

ECONOMICS OF CO₂ INJECTION AND STORAGE IN DEEP COAL SEAMS

Coal-Seq I Forum

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OUTLINE

- ◆ **Background**
- ◆ **Review of Performance**
- ◆ **Economic Cases**
 - **Current Case**
 - **High Gas Price/High Efficiency Case**
 - **Moderate Gas Price w/Incentives Case**
- ◆ **Summary**

BACKGROUND

Injection of CO₂ into deep coal seams can provide:

- ◆ Secure, long-term storage of CO₂
- ◆ Potential for “value added” production of natural gas

However, considerable uncertainty exists on the commercial readiness of this CO₂ sequestration option and particularly its economics.

N₂/CO₂ - ENHANCED COALBED METHANE RECOVERY PILOTS

1. Burlington Resources Allison Unit, San Juan Basin

- **4 injectors,
16 producers,
3 MMcfd injected**
- **Only multi-well
pilot to date**
- **6 years of CO₂
injection history**

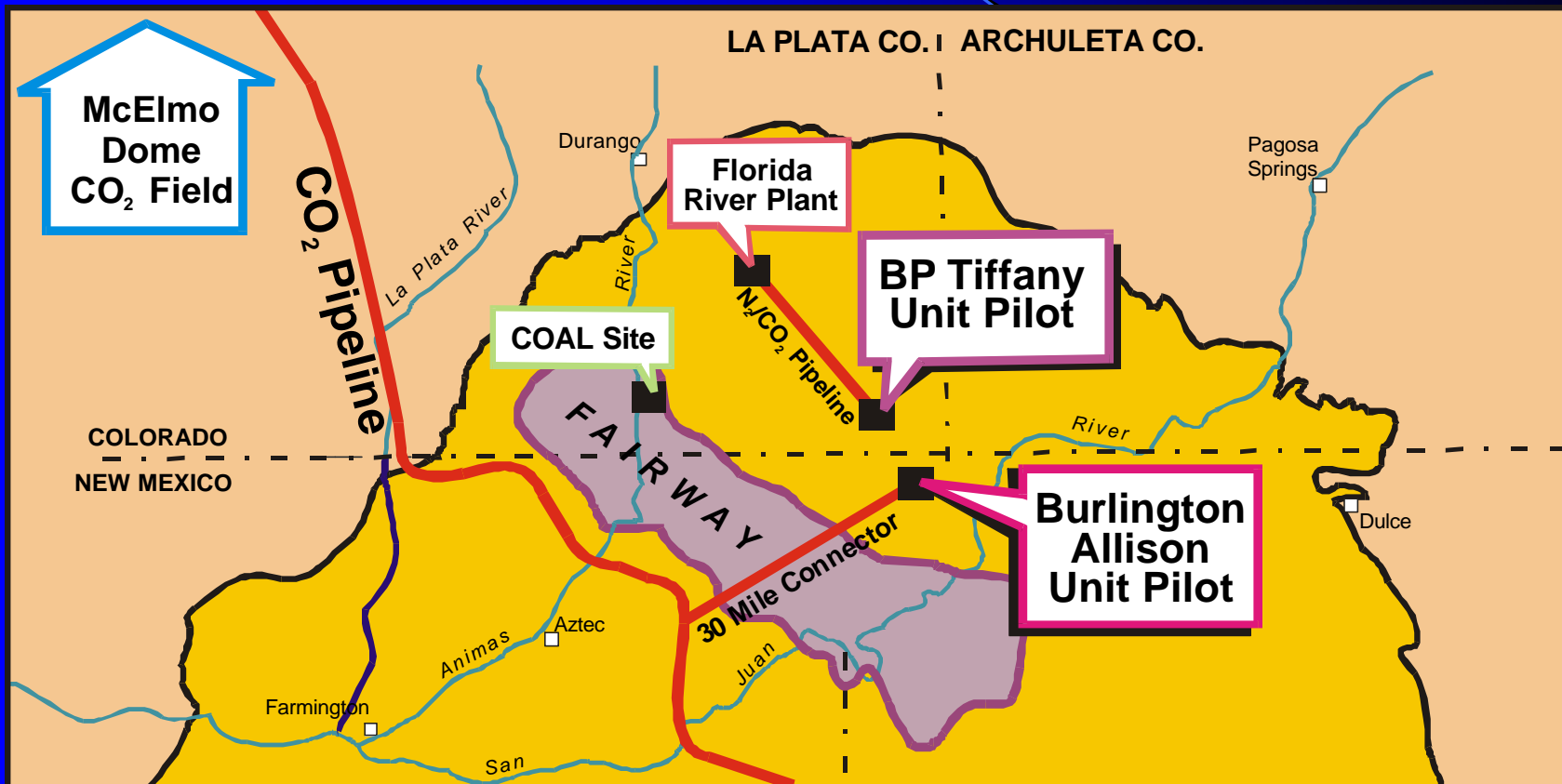
2. BP Tiffany Unit, San Juan Basin

- **12 injectors
34 producers**
- **ARI/BP/DOE joint
monitoring project**
- **N₂ pilot operating**
- **CO₂ pilot on hold**

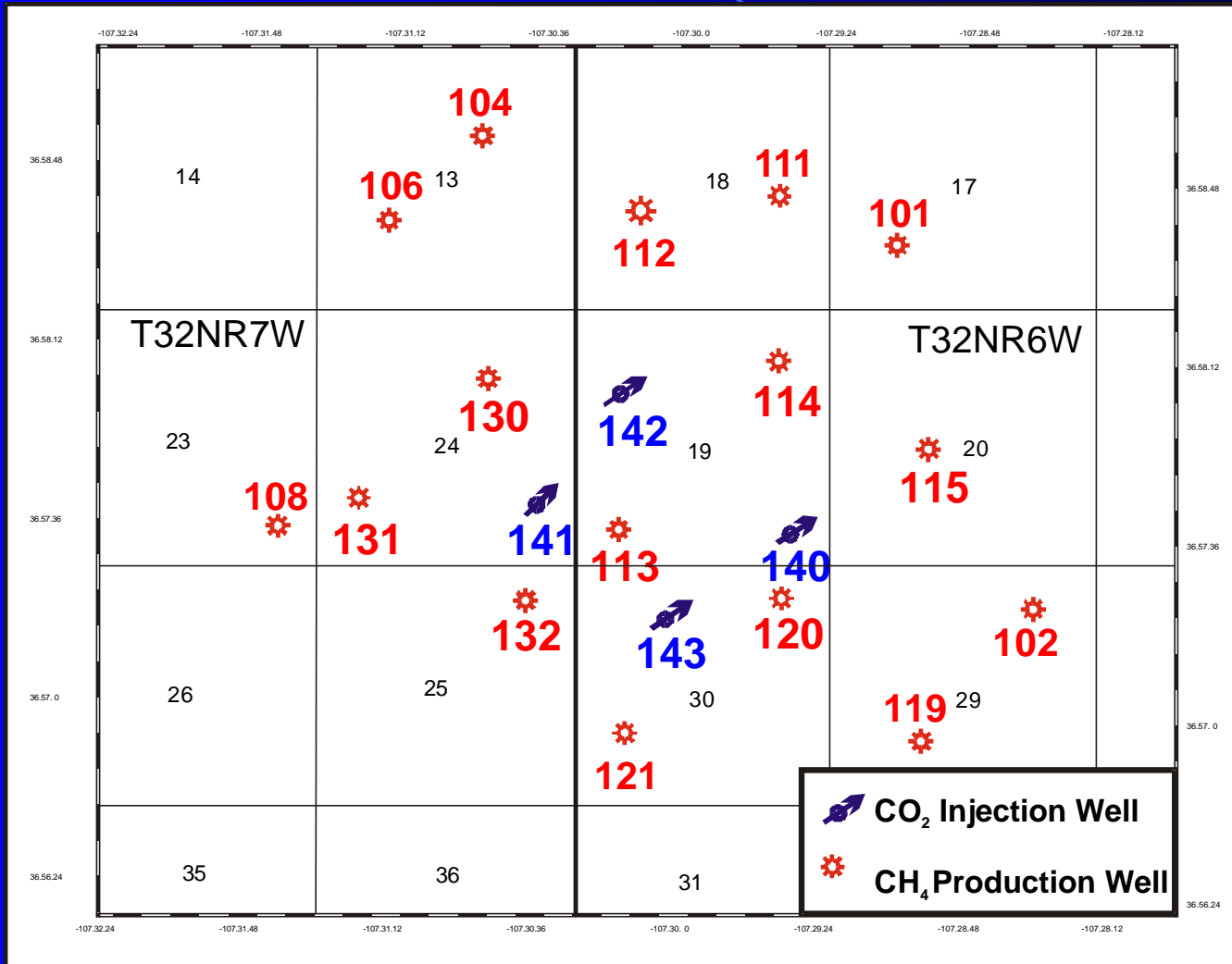
3. Alberta Research Council, Alberta Basin

- **Single-well,
short-term huff-
n-puff test
completed**
- **Plan 5-spot once
funding in place**

LOCATION OF ECBM PILOTS SAN JUAN BASIN, USA

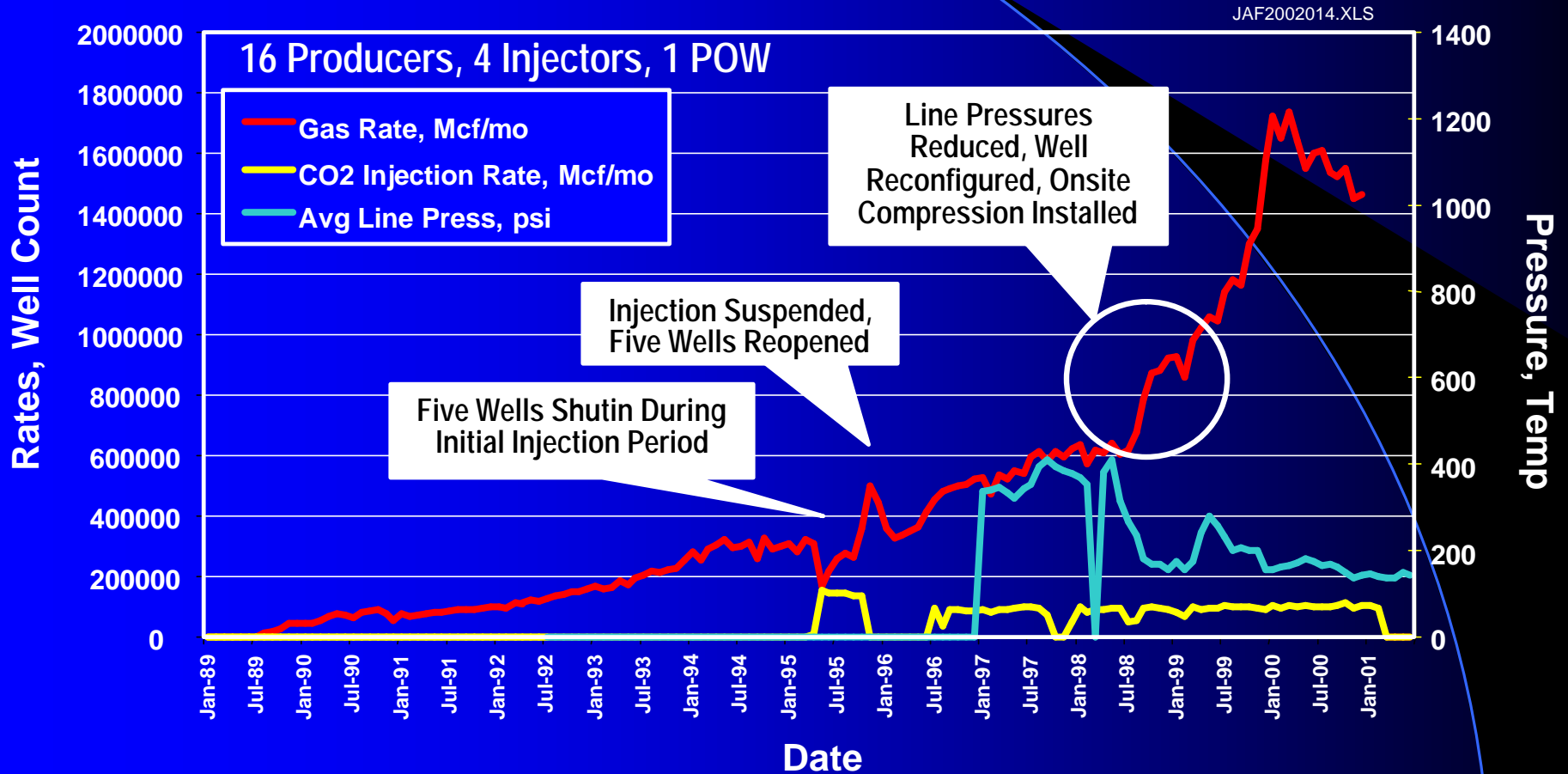


ALLISON UNIT CO₂-ECBM PILOT, SAN JUAN BASIN

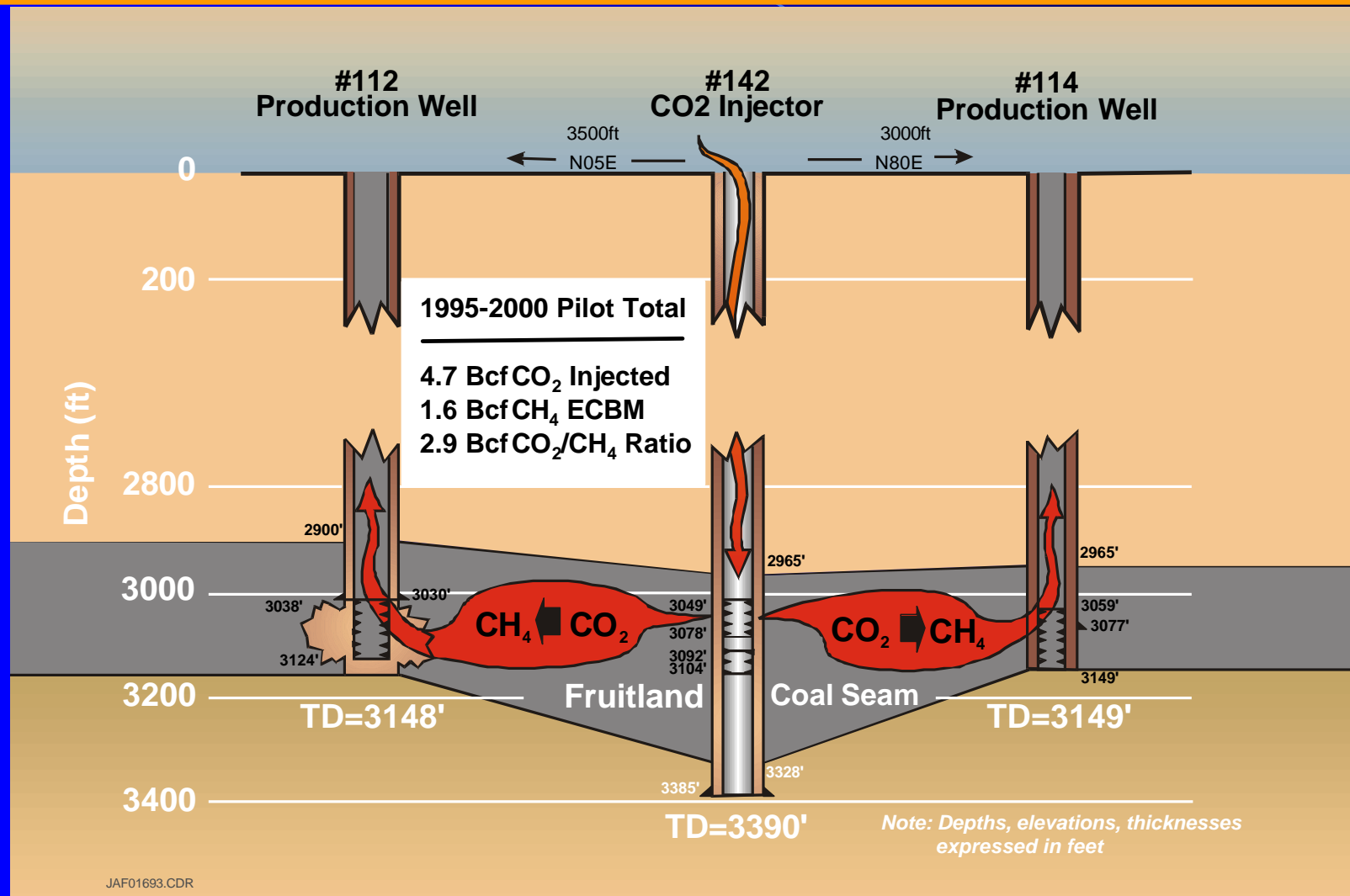


ALLISON PRODUCTION HISTORY

(cartesian scale)



CROSS-SECTIONAL VIEW OF THE ALLISON UNIT CO₂-ECBM PILOT, SAN JUAN BASIN



ECONOMIC CASES

- ◆ **Current Case**
- ◆ **High Case**
- ◆ **Incentives Case**

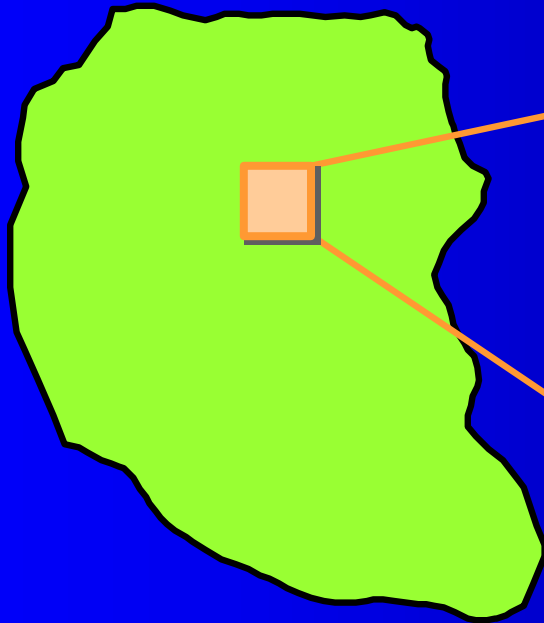
ECONOMICS OF CO₂ STORAGE IN DEEP COAL SEAMS

The example setting for CO₂ storage is a large, deep western coal basin:

- ◆ Gas in place - - 50 Tcf
- ◆ Conventional recovery - - 24 Tcf; 3 Bcf/well
- ◆ Inc. recovery by CO₂ Injection - - 1 to 2 Bcf/well
- ◆ CO₂ to CBM ratio - - 2 to 4 Mcf/Mcf
- ◆ Market price for CO₂ - - 3% of oil price
- ◆ Capital investment:
 - Cost of injection wells/facilities -- \$500,000 per I well
 - Inj. well to prod. well ratio – 1:3 to 1:1
 - Cost of SMV -- 50% increase

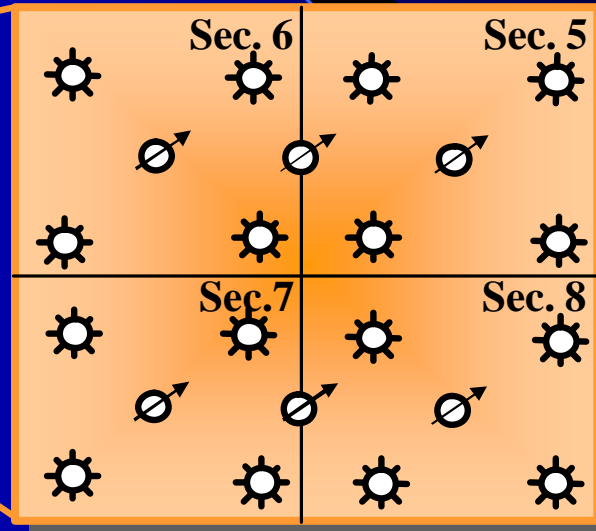
ECONOMICS OF CO₂ STORAGE IN DEEP COAL SEAMS (Cont'd)

Example CBM Basin



Gas In Place – 50 Tcf
Production Wells – 8,000
Depth – 3,000 ft

Current Case CO₂ Injection Pattern (4 Sections)



Gas In Place – 100 Bcf
Conventional Recovery – 48 Bcf
Incremental Recovery – 16 Bcf (est.)
Production Wells – 16
Injection Wells – 6 (new)

Economics Of CO₂ Storage: **CURRENT CASE**

The economics of CO₂ storage are first examined using expected natural gas prices, current CO₂ costs and assumed CO₂/CBM displacement performance:

◆ Wellhead	\$3.00/Mcf
◆ Oil Price	\$20/BO
◆ CO ₂ /CBM ratio	2.5 Mcf/Mcf
◆ Inc. Recovery	1 Bcf/well
◆ I well/P well ratio	1 to 3
◆ SMV costs	--
◆ Incentives	--

Economics Of CO₂ Storage:

CURRENT CASE (Cont'd)

	<u>Current Case (\$/Mcf)</u>
<u>Wellhead Gas Price</u>	<u>\$3.00</u>
Less: Basin Differential	(\$0.30)
BTU Adjustment (@ 5%)	(\$0.15)
Wellhead Netback	<u>\$2.55</u>
Less: Royalty/Prod. Taxes	(\$0.51)
O&M/Gas Processing	(\$0.50)
Gross Margin	<u>\$1.54</u>
Capital Costs⁽¹⁾	(\$0.38)
CO₂ Costs (@ ratio of 2.5 to 1)⁽²⁾	(\$1.50)
Net Margin	Negative

(1) Capital Costs = \$500,000 * 6 (l wells) = \$3,000,000/16 Bcfg
 = \$0.19/Mcfg * 2 = \$0.38/Mcfg

(2) CO₂ Costs = \$20/BO * 3% = \$0.60/Mcf * 2.5 = \$1.50/Mcf (CO₂)

Economics Of CO₂ Storage: **CURRENT CASE** (Cont'd)

Lower cost CO₂ would accelerate its injection and storage in deep coal seams.

CO₂ Cost (\$/Mcf)	CO₂/CBM Displacement Performance (2.5 Mcf/Mcf)	
	CO₂ Cost	Net Margin
\$0.60	\$1.50	(\$0.34)
\$0.50	\$1.25	(\$0.09)
\$0.40	\$1.00	\$0.16

At wellhead gas price (Henry Hub) of \$3/Mcf.

Economics Of CO₂ Storage: **HIGH GAS PRICE/HIGH EFFICIENCY CASE**

Higher natural gas prices and a lower CO₂/CBM ratio would improve the economics of CO₂ storage in deep coals:

◆ Wellhead natural gas price	\$4.00/Mcf
◆ Oil price	\$30/BO
◆ CO ₂ /CBM ratio	2 Mcf/Mcf
◆ Inc. recovery	1 Bcf/well
◆ I well/P well ratio	1 to 3
◆ SMV costs	--
◆ Incentives	--

Economics Of CO₂ Storage: **HIGH GAS PRICE/ HIGH EFFICIENCY CASE (Cont'd)**

	<u>High Case (\$/Mcf)</u>
<u>Wellhead Gas Price</u>	<u>\$4.00</u>
Less: Basin Differential	(\$0.30)
BTU Adjustment (@5%)	(\$0.20)
Wellhead Netback	<u>\$3.50</u>
Less: Royalty/Prod. Taxes	(\$0.70)
O&M/Gas Processing	(\$0.50)
Gross Margin	<u>\$2.30</u>
Capital Costs⁽¹⁾	(\$0.38)
CO₂ Costs (@ ratio of 2 to 1)⁽²⁾	<u>(\$1.80)</u>
Net Margin	\$0.12

(1) Capital Costs = \$500,000 * 6 (l wells) = \$3,000,000/16 Bcfg
 = \$0.19/Mcfg * 2 = \$0.38/Mcfg

(2) CO₂ Costs = \$30/BO * 3% = \$0.90/Mcf * 2 = \$1.80/Mcf (CO₂)

Economics Of CO₂ Storage: **MODERATE GAS PRICE W/INCENTIVES**

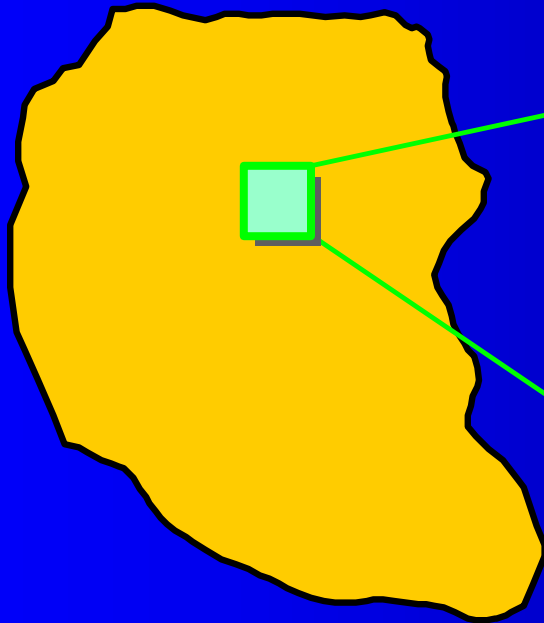
At moderate natural gas prices plus incentives for CO₂ sequestration, deep coals offer the potential for storing large volumes of CO₂:

Incentive Cases

◆ Wellhead natural gas price	\$3.00/Mcf	\$3.00/Mcf
◆ Oil price	\$25/BO	\$25/BO
◆ CO ₂ /CBM ratio	2.5 Mcf/Mcf	4 Mcf/Mcf
◆ Inc. recovery	2 Bcf/well	2 Bcf/well
◆ I well/P well ratio	1 to 1	1 to 1
◆ SMV costs	\$250,000/I well	\$250,000/I well
◆ Incentives	\$10/TCO ₂	\$15/TCO ₂

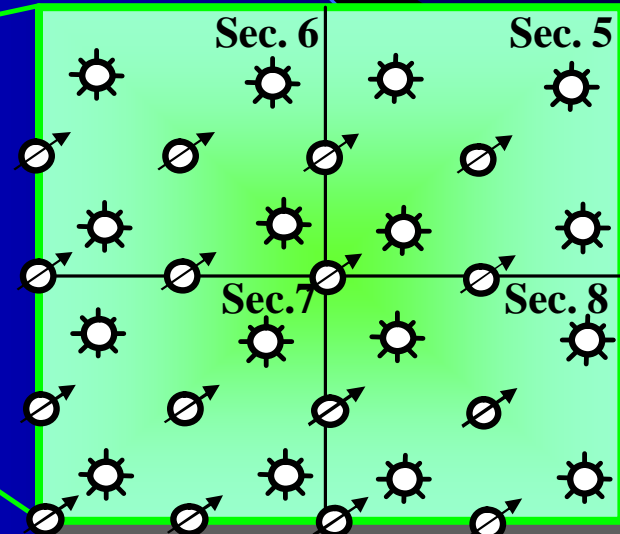
ECONOMICS OF CO₂ STORAGE IN DEEP COAL SEAMS (Cont'd)

Example CBM Basin



Gas In Place – 50 Tcf
Production Wells – 8,000
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Incentives Case CO₂ Injection Pattern (4 Sections)



Gas In Place – 100 Bcf
Conventional Recovery – 48 Bcf
Incremental Recovery – 32 Bcf (est.)
Production Wells – 16
Injection Wells – 16 (new)

CONVERTING CURRENT EOR PRACTICES TO CO₂ STORAGE

1. Assess and configure reservoir for long-term (~1,000 year) storage of CO₂.
2. Maintain CO₂ in reservoir (at pressure) rather than “blow down” reservoir and reuse the CO₂.
3. Install long-term monitoring and safety systems.

Economics Of CO₂ Storage: MODERATE GAS PRICE w/INCENTIVES (Cont'd)

	Incentive Cases	
	<u>\$10/T CO₂</u>	<u>\$15/T CO₂</u>
<u>Wellhead Gas Price</u>	<u>\$3.00</u>	<u>\$3.00</u>
Less: Basin Differential	(\$0.30)	(\$0.30)
BTU Adjustment (@5%)	(\$0.15)	(\$0.15)
Wellhead Netback	<u>\$2.55</u>	<u>\$2.55</u>
Less: Royalty/Prod. Taxes	(\$0.51)	(\$0.51)
O&M/Gas Process./SMV ⁽²⁾	(\$0.75)	(\$0.75)
Gross Margin	<u>\$1.29</u>	<u>\$1.29</u>
Capital Costs		
- I Wells ⁽¹⁾	(\$0.50)	(\$0.50)
- SMV ⁽²⁾	(\$0.25)	(\$0.25)
Net CO₂ Costs⁽³⁾⁽⁴⁾	<u>(\$0.43)</u>	<u>(0)</u>
Net Margin	<u>\$0.11</u>	<u>\$0.54</u>

(1) Capital Costs \$500,000 * 16 = \$8,000,000/ 32 Bcfg
= \$0.25 * 2 = \$0.50/Mcfg

(2) SMV Costs = plus 50%

(3) CO₂ Costs (@ \$10/T) = \$25/BO * 3% = (\$0.75/Mcf - \$0.58) Mcf
= \$0.17/Mcf * 2.5 = \$0.51/Mcf (CO₂)

(4) CO₂ Costs (@ 15/T) = (assume 0)

ECONOMICS OF CO₂ IN DEEP COAL SEAMS

The economic analysis of CO₂ sequestration in the example western coal basin is summarized below:

Outcomes	Current Case	High Price/High Efficiency Case	Modest Price w/ Sequestration Incentives	
			\$10/TCO ₂	\$15 /TCO ₂
Economic	No	Marginal	Marginal	Yes
CO ₂ Storage (MM Tons)*	-	930	2,330	3,720
Additional Natural Gas	-	8 Tcf	16 Tcf	16 Tcf
Capital Investment				
◆ Inj Wells	-	\$1.5 Billion	\$4 Billion	\$4 Billion
◆ SMV	-	-	\$2 Billion	\$2 Billion

*Using 17.2 Mcf CO₂/Ton CO₂.

SUMMARY

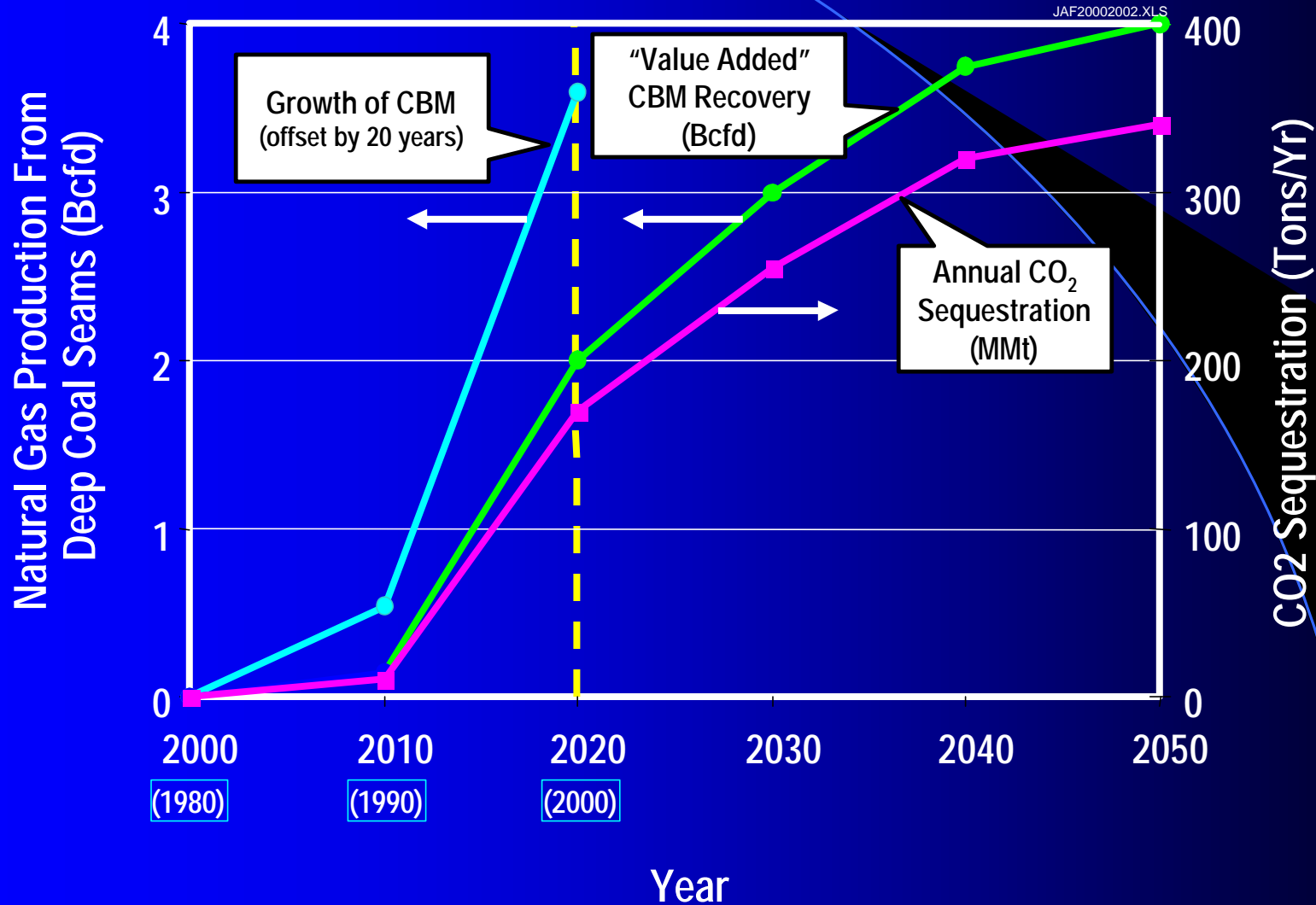
1. Considerably more laboratory and field work are required to provide confidence in the key variables controlling the economics of CO₂ injection in deep coal seams.
2. Lower cost CO₂, higher CO₂/CBM efficiencies and/or higher natural gas prices are required to encourage commercial use of this “value added” CO₂ sequestration technology.

SUMMARY (Cont'd)

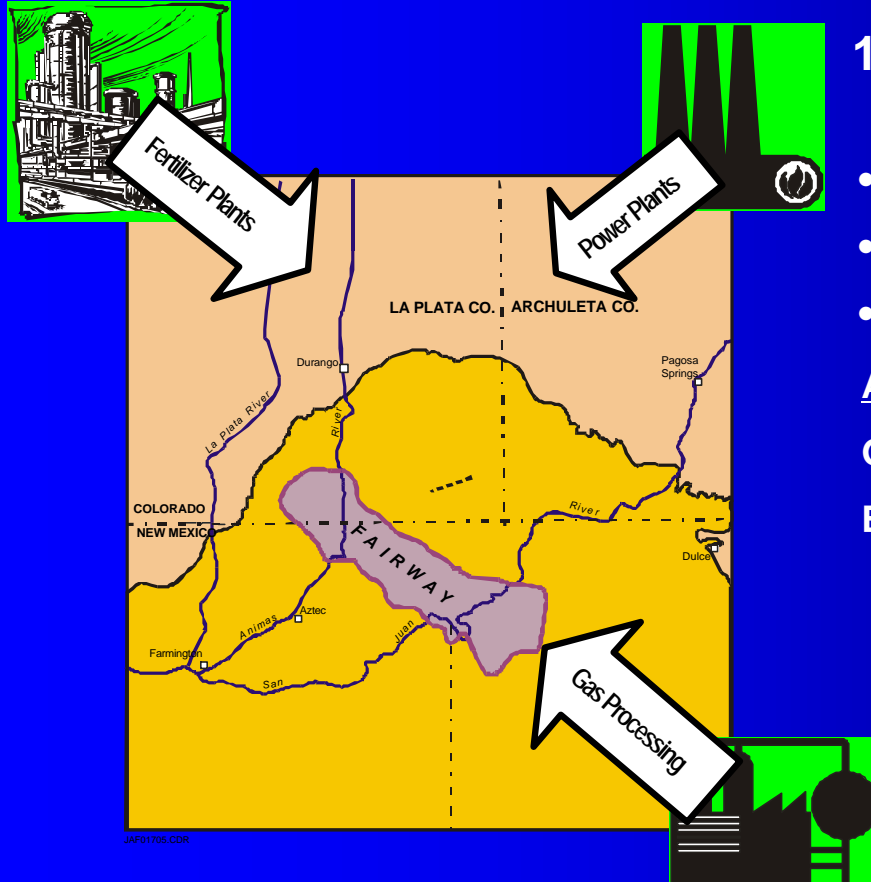
3. With appropriate incentives and technology however, deep coal seams offer the potential for:

- ◆ **Storing considerable volumes of CO₂ in the 2020 to 2050 timeframe.**
- ◆ **Providing important volumes of additional domestic natural gas production.**
- ◆ **Encouraging the development of CO₂ sequestration business units.**

SEQUESTRATION OF CO₂ USING DEEP COAL SEAMS



SCENARIO 2020: CO₂ SEQUESTRATION BUSINESS UNIT



170 MMt/yr CO₂ Injection Project (San Juan, Raton, Uinta, etc.)

- 8 Bcfd CO₂ Injection
- 4 Mcf CO₂/ Mcf CBM Ratio
- “Free” CO₂ to CBM Field Site

Annual Report

Gross Gas Revenues (@\$3.00/Mcf) = \$2,190 MM

Before Tax Net Revenues = 390 MM

CO₂ Sequestration Incentives
Make Uneconomic ECBM
Projects Economic



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