Integrated Midcontinent Stacked Carbon Storage Hub

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Project Team

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- ARI
- Battelle
- Berexco
- Conservation and Survey Div, SNR, UNL
- DGR&M
- Energy and Environment Research Center
- Great Plains Energy
- Great Plains Institute
- Improved Hydrocarbon Recovery
- Kansas Geologic Survey
- LANL
- Loudon Technical Services
- Nebraska Public Power District
- PNNL
- Schlumberger

Introduction

- The Integrated Midcontinent Stacked Carbon Storage Hub plans to gather CO_2 from eastern and central NE and transport it southwest toward Red Willow County, NE along a CO_2-source collection corridor. The CO_2 will then be piped south into central KS along a stacked storage corridor.
- CarbonSAFE Program Objective: Develop a midwestern carbon storage facility having multiple sites with a 50-Mt or greater capacity to safely, permanently, and economically store CO_2 by 2025.

Phase II IMSCS-HUB Objectives

- Objective 1: Demonstrate multiple 50 Mt storage sites for the IMSCS-HUB concept by evaluating a Kansas and Nebraska site, each with the ability to safely, permanently, and economically store anthropogenic CO_2 through stacked-storage.
- Objective 2: Develop 50 Mt+ storage scenarios and provide a basis for UIC permitting.
- Objective 3: Demonstrate long-term seal integrity and minimize induced seismicity.
- Objective 4: Develop strategies to manage and store CO_2 from multiple sources.
- Objective 5: Leverage the data collected to scale the project to develop a regional commercial enterprise (three to ten 50 Mt+ storage sites).
- Objective 6: Identify and mitigate public outreach and regulatory barriers
- Objective 7: Develop a detailed commercial development plan.

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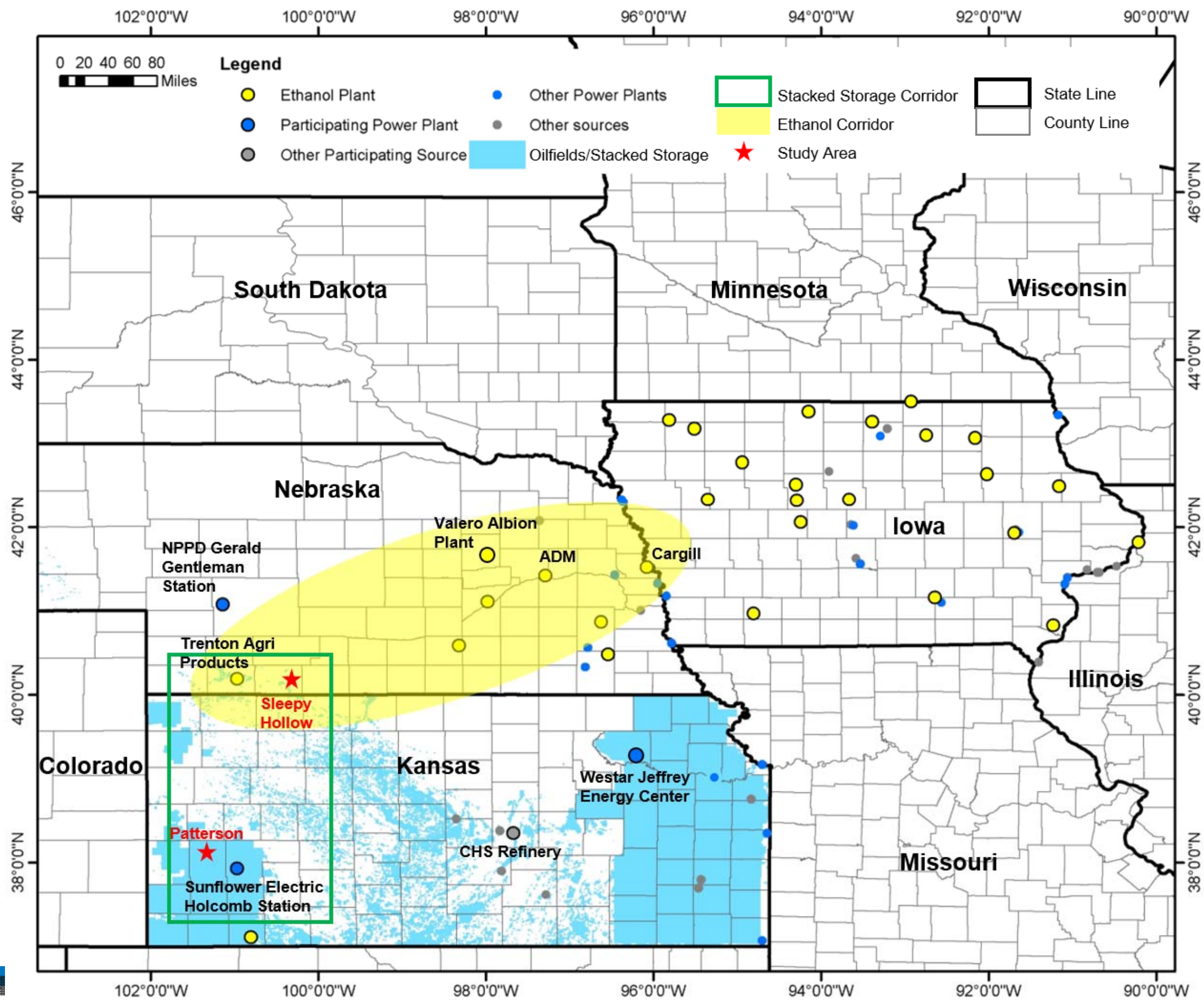
Project Area

- Kansas
- Nebraska
- Kansas



Corridors

- Source Corridor (Initially Ethanol Derived CO_2)
  - Run across IA into NE and then southwest across NE
  - Optimize maximize the number of sources/amount of CO_2 to develop market and infrastructure for CCUS
    - 16 Ethanol plants in the corridor with annual emissions of greater than 5 Mt. Capture in the $12/t range
    - Saline storage at many of the ethanol plants in NE
    - Bring in electric utility generated CO_2 as capture comes on line. Existing market from ethanol derived CO_2 will provide certainty that a utilization market and storage is possible
    - 5 other sources (4 electric utility and 1 refinery) with 20 Mt annual emissions. Capture in the $57/t range (NETL 2015)
- Stacked Storage Corridor
  - Run from SW NE southeast into SW KS
    - Saline storage and CO_2 EOR
    - Co-locate infrastructure for Saline and CO_2 EOR.

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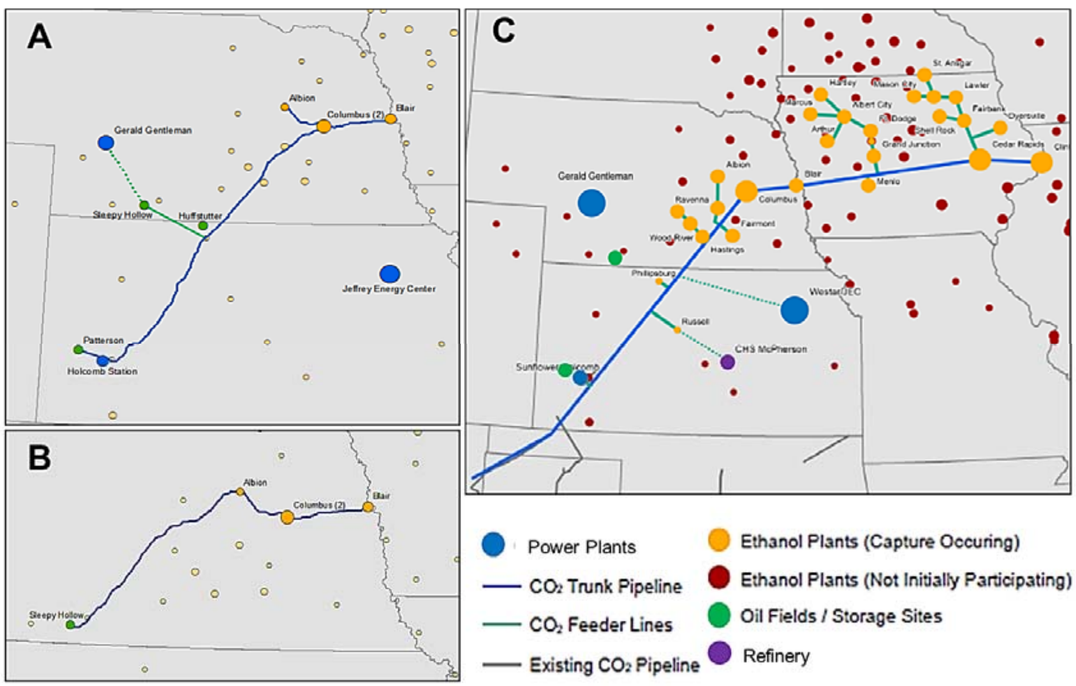
Phase I Economic Analysis

Scenario	Source(s)	Sink(s)	Pipeline (mi)	Pipeline Route
1	CAB ethanol plants	Sleepy Hollow	344	From sources to storage sites via oil fields
2	CAB ethanol plants	Sleepy Hollow	295	Direct from sources to storage site
3	GGS power plant	Sleepy Hollow	79	Direct from source to storage site
4	34 ethanol plants	Permian Basin	1,546	Direct from sources to Permian Basin



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Phase I Project Economics

Capture and Transport Cost Parameters	Source-Sink Scenarios and Costs* Summary			
	1	2	3	4
Pipeline CapEx ($Million**)	$303	$272	$80	$1,857
Pipeline Annual OpEx ($Million)***	$4.40	$3.70	$1.20	$47
Capture CapEx ($Million)	$132	$132	$1,143	$809
Capture Annual OpEx ($Million)	$16.80	$16.80	$17.20	$84.50
Economics - Capture and Transportation	**CO_2 Price Required for 7% Rate of Return**			
Pipeline Total ($/tonne)	$24.48	$22.13	$4.98	$31.99
Capture Total ($/tonne)	$18.30	$18.44	$71.49	$20.44
Combined Capture and Pipeline Total ($/tonne)	**$42.78**	**$40.57**	**$76.47**	**$52.43**

*2016 USD; **4, 6, 8, 12, 16, and 20-inch pipe size divisions

Deep Saline Storage Cost Parameters	Source-Sink Scenarios and Costs Summary		
	1	2	3
Number of Injection wells	3	3	3
Average Injection Rate Per Well (kt/day)	1.80	1.70	1.64
Average Storage Zone Depth (ft)	3,112	3,112	3,112
Injection Duration (years)	20	20	20
Total Annual Storage Rate (Mt/year)	1.96	1.96	2.00
Cumulative CO_2 Storage at 20 years (Mt)	39	39	40
Total OpEx ($Million)	$821	$821	$837
Total CapEx ($Million)	$94	$94	$96
Total Storage Project Costs ($Million)	**$915**	**$915**	**$933**
– in $/tonne CO_2	**$23**	**$23**	**$23**
Total Storage Project 45Q Credits ($MM)	$1,416	$1,416	$1,445
Net Present Value of Storage Project – w/45Q ($Million)	**$358**	**$358**	**$365**
– in $/tonne CO_2	**$9.13**	**$9.13**	**$9.14**

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Phase I CO_2 EOR

Per Pattern CO_2-EOR Cost Model Results		Source-Sink Scenario		
		1	2	3
CO_2 Cost ($/tonne)		$18.30	$18.44	$71.49
Total CO_2 stored (kilotonne)		70	70	70
w/45Q EOR Storage Credits	Net Revenue ($Million)	$12.58	$12.58	$12.58
	Total Capital Costs ($Million)	$1.17	$1.17	$1.17
	Total O&M Costs ($Million)	$6.36	$6.37	$10.06
	Total Project Costs ($Million)	$7.52	$7.53	$11.22
	Net Present Value of EOR - ($Million)	**$2.97**	**$2.96**	**$1.34**
	- in $/tonne CO_2	**$42.43**	**$42.29**	**$19.14**
w/out 45Q EOR Storage Credits	Net Revenue ($Million)	$11.08	$11.08	$11.08
	Total O&M Costs ($Million)	$1.13	$1.13	$1.13
	Total Capital Costs ($Million)	$6.10	$6.11	$9.80
	Total Project Costs ($Million)	$7.22	$7.23	$10.93
	Net Present Value of EOR - ($Million)	**$2.15**	**$2.14**	**$0.51**
	- in $/tonne CO_2	**$30.71**	**$30.57**	**$7.29**

Storage: Geology

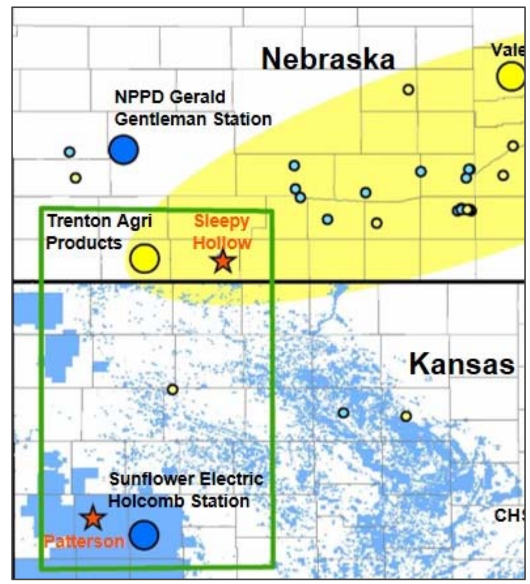
STRATIGRAPHY*

Era	Period	Southwest Nebraska		Southwest Kansas	
Paleozoic	Permian	Nippewalla	caprock	Nippewalla	caprock
		Sumner		Sumner	
		Chase	baffle	Chase	gas-bearing
		Council Grove	caprock	Council Grove	
	Pennsylvanian	Admire		Admire	baffle and deep saline
		Wabaunsee	deep saline	Wabaunsee	
		Shawnee		Shawnee	
		Douglas		Douglas	
		Lansing-Kansas City	oil-bearing	Lansing-Kansas City	oil-bearing
		Pleasanton	deep saline	Pleasanton	baffle and deep saline
		Marmaton		Marmaton	
		Cherokee		Cherokee	caprock
		basal sandstone	oil-bearing	Atoka	
				Morrow	oil-bearing
	Missippian			Chester	oil-bearing
				Meramec	baffle
				Osage	deep saline
				Kinderhook	baffle
	Devonian				
	Silurian				
	Ordovic-ian			Viola	deep saline
				Simpson	
				Arbuckle	
	Cambrian			Reagan	bottom barrier
Precambrian		crystalline basement			

** formal lithostratigraphic group and stage names used unless otherwise noted; not to scale*

LEGEND:

- *shale + limestone*
- *shale + sandstone + limestone*
- *shale + limestone ± evaporite*
- *shale + sandstone*
- *limestone ± shale*
- *sandstone + limestone ± shale*
- *sandstone*
- *dolomite*
- *igneous and metamorphic rocks*
- *major unconformity*



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Storage: Capacity

- The DOE-NETL volumetric methodology for deep saline formations was used to calculate the prospective storage resource of the deep saline storage zones at each potential site (DOE-NETL, 2010; Goodman et al., 2011, 2016).

Selected Area	Deep Saline Storage Zone	Prospective Storage Resource (Mt)		
		P_{10}	P_{50}	P_{90}
SW Kansas (Patterson)	Osage	12.3	24.6	49.0
	Viola	9.9	16.7	28.1
	Arbuckle	7.8	19.2	47.5
	Total	**30.0**	**60.4**	**124.6**
SW-Central Nebraska (Sleepy Hollow)	Wabaunsee	14.0	27.7	48.9
	Topeka	5.9	11.0	17.2
	Deer Creek-Oread	5.7	11.7	23.3
	Lansing-Kansas City A	2.5	7.0	13.9
	Lansing-Kansas City D-F	16.4	25.9	37.4
	Pleasanton-Marmaton	5.2	10.7	19.0
	Total	**49.7**	**94.0**	**159.6**

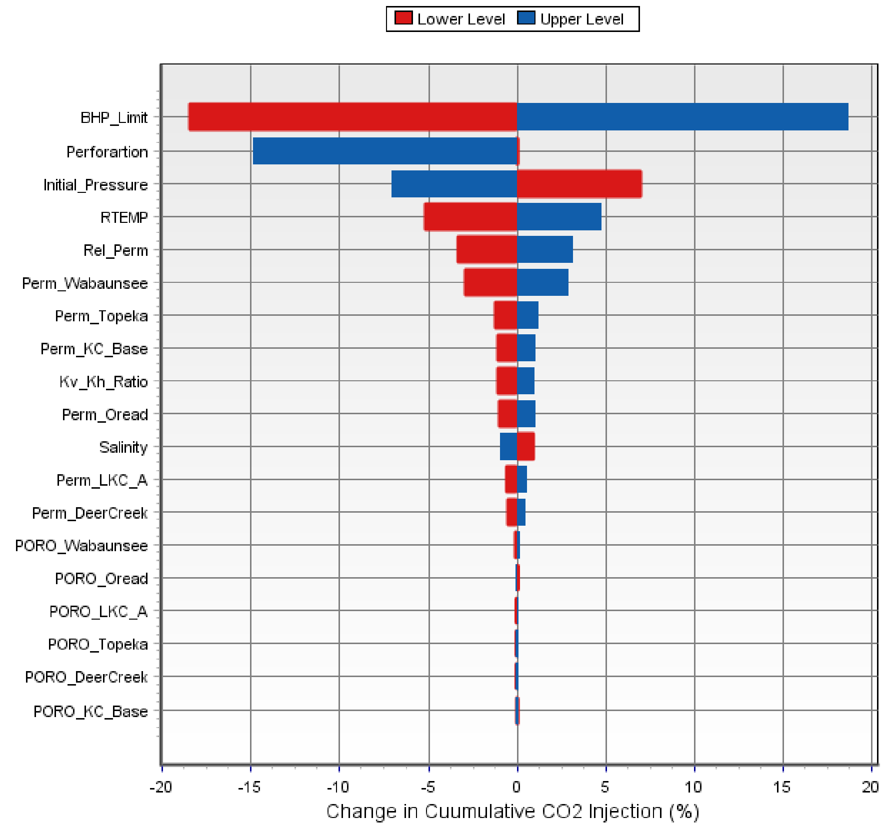
Storage: New Data Collection Planning

Data Gap Assessment. The team will consider the UIC Class VI requirements and storage model uncertainty to ensure that any data gaps for permitting are identified and filled.

- Identify gaps in each model
- Identify uncertainty in each model

Storage Complex Data Collection Plan. The plan will cover the seismic survey, new wells at all sites, and existing wells at Sleepy Hollow Field

- Rank gaps
- Prioritize missing data
- Create Data Collection Plan



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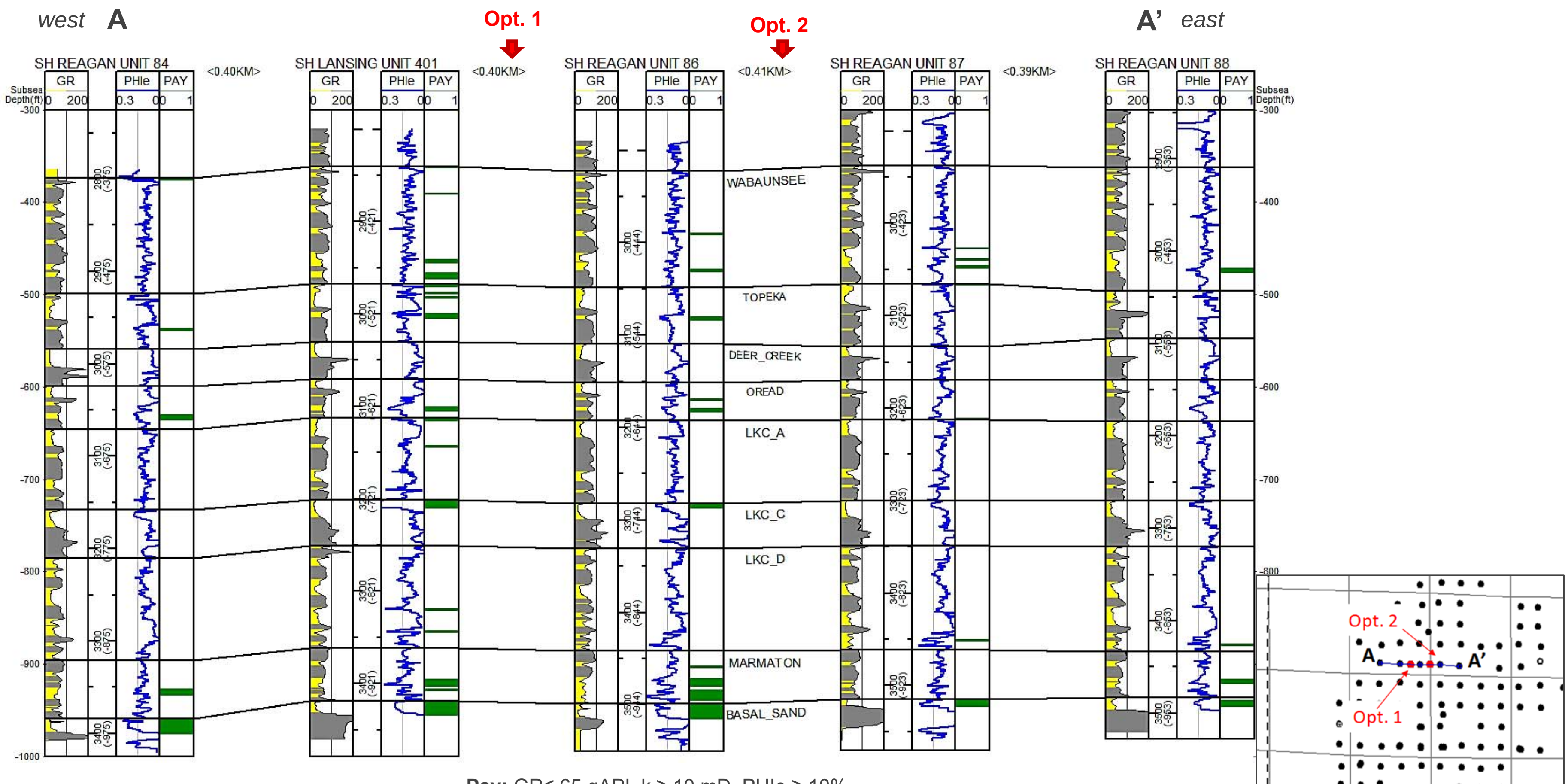
New Data Collection at Sleepy Hollow Field



Pay: GR≤ 65 gAPI, k ≥ 10 mD, PHIe ≥ 10%

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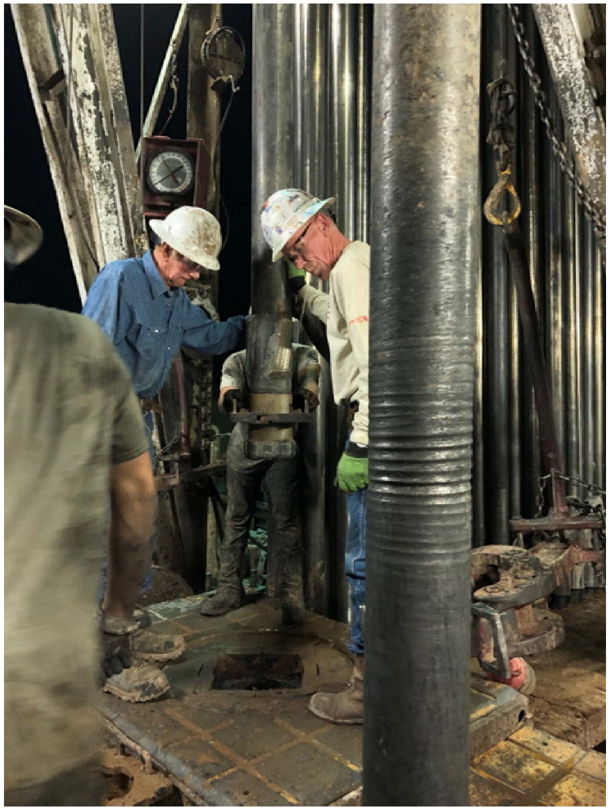
New Data Collection at Sleepy Hollow Field



- Focus on deep saline intervals in the Pennsylvanian Wabaunsee, Shawnee-Douglas, and Pleasanton-Maramaton groups and caprocks of the Council Grove and Sumner groups
- **Whole Core: 110 ft**
  - **Admire, Wabaunsee, Oread, Marmaton**
- **Sidewall cores: 28**
- **Logs:**
  - **Triple Combo**
  - **Nuclear Magnetic Resonance**
  - **Dipole Sonic**
  - **Formation Micro Image**
  - **Elemental Capture Spectroscopy**

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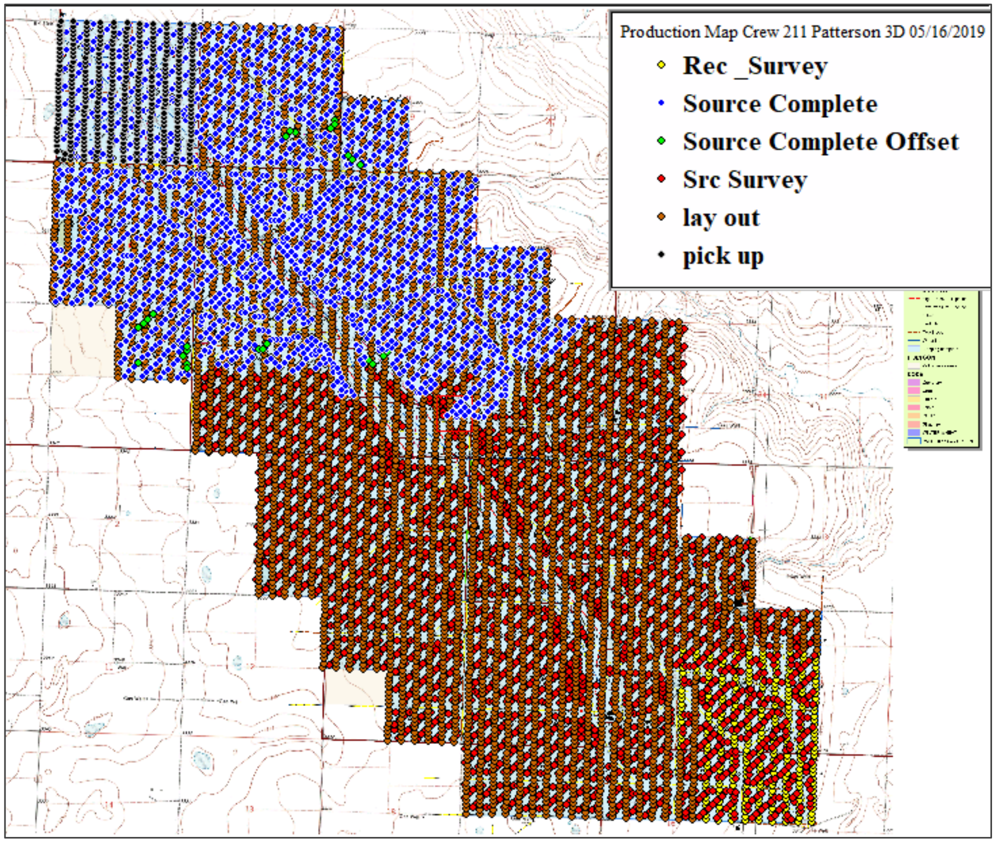
New Data Collection at Patterson Heinitz Hartland



Patterson will focus on Mississippian and Ordovician deep saline storage zones within the Osage, Viola, and Arbuckle formations, and confining units such as the Meramec, Morrow and Sumner Group.

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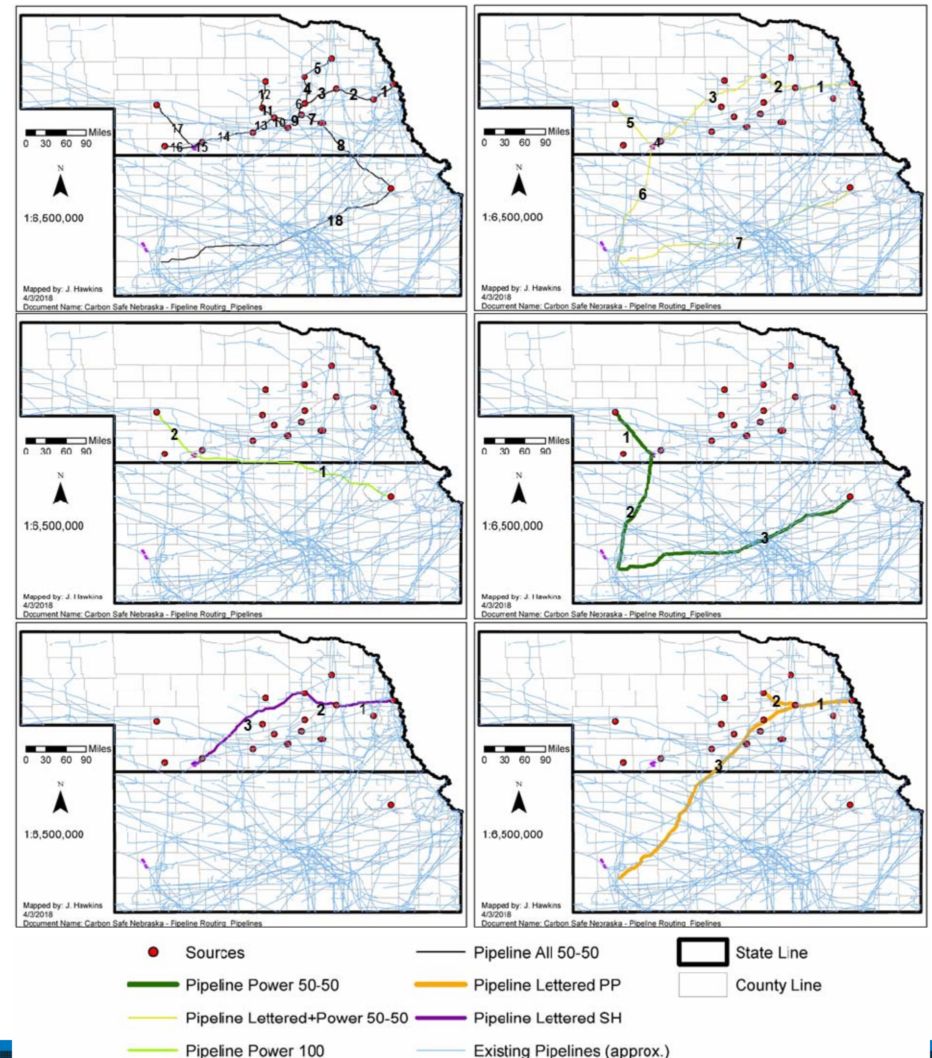
Pipeline Routing

- Ethanol plants in the region use natural gas as a fuel for processing corn.
  - Natural gas pipelines run to every ethanol plant in Nebraska and Kansas.
  - These pipelines occur within 3 miles of each potential site in Nebraska and Kansas.
- Routes generated the weighted-cost surface involves laying a grid overtop of the geographic area and determining the cost to traverse from one cell to a neighboring cell.
- Included Kansas and Nebraska existing pipeline rights of way
- Sources were hardwired into the system



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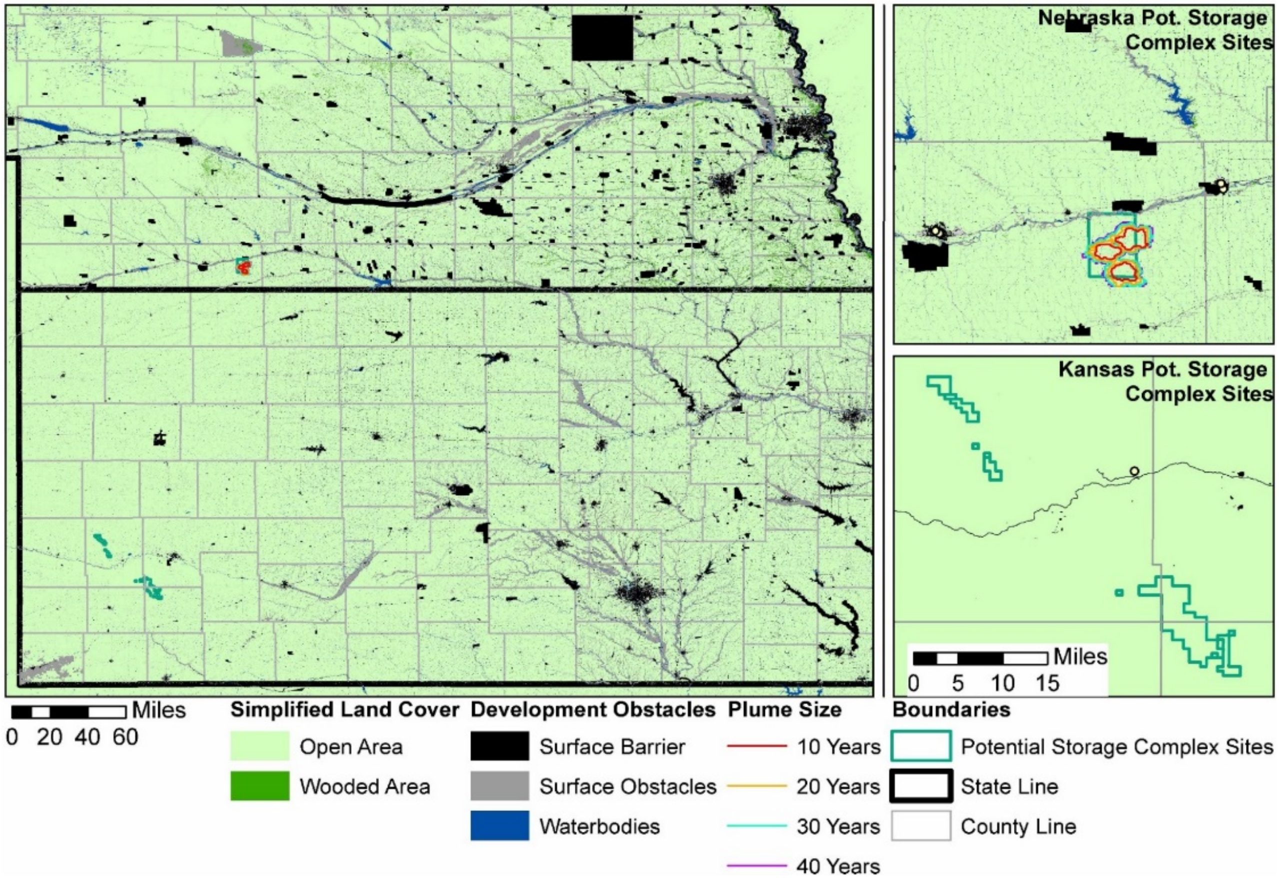
Geographic barriers

- Air Quality
- Surface Water
- Aquifers
- Wetlands
- Vegetation/Land Cover
- Land Ownership
- Protected Lands
- Historic Places
- Wildlife
- Mines
- Contaminated Sites
- Socioeconomic Resources



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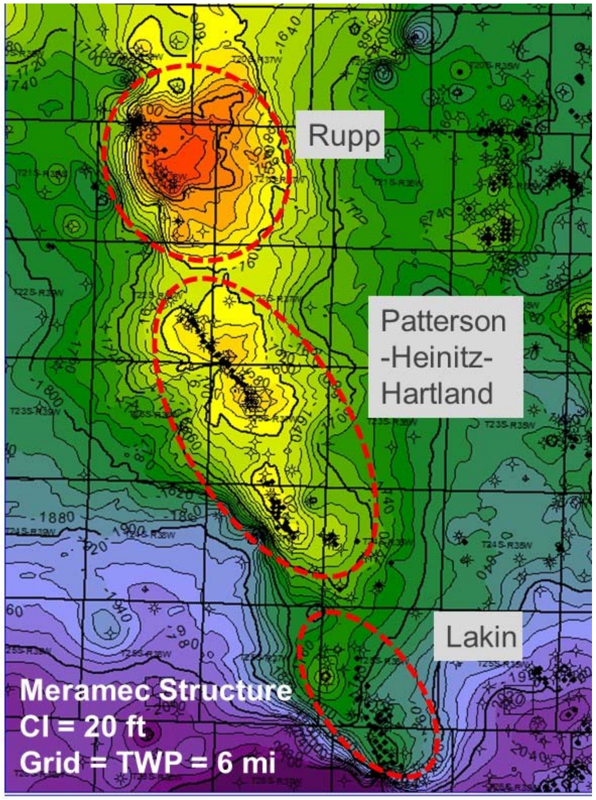
Summary

- New Data Collection based on uncertainty and gap assessment is ongoing
  - Sleepy Hollow Field: Characterization well drilled and cemented. Core, log, and teste data are under analysis or being added to the geologic model
  - Paterson Heinitz Hartland Field: 3D seismic collected for Patterson and Hartland was acquired and is being reprocessed
  - New data will be incorporated to site models to update the number and location of planned injection and monitoring wells allowing an update to the storage costs
- Updated pipeline model under development that will allow for better estimate of pipeline distances and diameters that will allow better estimate of transport costs



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Thank you!

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Companion Talk:

Integrated Midcontinent Stacked Carbon Storage Hub Phase II: Storage Complex Data Collection Planning

Joel Main

Session 10, 6:00-6:20 PM Wednesday July 17, 2019

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