A Forecast of Crude Oil Production from CO_2 EOR in the United States through 2018

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Presented to Dana VanWagner, Phil Budzig and others at the Energy Information Administration, March 7, 2013

U.S. DEPARTMENT OF ENERGY | National Energy Technology Laboratory

Acknowledgement / Disclaimer

- This work was done in collaboration with Glenn Murrell of the University of Wyoming. It also uses analyses developed for NETL by Matt Wallace and Vello Kuuskraa of Advanced Resources International. The Oil & Gas Journal provides foundational information in its biennial survey of EOR operations.

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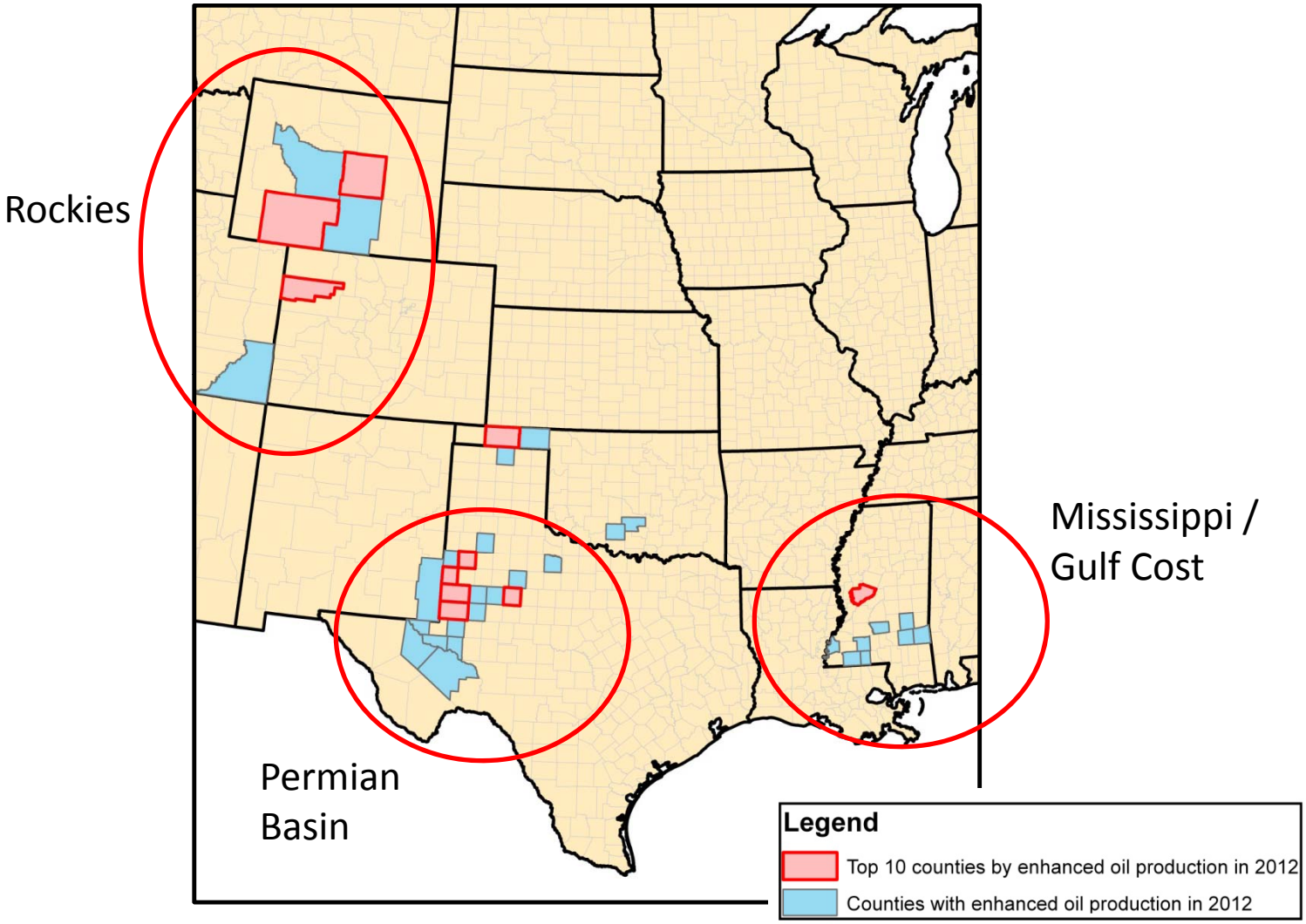
Summary

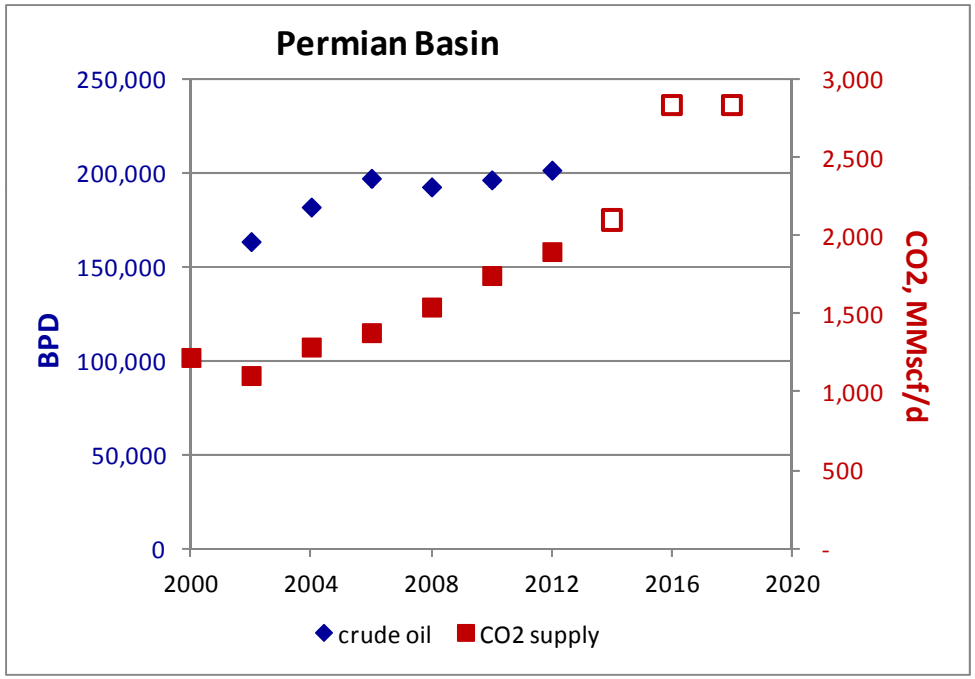
- **Total crude oil production from CO_2 EOR floods in the United States in 2012 was 272,000 bpd.**
- **CO_2 supply for enhanced oil recovery operations in the United States is expected to increase 64% between 2012 and 2018, from 3.3 BCFd to 5.4 BCFd.**
- **The CO_2 utilization rate (UR_{Net} the amount of CO_2 supplied per incremental barrel of crude oil produced) can be used to estimate crude oil production based on CO_2 supply rate**
- **Based on compiled historical data we estimate the following regional CO_2 Utilization rates:**
  - Permian basin, 8,500 scf/bbl
  - Rocky mountain, 8,000 scf/bbl
  - Gulf Coast, 25,000 scf/bbl
- **Applying these rates to the regional forecast for CO_2 supply we forecast production from CO_2 EOR in the United States in 2018 will be 500,000 bpd. This is higher than the forecast contained in the AEO 2013er, 255,000 bpd.**
- **A possible solution for EIA is to "hard wire" crude oil production from CO_2 EOR through 2018 and let the NEMS model take over from there.**

CO_2 EOR Regions



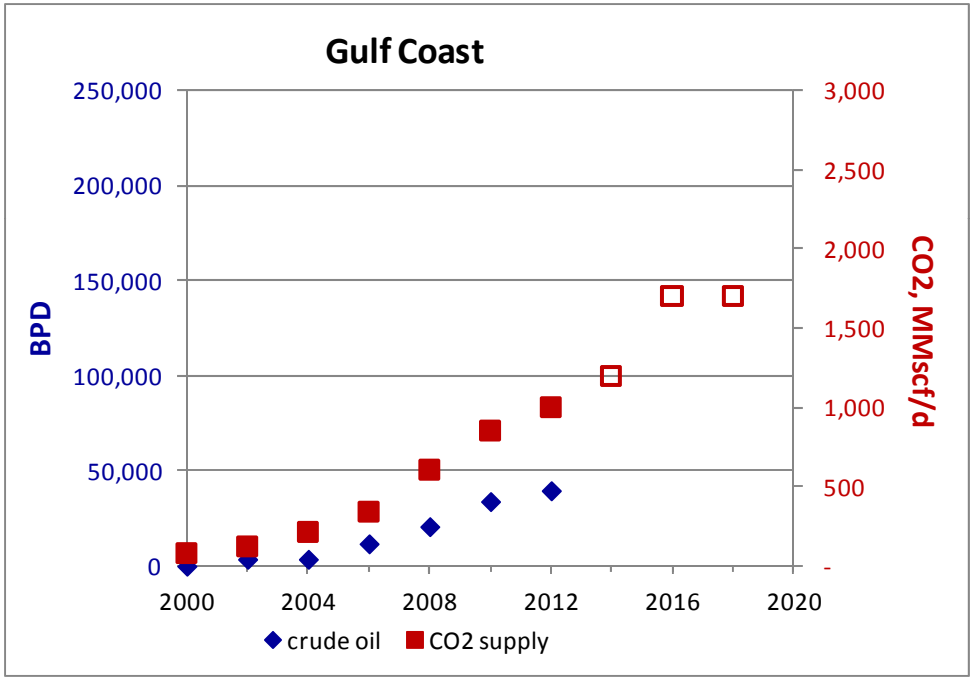
Data Source: Oil and Gas Journal Biennial EOR Survey

Regional CO_2 EOR Trends
Permian Basin



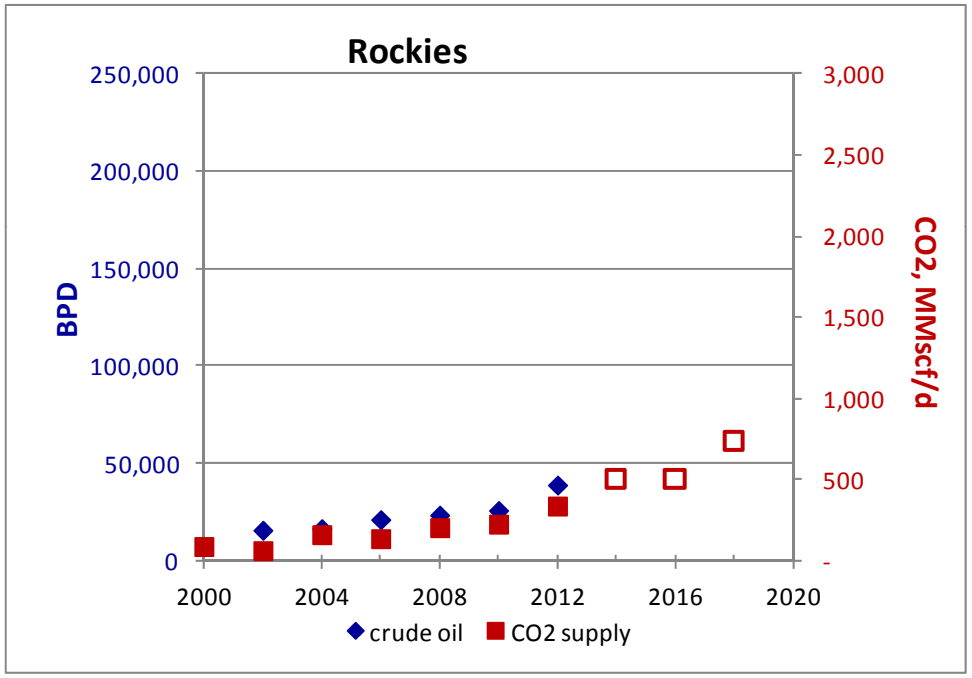
- **CO_2 supply has increased over the past five years but crude oil production is lagging**
- **New Sources of CO_2 Supply in the Permian System expected to come online 2012-2108**
  - McElmo (100)
  - Doe Canyon (100)
  - St. John's (450)
  - Century (160)
  - Summit (125)

Regional CO_2 EOR Trends
Mississippi / Gulf Coast



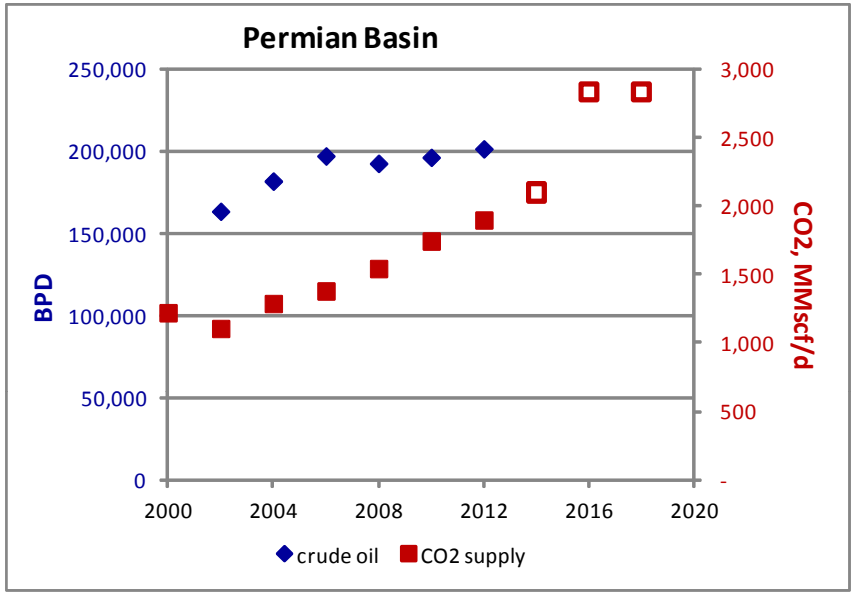
- **Floods in the MS/Gulf Coast region are 1) new and relatively immature and 2) characterized by high UR_{Net} flood designs (continuous injection vs WAG, immiscible floods)**
- **Growth in crude oil production has fallen off the pace of CO_2 supply (one project Denbury's flood in West Hastings may be having a significant impact)**
- **New Sources of CO_2 Supply in the Gulf Coast System expected to come online 2012-2108**
  - Jackson Dome (200)
  - Air Products H_2 (50)
  - Kemper Power (150)
  - NRG Power (75)
  - Leucadia Methanol (210)

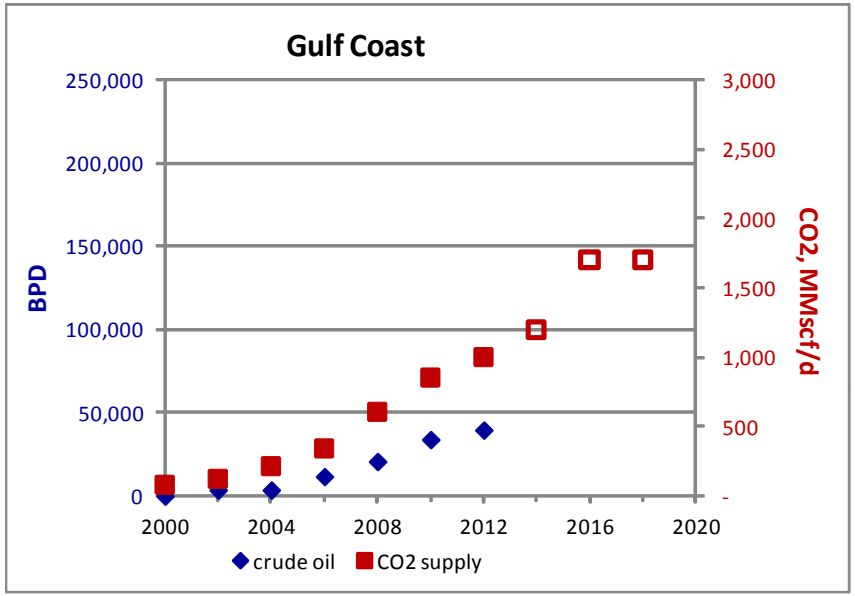
Regional CO_2 EOR Trends
Rockies

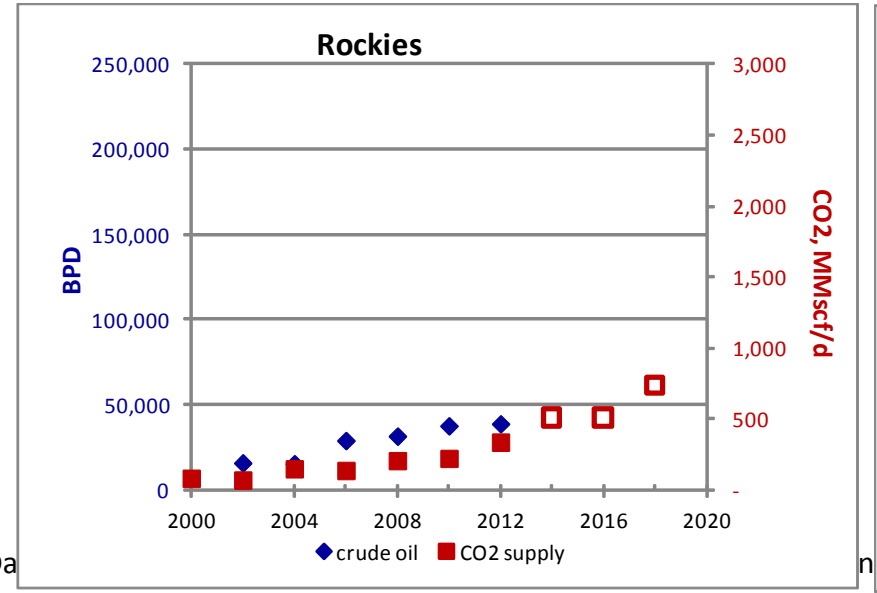


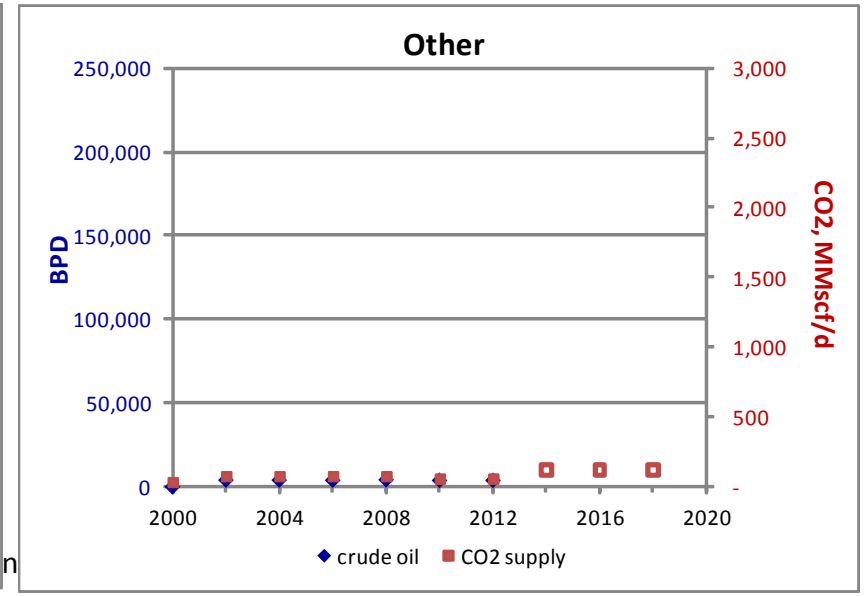
- **A reasonably mature system. New, and relatively immature, floods in the Rocky Mountain region have doubled the size of this system, consequently degrading the UR_{Net}**
- **New Sources of CO_2 Supply in the Rockies System expected to come online 2012-2108**
  - LaBarge (115)
  - Lost Cabin (50)
  - Riley Ridge (130)
  - DKRW (100)

Regional Trends in Crude Oil Production, CO_2 Use









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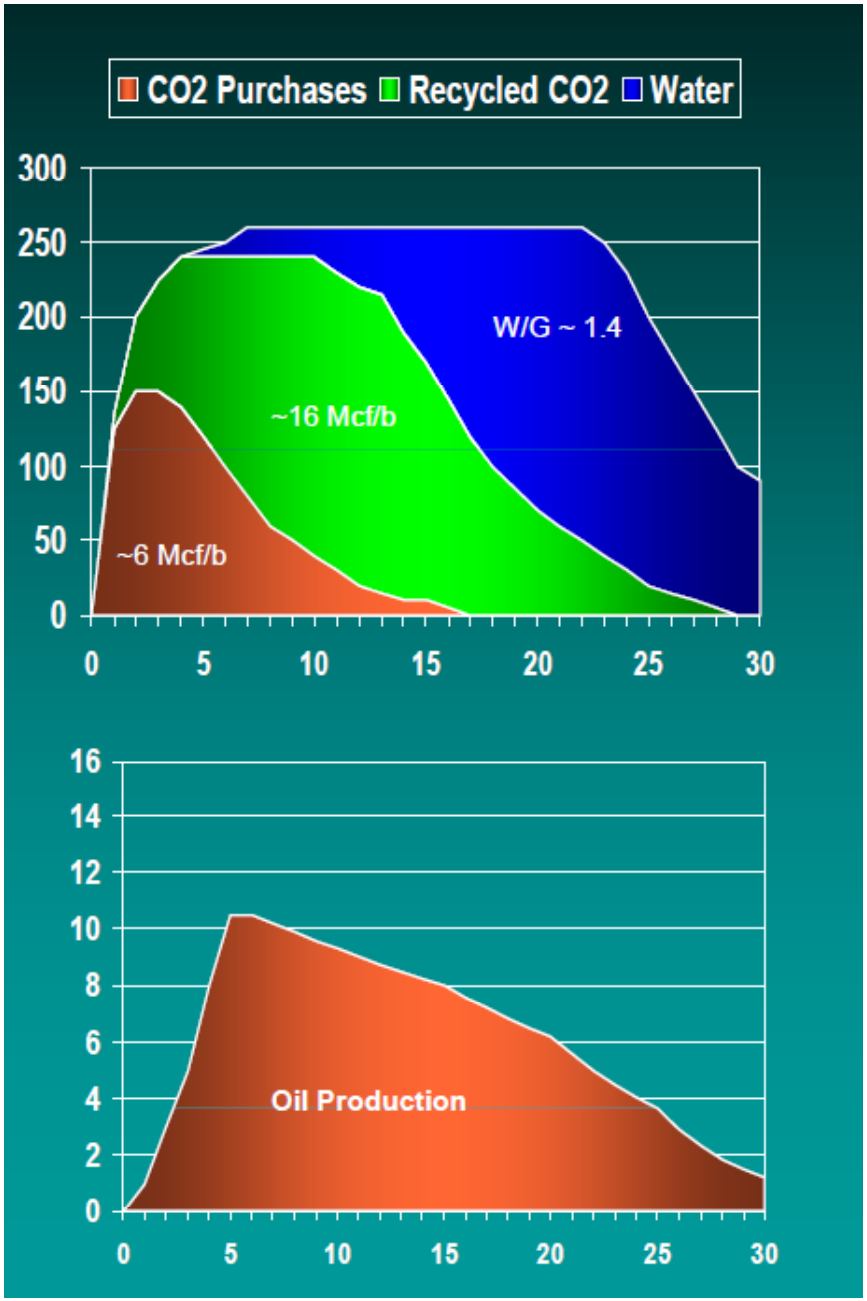
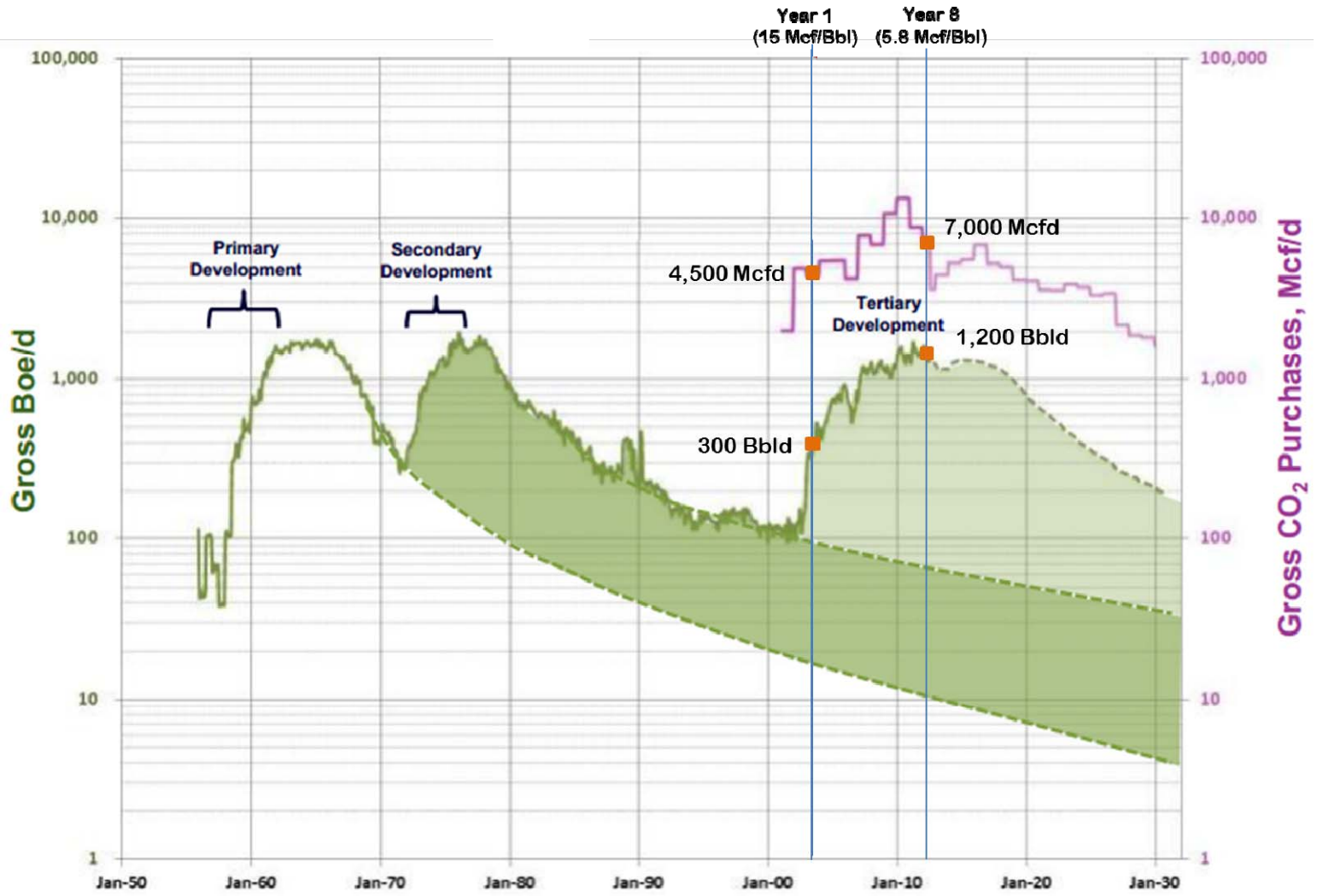


CO_2 EOR Profile

- **Information from Tim Bradley of Kinder Morgan shows the timing of CO_2 purchases and crude oil production from a "typical" CO_2 EOR flood**
  - Crude oil production occurs over a period of time 2-3 times longer than CO_2 purchase.
  - Over the life of the typical project shown the ratio of CO_2 purchased to crude oil produced is 6 Mscf/bbl
- **This ratio, CO_2 utilization rate, will vary depending on rock and crude oil characteristics and flood design and operational practices**

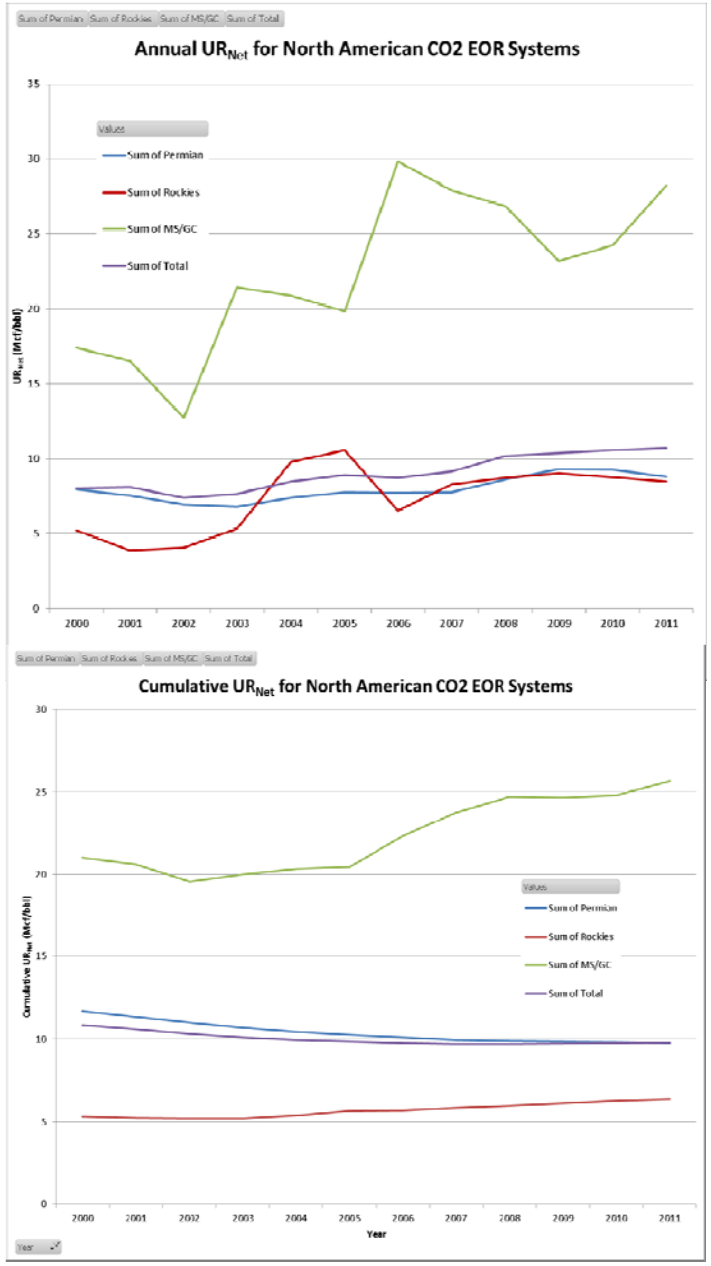
KinderMorgan 2012 Analysts Conference, http://kindermorgan.com/investor/presentations/presentations.cfm

CO_2 Utilization Rate over the Life of a Flood



* Tracy, Chaparral Energy, "CO2 Buyer's Perspective", Midland CO2 Conference 2012, Modifications to the figure made by Matt Wallace ARI

Regional CO_2 Utilization Rates



Source: Glenn Murrell, University of Wyoming

- In the Permian Basin, expansion of existing floods, and identification of new floods in Residual Oil Zones has degraded the average UR_{Net} in the region from 6 to 8.5 Mscf/bbl
- New, and relatively immature, floods in the Rocky Mountain region (Salt Creek, Monell, Beaver Creek) have doubled the size of this system. UR_{net} stable around 8 Mscf/bbl
- The Mississippi/Gulf Coast region UR_{net} is stable around 25 Mscf/bbl
- Cumulative Ur_{net} captures the life cycle of CO_2 utilization and shows more stable trends

Forecast Methodology, Crude Oil Production from CO_2 EOR

$$Prodn_{2018,R} = Prodn_{2012,R} * (CO_2S_{2018,R}/CO_2S_{2012,R}) * (UR_net_{2012,R}/UR_net_{2018,R})$$

Where:

$Prodn_{yr,R}$ – crude oil production from CO_2 EOR during year (yr) in region (R)

$CO_2S_{yr,R}$ – CO_2 supply during year (yr) in region (R)

$UR_net_{yr,R}$ – average CO_2 utilization rate during year (yr) in region (R), scf of CO_2 purchased per incremental barrel of crude oil production

Region	2012 Crude Oil Production, bpd	2012 CO2 Supply, MMscfd	2012 Utilization, scf/bbl	Increase in CO2 supply, 2012 to 2018	CO2 utilization rate in 2018, scf/bbl	Crude Oil Production in 2018, bpd
Permian	201,703	1,911	9,474	49%	8,500	334,824
Gulf Coast	39,650	1,000	25,221	69%	25,000	67,400
Rockies	27,000	230	8,519	220%	8,000	92,000
Other	3,825	58	15,163	172%	15,000	10,533
Total	**272,178**	**3,199**	**11,753**			**504,757**

Reversion to historic/expected CO_2 utilization rates gives a higher forecast for crude oil production

Region	2012 Crude Oil Production, bpd	2012 CO2 Supply, MMscfd	2012 Utilization, scf/bbl	Increase in CO2 supply, 2012 to 2018	CO2 utilization rate in 2018, scf/bbl	Crude Oil Production in 2018, bpd	Forecast CO2 utilization rate in 2018, scf/bbl	Forecast Crude Oil Production in 2018, bpd
Permian	201,703	1,911	9,474	49%	8,500	334,824	7,000	406,571
Gulf Coast	39,650	1,000	25,221	69%	25,000	67,400	20,000	84,250
Rockies	27,000	230	8,519	220%	8,000	92,000	7,000	105,143
Other	3,825	58	15,163	172%	15,000	10,533	15,000	10,533
Total	**272,178**	**3,199**	**11,753**			**504,757**		**606,498**

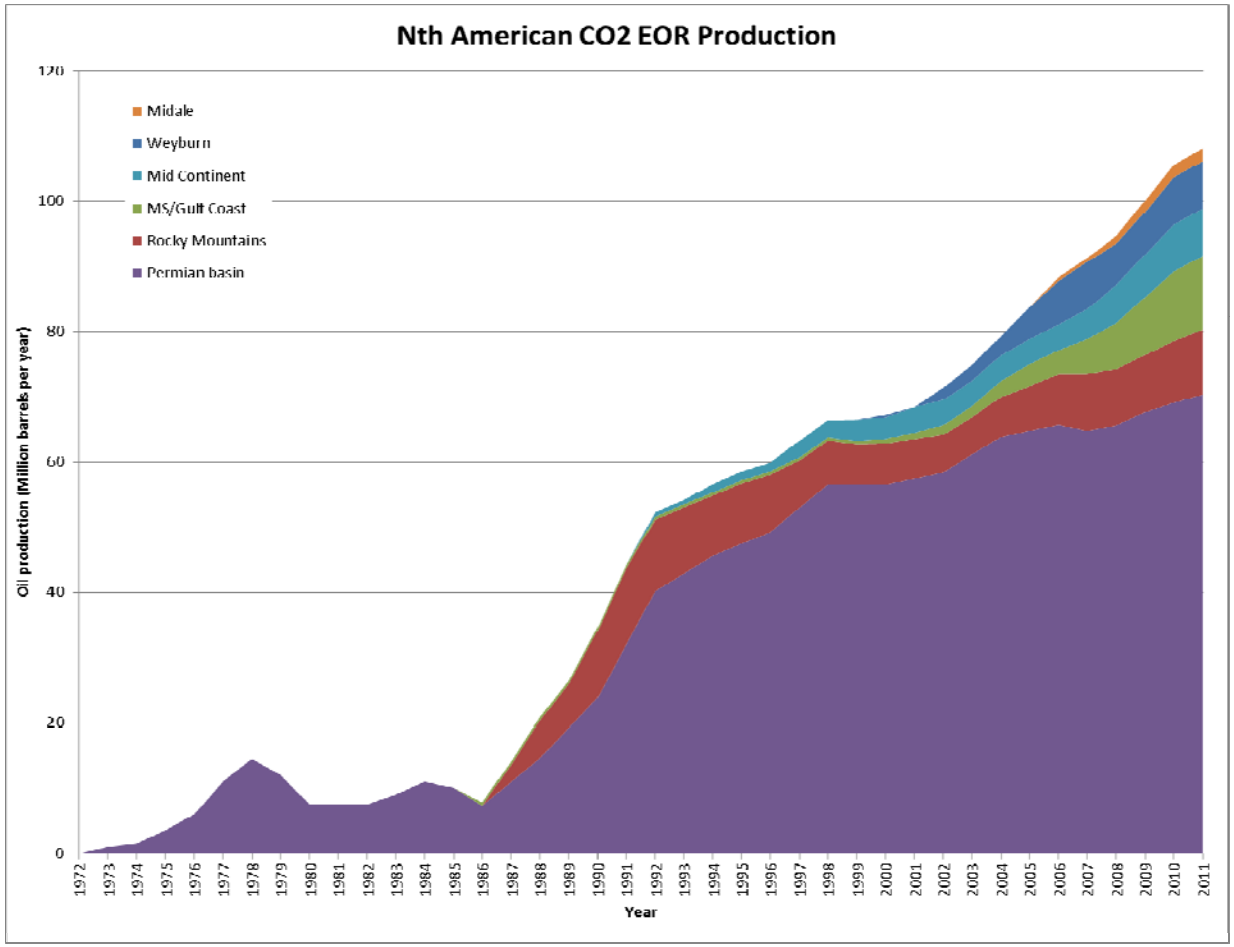
Application of this methodology is complicated by the fact that CO2 supply is growing and a preponderance of floods are in the early stages and will show poor UR_{Net} as the reservoirs 'fill-up' and the CO2 makes initial and progressive contact with the hydrocarbons. If the regional UR_{Net} approaches best practices values (7,000 scf/bbl for the Permian and Rockies and 20,000 scf/bbl for MS/GC, then 5.4 BCFd of CO2 supply indicates 600,000 bpd of crude oil production

The Forecast for Crude Oil Production from CO_2 EOR in the United States based on CO_2 Supply is Higher than the Forecast in the 2013 Annual Energy Outlook

Crude Oil Production from CO2 EOR Production		
	Annual Energy Outlook 2013 er*	NETL/EORI/ARI
2011	281	280
2012	237	272
2014	225	
2016	229	
2018	255	505
* U.S. DOE Energy Information Administration		

The forecast in the AEO is likely a model start-up anomaly where new projects take several years to deploy while a decline rate is applied to the current base of projects. We are suggesting to EIA that they hardwire CO_2 EOR production through 2018 based on the regional CO_2 supply forecast.

Crude oil production from CO_2 EOR has not declined since 1986, and there were some low crude oil price and stable CO2 supply years during that stretch



Source: Glenn Murrell, University of Wyoming

Further Analysis that Could be Done

- **This is a vanguard analysis. In order to do the job right, one would build a bottoms-up forecast form field-level CO_2 use and crude oil production profiles.**
  - Mr. Murrell has completed a bottoms up analysis for the Rocky Mountain region and this slide deck of that data
  - NETL is contemplating an effort to expand the field-level profiles to the other EOR regions
- **In the mean time the correlation-based approach could be refine**
  - Check the data on CO_2 supply and crude oil production (23% of the crude oil production in the 2012 OGJ survey was from existing floods that had the exact same reported production in 2010 and 2012). Some of the production numbers have been unchanged for ten years.
  - Estimate an uncertainty range for the regional CO_2 supply rates and CO_2 utilization rates – develop mini-monte-carlo to show a range of estimates for crude oil production in 2018

Thank You!

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Current CO_2 Supply for CO_2 -EOR

Current CO2 Supply for EOR (MMcfd)			
Region	Operation	Type	2012 Supply (MMcfd)
Permian Basin	McElmo Dome	N	1,150
	Bravo Dome	N	400
	Sheep Mountain	N	50
	Doe Canyon	N	110
	Century	GP	100
	TGRMP	GP	75
	Agrium, Inc.	HC	26
	Permian Basin Total		1,911
Gulf Coast	Jackson Dome	N	1,000
Rockies	LaBarge	GP	340
Mid Continent	Antrim	GP	11
	Koch	HC	35
	Conestoga	HC	4
	Mid Continent Total		50
	Total US CO2 Supply (MMcfd)		3,300

N = Natural Source

GP = Gas Processing Plant

HC = Hydrocarbon Conversion Facility

2012 CO2 Supply		
Source	(MMcfd)	% of Total
Natural Sources	2,710	82%
Gas Processing Plants	526	16%
Hydrocarbon Conversion	65	2%
Total	3,301	100%

Tables developed by Matt Wallace at ARI

Incremental CO_2 Supply, 2012 - 2018

Incremental CO2 Supply for EOR (MMcfd)				
Region	Operation	Type	Date	Incremental CO2 (MMcfd)
Permian Basin	McElmo Dome	N	2014	100
	Doe Canyon	N	2014	100
	St. John's	N	2016	450
	Century	GP	2015	160
	Summit	HC	2016	125
	Permian Basin Total			935
Gulf Coast	Jackson Dome	N	2016	200
	Air Products/Hydrogen	HC	2013	50
	Miss Power/Kemper	HC	2014	150
	NRG	HC	2015	75
	Leucadia	HC	2016	210
	Gulf Coast Total			685
Rockies	LaBarge	GP	2013	115
	Lost Cabin	GP	2013	50
	Riley Ridge	GP	2017	130
	DKRW	HC	2017	100
	Rockies Total			395
Mid Continent	Bonanza	HC	2013	8
	CVR/Coffeyville	HC	2013	50
	Mid Continent Total			58
CA	HECA	HC	2018	100
	Total US CO2 Supply (MMcfd)			2,173

N = Natural Source

GP = Gas Processing Plant

HC = Hydrocarbon Conversion Facility

2012 CO2 Supply		
Source	(MMcfd)	% of Total
Natural Sources	850	39%
Gas Processing Plants	455	21%
Hydrocarbon Conversion	868	40%
Total	2,173	100%

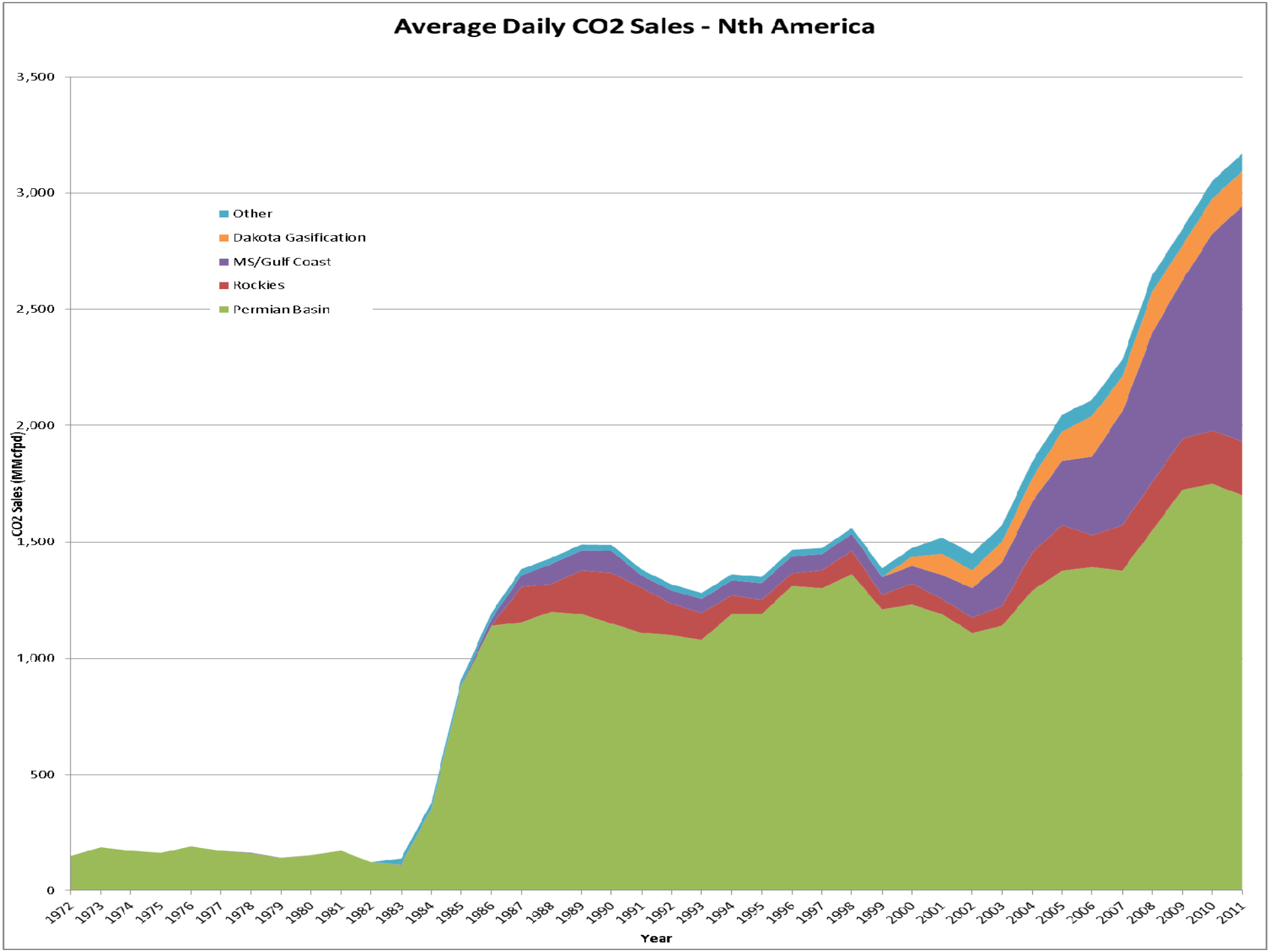
Tables developed by Matt Wallace at ARI

CO_2 Supply Projection

Much of the incremental CO_2 supply is on-stream by 2016 (1,843 MMcfd) due to availability of CO_2 from St. John's Dome (450 MMcfd), expansion of Jackson Dome (200 MMcfd), the completion of the Leucadia methanol plant (210 MMcfd), and the expansion of the Century gas plant (160 MMcfd) among others.

By 2018 about 50% of total CO_2 supply will be for the Permian Basin, 30% will be for the Gulf Coast, and 13% for the Rockies.

Total Annual CO2 Supply for EOR (MMcfd)							
	2012	2013	2014	2015	2016	2017	2018
Permian Basin	1,911	1,911	2,111	2,271	2,846	2,846	2,846
Gulf Coast	1,000	1,050	1,200	1,275	1,685	1,685	1,685
Rockies	340	505	505	505	505	735	735
Mid Continent	50	108	108	108	108	108	108
California	-	-	-	-	-	-	100
Total	3,301	3,574	3,924	4,159	5,144	5,374	5,474


Average Daily CO2 Sales - Nth America
3,500
3,000
2,500
2,000
1,500
1,000
500
0
CO2 Sales (MMcfpd)
Other
Dakota Gasification
MS/Gulf Coast
Rockies
Permian Basin
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
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1987
1988
1989
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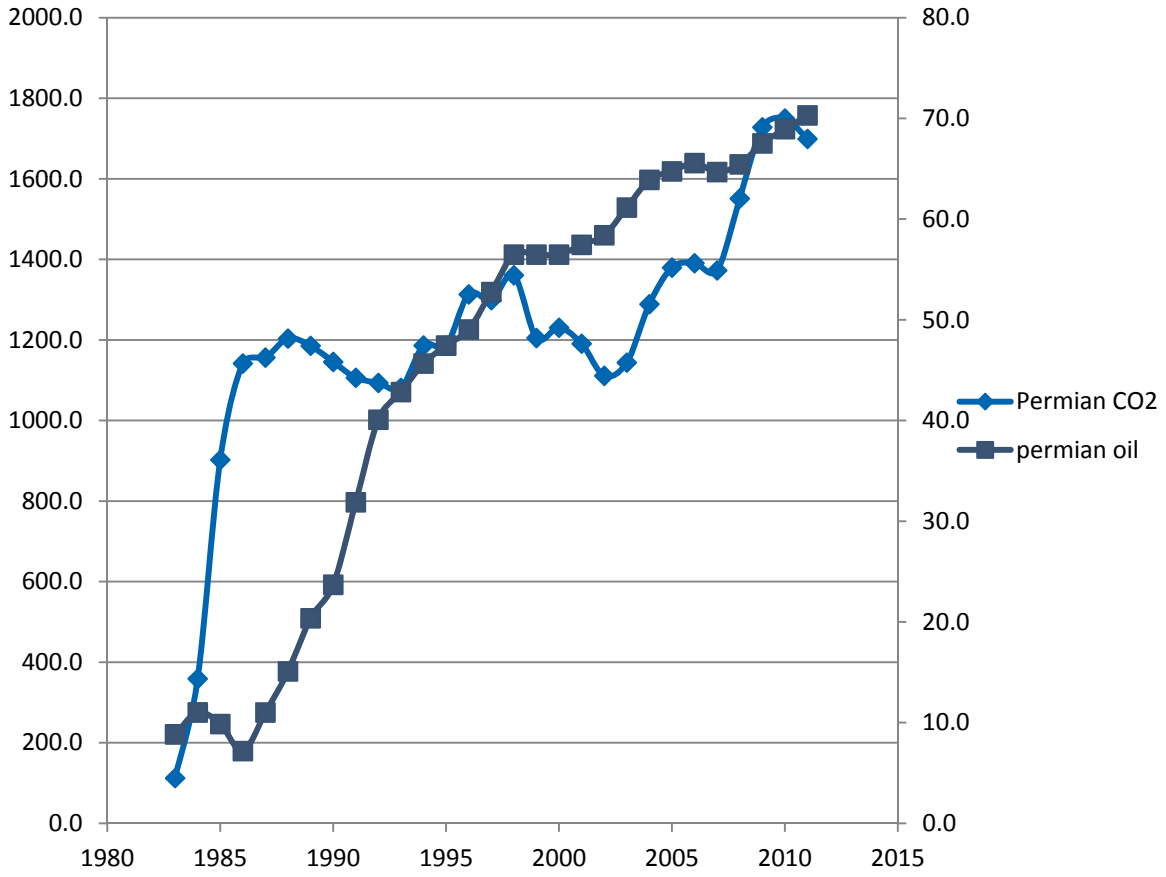
CO_2 and Crude Oil Trends in the Permian Show a Lag Between Increase in CO_2 and Crude Oil Production