

Integrated CCS for Kansas (ICKan)

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CarbonSAFE

- **Carbon Storage Assurance Facility Enterprise**
- Department of Energy, Office of Fossil Energy
- Recognizes need for CCS to operate on massive scale in order achieve U.S. and global clean energy goals, but commerciality hindered by:
 - Lack of economic incentives for private sector
 - Need for identification & certification of storage sites
- Major goal is to develop integrated CCS storage complex
 - Constructed and permitted for operation by 2025
 - Storage of 50+ million metric tons of CO₂

4 Phases of CarbonSAFE

- I. **Integrated CCS Pre-Feasibility (1.5 years)**
 - Complete in September 2018
- II. Storage Complex Feasibility (2 years)
 - Application due December 2017
- III. Site Characterization (2 years)
- IV. Permitting and Construction (3.5 years)

Project Overview

Goal & Objectives

- Identify and address major **technical and nontechnical challenges** of implementing CO₂ capture and transport and establishing secure geologic storage for CO₂ in Kansas
- Evaluate and **develop a plan and strategy** to address the challenges and opportunities for commercial-scale CCS in Kansas

Project Overview

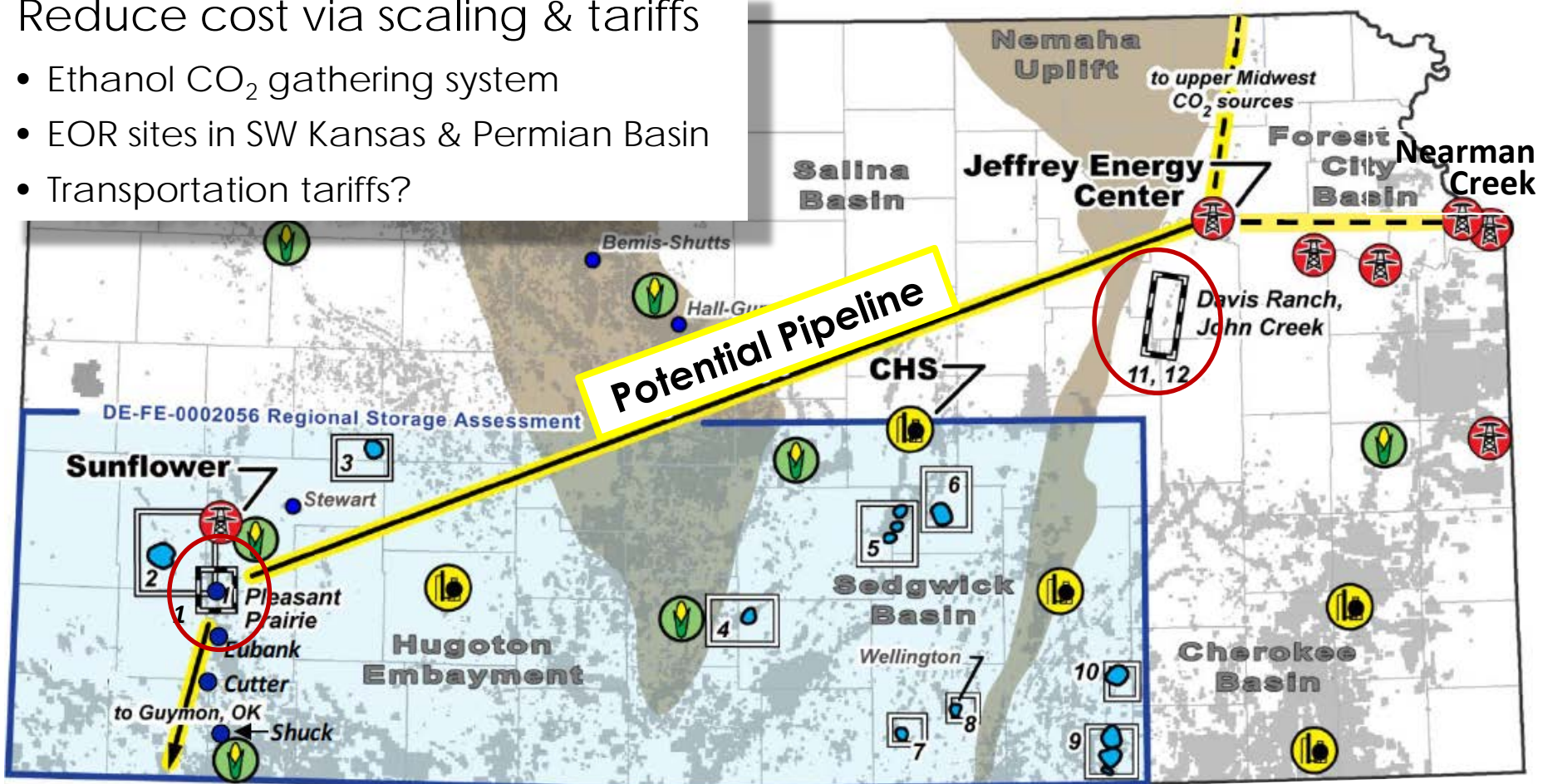
Base Case Scenario

- **Capture 50 million tonnes CO₂** from one of three Jeffrey Energy Center's 800 MWe plants over a 20 year period (2.5Mt/yr)
- Compress CO₂ and **transport 300 miles to Pleasant Prairie Field** in SW Kansas.
 - Alternative: 50 miles to Davis Ranch and John Creek Fields.
- Inject and permanently **store 50 million tonnes CO₂ in the Viola Formation and Arbuckle Group**

Jeffrey to SW Kansas

Reduce cost via scaling & tariffs

- Ethanol CO₂ gathering system
- EOR sites in SW Kansas & Permian Basin
- Transportation tariffs?



- coal-fired power plant
- petroleum refinery or manufacturing plant (cement & fertilizer)
- ethanol plant

- proposed geologic storage complex
- geologic storage complex study area and closure
- oil and gas fields



Technical Evaluations

Sub-Basinal Evaluations

Pleasant Prairie

- 170 Mt storage
- Viola & Arbuckle
- CO₂-EOR reservoirs
- Adequate data (core)
- Unitized; single operator

Davis Ranch-John Creek

- 50 Mt storage
- Simpson and Arbuckle
- Proximity to JEC
- CO₂-EOR reservoirs
- Adequate data
- Two operators

CO₂ Source Assessments

Westar Jeffrey Energy Center

- 2.4 GW & 12.5 million tonnes of CO₂

Sunflower's Holcomb Plant

CHS McPherson Refinery

KC Board of Public Utilities

CO₂ Transportation

Pipeline

- 300 mile trunk line
- Connect to Midwest ethanol CO₂ gathering system
- Connect to Permian through Oklahoma Panhandle

Non-Technical Evaluations

Implementation Plan

Economics

- Capture & transportation economic feasibility (with or w/o ethanol component)
- Financial backing
- Financial assurance under Class VI
- State incentives
- Federal tax policy



Legal & Regulatory

- Pore space property rights including force unitization
- CO₂ ownership & liability
- MVA requirements under UIC Class VI
- Varying stakeholder interests
- Right-of-ways
- Utility rate-payer obligations

Public Policy (Public Acceptance)

- Identify stakeholders
- Foster relationships
- Public perception
- Political challenges
- Injection-induced seismicity

Phase 1 Research Team

18 team members, 4 subcontractors and KGS staff

Project Management & Coordination, Geological Characterization

Kansas Geological Survey University of Kansas Lawrence, KS

Tandis Bidgoli, PI, Assistant Scientist
Lynn Watney, Senior Scientific Fellow
Eugene Holubnyak, Research Scientist
K. David Newell, Associate Scientist
John Doveton, Senior Scientific Fellow
Susan Stover, Outreach Manager
Mina FazelAlavi, Engineering Research Asst.
John Victorine, Research Asst., Programming
Jennifer Hollenbah - CO2 Programs Manager

Improved Hydrocarbon Recovery, LLC Lawrence, KS

Martin Dubois, Joint-PI, Project Manager

CO2 Source Assessments, Capture & Transportation, Economic Feasibility

Linde Group (Americas Division)

Houston, TX

Krish Krishnamurthy, Head of Group R&D
Kevin Watts, Dir. O&G Business Development

Energy, Environmental, Regulatory, & Business Law & Contracts

Depew Gillen Rathbun & McInteer, LC

Wichita, KS

Christopher Steincamp, Attorney at Law
Joseph Schremmer - Attorney at Law

Policy Analysis, Public Outreach & Acceptance

Great Plains Institute

Minneapolis, MN

Brendan Jordan, Vice President
Brad Crabtree, V.P. Fossil Energy
Jennifer Christensen, Senior Associate
Dane McFarlane, Senior Research Analyst

Industry Partners

Four CO₂ Sources

CO₂ Sources

Westar Energy

Brad Loveless, Exec. Director Environ. Services

Dan Wilkus, Director - Air Programs

Mark Gettys, Business Manager

Kansas City Board of Public Utilities

Ingrid Seltzer, Director of Environmental Services

Sunflower Electric Power Corporation

Clare Gustin, V.P. Member Services & Ext. Affairs

CHS, Inc. (McPherson Refinery)

Richard K. Leicht, Vice President of Refining

Rick Johnson, Vice President of Refining

Regulatory

Kansas Department of Health & Environment

Division of Environment

John W. Mitchell, Director

Bureau of Air

Rick Brunetti, Director

Five Oil & Gas Companies

Kansas Oil & Gas Operators

Blake Production Company, Inc.

(Davis Ranch and John Creek fields)

Austin Vernon, Vice President

Knighton Oil Company, Inc.

(John Creek Field)

Earl M. Knighton, Jr., President

Casillas Petroleum Corp.

(Pleasant Prairie Field)

Chris K. Carson, V.P. Geology and Exploration

Berexco, LLC

(Wellington, Cutter, and other O&G fields)

Dana Wreath, Vice President

Stroke of Luck Energy & Exploration, LLC

(Leach & Newberry fields)

Ken Walker, Operator

Storage Site Evaluations

Methodological Approach

Reservoir seals
Characterize primary and secondary seals

Fault reactivation & induced seismicity*

Map faults, characterize stresses, fault slip and dilation tendency analysis

Wellbore risk

Evaluate existing and plugged well construction, plugging records, and estimate risk

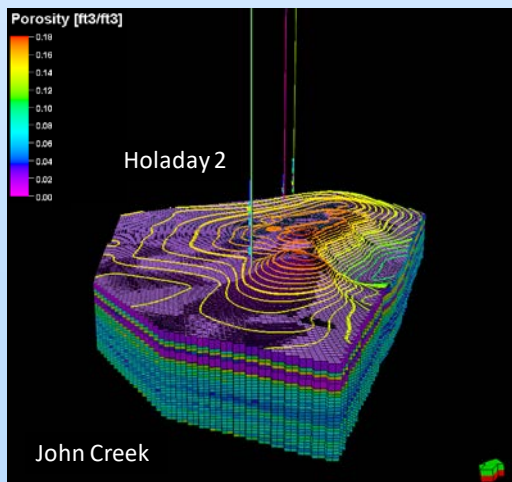
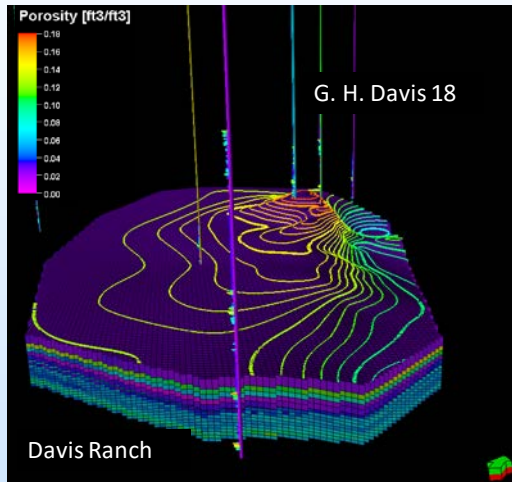
3D cellular geologic model
Utilize existing well and engineering data, 3D seismic, to build cellular static models

Reservoir simulation model
Use a compositional simulator to analyze capacity, injection rates, and pressure constrained by reservoir seal, fault and seismicity risk, and wellbore risk studies

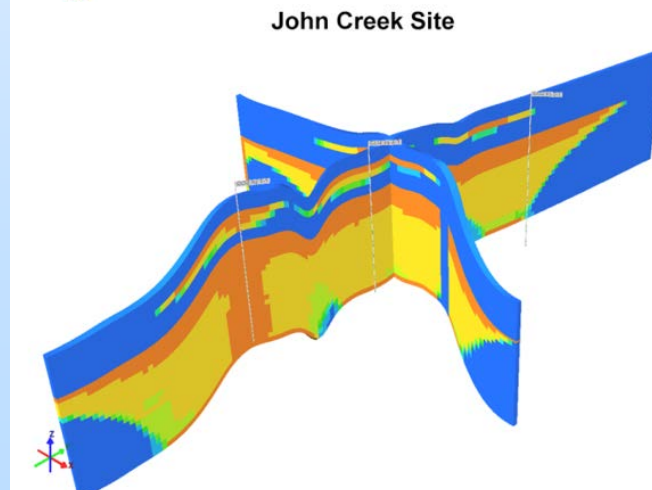
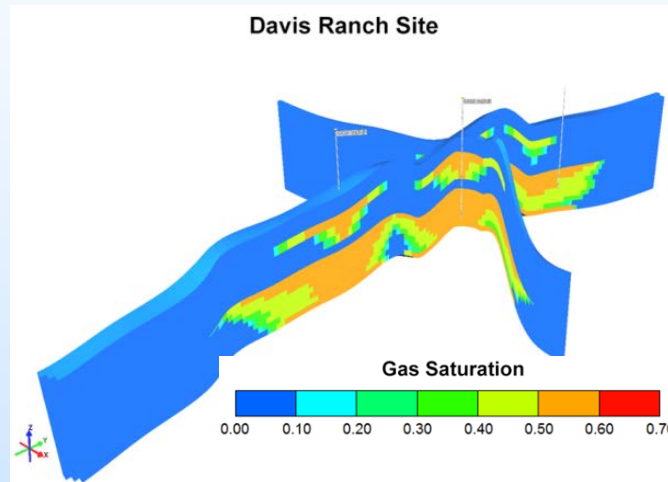
*Induced seismicity risks for CO₂-EOR sites are significantly lower

Storage Site Evaluations: Davis Ranch & John Creek

Static 3D cellular models:
Porosity & permeability in
3100-3400 ft-deep
reservoirs



Dynamic models: analyze
injectivity and storage capacity
in Simpson and Arbuckle



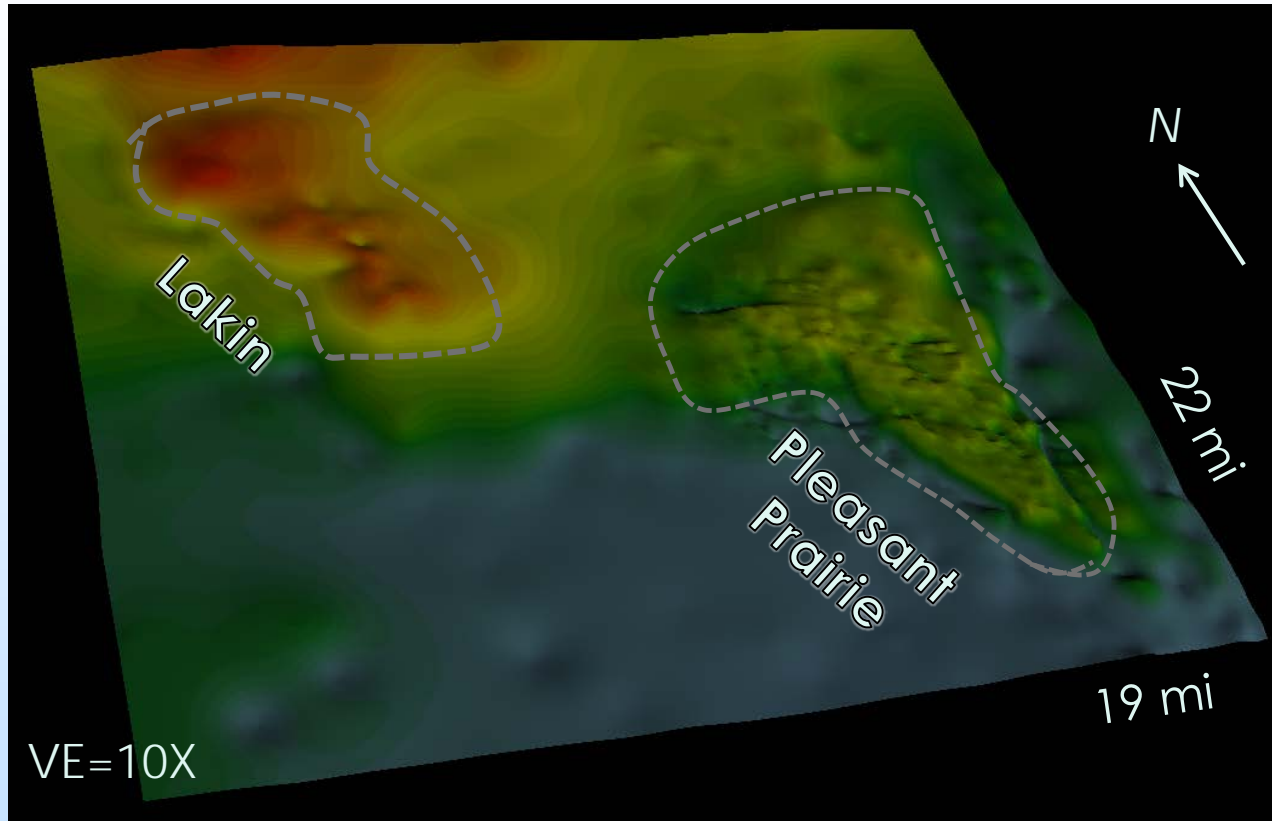
Two largest fields in FCB,
located ten miles apart
40-50 miles SW of JEC

Results:

- ✓ Injected for 25 years
- ✓ Combined injection rates: 2350 to 4000 tonnes/day
- ✓ Storage: 24.6 million tonnes
- ✓ Injection rate satisfactory
- ✓ Storage is half the 50 Mt target

Storage Site Evaluations:

Lakin and Pleasant Prairie Complex



- Target storage zones:
 - Miss. Osage, 5300-5450'
 - Viola, 5550-5750'
 - Arbuckle, 5800-6400'
- BHP 1650-1750 psi
- BHT 130-135F

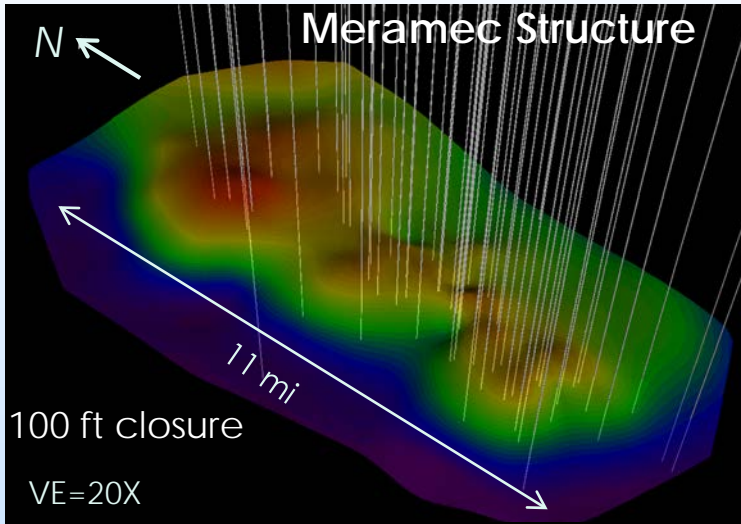
Large structures in parts of Kearny, Finney and Haskell counties

- > 100ft of structural closure
- Lakin: 14 mi²
- Pleasant Prairie: 22 mi²

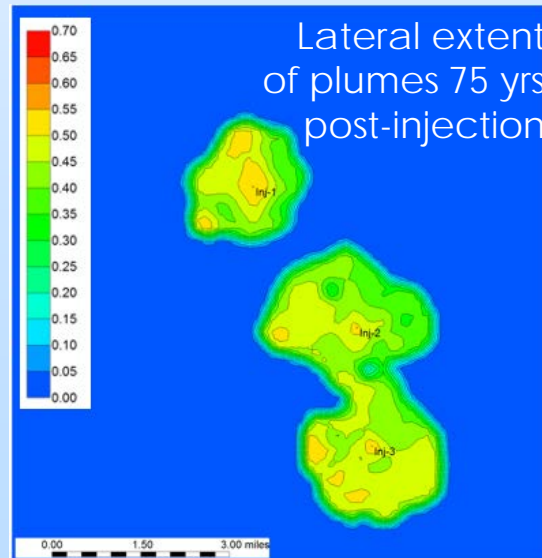
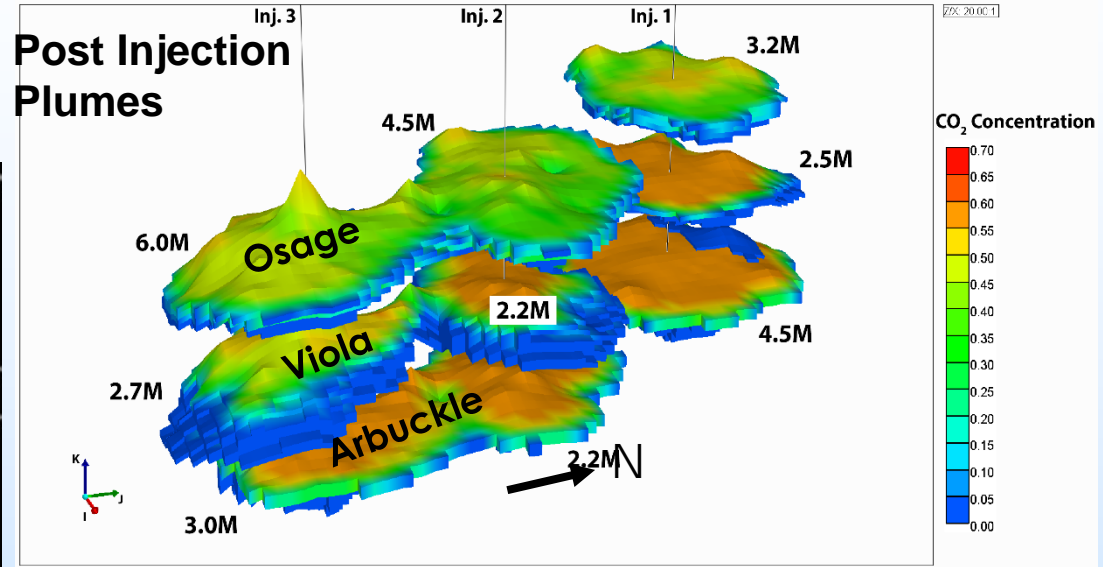
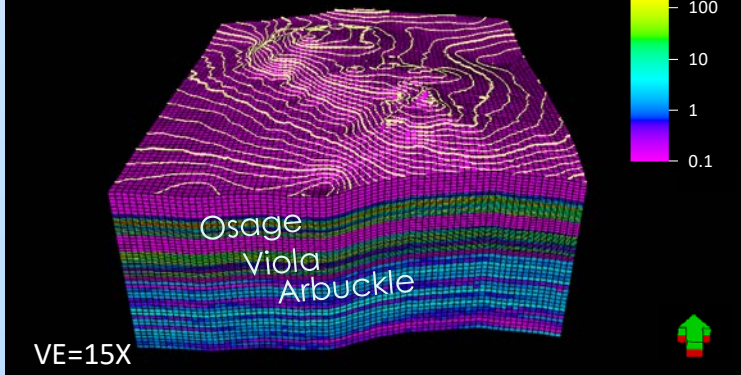
Storage Site Evaluations: Lakin Field

Static 3D cellular model:

- Discovered 1957, 63 well penetrations
- 4.6 MBO from Morrow and Meramec



3D static model



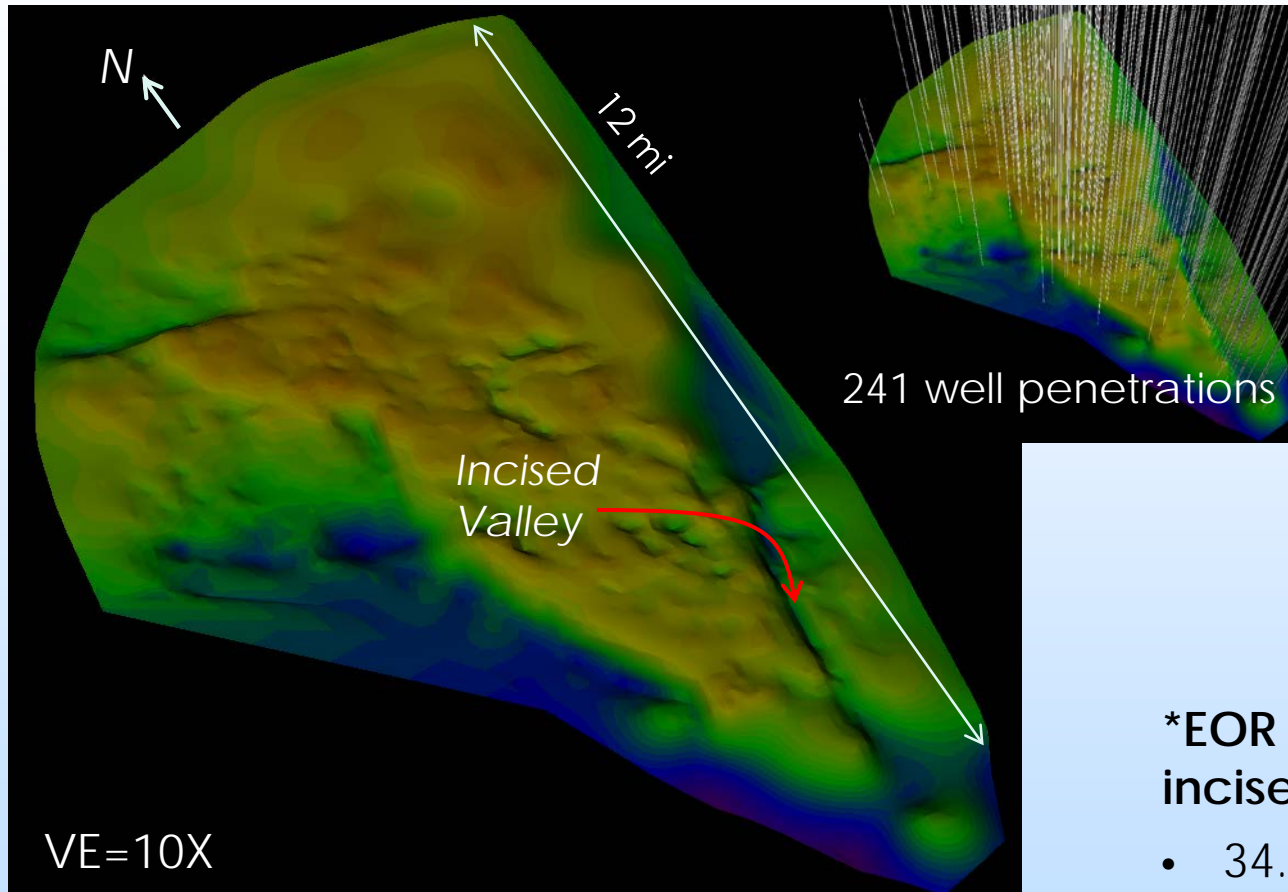
Initial simulation:

- ✓ Inject 30.2 Mt in 25 yrs
- ✓ Three wells, three zones

Increase storage volume:

- Extend perfs in zones
- Extend injection period beyond 25 yrs
- Evaluate plume extents

Storage Site Evaluations: Pleasant Prairie Field



Meramec Structure (*seismic and well control*)

- 100 ft closure, 22 mi²
- Discovered 1954

Status update:

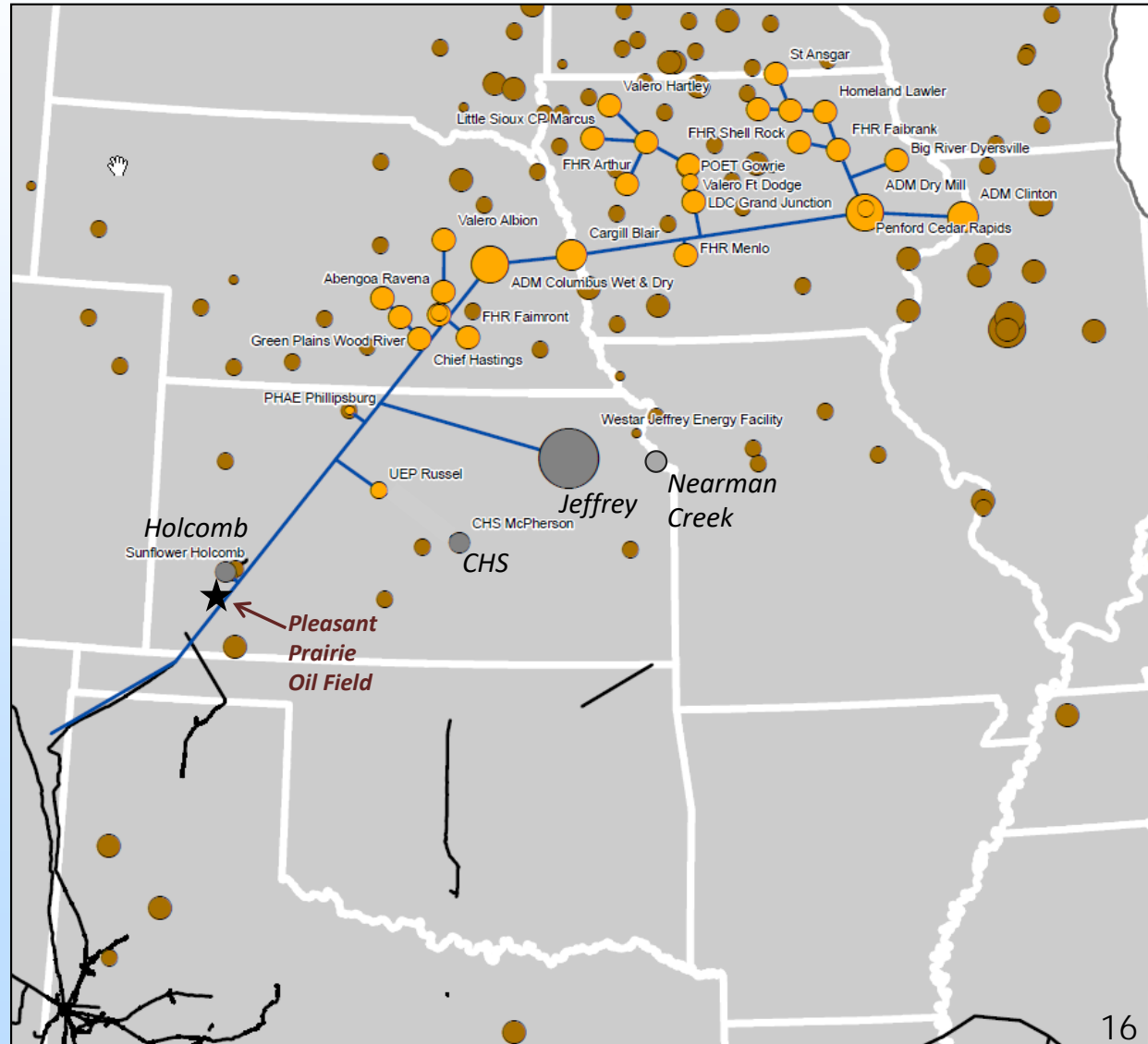
- ✓ Static modeling is underway
- ✓ Zones: Osage, Viola, and Arbuckle
- ✓ Anticipate having 1.5 to 2X the storage capacity as in Lakin

*EOR potential in Chester incised valley is a bonus

- 34.9 mmbo
- 2.6 BCF gas
- Miss. Chester and Meramec

Synergy Opportunities

- Link upper Midwest ethanol-based CO₂ with Kansas sources and reservoirs
- Complements on-going CarbonSAFE projects
- Collaboration with Battelle underway for Phase II



Questions?