Integrated CCS for Kansas (ICKan)

Project Number FE0029474

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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

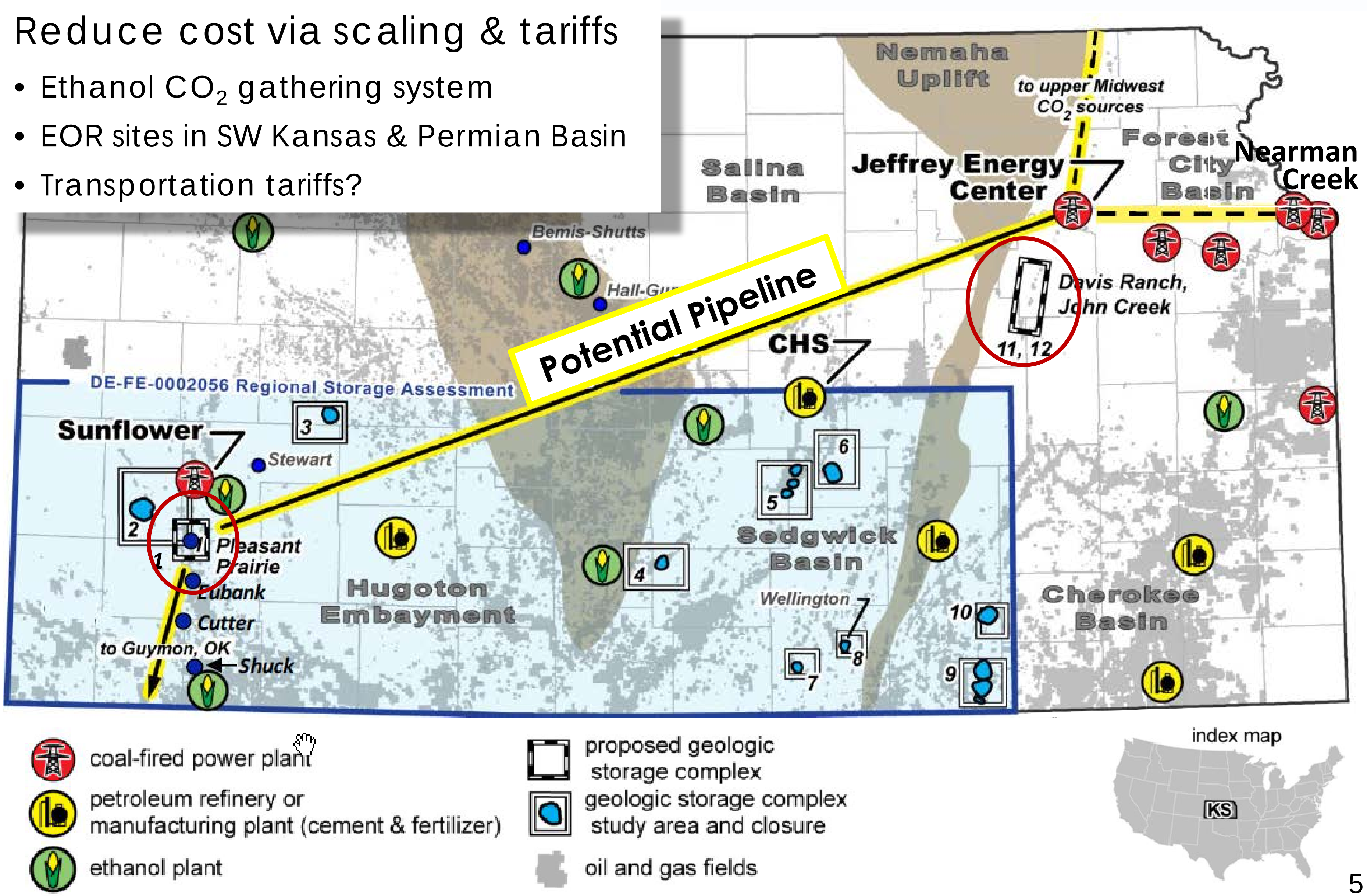
Project Overview: Base Case Scenario

- **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

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

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Minneapolis, MN
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
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
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John W. Mitchell, Director
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Five Oil & Gas Companies

Kansas Oil & Gas Operators
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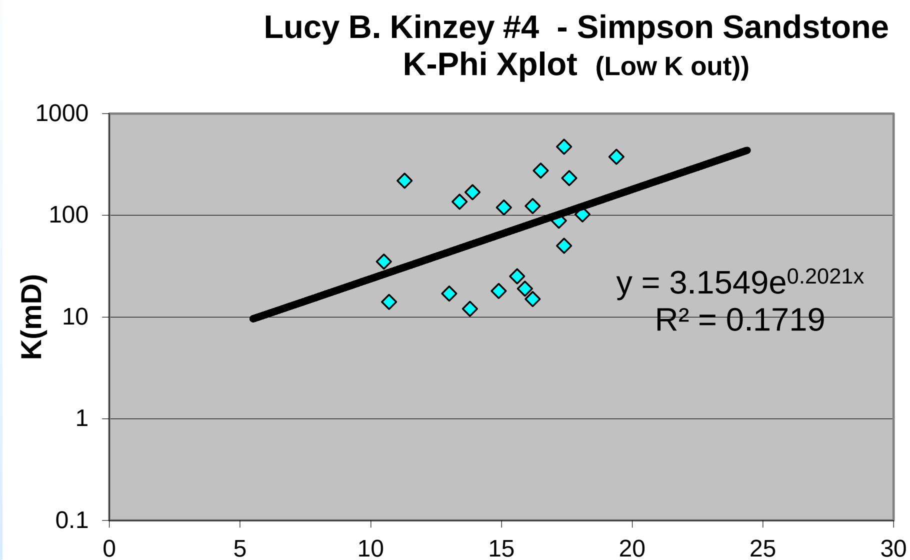
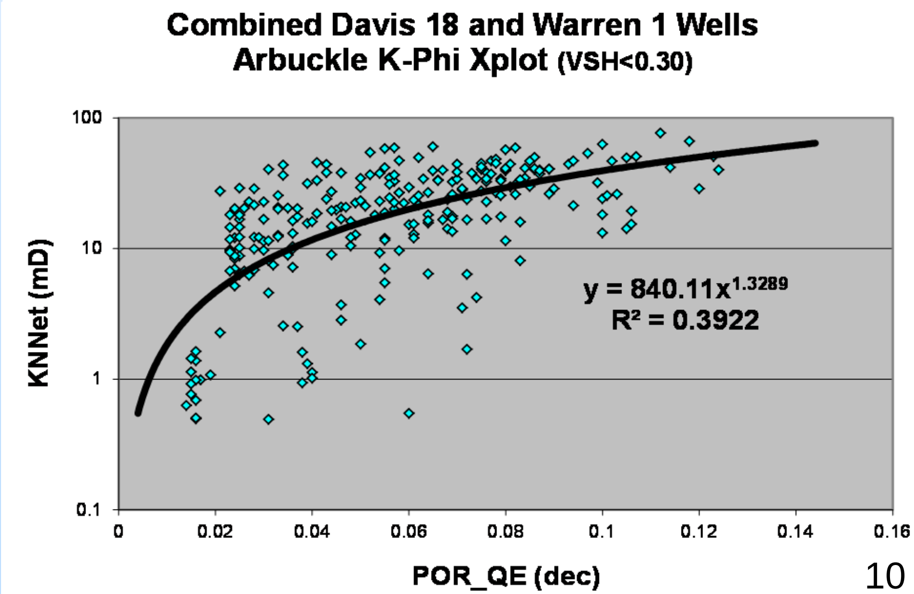
(Davis Ranch and John Creek fields)
Austin Vernon, Vice President
Knighton Oil Company, Inc.
(John Creek Field)
Earl M. Knighton, Jr., President
Casillas Petroleum Corp.
(Pleasant Prairie Field)
Chris K. Carson, V.P. Geology and Exploration
Berexco, LLC
(Wellington, Cutter, and other O&G fields)
Dana 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



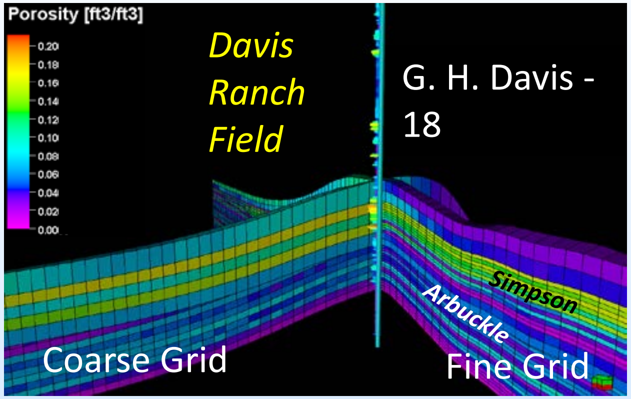


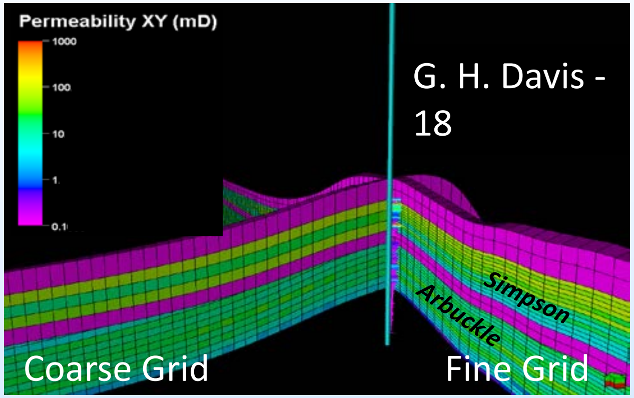
	Average K (mD)	h (ft)	Kh (mD-ft)
Simpson			
Core Analysis (Lucy B Kinzey	105	23	2415
DST Buildup (Vincent 1)	56	25	1400
DST Buildup (Eldridge 4))	182	25	4550
Arbuckle			
Injectivity Index	18	198	3564
Neural Network (Holoday 2)	13	198	2574
Neural Network (Davis 18)	19	60	1140
Neural Network (Warren 1)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

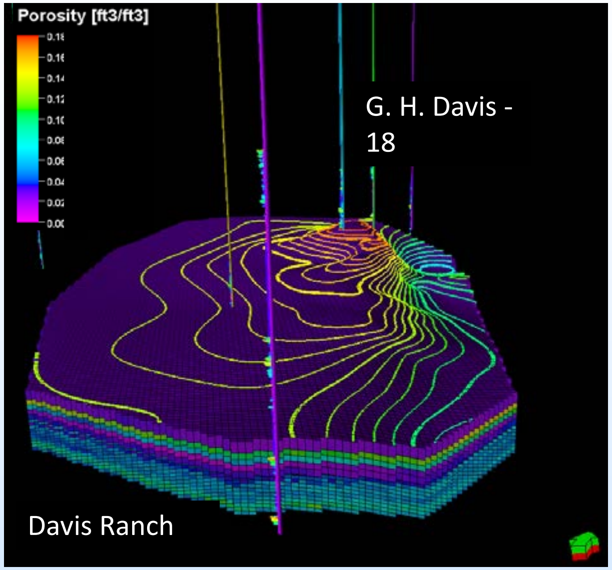
Technical Status

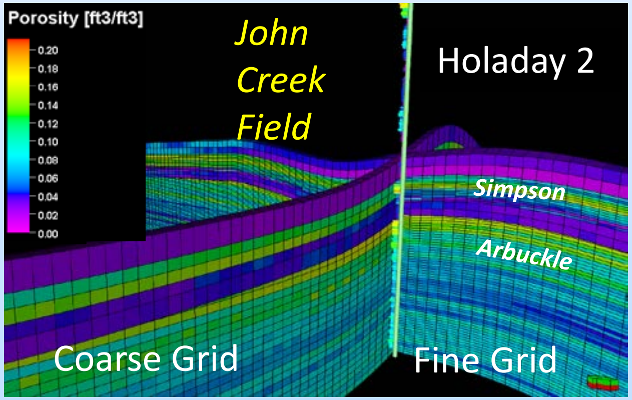
DR & JC Fields: 3D Static Model

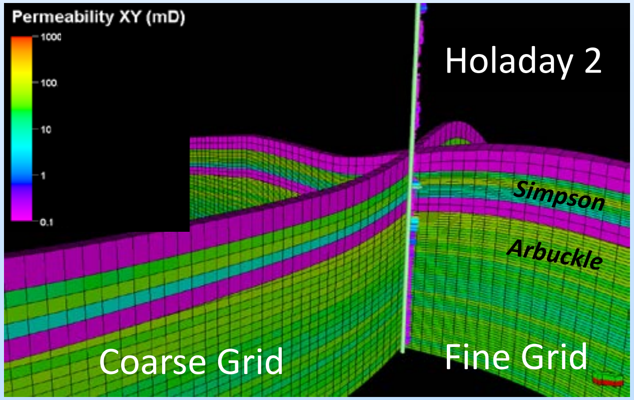
2 target CO_2 injection zones:
Simpson Sandstone and Arbuckle Group

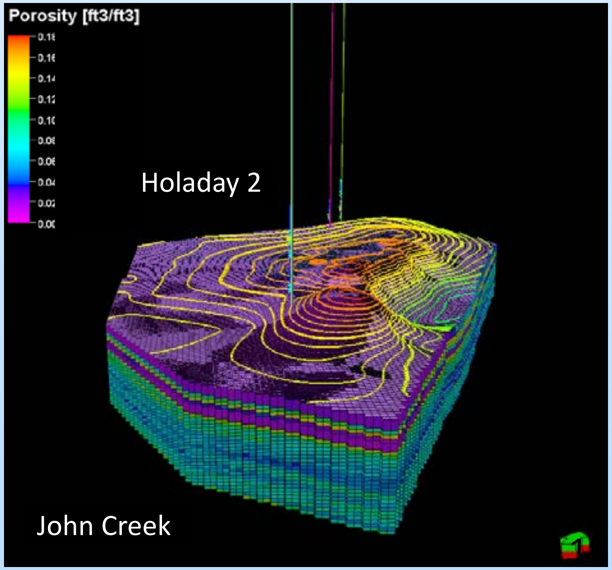












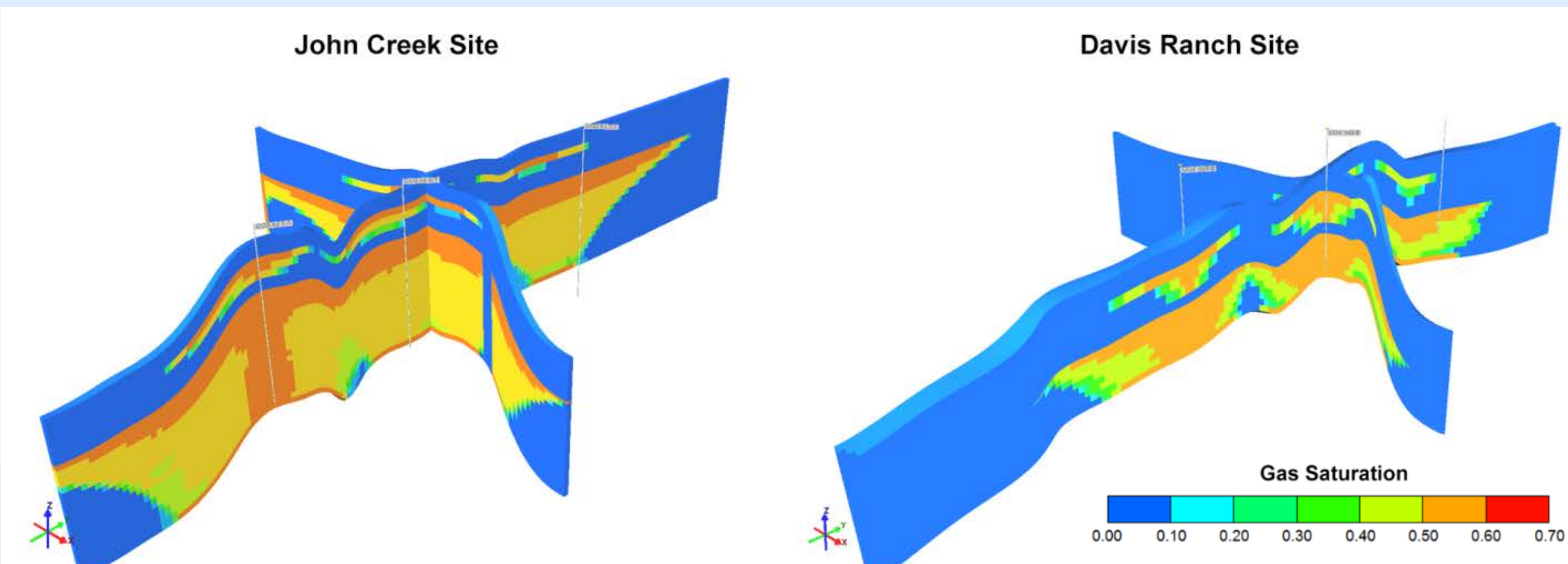
- 360 wells with tops for framework
- Well-scale porosity (half-foot) upscaled to layer-scale and distributed using Gaussian random function
- Permeability calculated using transform

Technical Status

DR & JC Fields: Dynamic Modeling

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

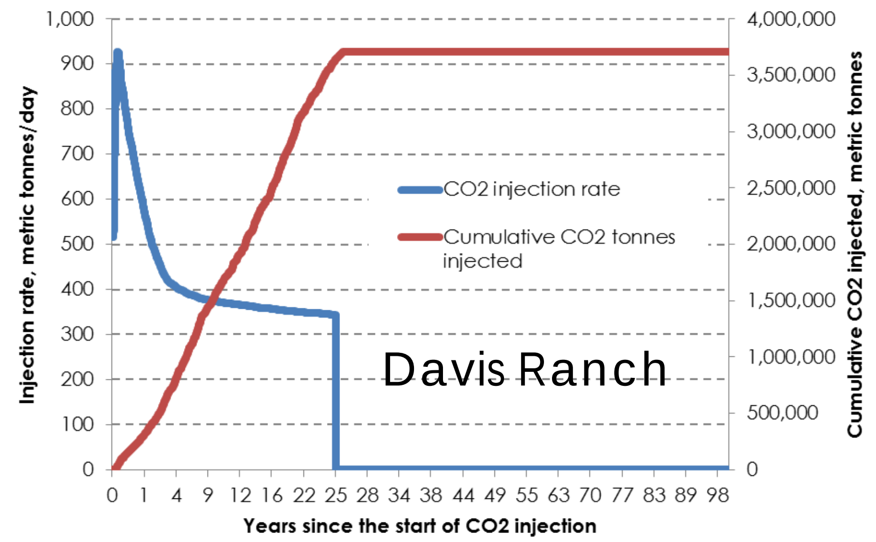
	John Creek	Davis Ranch
Temperature	41 °C (106 °F)	38 °C (100 °F)
Temperature Gradient	0.008 °C/ft	0.008 °C/ft
Pressure	1,160 psi (7.99 MPa)	1,200 psi (8.27 MPa)
TDS	30 g/l	24 g/l
Perforation Zone	Simpson, Arbuckle	Simpson, Arbuckle
Injection Period	25 years	25 years

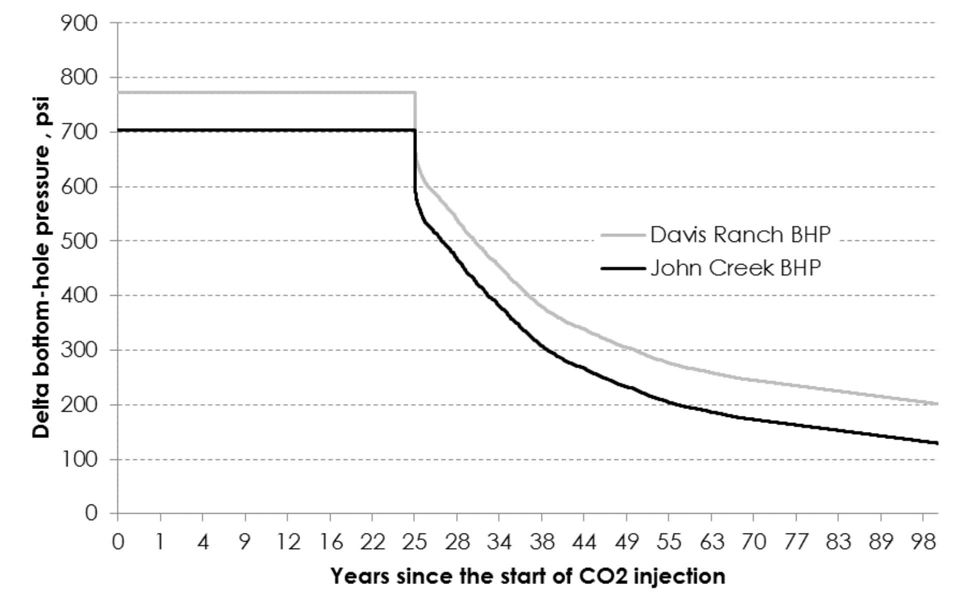


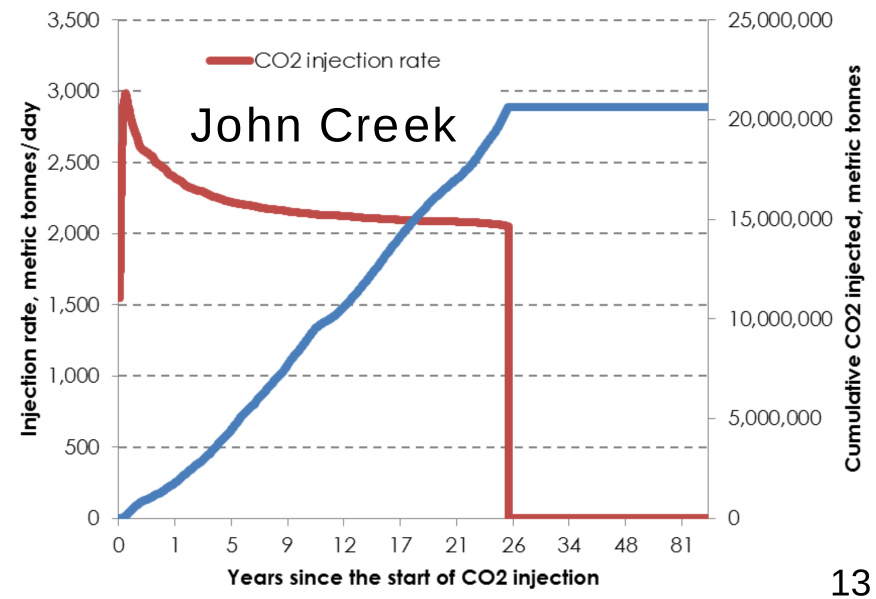
Technical Status

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

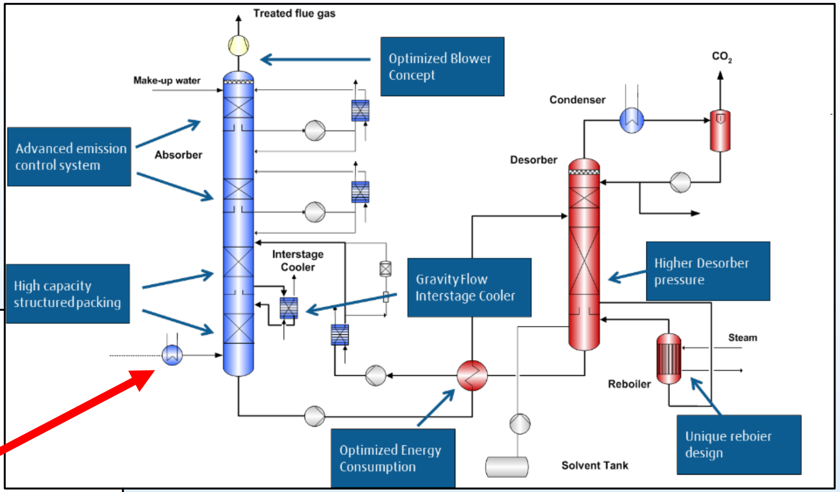
Accomplishments to date:

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)

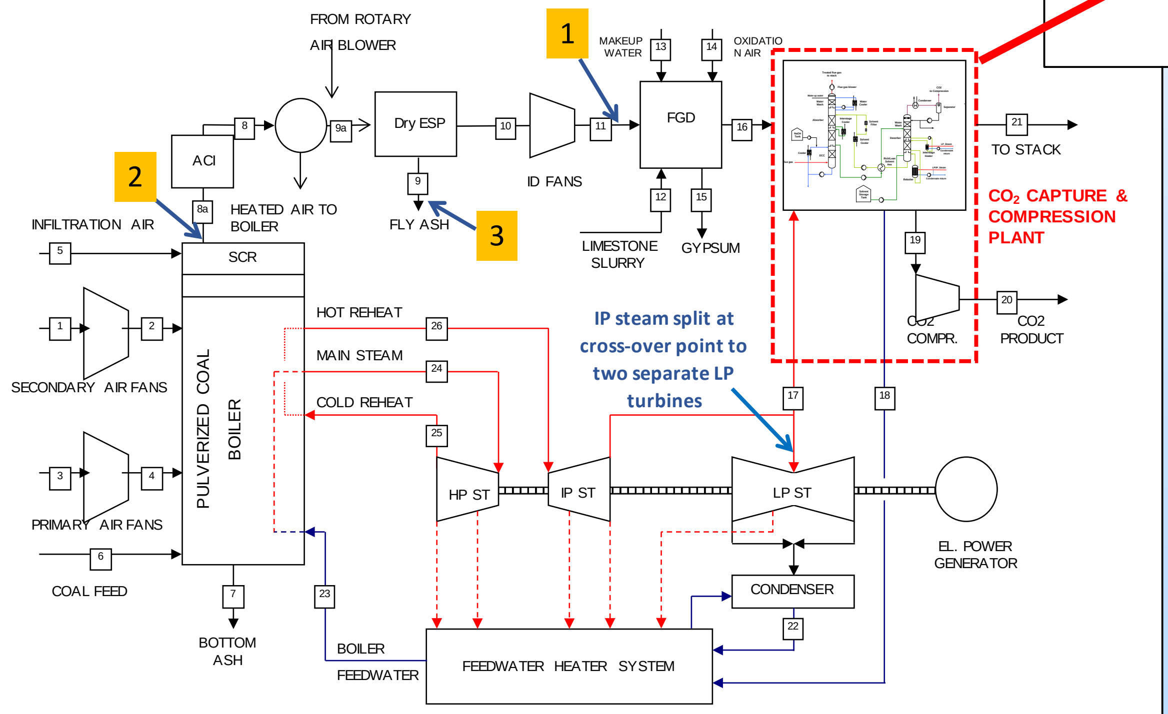
Technical Status
CO_2 Source Assessments

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



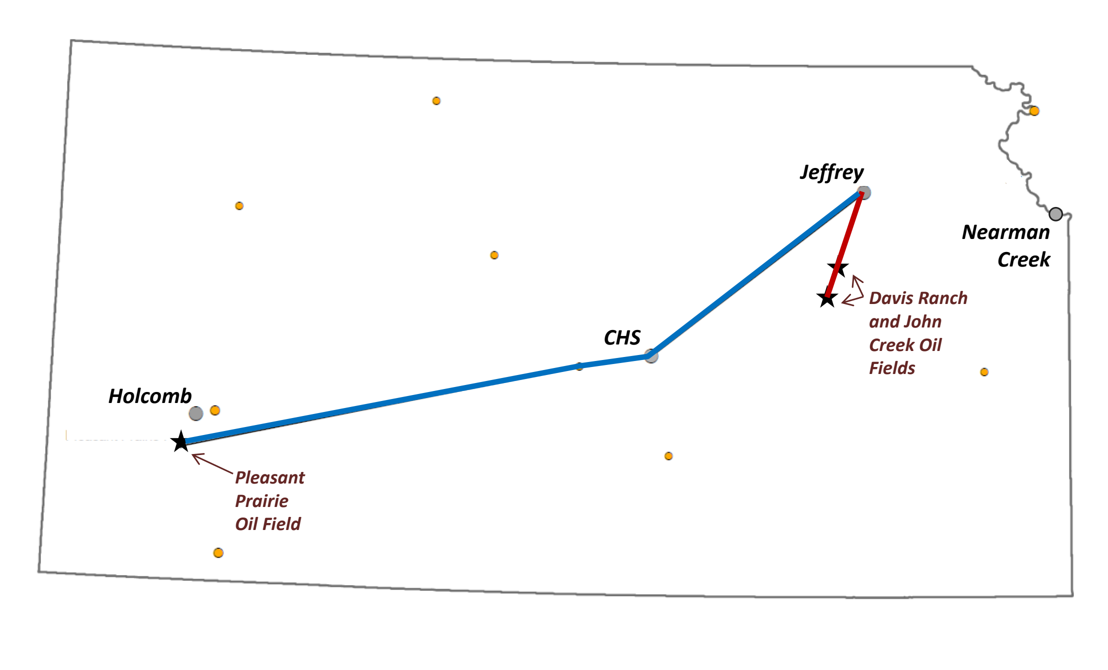
Linde-BASF system

- 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.

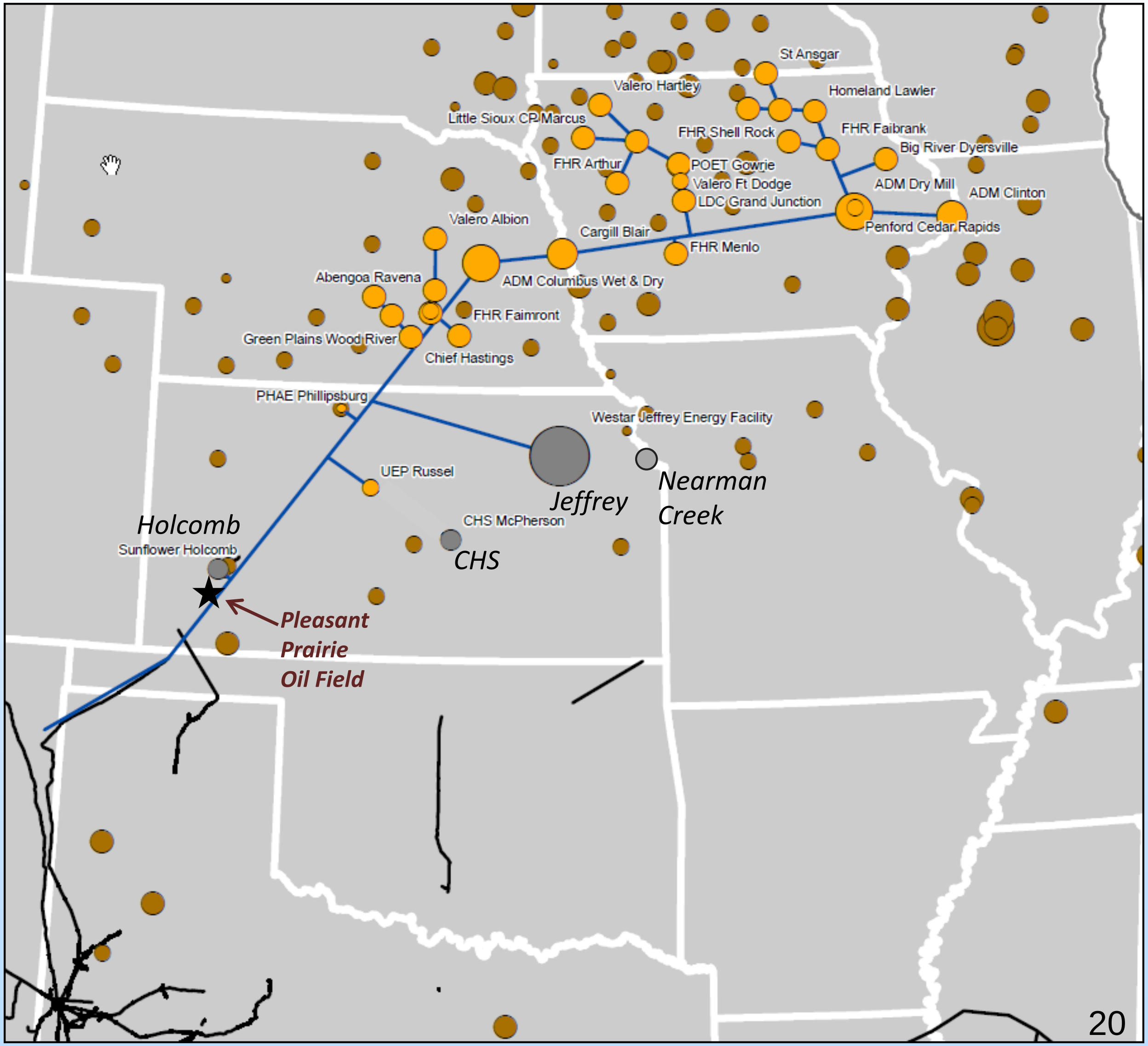
Technical Positives:
- Other saline aquifers (Osage and Viola) that should store 50Mt have been identified in SW Kansas.
- CO_2-EOR storage opportunities

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

DOE Program Goals

Goal 1: Develop & validate technologies to ensure 99 % storage permanence,

Goal 2: Develop technologies to improve reservoir storage efficiency while ensuring containment effectiveness

Goal 3: Support industry's ability to predict CO_2 storage capacity in geologic formations to within ±30 %

Goal 4: Develop best practices for commercial-scale CCS

This Study

Sub-basinal characterizations

Testing site screening tools (i.e., NRAP)

Reservoir & simulation models for geological storage

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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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Base Case Scenario

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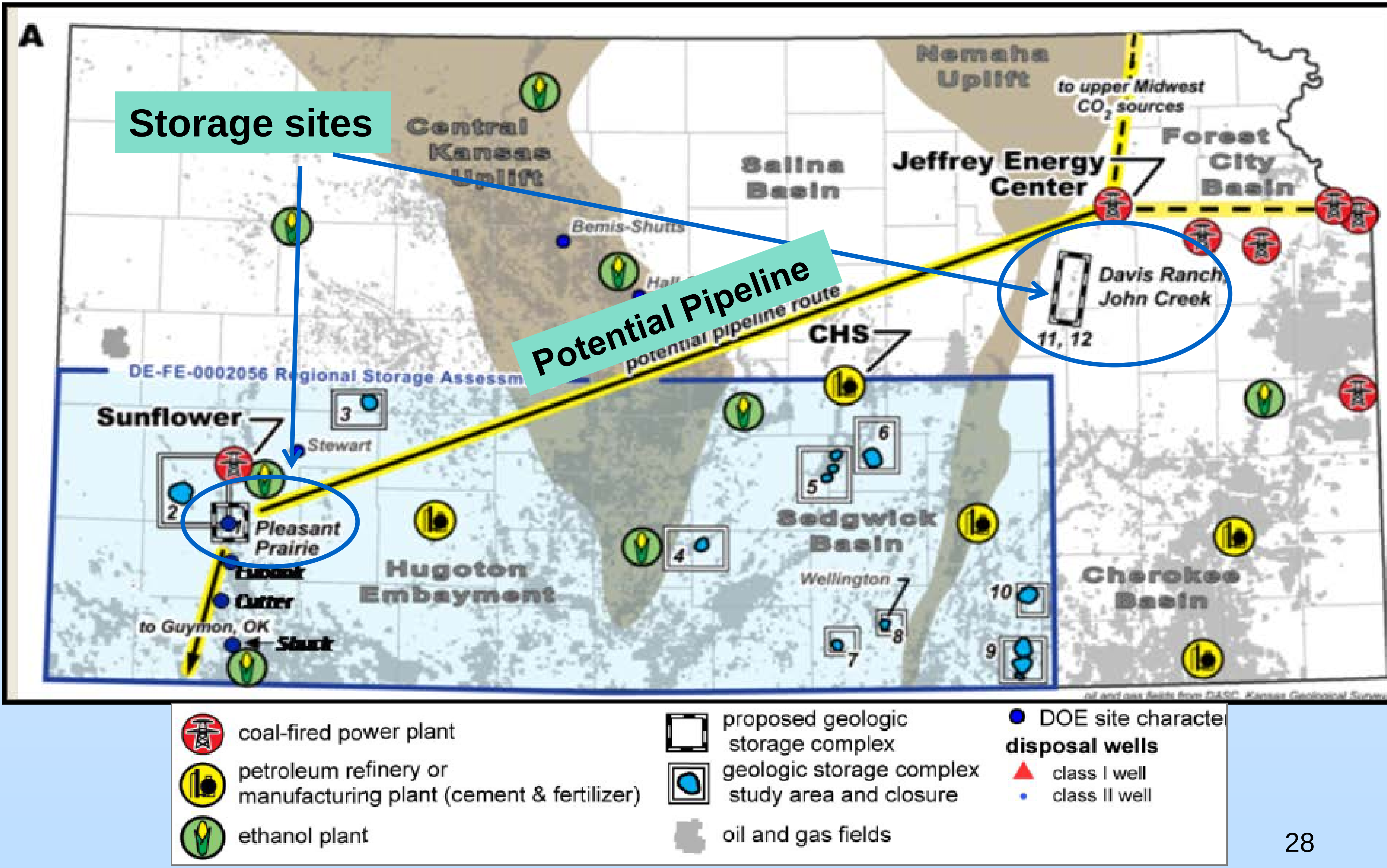
Jeffrey to SW Kansas



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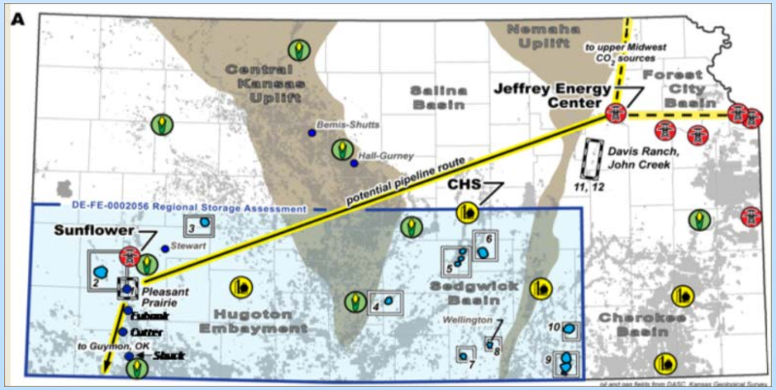
Base Case + Ethanol CO_2

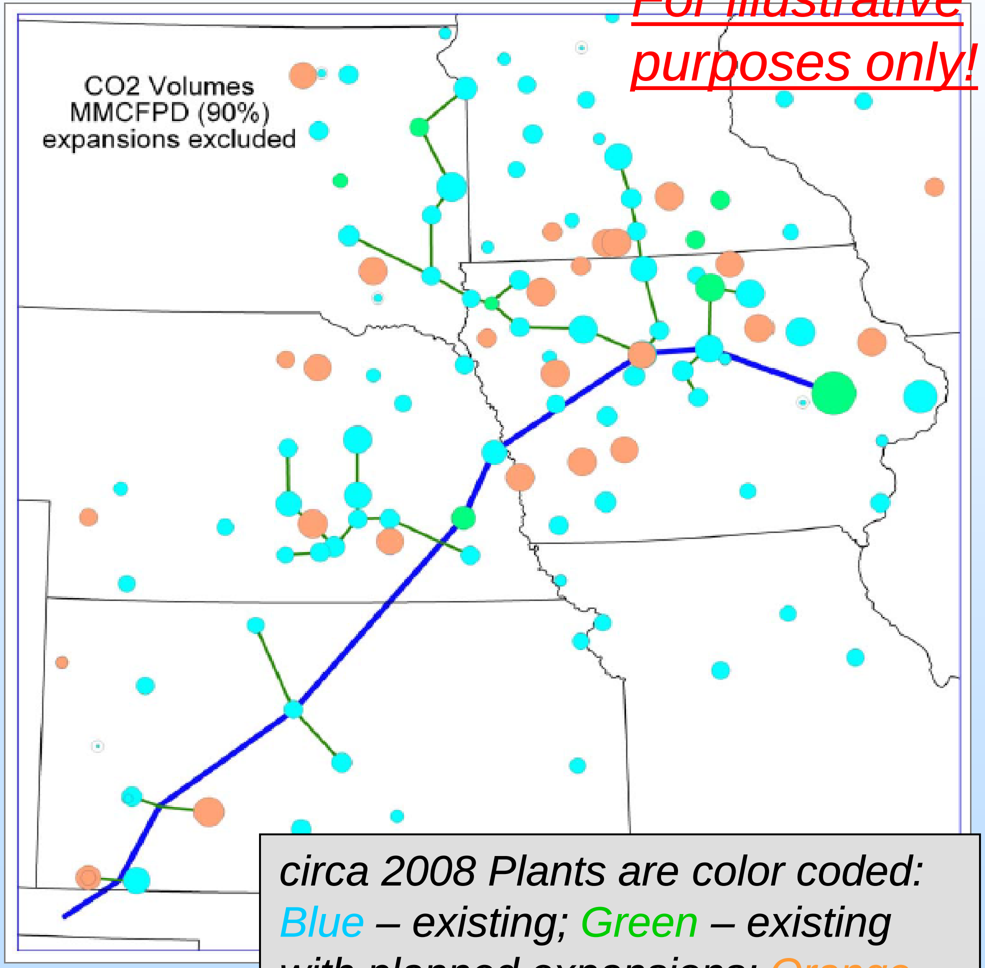
January 2008 private study

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.

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Public Policy (Public Acceptance))

- Identify stakeholders
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- 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

Organization: Phase I Research Team

18 team members, four subcontractors and KGS staff

Project Management & Coordination, Geological Characterization

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Tandis Bidgoli, PI, Assistant Scientist
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Organization: Phase I Industry Partners

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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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