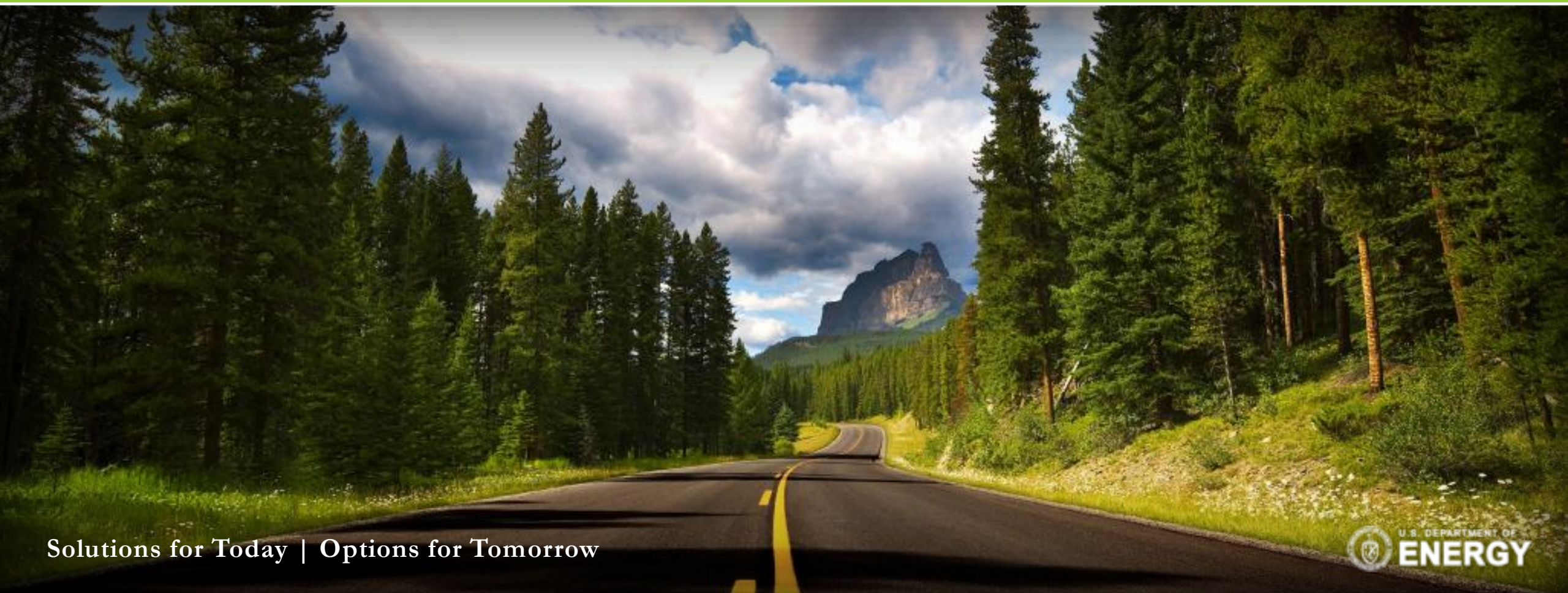


# U.S. DOE Regional Carbon Sequestration Partnership Initiative



Traci Rodosta - Carbon Storage Technology Manager

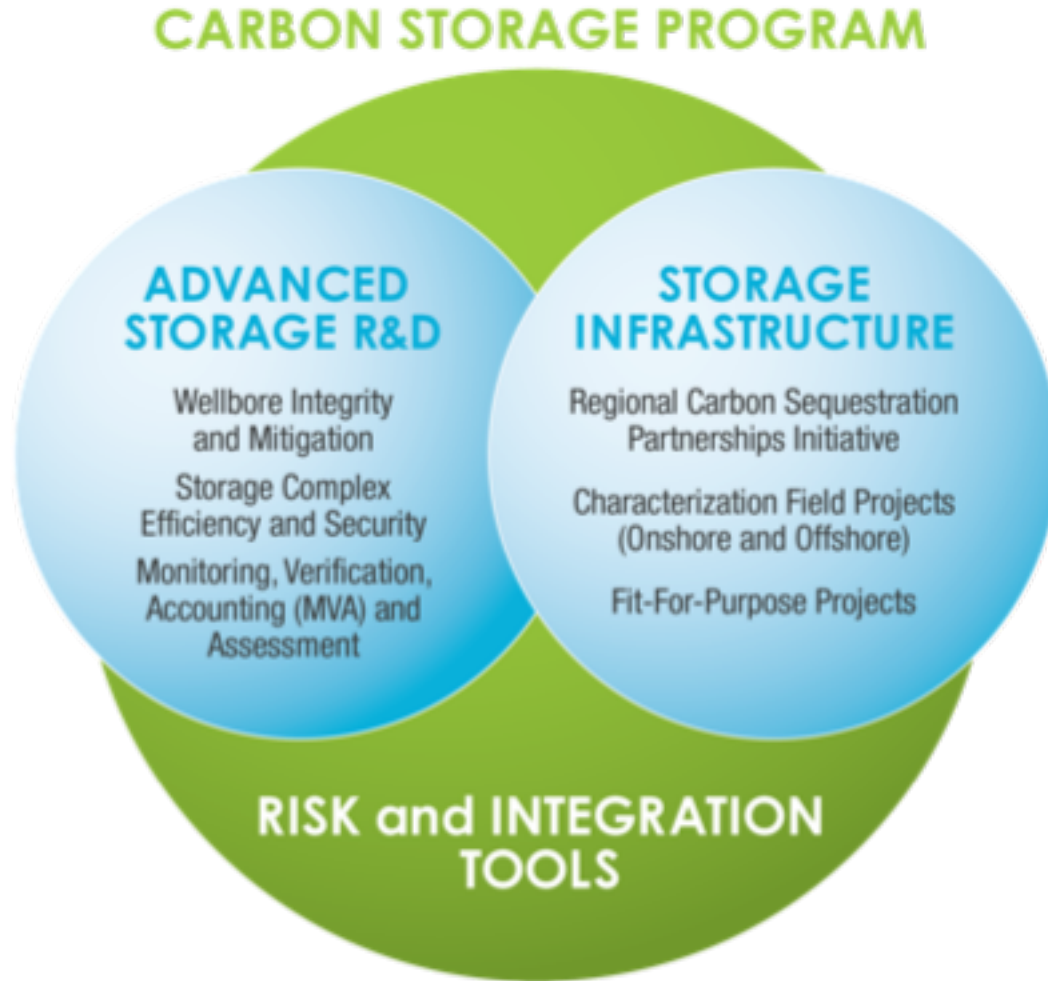
June 13, 2018



Solutions for Today | Options for Tomorrow



# Carbon Storage Program Structure



## Storage Infrastructure

- ◆ Field projects to validate storage technologies in different storage complexes in various geologic settings and address practical technical and non-technical issues of storage

## Advanced Storage R&D

- ◆ Applied R&D to improve wellbore integrity, increase reservoir storage efficiency, improve management of reservoir pressure, confirm permanent storage, and identify and mitigate potential induced seismicity and CO<sub>2</sub> release risks

## Risk and Integration Tools

- ◆ Development and validation of effective quantitative risk assessment tools and integration of knowledge and data

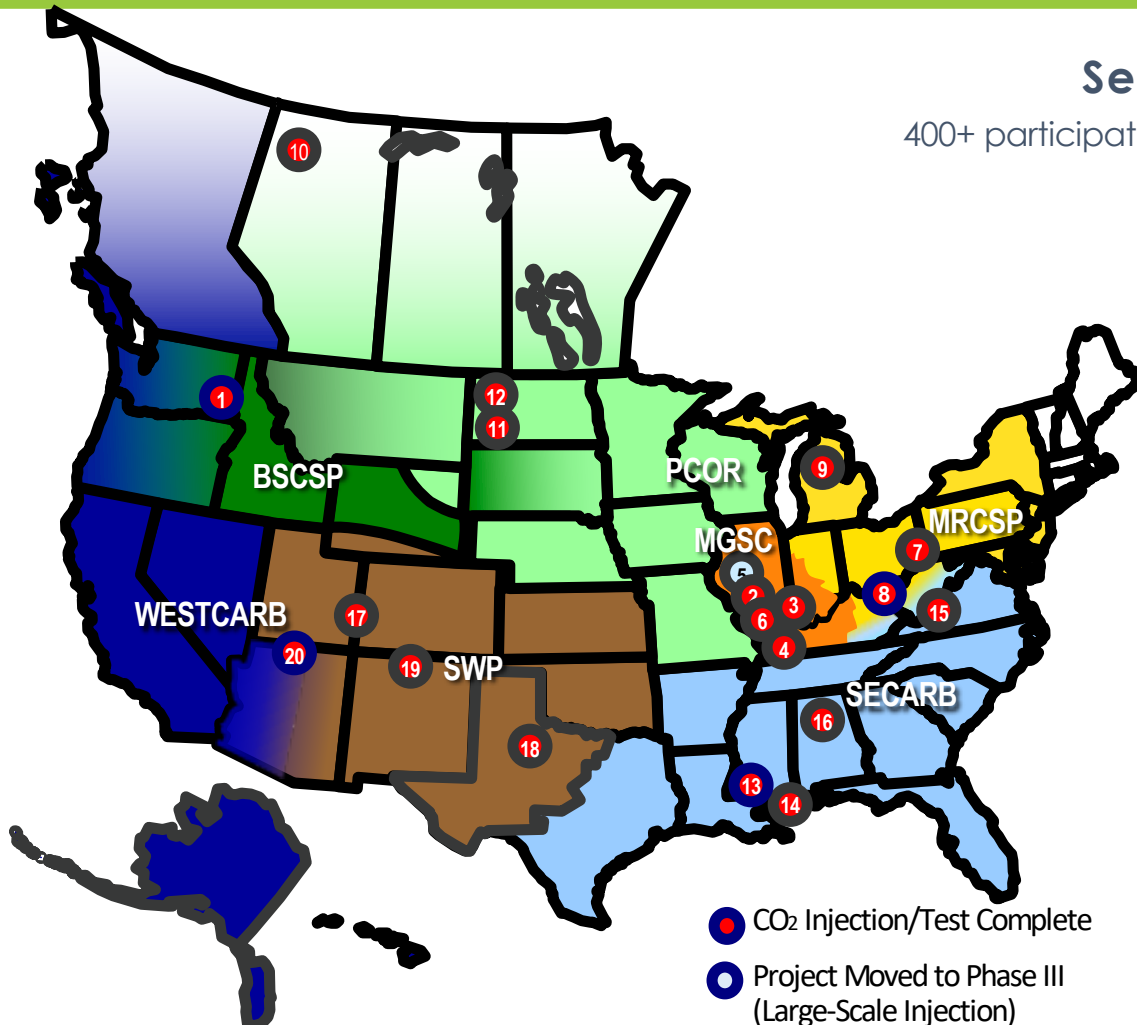


# Regional Carbon Sequestration Partnership (RCSP)

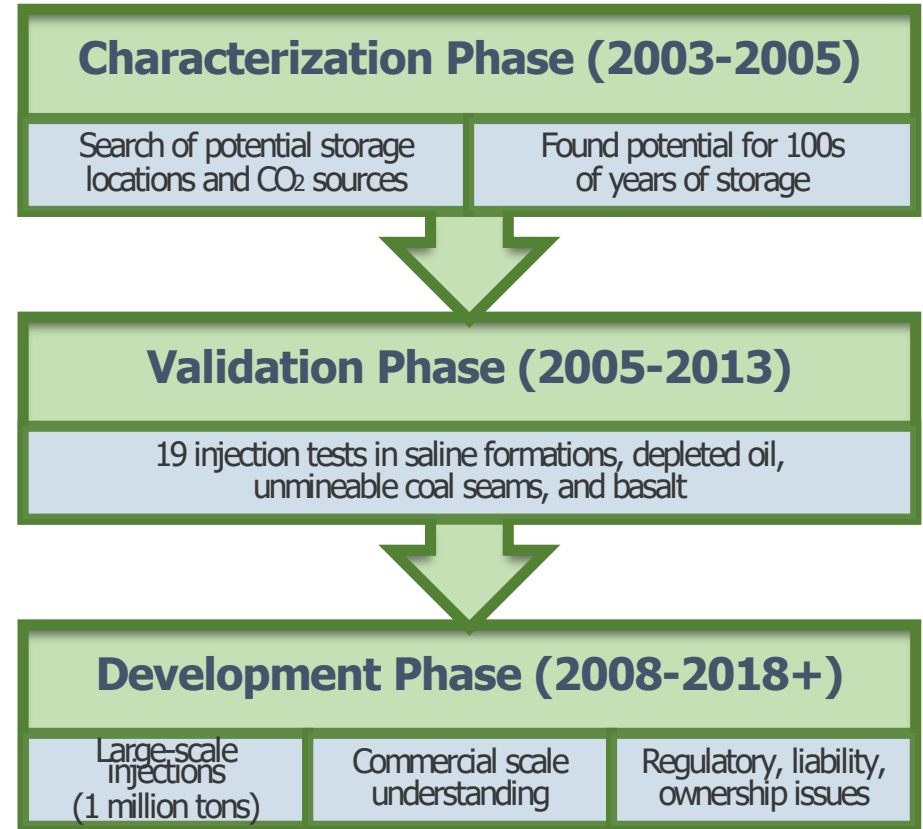


## Seven Regional Partnerships

400+ participating organizations, 43 states, 4 Canadian Provinces



**Completed 19 Injections  
More than 1.22 MMT injected**



# RCSP Development Phase Field Projects

Important step towards enabling 50+MMT scale storage sites

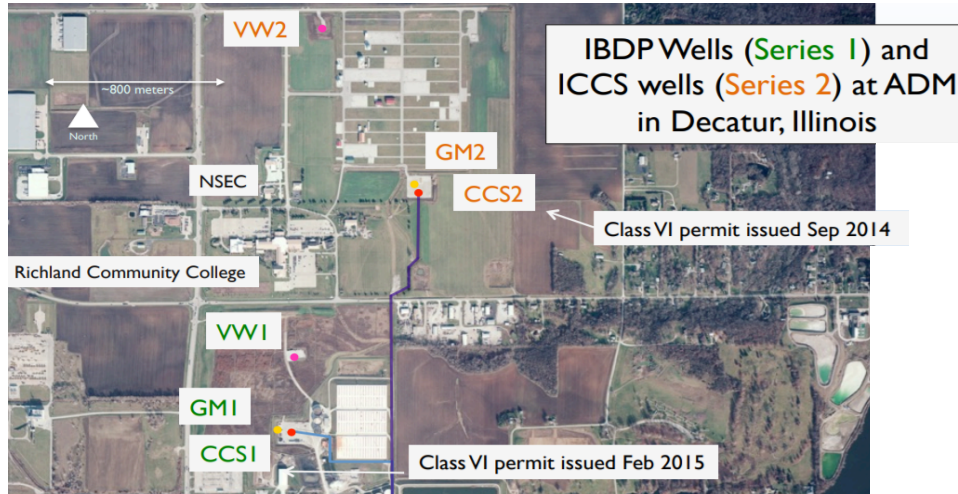


Number on Map	Project Name	Project Type	CO <sub>2</sub> Source	Geologic Basin	Metric Tons of CO <sub>2</sub> Stored
1	Big Sky Carbon Sequestration Partnership-Kevin Dome Project	Saline Storage	Kevin Dome (natural)	Kevin Dome	N/A
2	Midwest Geological Sequestration Consortium - Illinois Basin - Decatur Project	Saline Storage	ADM Ethanol Production Facility	Illinois Basin	999,215
3	Midwest Regional Carbon Sequestration Partnership - Michigan Basin Project	Enhanced Oil Recovery	Core CO <sub>2</sub> Services, LLC Natural Gas Processing Facility	Michigan Basin	993,034
4	The Plains CO <sub>2</sub> Reduction Partnership-Bell Creek Field Project	Enhanced Oil Recovery	Conoco Phillips Lost Cabin/Madden Natural Gas Processing Plant	Powder River Basin	2,982,000
5	Southeast Regional Carbon Sequestration Partnership - Citronelle Project	Saline Storage	Southern Company's Plant Barry Coal-Fired Power Plant	Interior Salt Basin, Gulf Coast Region	114,104
6	Southeast Regional Carbon Sequestration Partnership - Cranfield Project	Enhanced Oil Recovery/ Saline Storage	Jackson Dome (natural)	Interior Salt Basin, Gulf Coast Region	4,743,898
7	Southwest Regional Partnership on Carbon Sequestration - Farnsworth Unit Project	Enhanced Oil Recovery	Arkalon Ethanol Plant (Liberal, KS) Agrium Fertilizer Plant (Borger, TX)	Anadarko Basin	667,921

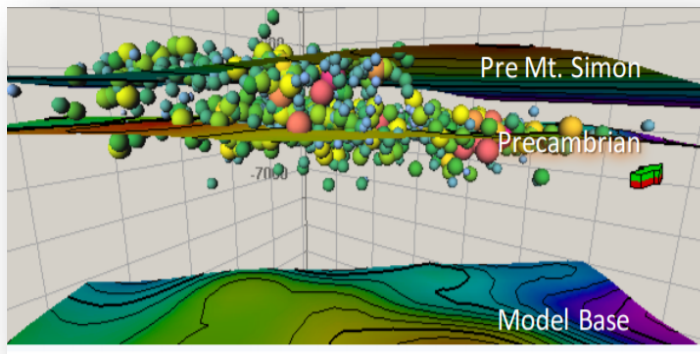


# Midwest Geological Sequestration Consortium

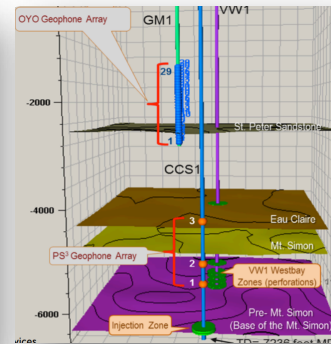
Illinois Basin - Decatur Project (IBDP)



Map depicting well locations and CO<sub>2</sub> transport pipeline



Microseismic Results



Subsurface Sensors

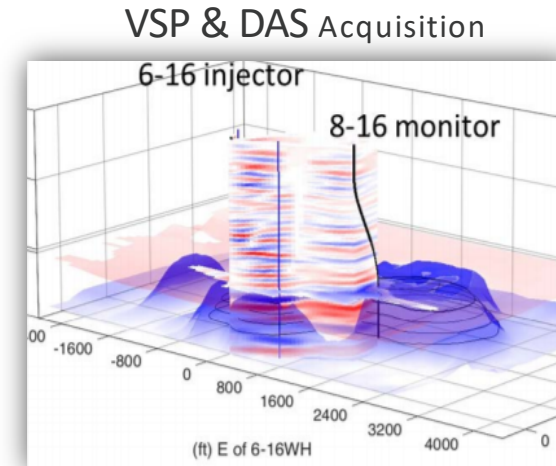
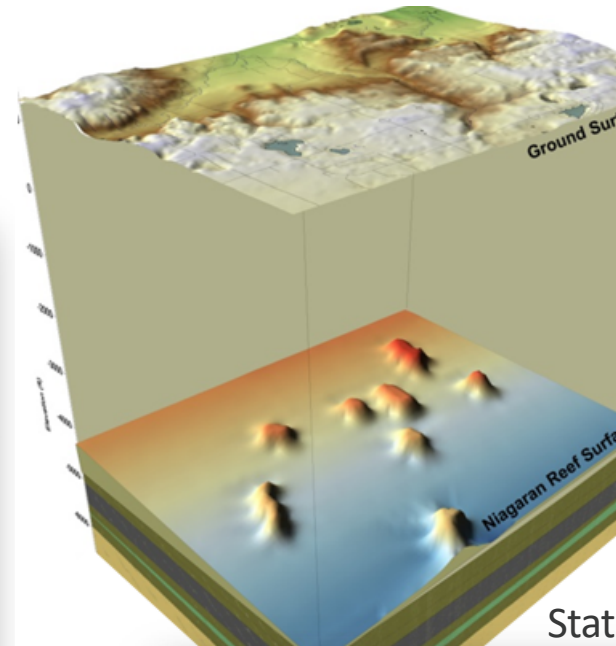
- Verified the storage capacity, injectivity, and containment of the Mount Simon Sandstone, the largest regional saline reservoir storage resource in the Illinois Basin
  - Importance of small scale reservoir baffle on plume and pressure migration
- Operational experience: integrated capture from ADM's ethanol facility with storage
- Effective detection and monitoring of microseismic events
- Technical data and results provided sound basis for a second, larger scale, project - the Illinois ICCS project

# Midwest Regional Carbon Sequestration Partnership

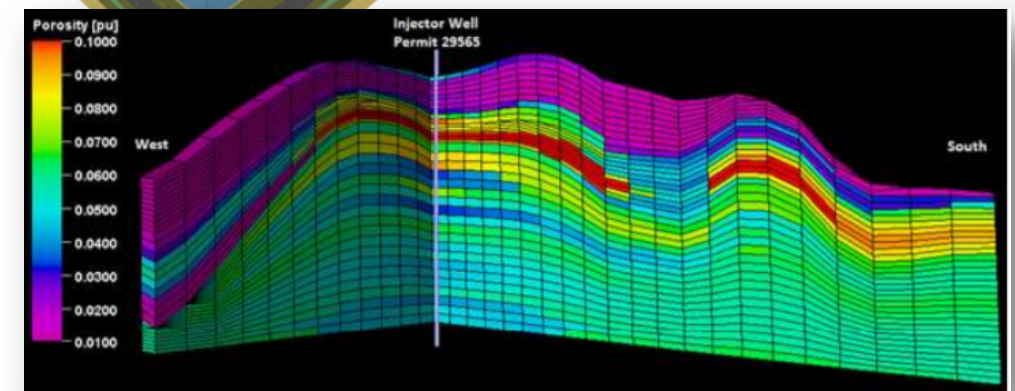
Michigan Basin Project



- Focused on storage associated with CO<sub>2</sub> EOR in pinnacle reefs -
  - Closely-spaced, highly compartmentalized, geologically complex carbonate reservoirs
  - Studies in conjunction with injection into a depleted reef, reefs under current production, and new development
- Developed workflows to integrate data and build geologic model of pinnacle reefs
  - Captures key aspects of asymmetrical geometry, complex internal architecture, and lithologic variations due to diagenetic overprint
- Carried out comprehensive analyses of pressure response to CO<sub>2</sub> injection in reefs
  - Continuous, long-term reservoir pressure data during all phases of operation - re-pressurization, production, and post-production



Static Earth Model of Reefs





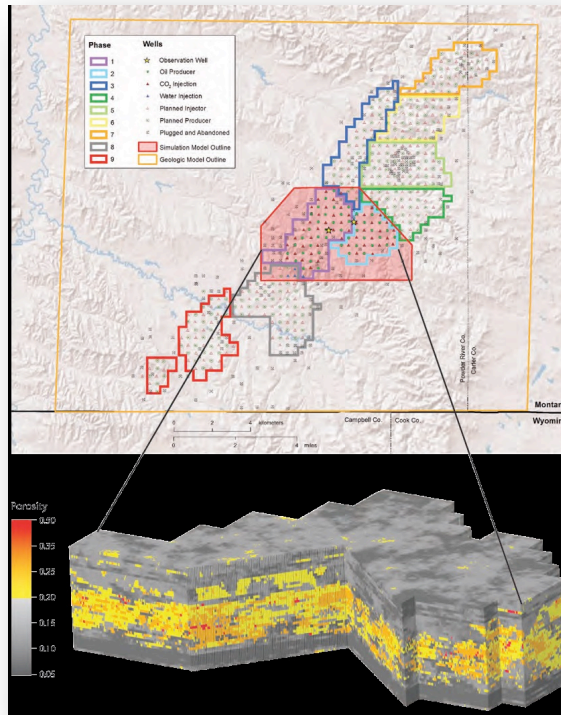
# Plains CO<sub>2</sub> Reduction Partnership



## Bell Creek Field Project

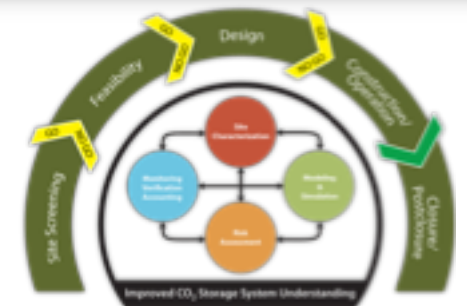
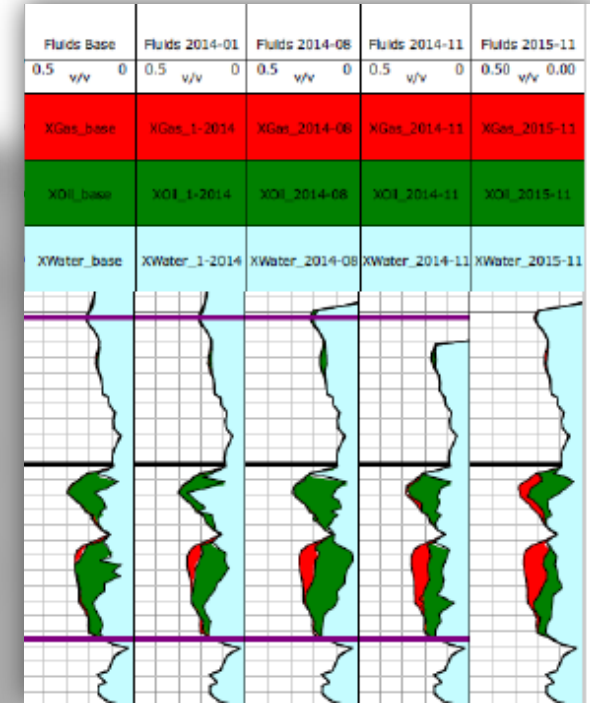


### Field Development and Reservoir Characterization



- Focused on storage associated with CO<sub>2</sub> EOR in 30 ft thick Muddy sandstone formation
- Developed Adaptive Management Approach (AMA) for CO<sub>2</sub> storage project
  - Integrates technical elements of site characterization, modeling and simulation, risk assessment, and MVA during each stage of a project's life-cycle
- Demonstrated use of pulsed neutron logs to map spatial and temporal changes in CO<sub>2</sub> saturation near wells
- Demonstrated value of 4-D seismic
  - Results showed location of a permeability barrier and preferential flow paths which improved geologic model and increased accuracy in predictive simulations
  - CO<sub>2</sub> saturation changes were clearly imaged

### Time-Lapse PNL Results





# Southeast Regional Carbon Sequestration Partnership

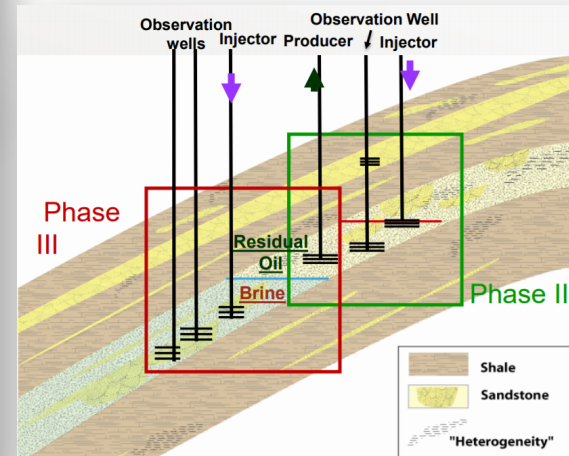
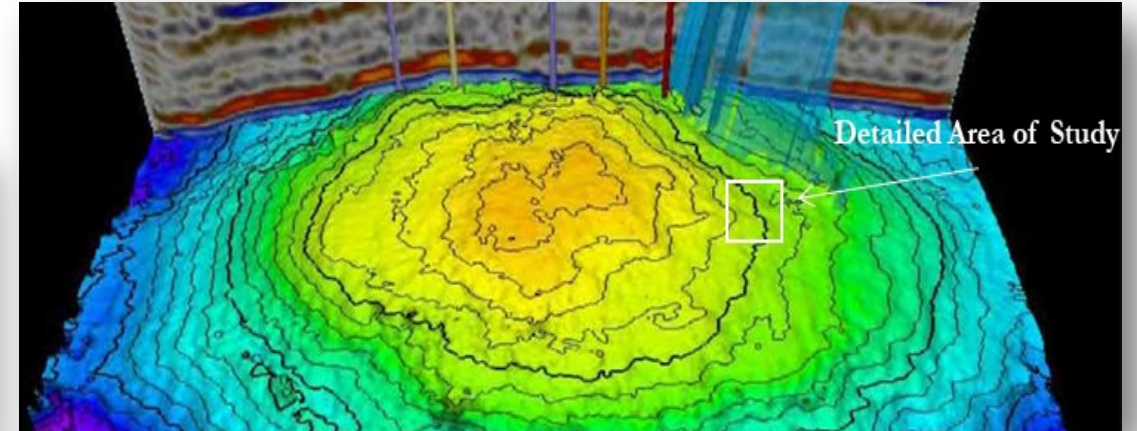


Cranfield Project

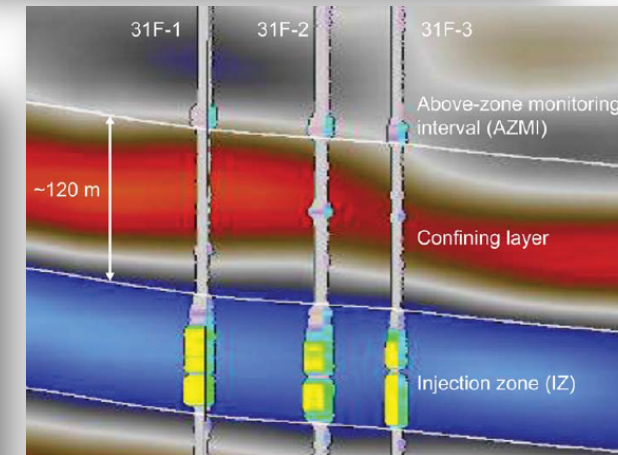


- 1st US and 5th worldwide project to reach 1 million metric tons of injection
  - Informed the development of the "sister" SECARB Citronelle project
- Storage associated with CO<sub>2</sub> EOR in Tuscaloosa sandstone formation
  - Deposited in complex valley-fill-fluvial environment
- Studies at different scales from detailed area study (DAS) to full field
  - At DAS, multiple MVA techniques used to evaluate the effect of multiple preferential flow paths on CO<sub>2</sub> movement
- Comprehensive analysis of in-zone and above-zone (AZMI) pressure response yielded new knowledge and new potential methods for leak detection using pressure
- Project advanced the concept of process-based surface leak detection using a package of soil gas geochemical relationships

Seismic Interpretation of Cranfield Dome



Cross Section of Phases II and III



Observation Wells (F2 and F3) and Injection Well F1

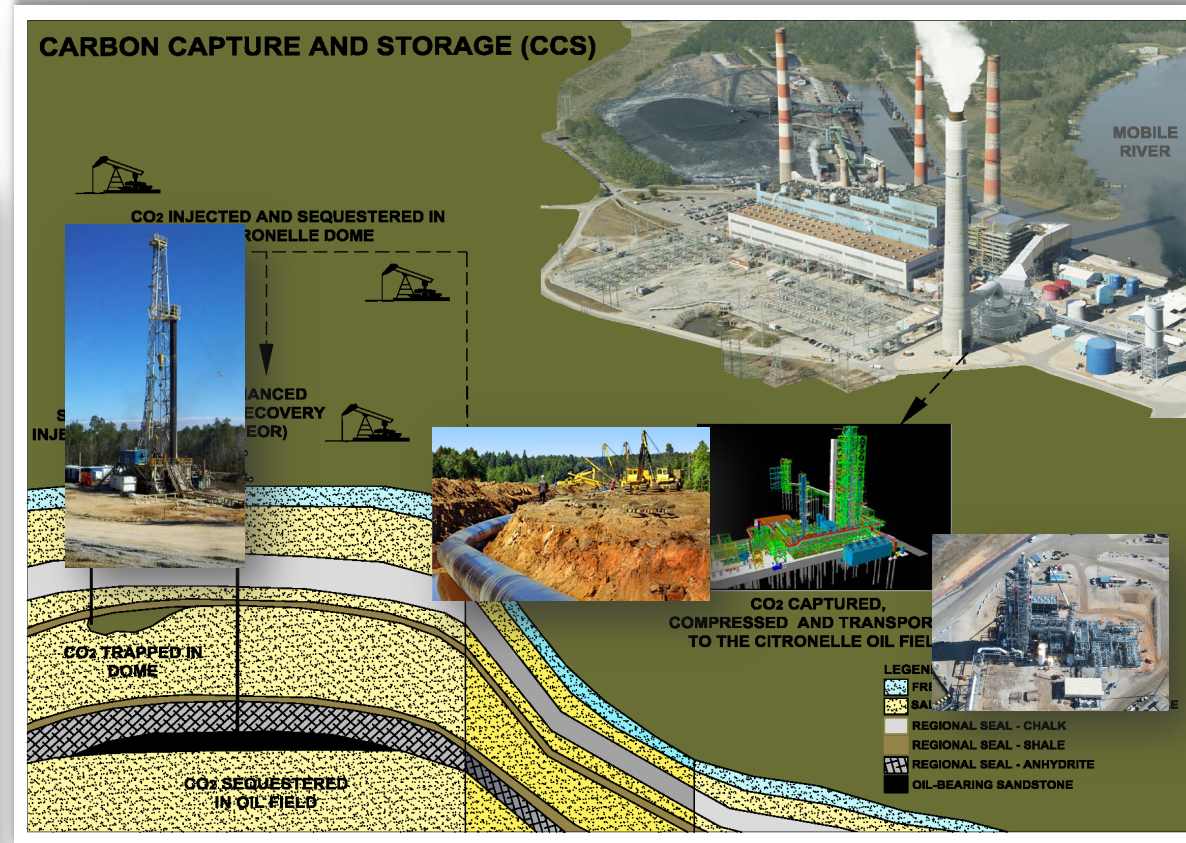
# Southeast Regional Carbon Sequestration Partnership



Citronelle Project



- Storage in Paluxy sandstone – a regionally extensive, thick, Gulf Coast saline formation
  - Potential stacked storage opportunities
- Operational experience: integrated storage and capture from 25 Mw demonstration scale post-combustion CO<sub>2</sub> capture facility
  - Demonstrated non-endangerment of USDWs and plume stabilization for site closure
- Field tested unique and innovative characterization and monitoring technologies
  - Use of neural network method to quantify porosity and lithology from vintage logs
  - First deployment of a multiple sensor system (pressure, distributed temperature, fluid sampling, and geophones) utilizing a "flatpack"
  - Successful test of fiber-optic Distributed Acoustic Sensing [DAS] system in VSP configuration

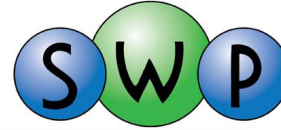


Summary of Overall Capture, Transport, and Injection Effort



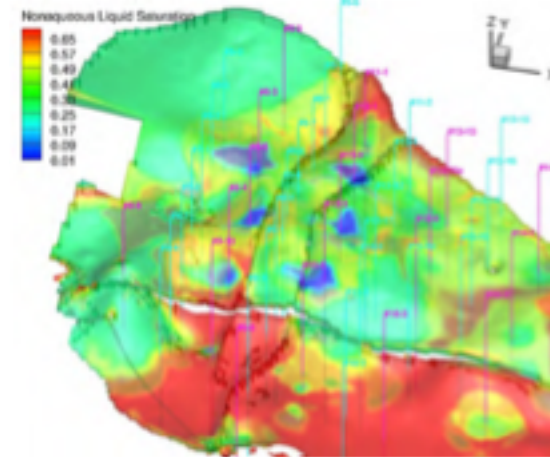
# Southwest Regional Partnership

Farnsworth Unit (FWU) – Ochiltree Project

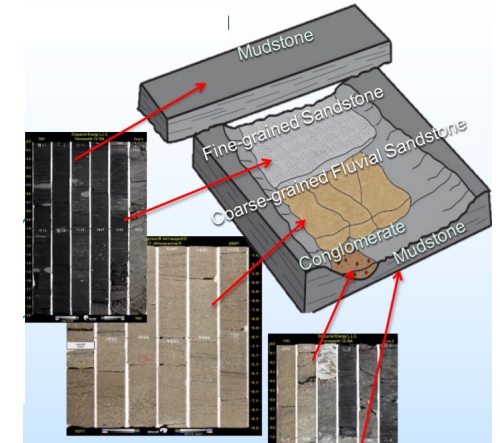


- Focused on storage associated with CO<sub>2</sub> EOR in sandstones of the regionally extensive Morrow formation
  - Represents a complex, faulted, “incised valley” geologic setting
- Operational experience: integrated associated storage with capture from two sources - Agrium fertilizer plant, and Arkalon ethanol plant
- Three scales of seismic data (surface seismic, 3D VSP, and cross-well) used to develop advanced geologic models which map sub-facies (multiple hydraulic flow units) in the reservoir
- Extensive USDW monitoring of regionally extensive Ogallala aquifer (including detailed geochemical analyses)
- Integrated geophysical data, tracer surveys, and history matching to delineate reservoir transport pathways

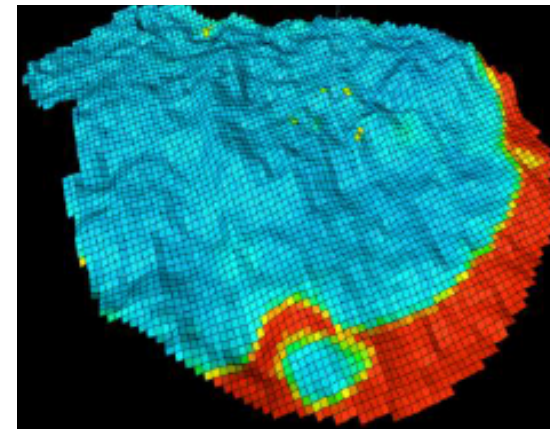
Nonaqueous Liquid Saturation



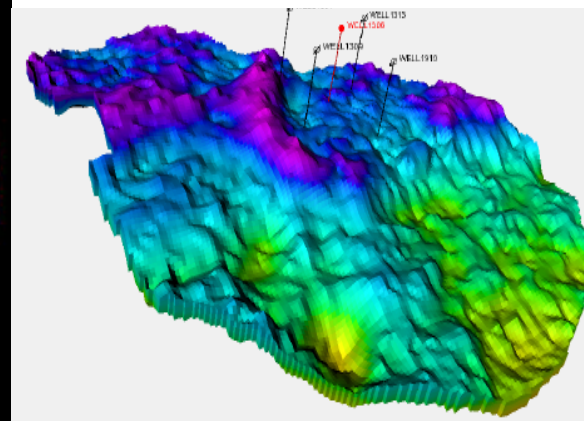
Depositional System



Water Saturation Simulation



Pressure Distribution Simulation



Simulation Model for Primary and Secondary Recovery History Matching



# Big Sky Carbon Sequestration Partnership



Kevin Dome Project

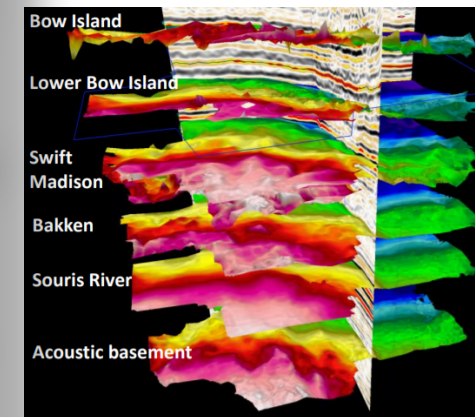


- Domes, like Kevin Dome, could become regional CO<sub>2</sub> hubs – storing CO<sub>2</sub> from sources and providing CO<sub>2</sub> to EOR fields
- Storage formation: Duperow – brine saturated carbonate on flank of Kevin Dome
  - Greenfield site; brine chemistry data only available from limited number of wells penetrating Duperow
  - Salinity of brine unexpectedly low so injection not undertaken
- Unique 3D, 9 component, seismic survey acquired for advanced characterization
- Advanced Multiple Interacting Continua (MINC) approach used to model plume movement in the fractured reservoir

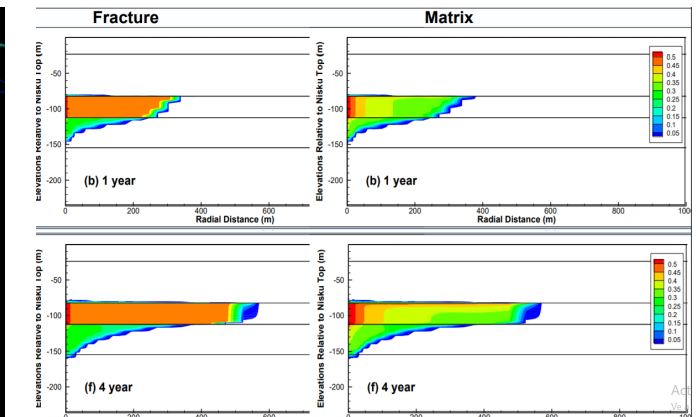
Map View, Kevin Dome



Well Location Map

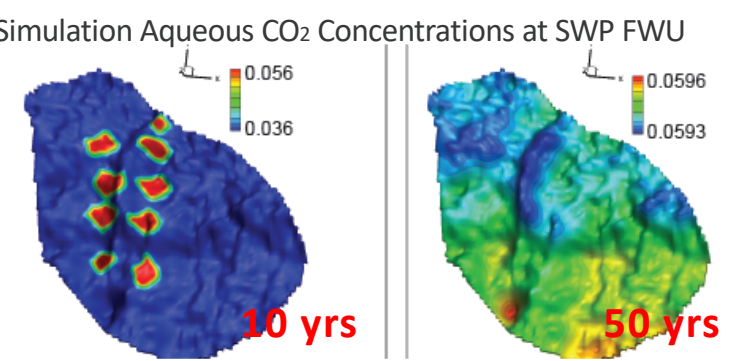
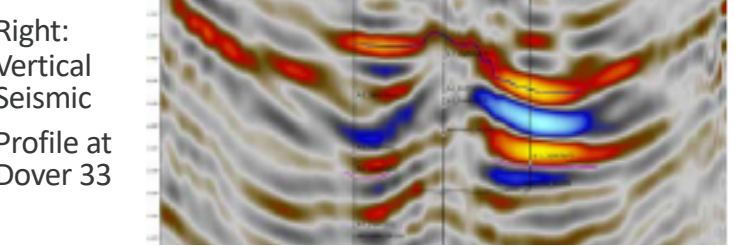
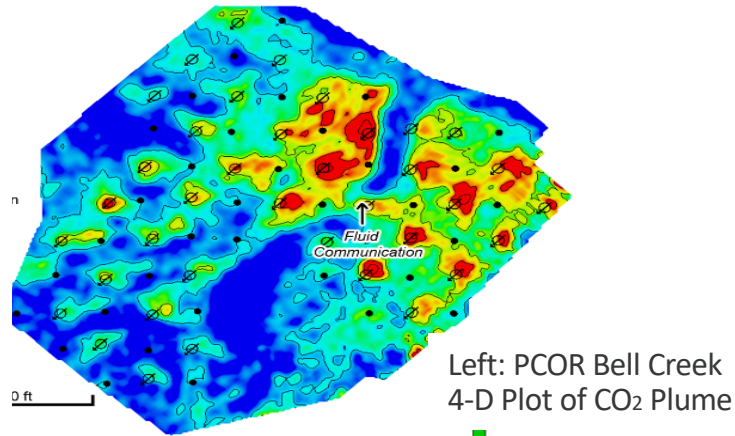


Structural Surfaces

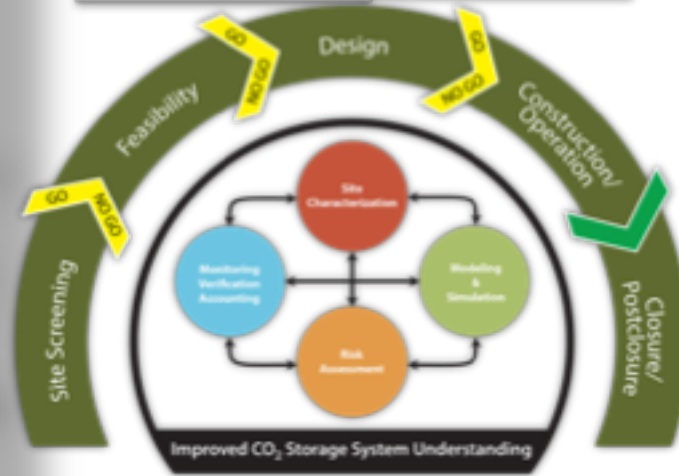


Simulated CO<sub>2</sub> Plumes

# RCSP Key Accomplishments



- Established the **first U.S. national network** of companies and professionals focused on carbon storage
- Proved adequate **large scale injectivity and available capacity** in regionally important storage formations
- Provided examples of simulation models and monitoring technologies that predict CO<sub>2</sub> movement and **confirm confining system integrity**
- Contributed toward developing/evaluating innovative storage technologies for a **cost-effective commercial toolbox**
- Developed and implemented expert panel-based **risk assessment strategies** such as the Adaptive Management Approach
- Demonstrated the benefits of early **engagement with local communities and stakeholders**
- Contributed to a series of **best practice manuals** on major topics associated with geologic storage implementation

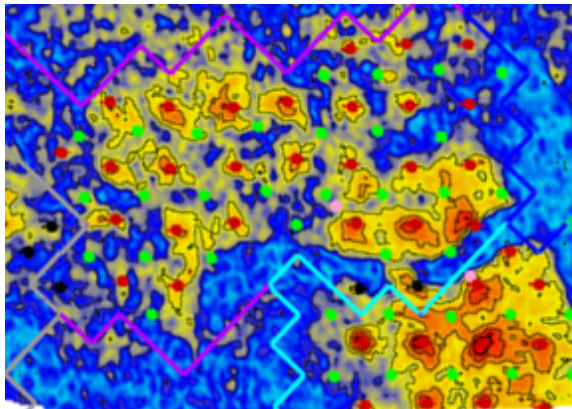
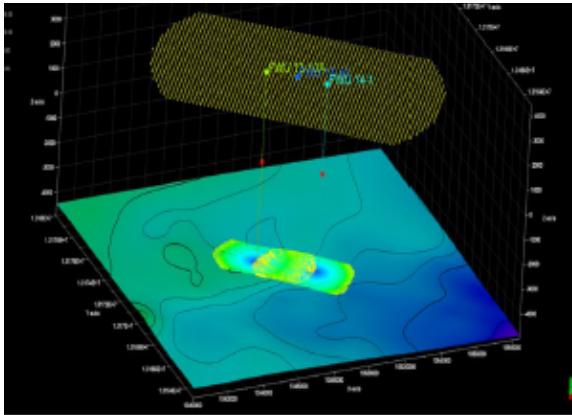




# RCSP Field Projects

## Identifying Further R&D Needs

4-D Time-Lapse CO<sub>2</sub> Plume

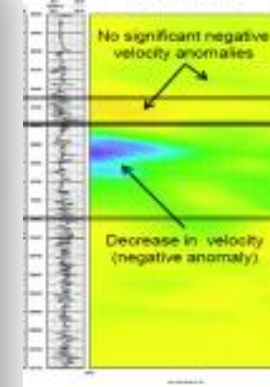


4-D Seismic Amplitude Response

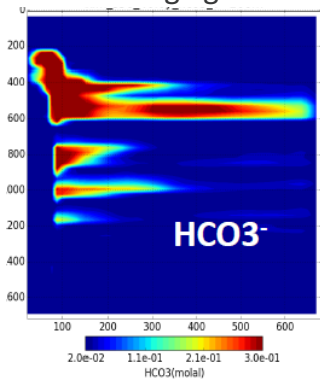
- **Transformative improvements** in modeling and monitoring technologies
- **Quantify CO<sub>2</sub> saturation** in the far field, away from wellbores
- Improve tools and methods to **reduce the potential for causing injection-induced microseismic events**
- **Intelligent monitoring systems** for real-time decision making
- Incorporate technology failure rates into **risk management strategies**

Real-Time Monitoring Systems

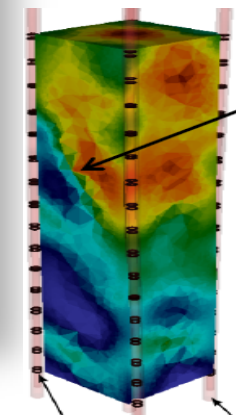
Cross well Seismic



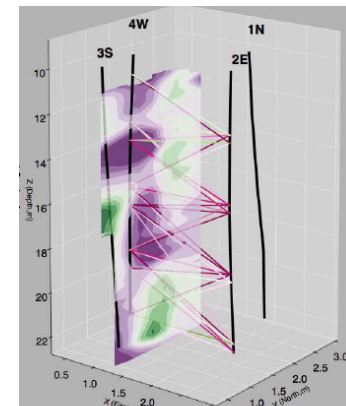
MT Imaging



ERT Imaging



DAS Imaging





# Carbon Storage Assurance Facility Enterprise

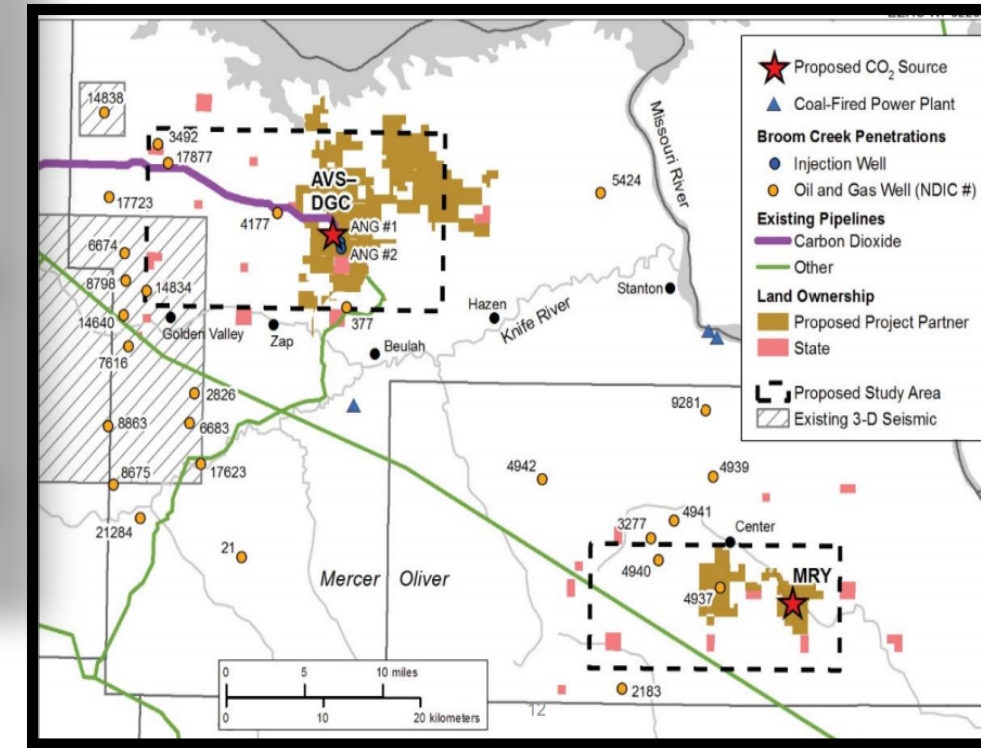
Address the knowledge gaps for 50-100 MMT CO<sub>2</sub> storage complexes

## Objectives:

- Perform risk reduction scenarios for site and source selection and operations of an integrated project
- Perform field testing of risk, geologic storage, modeling and monitoring technologies, and injection strategies for storage (50-100 MMT) complex
- Determine how to address challenges (both technical and non-technical) associated with storage (50-100 MMT) characterization and monitoring

## Phases:

- Integrated CCS Pre-Feasibility
- Storage Complex Feasibility
- Site Characterization
- Permitting and Construction

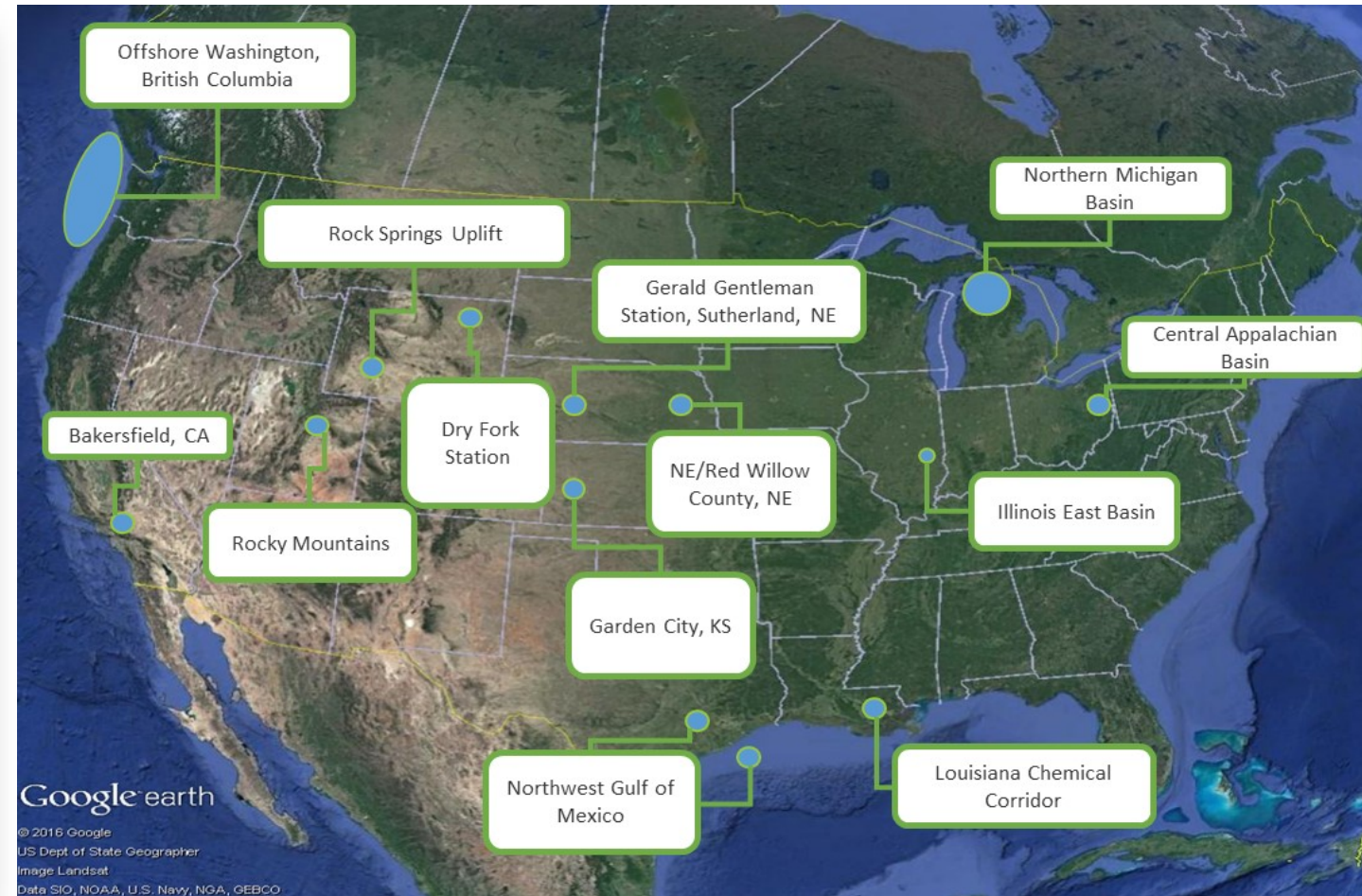


Map Depicting Two Study Areas of the North Dakota CarbonSAFE Feasibility Study

# CarbonSAFE

## Integrated CCS Pre-Feasibility Projects

- Formation of a **CCS coordination team**
- Development of a **plan for the storage complex** and storage site(s)
- Perform a high-level, technical **sub-basinal evaluation**
- Identify and evaluate **potential CO<sub>2</sub> sources**
- Document all data and results in the NETL **Energy Data Exchange (EDX)**

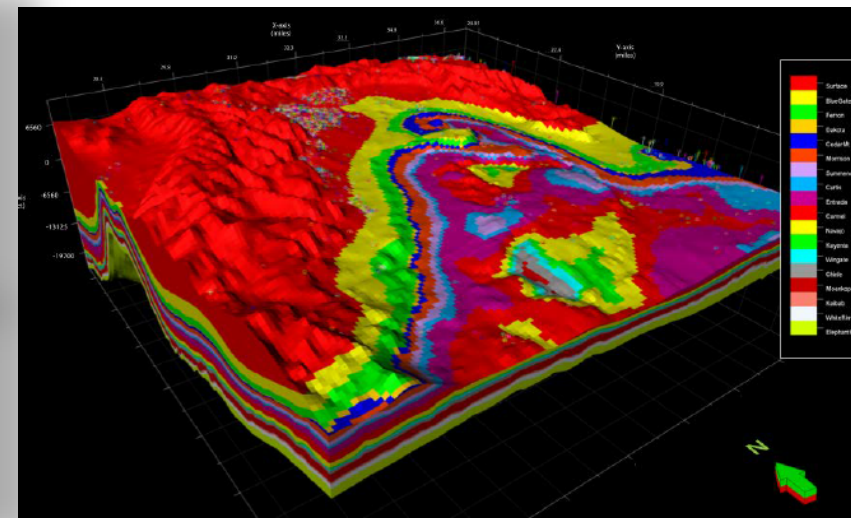




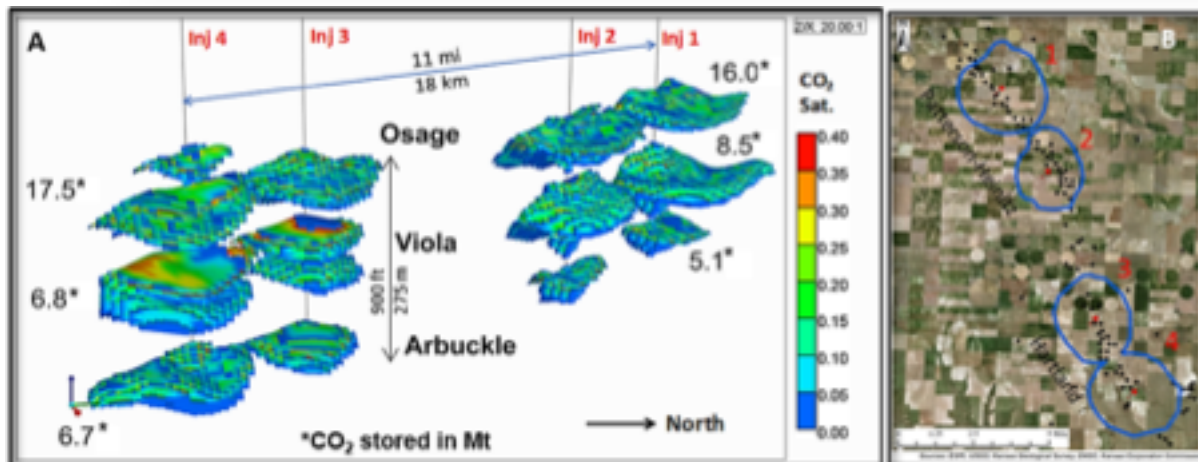
# Pre-Feasibility Project Update



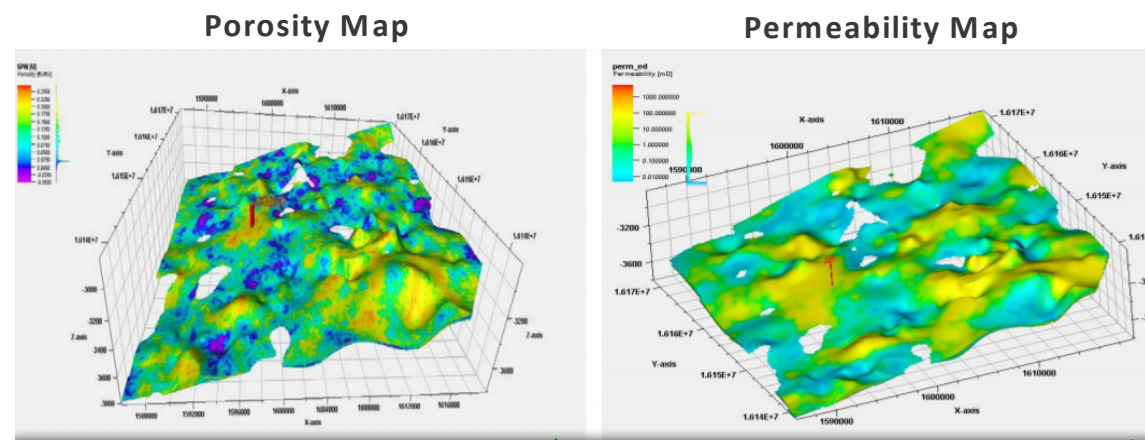
- Extensive regional data collected, analyzed, and modeled
- Identified multiple viable sites - evaluated storage complexes at scale
- Evaluated regional infrastructure and source(s) for sites
- Developed aspects of “business plan”



3D Geocellular Model, Rocky Mountain CarbonSAFE



CO<sub>2</sub> Saturation Model, Nebraska



Dry Fork Station, Wyoming

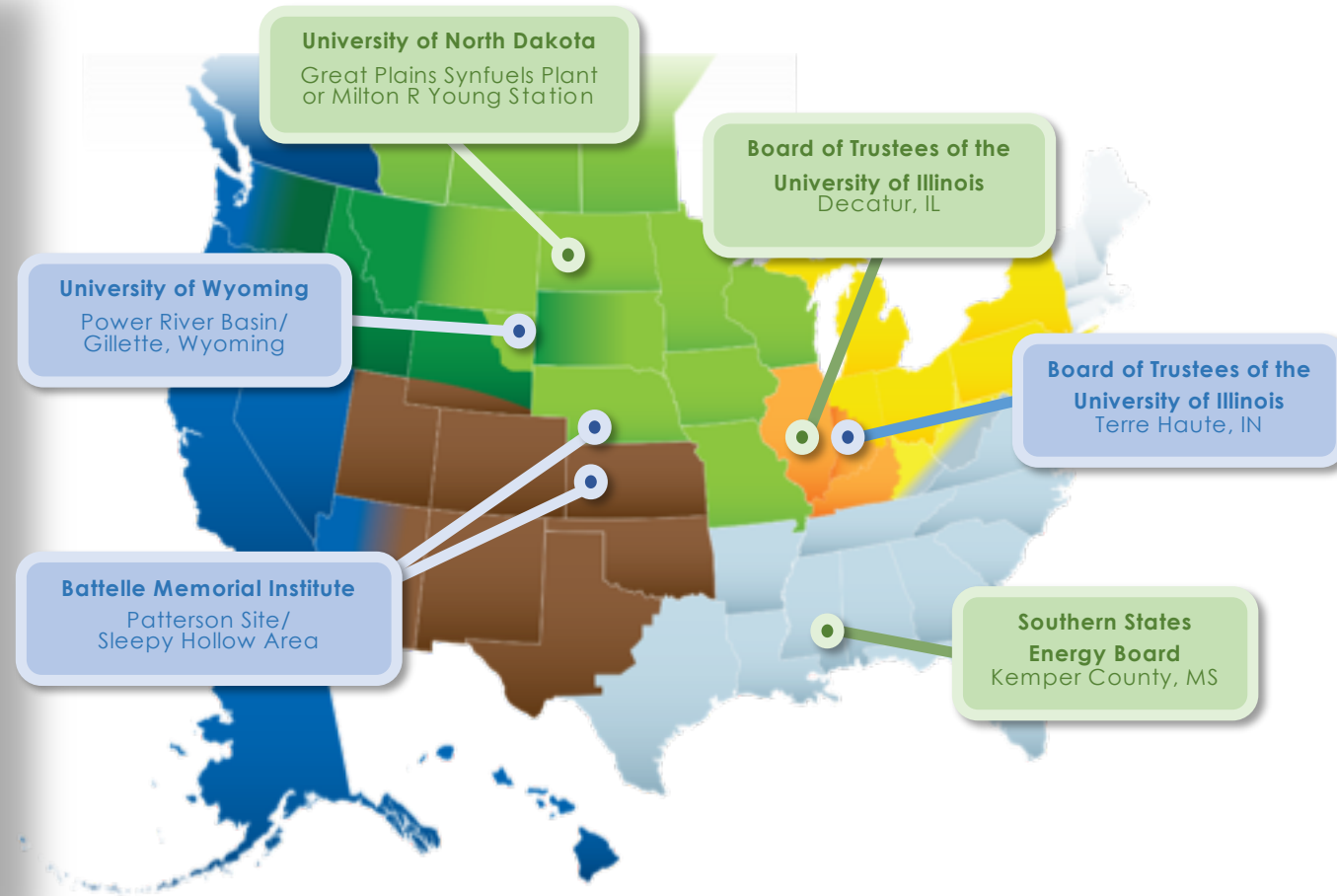


# CarbonSAFE

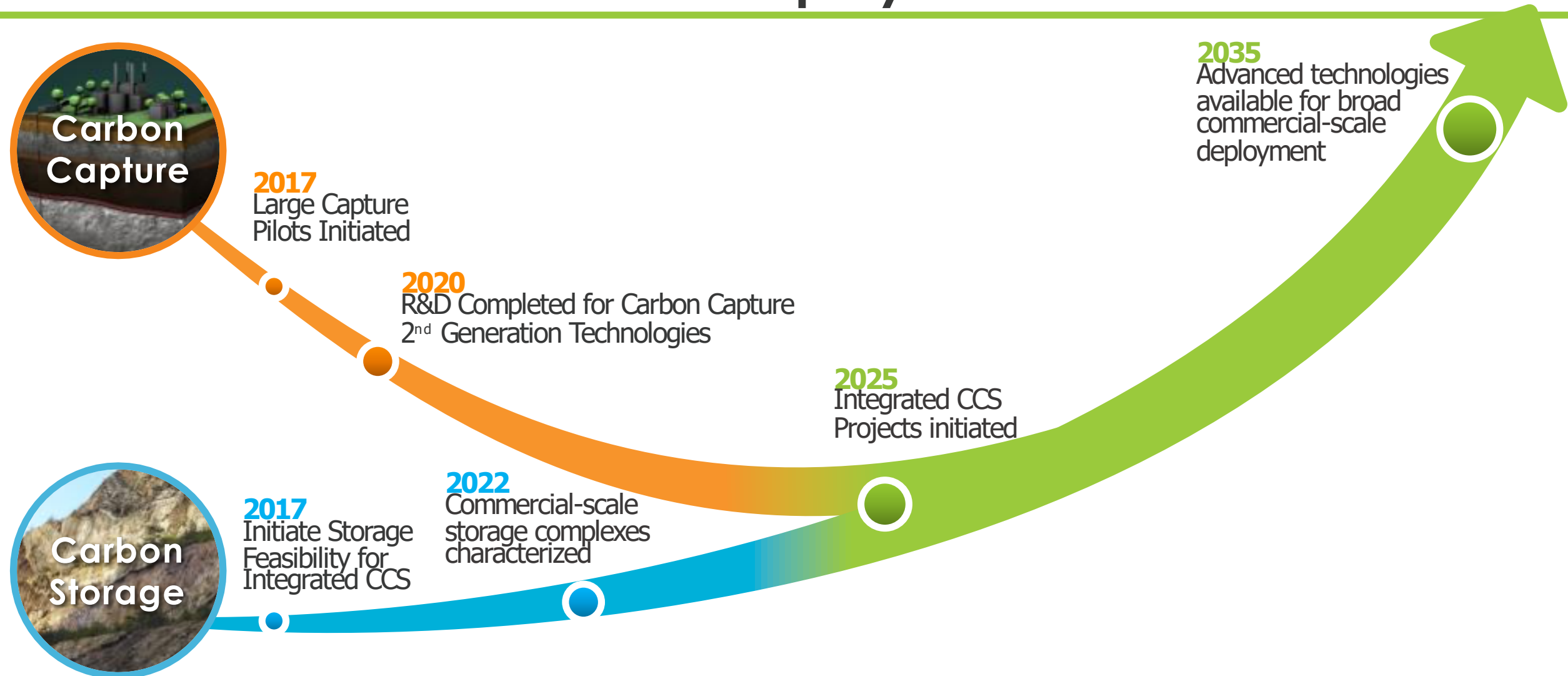
## Storage Complex Feasibility Projects

### Perform initial characterization of potential commercial-scale storage complex:

- Determine suitability of the potential 50+MMT geologic storage site (reservoir characteristics)
- Technical and Nontechnical Challenges
- Risk Assessment and CO<sub>2</sub> Management Strategy
- Validate National Risk Assessment Partnership (NRAP) Tools and other NETL Tools



# Integrated R&D Approach for Future Commercial-Scale Deployment





# Enhanced 45Q Tax Credit a.k.a. FUTURE Act

Effective January 1, 2018

Credit available to qualified facilities for 12 year period – awarded on an annual basis

- \$50 per metric ton for secure geologic storage
- \$35 per metric ton for EOR, EGR, or utilization

## Qualified facilities:

- Construction must begin by Jan 1, 2024
- Original planning/design must include carbon capture equipment
- EGF: 500,000 t/CO<sub>2</sub> captured/yr (for facilities that emit less than 500,000 t/CO<sub>2</sub>/yr, credits available for up to 25,000 t/CO<sub>2</sub> captured and used)

Excludes gases recaptured during EOR process

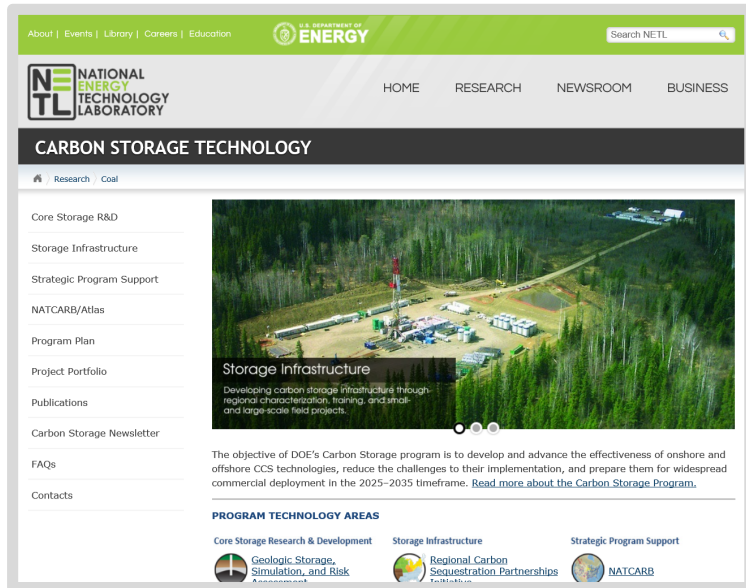
Credit can be claimed by owner of capture equipment or transferred to disposal/use entity



# For More Information



**NETL**  
[www.netl.doe.gov](http://www.netl.doe.gov)



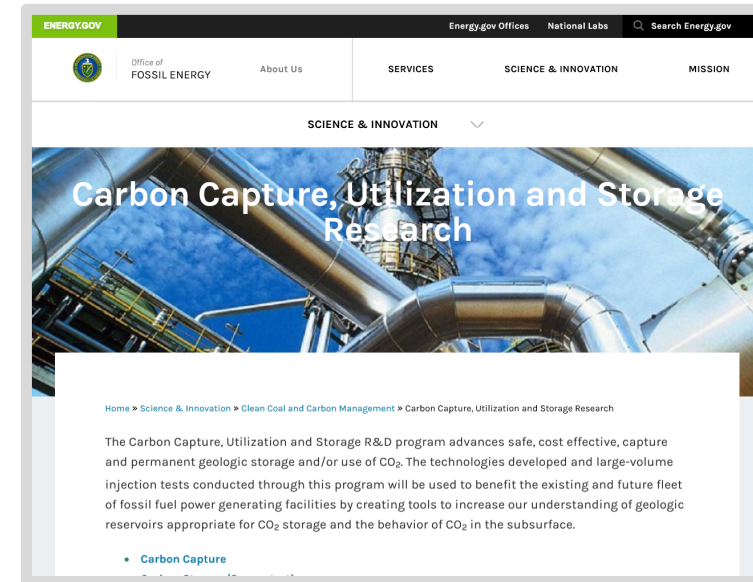
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