High-level Economic Analysis for CO2 Capture, Compression and Transportation

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In collaboration with
Kansas Geological Survey

Context

We outline a variety of scenarios for capture and transportation of large CO2 volumes that are economic at **$70-100 oil**.

4.3 million tonne/yr could be captured and transported to Kansas oil fields for **$35-$42 per tonne** (~$2/mcf).

Proposed **45Q credits ($35/tonne** - $1.85/mcf) make the business proposition very attractive.

4.3 Mt/yr (221 mmcf/d) used for EOR could increase production in **Kansas by 28%** (10 million BO/yr).

Outline

Focus mainly on CO2 capture from ethanol plants and transportation to EOR storage sites

1. Basis for capital and operating costs (CapX and OpX)
2. Describe financial modeling and assumptions
3. Economic analysis for multiple scenarios, small to very large
   - Summary of average costs
   - All the details for one scenario
   - Less detail for others
   - Transportation from larger industrial sources (power and refinery)
4. Summary and Discussion

Handy conversions, metrics and relationships

Conversions

- 6.624# CO_2 / gallon ethanol
- 1 tonne = 1.1 tons
- 1 tonne CO_2 = 19 mcf

Scales of CO_2 sources

• Small Ethanol (55 mgy)	8.6 mmcfd	0.17 million tonnes/yr
• Large Ethanol (313 mgy)	50 mmcfd	0.94 million tonnes/yr
• Coffeyville fertilizer plant	40 mmcfd	0.8 million tonnes/yr
• Jeffrey Energy Center	650 mmcfd	12.5 million tonnes/yr

Other

- Net Utilization (CO_2 stored EOR) ~ 8mcf/BO (0.42 tonne/BO)
  - ✓ *2.4 million BO recovered for million tonnes of CO_2*

• *Proposed* 45Q credits	$35/tonne	$1.84/mcf	$0.116/gal eth
• *Possible* LCFS credits	$70/tonne	$3.68/mcf	$0.232/gal eth

Basis for CapX and OpX for Ethanol Plant Capture, Dehydration and Compression

Capital Expense

- ✓ Cost data for three plant sizes from DOE-funded project reports
- ✓ Compression drives most of the cost
- ✓ Regression analysis - equation related to volume in MGY

CapX ($million) = 9 + 0.146* MGY

(MGY is plant size in million gallons per year)

Operating Expense

- ✓ Cost data for two 55 MGY plants from DOE-funded project reports
- ✓ Report cost data $0.0732/kWh. Average Kansas industrial - $0.0709/kWh
- ✓ Assumes electrical costs are main OpX and are directly proportional to HP

OpX ($) = $8.58/tonne

Pipeline assumptions and cost model

FE/NETL CO2 Transport Cost Model

Grant & Morgan, 2014

- NETL model provides itemized costs for capital and O&M
- Added an input/output table to calculate pipeline network segment costs

FE/NETL CO_2 Transport Cost Model

Version:	1
Status:	Final
Date:	July 11, 2014
NETL document number:	DOE/NETL-2014/1667

This model estimates costs for transporting dense phase (liquid) CO2 in a pipeline from a source, such as a power plant, to either a CO2 saline storage site or a CO2 EOR site. This is a point to point transport model and does not account for possible cost reductions from using a larger diameter trunk pipe as part of a pipeline network. The model includes costs for constructing the pipeline, including booster pumps if desired. The model also includes costs for operating the pipeline.
To use the model, change any of the inputs, which are always orange cells, to the values appropriate for your project.

The use of this model requires macros to be enabled.

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FE/NETL CO2 Transport Cost Model: Main Interface and Financial Model

Solve for Break-even First Year Price for Transporting CO2 in $/tonne

A. First year price per tonne	2011$/tonne	2011$/tonne first yr of proj	2014$/tonne first yr of transp
Price to Transport CO2 by Pipeline	2.10	2.10	2.29
Number of pumps	1		
Length of pipeline	26.6 mi		
Key Outputs			
Calculated Minimum Inner Diameter for Pipe	5.15 in		
Pipeline Nominal Diameter	6 in		
Net Present Value (NPV) of Cash to Owners	-8,024,583	201	
Rate of Return on Weighted Debt and Equity	NA		
Summary of Costs	**Real 2011$** **2011$**		
Capital Costs	21,980,185		
Operating Expenses	11,690,498		
Total Costs	33,670,682		
Weighted total tonnes of CO2 transp. (unweighted, escalated, escal. & discounted)	17,844,246		
Costs per tonne (using weighted total tonnes)	1.89		
Capital Costs per mile of pipeline	826,420		
Operating Expenses per mile of pipeline	439,544		
Operating Expenses per mile of pipeline per year of operation	14,651		
Total Costs per mile of pipeline	1,265,964		
Revenues	**Real 2011$** **2011$**		
Revenue	37,472,917		
Revenue per tonne (using weighted total tonnes)	2.10		
Revenue per mile of pipeline	1,408,922		

Run

Inputs								Pipeline Diameter	
	E14	E12	E67	E70	E75	E77	E79	E17	E18
Segment ID #	Length mi	# of Pumps #	Annual CO2 Mtonne/yr	Capacity factor Decimal Percent	Input Pressure psig	Outlet Pressure psig	Change in Elevation ft	Minimum Pipeline Inner Diameter in	Pipeline Nominal Diameter in
DEFAULT	50	1	5	0.8	2200	1200	0	12.03	16.00
20	44.6	2	1.24	0.8	2200	1600	0	6.97	8.00
13	47.8	2	0.30	0.8	2200	1600	0	4.11	6.00
16	43.0	2	0.30	0.8	2200	1600	0	4.03	6.00
26	0.7	1	0.14	0.8	2200	1600	0	1.47	4.00
11	8.6	1	1.06	0.8	2200	1600	0	5.17	6.00
27	3.5	1	0.14	0.8	2200	1600	0	1.98	4.00
12	21.5	1	0.60	0.8	2200	1600	0	4.96	6.00
23	31.9	2	0.98	0.8	2200	1600	0	5.98	6.00
30	46.1	2	0.30	0.8	2200	1600	0	4.08	6.00
29	63.0	2	2.18	0.8	2200	1600	0	9.27	12.00
3	25.6	1	0.30	0.8	2200	1600	0	3.94	4.00
31	0.6	1	0.34	0.8	2200	1600	0	1.98	4.00
15	15.5	1	1.91	0.8	2200	1600	0	7.26	8.00
14	18.7	1	2.09	0.8	2200	1600	0	7.79	8.00
5	32.6	2	2.39	0.8	2200	1600	0	8.44	12.00
7	48.0	2	0.33	0.8	2200	1600	0	4.27	6.00
8	8.8	1	0.81	0.8	2200	1600	0	4.67	6.00
22	37.1	2	1.25	0.8	2200	1600	0	6.76	8.00
6	49.8	2	0.28	0.8	2200	1600	0	4.01	6.00
24	29.5	1	0.32	0.8	2200	1600	0	4.15	6.00
4	14.7	1	0.30	0.8	2200	1600	0	3.54	4.00
1	17.9	1	0.12	0.8	2200	1600	0	2.59	4.00
10	24.0	1	0.26	0.8	2200	1600	0	3.70	4.00
2	48.9	2	0.17	0.8	2200	1600	0	3.29	4.00
21	36.4	2	0.30	0.8	2200	1600	0	3.90	4.00
25	35.6	2	0.33	0.8	2200	1600	0	4.03	6.00
17	466.9	15	10.97	0.8	2200	1600	0	18.36	20.00
18	75.4	3	7.25	0.8	2200	1600	0	14.39	16.00
19	272.4	9	6.62	0.8	2200	1600	0	14.92	16.00
28	91.0	3	0.71	0.8	2200	1600	0	6.12	8.00
9	26.6	1	0.59	0.8	2200	1600	0	5.15	6.00
	1686								**240**

	Capital Cost							
	E87	E88	E89	E90	E91	E92	E93	E94
Segment ID	Materials $	Labor $	ROW-Damages $	Miscellaneous $	CO2 Surge Tanks $	Pipeline Control system $	Pumps $	Total Capital $
DEFAULT	$ 13,884,459.77	$ 33,196,655.17	$ 11,437,733.93	$ 11,230,476.86	$ 1,244,743.66	$ 111,907.19	$ 2,695,877.77	$ 73,801,854.36
20	$ 4,879,941.37	$ 19,083,196.43	$ 3,869,035.76	$ 5,346,122.29	$ 1,244,743.66	$ 111,907.19	$ 930,929.42	$ 35,465,876.12
13	$ 4,198,644.03	$ 19,083,204.41	$ 3,148,778.44	$ 4,458,339.26	$ 1,244,743.66	$ 111,907.19	$ 352,543.05	$ 32,598,160.04
16	$ 3,786,373.95	$ 17,214,607.99	$ 2,839,448.24	$ 4,027,912.52	$ 1,244,743.66	$ 111,907.19	$ 352,543.05	$ 29,577,536.60
26	$ 122,136.51	$ 643,831.56	$ 88,110.47	$ 195,310.96	$ 1,244,743.66	$ 111,907.19	$ 125,291.96	$ 2,531,332.31
11	$ 811,672.34	$ 3,731,900.99	$ 607,501.08	$ 922,203.07	$ 1,244,743.66	$ 111,907.19	$ 410,777.54	$ 7,840,705.87
27	$ 317,507.60	$ 1,669,909.43	$ 227,051.02	$ 372,894.08	$ 1,244,743.66	$ 111,907.19	$ 125,291.96	$ 4,069,304.94
12	$ 1,925,575.02	$ 8,780,616.93	$ 1,443,272.94	$ 2,085,162.76	$ 1,244,743.66	$ 111,907.19	$ 268,961.66	$ 15,860,240.16
23	$ 2,827,384.24	$ 12,868,028.43	$ 2,119,909.06	$ 3,026,688.27	$ 1,244,743.66	$ 111,907.19	$ 773,356.18	$ 22,972,017.03
30	$ 4,055,516.03	$ 18,434,482.87	$ 3,041,388.12	$ 4,308,907.80	$ 1,244,743.66	$ 111,907.19	$ 352,543.05	$ 31,549,488.72
29	$ 10,563,609.89	$ 31,332,766.58	$ 9,175,636.06	$ 10,801,983.22	$ 1,244,743.66	$ 111,907.19	$ 1,514,877.23	$ 64,745,523.83
3	$ 1,871,657.81	$ 9,832,217.83	$ 1,332,304.00	$ 1,785,543.40	$ 1,244,743.66	$ 111,907.19	$ 176,271.53	$ 16,354,645.41
31	$ 110,062.25	$ 580,418.27	$ 79,523.72	$ 184,336.03	$ 1,244,743.66	$ 111,907.19	$ 188,321.22	$ 2,499,312.34
15	$ 1,746,953.31	$ 6,894,594.14	$ 1,382,131.99	$ 1,960,193.68	$ 1,244,743.66	$ 111,907.19	$ 672,163.68	$ 14,012,687.64
14	$ 2,083,985.28	$ 8,205,786.09	$ 1,649,661.28	$ 2,324,435.80	$ 1,244,743.66	$ 111,907.19	$ 727,777.75	$ 16,348,297.05
5	$ 5,507,134.43	$ 16,413,427.98	$ 4,778,802.72	$ 5,668,171.37	$ 1,244,743.66	$ 111,907.19	$ 1,640,935.76	$ 35,365,123.10
7	$ 4,216,982.95	$ 19,166,324.74	$ 3,162,538.30	$ 4,477,485.83	$ 1,244,743.66	$ 111,907.19	$ 371,081.07	$ 32,751,063.73
8	$ 830,307.37	$ 3,816,363.45	$ 621,483.12	$ 941,658.79	$ 1,244,743.66	$ 111,907.19	$ 331,990.92	$ 7,898,454.50
22	$ 4,068,803.27	$ 15,927,538.17	$ 3,225,170.43	$ 4,469,497.28	$ 1,244,743.66	$ 111,907.19	$ 940,198.43	$ 29,987,858.44
6	$ 4,371,759.87	$ 19,867,844.48	$ 3,278,668.91	$ 4,639,079.23	$ 1,244,743.66	$ 111,907.19	$ 337,712.61	$ 33,851,715.94
24	$ 2,618,064.50	$ 11,919,295.71	$ 1,962,854.45	$ 2,808,149.95	$ 1,244,743.66	$ 111,907.19	$ 182,759.81	$ 20,847,775.26
4	$ 1,101,974.09	$ 5,789,882.77	$ 784,933.98	$ 1,085,937.16	$ 1,244,743.66	$ 111,907.19	$ 176,271.53	$ 10,295,650.39
1	$ 1,333,075.48	$ 7,003,614.11	$ 949,284.57	$ 1,295,997.44	$ 1,244,743.66	$ 111,907.19	$ 120,657.45	$ 12,059,279.90
10	$ 1,757,286.44	$ 9,231,545.95	$ 1,250,967.40	$ 1,681,585.22	$ 1,244,743.66	$ 111,907.19	$ 165,148.71	$ 15,443,184.57
2	$ 3,510,426.95	$ 18,438,940.08	$ 2,497,734.77	$ 3,275,107.35	$ 1,244,743.66	$ 111,907.19	$ 269,121.93	$ 29,347,981.93
21	$ 2,635,473.06	$ 13,843,732.08	$ 1,875,500.58	$ 2,479,815.49	$ 1,244,743.66	$ 111,907.19	$ 352,543.05	$ 22,543,715.11
25	$ 3,152,081.77	$ 14,339,705.98	$ 2,363,532.73	$ 3,365,685.69	$ 1,244,743.66	$ 111,907.19	$ 371,081.07	$ 24,948,738.08
17	$ 191,676,889.08	$ 386,832,526.85	$ 156,135,446.89	$ 128,159,474.44	$ 1,244,743.66	$ 111,907.19	$ 52,025,174.89	$ 916,186,163.01
18	$ 20,893,335.74	$ 49,838,446.54	$ 17,218,425.57	$ 16,856,718.56	$ 1,244,743.66	$ 111,907.19	$ 6,963,362.89	$ 113,126,940.15
19	$ 75,296,094.23	$ 179,011,706.47	$ 62,088,041.26	$ 60,527,496.87	$ 1,244,743.66	$ 111,907.19	$ 19,138,245.52	$ 397,418,235.21
28	$ 9,878,215.66	$ 38,528,523.46	$ 7,836,566.74	$ 10,747,930.26	$ 1,244,743.66	$ 111,907.19	$ 909,770.90	$ 69,257,657.85
9	$ 2,369,809.12	$ 10,794,088.89	$ 1,776,586.06	$ 2,548,961.24	$ 1,244,743.66	$ 111,907.19	$ 267,107.84	$ 19,113,204.00
	$374,518,734	**$979,119,070**	**$302,810,291**	**$296,828,785**	**$38,587,053**	**$3,469,123**	**$91,534,814**	**$2,086,867,869**

	Annual O&M Cost			
	E97	E98	E99	E100
Segment ID	Pipeline O&M $	Pipeline related equipment and pumps O&M $	Electricity costs for pumps $	Total annual operating expenses $
DEFAULT	$ 423,845.47	$ 162,101.14	$ 1,413,050.29	$ 1,998,996.91
20	$ 378,087.74	$ 91,503.21	$ 413,138.67	$ 882,729.63
13	$ 404,778.52	$ 68,367.76	$ 100,276.38	$ 573,422.66
16	$ 364,354.99	$ 68,367.76	$ 100,276.38	$ 532,999.13
26	$ 6,229.86	$ 59,277.71	$ 22,562.19	$ 88,069.76
11	$ 72,682.32	$ 70,697.14	$ 176,987.81	$ 320,367.27
27	$ 29,756.54	$ 59,277.71	$ 22,562.19	$ 111,596.44
12	$ 181,901.67	$ 65,024.50	$ 100,276.38	$ 347,202.55
23	$ 270,325.03	$ 85,200.28	$ 327,903.74	$ 683,429.05
30	$ 390,744.66	$ 68,367.76	$ 100,276.38	$ 559,388.80
29	$ 534,093.95	$ 114,861.12	$ 729,009.27	$ 1,377,964.34
3	$ 216,908.04	$ 61,316.90	$ 50,138.19	$ 328,363.13
31	$ 4,775.87	$ 61,798.88	$ 56,656.15	$ 123,230.90
15	$ 131,797.12	$ 81,152.58	$ 318,377.49	$ 531,327.19
14	$ 158,291.89	$ 83,377.14	$ 348,460.40	$ 590,129.44
5	$ 276,724.32	$ 119,903.46	$ 797,197.19	$ 1,193,824.97
7	$ 406,576.67	$ 69,109.28	$ 110,304.02	$ 585,989.96
8	$ 74,509.50	$ 67,545.67	$ 134,370.34	$ 276,425.52
22	$ 314,322.51	$ 91,873.97	$ 418,152.49	$ 824,348.97
6	$ 421,752.71	$ 67,774.54	$ 92,254.26	$ 581,781.51
24	$ 249,801.00	$ 61,576.43	$ 53,647.85	$ 365,025.28
4	$ 124,222.37	$ 61,316.90	$ 50,138.19	$ 235,677.45
1	$ 152,051.70	$ 59,092.33	$ 20,055.28	$ 231,199.32
10	$ 203,135.39	$ 60,871.98	$ 44,121.61	$ 308,128.98
2	$ 414,249.40	$ 65,030.91	$ 55,152.01	$ 534,432.32
21	$ 308,887.04	$ 68,367.76	$ 100,276.38	$ 477,531.18
25	$ 302,161.97	$ 69,109.28	$ 110,304.02	$ 481,575.26
17	$ 3,957,521.01	$ 2,135,273.03	$ 27,463,429.67	$ 33,556,223.71
18	$ 639,024.70	$ 332,800.55	$ 3,631,007.53	$ 4,602,832.78
19	$ 2,309,241.67	$ 819,795.85	$ 9,945,410.95	$ 13,074,448.47
28	$ 771,012.35	$ 90,656.87	$ 356,482.48	$ 1,218,151.70
9	$ 225,459.30	$ 64,950.35	$ 99,273.61	$ 389,683.26
	$14,295,382	**$5,343,640**	**$46,348,479**	**$65,987,501**

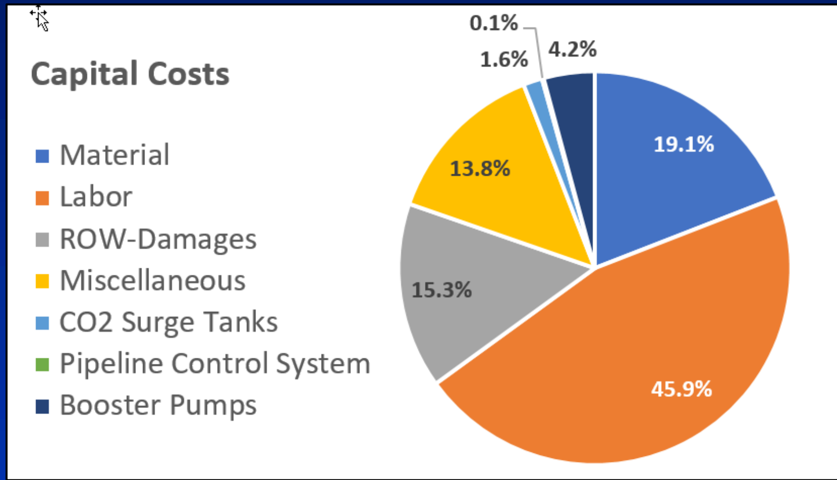
Pipeline assumptions and cost model

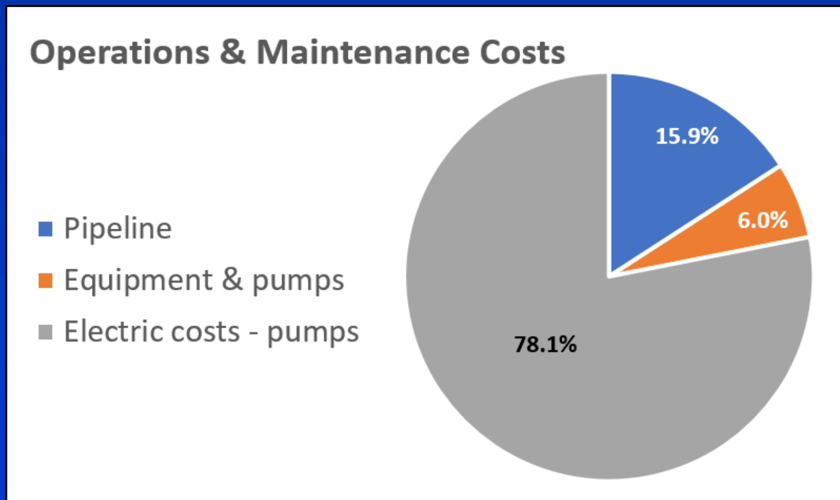
FE/NETL CO2 Transport Cost Model

Grant & Morgan, 2014

- NETL model provides itemized costs for capital and O&M
- Compared to $100k/inch-mile: Estimates ±10% for individual segments and ±3% for systems

CapX and OpX by expense category





Assumptions/Inputs

- 90% of plant rating for CO2 production (EIA 2016)
- 110% distance in miles
- 2000-1400 psi drops
- Booster stations
- Delivered to field at 1400 psi

Assumptions and methodology for simple financial model

- All financed in same manner: Ethanol plant capture, dehydration, and compression *and* pipeline construction
- All operations begin simultaneously: Capture facilities, pipeline, and sales points (oil fields)

✓ Twenty-two year project

✓ Two year construction phase

✓ 20-year operations and amortization

✓ Zero inflation

✓ ***Determine CO2 price required for CO2 to provide a specified ROR (NPV=0)***

Two Finance Scenarios

Weighted Average Return = 10.0%

Taxable Bond BBB- (50%@5%)

Regular LLC (50%@15%)

Weighted Average Return = 6.7%

Tax-Exempt PAB BBB (55%@4%)

Publicly Traded MLP (45%@10%)

Economic Analysis of Ethanol CO2 Capture and Transportation at Varying Scales

- Evaluated multiple scenarios - Four discussed today
- Range from simple, point-to-point (one source) to complex multi-source (up to 32 sources)
- Considered two Equity-Debt financing scenarios

Mean CO2 Price Required

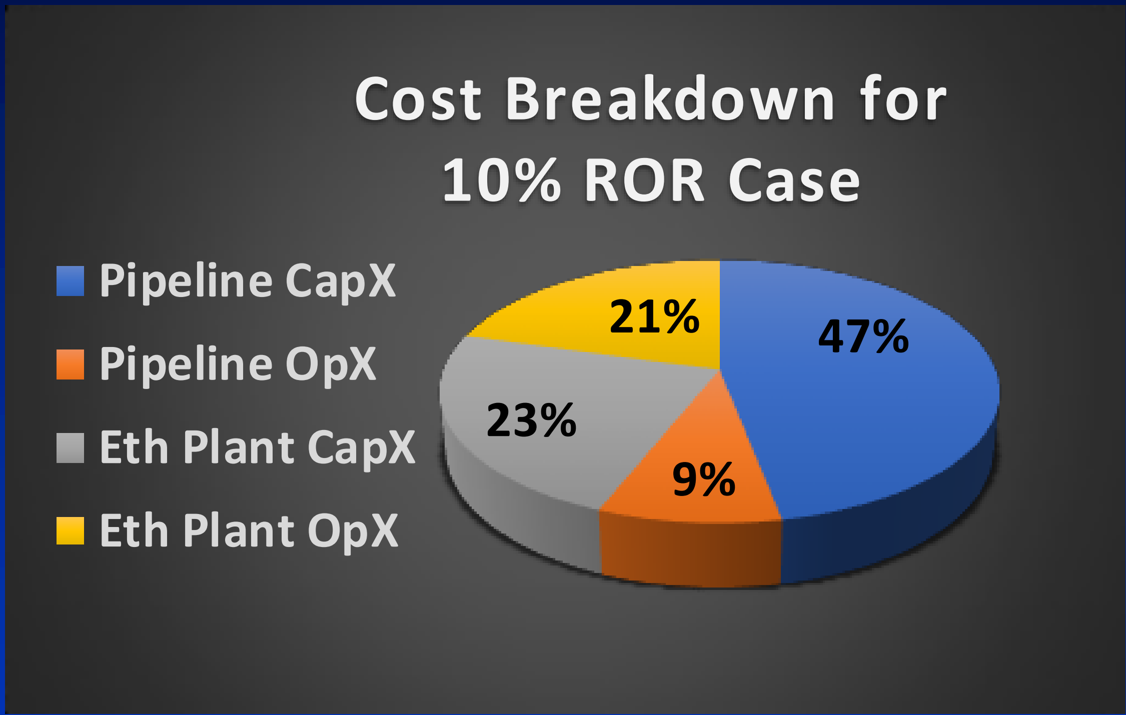
Required ROR	10%	6.7%
$/tonne	$42	$35
$/mcf	$2.20	$1.85
$/gal ethanol	$0.14	$0.12

(Scenarios 1A, 2, 3)

- Average for 3 of 4 of scenarios (1A, 2, 3) at two ROR
- Proposed 45Q tax credit ($35/tonne) could cover most of cost

CO2 price for required ROR (weighted average cost of capital)

Average cost allocation across three scenarios



For the 10% ROR Case

Ethanol plant (capture and compress)	$18 /tonne,	$0.85 /mcf,	$0.061 /gal
Pipeline (transport)	$23 /tonne,	$1.23 /mcf,	$0.78 /gal

More details on cost allocation

Perspective:

CO2 for EOR in W TX sells for $1/mcf *(2% of WTI price - $50/BO)*

Three years ago WTI was $100/BO ($2/mcf CO2)

Proposed 45Q tax credit is $1.85/mcf ($35/tonne)

Cost Breakdown for 6.7% ROR case

		$/tonne	$/mcf	$/gal
Pipelines	**CapX**	$15.15	$0.80	$0.051
	OpX	$3.79	$0.20	$0.013
Ethanol Plants	**CapX**	$7.55	$0.40	$0.025
	OpX	$8.58	$0.45	$0.029
		$35	**$1.85**	**$0.117**

Cost Breakdown for 10% ROR case

		$/tonne	$/mcf	$/gal
Pipelines	**CapX**	$19.60	$1.03	$0.065
	OpX	$3.79	$0.20	$0.013
Ethanol Plants	**CapX**	$9.77	$0.51	$0.033
	OpX	$8.58	$0.45	$0.029
		$42	**$2.20**	**$0.139**

Average for three of the four scenarios at two ROR

Simple summary for the four scenarios

CO2 price for required ROR of 10% and 6.7% (weighted average cost of capital)

Scenario	Ethanol Plants	Pipeline Miles	CO2 (Mt/yr)	Required Price $/tonne		Required Price $/mcf	
				10%	6.70%	10%	6.70%
1A	2(1)	201	1.12	$37	$31	$1.95	$1.64
1B	1	16	0.15	$33	$28	$1.75	$1.47
2	15	737	4.26	$42	$35	$2.19	$1.84
3	34	1546	9.85	$47	$39	$2.46	$2.06

1A Point-to-point, two ADM plants (413 MGY) to Sleepy Hollow field, Nebraska

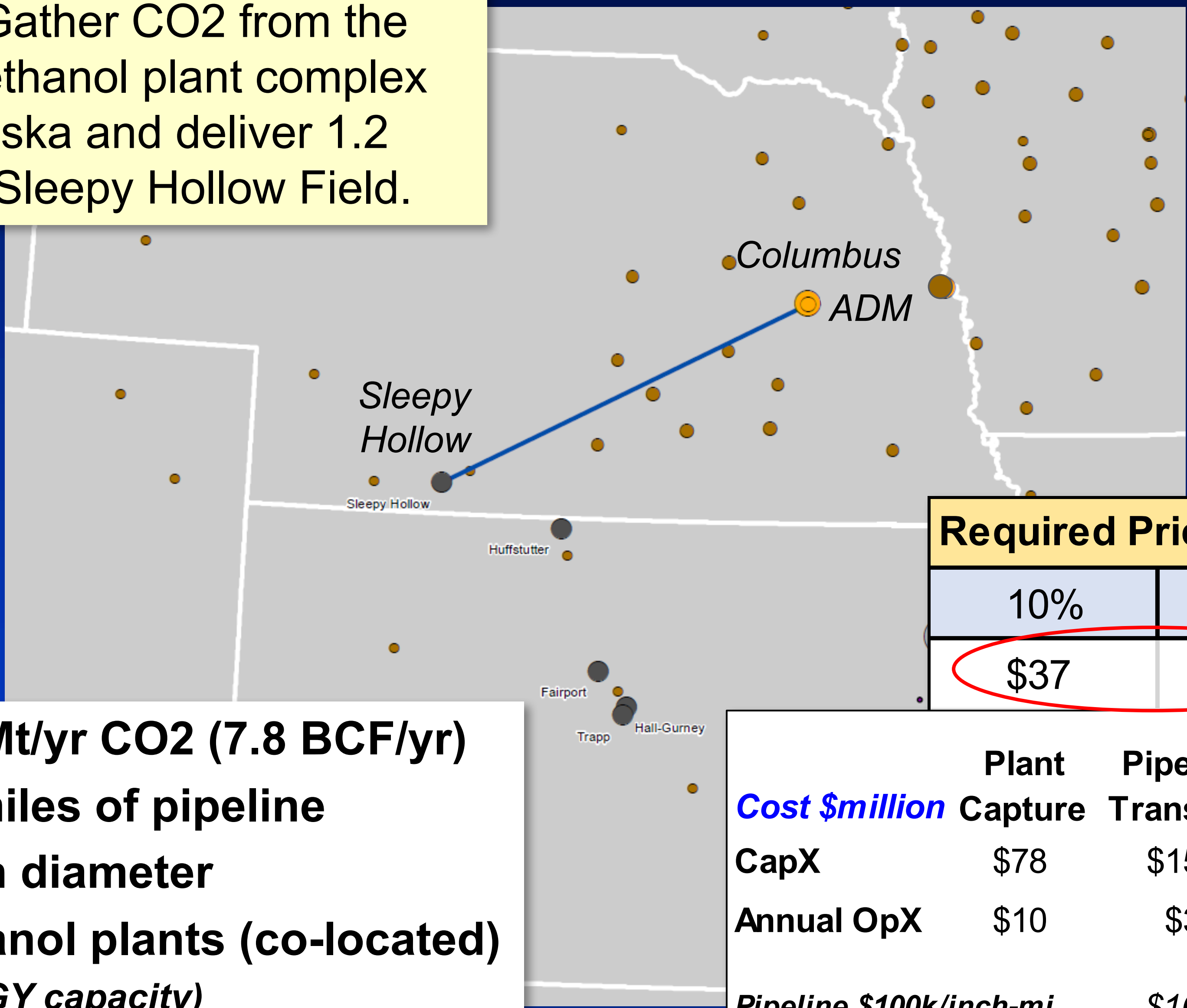
1B Generic Kansas point-to-point, 55 MGY plant to oil field within 16 miles

2 Fifteen plants (1575 MGY) to seven Kansas oil fields

3 Thirty-four plants (3643 MGY) through Kansas all the way to Permian Basin

Scenario 1A Large point-to-point

Logic: Gather CO2 from the largest ethanol plant complex in Nebraska and deliver 1.2 Mt/yr to Sleepy Hollow Field.



Required Price $/tonne	
10%	6.7%
$37	$31

- ✓ **1.12 Mt/yr CO2 (7.8 BCF/yr)**
- ✓ **201 miles of pipeline**
- ✓ **8 inch diameter**
- ✓ **2 ethanol plants (co-located)**
  (413 MGY capacity)

Cost $million	Plant Capture	Pipeline Transport	Total
CapX	$78	$154	$232
Annual OpX	$10	$3	$13
Pipeline $100k/inch-mi		*$161*	

Scenario 1B Small point-to-point

Kansas Examples:

Modeled: 148,000 tonnes/yr transported 16 miles

- ✓ Kansas Ethanol, Lyons (55MGY) to Geneseo Edwards Field
- ✓ USEP, Russell (55MGY) to Hall-Gurney
- ✓ Prairie Horizon, Phillipsburg (40MGY) to Huffstutter

*Could be attractive at **$75/BO***

45Q credits could make it lucrative at today's prices

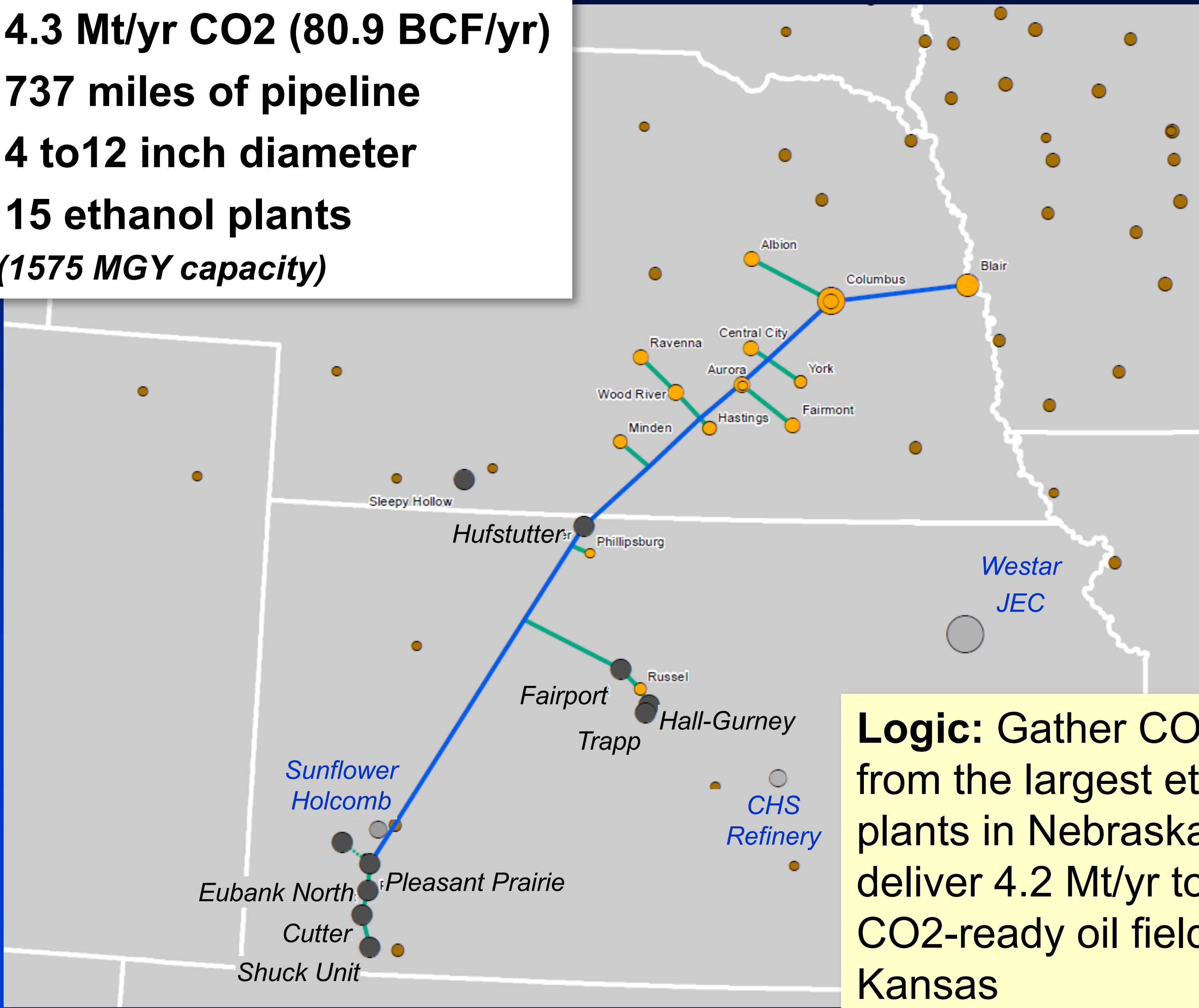
LCFS credits could make storage without EOR possible

Cost Breakdown ($/tonne)

	Required ROR	10%	6.7%
Pipelines	**CapX**	$9.12	$7.05
	OpX	$1.48	$1.48
Ethanol Plants	**CapX**	$14.09	$10.89
	OpX	$8.58	$8.58
TOTAL	**$/tonne**	**$33**	**$28**
	$/mcf	**$1.75**	**$1.47**
	$/gallon	**$0.11**	**$0.09**

Scenario 2: Fifteen plants to Kansas oil fields

- ✓ **4.3 Mt/yr CO2 (80.9 BCF/yr)**
- ✓ **737 miles of pipeline**
- ✓ **4 to12 inch diameter**
- ✓ **15 ethanol plants**
  (1575 MGY capacity)



Logic: Gather CO2 from the largest ethanol plants in Nebraska and deliver 4.2 Mt/yr to CO2-ready oil fields in Kansas

Scenario 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

Cost breakdown ($/unit CO2) for two Cost of Capital cases

Cost of Capital = 10%

	Pipeline	Ethanol	Combined
CapX ($/tonne)	$18.60	$10.55	$29.15
OpX ($/tonne)	$3.80	$8.58	$12.39
Total ($/tonne)	$22	$19	**$42**
			$/tonne
CapX ($/mcf)	$0.98	$0.56	$1.53
OpX ($/mcf)	$0.20	$0.45	$0.65
Total ($/mcf)	$1.18	$1.01	**$2.19**
			$/mcf

Cost of Capital = 6.7%

	Pipeline	Ethanol	Combined
CapX ($/tonne)	$14.37	$8.15	$22.52
OpX ($/tonne)	$3.80	$8.58	$12.39
Total ($/tonne)	$18	$17	**$35**
			$/tonne
CapX ($/mcf)	$0.76	$0.43	$1.19
OpX ($/mcf)	$0.20	$0.45	$0.65
Total ($/mcf)	$0.96	$0.88	**$1.84**
			$/mcf

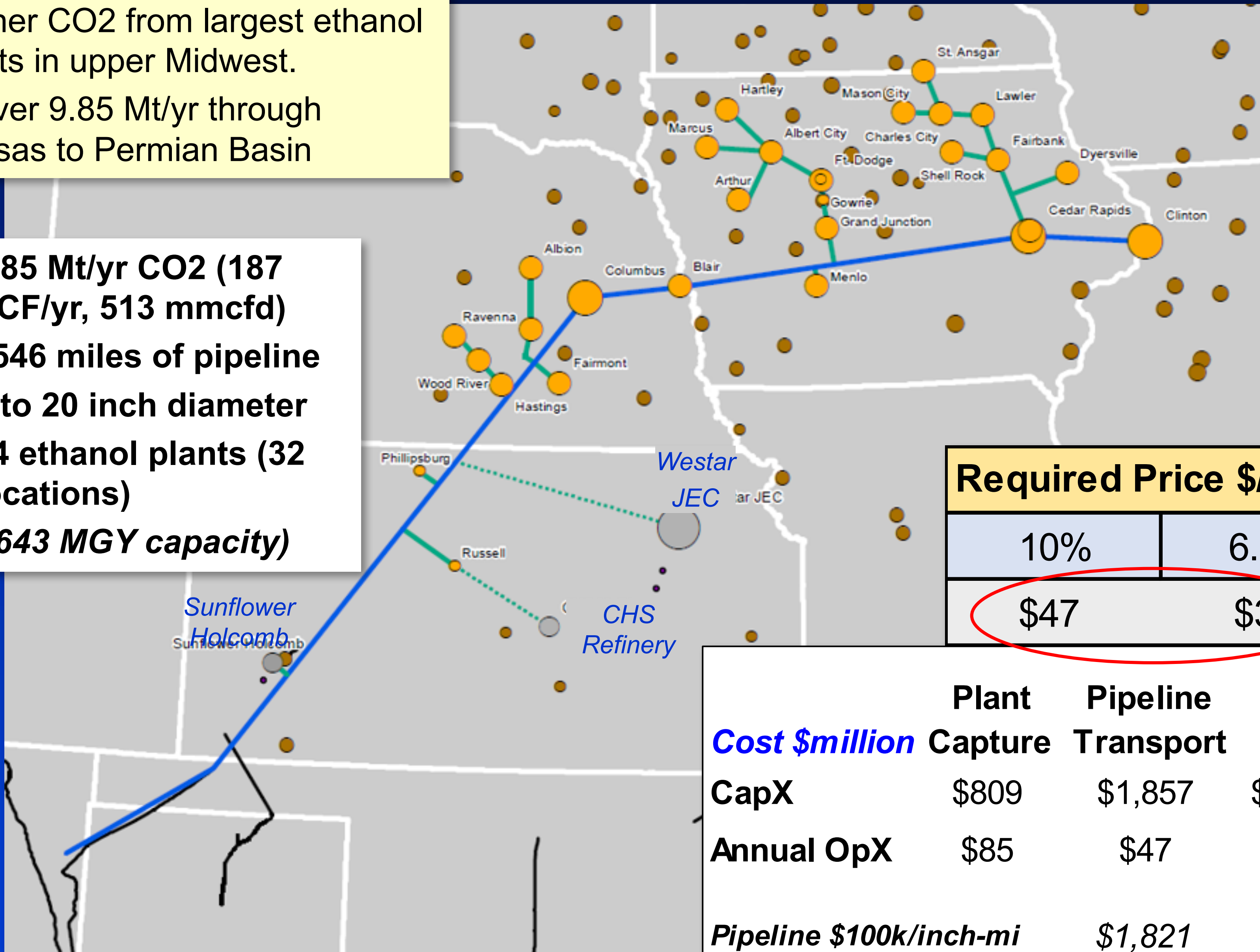
Scenario 3 Large-scale, 10 Mt/yr

Gather CO_2 from largest ethanol plants in upper Midwest.

Deliver 9.85 Mt/yr through Kansas to Permian Basin

- ✓ **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)

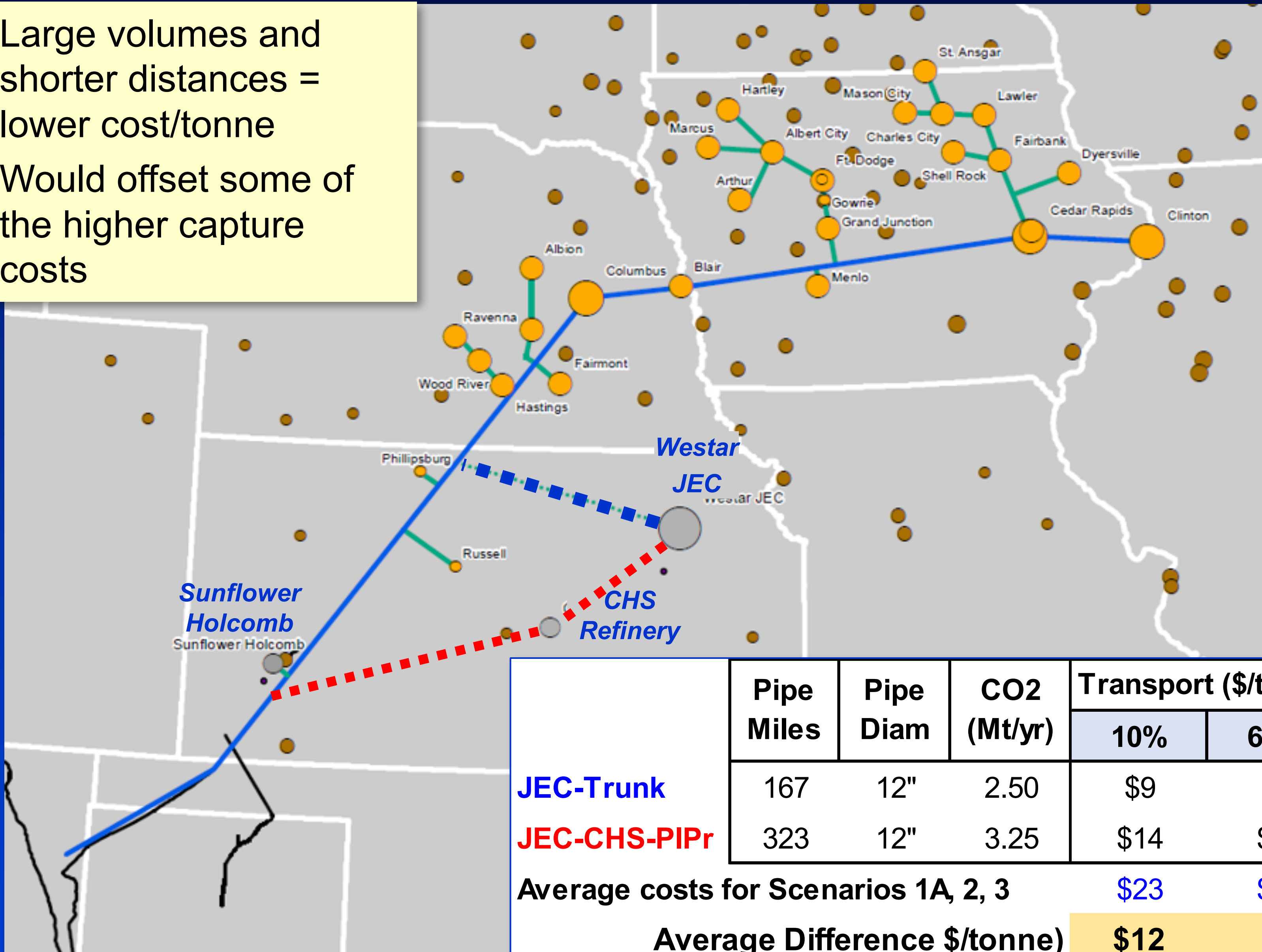


Required Price $/tonne	
10%	6.7%
$47	$39

Cost $million	**Plant Capture**	**Pipeline Transport**	**Total**
CapX	$809	$1,857	$2,667
Annual OpX	$85	$47	$131
Pipeline $100k/inch-mi		*$1,821*	

Westar and CHS would reduce overall transport cost

- ✓ Large volumes and shorter distances = lower cost/tonne
- ✓ Would offset some of the higher capture costs



	Pipe Miles	Pipe Diam	CO2 (Mt/yr)	Transport ($/tonne) 10%	Transport ($/tonne) 6.7%
JEC-Trunk	167	12"	2.50	$9	$7
JEC-CHS-PIPr	323	12"	3.25	$14	$12
Average costs for Scenarios 1A, 2, 3				$23	$19
Average Difference $/tonne)				**$12**	**$9**

Parting Comments

- 45Q passes – better move quickly
- If not, smaller scale projects possible
- Keep an eye on larger industrial source opportunities

Mean CO2 Price Required

Required ROR	10%	6.7%
$/tonne	$42	$35
$/mcf	$2.20	$1.85
$/gal ethanol	$0.14	$0.12

(Scenarios 1A, 2, 3)

Discussion

- Economic modeling?
- Potential for lowering costs?
- Kansas have the resource to support 4Mt?

Later today in open discussion

- Business model(s) to pull it all together
- How would credits be captured? And shared?
- Ins and outs of 45Q and LCFS credits?