CO_2-Enhanced Oil Recovery Potential for the MGA Region

Prepared for:

Midwestern Governers Association

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Background

The Midwestern Governors Association has formed an advisory group to examine potential CO_2 emissions management strategies. One important strategy for managing CO_2 emissions is to productively use and store CO_2 for Enhanced Oil Recovery.

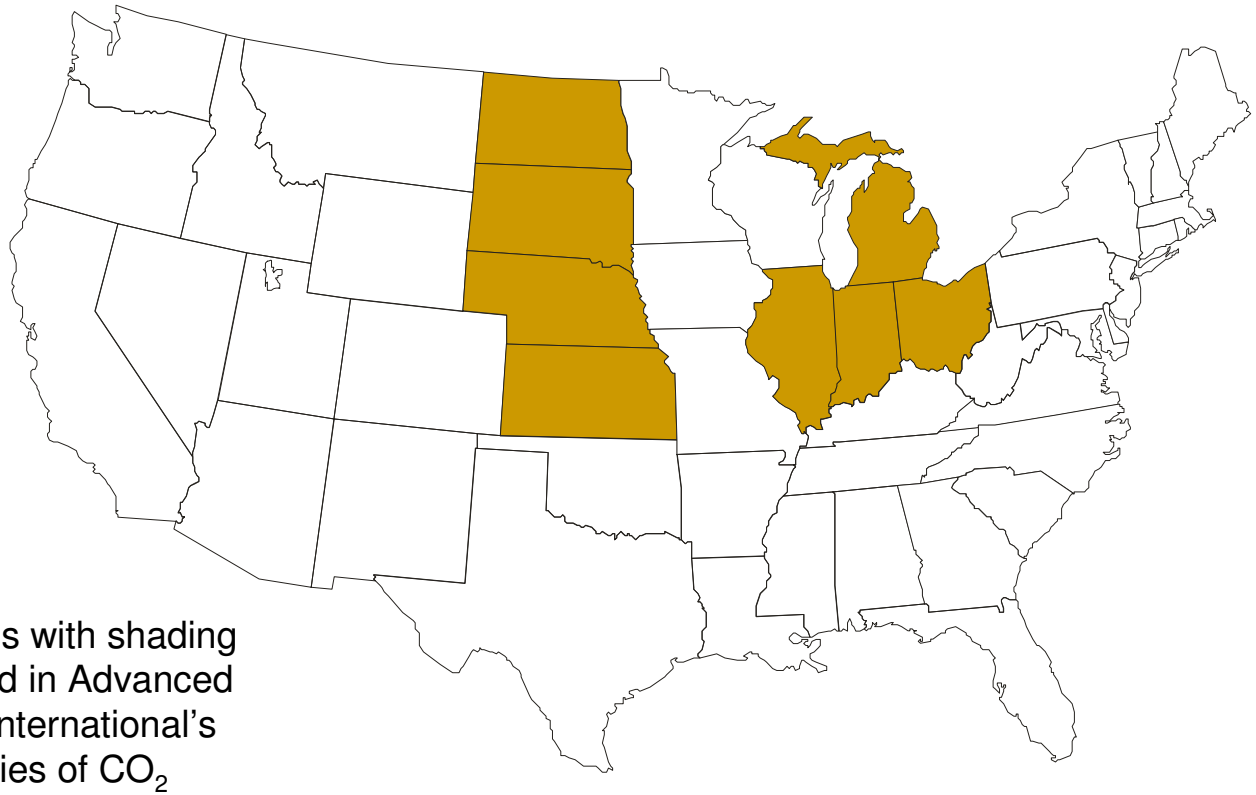
This report examines the size and economic feasibility of using CO_2 for Enhanced Oil Recovery in 8 of the 12 states in the Midwest.

Data and Methodology

Advanced Resources' database of CO_2-EOR oil fields includes potential candidate reservoirs from 8 of the 12 states within the Midwestern Governors Association region, listed below:

- Illinois
- Indiana
- Kansas
- Michigan
- Nebraska
- North Dakota
- South Dakota
- Ohio

Midwestern Region States with Favorable Reservoirs for CO_2-EOR



The 8 states with shading are included in Advanced Resource International's recent studies of CO_2 storage with enhanced oil recovery.

Technical Potential

Of the 349 individual reservoirs screened in the region, 175 reservoirs with 19.7 billion barrels of original oil in place screened as favorable for CO_2-EOR. The favorable reservoirs were then modeled, giving a technically recoverable resource of 4.0 to 7.5 billion barrels, depending on the technology applied.

State	# Reservoirs Amenable for EOR	Favorable Oil in Place (MM Bbls)	State of the Art Technically Recoverable (MM Bbls)	Next Generation Technically Recoverable (MM Bbls)
Illinois	75	5,260	494	2,276
Kansas	25	5,149	1,272	1,748
North Dakota	34	3,703	1,060	1,548
Ohio	19	3,906	853	1,495
Michigan	11	1,033	230	320
Nebraska	3	276	44	109
South Dakota	1	93	23	30
Indiana	7	241	18	19
Total	**175**	**19,661**	**3,994**	**7,545**

Illinois and Kansas have the largest technically recoverable resource totaling 1.8 to 4.0 billion barrels. The other six states add 2.2 to 3.5 billion barrels.

Economic Potential

Reservoirs that screen favorably for CO_2-EOR are first evaluated using a reservoir model and second evaluated using an economic model.

For this study, the Base Case is $70 per barrel of oil and $45 per metric ton of CO_2. In addition, four other cases are examined to assess the effects of oil price and CO_2 costs on economic feasibility.

At the base case of $70 per barrel of oil and $45 per metric ton of CO_2, the Midwestern Region could recover 2.2 billion barrels of oil, requiring purchase of 530 million metric tons of CO_2 under State of the Art Technology. Using Next Generation Technology, oil recovery increases to 3.9 billion barrels, requiring purchase of 830 million metric tons of CO_2.

Summary of Results

The results are shown separately for Kansas and Illinois and grouped together for the other six states. All individual state level results can be found in Appendix A.

State	Economically Recoverable Oil at $70/Bbl Oil and $45/mt CO2	
	State of the Art	Next Generation
Kansas	1,222	1,677
Illinois	425	1,578
All Others	527	608
Total	**2,174**	**3,863**

State	Purchased CO2 at $70/Bbl Oil and $45/mt CO2	
	State of the Art	Next Generation
Kansas	292	366
Illinois	100	339
All Others	135	128
Total	**527**	**833**

CO_2-EOR Activity in the Midwestern Region

The Midwestern Region contains several pilot-size CO_2-EOR projects.

Most notably, in Michigan, Core Energy had 8 miscible CO_2-EOR projects as of 2008. Core Energy is producing light oil from Silurian/Niagaran Reef structures in these 8 small projects. These structures are conducive to vertically stable CO_2-EOR using straight CO_2 rather than a water-alternating-gas (WAG) approach.

In Kansas, the Hall-Gurney field began a pilot flood on 10 acres with 2 wells. The CO_2 was delivered from an ethanol plant. Today the project is discontinued.

CO2-EOR Potential Near the Midwest Region

Although there is potential to sequester CO_2 within the Midwestern Region, the amount of CO_2 required (530 to 830 million metric tons) is small compared to the needs for CO_2 from other nearby regions.

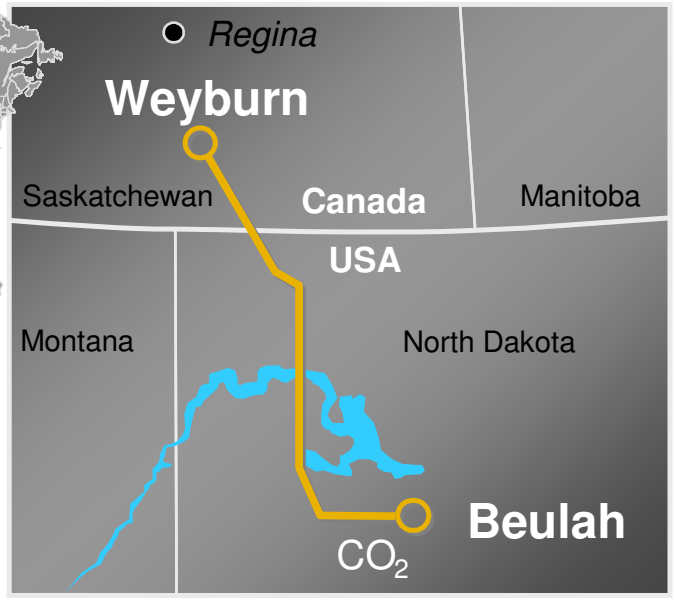
Advanced Resources' previous studies have found that, depending on the technology case, 12,000 to 14,000 million metric tons would be required nationwide for enhanced oil recovery under the base case of $70 per barrel of oil and $45 per metric ton of CO_2.

To the North, the opportunity in Canada has been exemplified at the Weyburn field by Encana. Producers in this region have indicated a need for additional CO_2.

To the South, companies like Denbury, who are expanding their CO_2-EOR operations, are looking to the Midwest for additional sources of CO_2.

The "Poster Child" - Weyburn Enhanced Oil Recovery Project

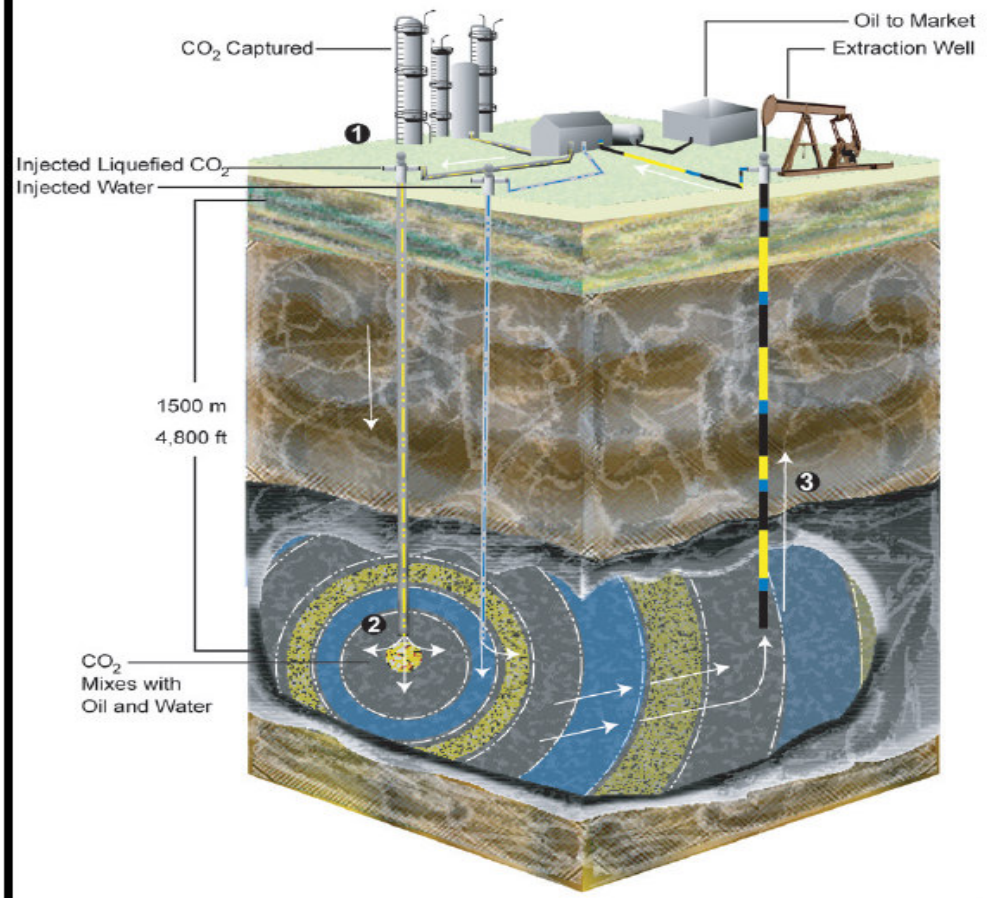
(Maximizing Oil Recovery and CO_2 Storage)



Source: EnCana, 2005

- **Largest CO_2 EOR project in Canada:**
  - **1.4 billion barrels (OOIP) oil field**
- **Outstanding EOR response**
- **World's largest geological CO_2 sequestration project**
  - **2.4 MMt/year**
  - **23 MMt with EOR**
  - **55 MMt with EOR/sequestration**

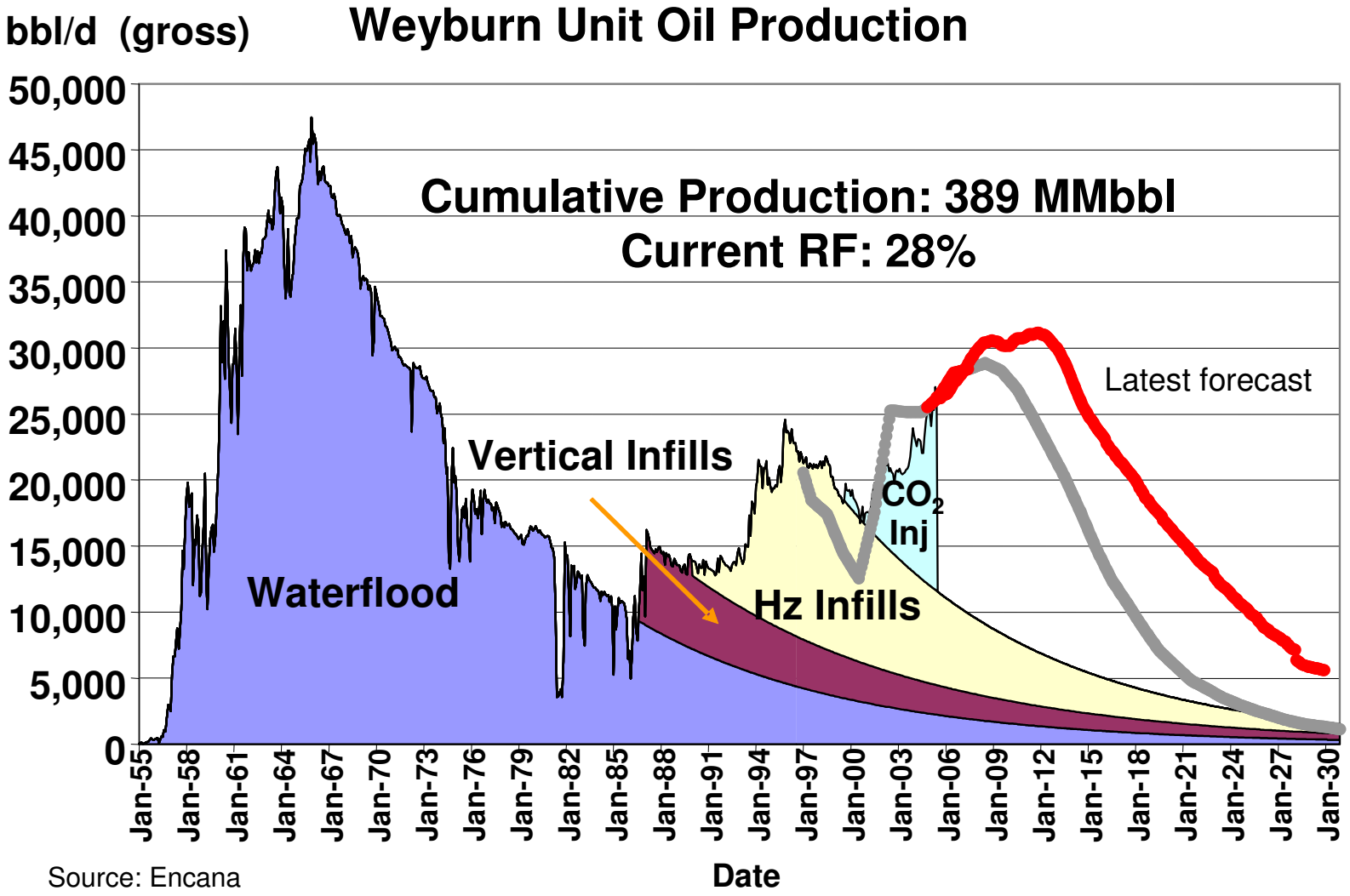
Weyburn CO_2 Sequestration
Environmental and Commercial Success



- **Outstanding EOR response**
  - ~200 MMbbls incremental production over 30 years
  - Recently celebrated 35 year production high
- **World's largest geological storage project**
  - ~ 55 million tonnes of potential CO_2 storage capacity
  - Studied intensively by the International Energy Agency
- **Nine years of commercial scale CO_2 storage**
  - ~13 million tonnes stored to date

www.encana.com

Production Curve from Weyburn Field



Source: Encana

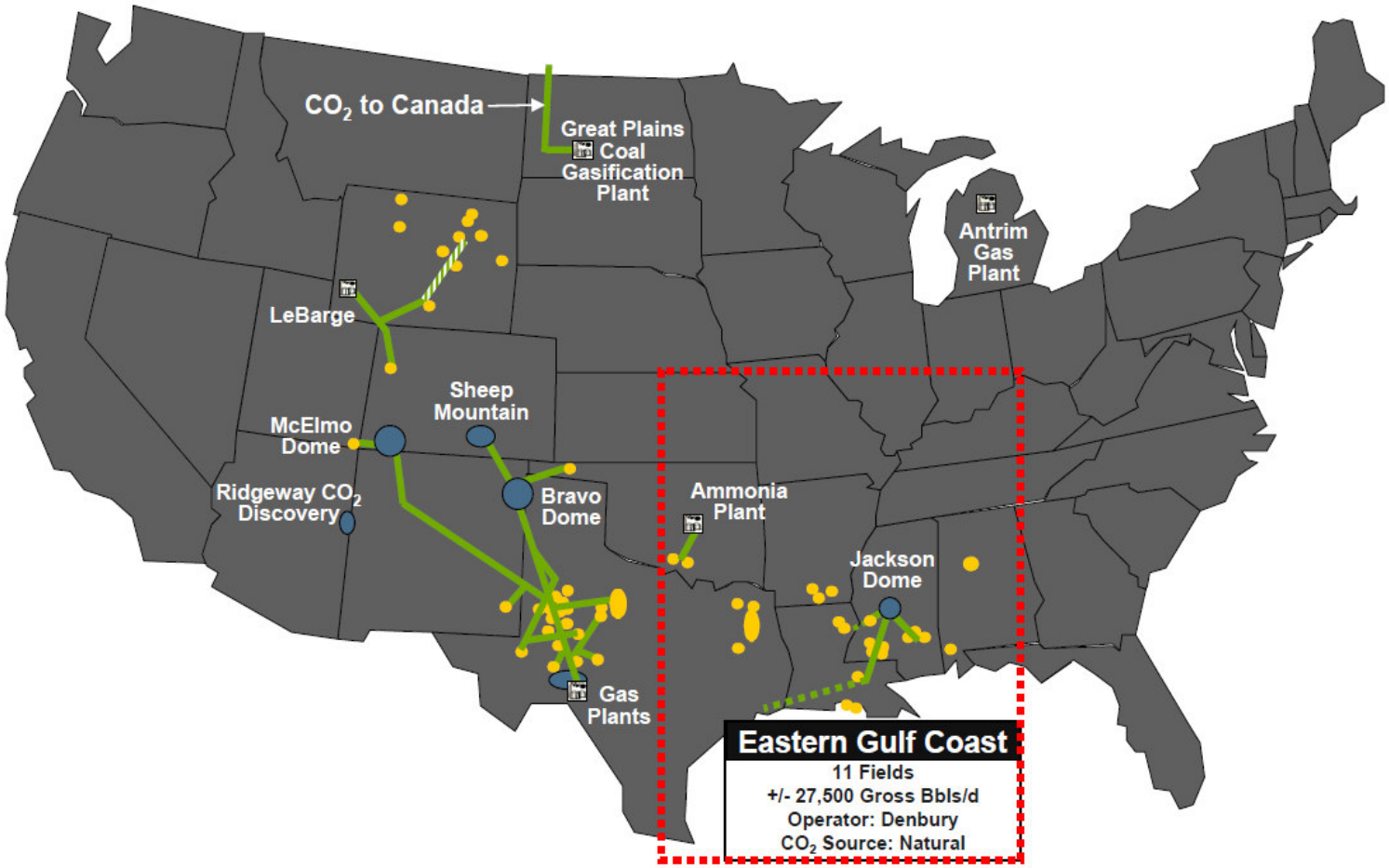
Gulf Coast CO_2-EOR

The high quality enhanced oil recovery potential of the Gulf Coast Region provides a strong demand for CO_2 that exceeds current natural sources.

CO_2 from Midwestern anthropogenic sources could play a major roll in CO_2-EOR development in that region.

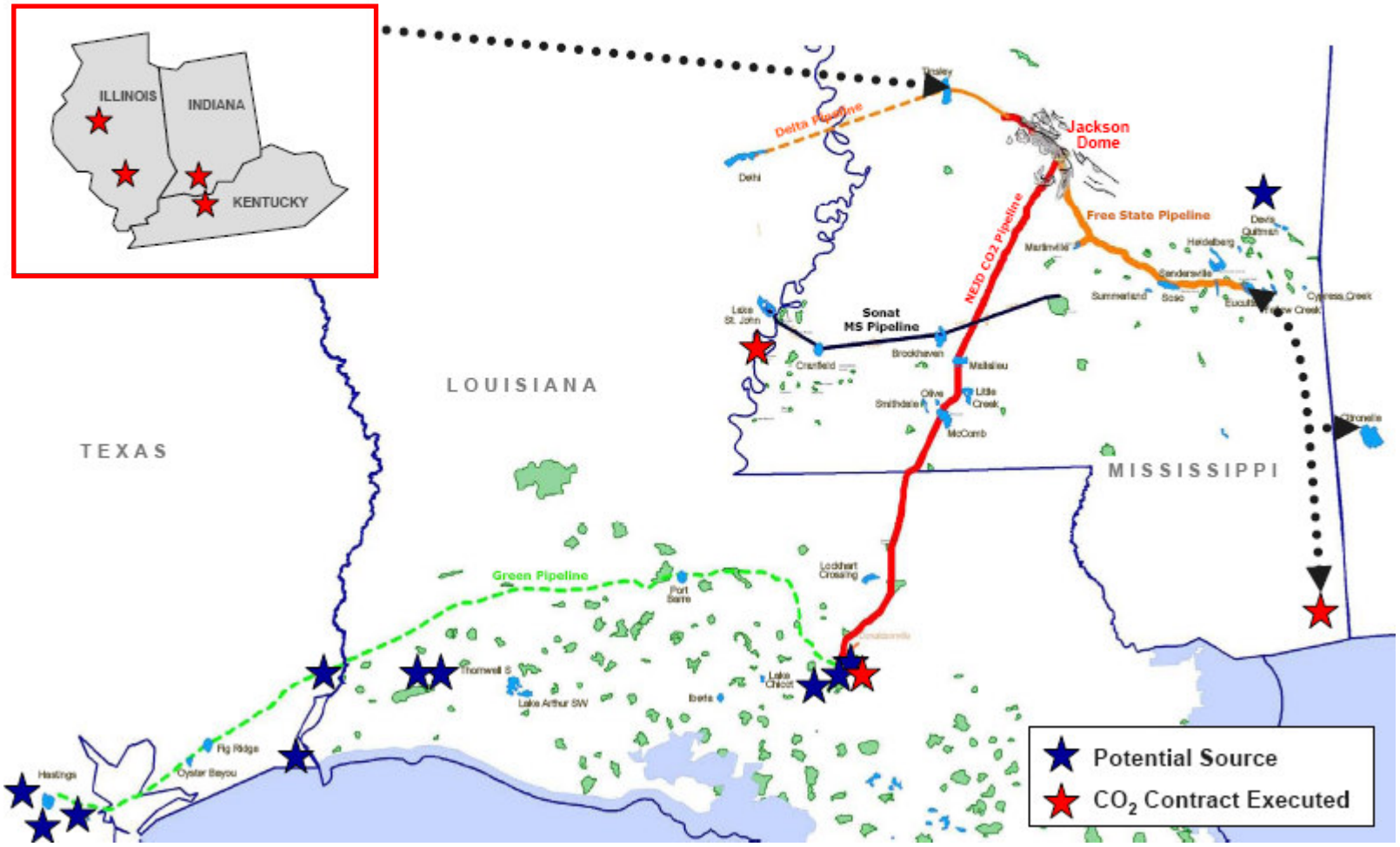
Denbury Resources is examining anthropogenic sources in the Midwest Region and hopes to begin using these anthropogenic sources to supplement their existing CO_2 sources in the next five years.

Opportunity to the South: Gulf Coast Region



Source: Denbury Resources

Potential Anthropogenic Sources of CO_2



Source: Denbury Resources

Potential Anthropogenic CO_2 Sources

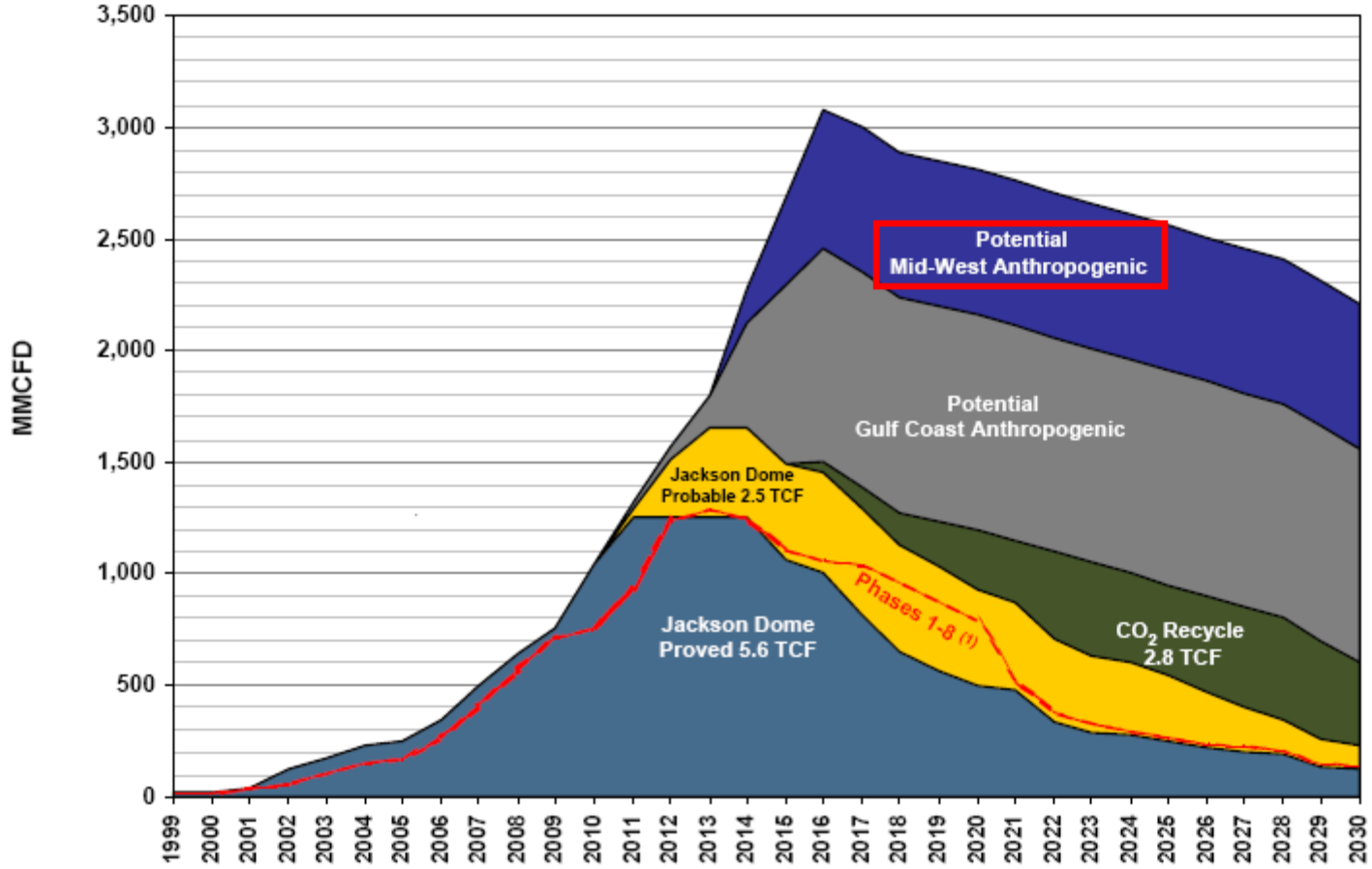
- **Denbury Purchase Contracts** (contingent on plants being completed)
  - Committed to take 100% of daily volume of CO_2

Source	MMCFD	Initial Production Expected
Faustina (Donaldsonville, LA)	190 – 225	2014
Rentech (Natchez, MS)	350 – 400	2013
Cash Creek Kentucky (SNG)*	190 – 210	2013
Power Holdings of Illinois (SNG)*	250 – 300	2013
Christian County Generation/Tenaska of Illinois (SNG)*	170 – 225	2013
Indiana Gasification of Indiana (SNG)*	230 – 300	2013
Mississippi Gasification of Mississippi (SNG)*	170 – 225	2013

*Requires additional supplies and additional pipeline

Source: Denbury Resources

Potential CO_2 Supply



Note: CO_2 recycle assumed to be 50% of proved; anthropogenic estimated based on anticipated pipeline capacity. Forecast based on internal management estimates. Actual results may vary.

Source: Denbury Resources

Summary Remarks

Within the Midwestern Region, Illinois and Kansas have a sizeable oil resource for CO_2 Enhanced Oil Recovery. Under Base Case economics and using Next Generation Technology, these two states alone could produce as much as 3.2 billion barrels of oil and purchase over 700 million metric tons of CO_2.

In addition to the productive use of CO_2 for Enhanced Oil Recovery in the Midwestern Region, there is potential for transporting anthropogenic CO_2 from the region both to the North and to the South.

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Appendix A: State Results

The following slides present the state level economically recoverable oil resource and required CO_2 at a series of oil prices and CO_2 costs.

State Results

Kansas

State of the Art Oil Recovery (MM Bbls)			
CO2 Cost	Oil Price		
$/ton	$50	$70	$100
$ 15.00		1,244	
$ 45.00	1,208	1,222	1,244
$ 75.00		1,060	

State of the Art CO2 Purchased (MM tons)			
CO2 Cost	Oil Price		
$/ton	$50	$70	$100
$ 15.00		300	
$ 45.00	287	292	300
$ 75.00		243	

Next Generation Oil Recovery (MM Bbls)			
CO2 Cost	Oil Price		
$/ton	$50	$70	$100
$ 15.00		1,697	
$ 45.00	1,338	1,677	1,697
$ 75.00		1,438	

Next Generation CO2 Purchased (MM tons)			
CO2 Cost	Oil Price		
$/ton	$50	$70	$100
$ 15.00		371	
$ 45.00	282	366	371
$ 75.00		305	

State Results

Illinois

State of the Art Oil Recovery (MM Bbls)			
CO2 Cost	Oil Price		
$/ton	$50	$70	$100
$ 15.00		463	
$ 45.00	350	425	469
$ 75.00		372	

State of the Art CO2 Purchased (MM tons)			
CO2 Cost	Oil Price		
$/ton	$50	$70	$100
$ 15.00		111	
$ 45.00	81	100	112
$ 75.00		86	

Next Generation Oil Recovery (MM Bbls)			
CO2 Cost	Oil Price		
$/ton	$50	$70	$100
$ 15.00		1,838	
$ 45.00	769	1,578	1,959
$ 75.00		921	

Next Generation CO2 Purchased (MM tons)			
CO2 Cost	Oil Price		
$/ton	$50	$70	$100
$ 15.00		406	
$ 45.00	160	339	433
$ 75.00		194	

State Results

Michigan

State of the Art Oil Recovery (MM Bbls)			
CO2 Cost	Oil Price		
$/ton	$50	$70	$100
$ 15.00		83	
$ 45.00	78	78	92
$ 75.00		78	

State of the Art CO2 Purchased (MM tons)			
CO2 Cost	Oil Price		
$/ton	$50	$70	$100
$ 15.00		22	
$ 45.00	21	21	25
$ 75.00		21	

Next Generation Oil Recovery (MM Bbls)			
CO2 Cost	Oil Price		
$/ton	$50	$70	$100
$ 15.00		105	
$ 45.00	99	105	105
$ 75.00		99	

Next Generation CO2 Purchased (MM tons)			
CO2 Cost	Oil Price		
$/ton	$50	$70	$100
$ 15.00		28	
$ 45.00	27	28	28
$ 75.00		27	

State Results

Indiana

State of the Art Oil Recovery (MM Bbls)			
CO2 Cost	Oil Price		
$/ton	$50	$70	$100
$ 15.00		10	
$ 45.00	0	0	15
$ 75.00		0	

State of the Art CO2 Purchased (MM tons)			
CO2 Cost	Oil Price		
$/ton	$50	$70	$100
$ 15.00		3	
$ 45.00	0	0	4
$ 75.00		0	

Next Generation Oil Recovery (MM Bbls)			
CO2 Cost	Oil Price		
$/ton	$50	$70	$100
$ 15.00		2	
$ 45.00	0	2	9
$ 75.00		0	

Next Generation CO2 Purchased (MM tons)			
CO2 Cost	Oil Price		
$/ton	$50	$70	$100
$ 15.00		1	
$ 45.00	0	1	3
$ 75.00		0	

State Results

Ohio

State of the Art Oil Recovery (MM Bbls)			
CO2 Cost	Oil Price		
$/ton	$50	$70	$100
$ 15.00		99	
$ 45.00	0	37	99
$ 75.00		19	

State of the Art CO2 Purchased (MM tons)			
CO2 Cost	Oil Price		
$/ton	$50	$70	$100
$ 15.00		31	
$ 45.00	0	10	31
$ 75.00		4	

Next Generation Oil Recovery (MM Bbls)			
CO2 Cost	Oil Price		
$/ton	$50	$70	$100
$ 15.00		0	
$ 45.00	0	0	116
$ 75.00		0	

Next Generation CO2 Purchased (MM tons)			
CO2 Cost	Oil Price		
$/ton	$50	$70	$100
$ 15.00		0	
$ 45.00	0	0	22
$ 75.00		0	

State Results

Nebraska

State of the Art Oil Recovery (MM Bbls)			
CO2 Cost	Oil Price		
$/ton	$50	$70	$100
$ 15.00		44	
$ 45.00	44	44	44
$ 75.00		44	

State of the Art CO2 Purchased (MM tons)			
CO2 Cost	Oil Price		
$/ton	$50	$70	$100
$ 15.00		10	
$ 45.00	10	10	10
$ 75.00		10	

Next Generation Oil Recovery (MM Bbls)			
CO2 Cost	Oil Price		
$/ton	$50	$70	$100
$ 15.00		109	
$ 45.00	109	109	109
$ 75.00		109	

Next Generation CO2 Purchased (MM tons)			
CO2 Cost	Oil Price		
$/ton	$50	$70	$100
$ 15.00		15	
$ 45.00	15	15	15
$ 75.00		194	

State Results

South Dakota

State of the Art Oil Recovery (MM Bbls)			
CO2 Cost	Oil Price		
$/ton	$50	$70	$100
$ 15.00		0	
$ 45.00	0	0	0
$ 75.00		0	

State of the Art CO2 Purchased (MM tons)			
CO2 Cost	Oil Price		
$/ton	$50	$70	$100
$ 15.00		0	
$ 45.00	0	0	0
$ 75.00		0	

Next Generation Oil Recovery (MM Bbls)			
CO2 Cost	Oil Price		
$/ton	$50	$70	$100
$ 15.00		0	
$ 45.00	0	0	0
$ 75.00		0	

Next Generation CO2 Purchased (MM tons)			
CO2 Cost	Oil Price		
$/ton	$50	$70	$100
$ 15.00		0	
$ 45.00	0	0	0
$ 75.00		0	

State Results

North Dakota

State of the Art Oil Recovery (MM Bbls)			
CO2 Cost	Oil Price		
$/ton	$50	$70	$100
$ 15.00		448	
$ 45.00	288	368	448
$ 75.00		368	

State of the Art CO2 Purchased (MM tons)			
CO2 Cost	Oil Price		
$/ton	$50	$70	$100
$ 15.00		116	
$ 45.00	74	93	116
$ 75.00		93	

Next Generation Oil Recovery (MM Bbls)			
CO2 Cost	Oil Price		
$/ton	$50	$70	$100
$ 15.00		391	
$ 45.00	175	391	520
$ 75.00		216	

Next Generation CO2 Purchased (MM tons)			
CO2 Cost	Oil Price		
$/ton	$50	$70	$100
$ 15.00		84	
$ 45.00	32	84	114
$ 75.00		39	

State Results

Total

State of the Art Oil Recovery (MM Bbls)			
CO2 Cost	Oil Price		
$/ton	$50	$70	$100
$ 15.00		2,391	
$ 45.00	1,969	2,174	2,411
$ 75.00		1,941	

State of the Art CO2 Purchased (MM tons)			
CO2 Cost	Oil Price		
$/ton	$50	$70	$100
$ 15.00		594	
$ 45.00	473	527	599
$ 75.00		457	

Next Generation Oil Recovery (MM Bbls)			
CO2 Cost	Oil Price		
$/ton	$50	$70	$100
$ 15.00		4,142	
$ 45.00	2,490	3,863	4,514
$ 75.00		2,783	

Next Generation CO2 Purchased (MM tons)			
CO2 Cost	Oil Price		
$/ton	$50	$70	$100
$ 15.00		905	
$ 45.00	516	833	986
$ 75.00		758	