CO₂ Capture and Utilization, a Genuine Opportunity for Kansas Operators

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In collaboration with
Kansas Geological Survey
Why we are here today

45Q tax credits are a game changer, making a variety of CCUS projects (CO₂ EOR) technically and economically feasible.

Kansas operators are well-positioned

- Kansas candidate oil fields delineated
- Within pathway of possible large-scale CO₂ pipeline system

CO₂ 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 (CO₂ market) to justify
Kansas Oil Production

Cumulative Production (Billion Barrels)

Year

Annual Production (Million Barrels)

El Dorado WWI

Single Pt Seismic on CKU

Middle East Unrest

Prices & Fracs

3D Seismic

2017

2022

2050

CO₂

EOR Oil?

6.7 Billion to date

50

75

124

KIOGA - CCUS Opportunities Kansas, 8-13-2018

KIOGA - CCUS Opportunities Kansas, 8-13-2018
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

<table>
<thead>
<tr>
<th>Rank in KS</th>
<th>Million BO/yr</th>
<th>% of Kansas</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.5</td>
<td>9.7</td>
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<tr>
<td>2</td>
<td>1.6</td>
<td>4.4</td>
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<tr>
<td>3</td>
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<td>3.5</td>
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<td>4</td>
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<td>5</td>
<td>0.9</td>
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<td>6</td>
<td>0.7</td>
<td>1.8</td>
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<tr>
<td>7</td>
<td>0.5</td>
<td>1.5</td>
</tr>
<tr>
<td>8</td>
<td>0.5</td>
<td>1.4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>9.9</strong></td>
<td><strong>27.8</strong></td>
</tr>
</tbody>
</table>
And, what tax credits could be captured?

Hypothetical Scenarios

- Construction in 2020; Injection in 2022
- Tax credits average $33/tonne CO₂ stored (for EOR) over 12 year period

<table>
<thead>
<tr>
<th>CO₂ Volume (Mt/yr)</th>
<th>Kansas ethanol plant</th>
<th>Potential Kansas Field</th>
<th>Large-scale pipeline to Kansas</th>
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</thead>
<tbody>
<tr>
<td>0.15</td>
<td>0.5</td>
<td>4.3</td>
<td></td>
</tr>
<tr>
<td>Annual Tax Credits ($Million)</td>
<td>$5M</td>
<td>$17M</td>
<td>$142M</td>
</tr>
<tr>
<td>12-years of Credits ($Million)</td>
<td>$59M</td>
<td>$198M</td>
<td>$1,703M</td>
</tr>
</tbody>
</table>
Outline

1. CO₂ Basics
   • The magical fluid
   • CO₂ 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
How “green” is anthropogenic CO₂ EOR?

- Combustion of 1 barrel of oil yields 8 mcf CO₂
- For every barrel produced ~8 mcf CO₂ is permanently left in the reservoir
- Stores as much CO₂ as is released upon combustion
CO₂ – the *magical* fluid

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**CO2 Phase Diagram**

- **SW KS Morrow and Chester CKU L-KC and Arbuckle**
- **Critical Point**
- **Kansas Reservoirs “Window”**
- **GAS**
- **LIQUID**
- **SOLID**

- **(1073 psi)**
- **(147 psi)**
- **(76 psi)**
- **(14.7 psi)**
- **(78°C)**
- **(57°C)**
- **(31°C)**

- **(8°F)**
- **(71°F)**
- **(12°F)**

**Pressures and Temperatures**

- **Pressure (atm)**
- **Temperature (°C)**

**Notes:**

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

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Modified after Condren  www.cbu.edu/~mcondren/CO2_phase_diagram.jpg
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
**CO₂ Processing Styles**

**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 CO₂ Pipeline Infrastructure

Source:
DOE/NETL-2014/1681
Permian Basin and OK-KS pipelines

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

Source:
DOE/NETL-2014/1681
Midwest Ethanol CO₂ to the Permian Plausible?

Gather CO₂ from largest ethanol plants in upper Midwest.
Deliver 9.85 Mt/yr through Kansas to Permian Basin

1546 miles total
755 mi. 16-20” trunk lines
CO₂ from 34 ethanol plants
~10 Mt/yr CO₂

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

Kansas Ethanol Plants (2008)

Blue – active, Tan - planned

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

1997

Transpetco builds CO₂ Pipeline from Denver City to Postle Field

2009

Chapparal buys Liberal Ethanol CO₂ for Okla. EOR

2009

Bereksco and KGS study Arbuckle CO₂ storage potential with $5M DOE grant.

2011

Bereksco and KGS to inject CO₂ into Wellington field in DOE study

2011

KCG denies pooling request for commercial Hall-Gurney flood

2015

Petrosandtander: Garden City Ethanol CO₂ to Stewart field

2009

Bereksco and KGS to inject CO₂ into Wellington field in DOE study

2011, 2015

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

2009

$2.3M DOE to CAP CO₂ and SWP EOR feasibility study

2009

Berexco and KGS to inject CO₂ into Wellington field in DOE study

2011

Chapparal and CVR ink deal for fertilizer CO₂ for EOR

2015

Murfin, KGS & TORP win $5M DOE award for CO₂ pilot

2016

DOE announced Phase II in DOE CarbonSAFE award

2018

KGS/industry partners land $1.5M for Phase I in DOE CarbonSAFE
## U.S. DOE’s 4-Phase CarbonSAFE Program

<table>
<thead>
<tr>
<th>Phase</th>
<th>Program Topic</th>
<th>Years</th>
<th>Start Date</th>
<th>Budget</th>
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<tr>
<td>I</td>
<td>Integrated CCS Pre-Feasibility</td>
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<td>Integrated CCS for Kansas (ICKan) nearing completion</td>
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<td>$1.2M DOE</td>
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<td>II</td>
<td>Storage Complex Feasibility</td>
<td>2</td>
<td>10-2018</td>
<td>$13.3M</td>
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<td></td>
<td>Proposed: Integrated Midcontinent Stacked Storage Hub – Battelle, KGS and EERC jointly</td>
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<td>$9.6M DOE</td>
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<td>III</td>
<td>Site Characterization</td>
<td>2</td>
<td>~2020</td>
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<td>IV</td>
<td>Permitting and Construction</td>
<td>3.5</td>
<td>~2022</td>
<td>TBD</td>
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## Project Partners and Participants

### Industry Partners and Supporters

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<tr>
<th>Category</th>
<th>Company Name</th>
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<tr>
<td>CO2 Sources</td>
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<td>Kansas City Board of Public Utilities</td>
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<td>Sunflower Electric Power Corporation</td>
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<td></td>
<td>CHS, Inc.</td>
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<tr>
<td>Oil &amp; Gas Operators</td>
<td>Berexco, LLC</td>
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<tr>
<td></td>
<td>Casillas Petroleum Corp.</td>
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<tr>
<td></td>
<td>Knighton Oil Co. Inc.</td>
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<td></td>
<td>Blake Production Co. Inc.</td>
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<td></td>
<td>Stroke of Luck Energy</td>
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### Research Team

<table>
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<th>Research Team</th>
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<tr>
<td>Kansas Geological Survey</td>
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<tr>
<td>Improved Hydrocarbon Recovery</td>
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<tr>
<td>The Linde Group</td>
</tr>
<tr>
<td>Great Plains Institute</td>
</tr>
<tr>
<td>Depew Gillen Rathburn &amp; McInteer</td>
</tr>
</tbody>
</table>

### 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

Analyse 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

CO₂ Plumes simulated in Patterson Structure
CO₂ Sources & Transportation Assessment

Preliminary Conclusions

- Davis Ranch and John Creek lack 50 Mt capacity. SW Kansas exceed 50 Mt 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.

Holcomb – still under study: 1 Mt/yr max, but close to storage sites.

CHS Refinery
- Maximum recovery 0.75 Mt/yr.
- More costly than JEC.

Jeffrey Energy Center, St. Marys, KS
- 3x 800 MWe plants -12.5 million tonnes/yr CO₂.
- Partial capture (~350 Mwe) yield 50 Mt over 20 years (2.5 Mt/yr).

Davis Ranch & John Creek Oil Fields

KIOGA - CCUS Opportunities Kansas, 8-13-2018
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)

<table>
<thead>
<tr>
<th>Agency</th>
<th>NGO/Association</th>
<th>Ethanol Producer</th>
<th>Electric Utility</th>
<th>Oil Producer</th>
<th>Other</th>
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<tr>
<td>KS Gov. Colyer</td>
<td>Clean Air Task Force</td>
<td>ADM</td>
<td>NPPD</td>
<td>Berexco</td>
<td>ION Engineering</td>
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<td>NE Ethanol Board</td>
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<td>Cargill</td>
<td>Westar Energy</td>
<td>Merit Energy</td>
<td>MV Purchasing</td>
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<td>NE Dept. of Agriculture</td>
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<td>NE Dept. of Environmental Quality</td>
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<td>NE Corn Board</td>
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<td>Pacific Eth.</td>
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<td>NE Energy Office</td>
<td></td>
<td>Kansas Ethanol</td>
<td></td>
<td></td>
<td></td>
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</table>
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
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.

<table>
<thead>
<tr>
<th>Basin</th>
<th>EOR potential (Mil bbl)</th>
<th>Net CO2 Demand (MMT)</th>
<th>Direct Jobs Created</th>
</tr>
</thead>
<tbody>
<tr>
<td>Illinois/Indiana</td>
<td>500</td>
<td>160 – 250</td>
<td>1,550 – 3,100</td>
</tr>
<tr>
<td>Ohio</td>
<td>500</td>
<td>190 – 300</td>
<td>1,550 – 3,100</td>
</tr>
<tr>
<td>Michigan</td>
<td>250</td>
<td>80 – 130</td>
<td>800 – 1,800</td>
</tr>
<tr>
<td>Kansas</td>
<td>750</td>
<td>240 – 370</td>
<td>2,300 – 4,600</td>
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<tr>
<td><strong>TOTALS</strong></td>
<td><strong>2,000</strong></td>
<td><strong>670 – 1,050</strong></td>
<td><strong>6,200 – 12,400</strong></td>
</tr>
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</table>

Byrnes et al., 1999 (Kansas Geological Survey)

**250 to 1,000 million barrels**
What’s required for 250 mmbo?

4.3 M tonne / yr CO₂ (220 mmcf/d) for 25 yrs

Ethanol CO₂ gathering scenario
✓ 4.3 Mt/yr from 15 plants
✓ To Kansas for EOR/storage

✓ 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 CO₂ EOR Project

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

Bonanza Bioenergy, Garden City

KGS Digital Petroleum Atlas

Stewart Field Production

Production chart from KGS website

Cumulative
11.7 Million BO

Monthly Field Production

Oil Production (barrels)

15 mi 4” pipeline

Conestoga CCUS report, 2016

Bonanza Bioenergy, Garden City
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
- SUCCESSFUL 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)

- 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 “CO₂ Ready”

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

Seismic depth-converted Meramec surfaces (by Hedke)
Pleasant Prairie So.
Chester IVF
Primary + Secondary
4.7 mmbo

Fig. 6.14 Lithofacies model

Incised Valley

PS2 upper surface
Eubank North Unit
Chester IVF

Primary + Secondary
7.4 mmbo
Here’s the upside potential: Arbuckle

Gravity-stable process successful in Canadian reefs

Kansas 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

<table>
<thead>
<tr>
<th>DOE Project</th>
<th>Cumulative Oil (mmbo)</th>
<th>CO2 stored</th>
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<tbody>
<tr>
<td></td>
<td>Gross</td>
<td>Arbuckle</td>
</tr>
<tr>
<td>Balance Geneseo-Edwards</td>
<td>30.2</td>
<td>26.3</td>
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<td>Stoltenberg</td>
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<td>Bloomer</td>
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<td>44.1</td>
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<tr>
<td>Kraft-Prusa</td>
<td>55.8</td>
<td>44.6</td>
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<td>Chase-Silica</td>
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<td></td>
<td>280.6</td>
<td>224.5</td>
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<tr>
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<td>618.7</td>
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### "CO₂ Ready" EOR candidates

<table>
<thead>
<tr>
<th></th>
<th>Inject. Rate (Mt/yr)</th>
<th>CO₂ Stored (Mt)</th>
<th>Primary &amp; Secondary (mmbo)</th>
<th>CO₂ EOR (mmbo)</th>
<th>Basis for Estimate</th>
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<tr>
<td>Shuck</td>
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<td>Pleasant Prairie</td>
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<td>Hall-Gurney</td>
<td>1</td>
<td>11.3</td>
<td>62.5</td>
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<td>DE-AC26-00BC15124 PILOT C12 Energy KCC Documents</td>
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<td>Trapp</td>
<td>0.5</td>
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<td>Wellington</td>
<td>0.6</td>
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<td><strong>Total</strong></td>
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<td><strong>22.8</strong></td>
<td><strong>135.4</strong></td>
<td><strong>55.7</strong></td>
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</table>

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

"CO₂ Ready" fields could take 3.9 million tonnes /year (200 mmcf/d) 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

<table>
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<tr>
<th></th>
<th>mbo/Acre</th>
<th>Million BO/Section</th>
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<tbody>
<tr>
<td>SW KS Study (Chester/Morrow)</td>
<td>4-5</td>
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<tr>
<td>Hall-Gurney (L-KC)</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>Arbuckle (Geneseo-Edwards)</td>
<td>15</td>
<td>9.5</td>
</tr>
</tbody>
</table>

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
- 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)

<table>
<thead>
<tr>
<th>Credits (no inflation)</th>
<th>EOR</th>
<th>Saline</th>
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<td>2017</td>
<td>$12.83</td>
<td>$22.66</td>
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<tr>
<td>2018</td>
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</tr>
<tr>
<td>2025</td>
<td>$32.54</td>
<td>$46.96</td>
</tr>
<tr>
<td>2026 - 2035</td>
<td>$35.00</td>
<td>$50.00</td>
</tr>
</tbody>
</table>

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

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

CO₂ volume is 90% of calculated nameplate
Sources for Economic Modeling and Resources

**Pipeline CapEx and OpEx** are derived from FE/NETL CO₂ 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:


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

**Generic economic model assumptions**

- Capture and compress *150 kt CO₂/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 CO₂
Case 1: Economic Summary

### Cost per tonne CO₂ (credits applied) $/tonne

<table>
<thead>
<tr>
<th></th>
<th>CapEx</th>
<th>OpEx (annual)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capture/Compression</td>
<td>$0.66</td>
<td>$8.58</td>
</tr>
<tr>
<td>Pipeline</td>
<td>$0.51</td>
<td>$1.71</td>
</tr>
</tbody>
</table>

** TOTAL **

<table>
<thead>
<tr>
<th>$/tonne</th>
<th>$/mcf</th>
</tr>
</thead>
<tbody>
<tr>
<td>$11.45</td>
<td>$0.60</td>
</tr>
</tbody>
</table>

45Q tax credits make this case economically viable

Market CO₂ value with WTI = $60

\[ $22.90/t \]

($1.20/mcf)

### Costs $ Million

<table>
<thead>
<tr>
<th></th>
<th>CapEx</th>
<th>OpEx (annual)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capture/Compression</td>
<td>$17.25</td>
<td>$1.28</td>
</tr>
<tr>
<td>Pipeline (20 mi, 4&quot;)</td>
<td>$13.21</td>
<td>$0.25</td>
</tr>
</tbody>
</table>

** TOTAL **

<table>
<thead>
<tr>
<th>CapEx</th>
<th>OpEx (annual)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$30.46</td>
<td>$1.53</td>
</tr>
</tbody>
</table>

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. CO₂ source (ethanol plant failure)
4. MVA and long-term liability

Benefit
1. Low-cost CO₂ 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 to 12 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 CO$_2$-ready oil fields in Kansas
10 mmbo/yr possible increased production

KEY:
- Ethanol Plants
- Other Sources
- Existing CO$_2$ Lines
- Potential CO$_2$ Lines
Case 2 Economics

### Estimated Project Costs

<table>
<thead>
<tr>
<th>Cost $million</th>
<th>Plant Capture</th>
<th>Pipeline Transport</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>CapX</td>
<td>$364</td>
<td>$642</td>
<td>$1,006</td>
</tr>
<tr>
<td>Annual OpX</td>
<td>$37</td>
<td>$16</td>
<td>$53</td>
</tr>
</tbody>
</table>

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 CO₂ (credits applied)

<table>
<thead>
<tr>
<th></th>
<th>Pipeline</th>
<th>Capture &amp; Compress</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>CapEx ($/t)</td>
<td>$1.71</td>
<td>$0.69</td>
<td>$1.90</td>
</tr>
<tr>
<td>OpEx ($/t)</td>
<td>$3.80</td>
<td>$8.58</td>
<td>$12.39</td>
</tr>
<tr>
<td><strong>Total ($/t)</strong></td>
<td><strong>$5.02</strong></td>
<td><strong>$9.27</strong></td>
<td><strong>$14.29</strong></td>
</tr>
</tbody>
</table>

**Without 45Q**

$47 / tonne  ($2.46 / mcf)

Market CO₂ value with WTI = $60 $22.90/t ($1.20/mcf)

Tax credits applied directly to CapEx in model to calculate price/tonne $/mcf $0.75
Case 3: Large-scale, 10 Mt/yr

- 9.85 Mt/yr CO$_2$ (187 BCF/yr, 513 mmcfd)
- 1546 miles of pipeline
- 4 to 20 inch diameter
- 34 ethanol plants (32 locations)
  (3643 MGY capacity)

Gather CO$_2$ from largest ethanol plants in upper Midwest.
Deliver 9.85 Mt/yr through Kansas to Permian Basin

**KEY:**
- Ethanol Plants
- Other Sources
- Existing CO$_2$ Lines
- Potential CO$_2$ Lines
Case 3 Economics

Estimated Project Costs

<table>
<thead>
<tr>
<th>Cost $million</th>
<th>Plant Capture</th>
<th>Pipeline Transport</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>CapX</td>
<td>$809</td>
<td>$1,857</td>
<td>$2,667</td>
</tr>
<tr>
<td>Annual OpX</td>
<td>$85</td>
<td>$47</td>
<td>$131</td>
</tr>
</tbody>
</table>

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 CO₂ (credits applied)

<table>
<thead>
<tr>
<th></th>
<th>Pipeline</th>
<th>Capture &amp; Compress</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>CapEx ($/t)</td>
<td>$4.28</td>
<td>$1.86</td>
<td>$6.14</td>
</tr>
<tr>
<td>OpEx ($/t)</td>
<td>$4.77</td>
<td>$8.58</td>
<td>$13.35</td>
</tr>
<tr>
<td>Total ($/t)</td>
<td>$9.05</td>
<td>$10.44</td>
<td>$19.49</td>
</tr>
</tbody>
</table>

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

$/mcf $1.03

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

Market CO₂ value with WTI = $60 $22.90/t ($1.20/mcf)
## Summary

<table>
<thead>
<tr>
<th>Challenge</th>
<th>Remedy</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Kansas Resource Base</strong></td>
<td>Adequate but disparate and many operators.</td>
</tr>
<tr>
<td></td>
<td>Needs further analysis.</td>
</tr>
<tr>
<td><strong>45Q tax credits</strong></td>
<td>Generous, but will <strong>Kansas</strong> operators be able to partake?</td>
</tr>
<tr>
<td><strong>Complex business model</strong></td>
<td><strong>CO₂</strong> sources - Adequate but disparate and many operators.</td>
</tr>
<tr>
<td></td>
<td>Anchor and secondary markets (KS) need to be defined.</td>
</tr>
</tbody>
</table>

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

Acknowledgements:

Thanks to all of the operators that have participated in the KGS CO2-related projects over the years, in particular:

- Berexco
- Murfin
- Merit Energy
- Casillas
- Cimarex
- Knighton Oil
- Blake Production
- Vess Oil
- John O. Farmer
- And many others

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