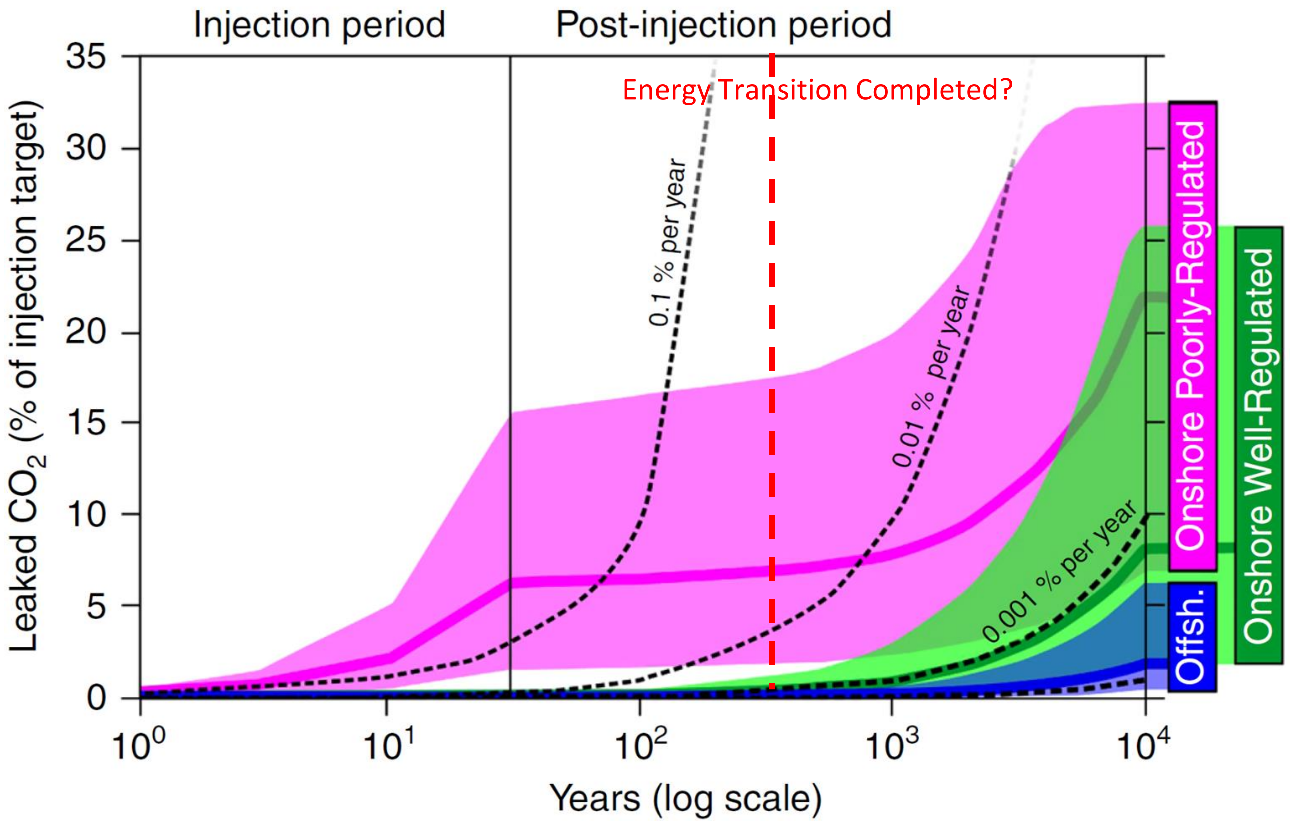
By Christa Marshall, ClimateWire on September 14, 2011

CO_2 Pipelines are safe.

- Nonflammable, Odorless, Colorless, and nonpoisonous.
- 40+ years of great safety record of 5150 miles of CO_2 pipelines in US.
- Safer than crude pipelines.
  - Since 2010, there have been 66 incidents on CO2 pipelines with **no fatalities** (PHMSA data).
  - 1.1 CO_2 pipeline incidents per 1,000 miles compared to 2.9 crude pipeline incidents per 1,000 miles (PHMSA data).
- Safer than electric transmission and distribution systems.

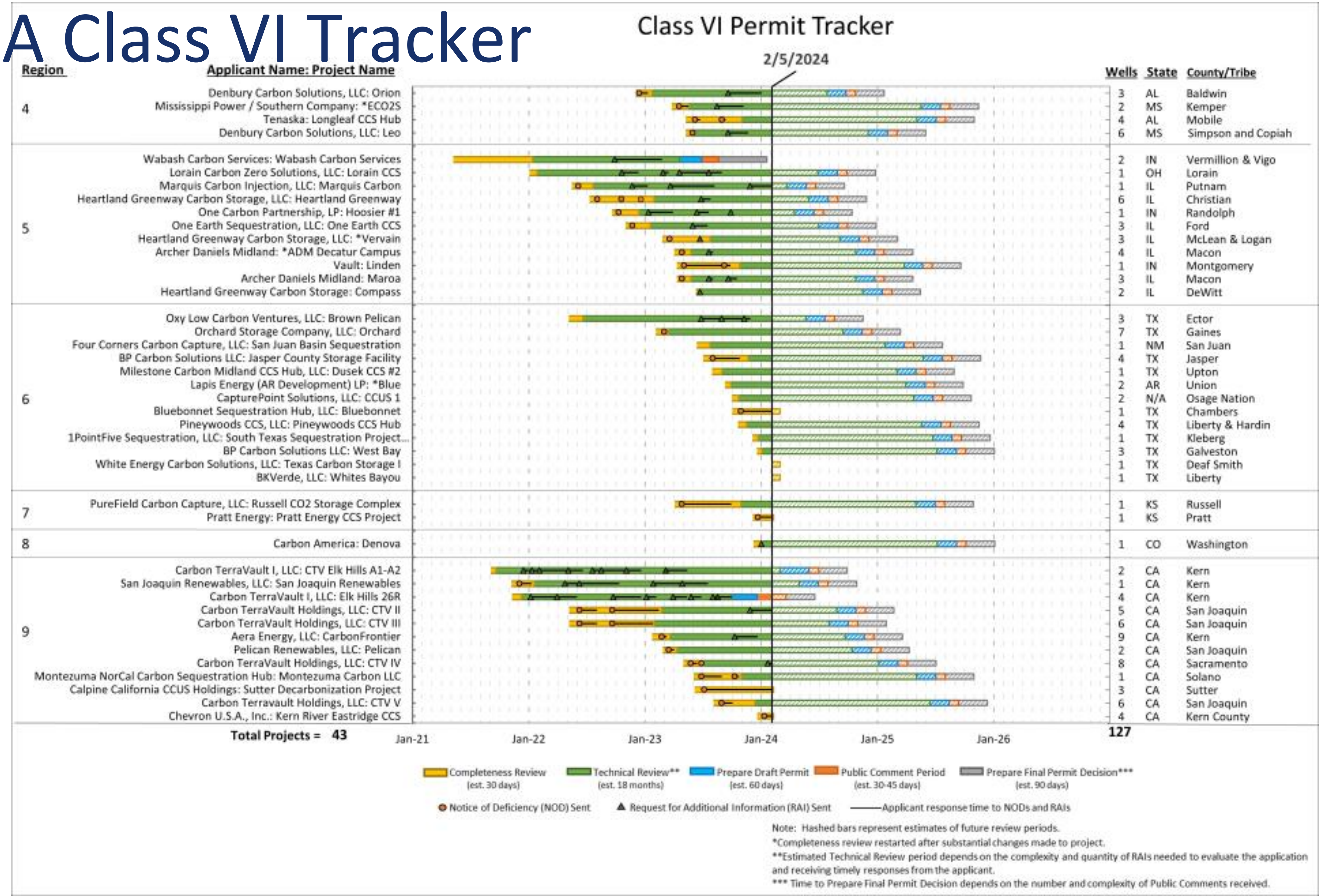
CCS Storage Sites are Safe

Store Type (Permit Awarded)	Description	Estimated worst-case amount as % of store capacity (125Mt CO_2)
Depleted Field Store	Leakage from all wells	0.070%
	Leakage from all geological features	0.002%
	Total leakage from storage complex	0.072%
1000 years	Total estimated contained mass at storage complex	99.928%
Fully or Partially Confined Saline Aquifer Storage Site	Leakage from all wells	0.064%
	Leakage from all geological features	0.024%
	Total leakage from storage complex	0.088%
1000 years	Total estimated contained mass at storage complex	99.912%



UK Dept of Business, Energy & Industrial Strategy

EPA Class VI Tracker



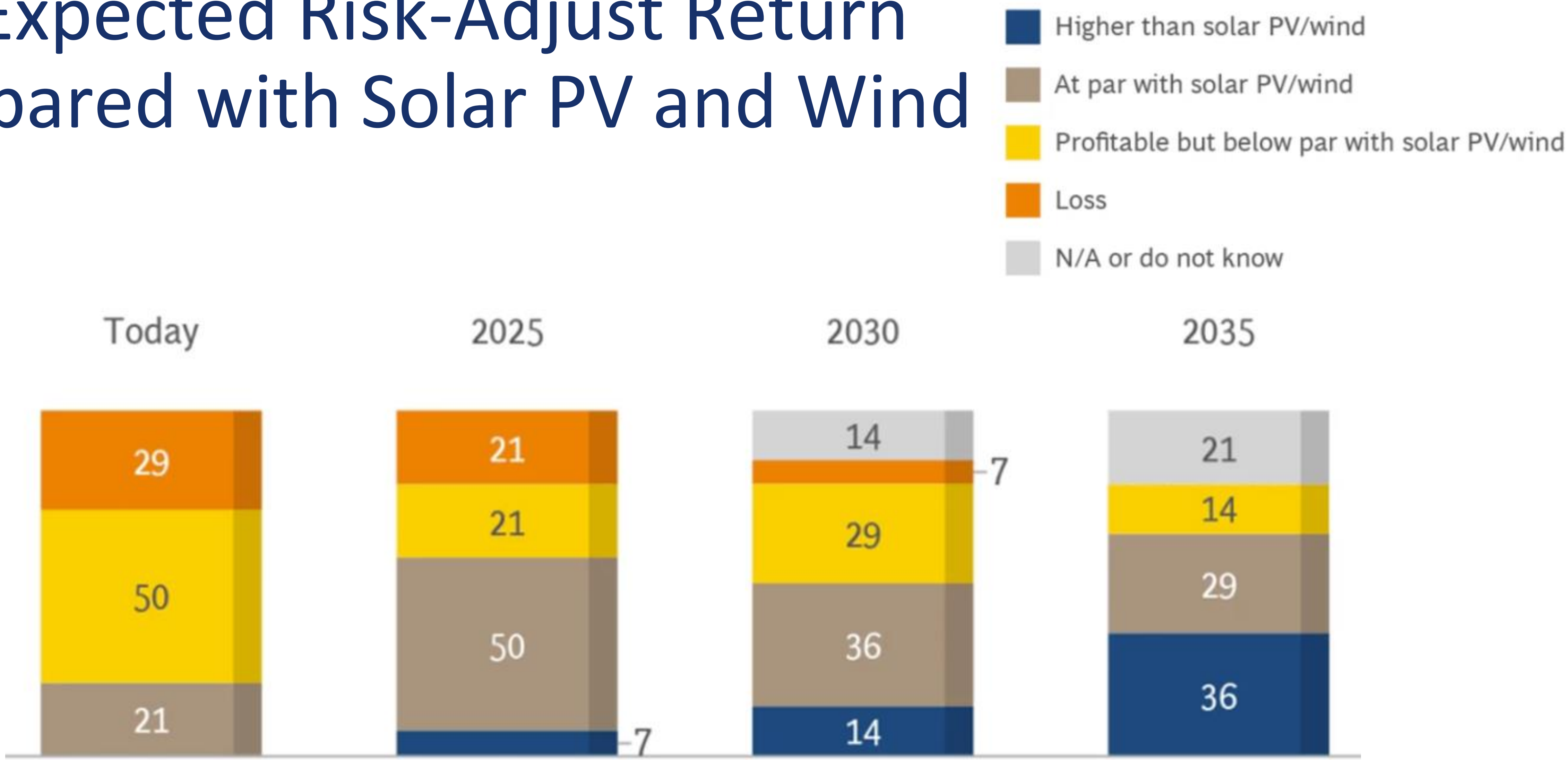
Challenge #4: Competition with Other Decarbonization Technologies

- Solar/Wind
  - Economy of scale.
  - Intermittence/Storage.
  - Location limit.
  - High land usage.
- Hydrogen
  - Clean.
  - New/unproven technologies.
  - No infrastructure.
  - High cost.
  - Blue hydrogen (CCS).
- CCS
  - Proven technology.
  - Cost.
  - No infrastructure.
- Geothermal
  - Location limit.
  - High cost.
- Renewable Fuel
  - High cost.
  - Feedstock limit.

Above all approach.

Selectively deploy technologies where it makes sense.

CCS Expected Risk-Adjust Return Compared with Solar PV and Wind



Sources: Survey of commercial banks that have evaluated hydrogen projects (45 respondents) and CCUS projects (14 respondents); BCG analysis.

Blue Flint CCS

(small scale, near site CCS, example)

Harvestone Low Carbon Partners Facilities

HarvestoneLCP.com

Blue Flint Ethanol
ICM/Fagen – 2007
74 MGY Ethanol; 25 M Bu Corn
200 K Tons of CO_2

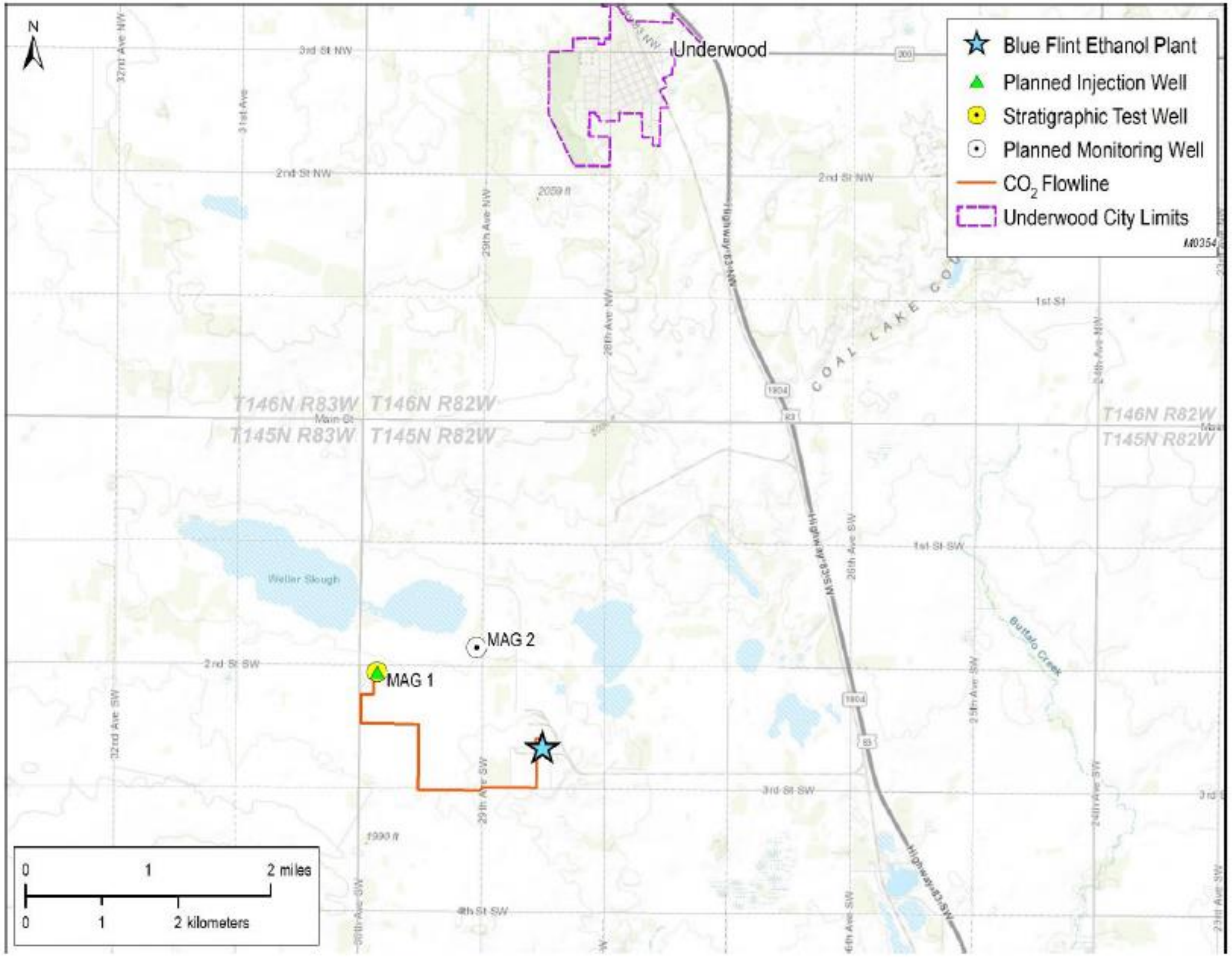
Dakota Spirit AgEnergy
KFI/McGough – 2015
77 MGY Ethanol; 25 M Bu Corn
210 K Tons of CO_2

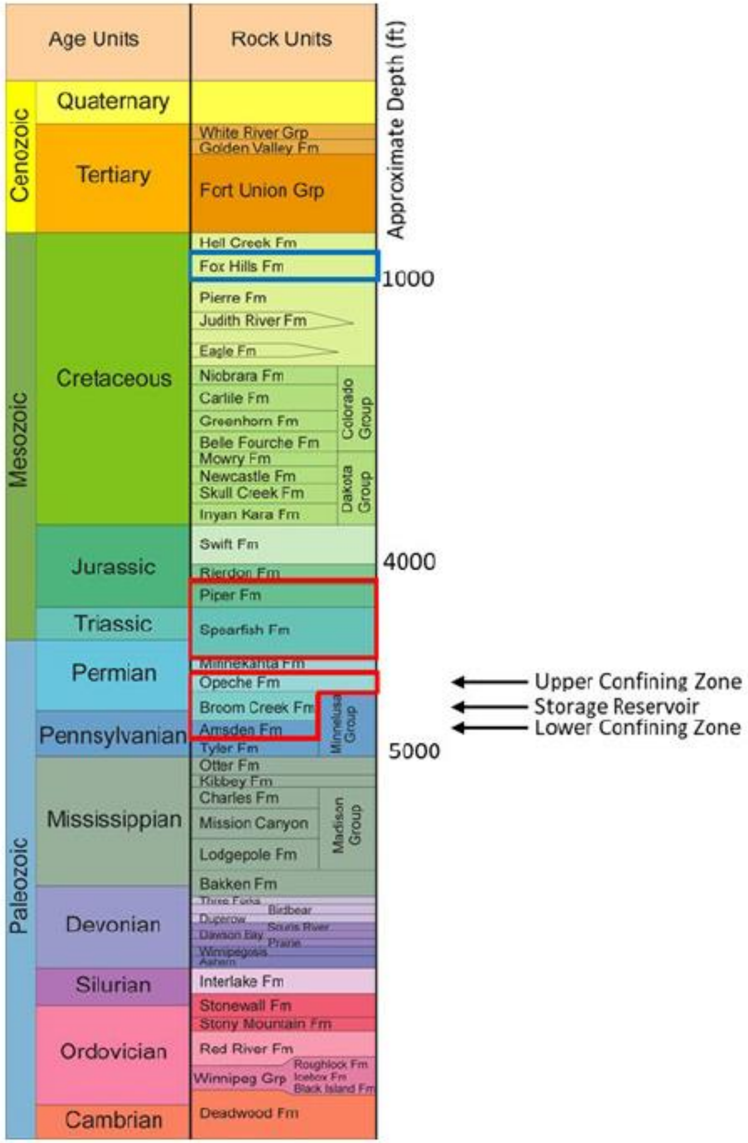
Iroquois Bio-Energy Company
ICM/Fagen – 2005
57 MGY Ethanol; 19 M Bu Corn
165 K Tons of CO_2

IBEC

Blue Flint CCS Video

Blue Flint Ethanol CCS (Oct 2023)





Blue Flint Ethanol CCS

- 200,000 TPA CO2 Injection Currently.
- Near site storage (3 mi pipeline).
- Broom Creek Formation ~4700 ft
- Underwood, North Dakota.
- Start injection on 10/28/2023.
  - 3rd Class VI injection in the US.

Takeaway Points

- **Challenges**
  - Economics.
  - Distance between source and sink.
  - Public perception of risk.
  - Competition from other decarbonization technologies.
- **Opportunities**
  - Blue oil (EOR).
  - Near site storage.
  - Capture Technology.
  - Pipeline network.
  - Economy of scale.
  - Educating the public.
  - Above all approach.

From: Exxon Investor Relations

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Opinions are the speaker's perspective, not necessarily their employer's.

Thanks
Q&(A or $\bar{A}$)