The Basics of Carbon Sequestration

An introduction to the science, technology, and potential of carbon capture and storage

SCS ENGINEERS

What is Carbon Sequestration?

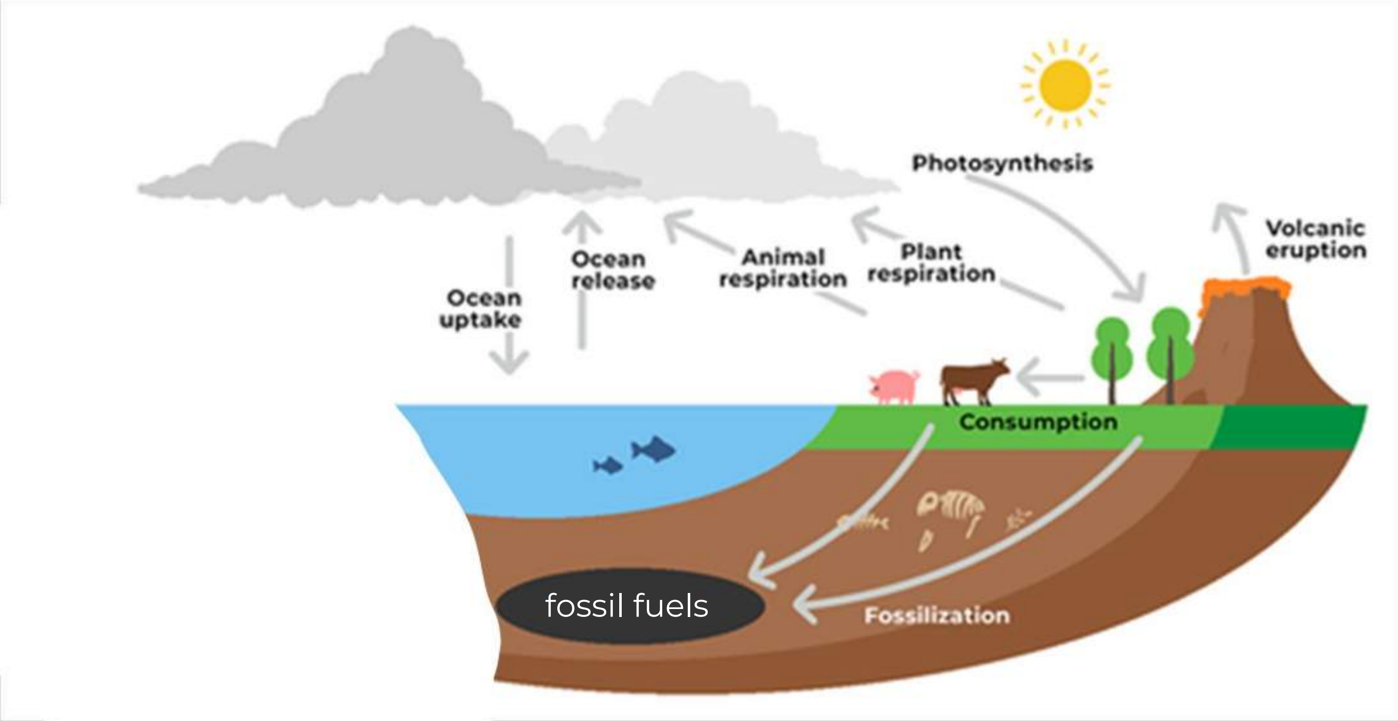
Carbon sequestration is the process of capturing and storing atmospheric carbon dioxide (CO_2) to mitigate climate change.

- CO_2 is a heat trapping gas produced naturally and by human activities.
- Man-made sources of CO_2 result from burning fossil fuels and other industrial activities.
- CO_2 is naturally released biologically via oceans, decomposition of organic matter and forest fires.

Carbon Cycle

in balance

The Earth contains a finite amount of carbon, which is cycled through different reservoirs, such as the atmosphere, the ocean, living organisms, and fossil fuels.



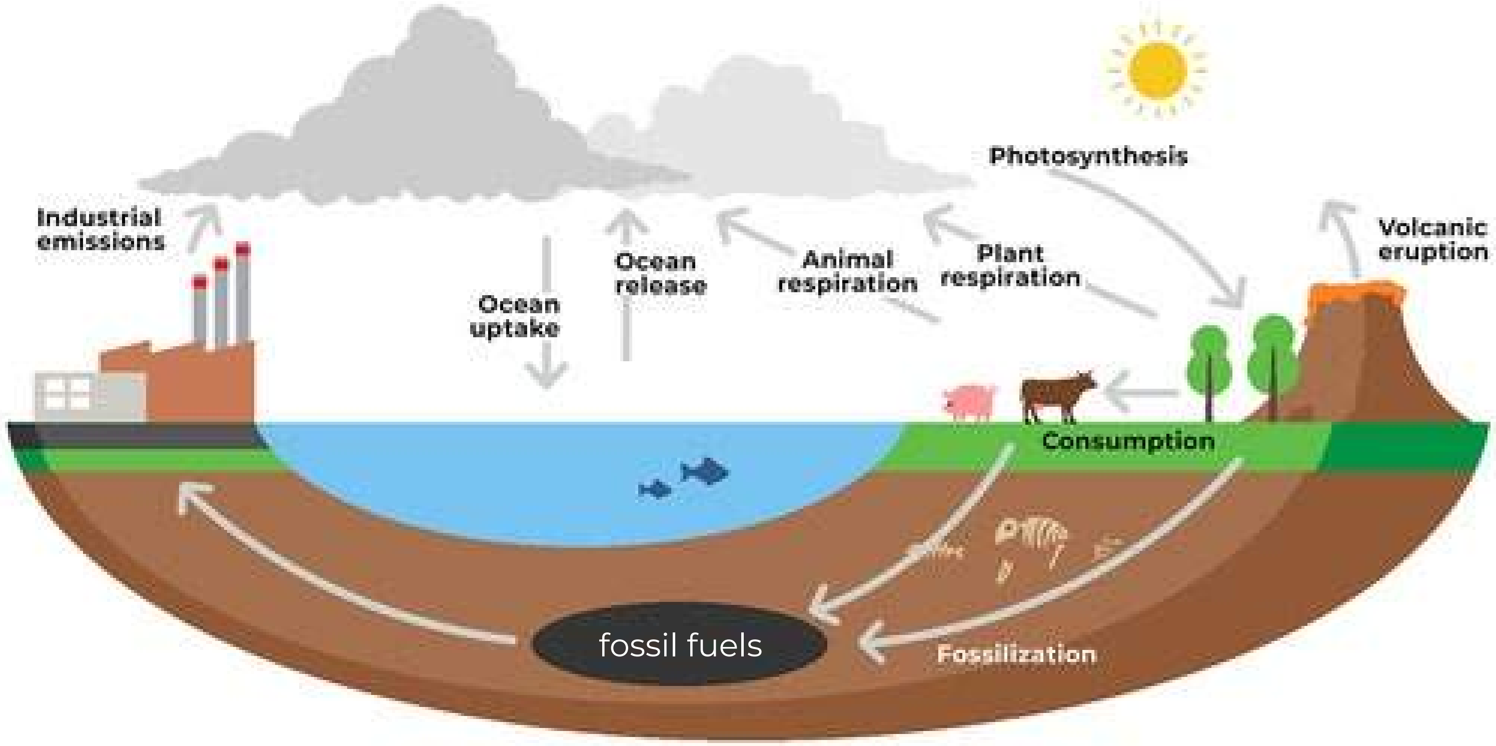
https://www.labster.com/

SCS ENGINEERS

Carbon Cycle
out of balance

The Earth contains a finite amount of carbon, which is cycled through different reservoirs, such as the atmosphere, the ocean, living organisms, and fossil fuels.

Fossil fuels are being burned faster than carbon is being deposited.



https://www.labster.com/

Types of Carbon Sequestartion

<u>Biologic</u>

Forrest Growth and Management

Improving Cropland Soil Management

Biomass Carbon Removal and Storage

Not permanent

<u>Geologic</u>

Saline Aquifers

Depleted Oil and Gas Reservoirs

Coal seams

Permanent when done safely

Benefits of Carbon Sequestration

Greenhouse Gas Emissions Reduction

Carbon sequestration helps remove and store carbon dioxide from the atmosphere, reducing the overall greenhouse gas emissions that contribute to climate change.

Climate Change Mitigation

By capturing and storing carbon, sequestration can help mitigate the effects of climate change, such as rising temperatures, sea level rise, and extreme weather events.

US Based Tax Credits

Tax credits vary between types of carbon captured and types of sequestration (permanent or EOR). All have varied sunset dates in the 2040's.

Enhanced Oil Recovery (EOR)

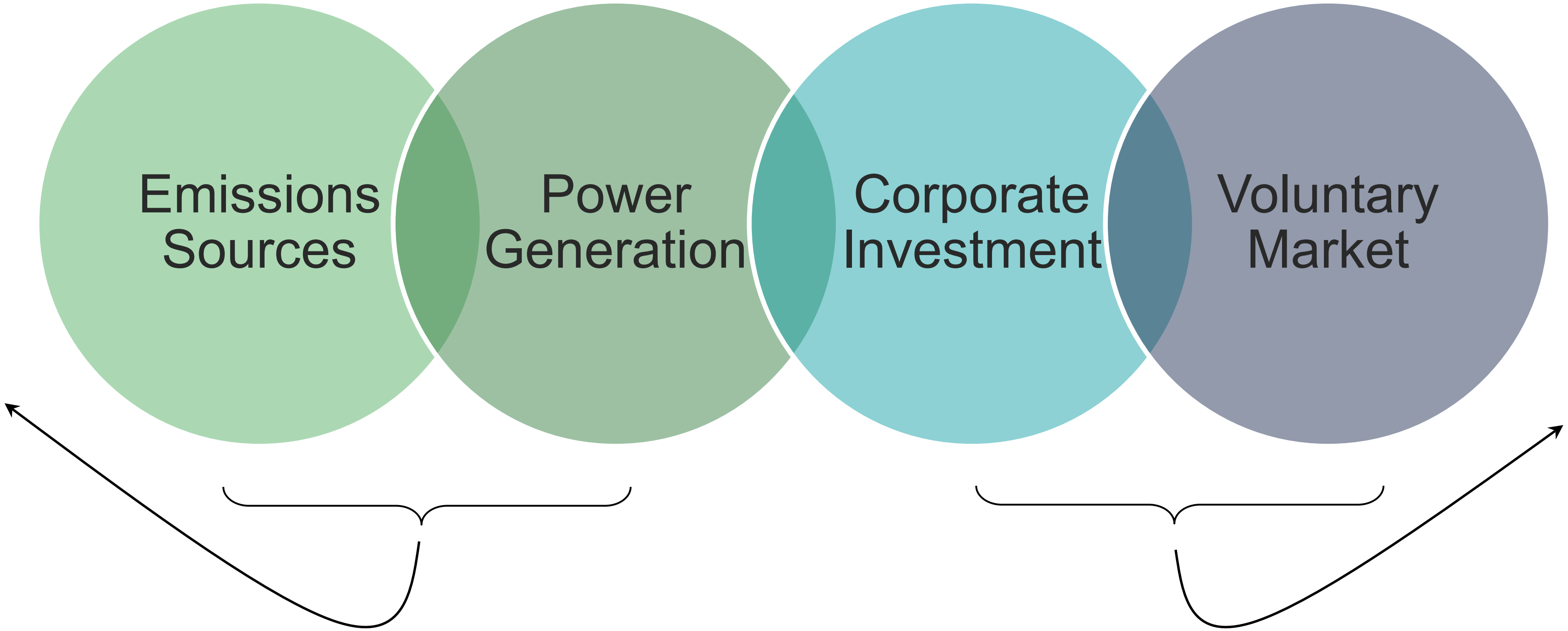
The process of carbon sequestration can also be used for enhanced oil recovery, where the captured CO_2 is injected into oil reservoirs to increase oil production, providing an additional economic benefit.

Carbon sequestration offers a comprehensive solution to address climate change by reducing greenhouse gas emissions, mitigating the impacts of climate change, and providing opportunities for enhanced oil recovery.

SCS ENGINEERS

Who is Carbon Sequestration right for

Single point sources of CO_2; ethanol plants, manufacturing, landfills, fertilizer plants, refineries, who need to reduce emissions



Investors who may not have emissions sources, but have funds to create commercial storage hub facilities for smaller emissions sources

All facilities with sources of Carbon Dioxide emissions would benefit from reviewing their emissions goals and determining if a sequestration project would positively impact their business.

SCS ENGINEERS

The History of Carbon Sequestration

1970s

Use of CO_2 for enhanced oil recovery (EOR) marks the beginning of carbon sequestration process.

1990s

Research and development efforts into geologic and biologic carbon sequestration techniques are initiated.

2000s

Pilot projects and demonstration plants are established to test and validate carbon sequestration technologies.

2005

The first large-scale carbon capture and storage (CCS) project, Sleipner, begins operation in the North Sea.

2010s

Governments and industries invest heavily in the scale-up and commercialization of carbon sequestration technologies.

2020

Carbon sequestration gains momentum as a critical tool in the fight against climate change, with numerous projects planned and under development worldwide.

SCS ENGINEERS

Sources and Sinks of CO_2

Primary Sources

Industrial and energy production facilities, such as power plants, refineries, and manufacturing plants, are the primary sources of CO_2 emissions.

Geologic Sinks

Geologic formations, such as depleted oil and gas reservoirs, deep saline aquifers, and unmineable coal seams, can be used as geologic sinks for CO_2 storage through carbon sequestration techniques.

Location of Sources

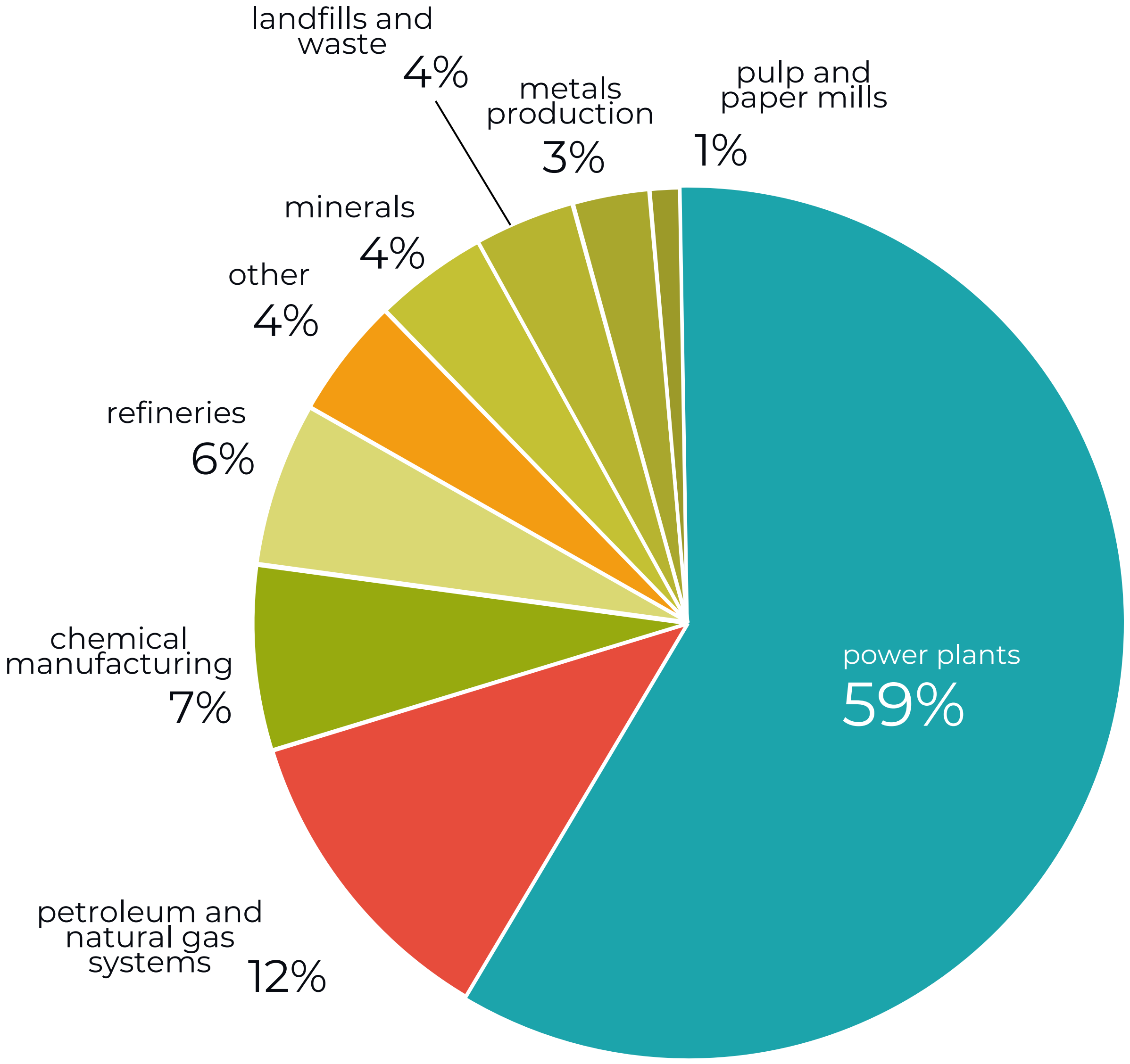
Major sources of CO_2 emissions are often located near industrial and urban centers, where energy demand and manufacturing activities are concentrated.

Location of Sinks

Suitable geologic formations for CO_2 storage are found in various regions, with research having focused on areas near major emission sources to minimize transportation costs and infrastructure.

SCS ENGINEERS

US based CO_2 sources



2,695

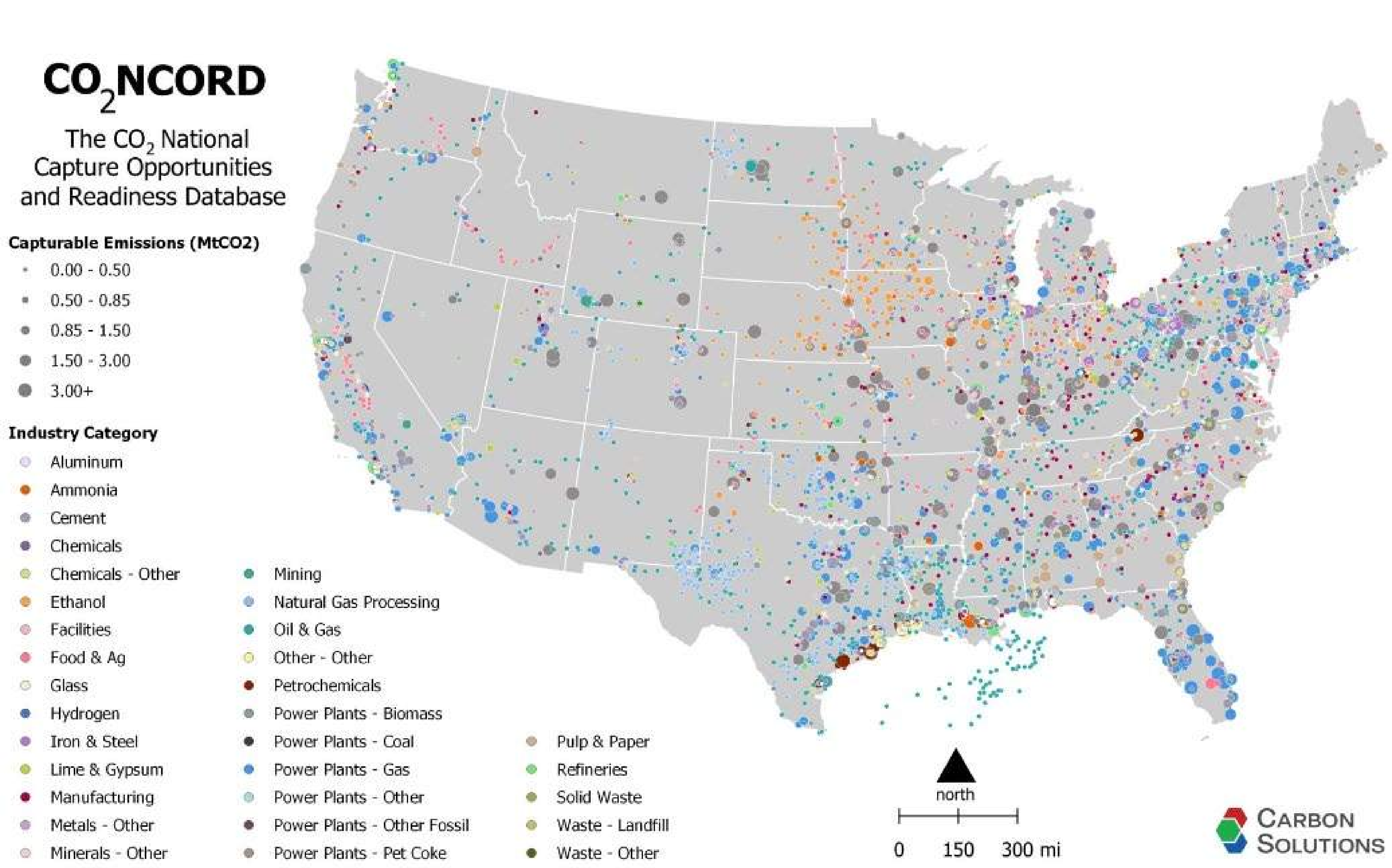
Million Metric Tons CO_2e

Reported to EPA in 2022 across 7,586 facilities

source: ghgdata.epa.gov

SCS ENGINEERS

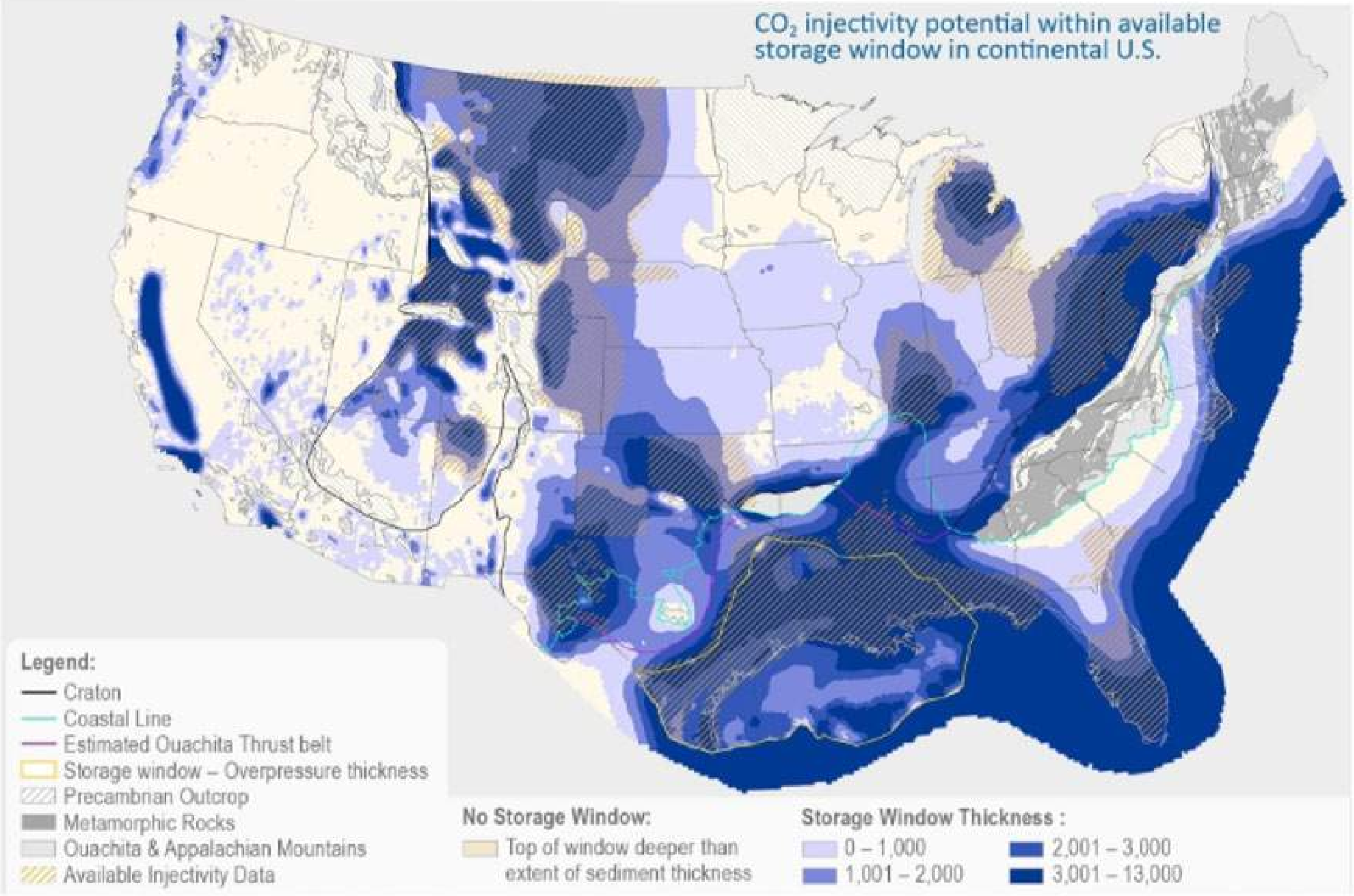
US Source Locations and Type



US Sinks

Sink requirements

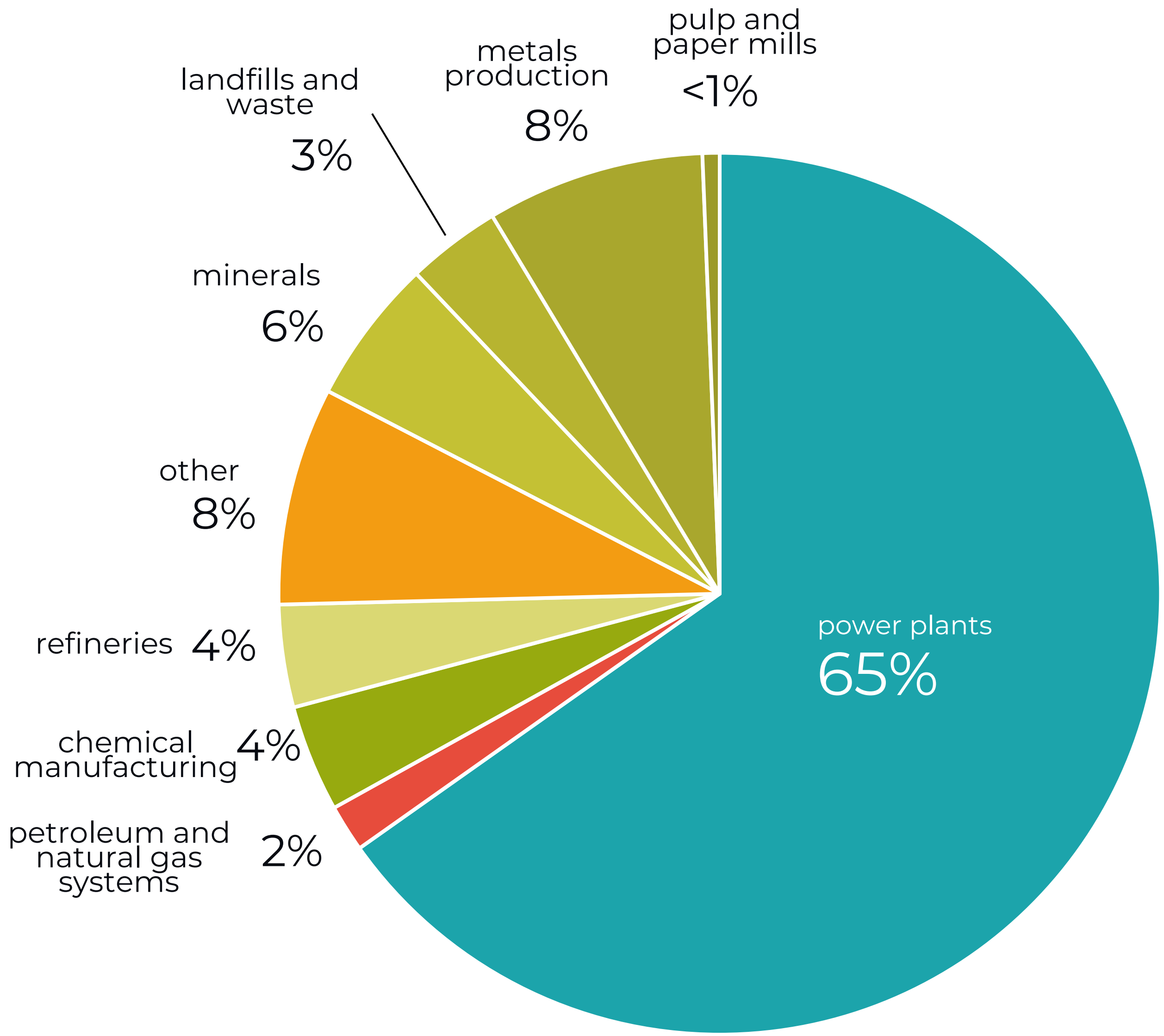
- Porous media at a depth of over 2800 ft (~850m)
  - Saline Reservoirs
  - Sedimentary basins
  - Depleted Oil and Gas Reservoirs
- Upper and lower seals
  - Low permeability rocks to prevent the upward flow of CO_2
- Trapping mechanism
  - Faults or Arches
  - Overlying strata
  - Capillary Trapping
- Minimal penetrations of the injection formation and confining unit



source: roads2removal.org

SCS ENGINEERS

Midwest CO_2 sources



638

Million Metric Tons CO_2e

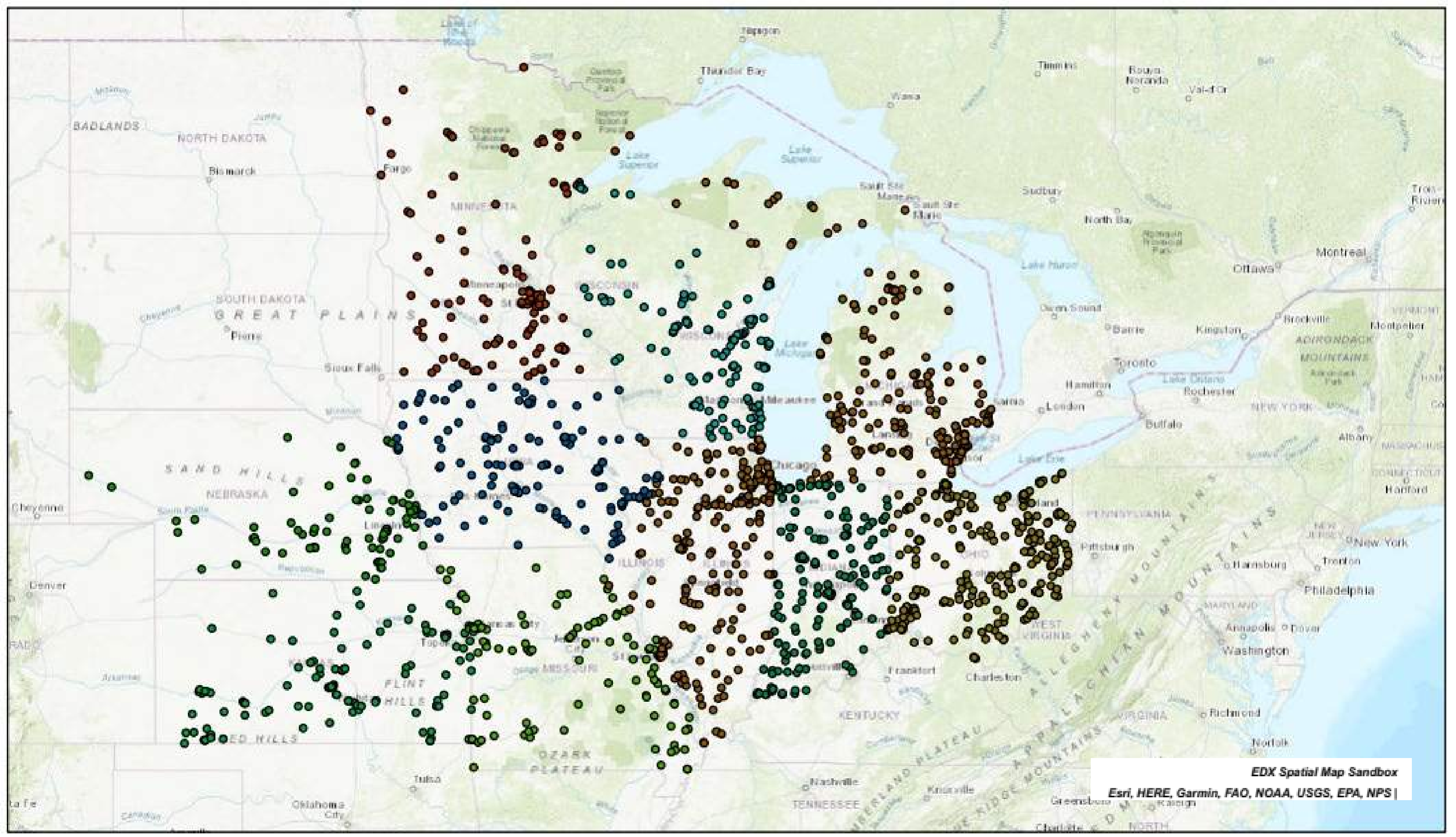
Reported in 2022

Reported to EPA in 2022 across 1,508 facilities in Regions 5 and 7

source: ghgdata.epa.gov

SCS ENGINEERS

Midwest Source Locations

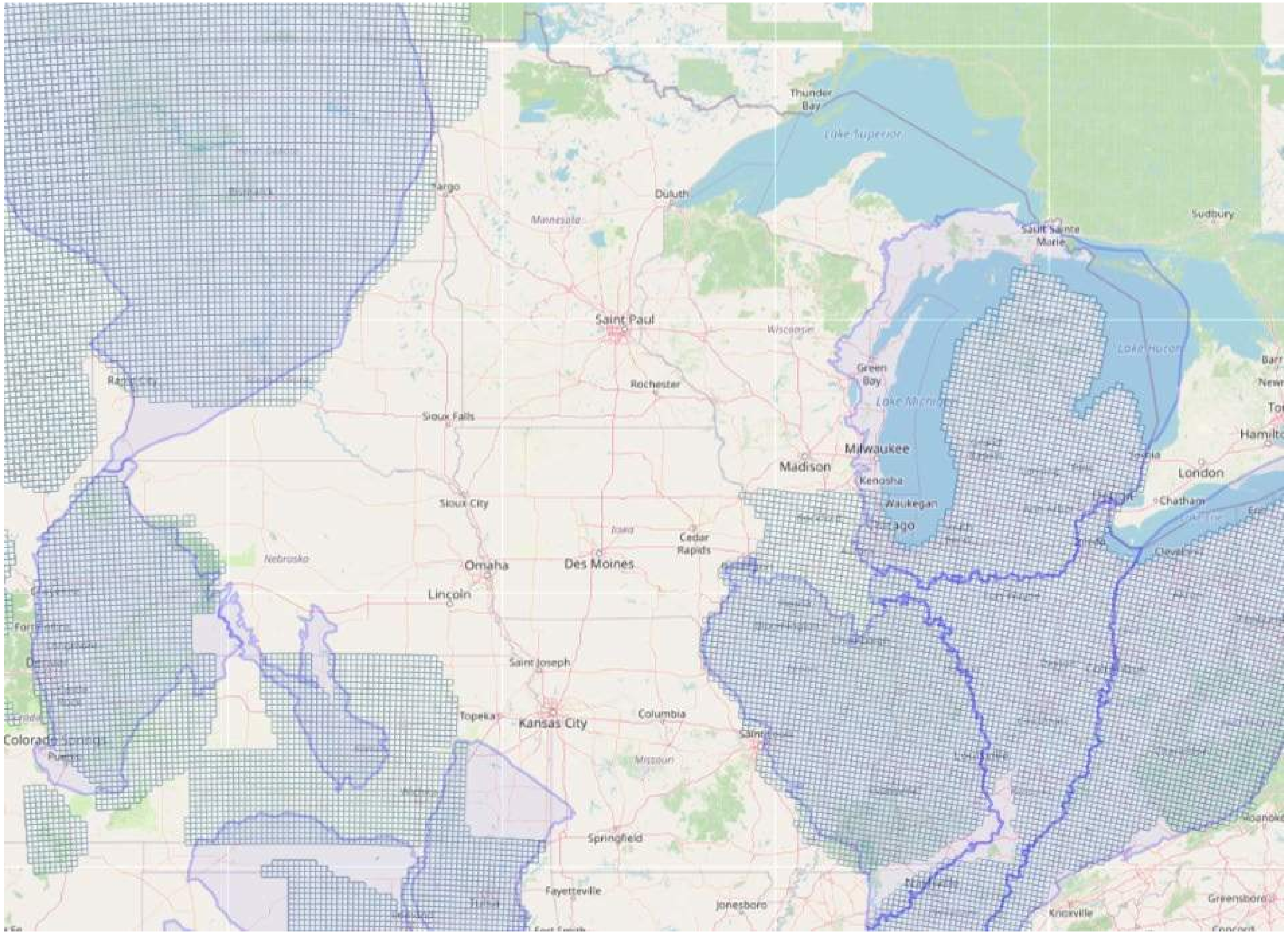


source: ghgdata.epa.gov

SCS ENGINEERS

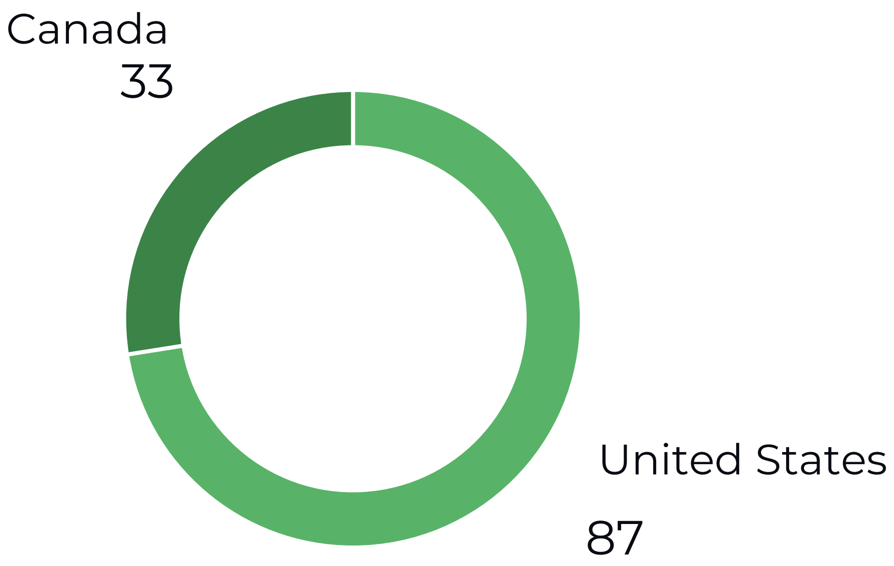
Midwestern Sinks

- Porous media at a depth of over 2800 ft (~850m)
  - Illinois Basin
    - Mt. Simon
  - Mid-Continent
    - Arbuckle Formation
- Upper and lower seals
  - Low permeability rocks to prevent the upward flow of CO_2
- Trapping mechanism
  - Faults or Arches
  - Overlying strata
  - Capillary Trapping

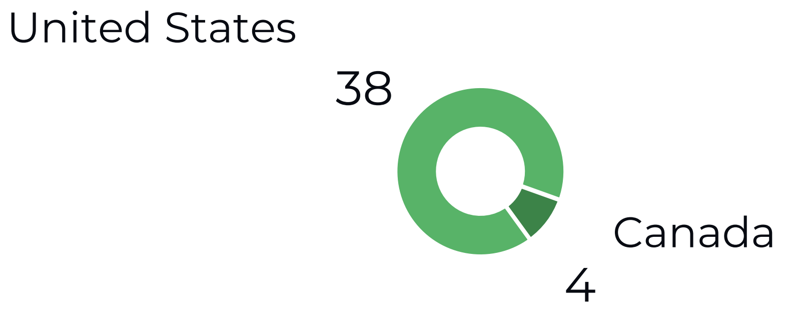


Ongoing carbon capture and storage projects across the US and Canada

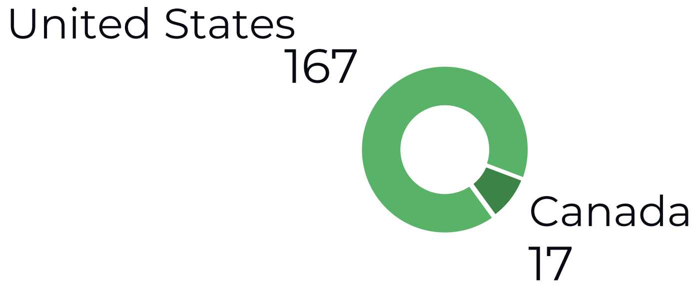
Storage Projects (Class VI) with submitted applications



EOR projects (Class II)



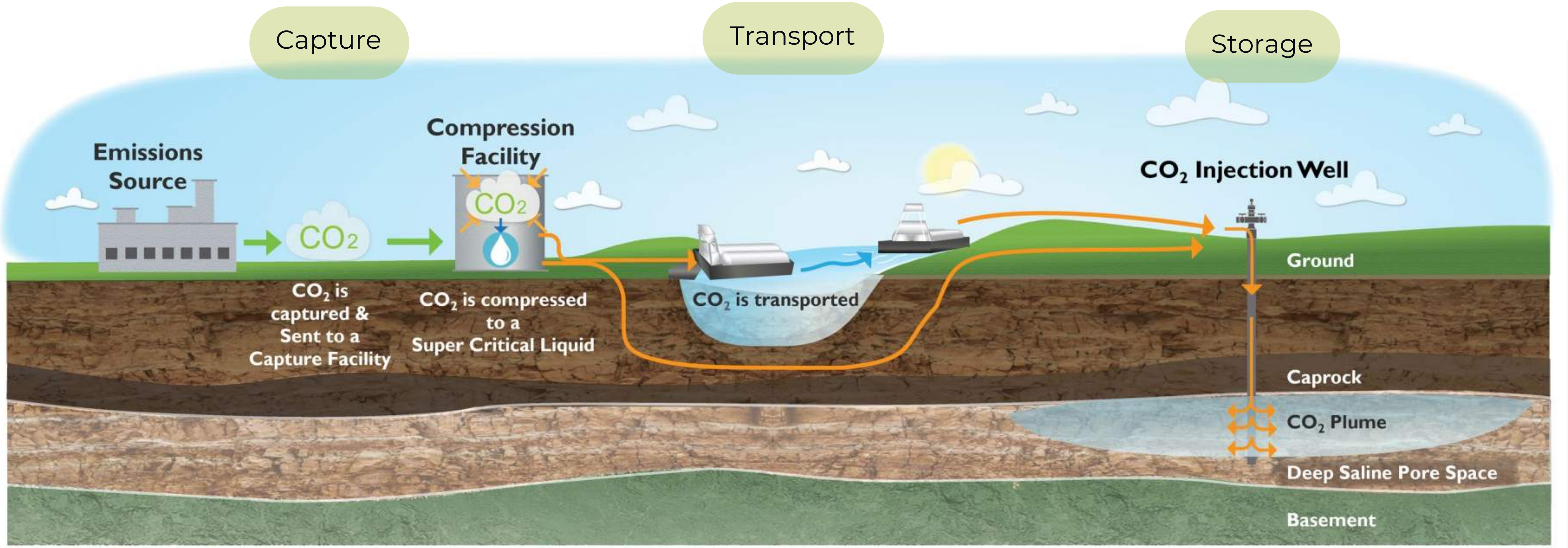
Capture Projects



Data Source: CCUSMap.com
June 2024

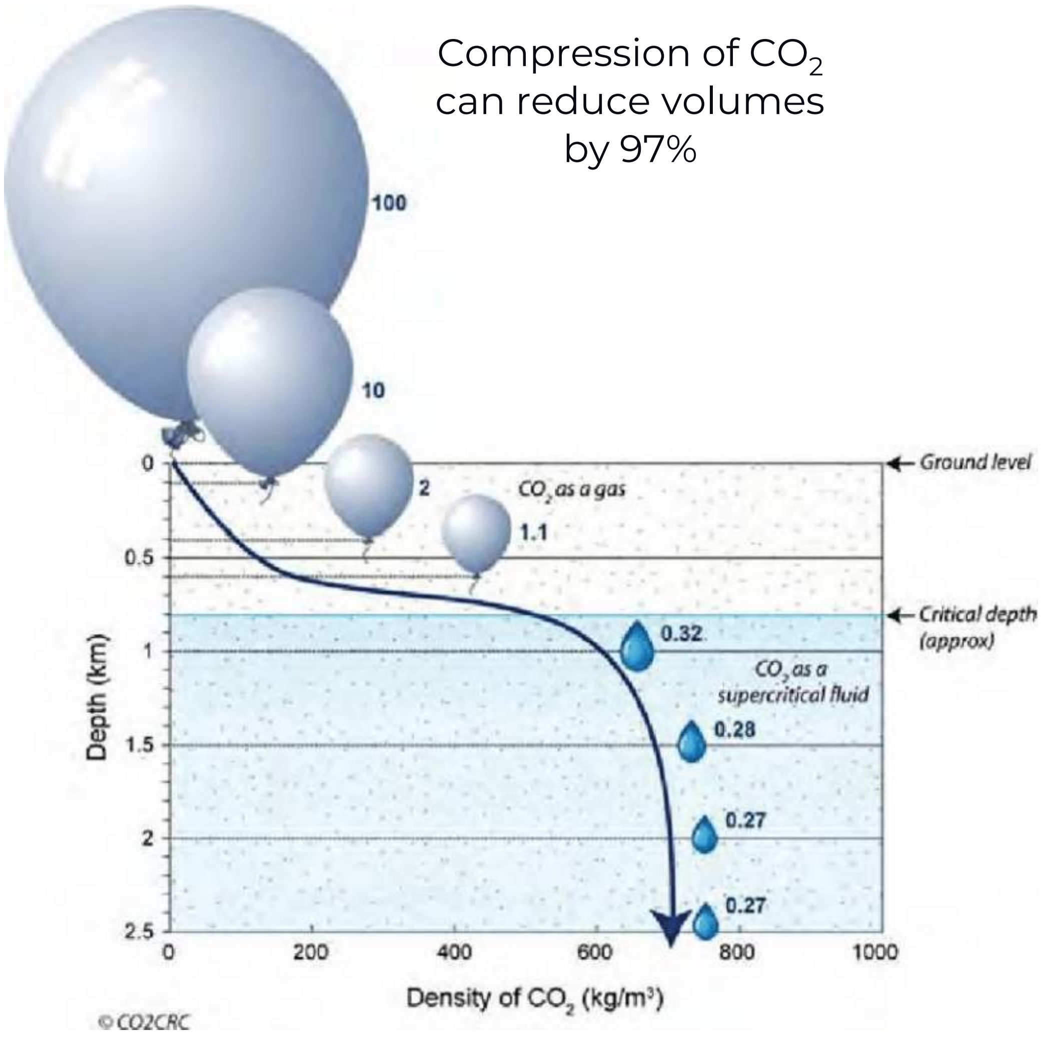
SCS ENGINEERS

Project Component Overview



SCS ENGINEERS

Carbon Capture



Compression of CO_2 can reduce volumes by 97%

Point Source Capture

Point source carbon capture involves collecting CO_2 emissions directly from large industrial facilities, such as refineries, power plants, or cement factories. This method targets specific emission sources where the CO_2 is highly concentrated, making it more efficient to capture.

Absorption Process

The captured CO_2 is then transported to an absorption unit, where it is dissolved into a chemical solvent, typically an amine-based solution. The CO_2-rich solvent is then heated, causing the CO_2 to be released from the solution, leaving behind the original solvent for reuse.

Compression

The CO_2 released from solution is then compressed into a dense, liquid state (super critical fluid) to facilitate transportation and storage. This process is also very energy intensive and would be best co-located with renewable or green energy infrastructure.

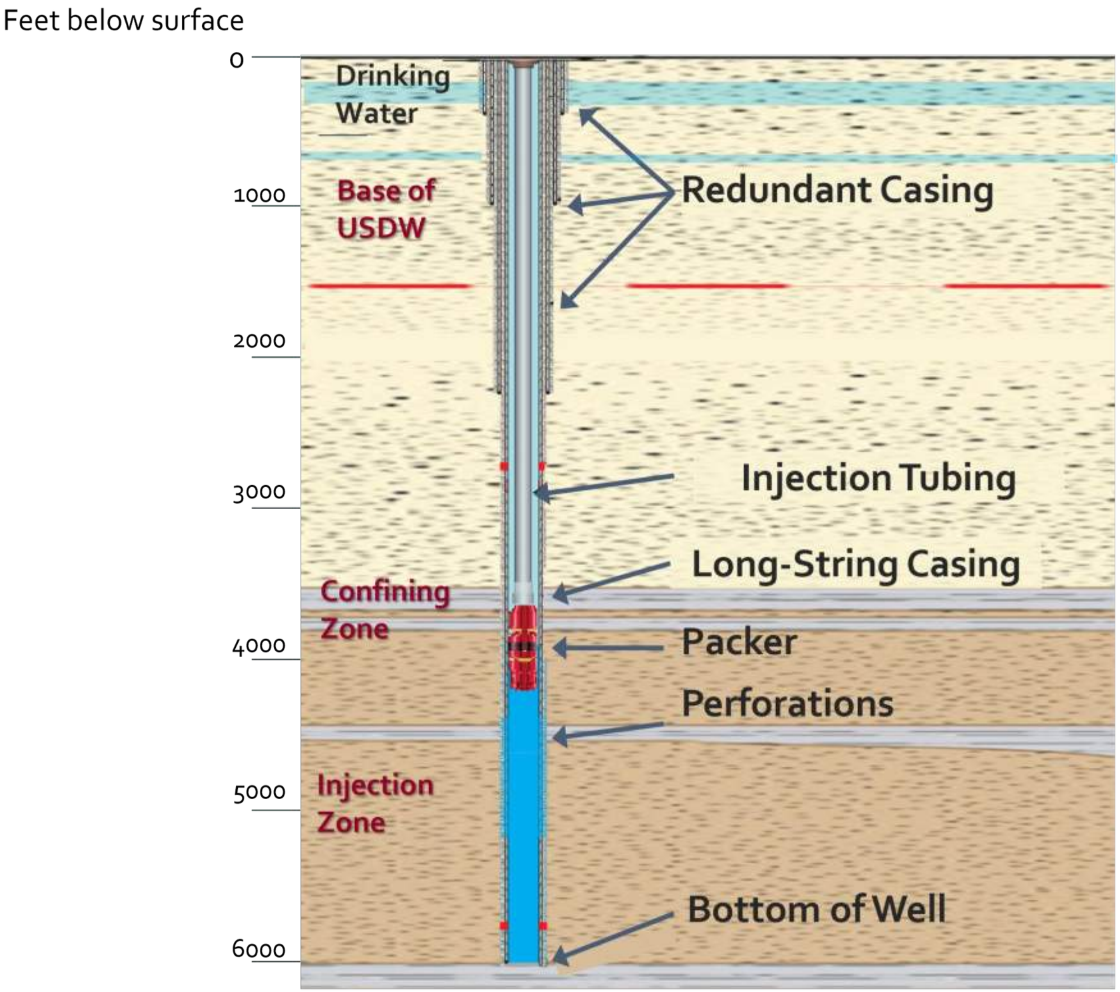
SCS ENGINEERS

Carbon Transportation

Pipeline Transportation	Truck and Rail Transport	Ship Transport	Multimodal Transport
Dedicated CO_2 pipelines transport super critical CO_2 from the sources (e.g., power plant, industrial facility) to the injection well site. Pipelines offer a safe and efficient method for large-scale, long-distance CO_2 transport.	For smaller-scale or remote projects, transport CO_2 in pressurized tanks or containers via trucks or railcars to the injection site. This method is suitable for shorter distances and lower volumes of CO_2.	For CO_2 capture from coastal facilities or when the injection site is located offshore, ships or tankers can transport compressed CO_2 to the injection location.	Combine different transportation methods, such as pipeline, truck, or ship, to optimize the logistics and cost-effectiveness of CO_2 transport.

SCS ENGINEERS

Carbon Storage



Inject CO_2 under pressure

- Through multiple series of cemented casing
- Continuous monitoring during injection
- Continuous monitoring for several decades post closure
- Prevent releases

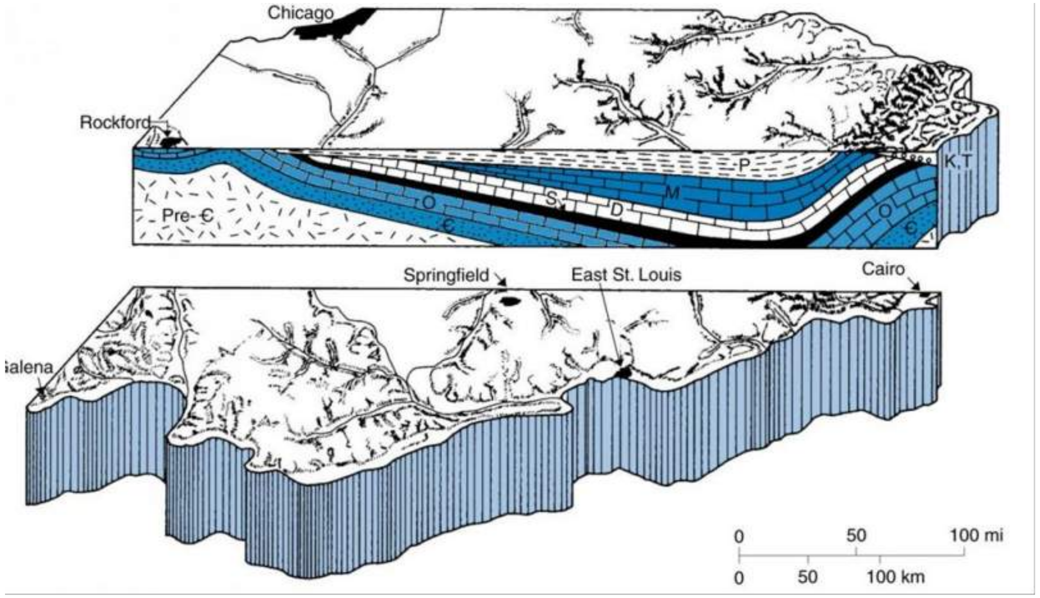
Ultimate Overarching Goal

Protect Underground Sources of Drinking Water (USDW)

SCS ENGINEERS

Subsurface Pre-Permitting Process

Class VI Considerations



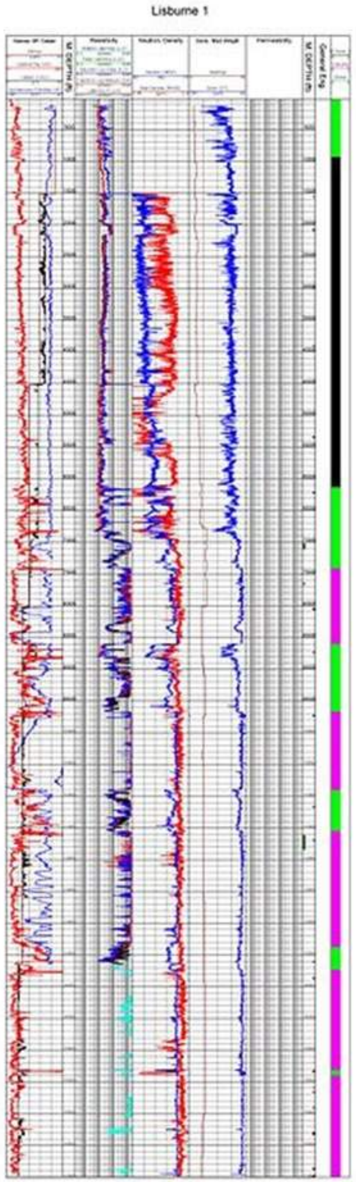
Source: Illinois State Geological Survey

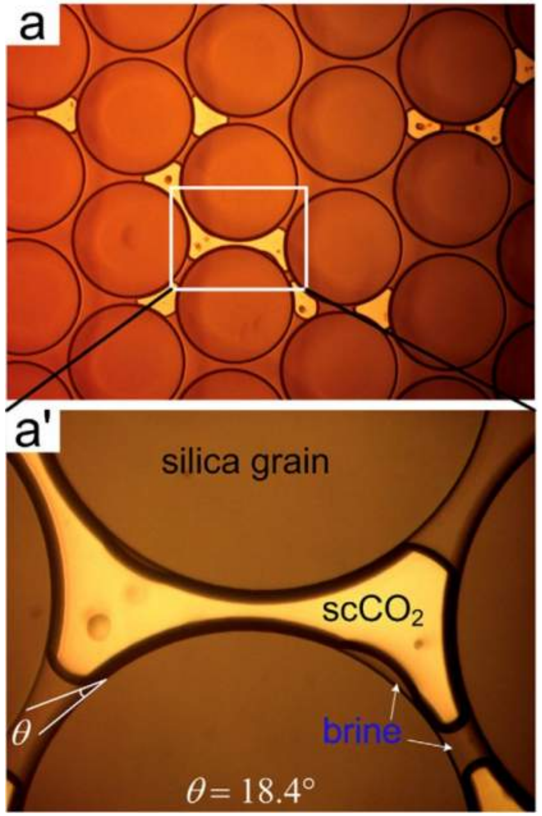
Feasibility Study

- Assess community support
- Cost assessment and Financial Considerations
- Analyze the regulatory environment
- Review Geology to ensure adequate reservoir properties
  - Depth for super critical storage
  - Adequate pore space to store desired volumes
  - Appropriate upper and lower confining zones to prevent migration
  - Identify paths for release
    - Faults
    - Artificial Penetrations

SCS ENGINEERS

Subsurface Permitting Consideration





Site Characterization
- Extensive Maps, Cross-Sections of all geologic zones related to storage and containment

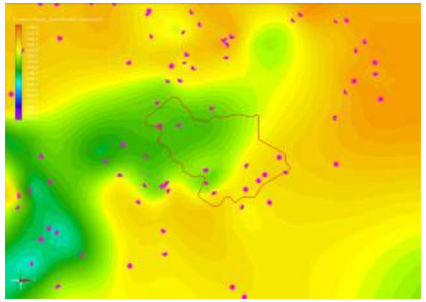
Area of Review
- Create computational plume model
- Review all wells in estimated plume footprint

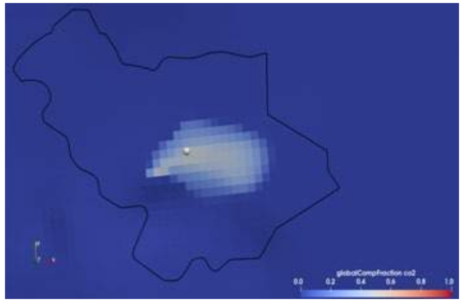
Corrective Action
- Address any unplugged wells or those with questionable records

Design and Engineering
- Casing, tubing, cement and packer design
- Completion details

Operational Details
- Rate, pressures, flow, recording devices, testing and monitoring

- Emergency Plans
- Plugging Plans
- Post Injection Site Care
- Financial Responsibility
- Environmental Justice

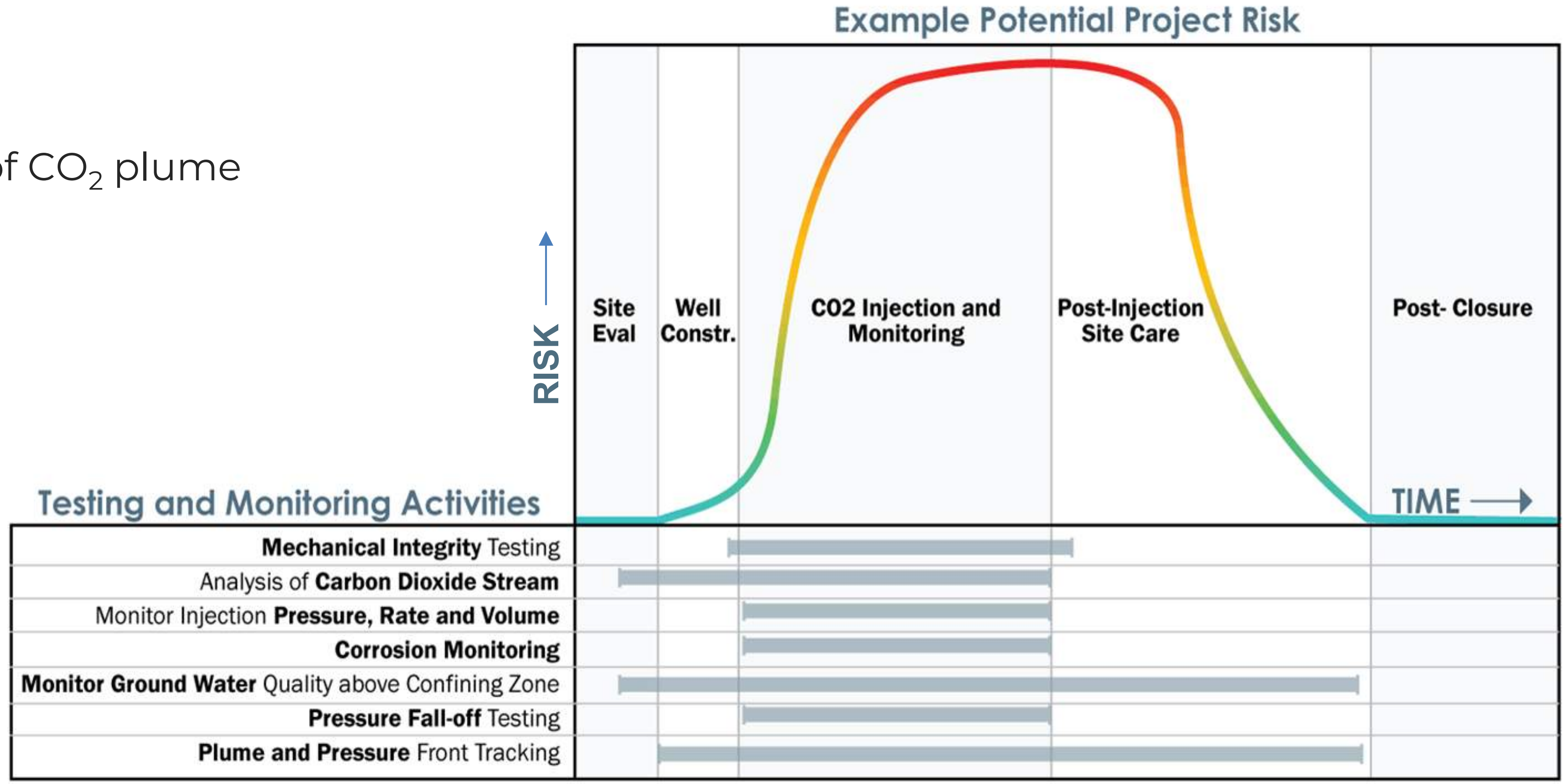




SCS ENGINEERS

Operational and Post-Closure Considerations

- Operational Testing and Monitoring
  - Mechanical Integrity Tests
  - Fall-Off testing
  - Vertical seismic profiling
  - Pressure Front monitoring of CO_2 plume
  - Groundwater Monitoring
  - Microseismicity monitoring
- Post-Injection Site Care
  - Plug back injection wells
  - Continued site monitoring



Modified from: EPA Draft UIC Class VI Guidance

Monitoring and Redundancy

Multi-Layer Monitoring System

Comprehensive system including surface, atmospheric, and subsurface monitoring to detect any potential CO_2 leakage.

Redundant Safeguards

Multiple layers of backup systems and fail-safe mechanisms to ensure containment and prevent unintended release of CO_2.

Continuous Data Analysis

Real-time monitoring and data analysis to quickly identify and address any irregularities or potential issues.

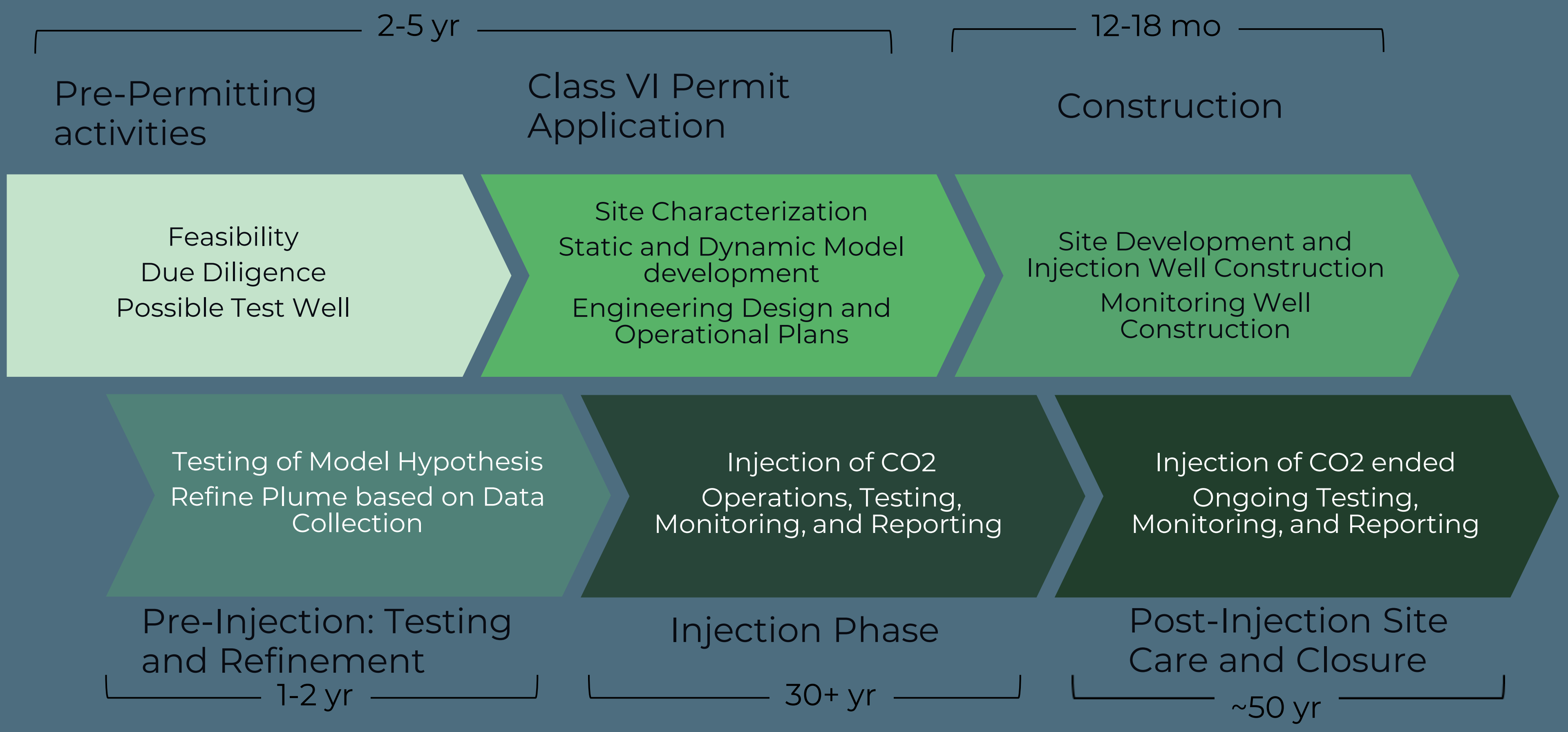
Groundwater Monitoring

Extensive monitoring of groundwater quality and levels to ensure the integrity of the storage site and protect local water resources.

Through these robust monitoring systems and redundant safeguards, the carbon sequestration process ensures the long-term containment and safe storage of CO_2, minimizing any risks to the environment and surrounding communities.

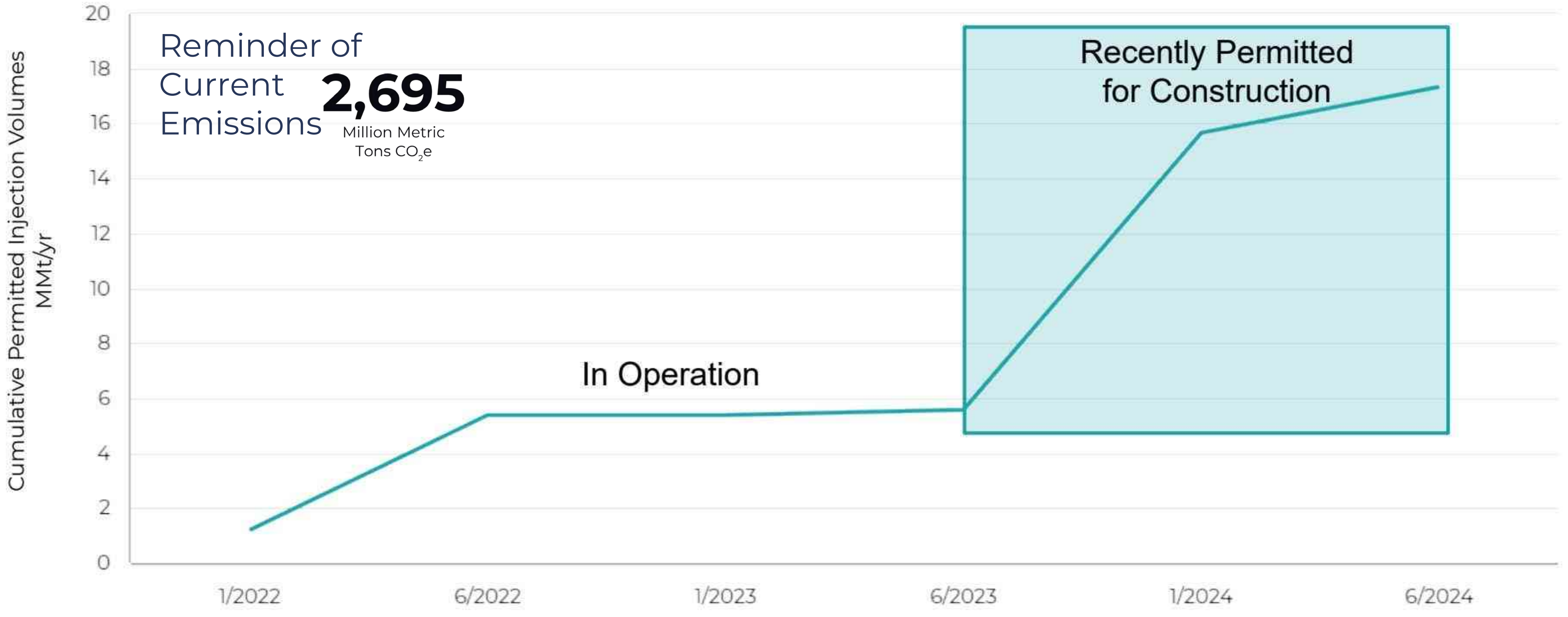
Process For Carbon Storage Project

Conception to Site Closure



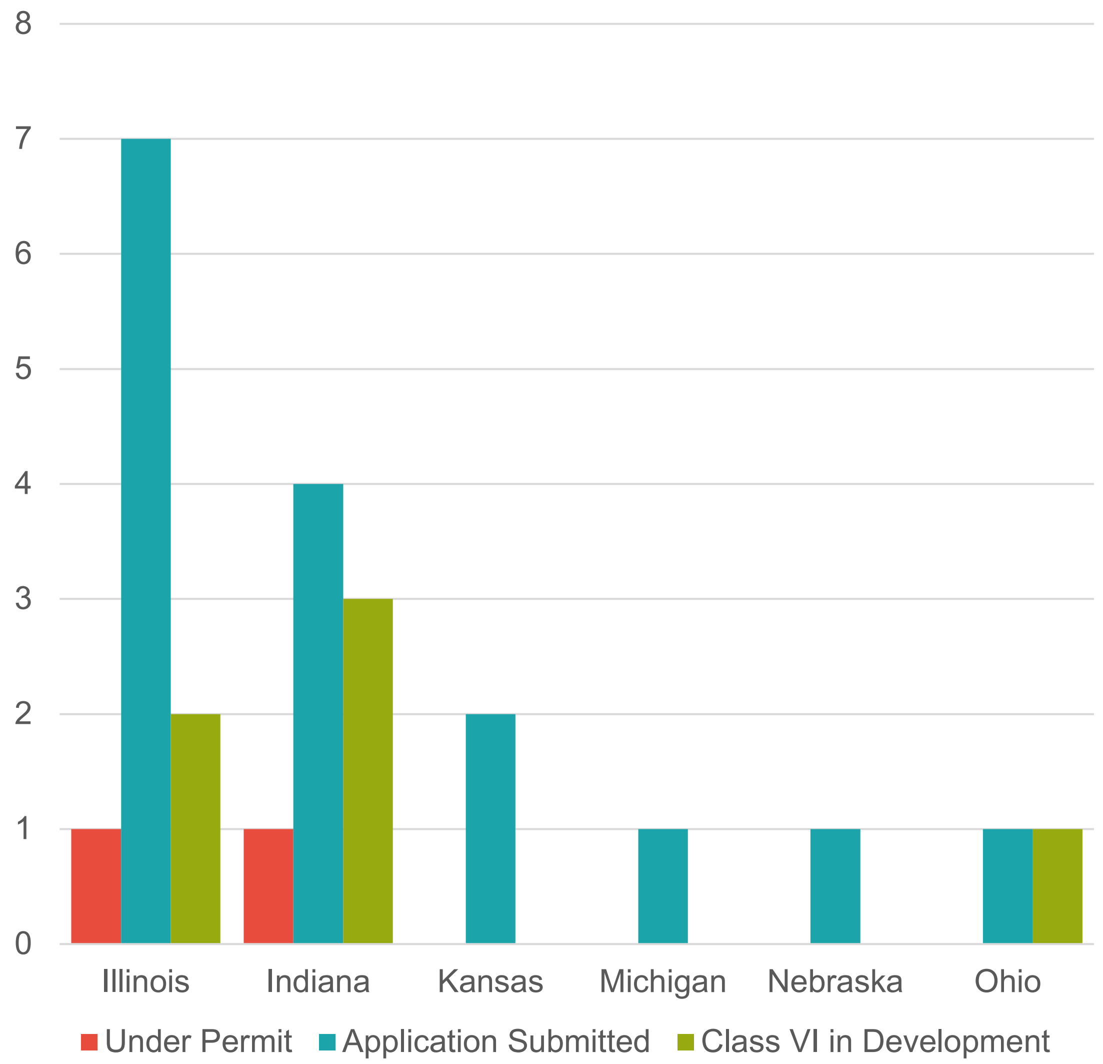
SCS ENGINEERS

US Based Cumulative Permitted Injection Volumes



SCS ENGINEERS

Midwest Class VI Project Activity



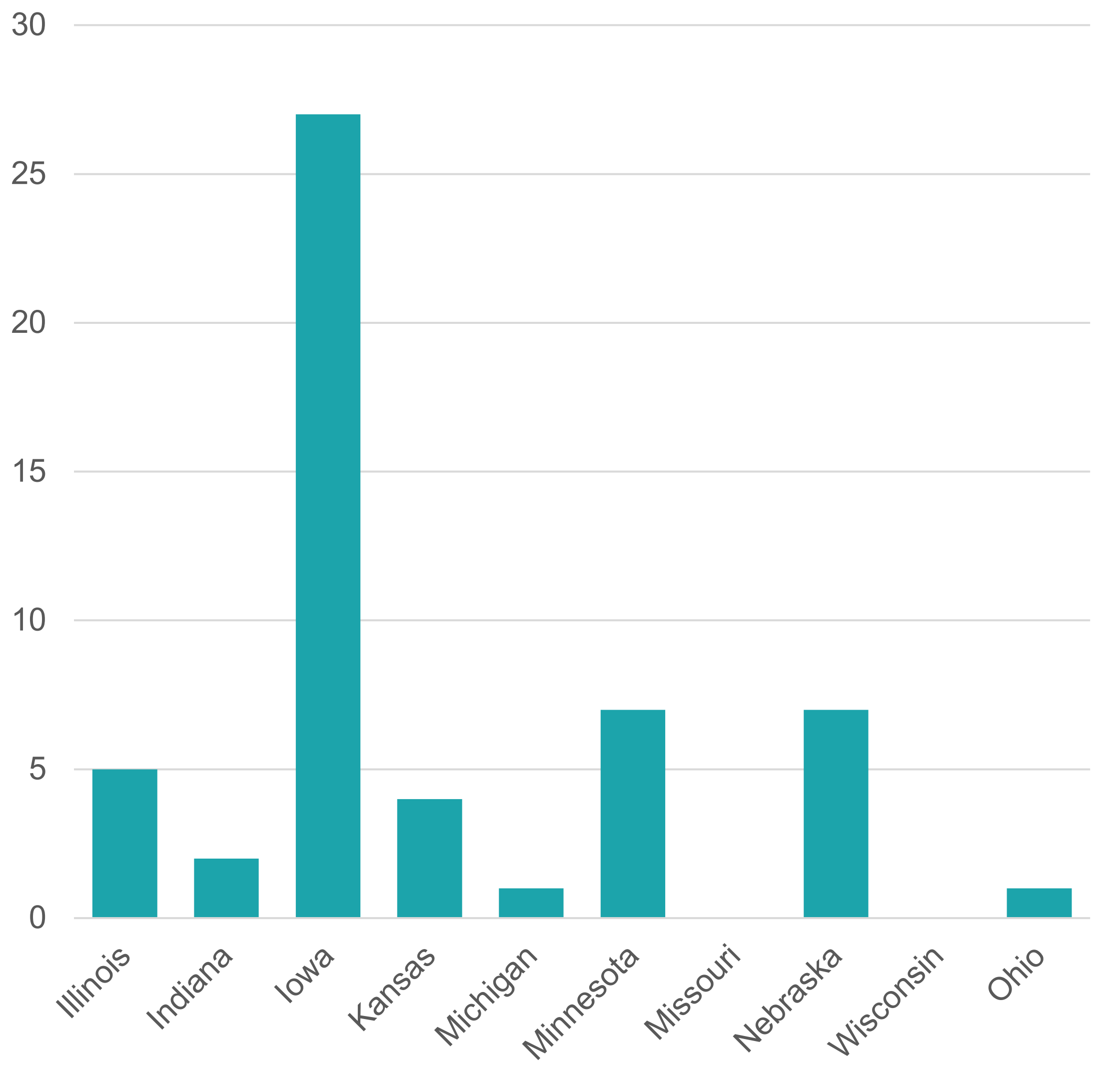
29 wells at 13 projects in Region 5

3 wells at 3 projects in Region 7

sources epa.gov
ccusmap.com

SCS ENGINEERS

Midwest Carbon Capture Project Activity



54 Independent Capture Projects underway in EPA Regions 5 and 7

- Biorefineries
- Ethanol Plants
- Refineries
- Steel Plants
- Sustainable Air Fuel
- Hydrogen Hub
- CCS Hubs

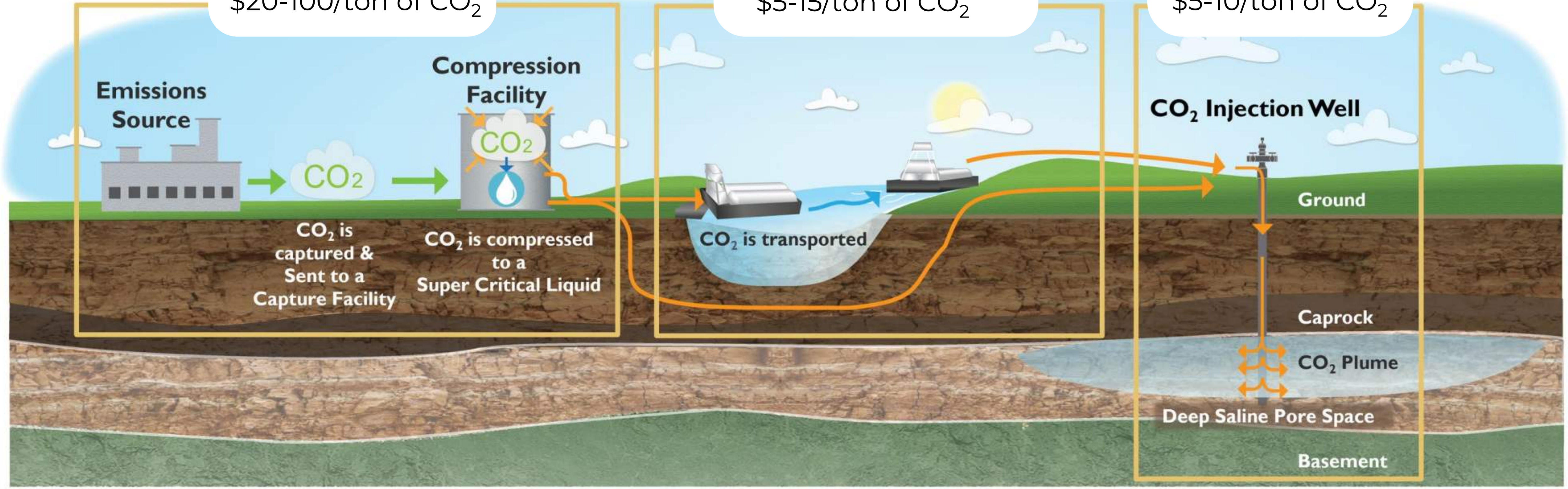
Source: ccusmap.com

Financial Project Considerations

Cost of Capture[1]
$20-100/ton of CO_2

Cost of Transport[2]
$5-15/ton of CO_2

Cost of Storage
$5-10/ton of CO_2



[1] Excluding DAC, Congressional Budget Office, 2023
[2] Global CCS Institute, 2022

SCS ENGINEERS

Community Engagement and Environmental Justice

- ## Transparent Communication

  Maintain open and transparent communication with local communities to build trust and address concerns.

- ## Inclusive Decision-Making

  Ensure local community members, including underrepresented groups, are involved in the decision-making process.

- ## Benefit Sharing

  Develop equitable benefit-sharing mechanisms to ensure communities near carbon sequestration sites also reap the rewards.

- ## Environmental Justice Assessment

  Conduct a thorough environmental justice assessment to identify and mitigate potential disproportionate impacts on marginalized communities. In the US EPA requires the use of their Environmental Justice Screening and Mapping Tool.

  https://www.epa.gov/ejscreen

Thank you

SCS Team

Carrie Ridley, PG

cridley@scsengineers.com

Gary Vancil Jr.

gvancil@scsengineers.com

Monte Markley, PG

mmarkley@scsengineers.com

National Practice Leader

For More Information on SCS Deep Well Services

SCS ENGINEERS