# Integrated CCS for Kansas (ICKan)

Project Number FE0029474

**Tandis Bidgoli**

Kansas Geological Survey

University of Kansas

**Martin Dubois**

Improved Hydrocarbon Recovery, LLC

U.S. Department of Energy

National Energy Technology Laboratory

Mastering the Subsurface Through Technology Innovation, Partnerships and Collaboration: Carbon Storage and Oil and Natural Gas Technologies Review Meeting

August 1-3, 2017

# Presentation Outline

- Technical Status
  - Project Overview
  - Goals & Objectives
  - CCS Team & Participants
  - Sub-basinal Evaluations
  - $CO_2$ Sources & Transportation Assessments
  - Legal, Regulatory, and Public Policy
- Accomplishments to Date
- Lessons Learned & Synergy Opportunities
- Project Summary

# Technical Status

## Project Overview: Goal & Objectives

- Identify and address major **technical and nontechnical challenges** of implementing $CO_2$ capture and transport and establishing secure geologic storage for $CO_2$ in Kansas
- Evaluate and **develop a plan and strategy** to address the challenges and opportunities for commercial-scale CCS in Kansas

# Technical Status

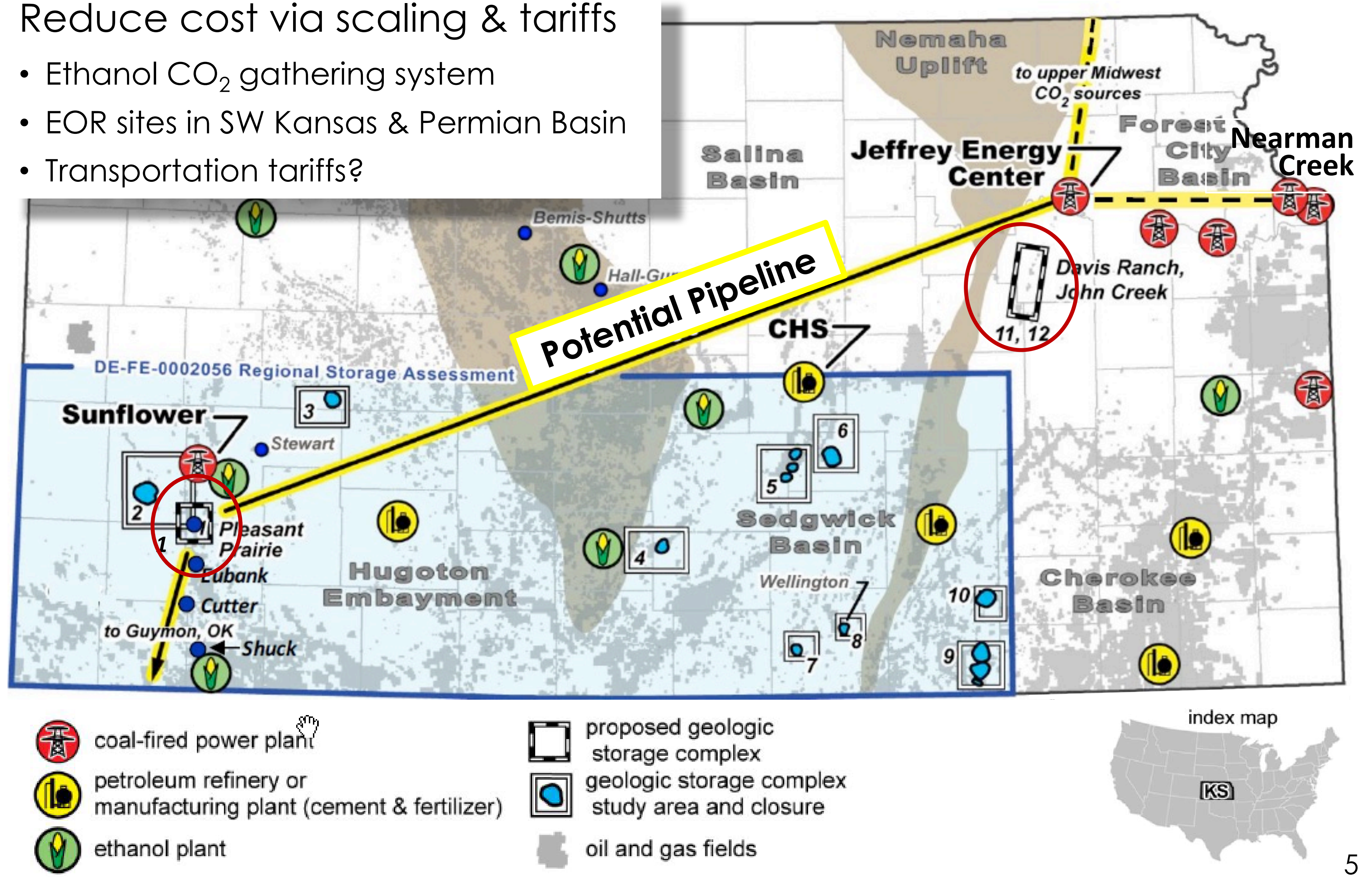
## Project Overview: Base Case Scenario

- **Capture 50 million tonnes $CO_2$** from one of three Jeffrey Energy Center's 800 MWe plants over a 20 year period (2.5Mt/yr)
- Compress $CO_2$ 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 $CO_2$ in the Viola Formation and Arbuckle Group**

# Jeffrey to SW Kansas

Reduce cost via scaling & tariffs

- Ethanol $CO_2$ gathering system
- EOR sites in SW Kansas & Permian Basin
- Transportation tariffs?



# Technical Evaluations

## Sub-Basinal Evaluations

### Pleasant Prairie

- 170 Mt storage
- Viola & Arbuckle
- $CO_2$-EOR reservoirs
- Adequate data (core)
- Unitized; single operator

### Davis Ranch-John Creek

- 50 Mt storage
- Simpson and Arbuckle
- Proximity to JEC
- $CO_2$-EOR reservoirs
- Adequate data
- Two operators

## $CO_2$ Source Assessments

### Westar Jeffrey Energy Center

- 2.4 GW & 12.5 million tonnes of $CO_2$

### Sunflower's Holcomb Plant

### CHS McPherson Refinery

### KC Board of Public Utilities

## $CO_2$ Transportation

### Pipeline

- 300 mile trunk line
- Connect to Midwest ethanol $CO_2$ 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
- $CO_2$ 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**

**<u>Kansas Geological Survey</u>**
**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

**<u>Improved Hydrocarbon Recovery, LLC</u>**
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Martin Dubois, Joint-PI, Project Manager

**CO2 Source Assessments, Capture & Transportation, Economic Feasibility**

**<u>Linde Group (Americas Division)</u>**
**Houston, TX**

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

**Energy, Environmental, Regulatory, & Business Law & Contracts**

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**Policy Analysis, Public Outreach & Acceptance**

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

# Industry Partners

Four $CO_2$ 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 |
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| Regulatory |
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| **Kansas Department of Health & Environment** |
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| John W. Mitchell, Director |
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Five Oil & Gas Companies

| Kansas Oil & Gas Operators |
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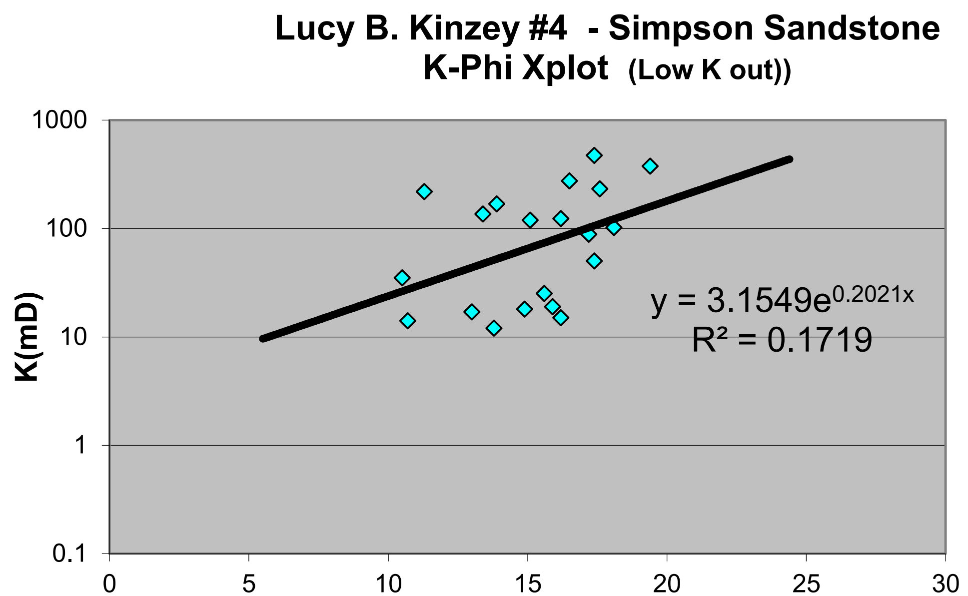
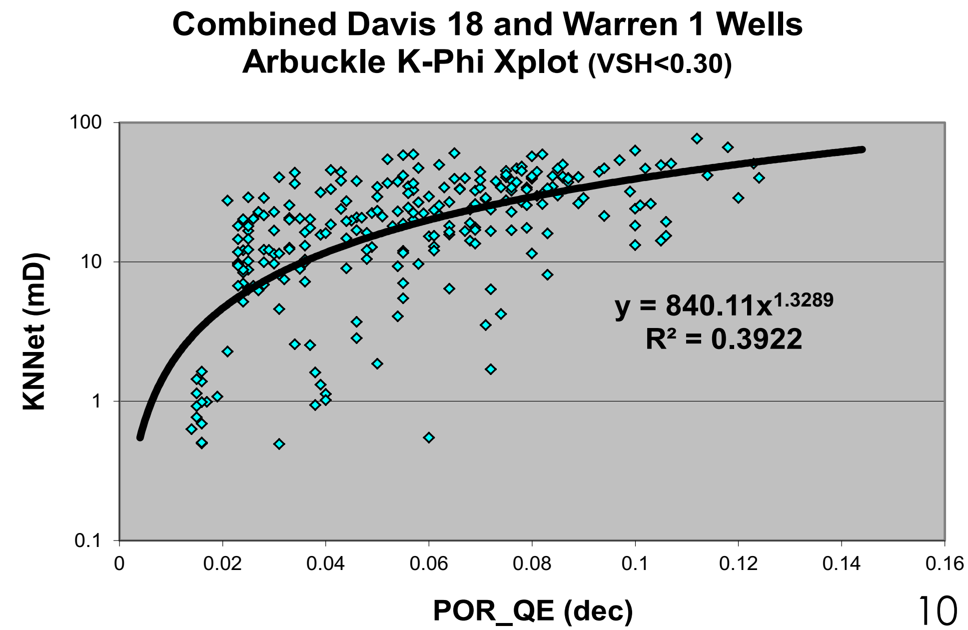
| **Blake Production Company, Inc.** |
| **(Davis Ranch and John Creek fields)** |
| Austin Vernon, Vice President |
| **Knighton Oil Company, Inc.** |
| **(John Creek Field)** |
| Earl M. Knighton, Jr., President |
| **Casillas Petroleum Corp.** |
| **(Pleasant Prairie Field)** |
| Chris K. Carson, 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 |

# Technical Status

## DR & JC Fields: Reservoir Properties

- Phi estimated via:
  - Multimineral FE (n=15)
  - Neutron-density porosity (n=8)
  - Neutron count logs (n=2)
- k from AFN & dynamic data
- Core analysis data for phi-K transform



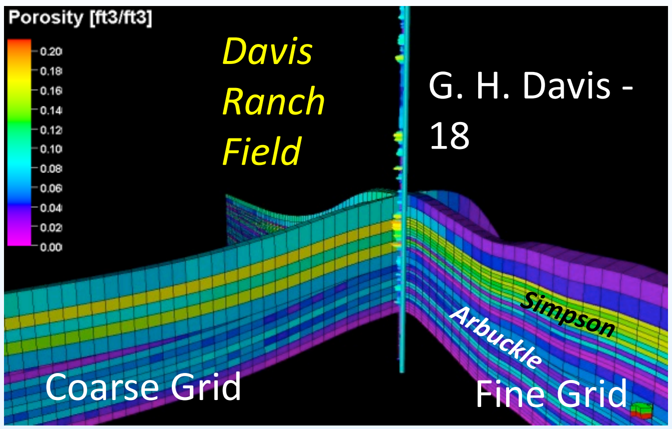



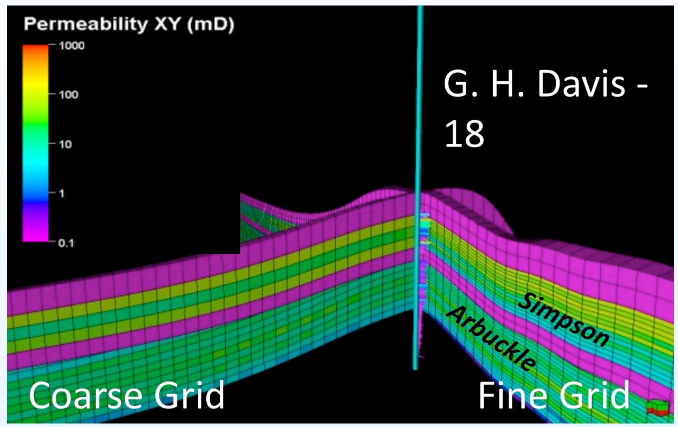

| | Average K (mD) | h (ft) | Kh (mD-ft) |
|---|---|---|---|
| **Simpson** | | | |
| Core Analysis (Lucy B Kinzey | 105 | 23 | 2415 |
| DST Buildup (Vincent 1) | 56 | 25 | 1400 |
| DST Buildup (Eldridge 4)) | 182 | 25 | 4550 |
| **Arbuckle** | | | |
| Injectivity Index | 18 | 198 | 3564 |
| Neural Network (Holoday 2) | 13 | 198 | 2574 |
| Neural Network (Davis 18) | 19 | 60 | 1140 |
| Neural Network (Warren 1) | 27 | 64 | 1728 |

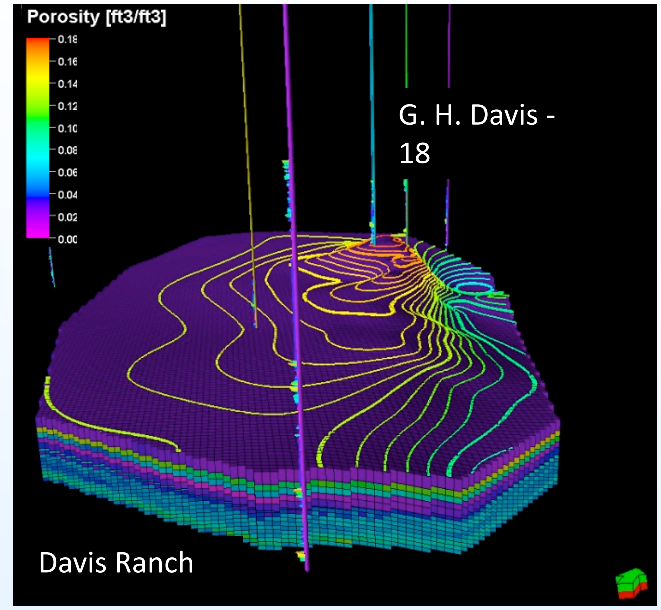
# Technical Status

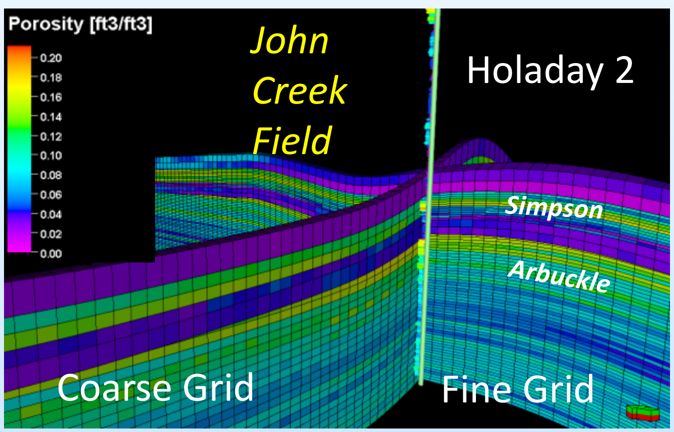
## DR & JC Fields: 3D Static Model

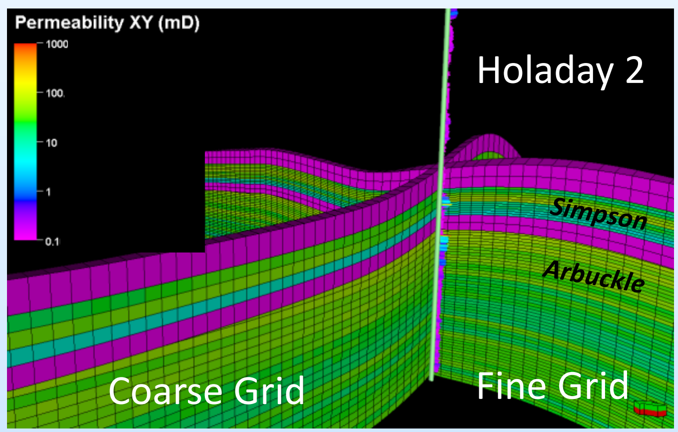
2 target $CO_2$ injection zones:
Simpson Sandstone and Arbuckle Group

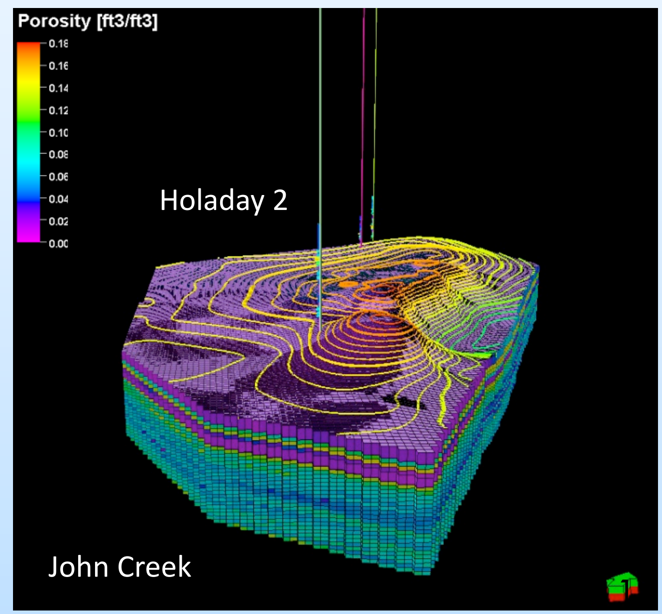


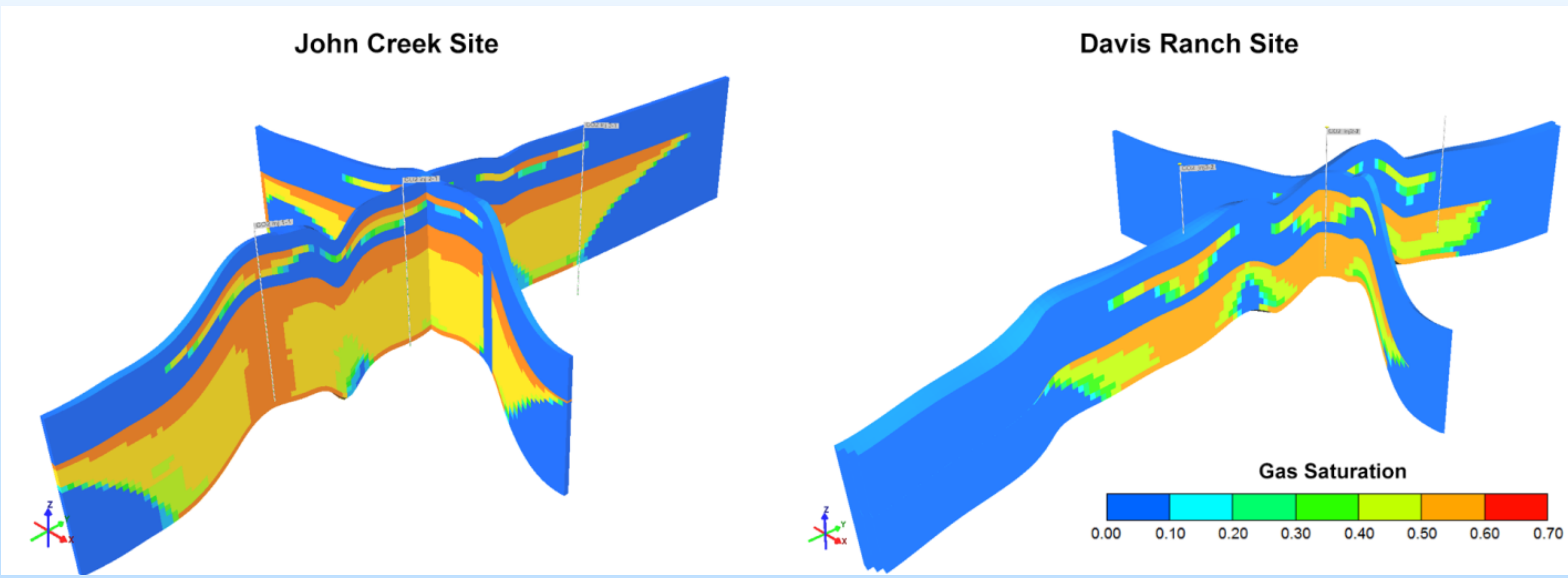

- 360 wells with tops for framework
- Well-scale porosity (half-foot) upscaled to layer-scale and distributed using Gaussian random function
- Permeability calculated using transform

# Technical Status

## DR & JC Fields: Dynamic Modeling

- CMG GEM
  - Carter-Tracy infinite aquifer
- Outputs:
  - Storage volume
  - Delta pressure
  - Gas saturation

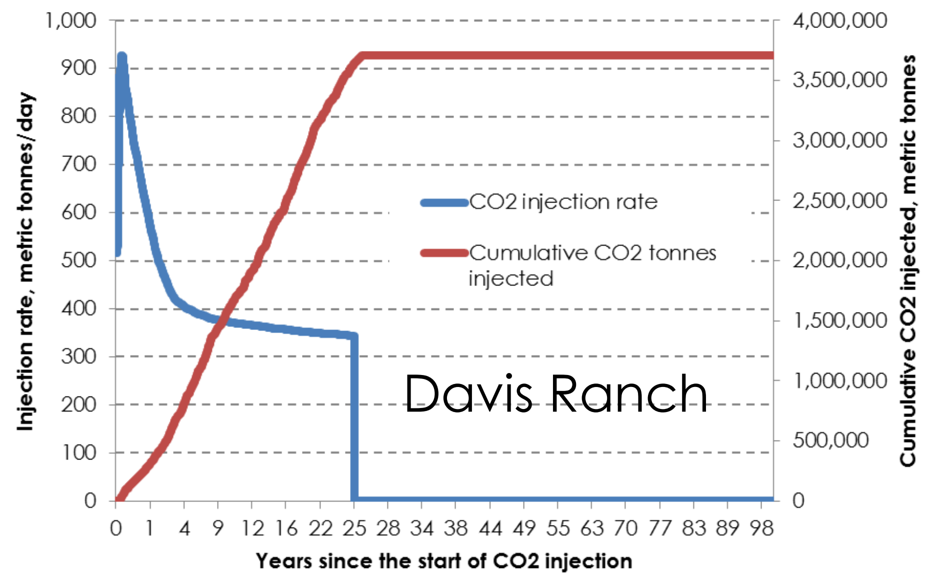
| | John Creek | Davis Ranch |
|---|---|---|
| Temperature | 41 °C (106 °F) | 38 °C (100 °F) |
| Temperature Gradient | 0.008 °C/ft | 0.008 °C/ft |
| Pressure | 1,160 psi (7.99 MPa) | 1,200 psi (8.27 MPa) |
| TDS | 30 g/l | 24 g/l |
| Perforation Zone | Simpson, Arbuckle | Simpson, Arbuckle |
| Injection Period | 25 years | 25 years |

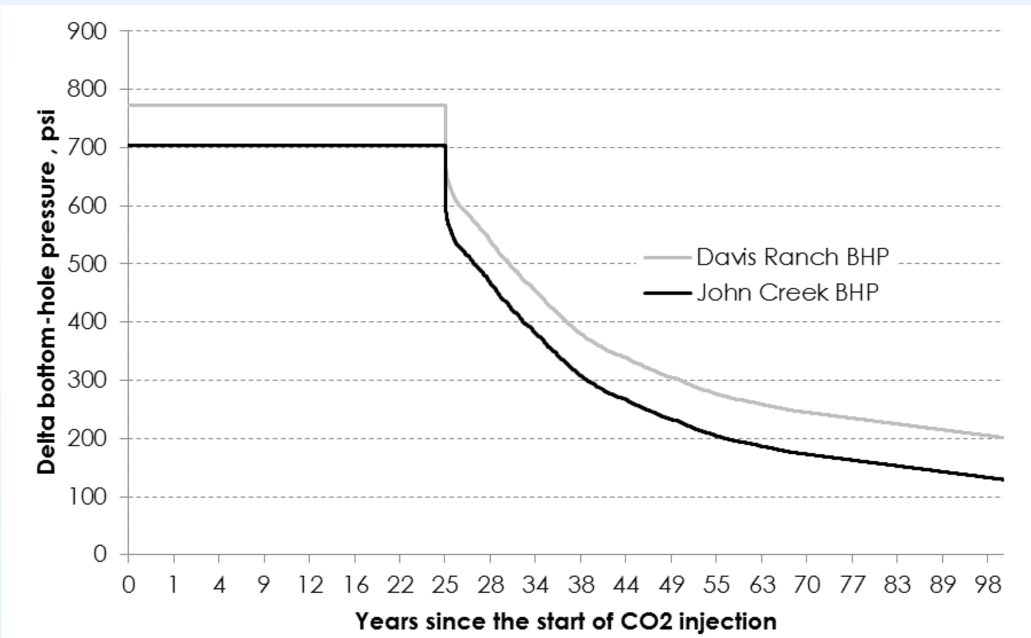


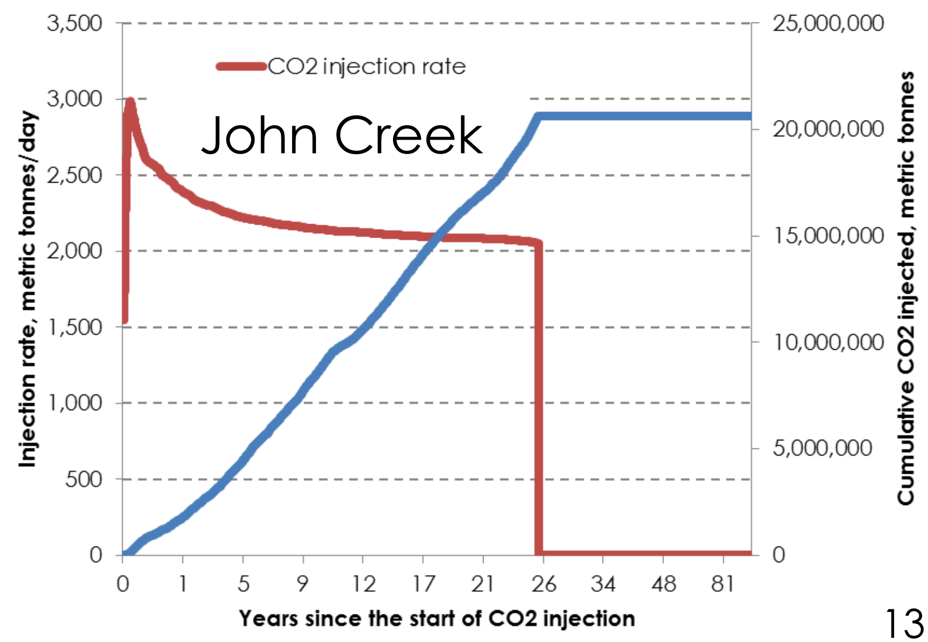
# Technical Status

## DR & JC Fields: Simulation Results

- Davis Ranch
  - 350-940 MT/day
  - 3.6 MMT storage
- John Creek
  - 2,000-3,000 MT/day
  - 21.0 MMT storage
- Evaluating alternative storage sites



# Technical Status
## $CO_2$ Source Assessments

**Jeffrey Energy Center**

- Three 800 MWe power plants: 12.5 Mt/yr CO2
- 2.5 Mt/yr $CO_2$ from ~350 Mwe (partial capture)
- Linde-BASF novel amine-based Post Combustion Capture (PCC) technology

**CHS refinery**

- Two steam methane reformer H2 plants
- 0.76 Mt/yr $CO_2$ capture from flue gas
- Two options: Solvent-based PCC from flue gas *or* Sorbent-based pressure or vacuum swing adsorption, but lower capture rate

**Accomplishments to date:**

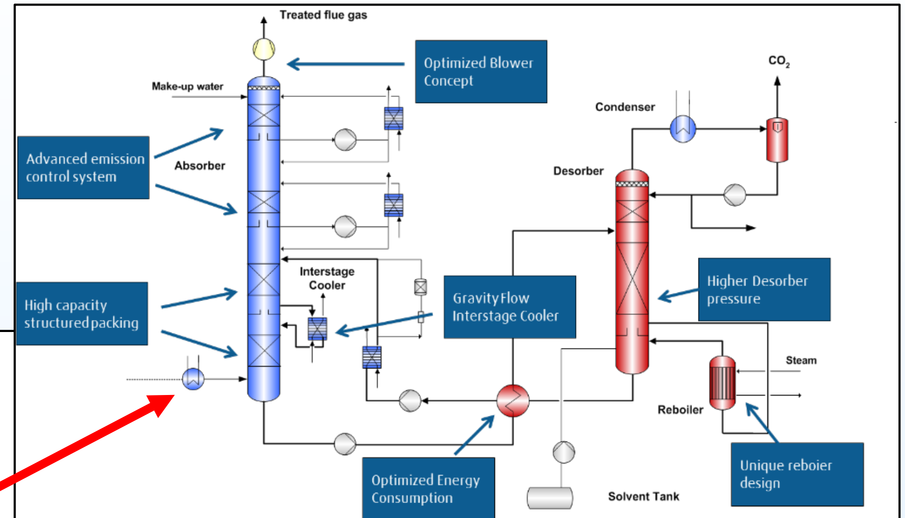
1. Site visits by Linde to identify optimization opportunities & data needs
2. Compiled technical data required for assessments
3. Submitted proposal for feasibility conducted by Linde (Q3 completion)

# Technical Status

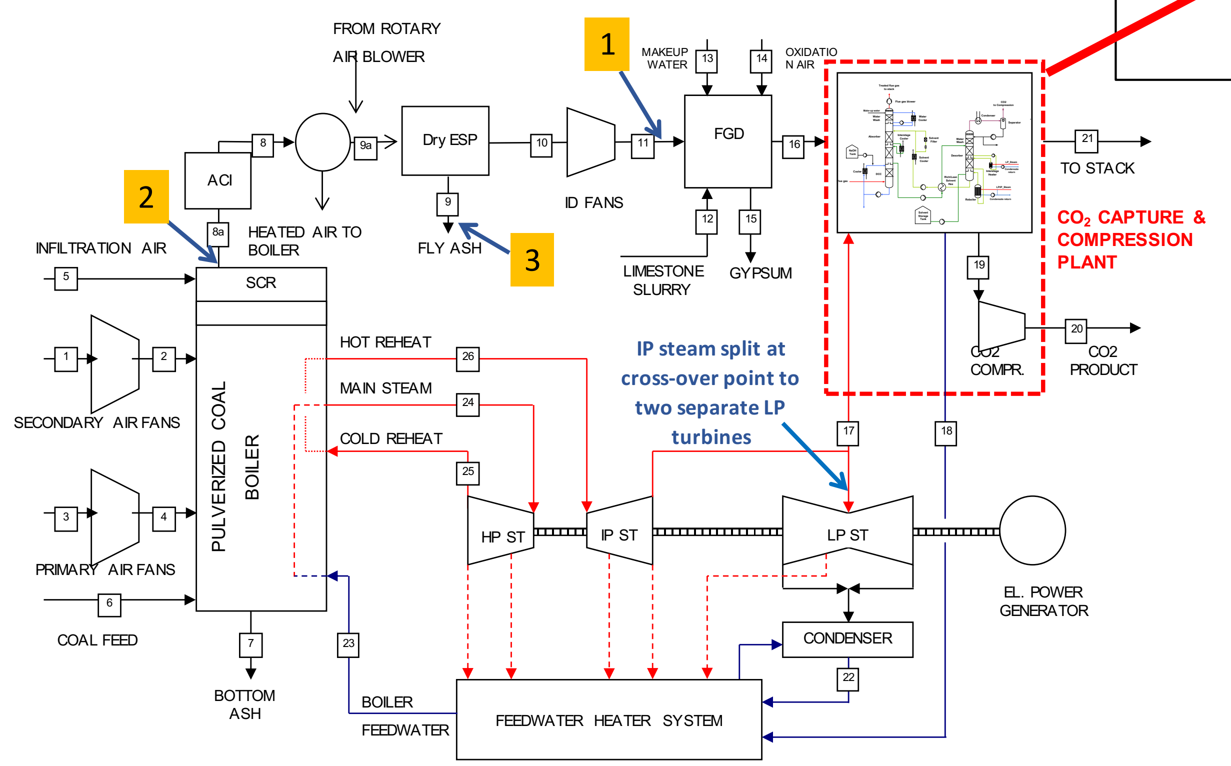
## $CO_2$ Source Assessments

### Waste heat from boiler operation for PCC

1. Heat recovery prior to entering FGD
2. From flue gas leaving SCR
3. Heat recovery from fly ash hopper




### Waste Heat Extraction from 3 Locations



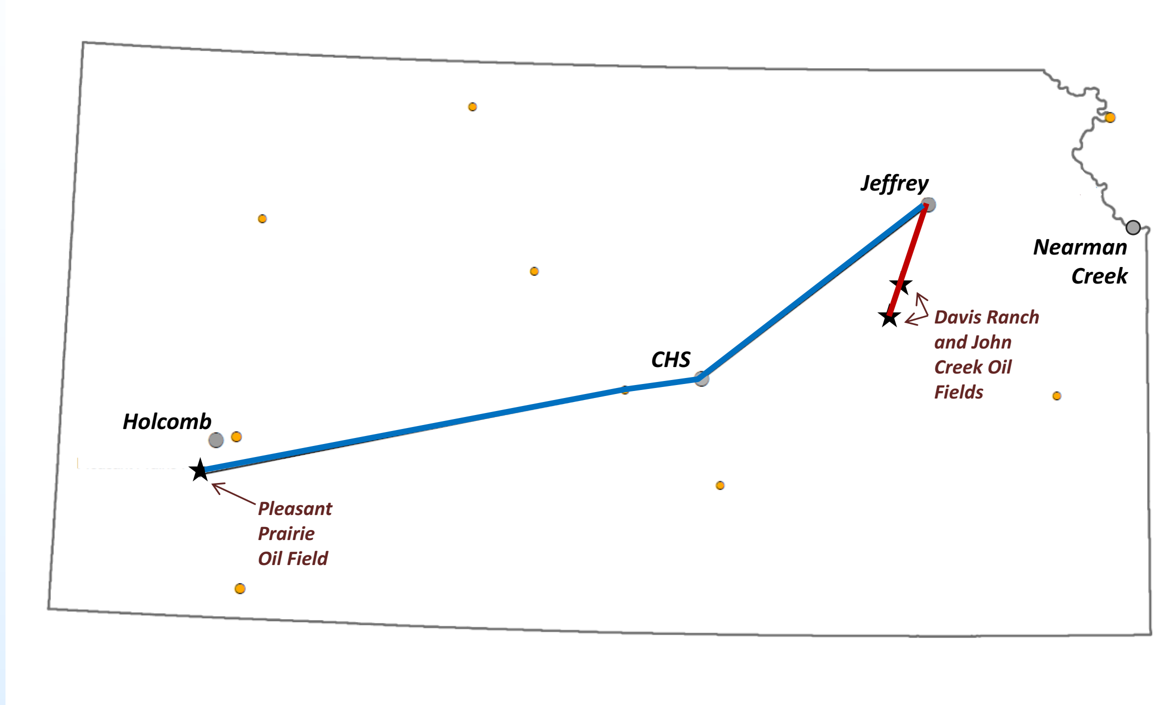

### Linde-BASF system

- Technology Readiness Level (TRL) of 6 (U.S. DOE, 2012)
- Demonstrated improvements to performance, efficiency and cost of electricity (Bostic et al. 2017)

# Technical Status

## $CO_2$ Transportation Assessment

- Modified FE/NETL $CO_2$ Transport Cost Model
- 7 inputs (e.g., length, pumps, capacity, pressures, etc.)
- 12 outputs, including CapEx and OpEx




| | Scenario | Distance (mi) | Distance (mi) X 1.2 | Volume (MT/yr) | Size (inches) | CapEx ($M) | Annual OpEx ($M) |
|---|---|---|---|---|---|---|---|
| **Jeffrey to MidCon Trunk** | **part of 1** | 151 | 181 | 2.5 | 12" | $164 | $3.8 |
| **Jeffrey to Davis Ranch and John Creek** | **2** | 42 | 51 | 2.5* | 12" & 8" | $47 | $1.3 |
| **Jeffrey to CHS and Pleasant Prairie** | **3** | 294 | 353 | 3.25** | 12" | $323 | $8.0 |
| **Jeffrey to Pleasant Prairie** | **4** | 294 | 353 | 2.5 | 12" | $322 | $7.2 |

# Technical Status

## Legal, Regulatory, & Public Policy

1. Key challenges identified & conditions in Kansas defined
2. Possible remedies developed
3. Plans and strategies for implementation, including development of model statutes (draft complete)
4. Identified additional CCS team members & stakeholders

| Nontechnical Challenges | | Conditions | Remedy | Plan Status |
|---|---|---|---|---|
| **Statutory framework** | Overarching challenge | X | X | IP |
| **Pore space** | Ownership - who owns the pore space? | X | X | IP |
| | Aggregation or pooling of pore space | X | X | IP |
| **Transportation** | ROW difficulties | X | X | IP |
| **Regulation of Injection & Storage** | Class VI well permitting | X | X | IP |
| | $CO_2$ ownership from emission through capture, transportation, & injection | X | X | IP |
| | Post-closure, long-term liability is costly and a major impediment | X | X | IP |
| **Public acceptance** | Capture | X | X | IP |
| | Transportation | | | IP |
| | Injection and storage | X | X | IP |

# Accomplishments to Date

- ✓ Davis Ranch & John Creek site evaluation complete and alternative storage sites identified
- ✓ Site visits & data collection for $CO_2$ source assessments for 2 of 3 sources complete
  - ✓ Candidate technologies for PCC identified
  - ✓ Proposal for conceptual development in progress
- ✓ FE/NETL $CO_2$ Transport Cost Model modified to enable detailed cost estimates for complicated pipeline scenarios
- ✓ Draft model statutes that could pave the way for $CO_2$ transportation, injection, and storage in Kansas.
- ✓ Meetings with individuals and organizations for data & information, and feedback on conceptual plans

# Lessons Learned

**Non-Technical Negative:**
Longevity of coal-based $CO_2$ sources

- Quickly being replaced by wind and natural gas
- Economic life of plants < than life of capture facility

**Non-Technical Positive:**
Alternative ethanol $CO_2$ sources

- Capture cost << transportation cost
- Infrastructure concepts gaining traction (e.g., State $CO_2$ Deployment Work Group and NEORI)
- 45Q expansion proposal

**Technical Negatives:**

- Site closest to largest source has insufficient capacity
- Fluid levels/pressure in main disposal zone (Arbuckle) are rising.

**Technical Positives:**

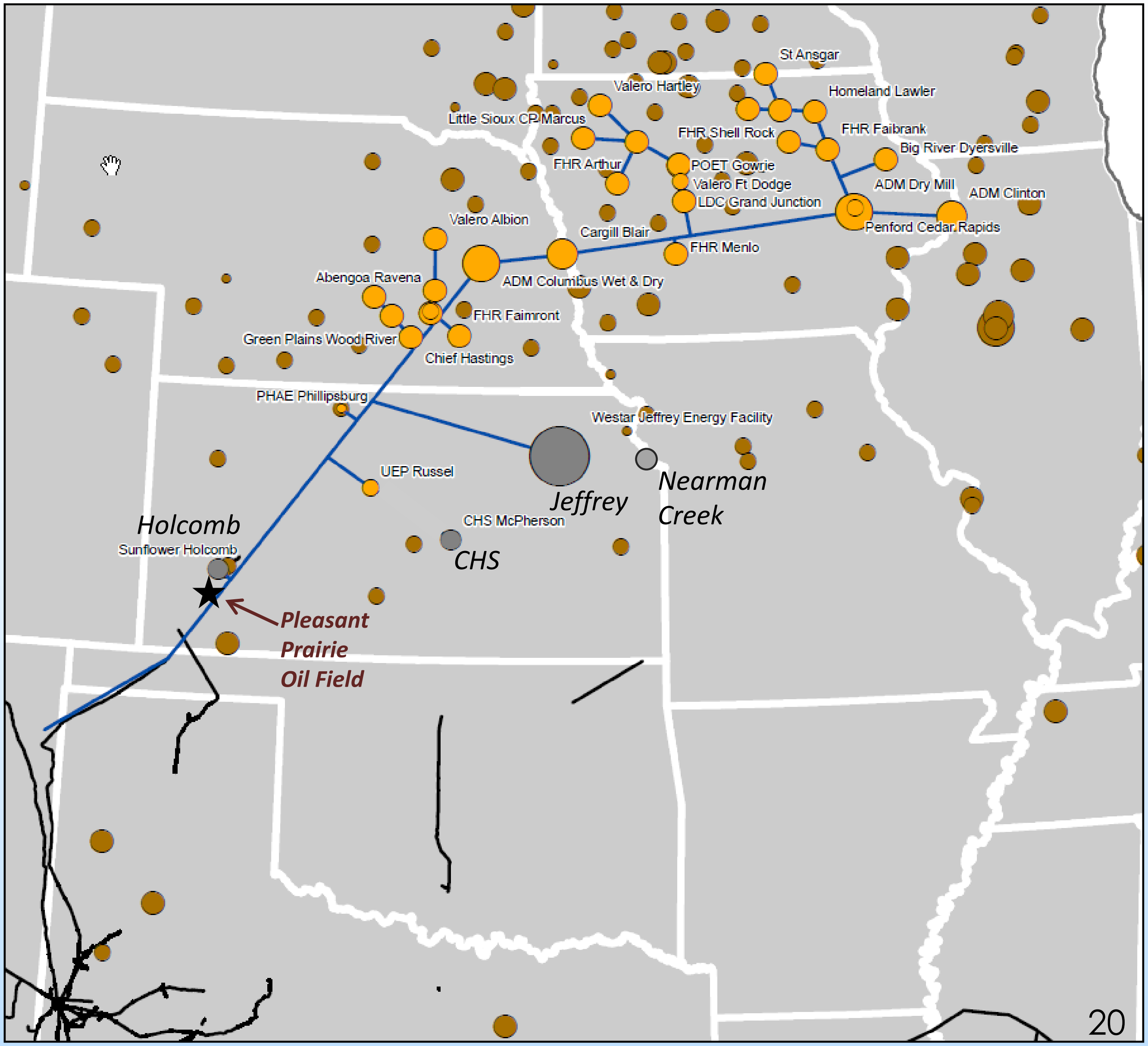
- Other saline aquifers (Osage and Viola) that should store 50Mt have been identified in SW Kansas.
- $CO_2$-EOR storage opportunities

**Possible change for Phase II** – *focus on a program that makes economic sense*

- Evaluate large-scale capture & transportation system from ethanol and fertilizer plants in upper Midwest for EOR and storage in Nebraska, Kansas, Oklahoma and Texas.

# Synergy Opportunities

- Link upper Midwest ethanol-based $CO_2$ with Kansas sources and reservoirs
- Complements on-going CarbonSAFE projects
- Potential for collaborations with Battelle & UND-EERC



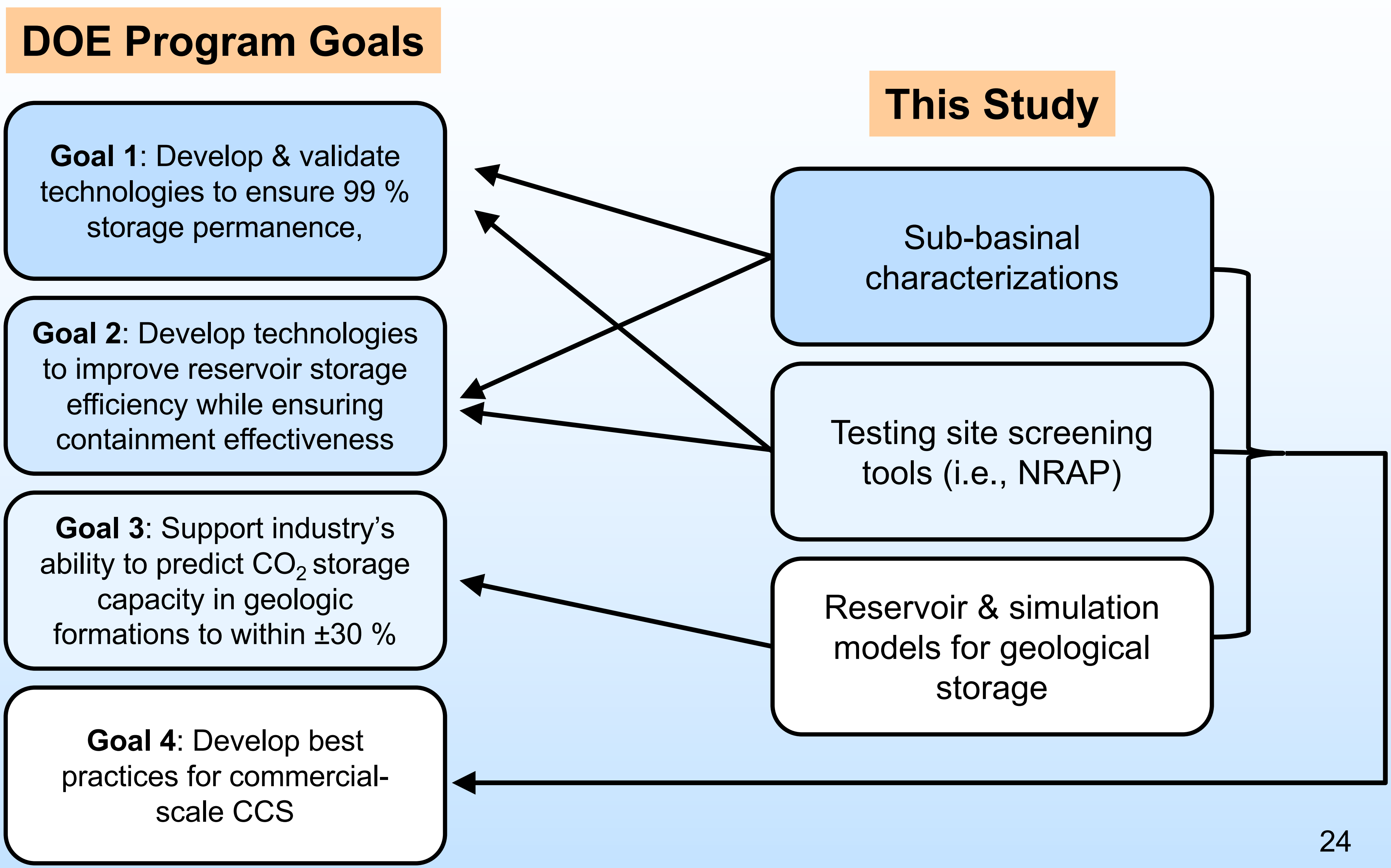
# Project Summary

- ICKan team is identifying and addressing major **technical and non-technical challenges** of implementing commercial-scale CCS in Kansas
- Reservoir characterization, geologic modeling, and dynamic simulations suggest that **eastern KS site may not be suitable for scale of injection**
- $CO_2$ source assessments are being used to identify the most suitable post-combustion capture technologies
- CCS model being evaluated requires **substantial transportation infrastructure** and various pipeline scenarios are being evaluated, including **linkages to upper Midwest ethanol $CO_2$ source**
- Continue to develop strategy to address the challenges and opportunities for commercial-scale CCS in Kansas

# Questions?

# Appendix

# Benefit to the Program





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# Benefit Statement

ICKan will address the handling of $CO_2$ emissions from the source and transport them to the storage site utilizing the combined knowledge and experience of The Linde Group including their own research on post-combustion 2nd Generation $CO_2$ capture currently sponsored by the DOE, the electrical utilities, refinery, and the latest R&D efforts such as DOE's Carbon Capture Simulation Initiative. The knowledge, experience, and lessons learned by the KGS regarding regional studies, site characterization, monitoring, EPA Class VI permitting, and incorporating NRAP models and tools will be bring best-practices to bear on proving up a commercial-scale carbon storage complex that is safe and dependable. In this Phase I: Integrated CCS Pre-Feasibility Study, ICKan will complete the formation of the CCS Coordination Team who will deliver a plan and strategy to address the technical and non-technical challenges specific to commercial-scale deployment of a $CO_2$ storage project utilizing the experience and the expertise of the Team. A development plan will address technical requirements, economic feasibility, and public acceptance of an eventual storage project at the primary source-sink site at Westar Energy's Jeffrey Energy Center. High-level technical evaluations will also be made of sub-basin and potential $CO_2$ sources utilizing prior experience and methodologies developed previously and for this project. The ICKan and CCS Coordination Team will generate information that will allow DOE to make a determination of the proposed storage complex's level of readiness for additional development under Phase II, based upon the findings for commercial-scale capture, transportation, and storage sites identified as part of this investigation. Information acquired will be shared via the NETL-EDX data portal.



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# **Project Overview:** Goals & Objectives

- Identify and address major **technical and nontechnical challenges** of implementing $CO_2$ capture and transport and establishing secure geologic storage for $CO_2$ in Kansas
- Evaluate and **develop a plan and strategy** to address the challenges and opportunities for commercial-scale CCS in Kansas


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# **Project Overview:**
## Base Case Scenario

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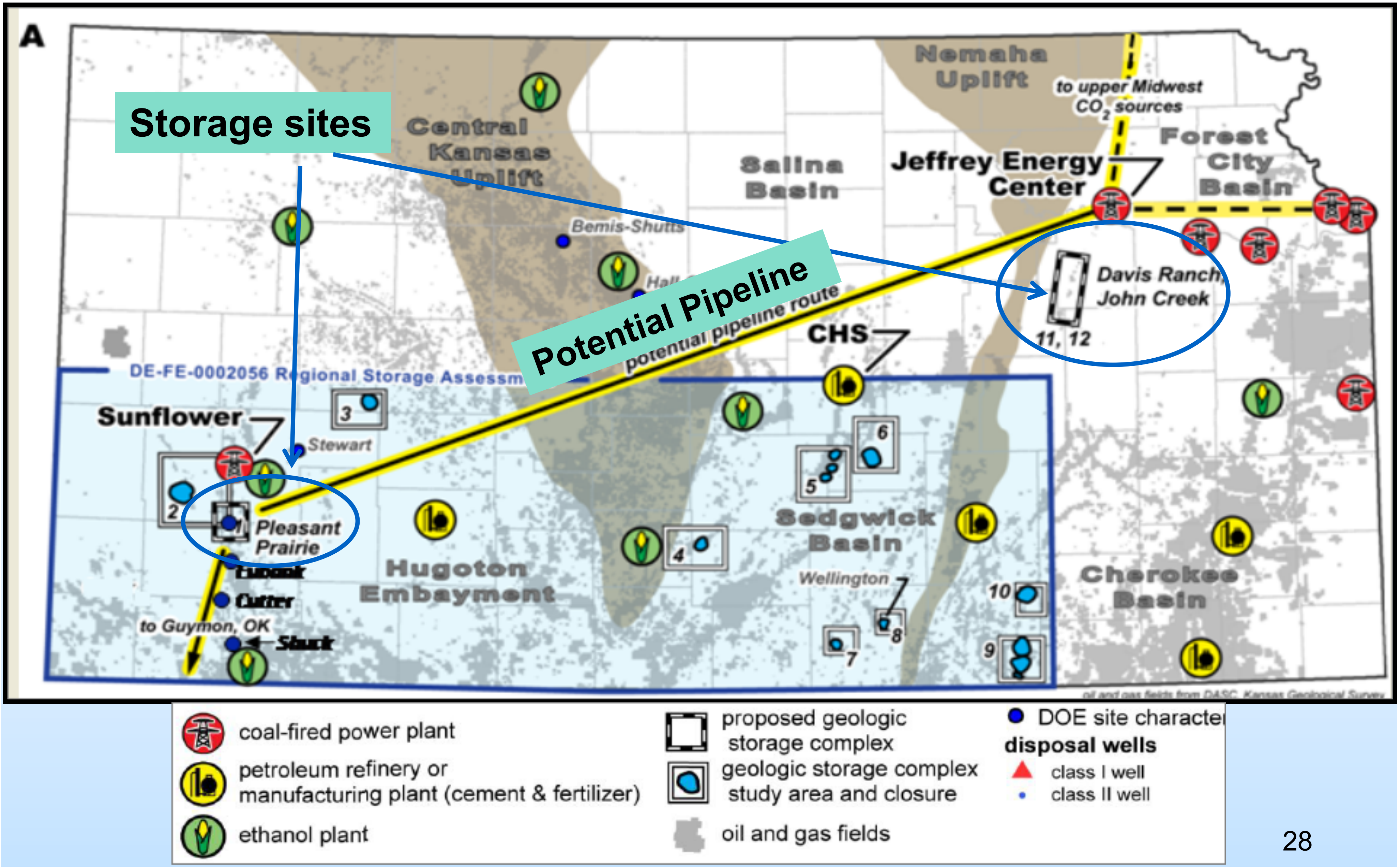


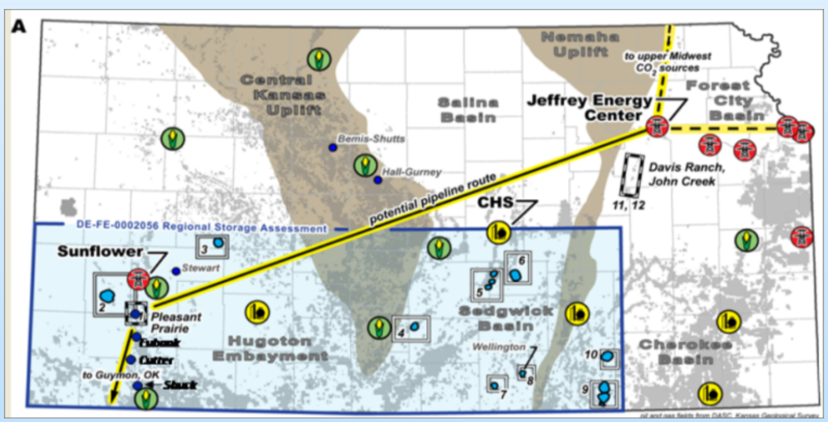
# Base Case + Ethanol $CO_2$

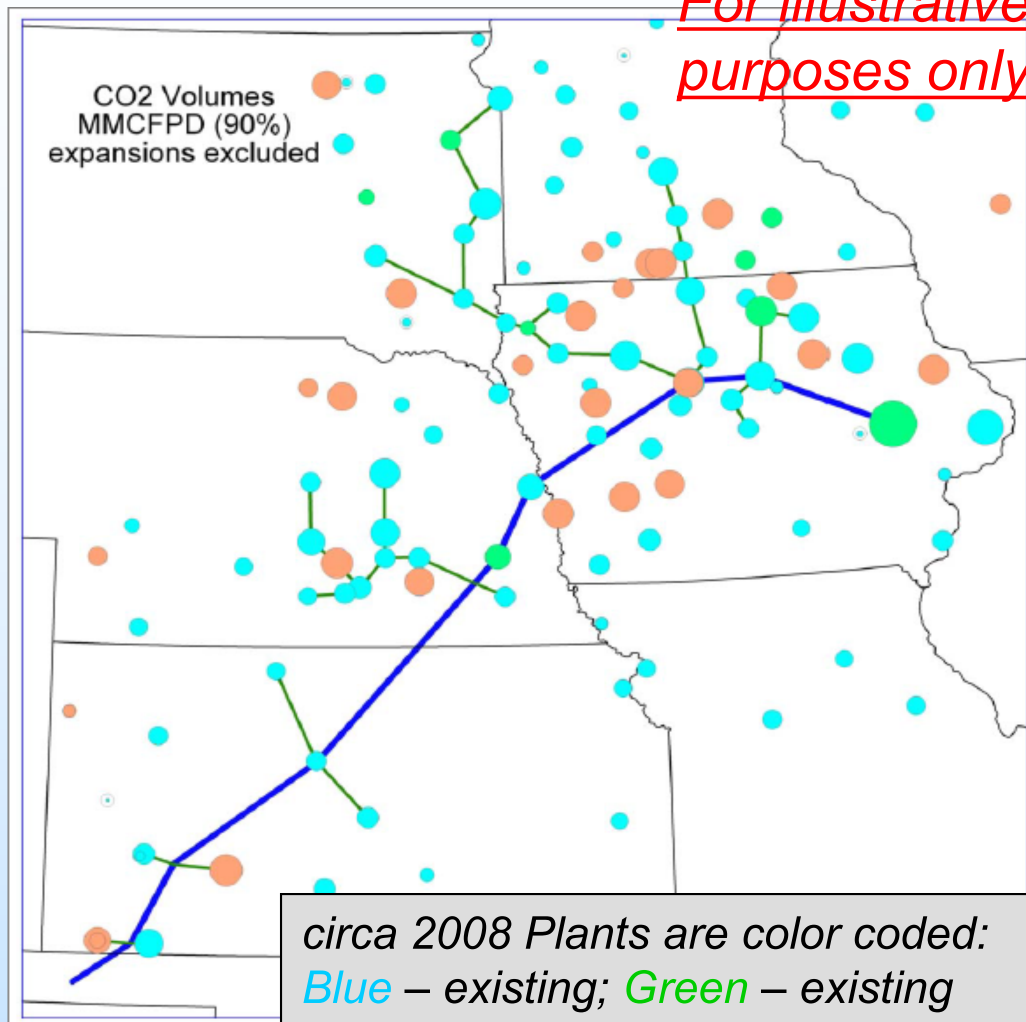
January 2008 private study

Gathering system connecting 44 ethanol plants

**Could reduce net cost through scaling and tariffs**

- Capture Ethanol CO2
- Build extensive gathering system
- Join trunk line and transport to SW Kansas and possibly to Permian Basin for EOR
- Collect tariffs for transporting Ethanol CO2




For illustrative purposes only!

*circa 2008 Plants are color coded: Blue – existing; Green – existing with planned expansions; Orange – proposed or under construction.*

# Technical Evaluations

## Sub-Basinal Evaluations

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# Non-Technical Evaluations

## Implementation Plan

### Economics ⇔ Legal & Regulatory

### Public Policy (Public Acceptance))

**Economics**

- Capture & transportation economic feasibility (with or w/o ethanol component)
- Financial backing
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- Pore space property rights including force unitization
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**Public Policy (Public Acceptance))**

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


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# Success Criteria

- ✓ CCS Coordination Team
- ✓ Reservoirs characterized
- ✓ CO2 source assessments
- ✓ CO2 transportation assessment
- ✓ Implementation plan

- Go-No Go decision point in November 2017
- Tied to application for Phase II of CarbonSAFE

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# Organization: Phase I Research Team

*18 team members, four subcontractors and KGS staff*

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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

# Organization: Phase I
# Industry Partners

Four $CO_2$ Sources

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| Dan Wilkus, Director - Air Programs |
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| **Stroke of Luck Energy & Exploration, LLC** |
| **(Leach & Newberry fields)** |
| Ken Walker, Operator |

# Gantt Chart

| | | 2017 | | | | | | | | | | | | 2018 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Task** | **Task Name** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 |
| **Task 1.0** | **Project Management & Planning Integrated CCS for Kansas (ICKan)** | | | | | | | | | | | | | | | | | | |
| Subtask 1.1 | Fulfill requirements for National Environmental Policy Act (NEPA | | | | | | | | | | | | | | | | | | |
| Subtask 1.2 | Conduct a kick-off meeting to set expectations | | | | | | | | | | | | | | | | | | |
| Subtask 1.3 | Conduct regularly scheduled meetings and update tracking | | | | | | | | | | | | | | | | | | |
| Subtask 1.4 | Monitor and control project scope | | | | | | | | | | | | | | | | | | |
| Subtask 1.5 | Monitor and control project schedule | | | | | | | | | | | | | | | | | | |
| Subtask 1.6 | Monitor and control project risk | | | | | | | | | | | | | | | | | | |
| Subtask 1.7 | Maintain and revise the Data Management Plan including submital of data to NETL-EDX | | | | | | | | | | | | | | | | | | |
| Subtask 1.8 | Revisions to the Project Management Plan after submission | | | | | | | | | | | | | | | | | | |
| **Task 2.0** | **Establish a Carbon Capture & Storage (CCS) Coordination Team** | | | | | | | | | | | | | | | | | | |
| Subtask 2.1 | Identify additional CCS team members | | | | | | | | | | | | | | | | | | |
| Subtask 2.2 | Identify additional stakeholders that should be added to the CCS team | | | | | | | | | | | | | | | | | | |
| Subtask 2.3 | Recruit & gain commitment of additional CCS team members identified | | | | | | | | | | | | | | | | | | |
| Subtask 2.4 | Conduct a formal meeting that includes Phase I team & committed Phase II team members | | | | | | | | | | | | | | | | | | |
| **Task 3.0** | **Develop a plan to address challenges of a commercial-scale CCS Project** | | | | | | | | | | | | | | | | | | |
| Subtask 3.1 | Identify challenges & develop a plan to address challenges for CO2 capture from anthropogenic sources | | | | | | | | | | | | | | | | | | |
| Subtask 3.2 | Identify challenges & develop a plan to address challenges for CO2 transportation & injection | | | | | | | | | | | | | | | | | | |
| Subtask 3.3 | Identify challenges & develop a plan to address challenges for CO2 storage in geologic complexes | | | | | | | | | | | | | | | | | | |
| **Task 4.0** | **Perform high level sub-basinal evaluations using NRAP & related DOE tools** | | | | | | | | | | | | | | | | | | |
| Subtask 4.1 | Review storage capacity of geologic complexes identified in this proposal & consider alternatives | | | | | | | | | | | | | | | | | | |
| Subtask 4.2 | Conduct high-level technical analysis of suitable geologic complexes using NRAP-IAM-CS & other tools for integrated assessment | | | | | | | | | | | | | | | | | | |
| Subtask 4.3 | Compare results using NRAP with methods used in prior DOE contracts including regional & subbasin CO2 storage & Class VI permit | | | | | | | | | | | | | | | | | | |
| Subtask 4.4 | Develop an implementation plan & strategy for commercial-scale, safe & effective CO2 storage | | | | | | | | | | | | | | | | | | |
| **Task 5.0** | **Perform a high level technical CO2 source assessment for capture** | | | | | | | | | | | | | | | | | | |
| Subtask 5.1 | Review current technologies & CO2 sources of team members & nearby sources using NATCARB, Global CO2 Storage Portal, & KDM | | | | | | | | | | | | | | | | | | |
| Subtask 5.2. | Determine novel technologies or approaches for CO2 capture | | | | | | | | | | | | | | | | | | |
| Subtask 5.3 | Develop an implementation plan & strategy for cost effective & reliable carbon capture | | | | | | | | | | | | | | | | | | |
| **Task 6.0** | **Perform a high level technical assessment for CO2 transportation** | | | | | | | | | | | | | | | | | | |
| Subtask 6.1 | Review current technologies or CO2 transportation | | | | | | | | | | | | | | | | | | |
| Subtask 6.2 | Determine novel technologies or approaches for CO2 capture | | | | | | | | | | | | | | | | | | |
| Subtask 6.3 | Develop a plan for cost-efficient & secure transportation infrastructure | | | | | | | | | | | | | | | | | | |
| **Task 7.0** | **Technology Transfer** | | | | | | | | | | | | | | | | | | |
| Subtask 7.1 | Maintain website on KGS server to facilitate effective & efficient interaction of the team | | | | | | | | | | | | | | | | | | |
| Subtask 7.2 | Public presentations | | | | | | | | | | | | | | | | | | |
| Subtask 7.3 | Publications | | | | | | | | | | | | | | | | | | |


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# Bibliography


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- Hollenbach, A., Bidgoli, T.S., Dubois, M., Holubnyak, Y., and FazelAlavi, M., 2017, Evaluating the Feasibility of CO2 Storage through Reservoir Characterization and Geologic Modeling of the Viola Formation and Arbuckle Group in Kansas: AAPG Midcontinent Section Meeting, Oklahoma City, OK.
- Jennings, J. and Bidgoli, T.S., 2017, Identifying at Risk Areas for Injection-Induced Seismicity through Subsurface of Southern Kansas: AAPG Midcontinent Section Meeting, Oklahoma City, OK.