CO_2 Capture and Utilization, a Genuine Opportunity for Kansas Operators

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(email for copy)

In collaboration with

Kansas Geological Survey

Why we are here today

45Q tax credits are a game changer, making a variety of CCUS projects (CO_2 EOR) technically and economically feasible.

Kansas operators are well-positioned

- Kansas candidate oil fields delineated
- Within pathway of possible large-scale CO_2 pipeline system

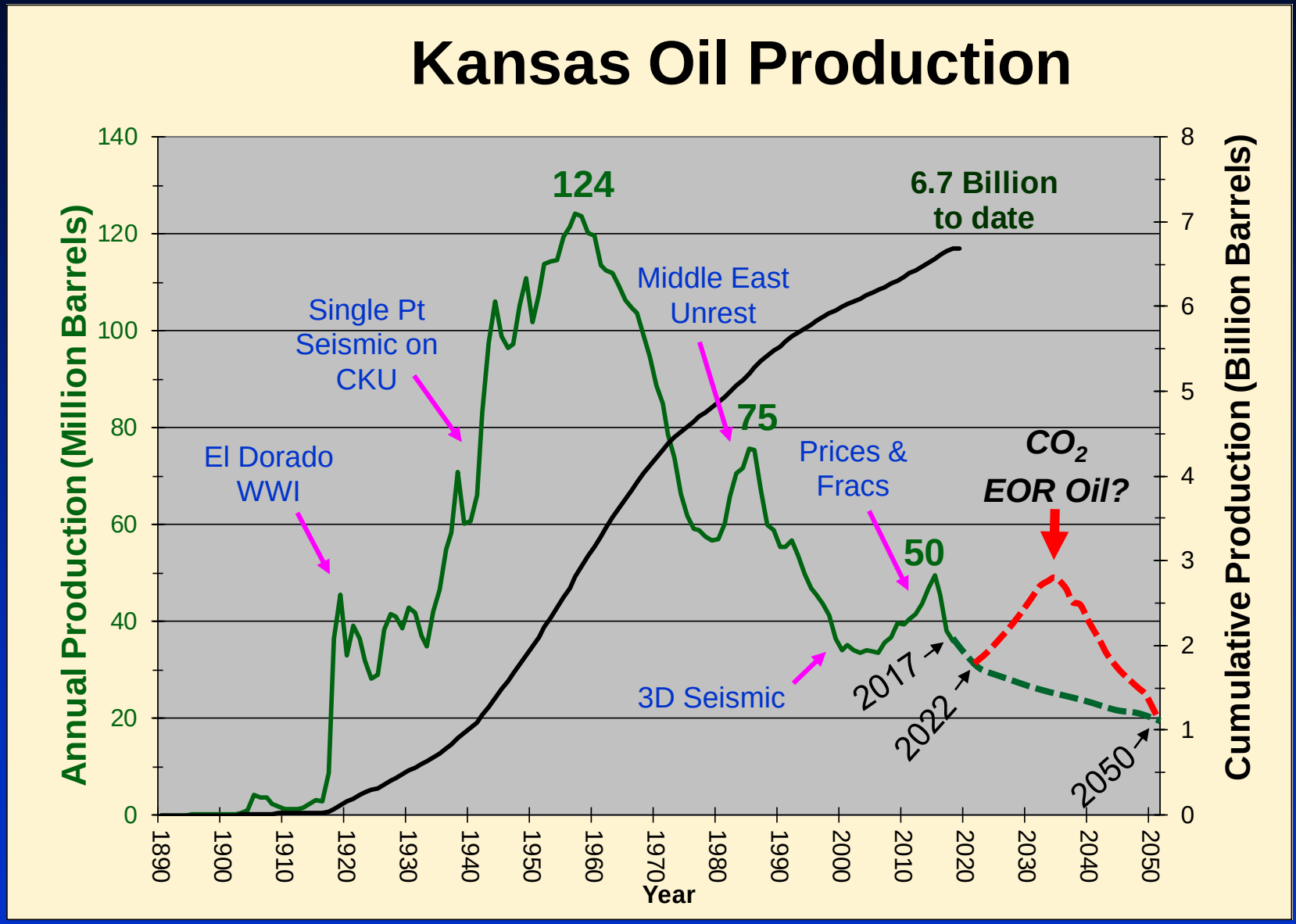
CO_2 captured in NE and KS ethanol plants could be transported to Kansas oil fields for $14 per tonne ($0.75/mcf).

- Kansas oil production could increase by 28% (10 million BO/yr) through EOR by injecting 4.3 Mt/yr (221 mmcf/d).

Hurdles yet to cross

- 45Q tax credit implementation rules resolution
- Aggregation of sufficient oil field assets (CO_2 market) to justify

Kansas Oil Production



So, how much is 10 million barrels per year?

- ✓ 28% of Kansas current production
- ✓ 27,000 BOPD
- ✓ Equals top 8 Kansas producers combined
- ✓ $600,000,000 gross sales @ $60/barrel
- ✓ $12 Billion over 20 years

Top 8 Producers in Kansas

Rank in KS	Million BO/yr	% of Kansas
1	3.5	9.7
2	1.6	4.4
3	1.2	3.5
4	1.1	3
5	0.9	2.5
6	0.7	1.8
7	0.5	1.5
8	0.5	1.4
Total	9.9	27.8

And, what tax credits could be captured?

Hypothetical Scenarios

- ✓ Construction in 2020; Injection in 2022
- ✓ Tax credits average $33/tonne CO_2 stored (for EOR) over 12 year period

	Kansas ethanol plant	Potential Kansas Field	Large-scale pipeline to Kansas
CO_2 Volume (Mt/yr)	0.15	0.5	4.3
Annual **Tax Credits** ($Million)	$5M	$17M	$142M
12-years of Credits ($Million)	$59M	$198M	$1,703M

Outline

1. CO_2 Basics
   - The magical fluid
   - CO_2 EOR for 40+ years
   - Expansion of industrial CO2 for EOR
2. Kansas Readiness
   - Industry-Kansas Geological Survey collaborations
   - Integrated CCS for Kansas (current)
   - Kansas CO2 EOR oil resources
3. 45Q tax incentives expansion and extension
   - 45Q tax credits discussion
   - Economics for capture, transportation, injection
4. Wrap-up and Q&A

CO_2 conversions, scales and "green" oil

Units/volumes

• 1 tonne (metric ton)	1.1 tons
• **1 tonne CO_2**	**19 mcf**
• 1 million tonnes	19 bcf

CO_2 production at varying scales

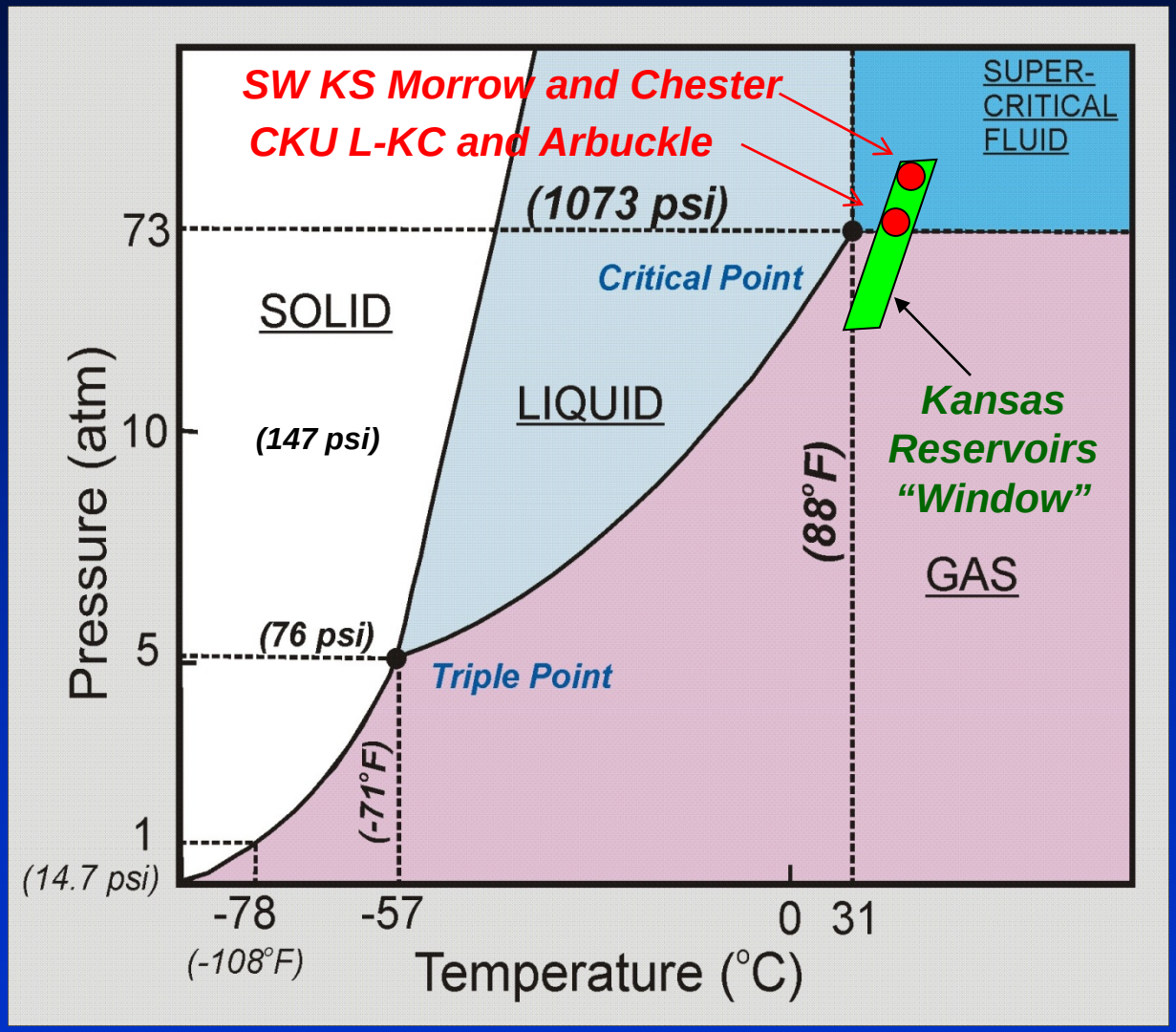
• **Small Ethanol plant (55mgy)**	**8.3 mmcfd**	**0.17 Mt/yr**
• Large Ethanol plant (313mgy)	50 mmcfd	0.94 Mt/yr
• **Jeffrey Energy Center**	**650 mmcfd**	**12.5 Mt/yr**
• **CO_2 delivered for EOR**	**3500 mmcfd**	**66.3 Mt/yr**

How "green" is anthropogenic CO_2 EOR?

- Combustion of 1 barrel of oil yields 8 mcf CO_2
- For every barrel produced ~8 mcf CO_2 is permanently left in the reservoir
- Stores as much CO_2 as is released upon combustion

CO_2 – the *magical* fluid

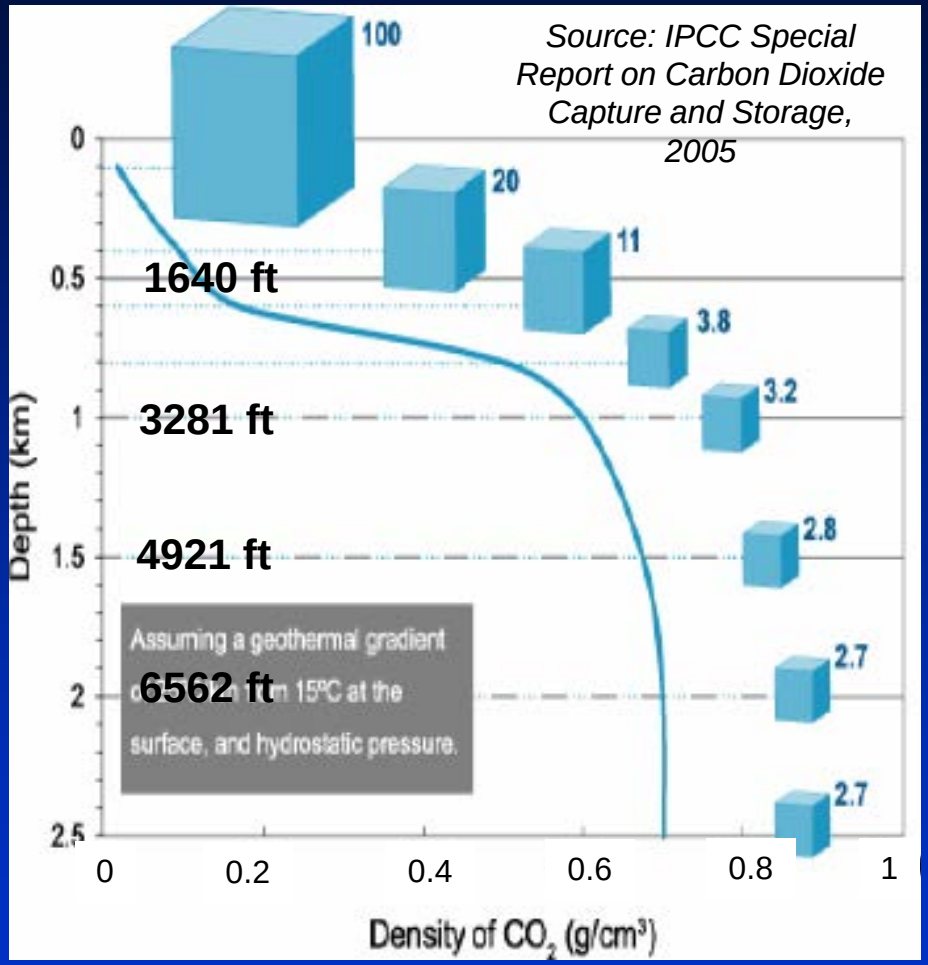
CO2 Phase Diagram



Modified after Condren www.cbu.edu/~mcondren/CO2_phase_diagram.jpg

- Miscible floods must operate at greater than supercritical (1073 psi) and MMP (>1200 psi)
- Kansas reservoirs ambient properties range: 400 psi and 85F at 1000 ft and 1600 psi and 125 F at 6000 ft.

CO_2 Volume with Depth (P&T)



Relative volume for CO2 under "normal" pressure and temperature conditions. Kansas is under-pressure

Relevance to storage capacity

SW KS Morrow and Chester

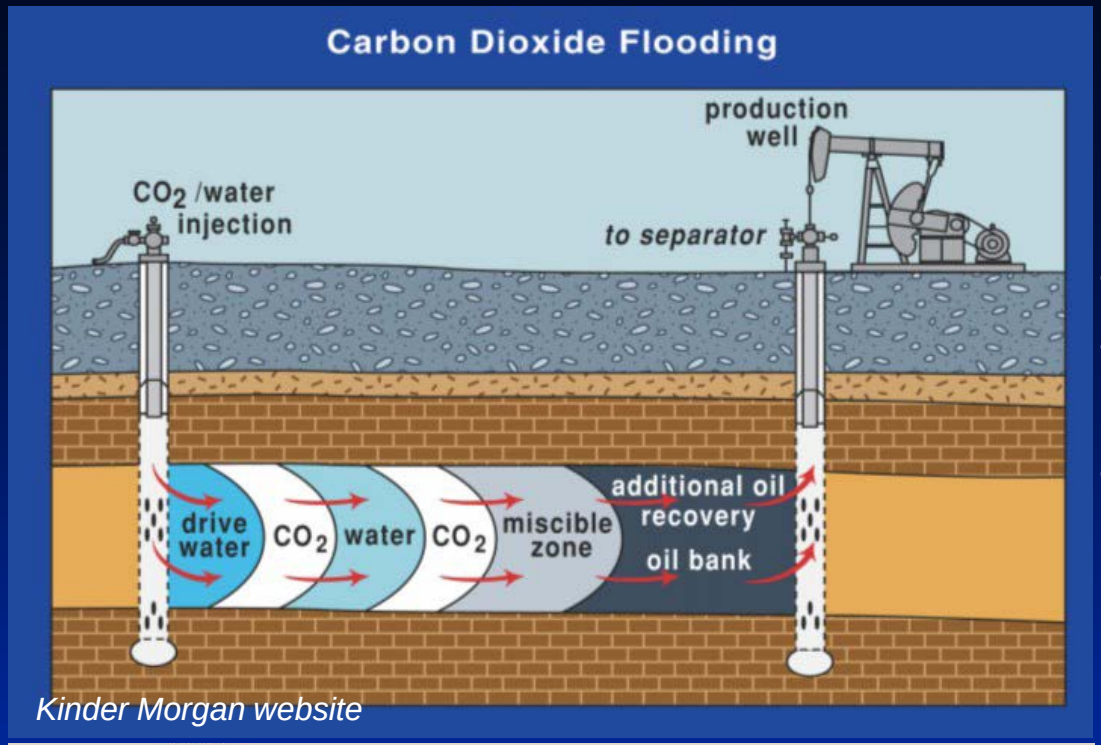
- 6000 ft, 125F, 2100 psi
- CO2 - 0.5 bbl/mcf (9.5 bbl/tonne)

CKU L-KC and Arbuckle

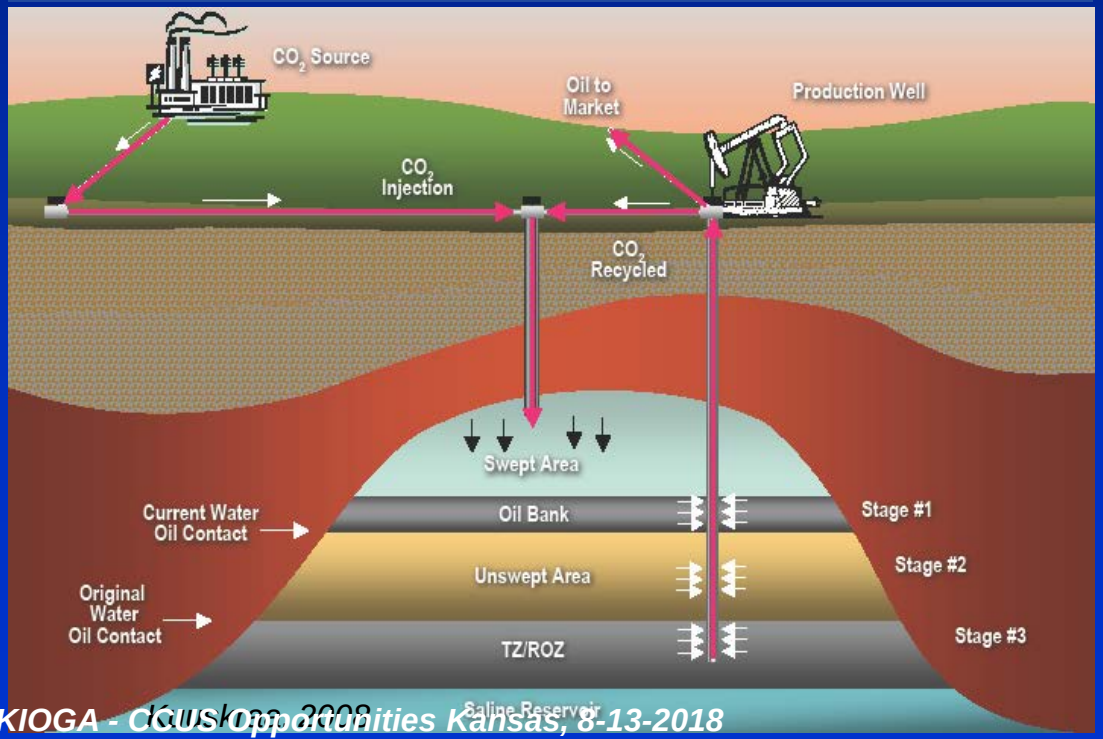
- 3200 ft, 110F, 1200psi
- CO2 -1.2 bbl/mcf (22.8 bbl/tonne)

Conversions tool:
http://www.kgs.ku.edu/Magellan/Midcarb/co2_prop.html

CO_2 Processing Styles



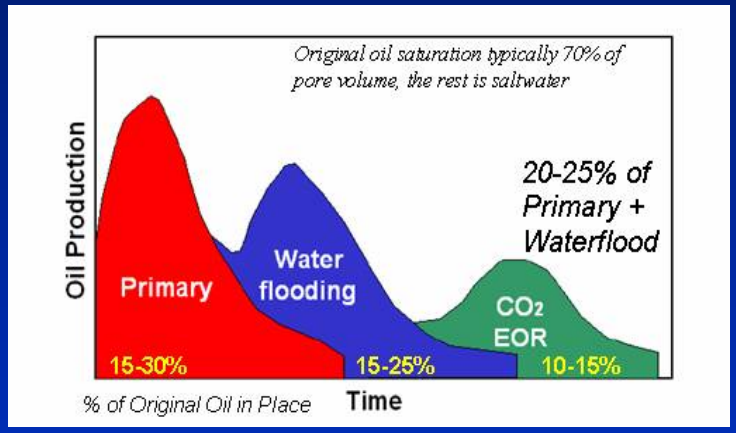
Kinder Morgan website



Kuuskraa, 2008

Horizontal (piston) flood

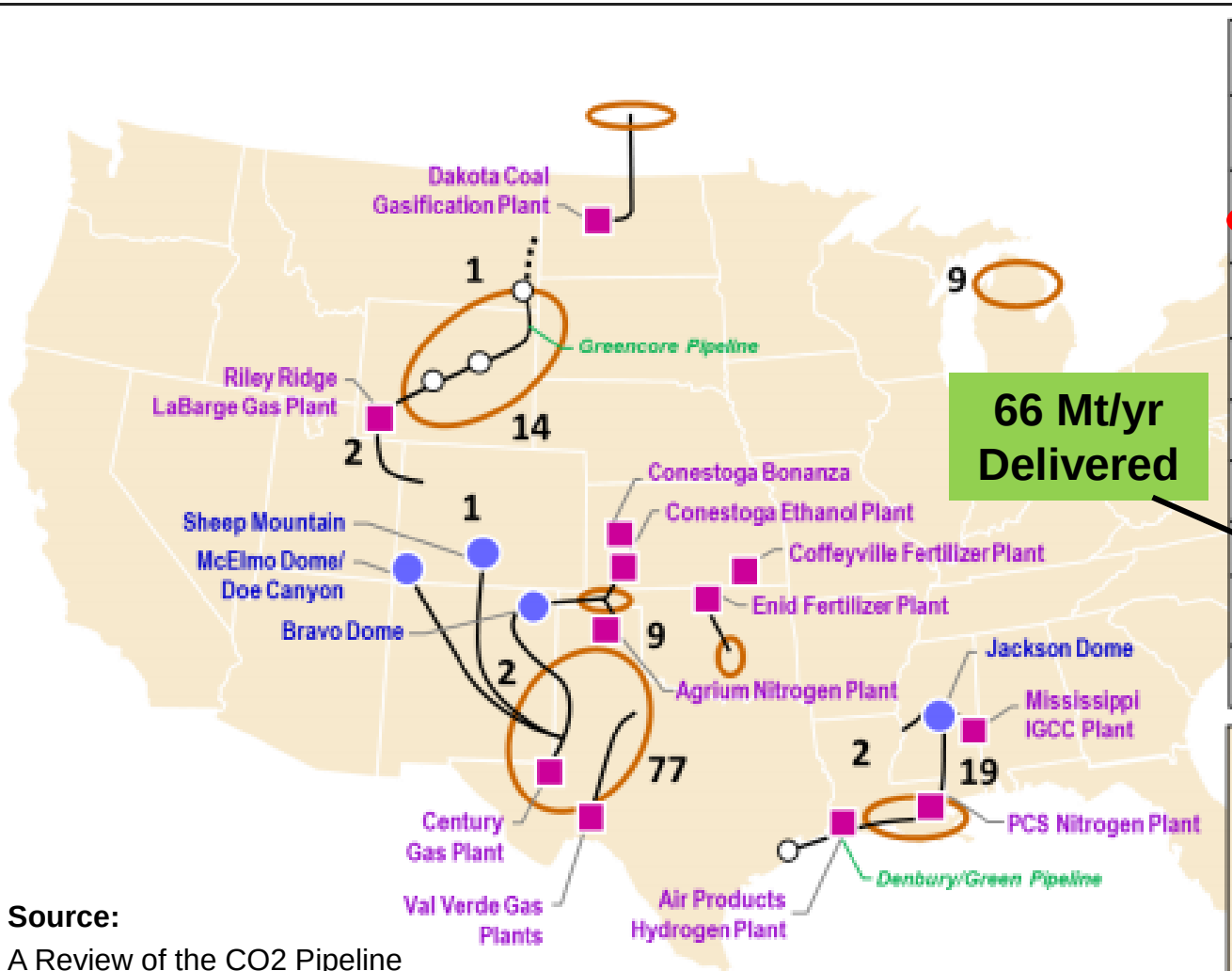
- Application: Follow waterfloods
- KS targets: L-KC, Morrow, Chester
- Well documented



Gravity-stable flood

- Application: bottom-water drive reservoirs
- KS targets: Arbuckle, Simpson, Viola
- Fewer analogues

US CO_2 Pipeline Infrastructure



66 Mt/yr Delivered

Oil Production (2014)	
CO_2-EOR Projects	136
Oil Production (MBbl/d)	300
CO_2 Supplies (2014)	
Number of Sources	17
• *Natural*	*5*
• *Industrial*	*12*
CO_2 Supply (Bcf/d)	3.5
• *Natural*	*2.8*
• *Industrial*	*0.7*

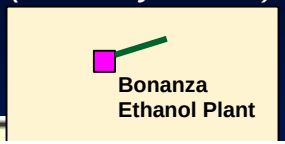
136 No. of U.S. CO_2-EOR Projects
Natural CO_2 Source
Industrial CO_2 Source
CO_2 Pipeline
CO_2 Proposed Pipeline
CO_2-EOR Region

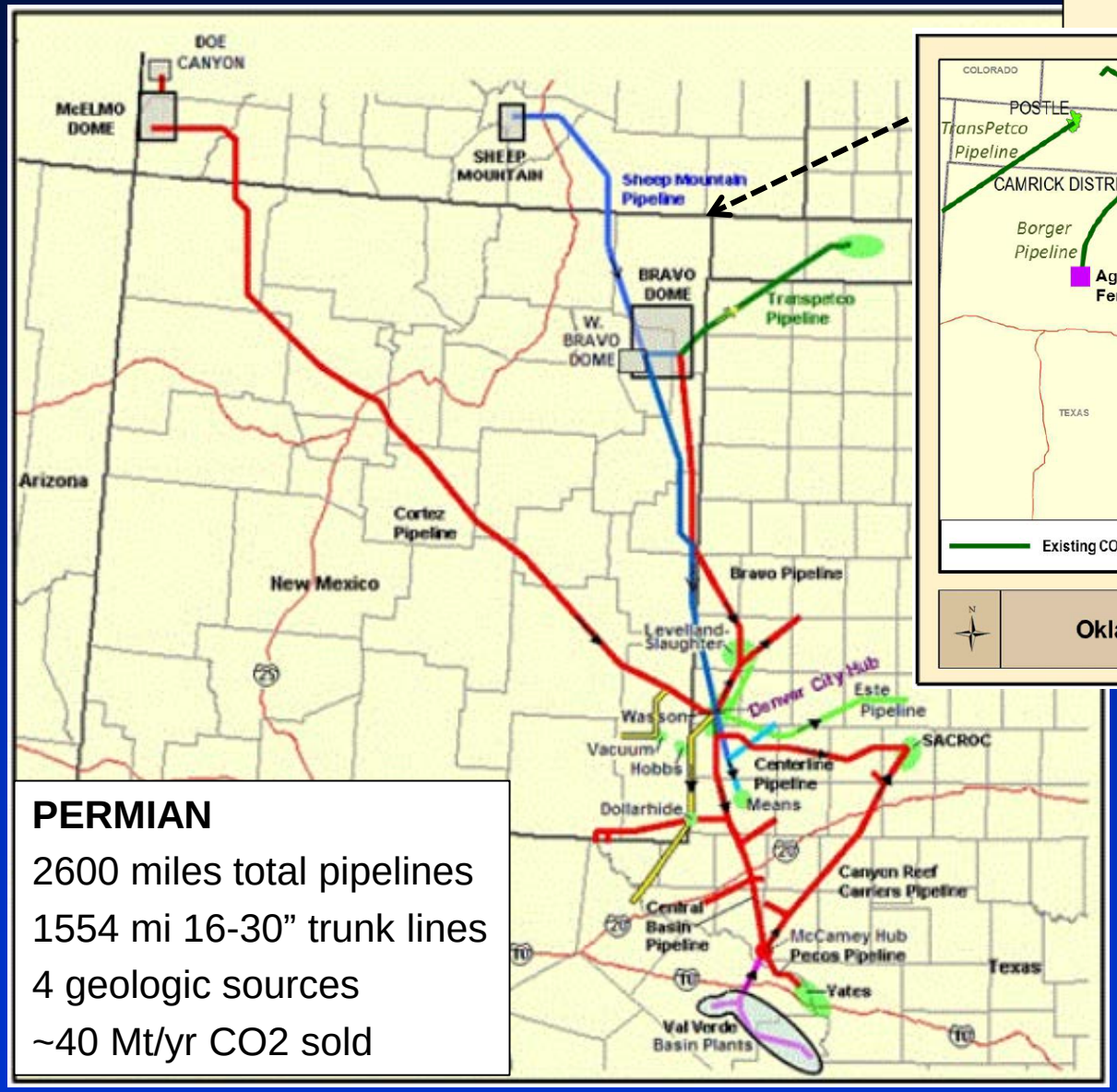
Source: Advanced Resources International, Inc., based on Oil and Gas Journal, 2014 and industry sources.

Source:
A Review of the CO2 Pipeline Infrastructure in the U.S. (2015)
DOE/NETL-2014/1681

Permian Basin and OK-KS pipelines

(Added by Dubois)





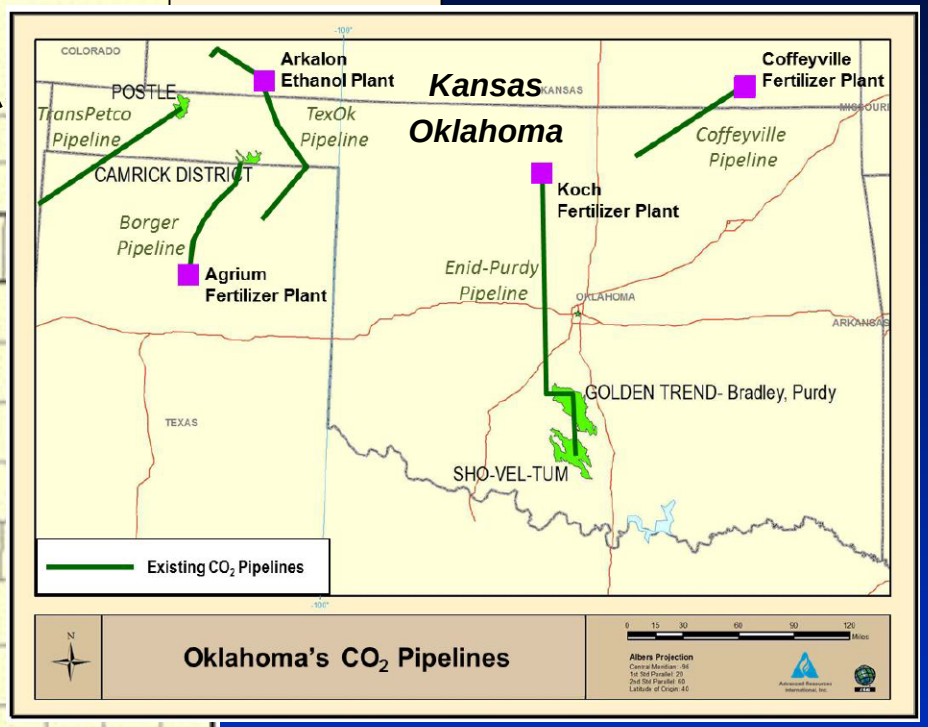
PERMIAN

2600 miles total pipelines

1554 mi 16-30” trunk lines

4 geologic sources

~40 Mt/yr CO2 sold

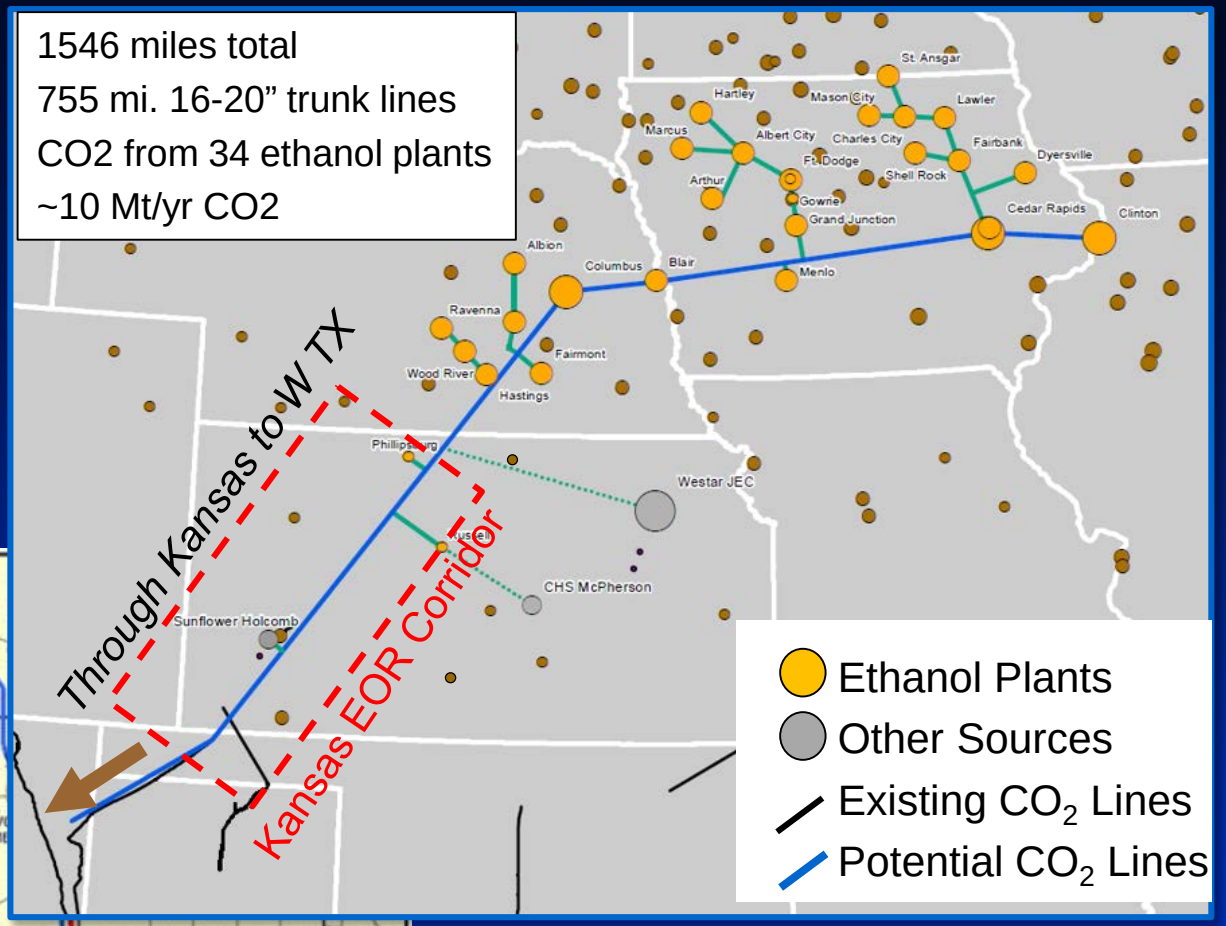


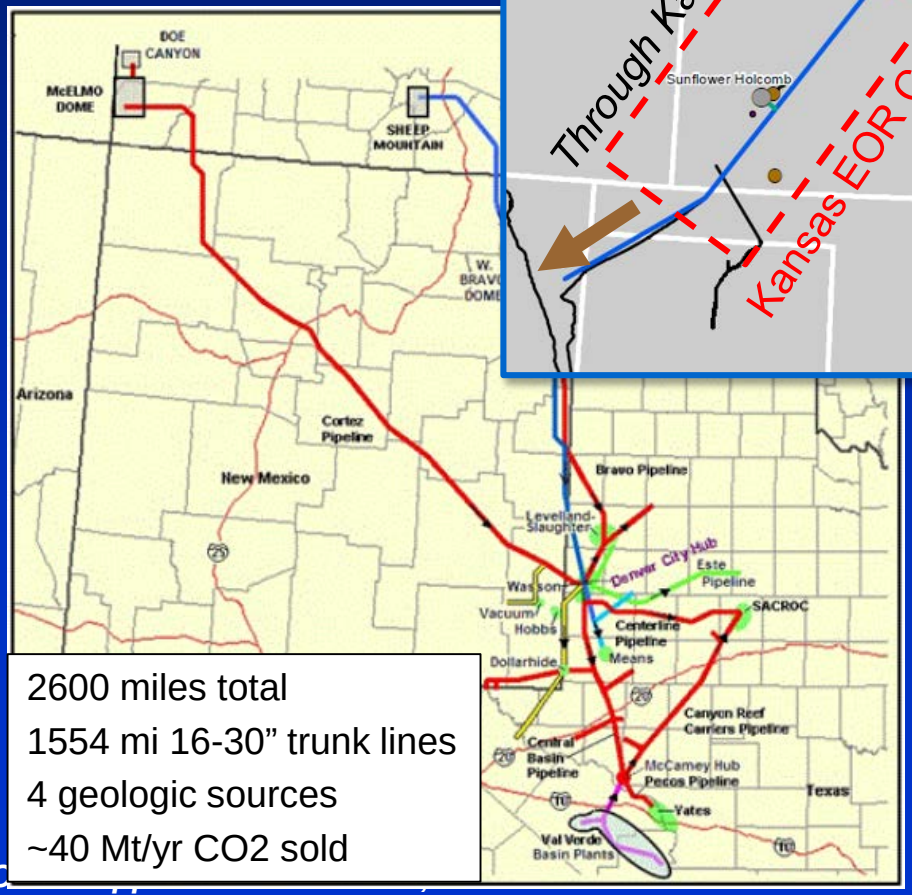
Source:

A Review of the CO2 Pipeline Infrastructure in the U.S. (2015)

DOE/NETL-2014/1681

Midwest Ethanol CO_2 to the Permian Plausible?





2600 miles total
1554 mi 16-30” trunk lines
4 geologic sources
~40 Mt/yr CO2 sold

Gather CO_2 from largest ethanol plants in upper Midwest.

Deliver 9.85 Mt/yr through Kansas to Permian Basin

Questions on CO_2 Basics?

Move on to Section 2:

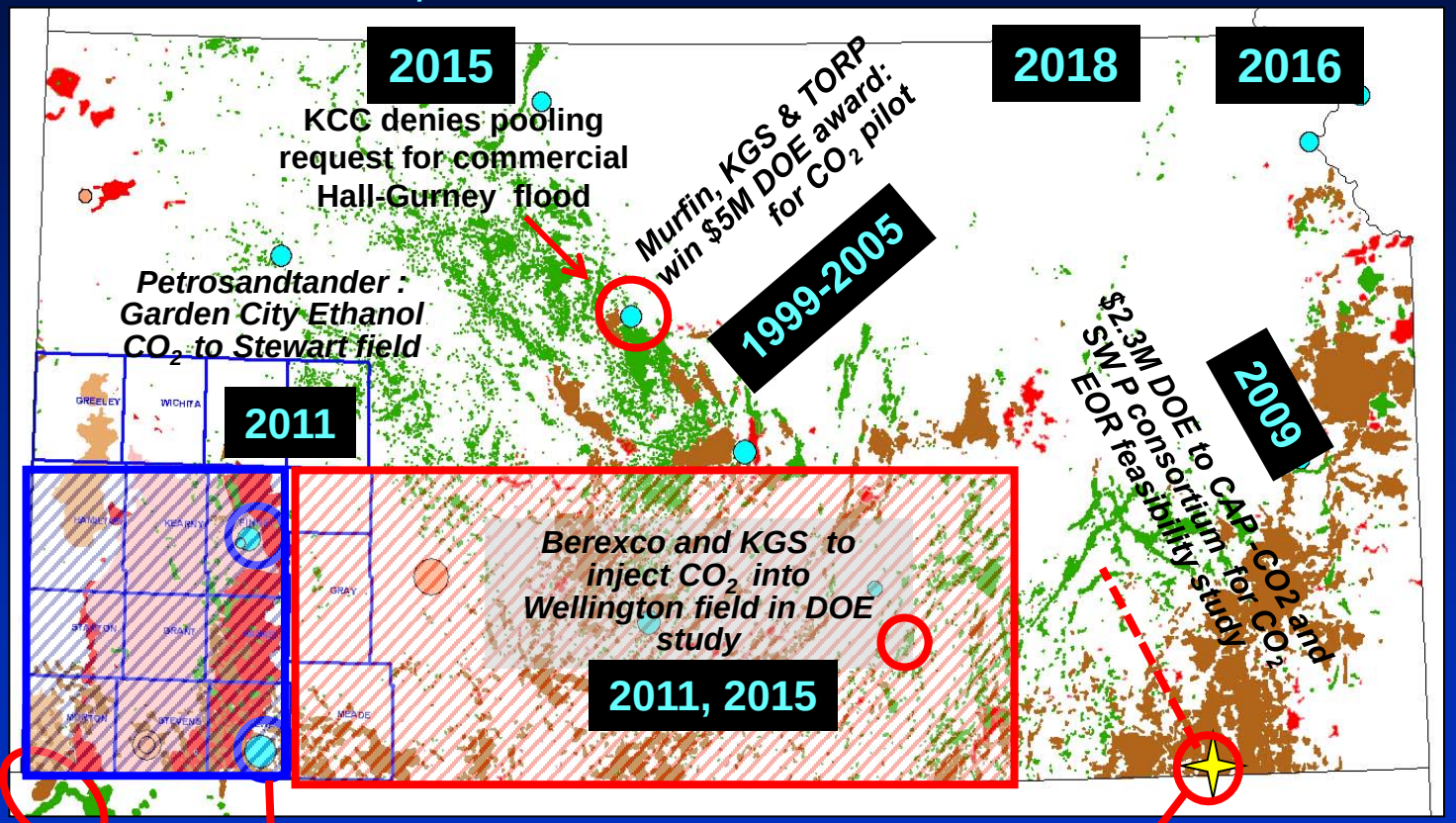
Kansas Readiness

- Industry-Kansas Geological Survey collaborations
- Integrated CCS for Kansas (current)
- Kansas CO2 EOR oil resources

CO_2 EOR and CCUS Headlines

Kansas Ethanol Plants (2008)

Blue – active, Tan - planned



DOE announced Phase II in DOE CarbonSAFE award

KGS/industry partners land $1.5M for Phase I in DOE CarbonSAFE

KGS and five industry partners expand CCS and EOR study with another $5M DOE grant.

2010

Transpetco builds CO_2 pipeline from Denver City to Postle Field

1997

Chapparal buys Liberal Ethanol CO_2 for Okla. EOR

2009

Berexco and KGS study Arbuckle CO_2 storage potential with $5M DOE grant.

2009

Chapparal and CVR ink deal for fertilizer CO_2 for EOR

2011

KGS' Current DOE-Funded Project(s)

U.S. DOE's 4-Phase CarbonSAFE Program

Phase	Program Topic	Years	Start Date	Budget
I	Integrated CCS Pre-Feasibility	1.5	3-2017	$1.5M
	Integrated CCS for Kansas (ICKan) nearing completion			*$1.2M DOE*
II	Storage Complex Feasibility	2	10-2018	$13.3M
	Proposed: Integrated Midcontinent Stacked Storage Hub – Battelle, KGS and EERC jointly			*$9.6M DOE*
III	Site Characterization	2	~2020	TBD
IV	Permitting and Construction	3.5	~2022	TBD

Project Partners and Participants

Industry Partners and Supporters	
CO2 Sources	Westar Energy
	Kansas City Board of Public Utilities
	Sunflower Electric Power Corporation
	CHS, Inc.
Oil& Gas Operators	Berexco, LLC
	Casillas Petroleum Corp.
	Knighton Oil Co. Inc.
	Blake Production Co. Inc.
	Stroke of Luck Energy

Research Team
Kansas Geological Survey
Improved Hydrocarbon Recovery
The Linde Group
Great Plains Institute
Depew Gillen Rathburn & McInteer

Research team

1. Investigated CO2 capture at CO2 Sources
2. Evaluated geologic structures for capacity to store 50Mt CO2
3. Legal, regulatory and public policy issues

Storage Site Evaluations: North Hugoton Storage Complex

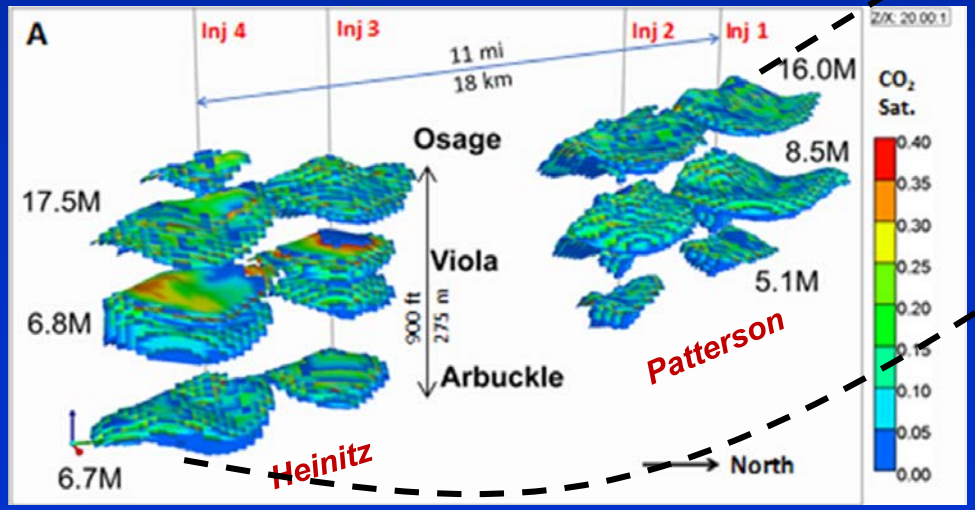
Analyze storage capacity on four structures

- Build 3D geologic model
- Run reservoir simulation to determine capacity
- 3 of 4 structures capable of storing 50 Mt CO2

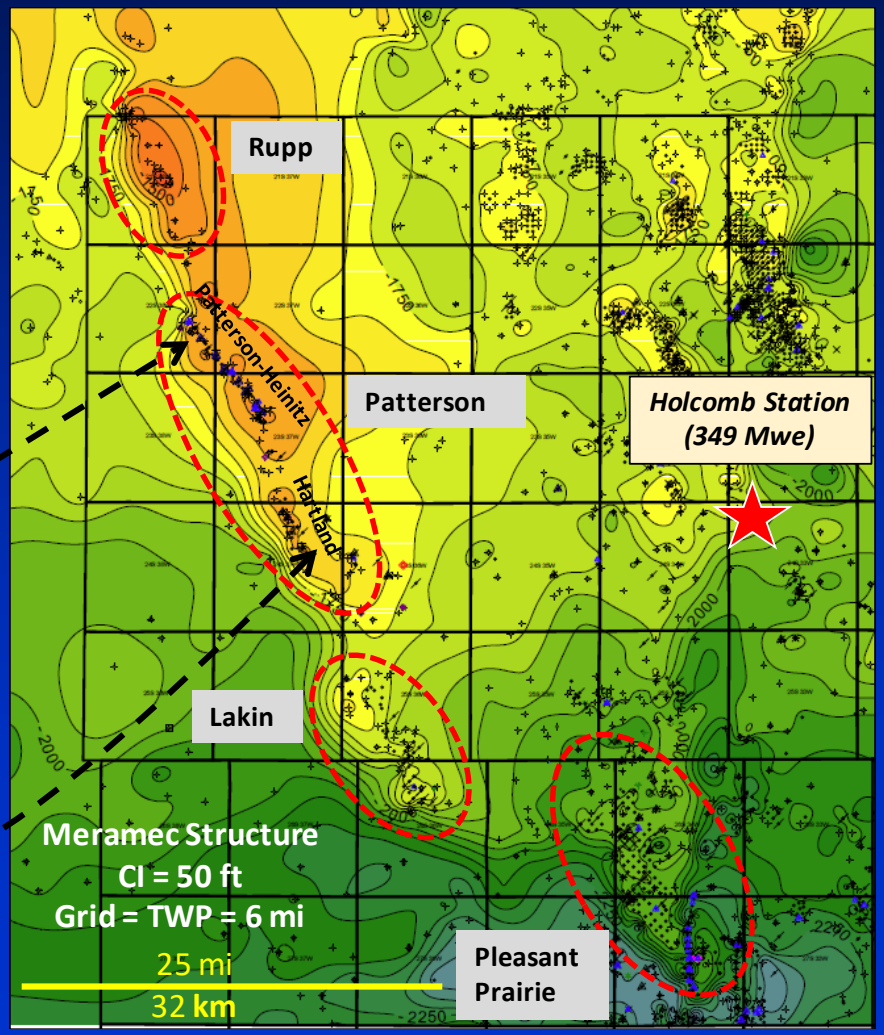
Patterson Structure Simulation Example

- ✓ Inject 5,800 metric tonnes/day
- ✓ 60.6 Mt in 30 yrs
- ✓ Four wells, three zones

CO_2 Plumes simulated in Patterson Structure



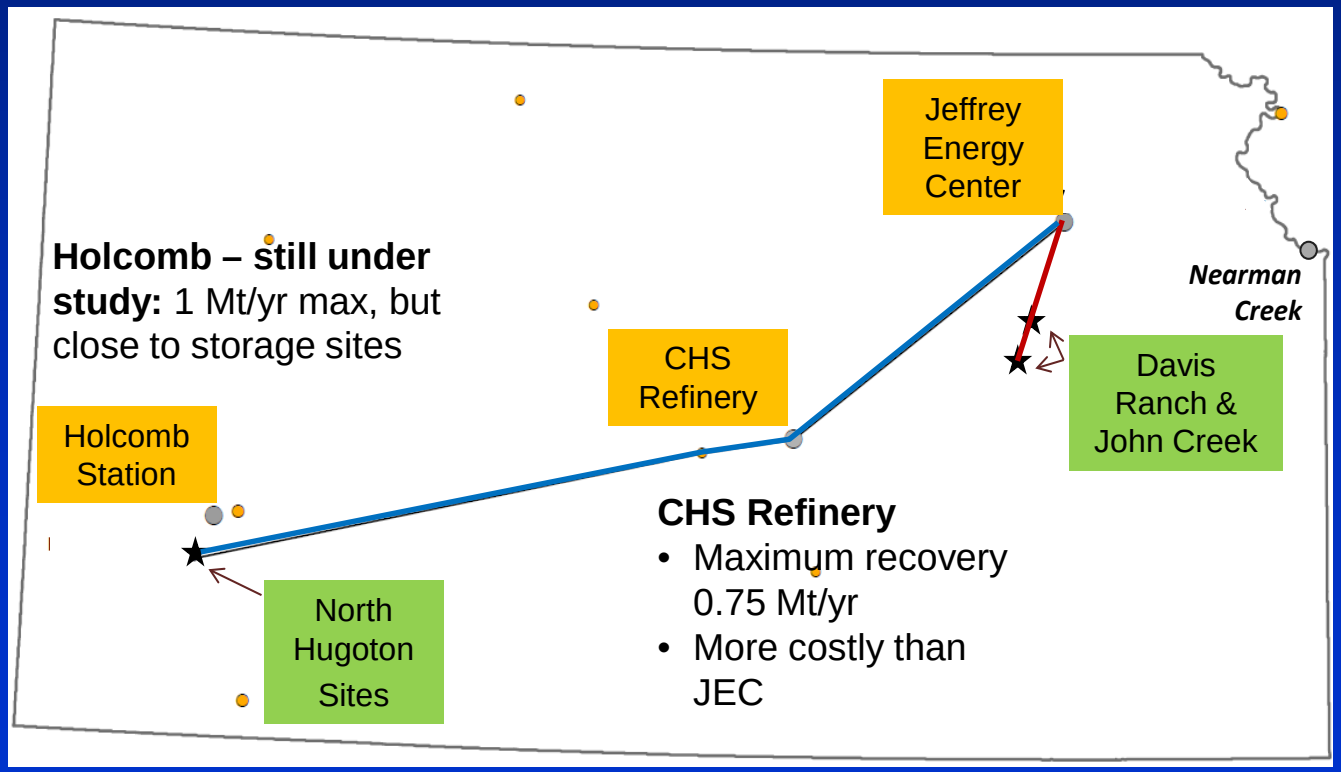
Four structures in the North Hugoton



CO_2 Sources & Transportation Assessment

Preliminary Conclusions

- Davis Ranch and John Creek lack 50 Mt capacity. SW Kansas exceed 50Mt capacity
- Cost for Capture/Compression at JEC is $46 - $78/tonne
- Transportation (pipeline) to SW Kansas cost is ~$14/tonne
- Too high even with $50/tonne 45Q credits



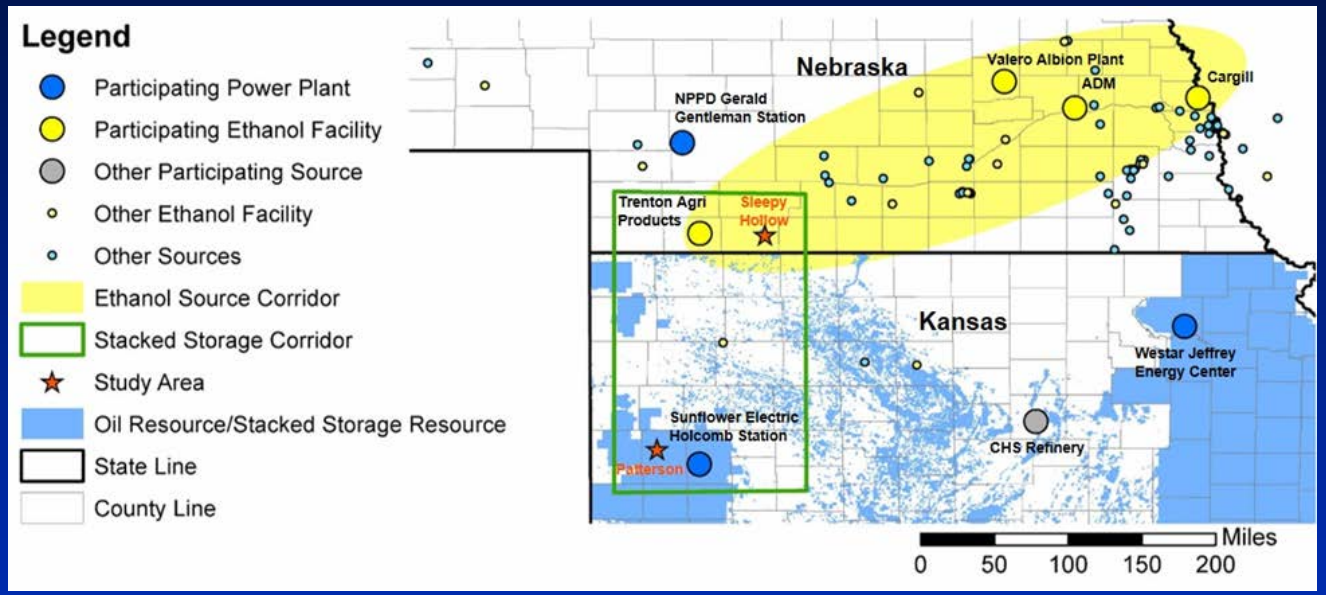
Jeffrey Energy Center, St. Marys, KS

- 3 x 800 MWe plants -12.5 million tonnes/yr CO_2
- Partial capture (~350 Mwe) yield 50 Mt over 20 years (2.5 Mt/yr)

Phase II: Midcontinent Stacked Carbon Storage Hub

Phase II proposal

- Capture CO2 from Ethanol plants
- Transport to SW Nebraska and SW Kansas
- Inject for storage (saline aquifer)
- Sell for EOR to offset costs
- Monetize 45Q credits

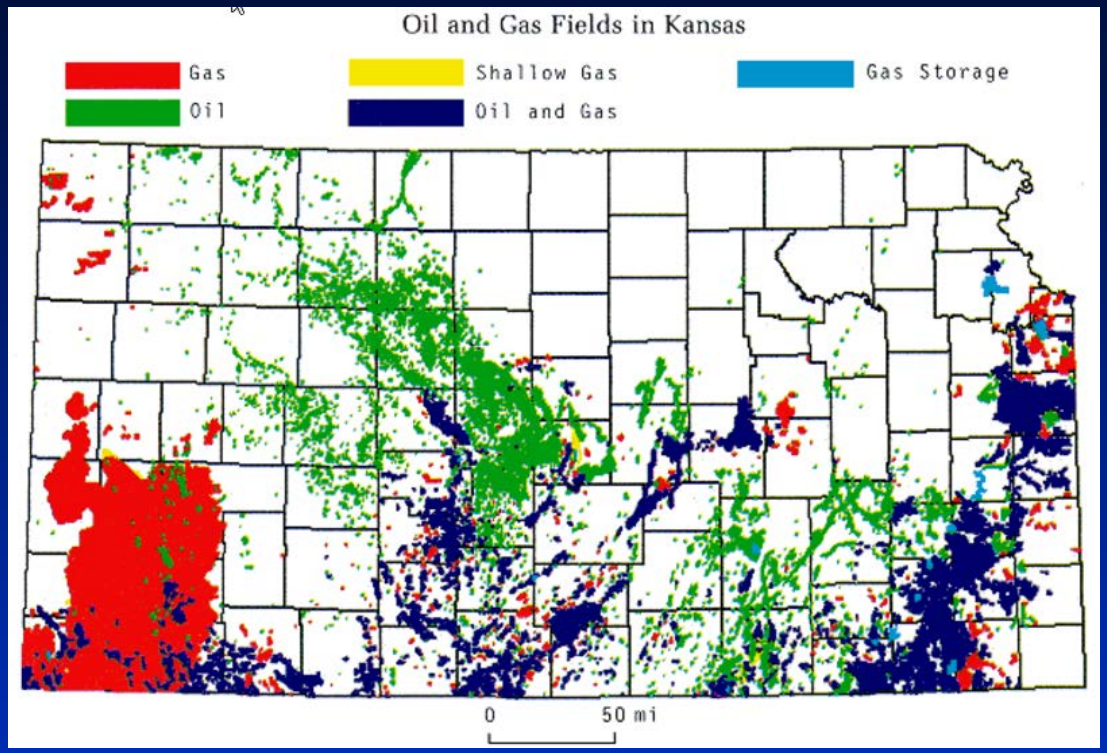


Participants / Supporters (Kansas affiliated in red)

Agency	NGO/Association	Ethanol Producer	Electric Utility	Oil Producer	Other
KS Gov. Colyer	Clean Air Task Force	ADM	NPPD	Berexco	ION Engineering
NE Ethanol Board	Great Plains Institute	Cargill	Westar Energy	Merit Energy	MV Purchasing
NE Dept. of Agriculture	KIOGA	Trenton Agri Products	Sunflower Electric Power	Great Plains Energy	The Linde Group
NE Dept. of Environmental Quality	NE Petroleum Producers Association	Valero Renewables	Kansas City Board of Public Utilities	Casillas Petroleum	
NE Corn Board	Renew Kansas	Pacific Eth.		Central Operating	
NE Energy Office		Kansas Ethanol			

Switch gears to Kansas CO2 EOR oil resources

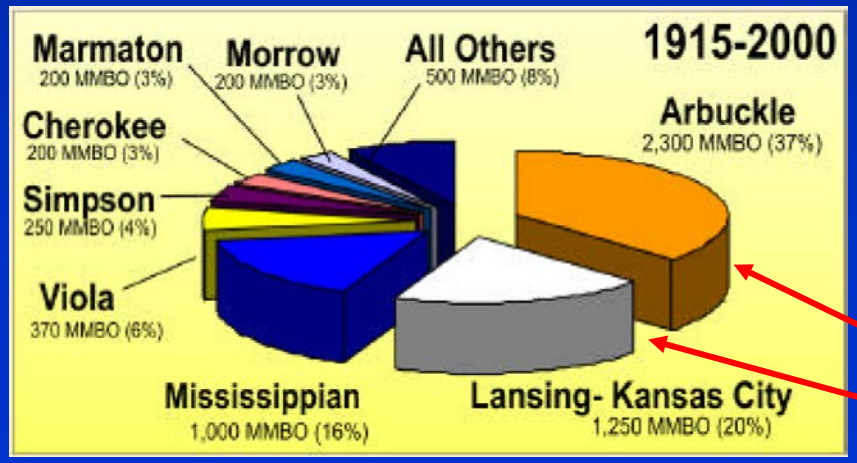
Oil-rich state, but no appreciable CO_2 available



6.7 Billion barrels total

Now at 36 mmbo/yr

+10 mmbo/yr possible from CO2 EOR?



Most prolific:
Arbuckle
L-KC

The Big Picture

From the Midwest Governor's Association and ARI (2009)

- Kansas holds > **750 million barrels** of technical CO2-EOR potential.
- Kansas has the largest oil resources in the MGA region.

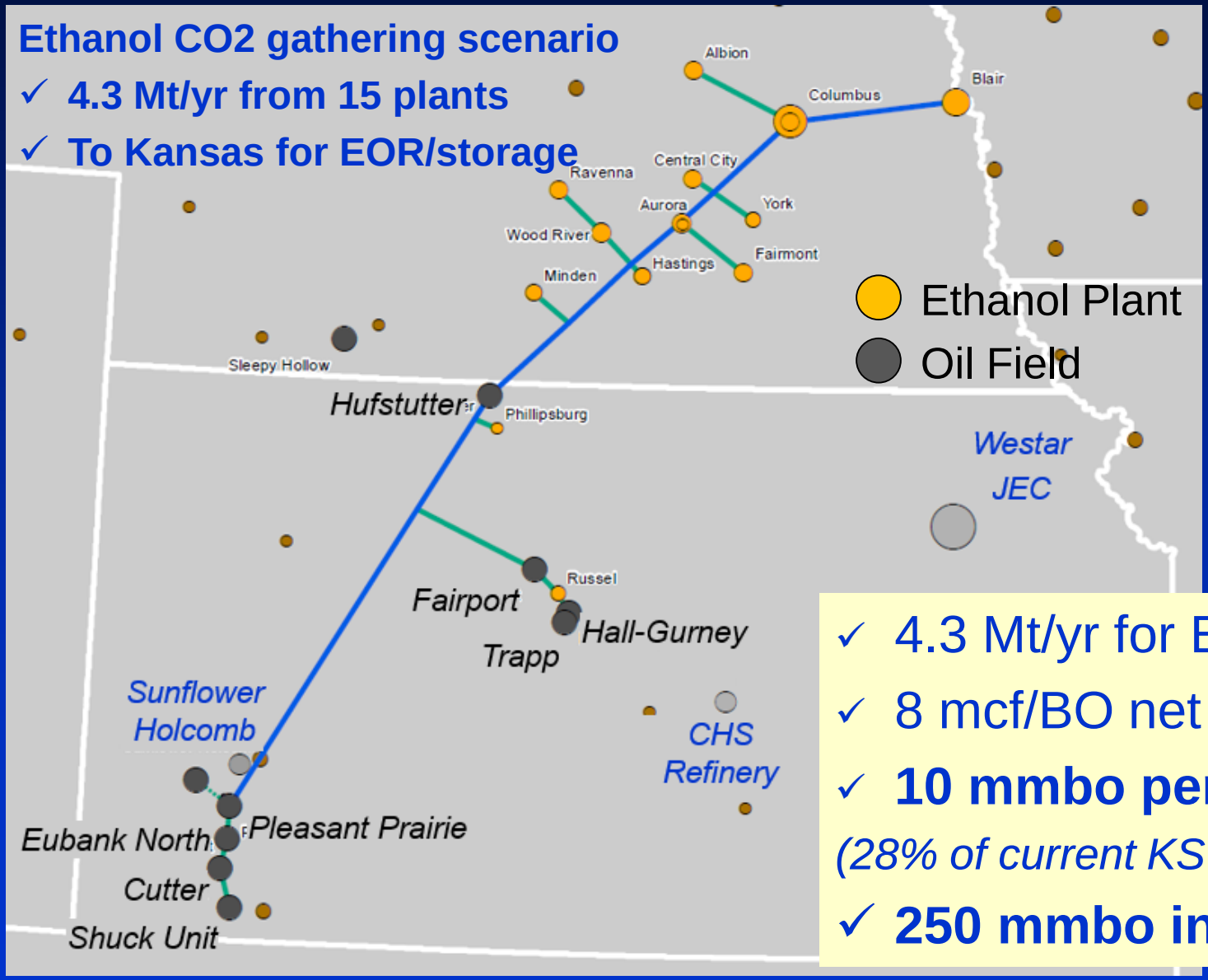
Basin	EOR potential (Mil bbl)	Net CO_2 Demand (MMT)	Direct Jobs Created
Illinois/Indiana	500	160 – 250	1,550 – 3,100
Ohio	500	190 – 300	1,550 – 3,100
Michigan	250	80 – 130	800 – 1,800
Kansas	750	240 – 370	2,300 – 4,600
TOTALS	**2,000**	**670 – 1,050**	**6,200 – 12,400**

Byrnes et al., 1999 (Kansas Geological Survey)

250 to 1,000 million barrels

What's required for 250 mmbo?

4.3 M tonne / yr CO_2 (220 mmcfd) for 25 yrs



- ✓ 4.3 Mt/yr for EOR
- ✓ 8 mcf/BO net utilization
- ✓ **10 mmbo per year**

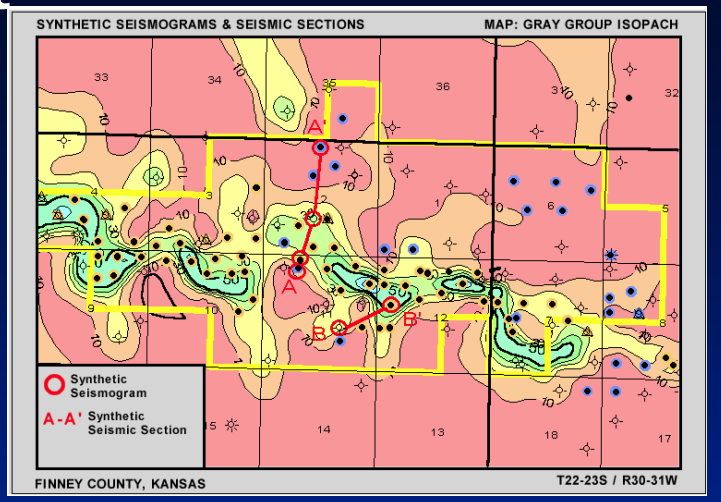
(28% of current KS production)

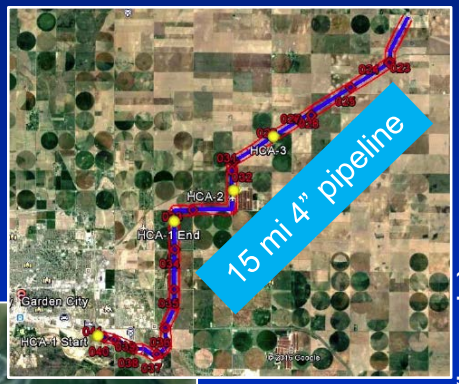
- ✓ **250 mmbo in 25 years**

Kansas First CO_2 EOR Project

- Bonanza ethanol plant (Garden City) to PetroSantander's Stewart Field
- 100-130 k tonnes/yr (5-7 mmcfd) CO2
- Increased production from 250 to 750 bopd
- Has not performed as expected – multiple reasons

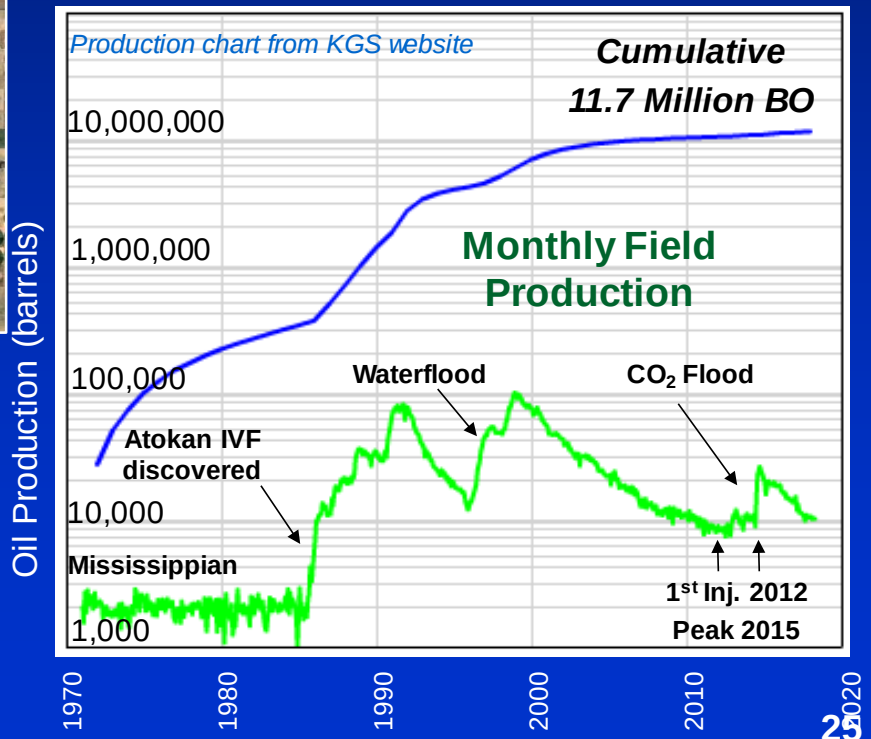
KGS Digital Petroleum Atlas





Conestoga CCUS report, 2016

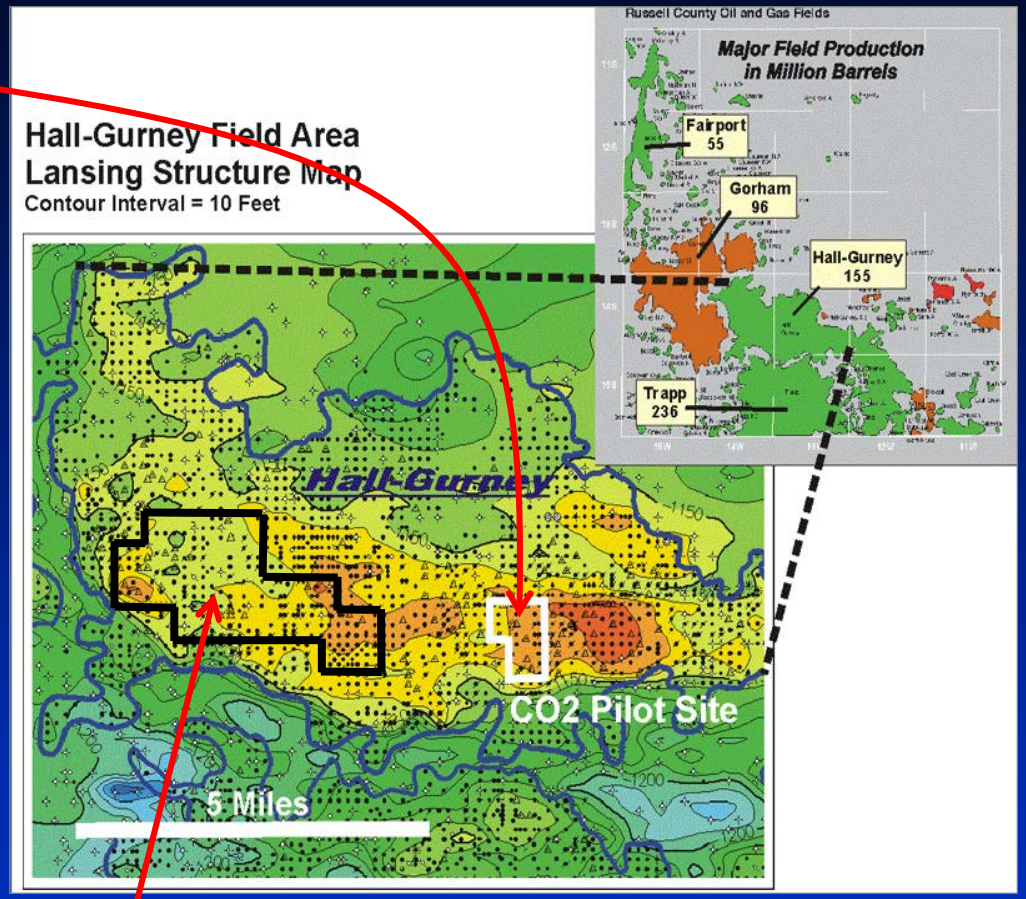
Stewart Field Production



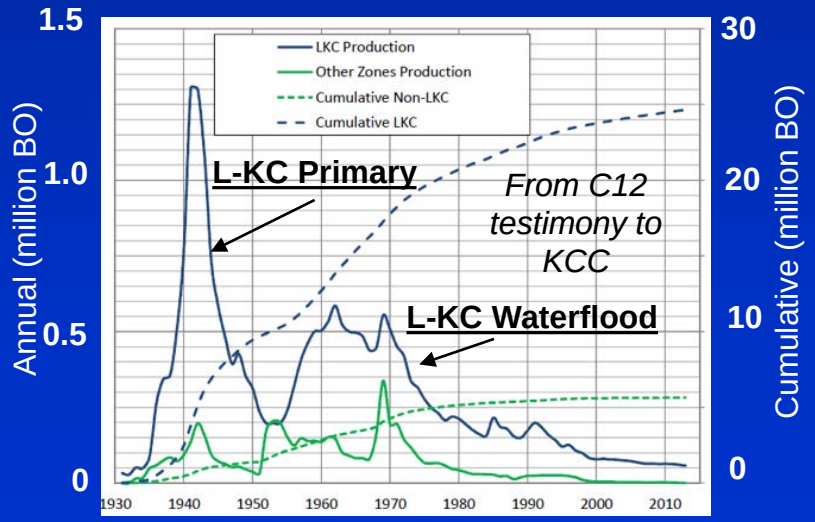
Hall-Gurney Field Investigations

Murfin's Hall Gurney (Russell) Pilot (2005)

- Trucked CO2 from USEP Russell ethanol plant
- Injected 140 mmcf (7400 tonnes CO2)
- Produced an estimated 27.9 mbo incremental oil
- SUCESSFUL demonstration



Oil Production in Proposed C12 Unit

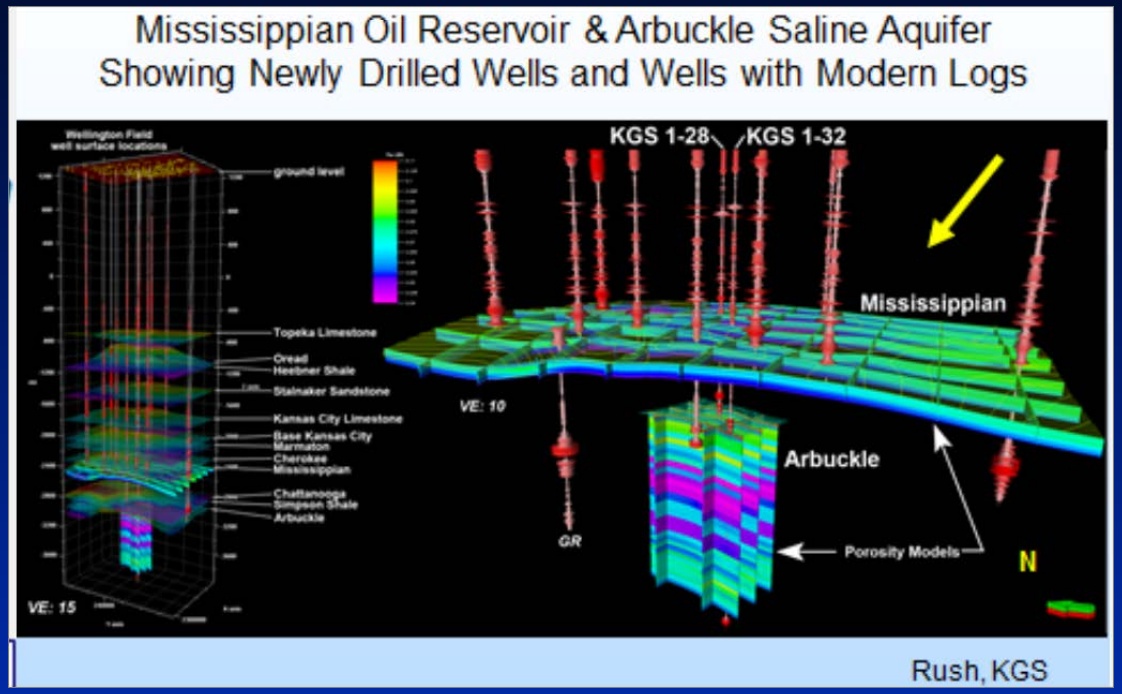


C12 Energy (2015)

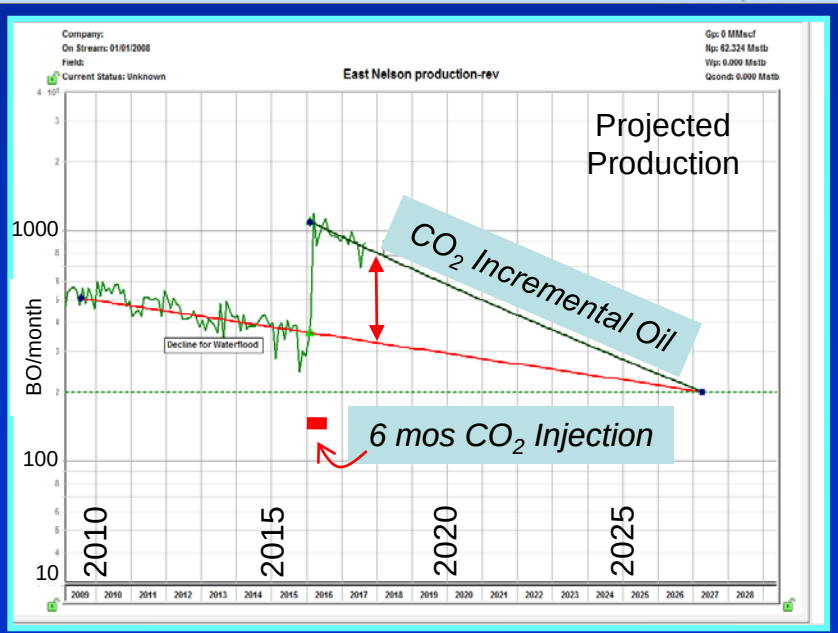
- Projected 10.7 MBO recovery from proposed Unit
- KCC denied pooling application

Berexco's (*and KGS*) Wellington Pilot (2016)

DOE-FE-006821

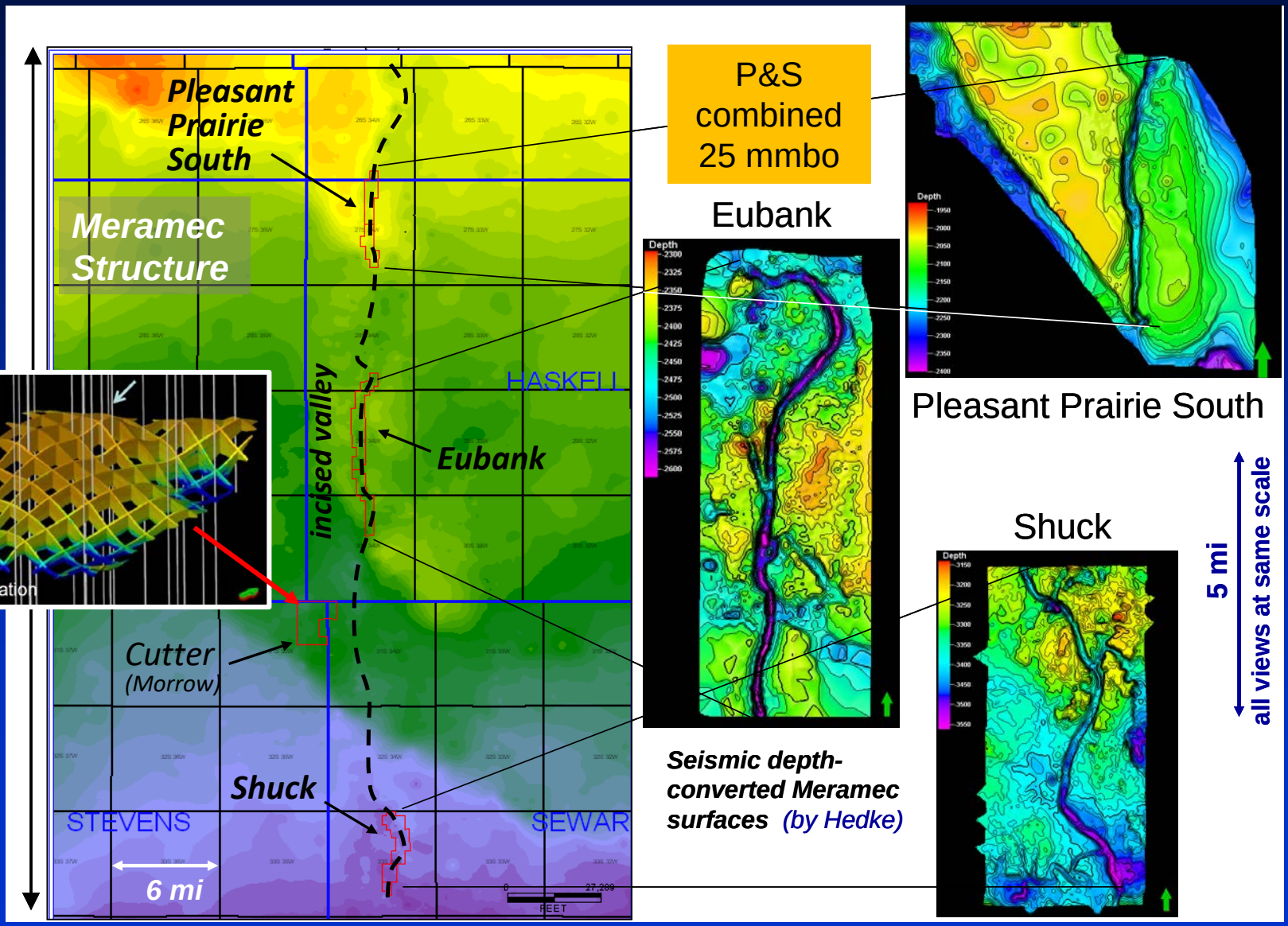


- Injected 374 mmcf CO2 (19,700 tonnes) over 165 days through June 2016
- 83% CO2 still in reservoir (6/1/2018)
- 16 mbo through June 1, 2018
- Projected Incremental oil - 32.4 mbo
- Projected Gross utilization: 11.5 mcf/BO



Four fields in KGS/DOE study "CO_2 Ready"

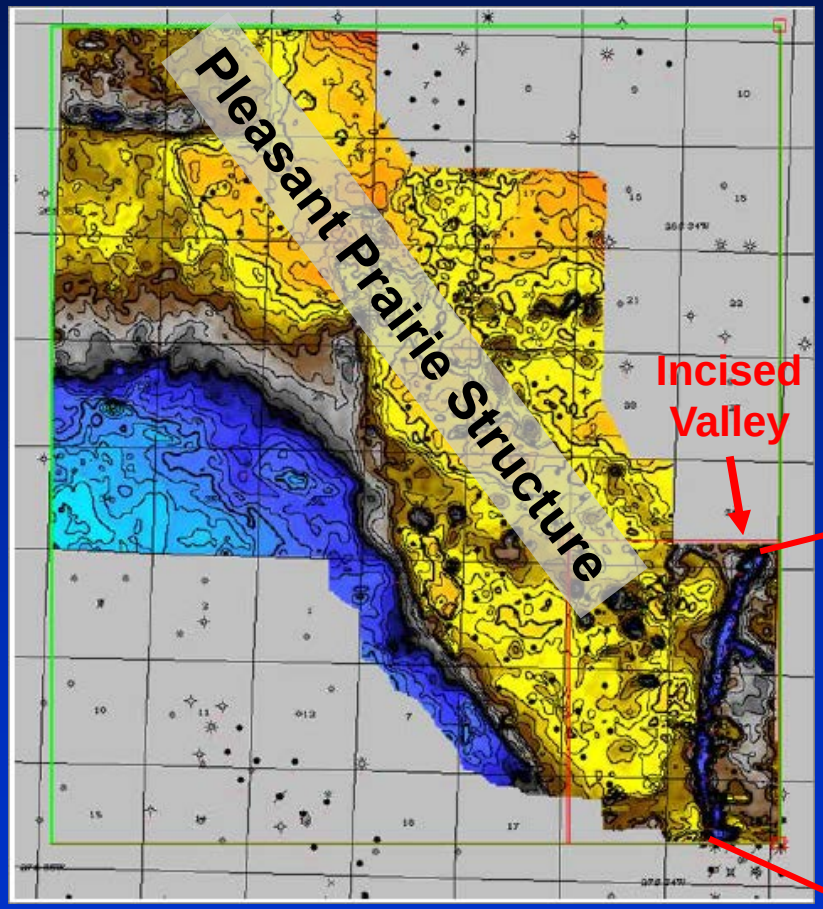
(2012-2015) Could take **2 Mt/yr** + **13.2 mmbo** from EOR



Pleasant Prairie So. Chester IVF

Primary + Secondary

4.7 mmbo



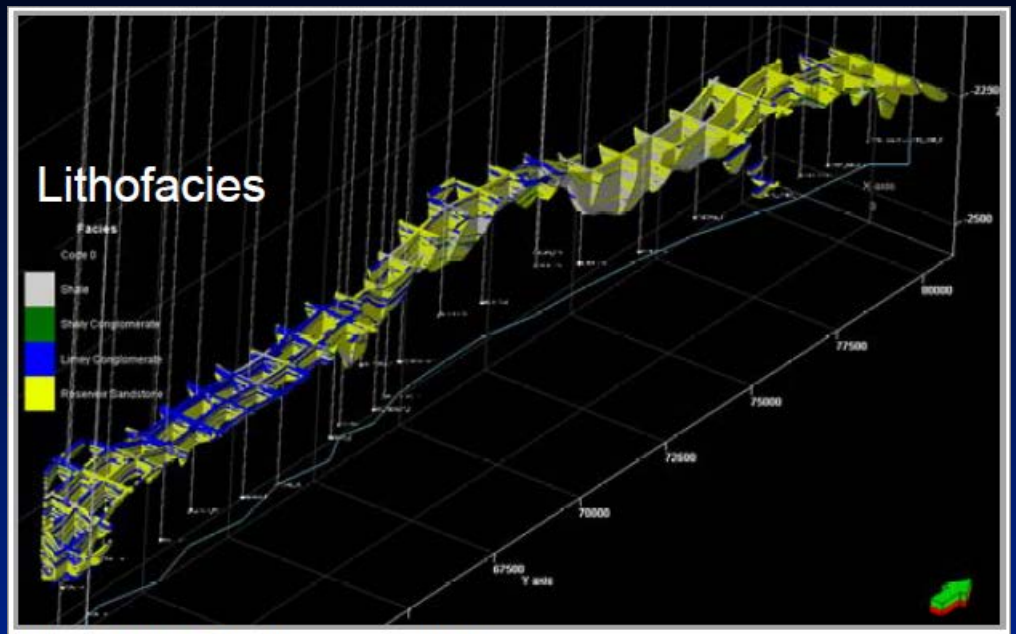
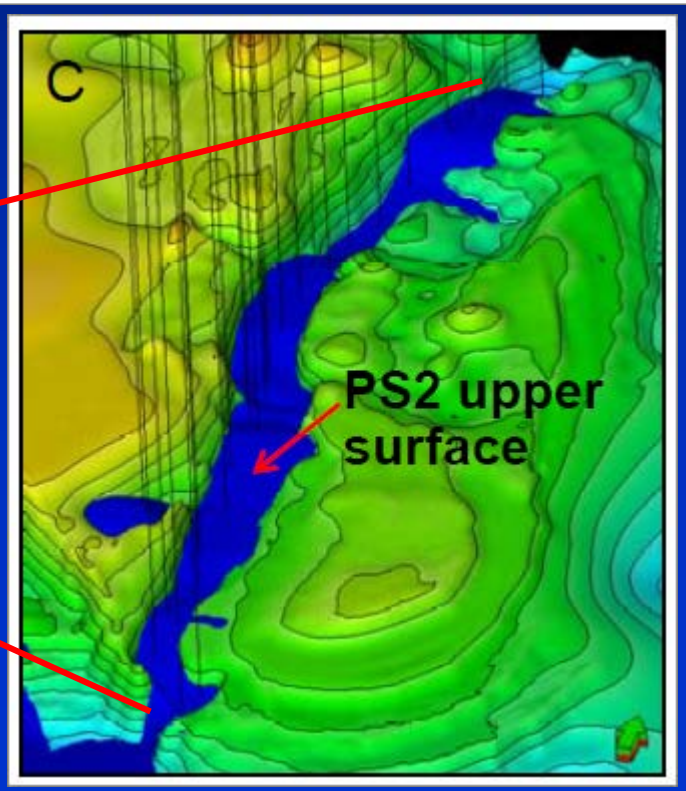
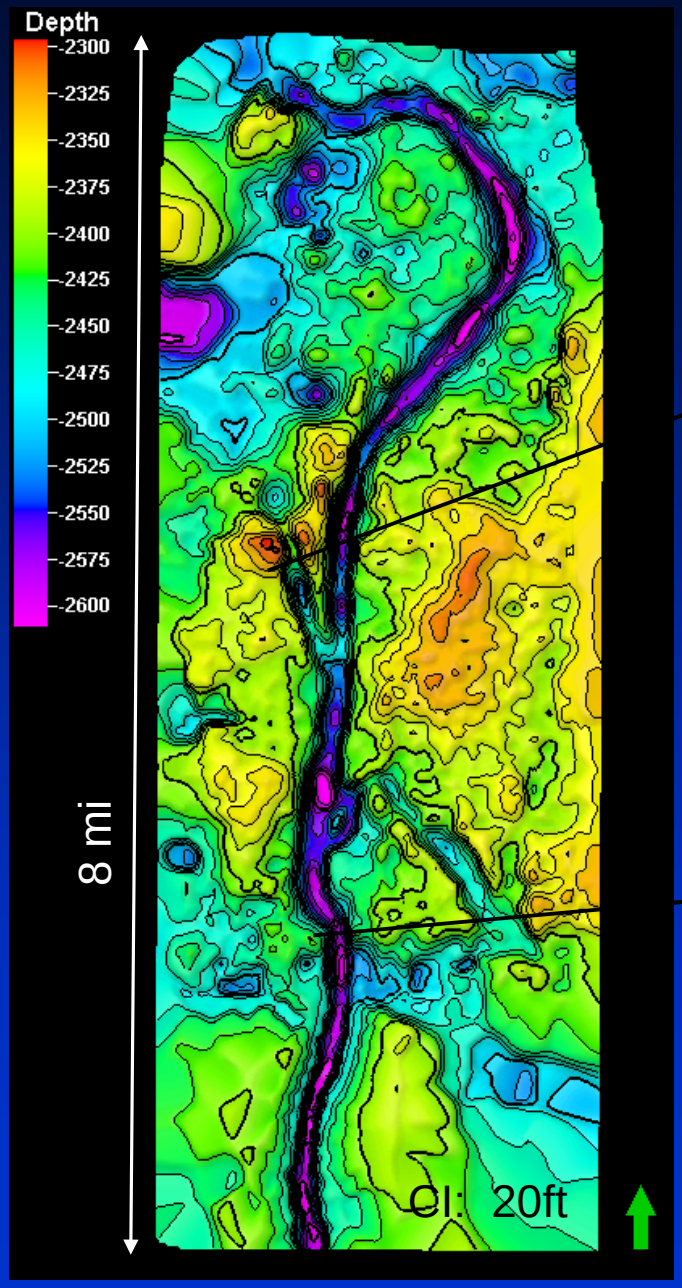
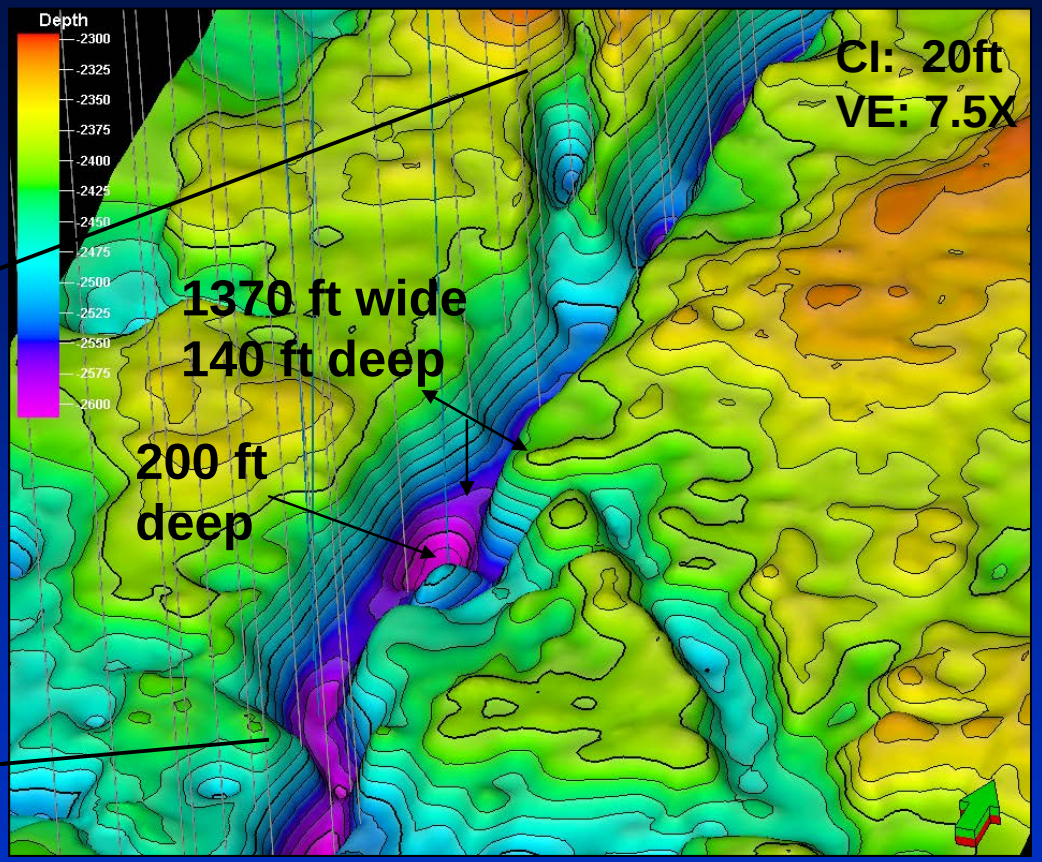


Fig. 6.14 Lithofacies model



Eubank North Unit
Chester IVF

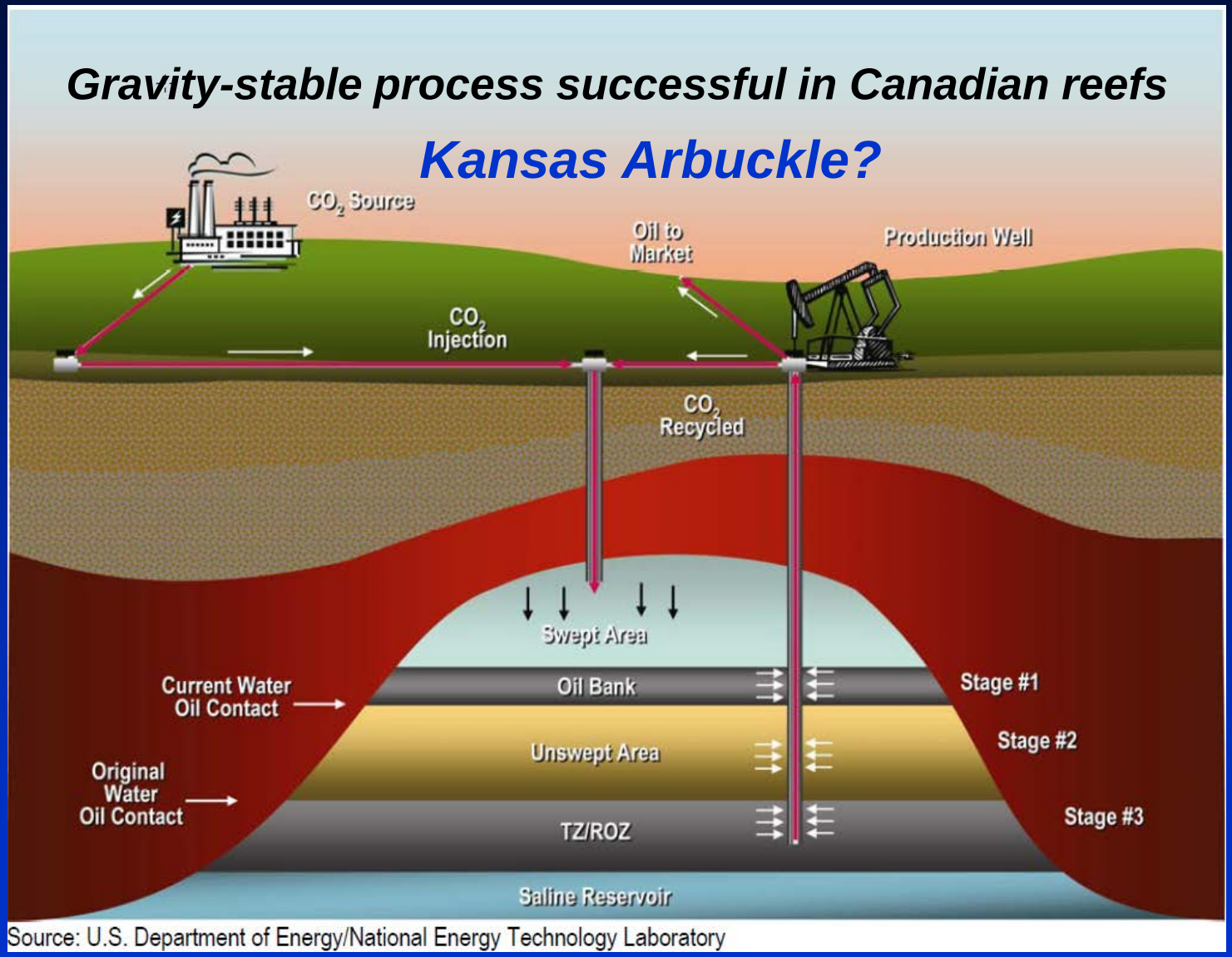




Primary + Secondary

7.4 mmbo

Here's the upside potential: Arbuckle

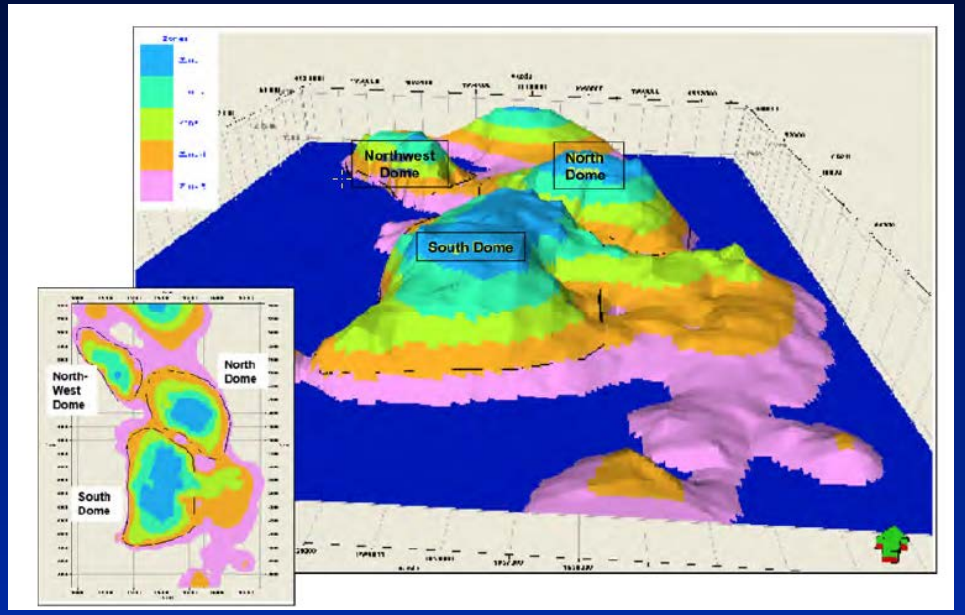


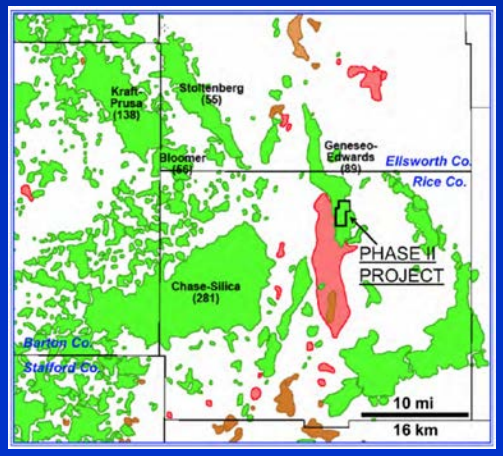
Source: U.S. Department of Energy/National Energy Technology Laboratory

Geneseo-Edwards study

Kansas Ethanol, LLC (Lyons, KS) and CAP CO2, LLC, with support from Daystar and Scheck, 2010

- 55 MGY plant 15 miles to Geneseo-Edwards oilfield
- Did not go forward
  1. Not funded in DOE Phase II
  2. Drop in oil prices
  3. Geologic risk





	Cumulative Oil (mmbo)			CO2 stored		
	Gross	Arbuckle	CO2 EOR	mmcf	Million Tonnes	Ethanol plant years
DOE Project	30.2	26.3	6.1	9,613	0.50	3.5
Balance Geneseo-Edwards	59.2	47.4	11.0	17,311	0.90	6.3
Stoltenberg	55.1	44.1	10.2	16,112	0.84	5.9
Bloomer	55.8	44.6	10.4	16,316	0.85	6.0
Kraft-Prusa	137.8	110.2	25.6	40,294	2.09	14.7
Chase-Silica	280.6	224.5	52.1	82,050	4.26	30.0
	618.7	**497.1**	**115.3**	**181,695**	**9.4**	**66.4**

"CO_2 Ready" EOR candidates

	Inject. Rate (Mt/yr)	CO2 Stored (Mt)	Primary & Secondary (mmbo)	CO2 EOR (mmbo	Basis for Estimate
Shuck	0.4	1.5	7.9	3.6	DE-FE000256
Cutter	0.5	1.3	5.4	2.8	DE-FE000256
N Eubank	0.6	1.5	7.4	4.6	DE-FE000256
Pleasant Prairie	0.3	0.5	4.7	2.2	DE-FE000256
Hall-Gurney	1	11.3	62.5	26.8	DE-AC26-00BC15124 **PILOT** C12 Energy KCC Documents
Trapp	0.5	4.3	31.3	10.3	KGS reports
Wellington	0.6	2.2	16.2	5.3	DE-FE0002056 and **PILOT**
	3.9	**22.8**	**135.4**	**55.7**	

** P&S production is for portion of field that could be flooded*

"CO2 Ready" fields could take
3.9 million tonnes /year (200 mmcfd)
And recover 56 mmbo

Kansas Field Candidate Guidelines

1. Relatively **large fields**
   - >20 million barrels recovered
   - Or multiple smaller fields in close proximity adding to > 20 mmbo

2. **High recovery rates** on per-acre basis are most ideal

	mbo/Acre	Million BO/Section
SW KS Study (Chester/Morrow)	4-5	3
Hall-Gurney (L-KC)	8	5
Arbuckle (Geneseo-Edwards)	15	9.5

3. Large fields that were **good waterfloods**
   - Hall-Gurney - (63 Mbo from L-KC waterfloods)
   - Others possible (to name a few) – Huffstutter, Fairport, Trapp, Wellington

Questions?

Move on to Section 3:

45Q tax incentives expansion and extension

- 45Q tax credits discussion
- Economics for capture, transportation, injection

45 Q Tax Credits Applied

45Q specifics*

Enacted 2/9/2018 as part of a Federal budget bill

- Construction before February 9, 2025
- Credits claimed 12 yrs from day capture begins
- Claimed by capture facility, transferrable to storage site (field), but not directly to transporter
- 2017 tax: $12.83/tonne for EOR and $22.66/tonne for saline storage.
- Escalates linearly through 2026 to $35 for EOR and $50 for saline storage, flat thereafter.
- Adjusted for inflation.
- Injected into a qualified EOR project in a secure geologic storage.

** Sources: NEORI (Kurt Walzer), CLATF, State CO2 EOR Workgroup (Brad Crabtree), and S. 1535 document*

Credit Values ($/tonne)

Credits (no inflation)		
	EOR	Saline
2017	$12.83	$22.66
2018	$15.29	$25.70
2019	$17.76	$28.74
2020	$20.22	$31.77
2021	$22.68	$34.81
2022	$25.15	$37.85
2023	$27.61	$40.89
2024	$30.07	$43.92
2025	$32.54	$46.96
2026 - 2035	$35.00	$50.00

Inflation adjustment after 2026 not applied here

Strings attached and/or complexities

Rumblings regarding rules to qualify for credits

- Definition for “Secure geologic storage”
- Monitoring Verification and Accounting requirements – for proof of injection and storage

Complexity of business plan/contracts

- Credit transfer agreements from capture facility to field operator
- Long term responsibility and liability

Capture and Storage at Variable Scales

Project types and scales are nearly limitless in MidCon

Range from

- Simple: point-to-point (150,000 tonnes/yr)
- Somewhat complex: multiple sources to single market for EOR
- Very complex: multiple sources to multiple fields for EOR

Scenarios presented involve the highlighted boxes

Source Type	Description	Ethanol Volume (Mg/yr)	CO2 Volume (Mt/yr)
Ethanol plants	Single Small	55-110	0.15-0.3
	Single Large	300	0.8
	Multiple - 15 plants	1575	4.3
	Multiple - 34 plants	3643	9.9
Coal Power	Single		1-4
Storage (Market)			
EOR	Single field - small (KS)		0.15-0.3
	Mutliple small fields (KS)		2-4
	Large market (W. TX)		4-10
Saline aquifer	Small local (KS)		0.15-0.3
	Single structure (KS)		1.5-3
	Multi-structure storage complex (KS)		6

CO_2 volume is 90% of calculated nameplate

Sources for Economic Modeling and Resources

Pipeline CapEx and OpEx are derived from FE/NETL CO_2 Transport Cost Model

(Grant & Morgan, 2014), modified by Dubois and McFarlane (2017)

Capture and compression CapEx and OpEx are based on cost data from three DOE-funded projects

(Details in White Paper: Capturing and Utilizing CO2 from Ethanol)

References:

Dubois, M.K., D. McFarlane, and T, Bidgoli, 2017, CO2 Pipeline Cost Analysis Utilizing and Modified FE/NETL Cost Model Tool, poster presented at the Carbon Storage and Oil and Natural Gas Technologies Review Meeting, Pittsburgh PA, August 3, 2017, Pittsburgh PA, August 3, 2017.

Grant, T., D. Morgan, and K. Gerdes, 2013, Carbon Dioxide Transport and Storage Costs in NETL Studies: Quality Guidelines for Energy Systems Studies: DOE/NETL-2013/1614, 22 p.

Grant, T. and D. Morgan, 2014, FE/NETL CO2 Transport Cost Model. National Energy Technology Laboratory. DOE/NETL-2014/1667. https://www.netl.doe.gov/research/energy-analysis/analytical-tools-and-data/co2-transport.

Three cases discussed today

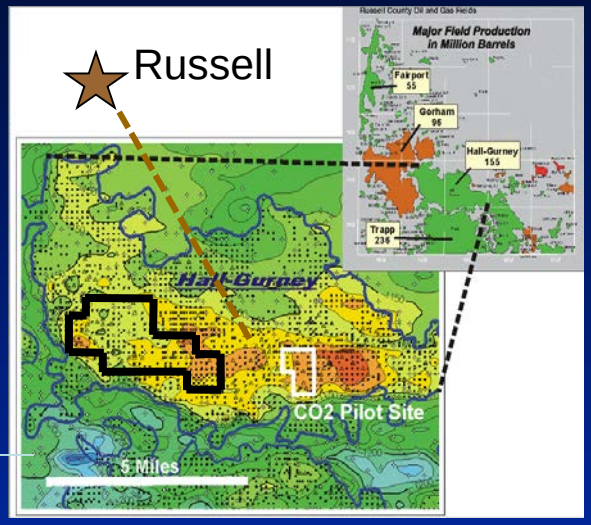
1. Small-scale Point-to-Point for EOR (0.15 Mt/yr – 2.9 BCF/yr)
2. Aggregate 15 ethanol plants and transport to multiple Kansas fields (4.3 Mt/yr – 82 BCF/yr)
3. Aggregate 34 ethanol plants and transport to Permian Basin (9.9 Mt/yr – 188 BCF/yr)

Case 1: Small-scale Point-to-Point for EOR,

Oil Operator Owns CCT System

Current Kansas example: Conestoga's (Garden City KS) to Stewart Oil Field since 2012: 55 mgy plant, 15 miles to field

Future EOR example? Russell Ethanol to Hall-Gurney field via 10-mile line



Modified from Dubois etal. (2002)

Generic economic model assumptions

- Capture and compress 150 kt CO_2/yr
- 20-mile, 4" pipeline
- Owner equity and secured note (net 5% interest)
- 14-yr project, 2 yrs construction, 12 yrs operations
- Injection begins in 2022
- 45Q credits ($25-$35, avg. $33)
- No inflation is factored
- Pay Ethanol plant $10/tonne CO_2

Case 1: Economic Summary

Cost per tonne CO_2 (credits applied)		**$/tonne**
Capture/Compression	**CapEx**	$0.66
	OpEx (annual)	$8.58
Pipeline	**CapEx**	$0.51
	OpEx (annual)	$1.71
TOTAL	**$/tonne**	**$11.45**
	$/mcf	**$0.60**

Tax credits applied directly to CapEx in model to calculate price/tonne

45Q tax credits make this case economically viable

Market CO_2 value with WTI = $60
$22.90/t
($1.20/mcf)

Compare

Costs		**$ Million**
Capture/Compression	CapEx	$17.25
	OpEx (annual)	$1.28
Pipeline (20 mi, 4")	CapEx	$13.21
	OpEx (annual)	$0.25
TOTAL	**CapEx**	**$30.46**
	OpEx (annual)	**$1.53**

Cost without 45Q
$34/tonne
($1.80/mcf)

Compare

Case 1: Risk and Benefit

Oil Operator

Risks

1. Capital exposure
   - $30 M for CCT
   - $5+M for field upgrade
2. Oil field flood failure
3. CO_2 source (ethanol plant failure)
4. MVA and long-term liability

Benefit

1. Low-cost CO_2..... *because of* ***$59 Million 45Q tax credits***

Ethanol Plant

Risks

1. Almost none

Benefit

1. Revenue: $1.5 M/yr ($0.027/ gal) – for this case
2. Greatly reduced carbon intensity

Case 2: Fifteen plants to Kansas oil fields

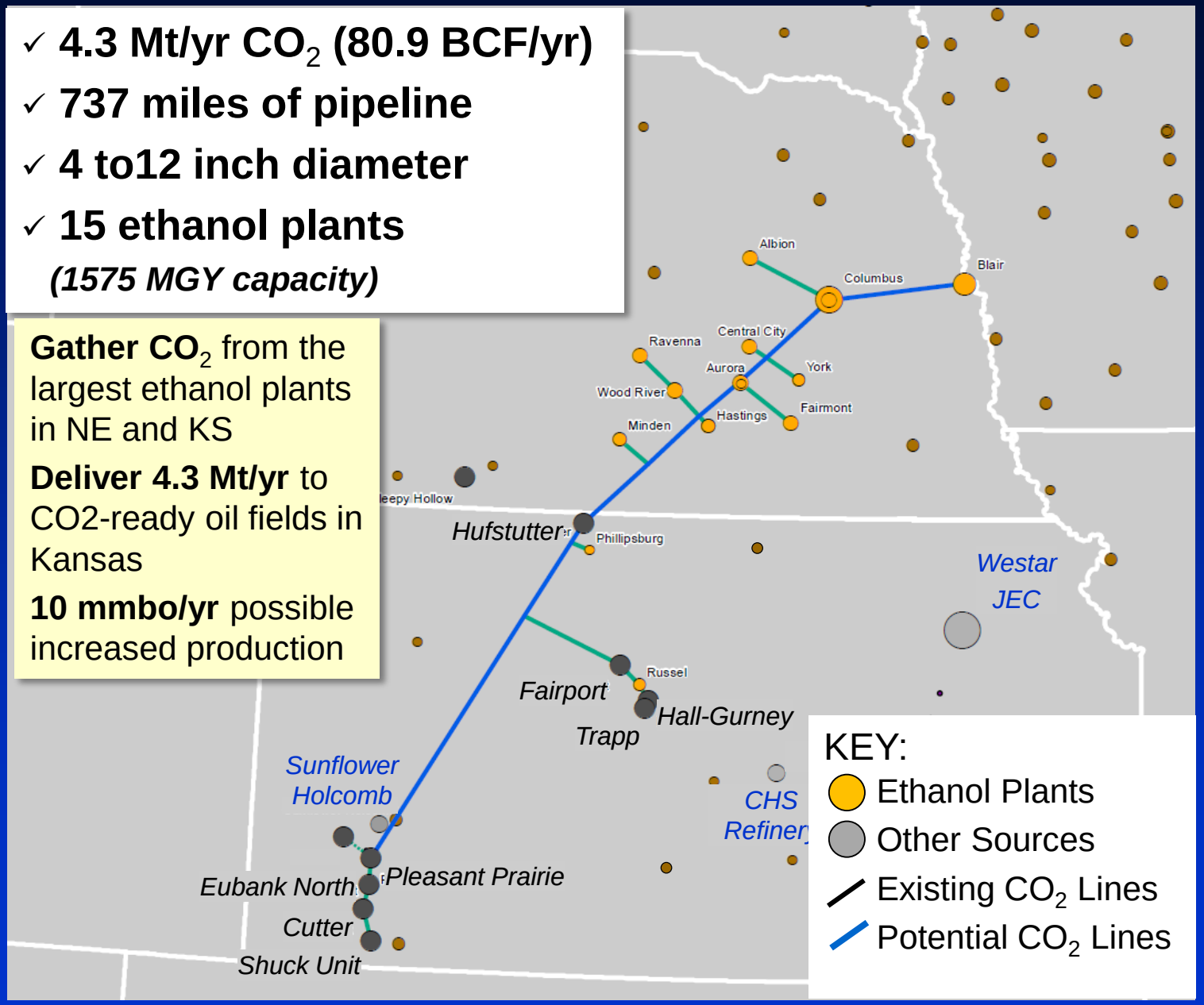
- ✓ **4.3 Mt/yr CO_2 (80.9 BCF/yr)**
- ✓ **737 miles of pipeline**
- ✓ **4 to12 inch diameter**
- ✓ **15 ethanol plants**

(1575 MGY capacity)

Gather CO_2 from the largest ethanol plants in NE and KS

Deliver 4.3 Mt/yr to CO2-ready oil fields in Kansas

10 mmbo/yr possible increased production



Case 2 Economics

Estimated Project Costs

Cost $million	Plant Capture	Pipeline Transport	Total
CapX	$364	$642	$1,006
Annual OpX	$37	$16	$53

*Note: Rule of thumb $100k/inch-mile yields **$613** million CapX for pipeline*

Summary:

- **Total CapEx $1,006 M**
- **45Q tax credits $1,774 M**
- **Cost of Capital = 10%**
- 2-yr construction and 20 yrs operations (operations begin 2024)
- 12 yrs of 45Q credits - Avg. $34.48/t

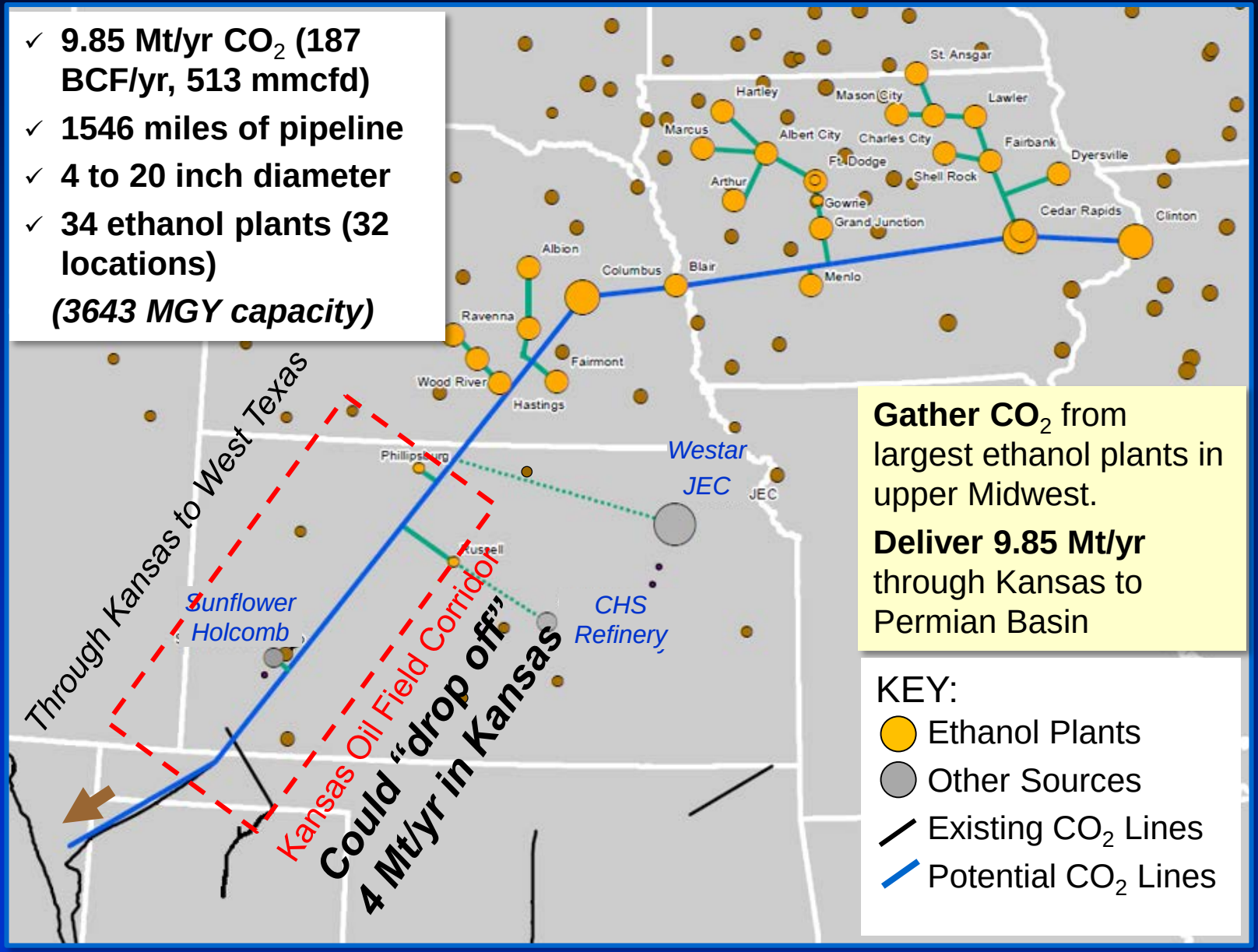
Costs per Tonne of CO_2 (credits applied)

	Pipeline	Capture & Compress	Combined
CapEx ($/t)	$1.71	$0.69	$1.90
OpEx ($/t)	$3.80	$8.58	$12.39
Total ($/t)	**$5.02**	**$9.27**	**$14.29**
Tax credits applied directly to CapEx in model to calculate price/tonne		**$/mcf**	**$0.75**

Market CO_2 value with WTI = $60 $22.90/t ($1.20/mcf)

Without 45Q $47 / tonne ($2.46 / mcf)

Case 3: Large-scale, 10 Mt/yr



Case 3 Economics

Estimated Project Costs

Cost $million	Plant Capture	Pipeline Transport	Total
CapX	$809	$1,857	$2,667
Annual OpX	$85	$47	$131

*Note: Rule of thumb **$100k/inch-mile** yields **$1821** million CapX for pipeline*

Summary:

- **Total CapEx $2.7 Billion**
- **45Q credits $4.1 Billion**
- **Cost of Capital = 10%**
- 2-yr construction and 20 yrs operations (ops in 2024)
- 12 yrs of 45Q tax credits, Avg. $34.48/t

Costs per Tonne of CO_2 (credits applied)

	Pipeline	Capture & Compress	Combined
CapEx ($/t)	$4.28	$1.86	$6.14
OpEx ($/t)	$4.77	$8.58	$13.35
Total ($/t)	**$9.05**	**$10.44**	**$19.49**
Tax credits applied directly to CapEx in model to calculate price/tonne		**$/mcf**	**$1.03**

Market CO_2 value with WTI = $60 $22.90/t ($1.20/mcf)

Without 45Q $47 / tonne ($2.46 / mcf)

Summary

	Challenge	Remedy
Kansas Resource Base	Adequate but disparate and many operators.	Collaboration between operators. Consortium? Led by whom? (KGS, KIOGA, other)
	Needs further analysis.	
45Q tax credits	Generous, but will Kansas operators be able to partake?	Need clarification and possible involvement in final rules.
Complex business model	CO_2 sources - Adequate but disparate and many operators.	Need “Big Players” to get involved.
	Anchor and secondary markets (KS) need to be defined.	

- ✓ ***Help shape the outcome.***
- ✓ ***Make appropriate and timely investments to participate in developing the opportunity at hand.***

Questions?

Acknowledgements:

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Cimarex	And many others

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