CO_2SCOPE™

EORI's Scoping Model

BENJAMIN R. COOK, PHD

EORI/UNIVERSITY OF WYOMING

Presented at the 19th Annual CO_2 Flooding Conference
December 11-13, 2013
Midland, Texas

ENHANCED OIL RECOVERY INSTITUTE

UNIVERSITY OF WYOMING

Disclaimer & Acknowledgements

All data and information contained within this presentation are from public sources. Furthermore, all analyses and interpretations have been conducted with publically available data.

THIS MATERIAL WAS PREPARED AS AN ACCOUNT OF WORK PRODUCED BY AN AGENCY OF THE STATE OF WYOMING. NEITHER THE STATE OF WYOMING, NOR THE UNIVERSITY OF WYOMING, NOR THE ENHANCED OIL RECOVERY INSTITUTE (EORI), NOR ANY OF THEIR EMPLOYEES, MAKES ANY WARRANTY, EXPRESS OR IMPLIED, OR ASSUMES ANY LEGAL LIABILITY OR RESPONSIBILITY FOR THE ACCURACY, COMPLETENESS, OR USEFULNESS OF ANY INFORMATION, APPARATUS, PRODUCT, OR PROCESS DISCLOSED, OR REPRESENTS THAT ITS USE WOULD NOT INFRINGE PRIVATELY OWNED RIGHTS. THE EORI RESERVES THE RIGHT TO CHANGE, AMEND, ALTER, ADDEND OR REMOVE THE CONTENTS OF THIS MATERIAL IN FUTURE EDITIONS BOTH IN PART OR IN ITS ENTIRETY. THIS DISCLAIMER IS MADE WITH RESPECT TO THE DOCUMENT AS WELL AS THE ASSOCIATED DATA.

- The author acknowledges the assistance & contributions of the following:
  Klaas van ‘t Veld
  Shaochang Wo
  Glen Murrell
  Laura Dalles
  David Mohrbacher
  EORI/COB/SER

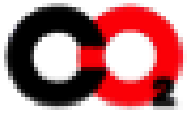
EORI's CO_2-EOR Scoping History

Purpose of Work

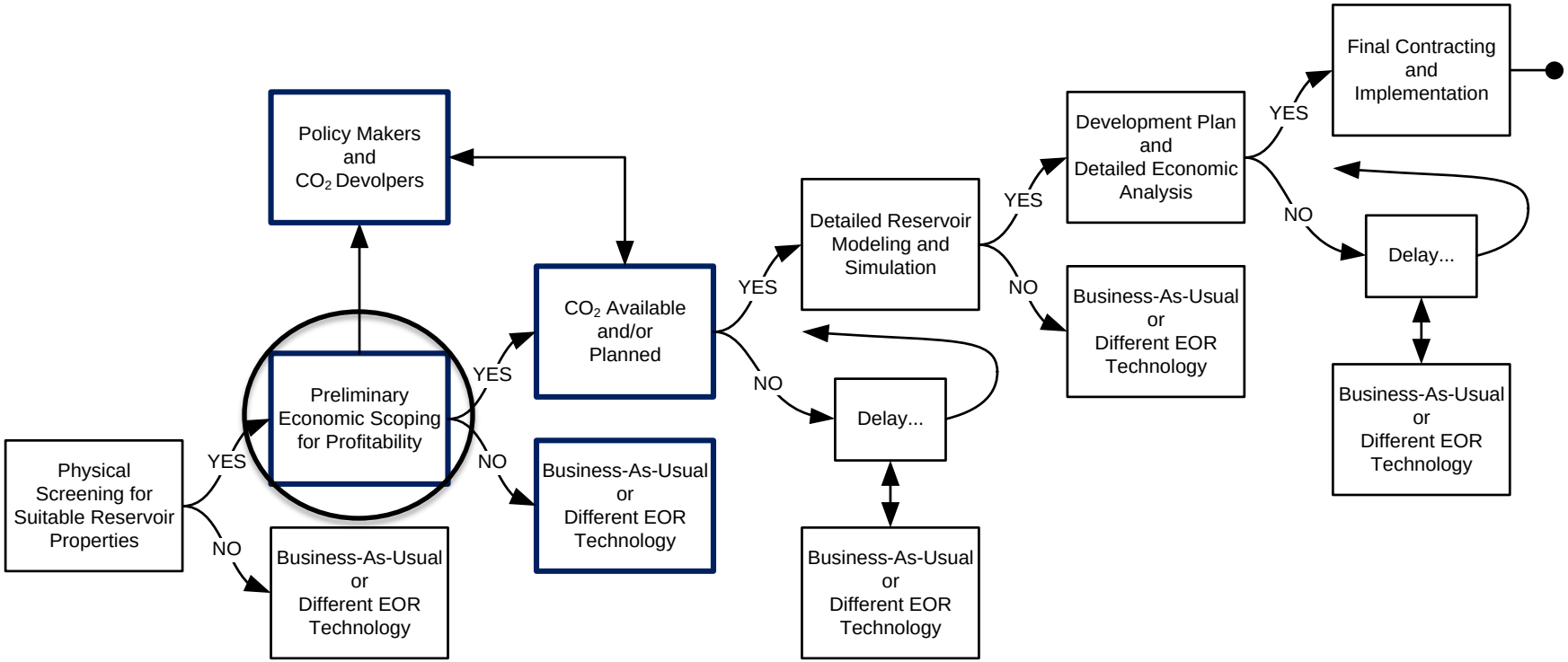
- Identify Promising CO_2-EOR Candidates in Wyoming
- Characterize Geographic Outlay for Pipeline Planning
- Estimate Incremental Oil Recovery Potential
- Estimate CO_2 Purchase Demand Volumes

Finally, Technology Transfer

- One of EORI's Missions is Technology Transfer through Non-Confidential Research, Conferences and Workshops
- Create a Distributable Excel Version of the CO_2 Scoping Model
- Freely Available to WY Owner/Operators to Evaluate WY Projects



Scoping Studies



EORI's CO_2-EOR Scoping History

Initial MATLAB Model

- Analog Technique as in the "Kinder Morgan" Spreadsheet Model
- KM San Andres Analog, and WY Lost-Soldier Tensleep Analog
- Quarterly Cash Flows, Quickly Analyze 100s of FRCs & Scenarios

van't Veld & Phillips (Energy Journal,2010)

- Applied Model to Powder River Basin FRCs >5 Mmbo Cumulative
- Two Analogs (17.4% Incremental, 7.7%,) with Minimum 20% IRR

Cook Dissertation (2011) with Monte Carlo

- Statewide Database of Miscible FRCs >5 Mmbo Cumulative
- Updated Costs Estimates & Other Refinements
- Used Monte Carlo to Characterize the Outcome Sensitivity

Latest WY Scoping Work

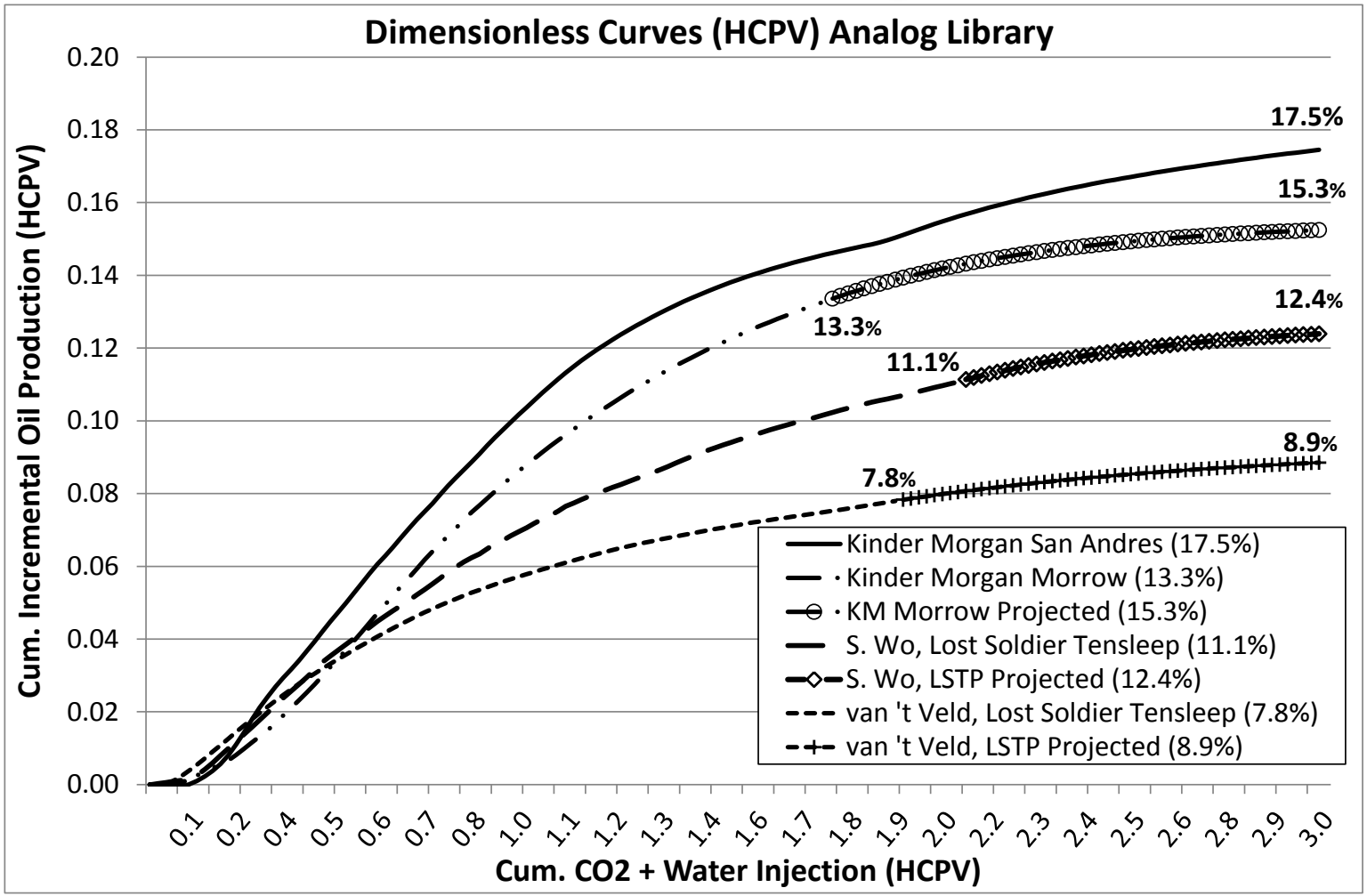
Database of WY FRCs

- Oil gravity 22º - 48º API, MMP < Fracture pressure
- 723 FRCs in 415 Fields
- 4.9 Billion Cum. Production (~13.9 Billion OOIP)

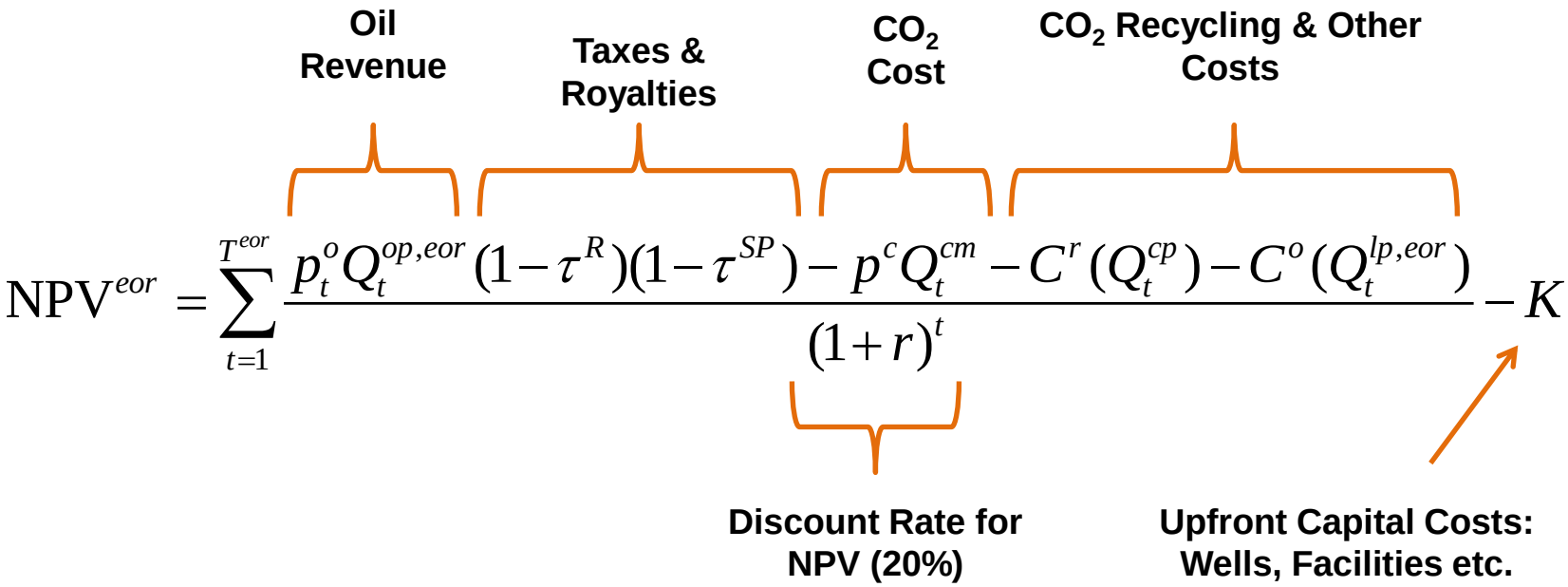
Flexible Excel-Based Model

- Easily Customized with Alternative Scenarios
- 3 Core Analog Projects with 7 Scalable Variations
- Integrated IMPLAN Model to Estimate Economic Impacts

Incremental Oil Analogs



NPV & Cash Flows



Core Assumptions

Vertical Well Patterns & WAG Injection

- Injection Rate Based on Number of Injectors
- WAG & Incremental Oil Based on Analog
- HCPV = OOIP x Initial Oil Formation Volume Factor

Default Cost Assumptions

- New Well Drilling, Completions & Existing Well Workovers
- Size/Cost of Recycling Based on Max MMcfd CO_2 Production
- Pipeline Construction Costs
- Option to Include Property Acquisition & New Electrical Infrastructure
- Recycling Labor, Maintenance & Electricity Based on HP Rating
- Taxes, Royalties, Liquid Lift Costs, and Other Annual Well Work

Licensing Options

Availability

- http://www.uwyo.edu/eori
- Register for a 10-day Full Working Trial
- Various Options for 1-Year Activation

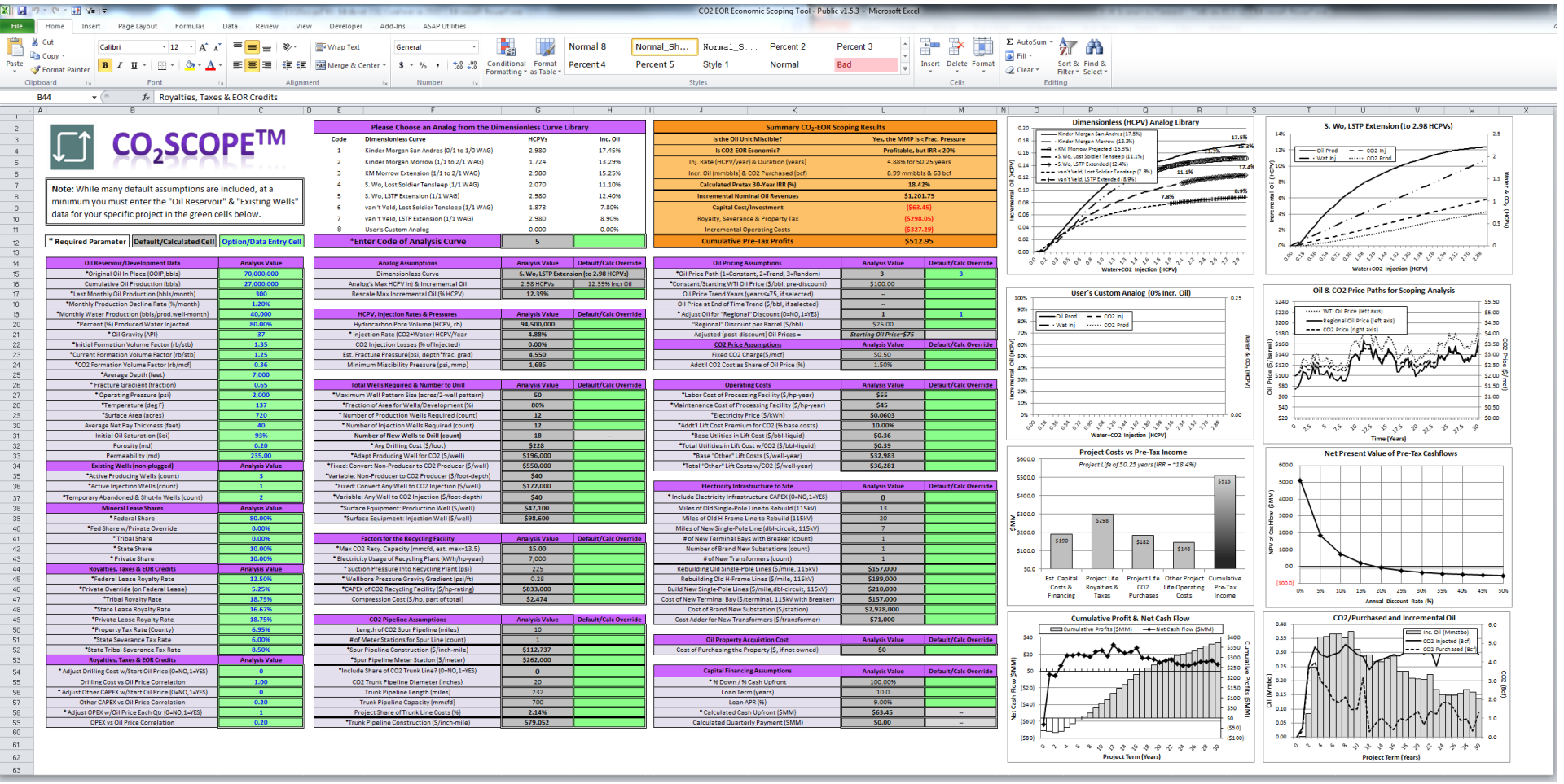
Licenses

- WY Company Analyzing WY Projects (FREE 1-Year Renewable Licenses)*
- WY Company, Extensive Use for Non-WY Projects ($300/Year/Install)*
- Non-WY Users Based in the United States ($500/Year/Install)
- Installation of CO_2Scope^{TM} Outside the United States ($750/Year/Install)
- Consulting, Each Project Application ($500/Install/90-Days)

*A “Wyoming Company” is a company operating and paying mineral taxes in WY.

CO_2SCOPE^{TM}

Main Dashboard



ENHANCED OIL RECOVERY INSTITUTE

UNIVERSITY OF WYOMING

CO_2SCOPE^{TM}

Main Dashboard

* Required Parameter	Default/Calculated Cell	Option/Data Entry Cell

Oil Reservoir/Development Data	Analysis Value
*Original Oil In Place (OOIP,bbls)	70,000,000
Cumulative Oil Production (bbls)	27,000,000
*Last Monthly Oil Production (bbls/month)	300
*Monthly Production Decline Rate (%/month)	1.20%
*Monthly Water Production (bbls/prod.well-month)	40,000
*Percent (%) Produced Water Injected	80.00%
* Oil Gravity (API)	37
*Initial Formation Volume Factor (rb/stb)	1.35
*Current Formation Volume Factor (rb/stb)	1.25
*CO2 Formation Volume Factor (rb/mcf)	0.36
*Average Depth (feet)	7,000
* Fracture Gradient (fraction)	0.65
* Operating Pressure (psi)	2,000
*Temperature (deg F)	137
*Surface Area (acres)	720
Average Net Pay Thickness (feet)	40
Initial Oil Saturation (Soi)	93%
Porosity (md)	0.20
Permeability (md)	235.00
Existing Wells (non-plugged)	**Analysis Value**
*Active Producing Wells (count)	3
*Active Injection Wells (count)	1
*Temporary Abandoned & Shut-In Wells (count)	2

Many Other Parameters

- Taxes & Royalties
- Oil Price & Cost Correlation
- Injection Rates

CAPEX

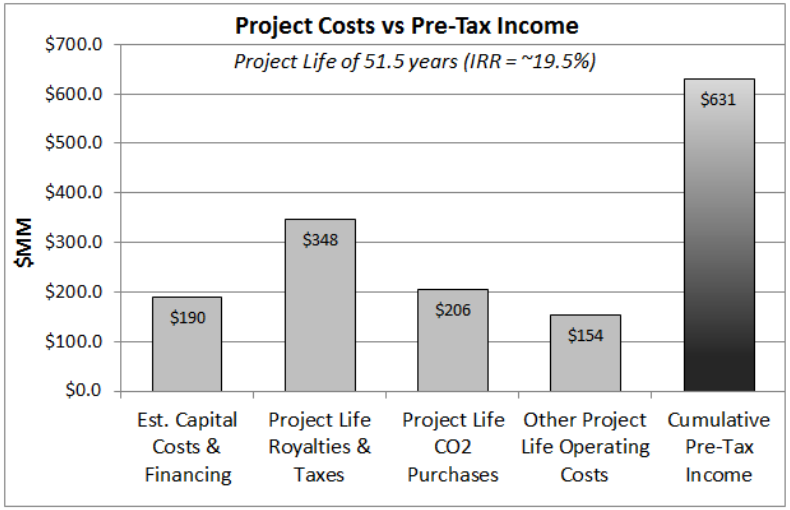
- Drilling & Workover Costs
- Recycling Plant Costs
- Pipeline Costs
- Power Infrastructure

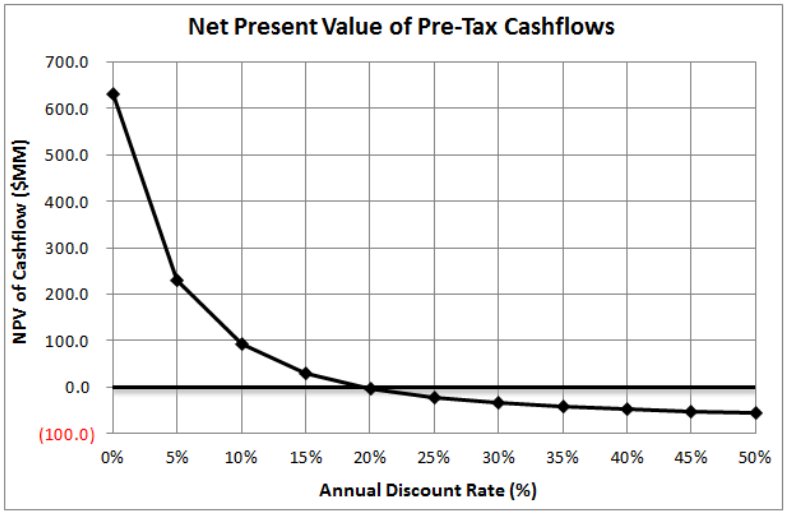
OPEX

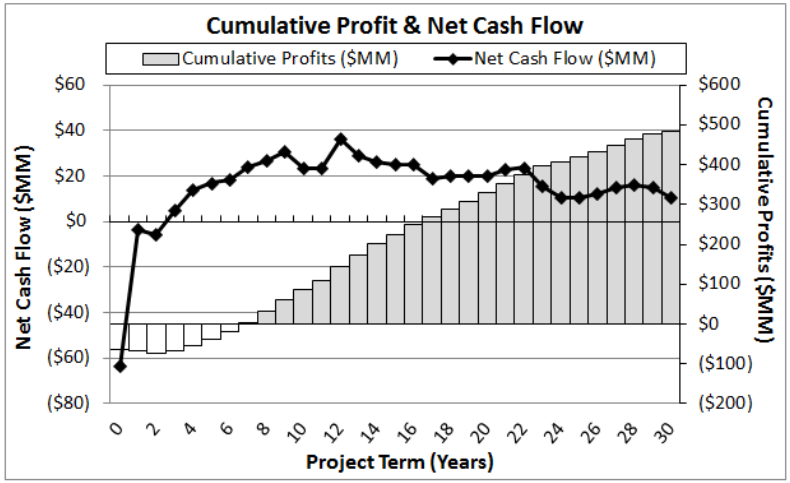
- Plant L&M + Electricity
- Lift & Other Well Costs
- CO_2 Purchasing

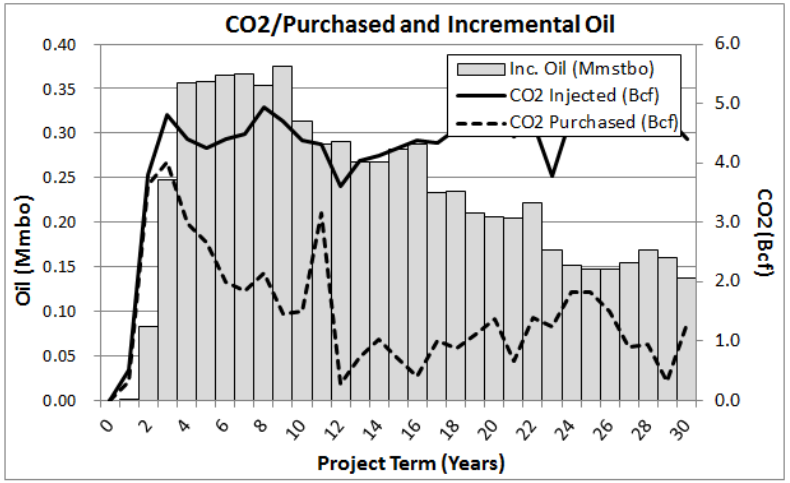
CO_2SCOPE^{TM}

Main Dashboard



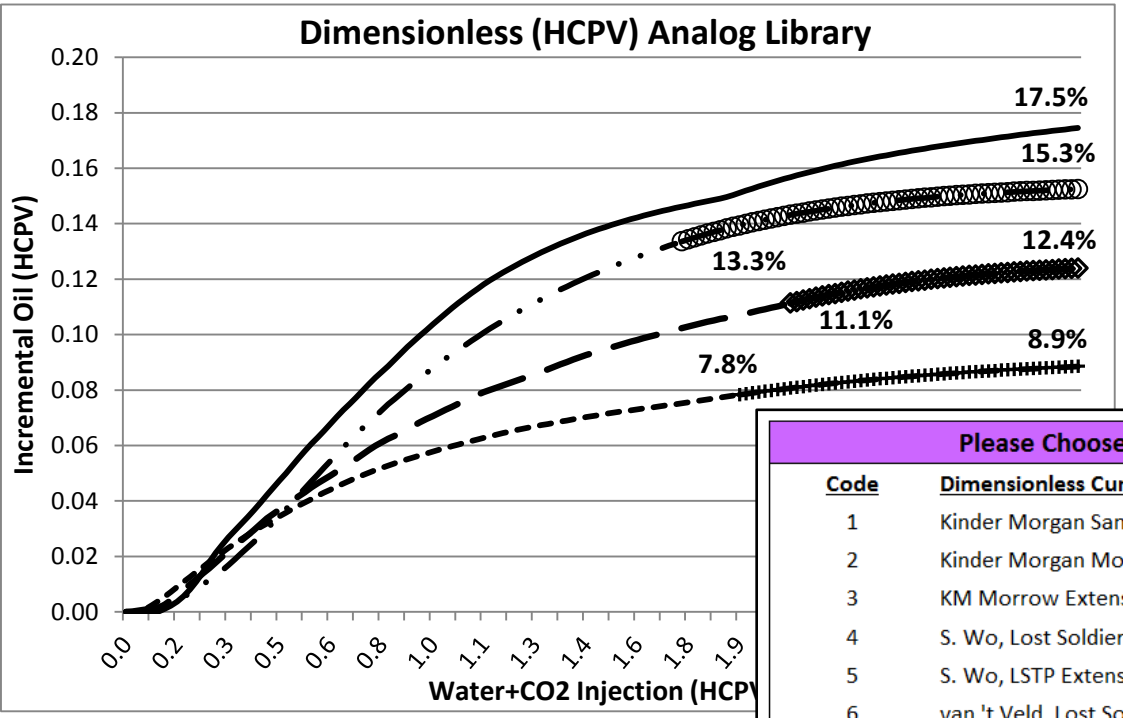






CO_2SCOPE^{TM}

Main Dashboard

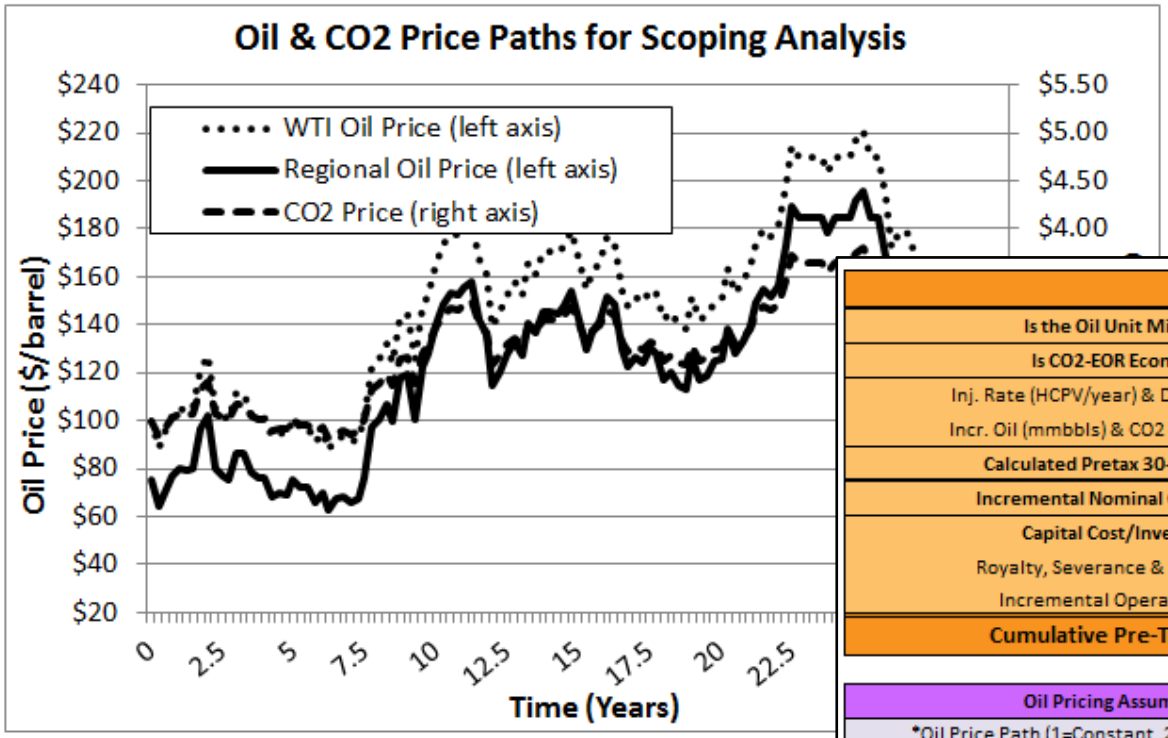


Please Choose an Analog from the Dimensionless Curve Library			
Code	Dimensionless Curve	HCPVs	Inc. Oil
1	Kinder Morgan San Andres (0/1 to 1/0 WAG)	2.980	17.45%
2	Kinder Morgan Morrow (1/1 to 2/1 WAG)	1.724	13.29%
3	KM Morrow Extension (1/1 to 2/1 WAG)	2.980	15.25%
4	S. Wo, Lost Soldier Tensleep (1/1 WAG)	2.070	11.10%
5	S. Wo, LSTP Extension (1/1 WAG)	2.980	12.40%
6	van 't Veld, Lost Soldier Tensleep (1/1 WAG)	1.873	7.80%
7	van 't Veld, LSTP Extension (1/1 WAG)	2.980	8.90%
8	User's Custom Analog	0.000	0.00%
*Enter Code of Analysis Curve		5	

Analog Assumptions	Analysis Value	Default/Calc Override
Dimensionless Curve	S. Wo, LSTP Extension (to 2.98 HCPVs)	
Analog's Max HCPV Inj & Incremental Oil	2.98 HCPVs	12.39% Incr Oil
Rescale Max Incremental Oil (% HCPV)	12.39%	

CO_2SCOPE^{TM}

Main Dashboard



Summary CO_2-EOR Scoping Results	
Is the Oil Unit Miscible?	Yes, the MMP is < Frac. Pressure
Is CO2-EOR Economic?	Profitable, but IRR < 20%
Inj. Rate (HCPV/year) & Duration (years)	4.88% for 50.25 years
Incr. Oil (mmbbls) & CO2 Purchased (bcf)	8.99 mmbbls & 63 bcf
Calculated Pretax 30-Year IRR (%)	18.42%
Incremental Nominal Oil Revenues	$1,201.75
Capital Cost/Investment	($63.45)
Royalty, Severance & Property Tax	($298.05)
Incremental Operating Costs	($327.29)
Cumulative Pre-Tax Profits	$512.95

Oil Pricing Assumptions	Analysis Value	Default/Calc Override
*Oil Price Path (1=Constant, 2=Trend, 3=Random)	3	3
*Constant/Starting WTI Oil Price ($/bbl, pre-discount)	$100.00	
Oil Price Trend Years (years<=75, if selected)	--	
Oil Price at End of Time Trend ($/bbl, if selected)	--	
* Adjust Oil for "Regional" Discount (0=NO,1=YES)	1	1
"Regional" Discount per Barrel ($/bbl)	$25.00	
Adjusted (post-discount) Oil Prices =	*Starting Oil Price=$75*	--
CO2 Price Assumptions	**Analysis Value**	**Default/Calc Override**
Fixed CO2 Charge($/mcf)	$0.50	
Addt'l CO2 Cost as Share of Oil Price (%)	1.50%	

CO_2SCOPE™

CAPEX Calculations

CO_2SCOPE™

Note: Nearly all of these values depend on and can be manipulated indirectly by changing the variables/assumptions on the "Dashboard".

Summary CO_2-EOR Scoping Results	
Is the Oil Unit Miscible?	Yes, the MMP is < Frac. Pressure
Is CO2-EOR Economic?	Profitable, but IRR < 20%
Inj. Rate (HCPV/year) & Duration (years)	4.88% for 51.5 years
Incr. Oil (mmbbls) & CO2 Purchased (bcf)	9.05 mmbbls & 65 bcf
Calculated Pretax 30-Year IRR (%)	19.53%
Incremental Nominal Oil Revenues	$1,401.26
Capital Cost/Investment	($63.45)
Royalty, Severance & Property Tax	($347.52)
Incremental Operating Costs	($359.65)
Cumulative Pre-Tax Profits	$630.64

Capital Cost Calculations

Total Well Related Costs	Estimate
Existing Production Wells ($MM)	$0.59
All Other Production Wells ($MM)	$7.47
All Injection Wells ($MM)	$5.42
Injection Surface Lines/Misc ($MM)	$1.18
Production Surface Lines/Misc ($MM)	$0.57
Total Capital Cost of New Well Drilling ($MM)	$28.70
Total of All Well Based Costs ($MM)	**$43.93**

Pipeline Costs	Estimate
Major CO2 Delivery Trunk Pipeline Costs ($MM)	$0.00
Project's Share of Trunk Pipeline (%)	0.00%
Capital Share to Trunk Pipeline ($MM)	**$0.00**
CO_2 Spur Pipeline Cost ($MM)	$6.76
Meter Station for Spur Pipeline ($MM)	$0.26
Total Spur Pipeline and Meter Cost ($MM)	**$7.03**
Total CO_2 Pipeline Costs ($MM)	**$7.03**

Electricity Infrastructure Costs	Estimate
Cost of Rebuilding Single-Pole Electric Lines ($MM)	$0.00
Cost of Rebuilding H-Frame Electric Lines ($MM)	$0.00
Cost of Constructing New Electric Lines ($MM)	$0.00
Cost for New Terminal Bays ($MM)	$0.00
Cost of New Substation ($MM)	$0.00
Cost for Additional Transformers ($MM)	$0.00
Total Electricity Infrastructure Costs ($MM)	**$0.00**

Recycling Facility Costs	Estimate
Method 1: Horsepower Rating ($MM)	**$4.28**
Method 2: MMcfd Capacity ($MM)	**$12.50**
Est. Cost of Recycling Plant MAX(Method 1 & 2) ($MM)	**$12.50**

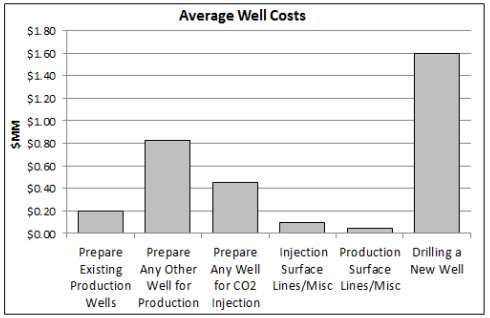
Oil Property Acquisition Cost ($MM)	**$0.00**
CO_2-EOR Development Costs ($MM)	**$63.45**
Total Capital Cost Estimate ($MM)	**$63.45**

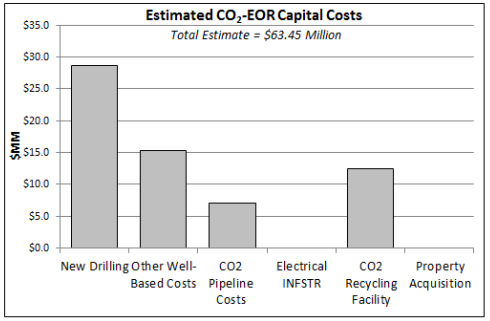
Miscellaneous Calculations & Values

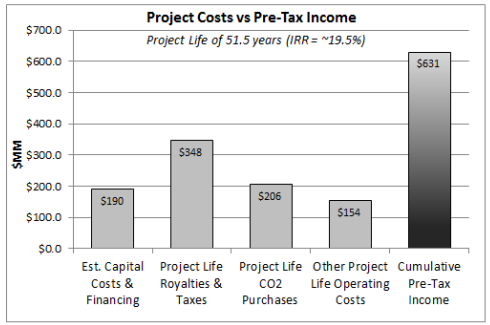
Average Well Costs	Estimate
Prepare Existing Production Wells ($/well)	$196,000
Prepare Any Other Well for Production ($/well)	$830,000
Prepare Any Well for CO_2 Injection ($/well)	$452,000
Injection Surface Lines/Misc ($/well)	$98,600
Production Surface Lines/Misc ($/well)	$47,100
Drilling a New Well ($/well)	$1,594,387

Misc Project Calculations	Value
Hydrocarbon Pore Volume (hcpv, rb)	**94,500,000**
HCPV per Injector (rb/pattern)	7,875,000
Pre-CO_2 Injection Rate (hcpv/year)	4.88%
Injection Adjustment Factor (fraction)	1.00
Adjusted Injection Rate (hcpv/year)	**4.88%**
Estimated Spur Pipe Diameter (inches)	6
Current Daily Oil Production (bbls/day)	9.9
Current Daily Water Production (bbls/day)	1,314
Annual Decline Rate of Oil (fraction/year)	**13.49%**

Calculate CO2 Recycling Plant Specs	Value
Discharge Pressure of Processing Facility (psi)	1,300
Compression Ratio per Stage (1 Stage)	5.7778
Compression Ratio per Stage (2 Stages)	2.4037
Compression Ratio per Stage (3 Stages)	1.7944
Theoretical Optimum Compression (1 Stage)	N/A
Theoretical Optimum Compression (2 Stages)	2.0745
Theoretical Optimum Compression (3 Stages)	2.6578
Correction Factor for Compression Drop: Stage 1	1.0000
Correction Factor for Compression Drop: Stage 2	1.0800
Correction Factor for Compression Drop: Stage 3	1.1000
HP Required by Compression Plant (1 Stage)	N/A
HP Required by Compression Plant (2 Stage)	1,777
HP Required by Compression Plant (3 Stage)	1,731
Compression Stages Required	3
Compression Ratio per Stage	2.66
Horsepower Rating of Installed Compression (hp)	**1,731**







ENHANCED OIL RECOVERY INSTITUTE

UNIVERSITY OF WYOMING

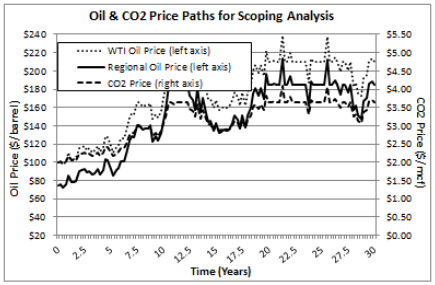
CO_2SCOPE™

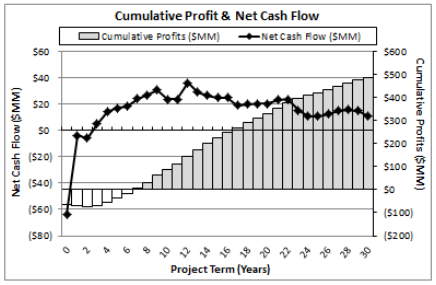
Annual Cash Flows

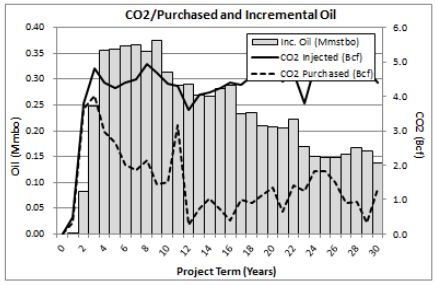
Summary CO_2-EOR Scoping Results	
Is the Oil Unit Miscible?	Yes, the MMP is < Frac. Pressure
Is CO2-EOR Economic?	Profitable, but IRR < 20%
Inj. Rate (HCPV/year) & Duration (years)	4.88% for 51.5 years
Incr. Oil (mmbbls) & CO2 Purchased (bcf)	9.05 mmbbls & 65 bcf
Calculated Pretax 30-Year IRR (%)	19.53%
Incremental Nominal Oil Revenues	$1,401.26
Capital Cost/Investment	($63.45)
Royalty, Severance & Property Tax	($347.52)
Incremental Operating Costs	($359.65)
Cumulative Pre-Tax Profits	$630.64

Incremental Annual Cash Flows

CO_2SCOPE™







CO_2-EOR Operating Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
CO_2 Injected (Bcf)	0.00	0.51	3.80	4.80	4.40	4.25	4.40	4.48	4.94	4.70	4.38	4.31	3.60	4.04	4.12	4.25	4.39
CO_2 Purchased (Bcf)	0.00	0.33	3.64	4.01	2.97	2.66	2.00	1.85	2.15	1.46	1.49	3.17	0.28	0.74	1.04	0.71	0.40
Incr. Oil (MMbbls)	0.00	0.00	0.08	0.25	0.36	0.36	0.37	0.37	0.35	0.37	0.31	0.29	0.29	0.27	0.27	0.28	0.29
Oil Price ($/Bbl)	$77.55	$81.36	$90.59	$88.23	$97.64	$93.11	$115.45	$136.32	$134.18	$132.14	$176.84	$185.00	$170.87	$165.04	$141.54	$134.02	$143.84
Gross Incr. Oil Revenue ($MM)	**$0.00**	**$0.17**	**$6.91**	**$22.45**	**$31.42**	**$34.97**	**$34.06**	**$42.28**	**$48.16**	**$50.30**	**$41.34**	**$50.91**	**$53.86**	**$45.92**	**$44.14**	**$39.87**	**$38.60**
Federal Royalties ($MM)	$0.00	($0.05)	($0.65)	($2.11)	($2.95)	($3.29)	($3.20)	($3.97)	($4.53)	($4.73)	($3.89)	($4.79)	($5.06)	($4.32)	($4.15)	($3.75)	($3.63)
Tribal Royalties ($MM)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
State Royalties ($MM)	$0.00	($0.01)	($0.11)	($0.35)	($0.49)	($0.55)	($0.53)	($0.66)	($0.75)	($0.79)	($0.65)	($0.80)	($0.84)	($0.72)	($0.69)	($0.62)	($0.60)
Private Royalties ($MM)	$0.00	($0.01)	($0.12)	($0.40)	($0.55)	($0.62)	($0.60)	($0.75)	($0.85)	($0.89)	($0.73)	($0.90)	($0.95)	($0.81)	($0.78)	($0.70)	($0.68)
Total Royalties ($MM)	$0.00	($0.06)	($0.88)	($2.86)	($4.00)	($4.45)	($4.34)	($5.38)	($6.13)	($6.40)	($5.26)	($6.48)	($6.86)	($5.85)	($5.62)	($5.07)	($4.91)
Severance Taxes ($MM)	$0.00	($0.03)	($0.41)	($1.35)	($1.88)	($2.10)	($2.04)	($2.54)	($2.89)	($3.02)	($2.48)	($3.05)	($3.23)	($2.76)	($2.65)	($2.39)	($2.32)
Ad Valorem Taxes ($MM)	$0.00	($0.03)	($0.42)	($1.36)	($1.91)	($2.12)	($2.07)	($2.56)	($2.92)	($3.05)	($2.51)	($3.09)	($3.27)	($2.79)	($2.68)	($2.42)	($2.34)
Total Royalties., Severance & Ad Valorem ($MM)	$0.00	($0.12)	($1.71)	($5.57)	($7.79)	($8.67)	($8.44)	($10.48)	($11.94)	($12.47)	($10.25)	($12.62)	($13.35)	($11.39)	($10.94)	($9.88)	($9.57)
Incr. Oil Revenue Net of RSAV ($MM)	**$0.00**	**$0.05**	**$5.20**	**$16.89**	**$23.63**	**$26.30**	**$25.61**	**$31.80**	**$36.22**	**$37.83**	**$31.09**	**$38.29**	**$40.51**	**$34.53**	**$33.19**	**$29.98**	**$29.03**
Liquid Lifting Costs ($MM, mainly elec.)	$0.00	($1.43)	($1.62)	($1.55)	($1.44)	($1.45)	($1.31)	($1.35)	($1.39)	($1.31)	($1.37)	($1.82)	($1.44)	($1.42)	($1.44)	($1.29)	($1.20)
Other Per-Well Lifting Costs ($MM)	$0.00	($0.75)	($0.75)	($0.77)	($0.76)	($0.78)	($0.77)	($0.82)	($0.86)	($0.86)	($0.85)	($0.94)	($0.96)	($0.93)	($0.92)	($0.87)	($0.86)
Total Per-Barrel & Per-Well Lift Costs	$0.00	($2.18)	($2.37)	($2.32)	($2.20)	($2.23)	($2.09)	($2.17)	($2.25)	($2.17)	($2.22)	($2.76)	($2.40)	($2.35)	($2.36)	($2.16)	($2.05)
CO_2 Transport ($MM)	$0.00	($0.17)	($1.82)	($2.00)	($1.49)	($1.33)	($1.00)	($0.92)	($1.07)	($0.73)	($0.75)	($1.58)	($0.14)	($0.37)	($0.52)	($0.35)	($0.20)
CO_2 Tie to Oil Price ($MM)	$0.00	($0.55)	($5.86)	($6.96)	($5.05)	($4.91)	($3.54)	($3.90)	($5.20)	($3.49)	($3.59)	($9.54)	($0.89)	($2.13)	($2.97)	($1.77)	($0.96)
Total CO_2 Purchase Costs ($MM)	$0.00	($0.72)	($7.68)	($8.97)	($6.53)	($6.24)	($4.55)	($4.83)	($6.28)	($4.22)	($4.34)	($11.12)	($1.03)	($2.50)	($3.49)	($2.13)	($1.16)
CO_2 Plant - Labor ($MM)	$0.00	($0.10)	($0.10)	($0.10)	($0.10)	($0.10)	($0.10)	($0.10)	($0.10)	($0.10)	($0.10)	($0.10)	($0.10)	($0.10)	($0.10)	($0.10)	($0.10)
CO_2 Plant- Maintenance ($MM)	$0.00	($0.08)	($0.08)	($0.08)	($0.08)	($0.08)	($0.08)	($0.08)	($0.08)	($0.08)	($0.08)	($0.08)	($0.08)	($0.08)	($0.08)	($0.08)	($0.08)
CO_2 Plant - Electricity ($MM)	$0.00	($0.73)	($0.73)	($0.73)	($0.73)	($0.73)	($0.73)	($0.73)	($0.73)	($0.73)	($0.73)	($0.73)	($0.73)	($0.73)	($0.73)	($0.73)	($0.73)
Total CO_2 Plant/Recycling Costs ($MM)	$0.00	($0.90)	($0.90)	($0.90)	($0.90)	($0.90)	($0.90)	($0.90)	($0.90)	($0.90)	($0.90)	($0.90)	($0.90)	($0.90)	($0.90)	($0.90)	($0.90)
Total Incremental Operating Costs ($MM)	**$0.00**	**($3.80)**	**($10.95)**	**($12.19)**	**($9.64)**	**($9.37)**	**($7.54)**	**($7.90)**	**($9.43)**	**($7.29)**	**($7.46)**	**($14.79)**	**($4.33)**	**($5.75)**	**($6.75)**	**($5.19)**	**($4.12)**
Upfront CO_2-EOR Capital Cost($MM)	**($63.45)**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**
Net Cash Flow / Pre-Tax Profit ($MM)	**($63.45)**	**($3.75)**	**($5.75)**	**$4.70**	**$13.99**	**$16.92**	**$18.08**	**$23.90**	**$26.78**	**$30.54**	**$23.62**	**$23.50**	**$36.18**	**$28.78**	**$26.44**	**$24.79**	**$24.91**
Cumulative Pre-Tax Profits ($MM)	($63.45)	($67.20)	($72.95)	($68.26)	($54.27)	($37.35)	($19.27)	$4.63	$31.42	$61.96	$85.58	$109.09	$145.26	$174.04	$200.48	$225.27	$250.18

ENHANCED OIL RECOVERY INSTITUTE

UNIVERSITY OF WYOMING

CO_2SCOPE™

Custom Analog Entry

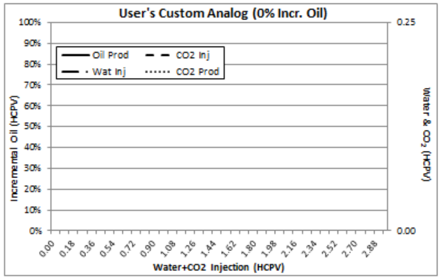
CO_2Scope Dimensionless Analog Library

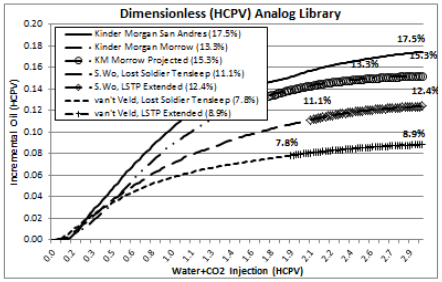
Code	Dimensionless Curve	WAG	HCPVs	Inc. Oil
1	Kinder Morgan San Andres	0/1 to 3/1	2.9800	17.50%
2	Kinder Morgan Morrow	1/1 to 2/1	1.7238	13.29%
3	KM Morrow Extension	1/1 to 4/1	2.9800	15.25%
4	S. Wo, Lost Soldier Tensleep	2/1	2.0702	11.10%
5	S. Wo, LSTP Extension	2/1	2.9800	12.40%
6	van 't Veld, Lost Soldier Tensleep	1/1	1.8730	7.80%
7	van 't Veld, LSTP Extension	1/1	2.9800	8.90%
8	User's Custom Analog (0% Incr. Oil)	N/A	N/A	N/A

Selected Curve

(5) S. Wo, LSTP Extension

CO_2SCOPE™





Custom Analog: In order to create and use a custom analog curve your must complete all cells in the six light green columns below. On the CO2Scope Dashboard you can then use this curve by setting the "Code for Analysis Curve" (Code=8).

User's Custom Analog

Time	CO2 Inj	Wat Inj	Oil Prod	CO2 Prod	HC GOR, MCF/BBL	RATE
0.0000						
0.0000						
0.0000						
0.0000						
0.0000						
0.0000						
0.0000						
0.0000						
0.0000						
0.0000						
0.0000						
0.0000						
0.0000						
0.0000						
0.0000						
0.0000						
0.0000						
0.0000						
0.0000						
0.0000						
0.0000						
0.0000						
0.0000						
0.0000						
0.0000						
0.0000						
0.0000						
0.0000						
0.0000						
0.0000						
0.0000						
0.0000						
0.0000						
0.0000						

Kinder Morgan San Andres (0/1 to 3/1 WAG)

Time	CO2 Inj	Wat Inj	Oil Prod	CO2 Prod	HC GOR, MCF/BBL	RATE	Time
0.0000	0.0000	0.0000	0.0000	0.0000	0.6850	1.0000	0.0000
0.0200	0.0200	0.0000	-0.0004	0.0001	0.6850	1.4082	0.0102
0.0400	0.0400	0.0000	-0.0008	0.0004	0.6773	1.3710	0.0204
0.0600	0.0600	0.0000	-0.0008	0.0011	0.7066	1.3158	0.0306
0.0800	0.0800	0.0000	-0.0006	0.0023	0.7249	1.2305	0.0409
0.1000	0.1000	0.0000	0.0001	0.0042	0.9048	1.2439	0.0511
0.1200	0.1200	0.0000	0.0010	0.0069	0.7173	1.2171	0.0613
0.1400	0.1397	0.0003	0.0022	0.0106	0.8750	1.2006	0.0715
0.1600	0.1585	0.0015	0.0038	0.0150	0.8436	1.1884	0.0817
0.1800	0.1758	0.0042	0.0057	0.0203	0.8455	1.1806	0.0919
0.2000	0.1916	0.0085	0.0081	0.0263	0.8037	1.2005	0.1022
0.2200	0.2062	0.0138	0.0110	0.0331	0.9511	1.2253	0.1124
0.2400	0.2202	0.0198	0.0144	0.0402	0.8410	0.9243	0.1226
0.2600	0.2340	0.0260	0.0179	0.0466	0.7827	0.9892	0.1328
0.2800	0.2479	0.0321	0.0212	0.0520	0.8313	0.8807	0.1430
0.3000	0.2619	0.0381	0.0242	0.0564	0.7422	0.9192	0.1532
0.3200	0.2760	0.0440	0.0269	0.0608	0.7783	0.9697	0.1634
0.3400	0.2901	0.0499	0.0294	0.0663	0.8234	1.0429	0.1737
0.3600	0.3040	0.0560	0.0317	0.0730	0.8969	1.1087	0.1839
0.3800	0.3174	0.0626	0.0341	0.0812	0.9358	1.1590	0.1941
0.4000	0.3303	0.0697	0.0367	0.0905	0.9574	1.2077	0.2043
0.4200	0.3427	0.0773	0.0394	0.0998	0.9549	0.9817	0.2145
0.4400	0.3545	0.0855	0.0421	0.1080	0.9104	0.9787	0.2247
0.4600	0.3655	0.0945	0.0448	0.1142	0.8833	0.9659	0.2349
0.4800	0.3760	0.1040	0.0474	0.1190	0.7696	0.9518	0.2452
0.5000	0.3868	0.1132	0.0500	0.1240	0.7632	1.0097	0.2554
0.5200	0.3987	0.1213	0.0526	0.1303	0.8132	1.0843	0.2656
0.5400	0.4118	0.1283	0.0554	0.1377	0.8922	0.8784	0.2758
0.5600	0.4252	0.1348	0.0581	0.1452	0.9002	0.8659	0.2860
0.5800	0.4383	0.1417	0.0606	0.1523	0.8928	1.0728	0.2962
0.6000	0.4510	0.1490	0.0629	0.1594	0.8813	1.1284	0.3065
0.6200	0.4638	0.1562	0.0654	0.1675	0.8836	1.0983	0.3167
0.6400	0.4769	0.1631	0.0679	0.1761	0.9357	0.9616	0.3269
0.6600	0.4898	0.1702	0.0704	0.1845	0.9325	0.9912	0.3371

CO_2SCOPE^{TM}

Quarterly Breakdown

CO_2SCOPE^{TM}

CO2-EOR Incremental Costs & Cashflows ($MM, Quarterly)

Summary CO_2-EOR Scoping Results	
Is the Oil Unit Miscible?	Yes, the MMP is < Frac. Pressure
Is CO2-EOR Economic?	Profitable, but IRR < 20%
Inj. Rate (HCPV/year) & Duration (years)	4.88% for 51.5 years
Incr. Oil (mmbbls) & CO2 Purchased (bcf)	9.05 mmbbls & 65 bcf
Calculated Pretax 30-Year IRR (%)	19.53%
Incremental Nominal Oil Revenues	$85.01
Capital Cost/Investment	($63.45)
Royalty, Severance & Property Tax	($347.52)
Incremental Operating Costs	($359.65)
Cumulative Pre-Tax Profits	$630.64

Oil & CO2 Prices | Oil Price vs Cost Correlation Adjustments | Incremental Volumes: Oil & CO2 | Incremental CO2-EOR Costs & Cash Flows

Time	WTI Oil Price	Regional Oil Price	CO2 Price	Oil Price Change	Lift Power Adj	"Other" Lift Adj	CO2 Plant Labor Adj.	CO2 Plan Maint. Adj.	Oil Production	CO2 Injection	CO2 Purchases	Gross Oil Revenues	Fed. Royalties	Tribal Royalties	State Royalties	Private Royalties	Total Roy
years	$/bo	$/bo	$/mcf	%	fraction	fraction	fraction	fraction	mmbls	bcf	bcf	$mm	$mm	$mm	$mm	$mm	$mm
0	$100.00	$75.00	$2.00		1.00000	1.00000	1.00000	1.00000	0.0000	0.0000	0.0000	$0.0000	$0.0000	$0.0000	$0.0000	$0.0000	$0.00
0.25	$100.92	$75.92	$2.01	1.23%	1.00246	1.00246	1.00246	1.00246	(0.0021)	0.0423	0.0000	-$0.1627	$0.0000	$0.0000	$0.0000	$0.0000	$0.00
0.5	$97.37	$72.37	$1.96	-3.51%	1.00702	1.00702	1.00702	1.00702	(0.0022)	0.0634	0.0000	-$0.1567	$0.0000	$0.0000	$0.0000	$0.0000	$0.00
0.75	$101.21	$76.21	$2.02	1.61%	1.00322	1.00322	1.00322	1.00322	0.0016	0.0469	0.0000	$0.1211	$0.0114	$0.0000	$0.0019	$0.0021	$0.01
1	$110.70	$85.70	$2.16	14.27%	1.02853	1.02853	1.02853	1.02853	0.0043	0.3538	0.3311	$0.3646	$0.0343	$0.0000	$0.0057	$0.0064	$0.04
1.25	$102.68	$77.68	$2.04	3.57%	1.00714	1.00714	1.00714	1.00714	0.0069	0.7550	0.7569	$0.5386	$0.0506	$0.0000	$0.0084	$0.0095	$0.06
1.5	$103.63	$78.63	$2.05	4.84%	1.00968	1.00968	1.00968	1.00968	0.0148	0.7753	0.7720	$1.1656	$0.1096	$0.0000	$0.0183	$0.0205	$0.14
1.75	$104.17	$79.17	$2.06	5.56%	1.01113	1.01113	1.01113	1.01113	0.0245	0.9493	0.9084	$1.9369	$0.1821	$0.0000	$0.0304	$0.0341	$0.24
2	$114.97	$89.97	$2.22	19.95%	1.03991	1.03991	1.03991	1.03991	0.0364	1.3207	1.2009	$3.2707	$0.3074	$0.0000	$0.0513	$0.0576	$0.41
2.25	$116.07	$91.07	$2.24	21.43%	1.04287	1.04287	1.04287	1.04287	0.0479	1.3642	1.2123	$4.3652	$0.4103	$0.0000	$0.0684	$0.0769	$0.55
2.5	$117.48	$92.48	$2.26	23.31%	1.04662	1.04662	1.04662	1.04662	0.0589	1.3006	1.1249	$5.4442	$0.5118	$0.0000	$0.0853	$0.0960	$0.69
2.75	$113.43	$88.43	$2.20	17.91%	1.03581	1.03581	1.03581	1.03581	0.0668	1.1099	0.8905	$5.9066	$0.5552	$0.0000	$0.0926	$0.1041	$0.75
3	$115.37	$90.37	$2.23	20.50%	1.04099	1.04099	1.04099	1.04099	0.0746	1.0296	0.7820	$6.7372	$0.6333	$0.0000	$0.1056	$0.1187	$0.85
3.25	$111.00	$86.00	$2.17	14.67%	1.02934	1.02934	1.02934	1.02934	0.0821	1.0528	0.7917	$7.0646	$0.6641	$0.0000	$0.1107	$0.1245	$0.89
3.5	$112.85	$87.85	$2.19	17.14%	1.03427	1.03427	1.03427	1.03427	0.0895	1.0937	0.7291	$7.8618	$0.7390	$0.0000	$0.1232	$0.1386	$1.00
3.75	$117.21	$92.21	$2.26	22.95%	1.04590	1.04590	1.04590	1.04590	0.0941	1.1263	0.6904	$8.6779	$0.8157	$0.0000	$0.1360	$0.1529	$1.10
4	$111.86	$86.86	$2.18	15.81%	1.03162	1.03162	1.03162	1.03162	0.0899	1.1236	0.7632	$7.8111	$0.7342	$0.0000	$0.1224	$0.1377	$0.99
4.25	$116.84	$91.84	$2.25	22.45%	1.04490	1.04490	1.04490	1.04490	0.0878	1.1066	0.7786	$8.0666	$0.7583	$0.0000	$0.1264	$0.1422	$1.02
4.5	$128.16	$103.16	$2.42	37.55%	1.07510	1.07510	1.07510	1.07510	0.0872	1.0796	0.7548	$8.9926	$0.8453	$0.0000	$0.1409	$0.1585	$1.14
4.75	$127.60	$102.60	$2.41	36.80%	1.07360	1.07360	1.07360	1.07360	0.0909	1.0439	0.6158	$9.3296	$0.8770	$0.0000	$0.1462	$0.1644	$1.18
5	$117.96	$92.96	$2.27	23.95%	1.04789	1.04789	1.04789	1.04789	0.0923	1.0215	0.5148	$8.5769	$0.8062	$0.0000	$0.1344	$0.1512	$1.09
5.25	$110.59	$85.59	$2.16	14.12%	1.02824	1.02824	1.02824	1.02824	0.0878	1.0291	0.5094	$7.5130	$0.7062	$0.0000	$0.1177	$0.1324	$0.95
5.5	$116.26	$91.26	$2.24	21.67%	1.04335	1.04335	1.04335	1.04335	0.0893	1.0915	0.5189	$8.1504	$0.7661	$0.0000	$0.1277	$0.1437	$1.03
5.75	$119.22	$94.22	$2.29	25.63%	1.05126	1.05126	1.05126	1.05126	0.0937	1.1756	0.5322	$8.8258	$0.8296	$0.0000	$0.1383	$0.1556	$1.12
6	$126.38	$101.38	$2.40	35.17%	1.07034	1.07034	1.07034	1.07034	0.0944	1.1024	0.4441	$9.5685	$0.8994	$0.0000	$0.1499	$0.1686	$1.21
6.25	$125.97	$100.97	$2.39	34.63%	1.06925	1.06925	1.06925	1.06925	0.0930	1.0830	0.4174	$9.3934	$0.8830	$0.0000	$0.1472	$0.1656	$1.19
6.5	$133.92	$108.92	$2.51	45.23%	1.09045	1.09045	1.09045	1.09045	0.0885	1.1475	0.4863	$9.6341	$0.9056	$0.0000	$0.1510	$0.1698	$1.22
6.75	$148.67	$123.67	$2.73	64.89%	1.12978	1.12978	1.12978	1.12978	0.0905	1.1365	0.4810	$11.1971	$1.0525	$0.0000	$0.1755	$0.1973	$1.42
7	$153.24	$128.24	$2.80	70.99%	1.14198	1.14198	1.14198	1.14198	0.0940	1.1157	0.4628	$12.0564	$1.1333	$0.0000	$0.1889	$0.2125	$1.53
7.25	$152.52	$127.52	$2.79	70.03%	1.14007	1.14007	1.14007	1.14007	0.0906	1.2204	0.5420	$11.5566	$1.0863	$0.0000	$0.1811	$0.2037	$1.47
7.5	$165.65	$140.65	$2.98	87.54%	1.17507	1.17507	1.17507	1.17507	0.0881	1.2670	0.5750	$12.3917	$1.1648	$0.0000	$0.1942	$0.2184	$1.57
7.75	$165.98	$140.98	$2.99	87.98%	1.17596	1.17596	1.17596	1.17596	0.0866	1.2479	0.5557	$12.2046	$1.1472	$0.0000	$0.1912	$0.2151	$1.55
8	$161.11	$136.11	$2.92	81.48%	1.16297	1.16297	1.16297	1.16297	0.0882	1.2011	0.4767	$12.0061	$1.1286	$0.0000	$0.1881	$0.2116	$1.52
8.25	$162.22	$137.22	$2.93	82.96%	1.16591	1.16591	1.16591	1.16591	0.0907	1.1635	0.4025	$12.4461	$1.1699	$0.0000	$0.1950	$0.2194	$1.58
8.5	$162.23	$137.23	$2.93	82.97%	1.16594	1.16594	1.16594	1.16594	0.0941	1.1909	0.4025	$12.9076	$1.2133	$0.0000	$0.2023	$0.2275	$1.64
8.75	$164.90	$139.90	$2.97	86.54%	1.17308	1.17308	1.17308	1.17308	0.0953	1.1861	0.3621	$13.3379	$1.2538	$0.0000	$0.2090	$0.2351	$1.69
9	$147.36	$122.36	$2.71	63.15%	1.12631	1.12631	1.12631	1.12631	0.0949	1.1547	0.2882	$11.6110	$1.0914	$0.0000	$0.1819	$0.2046	$1.47
9.25	$152.95	$127.95	$2.79	70.60%	1.14120	1.14120	1.14120	1.14120	0.0851	1.0974	0.2637	$10.8913	$1.0238	$0.0000	$0.1707	$0.1920	$1.38
9.5	$148.42	$123.42	$2.73	64.56%	1.12913	1.12913	1.12913	1.12913	0.0770	1.0638	0.2698	$9.5070	$0.8937	$0.0000	$0.1490	$0.1676	$1.21
9.75	$156.49	$131.49	$2.85	75.32%	1.15064	1.15064	1.15064	1.15064	0.0762	1.1036	0.3468	$10.0226	$0.9421	$0.0000	$0.1571	$0.1766	$1.27

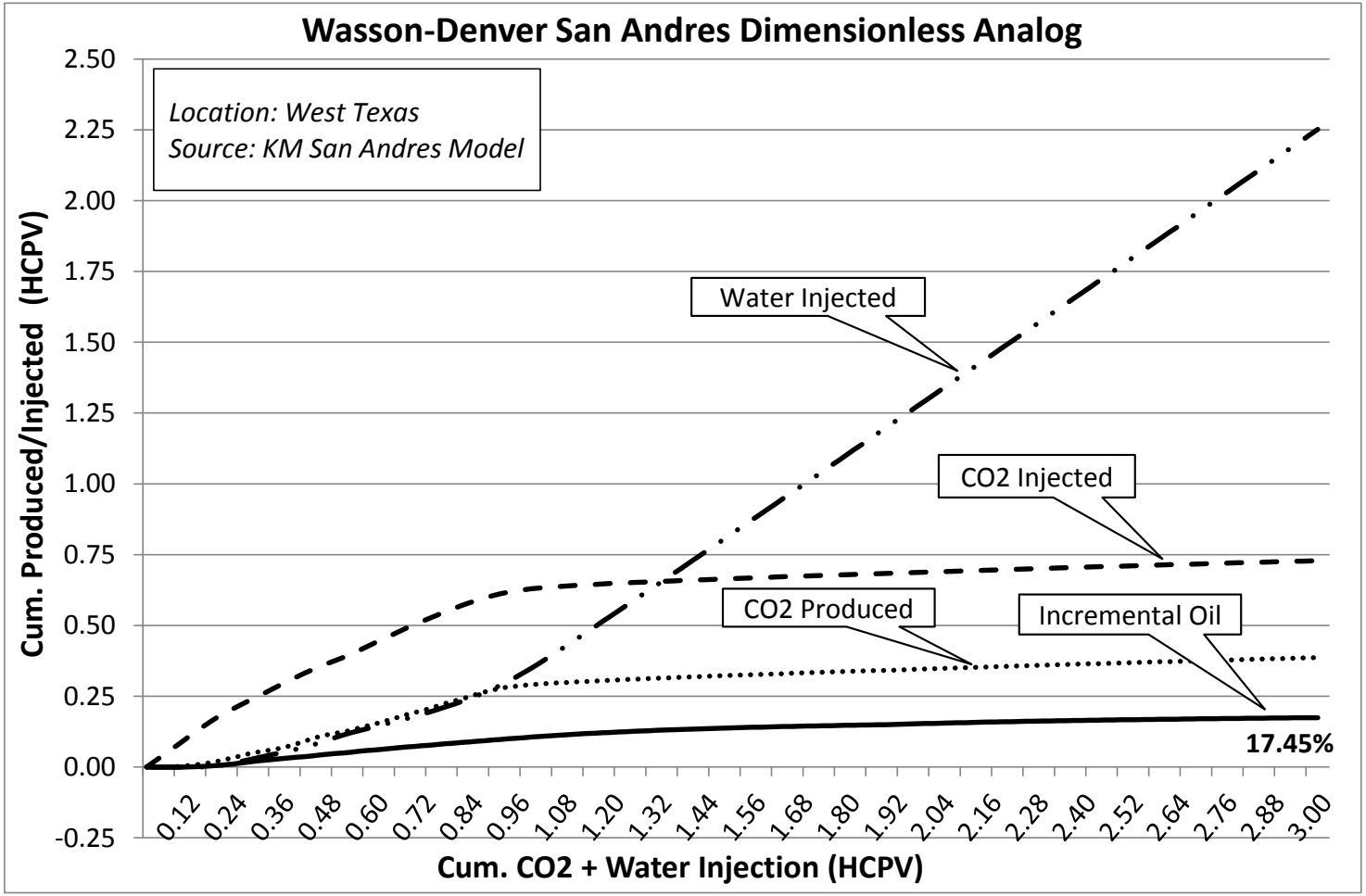
Questions & Feedback

Supplemental Slides

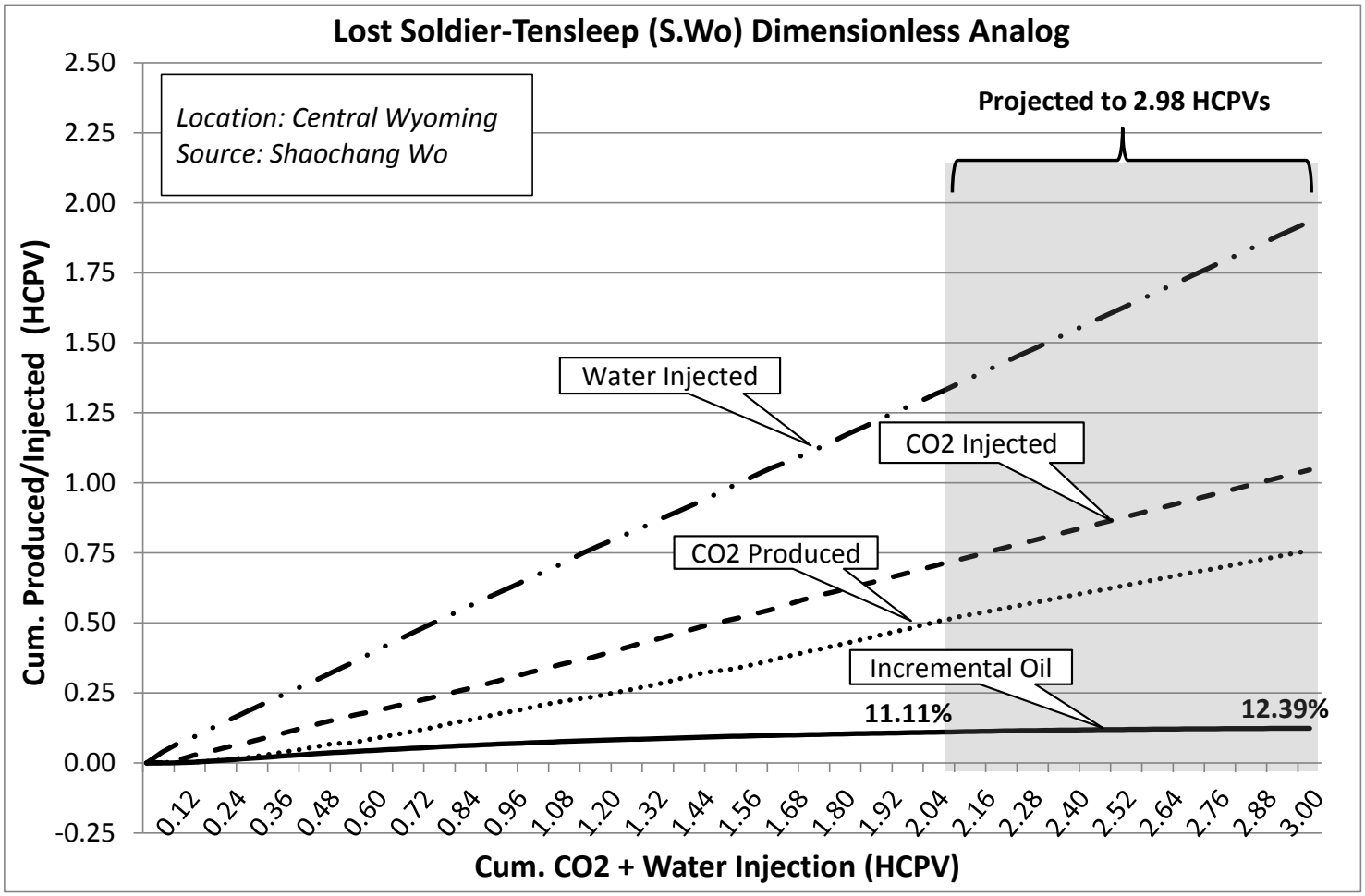
ENHANCED OIL RECOVERY INSTITUTE

UNIVERSITY OF WYOMING

Injection-Prod Profile (KMSA)



Injection-Prod Profile (LSTP)



WY's Miscible CO_2EOR Potential

Wyoming's Miscible CO_2 Enhanced Oil Recovery Potential from Main Pay
An Economic Scoping

Benjamin R. Cook,

University of Wy
Department of Economi
Enhanced Oil Recov

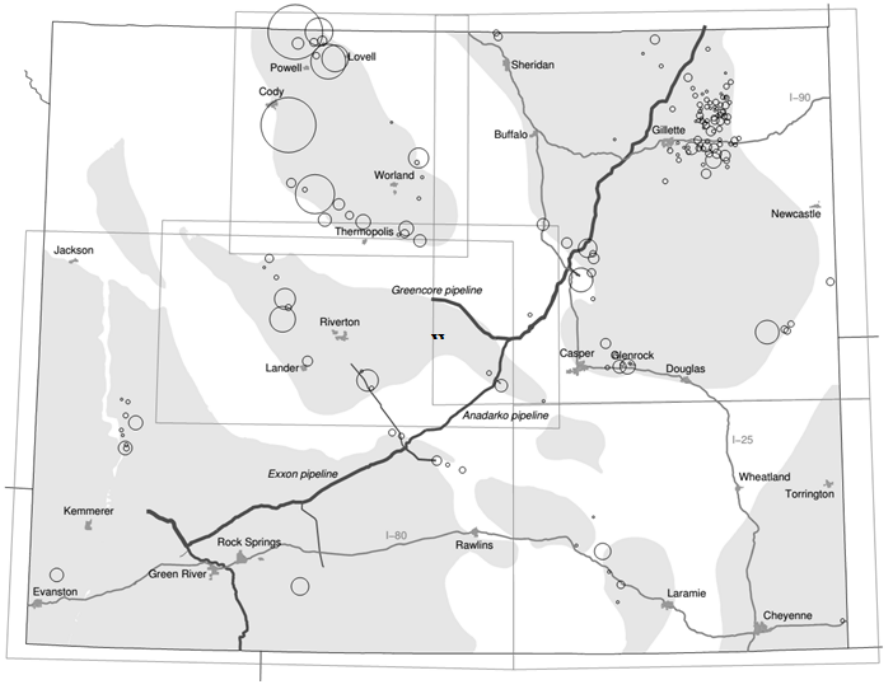
Novembe

*Benjamin R. Cook, PhD, College
E. University Ave., Laramie, W
bencook@uwyo.edu

†Funding for this study was pr
part of the School of Energy
services were provided by Kb
University of Wyoming. Additional
Glen Murrell, Associate Director (EORI), Nick
Ouachi, Research Assistant, and Professor Owen R. Phillips,
& Finance, University of Wyoming.

Figure 13 Wyoming Location & Incremental Oil from Potentially Profitable Oil Fields

Rank	Field	Basin
1	Oregon Basin	BHB
2	Elk Basin	BHB
3	Grass Creek	BHB
4	Garland	BHB
5	Frannie	BHB
6	Byron	BHB
7	Winkleman	WRB
8	Salt Creek	PRB
9	Lance Creek	PRB
10	Big Sand Draw	WRB
11	Steamboat Butte	WRB
12	Bonanza	BHB
13	Sussex	PRB
14	Brady	GRB
15	Rock River	LB
16	Raven Creek	PRB
17	Glenrock South	PRB
18	Murphy Dome	BHB
19	Gebo	BHB
20	McDonald Draw	GRB
21	LaBarge	GRB
22	Ryckman Creek	OTB
23	Big Muddy	PRB
24	Hamilton Dome	BHB
25	Grieve	WRB
26	Timber Creek	PRB
27	Black Mountain	BHB
28	North Fork	PRB
29	Elk Basin South	BHB
30	Golden Eagle	BHB
31	Coyote Creek	PRB
32	Meadow Creek	PRB
33	Sussex West	PRB
34	Cole Creek	WRB
35	Lander	WRB



ENHANCED OIL RECOVERY INSTITUTE

UNIVERSITY OF WYOMING

WY's Miscible CO_2EOR Potential

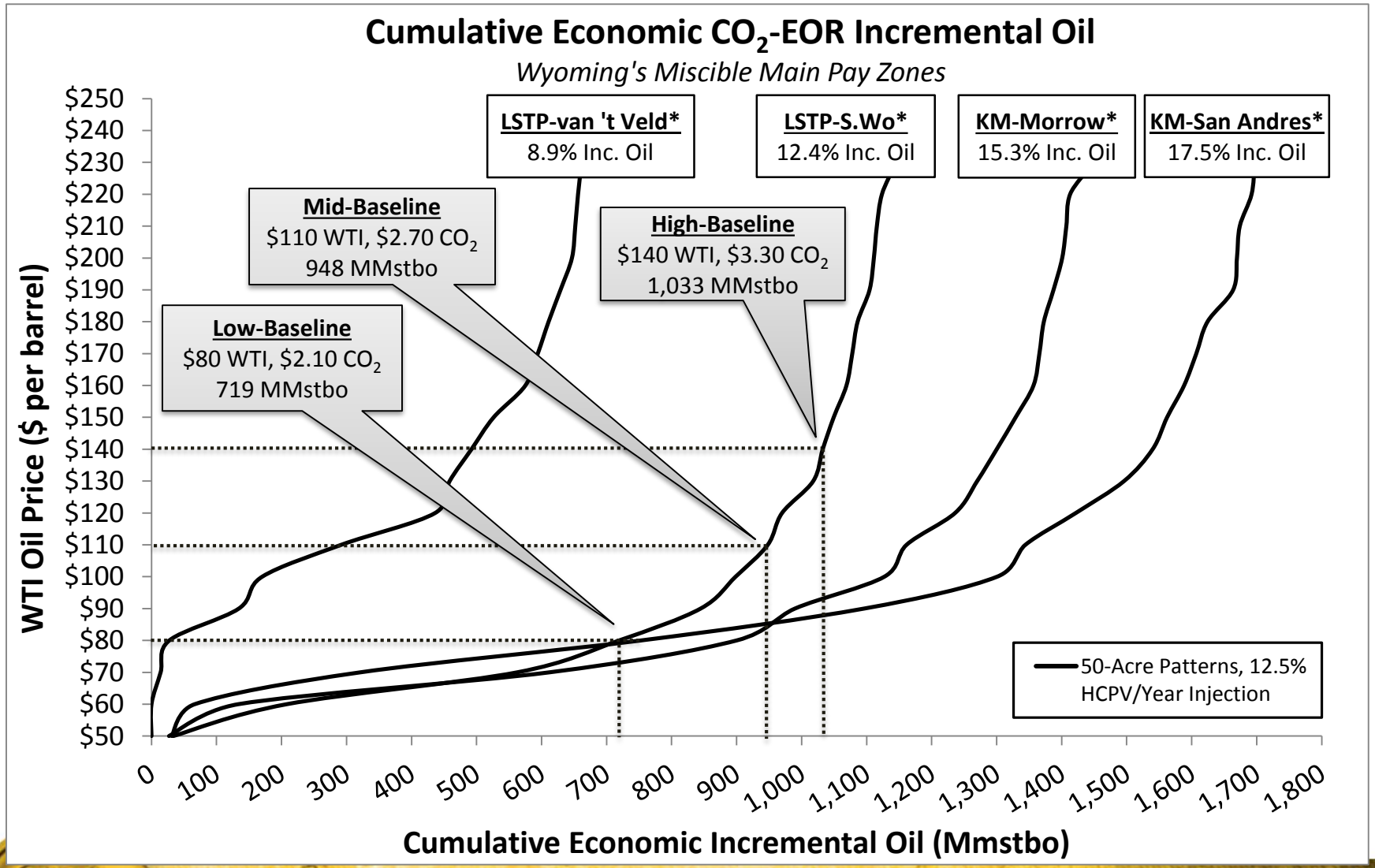
				BASELINE		
CO_2 Contract	**$0.50 + 1.0%**			**$0.50 + 2.0%**		
WTI Oil Price	**$80**	**$110**	**$140**	**$80**	**$110**	**$140**
~WY Oil Price	$65.46	$95.46	$125.96	$65.46	$95.46	$125.96
~CO_2 Price	$1.30	$1.60	$1.90	$2.10	$2.70	$3.30
Big Horn Basin	621	643	650	554	621	636
Denver Basin			1			
Green River Basin	42	50	52	22	47	50
Hanna Basin			0			
Laramie Basin	9	11	11		11	11
Overthrust Belt		9	10			9
Powder River Basin	107	184	250	83	161	217
Wind River Basin	93	111	117	60	108	110
Total	**872**	**1,008**	**1,091**	**719**	**948**	**1,033**
# of FRCS (20% IRR)	66	121	150	46	100	129

LSTP Analog (12.4% Incr.), 50-Acre Patterns
12.5% HCPV/Year
719 – 1,091 MMbbls

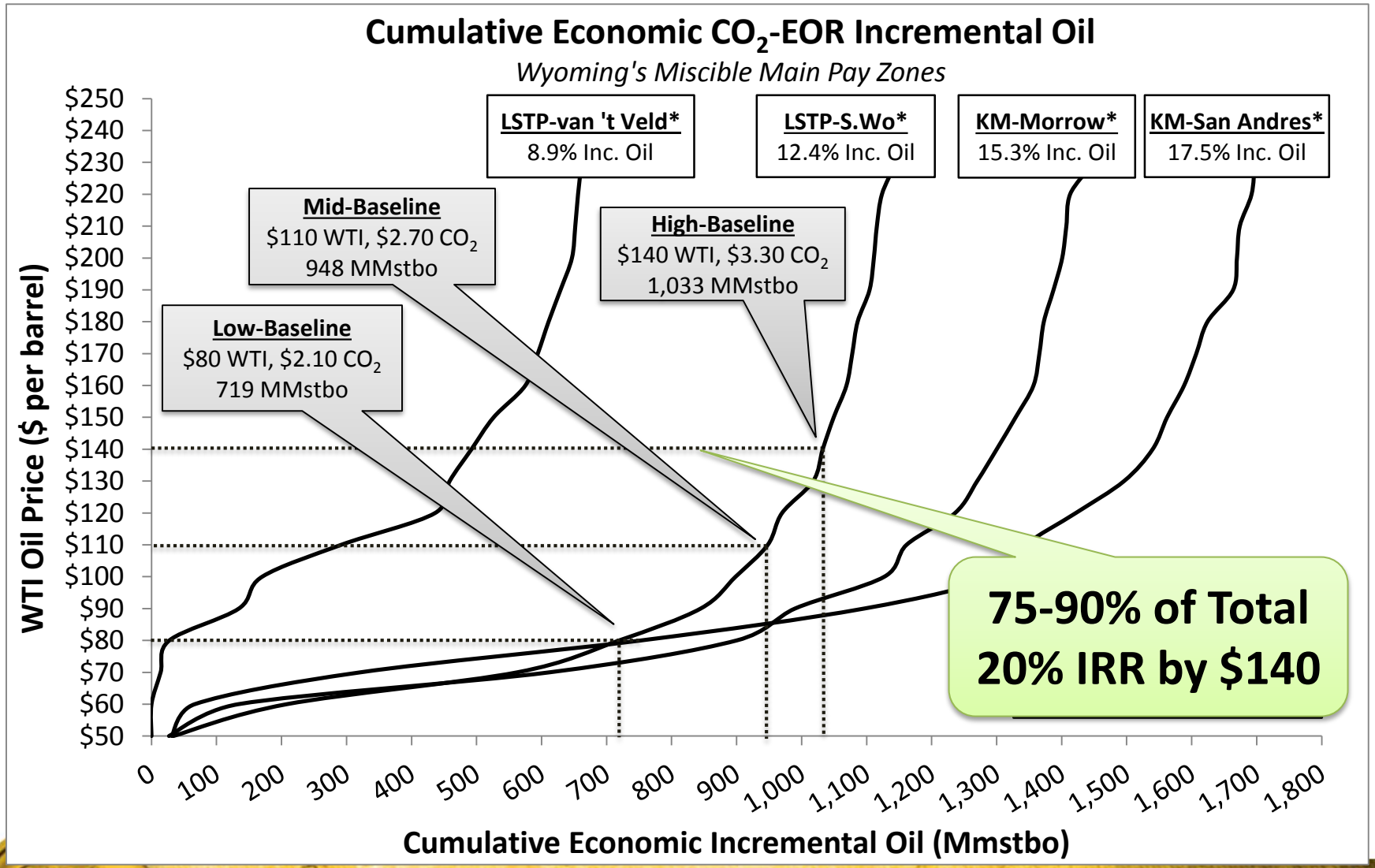
CO_2 Contract	$0.50 + 1.0%			BASELINE $0.50 + 2.0%		
WTI Oil Price	**$80**	**$110**	**$140**	**$80**	**$110**	**$140**
~WY Oil Price	$65.46	$95.46	$125.96	$65.46	$95.46	$125.96
~CO_2 Price	$1.30	$1.60	$1.90	$2.10	$2.70	$3.30
Big Horn Basin	621	643	650	554	621	636
Denver Basin			1			
Green River Basin	42	50	52	22	47	50
Hanna Basin						
Laramie Basin					11	11
Overthrust Belt						9
Powder River Basin	107	184	250	83	161	217
Wind River Basin	93	111	117	60	108	110
Total	**872**	**1,008**	**1,091**	**719**	**948**	**1,033**
# of FRCS (20% IRR)	66	121	150	46	100	129

62% of Total
Big Horn Basin

WY's Miscible CO_2EOR Potential



WY's Miscible CO_2EOR Potential



WY's CO_2 Purchase Demand

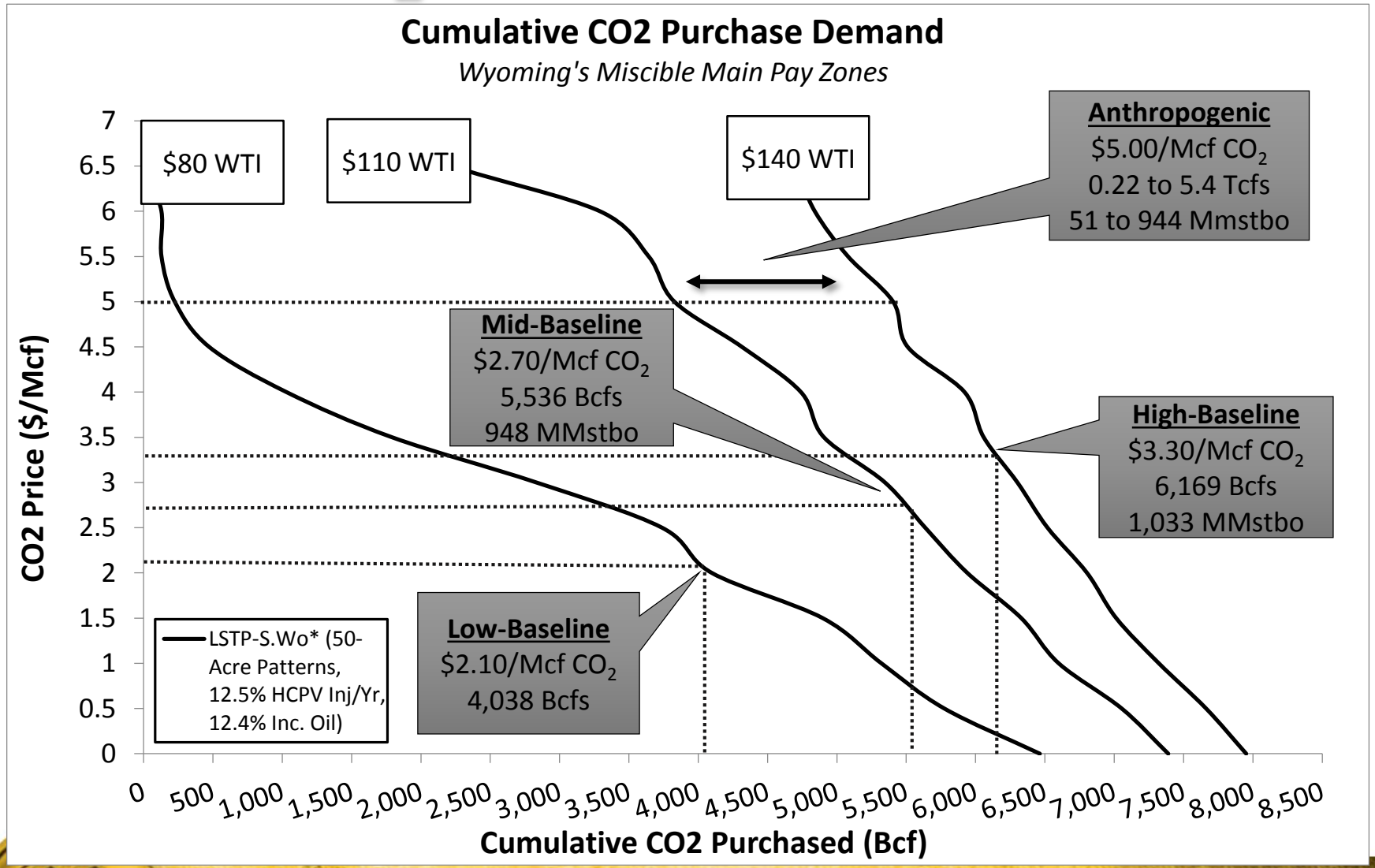
CO_2 Contract	$0.50 + 1.0%			BASELINE $0.50 + 2.0%		
WTI Oil Price	**$80**	**$110**	**$140**	**$80**	**$110**	**$140**
~WY Oil Price	$65.46	$95.46	$125.96	$65.46	$95.46	$125.96
~CO_2 Price	$1.30	$1.60	$1.90	$2.10	$2.70	$3.30
Big Horn Basin	3,622	3,909	4,056	3,131	3,616	3,777
Denver Basin			5			
Green River Basin	269	333	351	106	306	328
Hanna Basin			3			
Laramie Basin	56	66	69		62	65
Overthrust Belt		84	88			81
Powder River Basin	627	1,113	1,539	473	933	1,279
Wind River Basin	538	662	732	328	619	639
Total	**5,112**	**6,167**	**6,843**	**4,038**	**5,536**	**6,169**
# of FRCS (20% IRR)	66	121	150	46	100	129

LSTP Analog (12.4% Incr.), 50-Acre Patterns
12.5% HCPV/Year
719 – 1,091 MMbbls

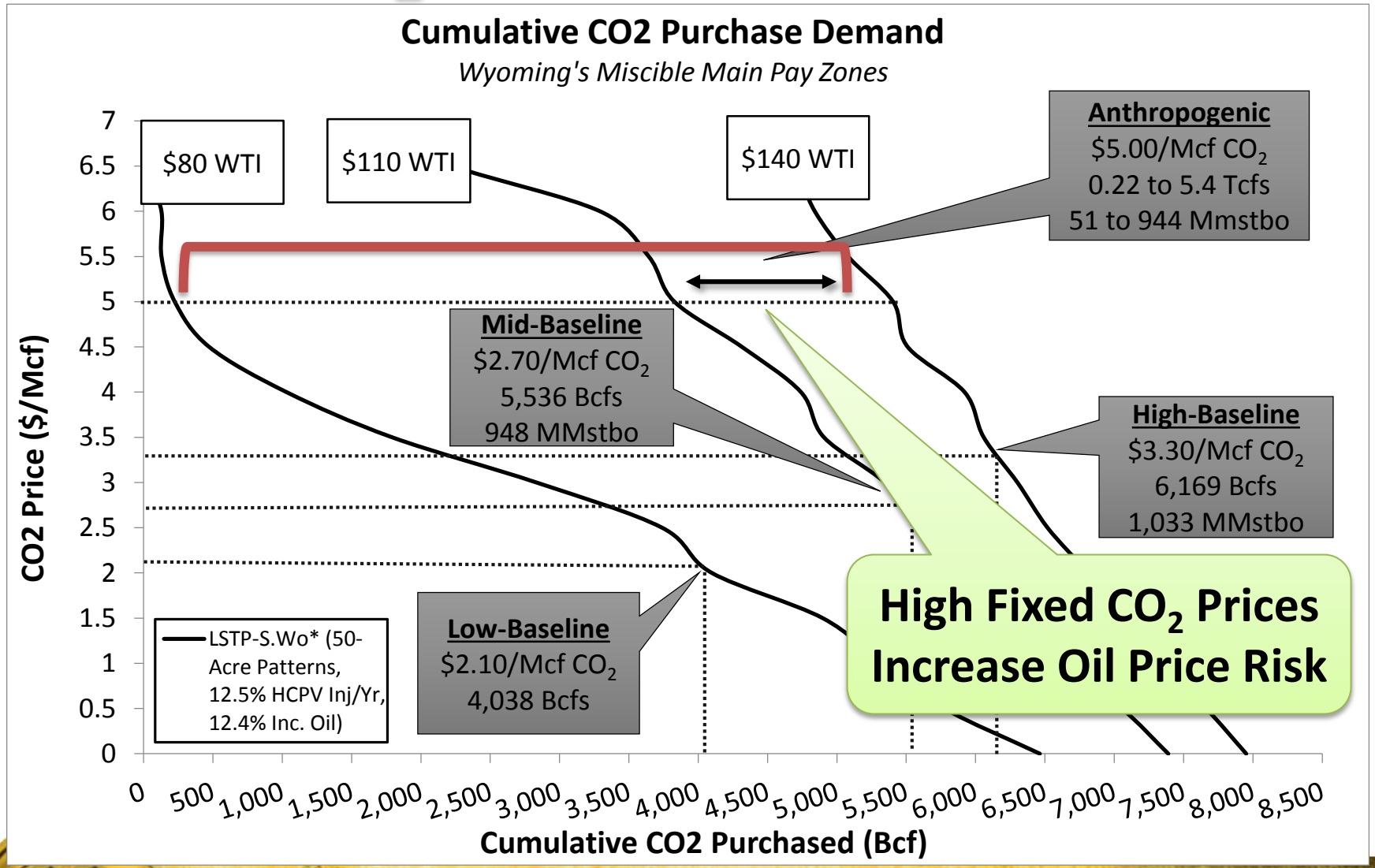
CO_2 Contract	$0.50 + 1.0%			BASELINE $0.50 + 2.0%		
WTI Oil Price	**$80**	**$110**	**$140**	**$80**	**$110**	**$140**
~WY Oil Price	$65.46	$95.46	$125.96	$65.46	$95.46	$125.96
~CO_2 Price	$1.30	$1.60	$1.90	$2.10	$2.70	$3.30
Big Horn Basin	3,622	3,909	4,056	3,131	3,616	3,777
Denver Basin			5			
Green River Basin	269	333	351	106	306	328
Hanna Basin						
Laramie Basin					62	65
Overthrust Belt		84				81
Powder River Basin	627	1,113	1,53	473	933	1,279
Wind River Basin	538	662	732	328	619	639
Total	**5,112**	**6,167**	**6,843**	**4,038**	**5,536**	**6,169**
# of FRCS (20% IRR)	66	121	150	46	100	129

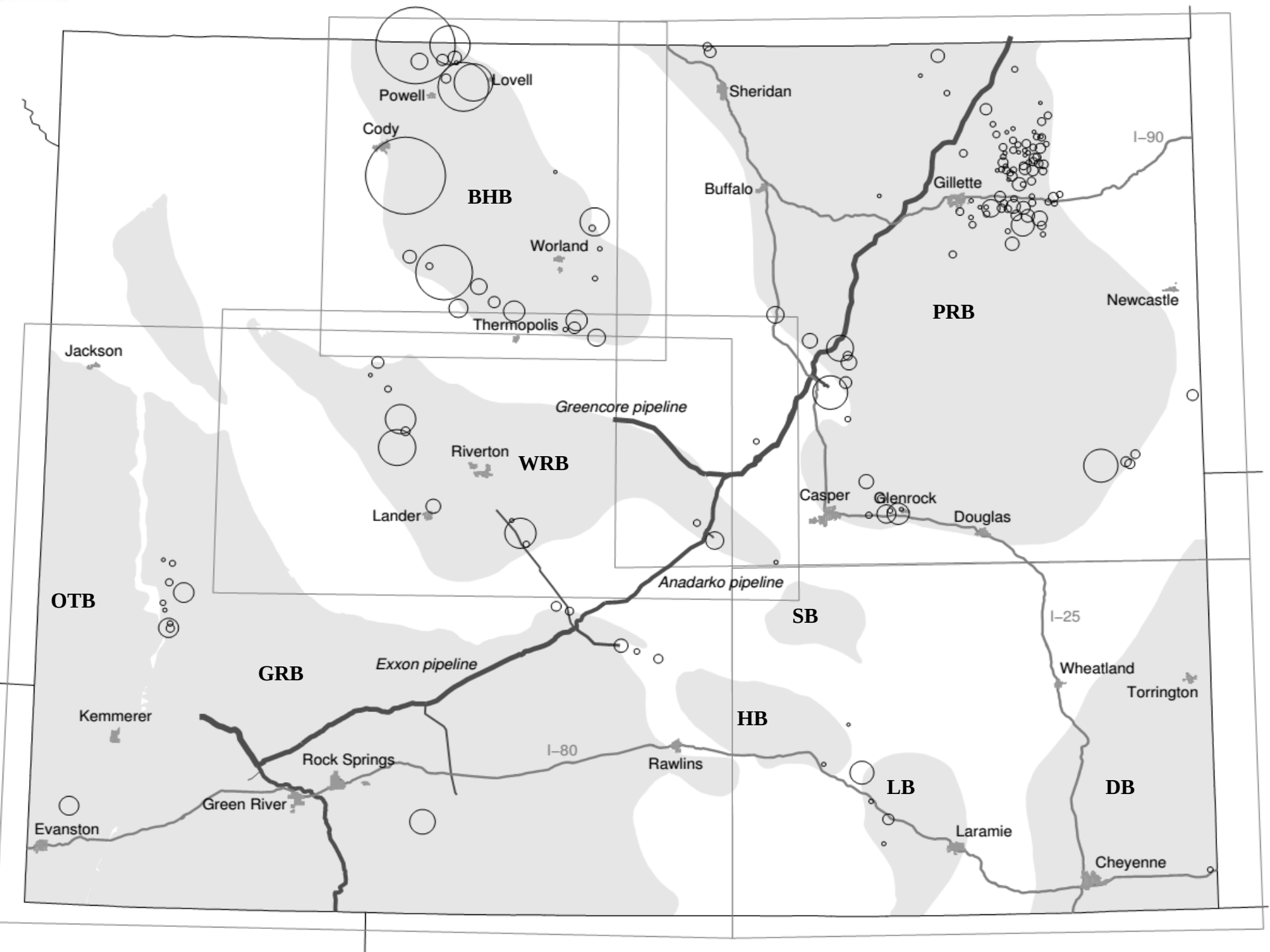
~6.2 Tcf of CO_2

WY's CO_2 Purchase Demand



WY's CO_2 Purchase Demand




Powell
Lovell
Cody
BHB
Worland
Thermopolis
Sheridan
Buffalo
Gillette
I–90
PRB
Newcastle
Jackson
Greencore pipeline
Riverton
WRB
Lander
Casper
Glenrock
Douglas
Anadarko pipeline
OTB
SB
I–25
Exxon pipeline
GRB
Wheatland
Torrington
Kemmerer
HB
Rock Springs
I–80
Rawlins
LB
DB
Green River
Evanston
Laramie
Cheyenne

Potential Economic Contribution?

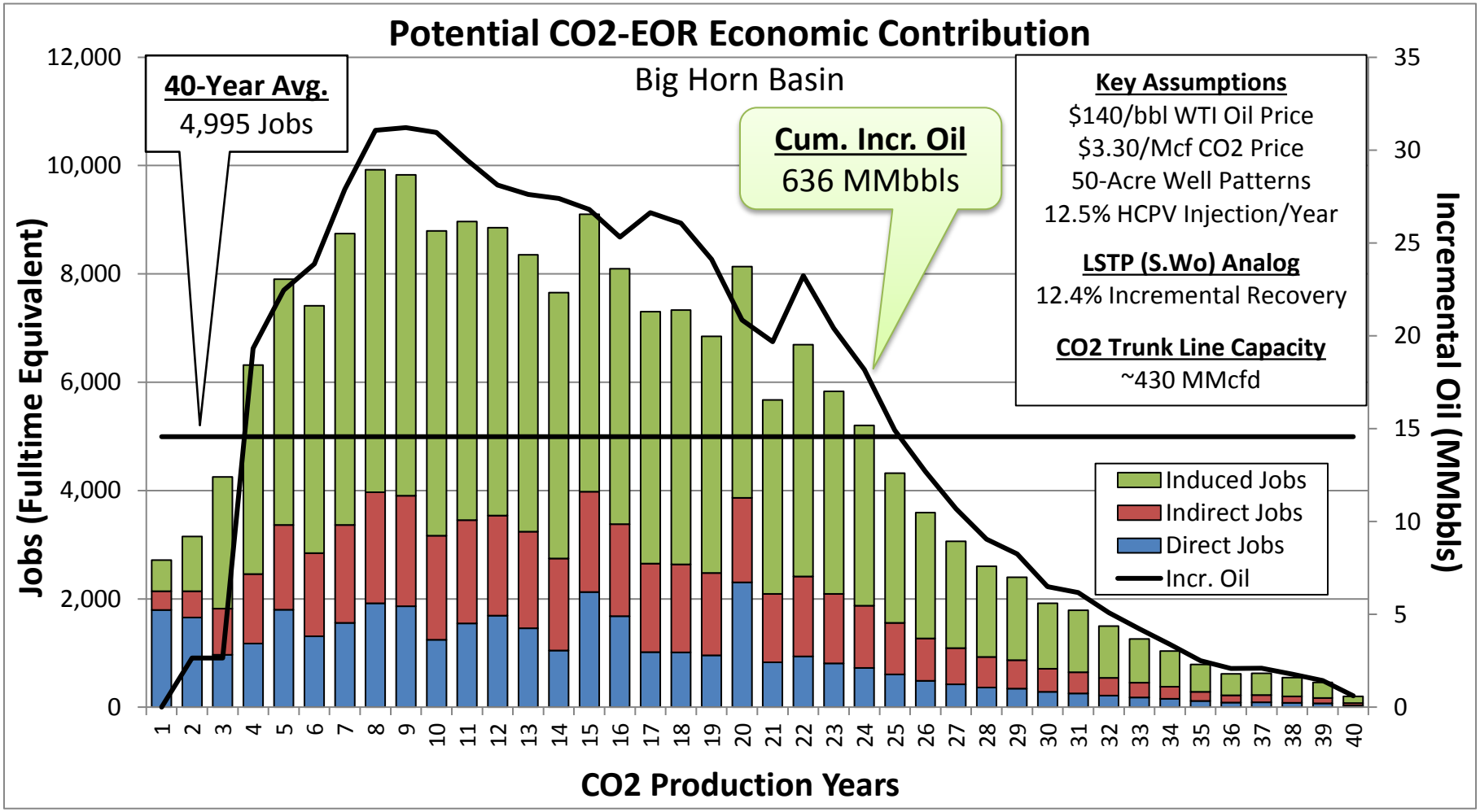
High-Baseline Scenario for BHB

BHB Cum. Incr. Oil
636 MMbbls

Key Assumptions
$140/bbl WTI Oil Price
$3.30/Mcf CO2 Price
50-Acre Well Patterns
12.5% HCPV Injection/Year

LSTP (S.Wo) Analog
12.4% Incremental Recovery

Max Daily CO2
~430 MMcfd

	BASELINE		
CO_2 Contract	**$0.50 + 2.0%**		
WTI Oil Price	**$80**	**$110**	**$140**
~WY Oil Price	$65.46	$95.46	$125.96
~CO_2 Price	$2.10	$2.70	$3.30
Big Horn Basin	554	621	636
Denver Basin			
Green River Basin	22	47	50
Hanna Basin			
Laramie Basin		11	11
Overthrust Belt			9
Powder River Basin	83	161	217
Wind River Basin	60	108	110
Total	**719**	**948**	**1,033**
# of FRCS (20% IRR)	46	100	129

Potential Economic Contribution