

Sixth Annual Conference on Carbon Capture and Sequestration

Coupling Enhanced Oil Recovery with the Demand for CCS – A Viable Interim Solution for Power Generating Facilities

EOR – A Well Grounded System for Deep Geological Sequestration of CO₂

**Pete Hagist
Vice President Operations – Permian
Whiting Oil and Gas Corporation**

**Wednesday, May 9, 2007
Pittsburgh, Pennsylvania**

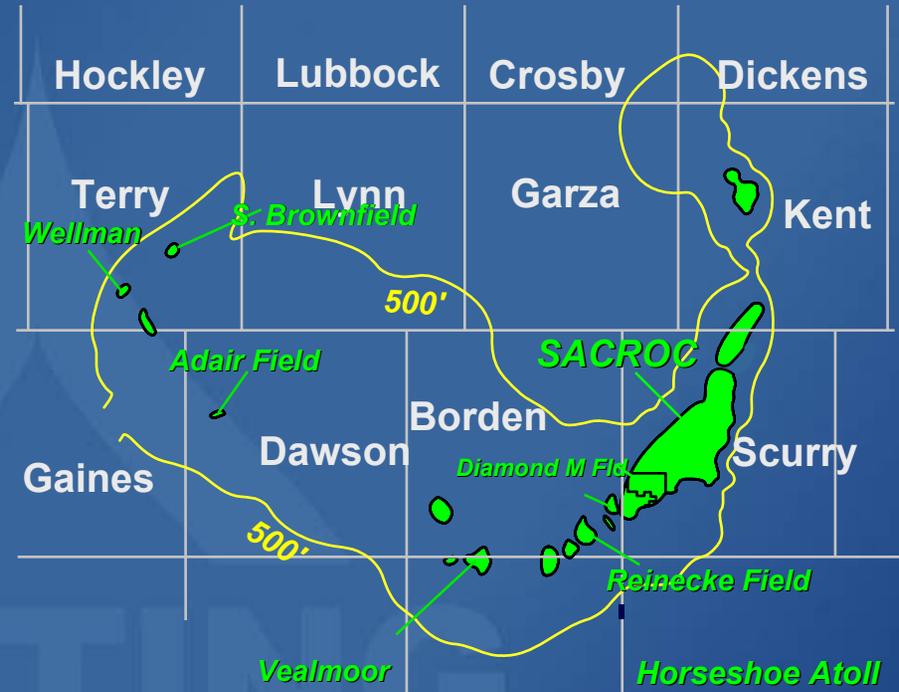
- ◆ The EOR Industry has been capturing, transporting, injecting and managing CO₂ for over 35 years
- ◆ 38 million tonnes of CO₂ are injected each year
- ◆ 80+ projects worldwide
- ◆ 230,000+ bbls of oil are produced each day
- ◆ Extensive regulatory experience

EOR is A Well Grounded System for Deep Geological Sequestration of CO₂

SACROC Unit



- ◆ First CO₂ injection in 1972
- ◆ 68 million tonnes CO₂ injected
- ◆ Current Injection: 5 MMtpy
- ◆ Current Production: 30,000 bopd
- ◆ 3,000+ wellbore penetrations



Notes:

Initial CO₂ (35 MMt) came from high CO₂ content natural gas production in Val Verde Basin. Prior to SACROC, CO₂ was being vented to Atmosphere.

Weyburn: 9 million tonnes to-date

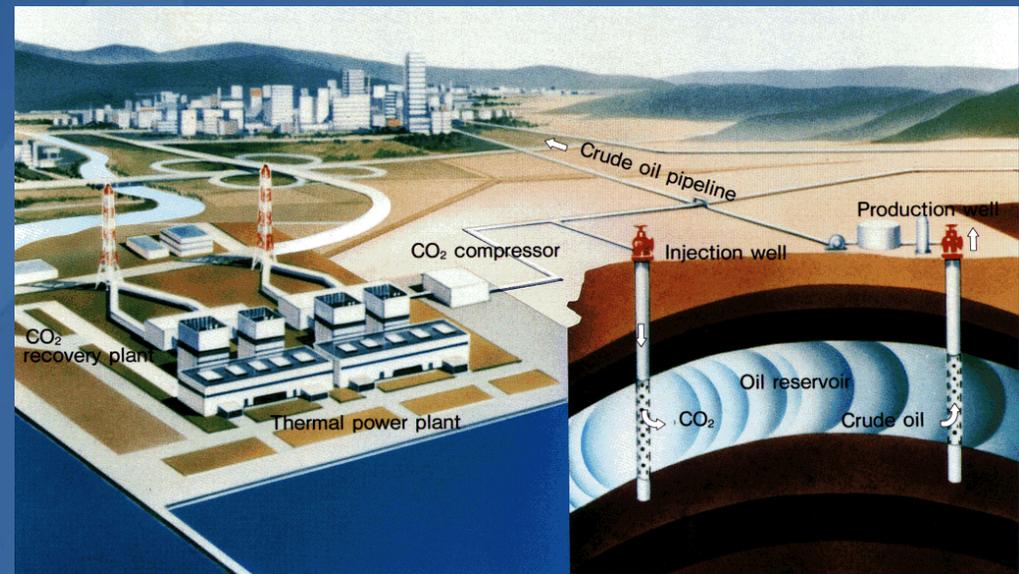
Sleipner: 7 million tonnes to-date



Enhanced Oil Recovery with CO₂

Five primary Components

- ◆ CO₂ Source
 - ◆ Natural
 - ◆ Anthropogenic
- ◆ Transportation
- ◆ Injection
- ◆ Management
- ◆ Production



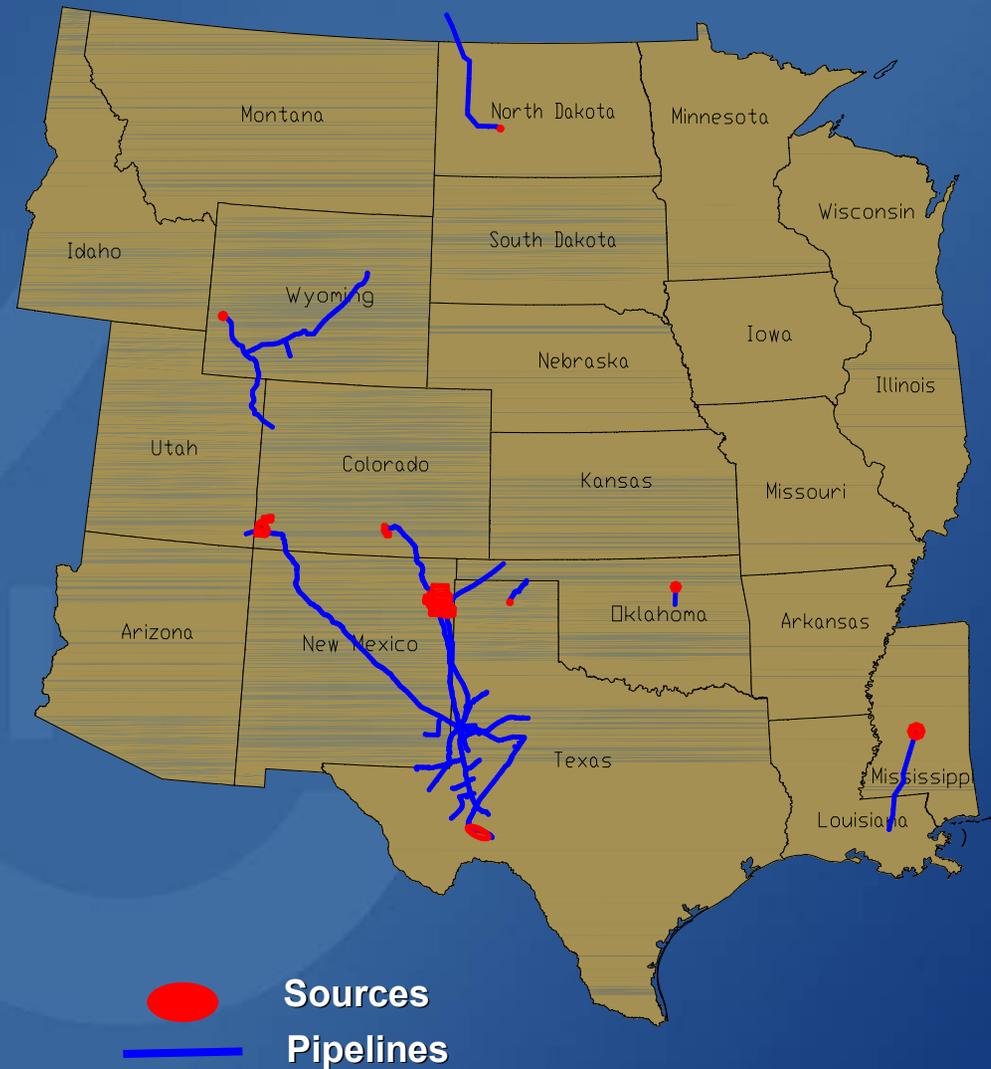
From Mitsubishi Heavy Industries

All Components have direct applicability to CO₂ Sequestration

Transportation – U.S. Network



- ◆ 4,000+ miles
- ◆ Nine States
- ◆ Extensive Regulations
 - ◆ State
 - ◆ Federal - DOT
 - ◆ CFR 49, Part 195
 - ◆ “Transportation of hazardous liquids by pipeline”
- ◆ High reliability – 99%+



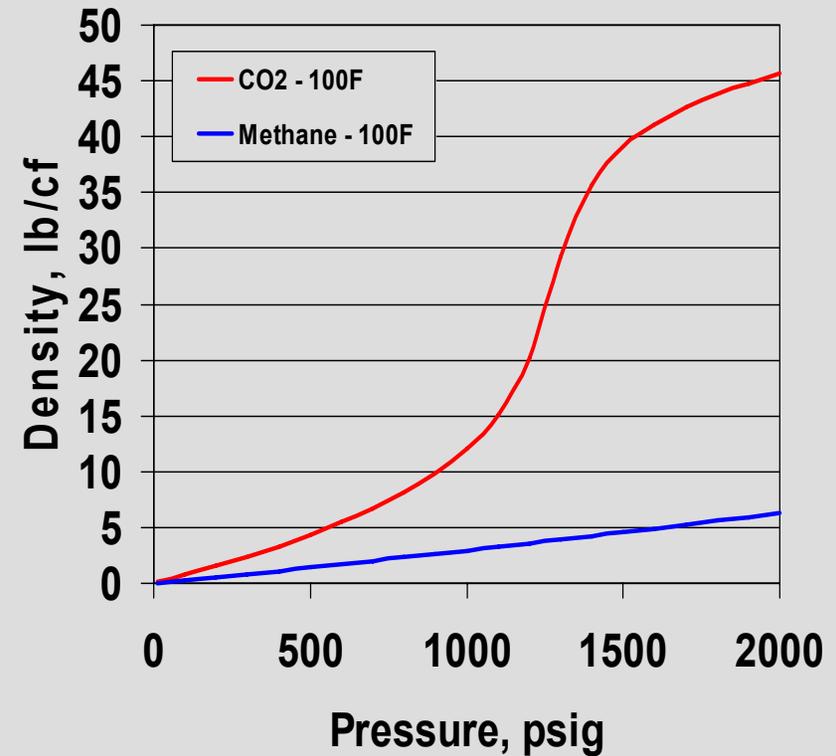
Transportation – CO₂ is Unique



- Efficient to transportation
- Non-Combustible
- Non-Corrosive
- Liquid above 1,200 psig
- Low Viscosity



Kinder Morgan CO₂ Pump at SACROC



CO₂ Injection Facilities



- ◆ **Specialized Designs**
 - ◆ Optimized for CO₂
 - ◆ Rotation Speed
 - ◆ Valves
 - ◆ Lube Oils
- ◆ **Highly Instrumented**
- ◆ **Real Time Monitoring**
- ◆ **Modular**
- ◆ **Rapid deployment**
- ◆ **High Reliability – 95%+**



WOG Dry Trail Plant CO₂ Injection Compressor

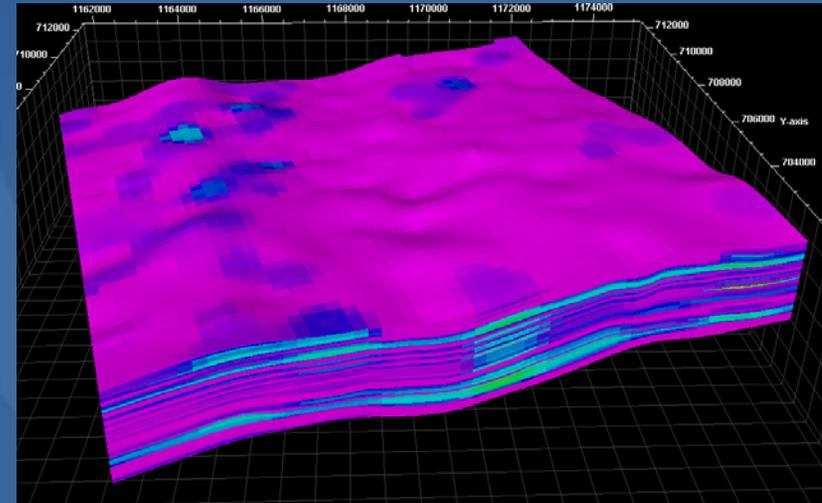


Injection Control Skid at Whiting North Ward Estes Field

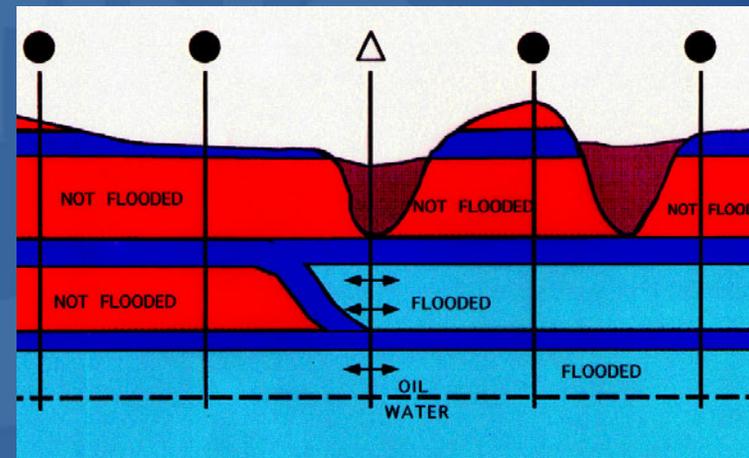
New Techniques

- ◆ **Advanced Interpretation methods**
 - ◆ Stratigraphy
 - ◆ 3D Seismic
 - ◆ Downhole logging
- ◆ **Visualization tools**
 - ◆ Workstations
 - ◆ Software
- ◆ **Wellbore Control**

New Understanding



3D Reservoir Model of Porosity



Compartmentalized Reservoir ...

Management – Monitoring Gas Movement

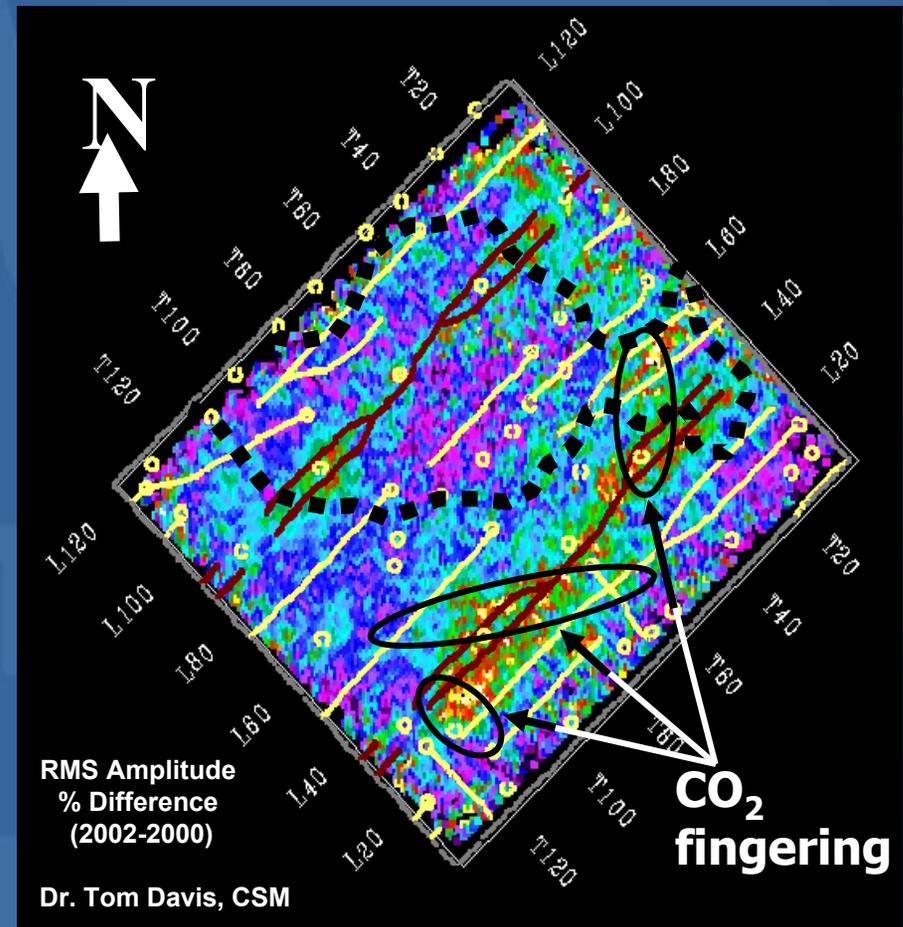


Weyburn Time-Lapse (2002-2000)

Many Methods

- ◆ Observation wells
- ◆ Downhole logging
- ◆ 4D Surface Seismic
- ◆ 3D Cross-Wellbore Seismic

Technology Continues to Evolve



Whiting North Ward Estes CO₂ Project

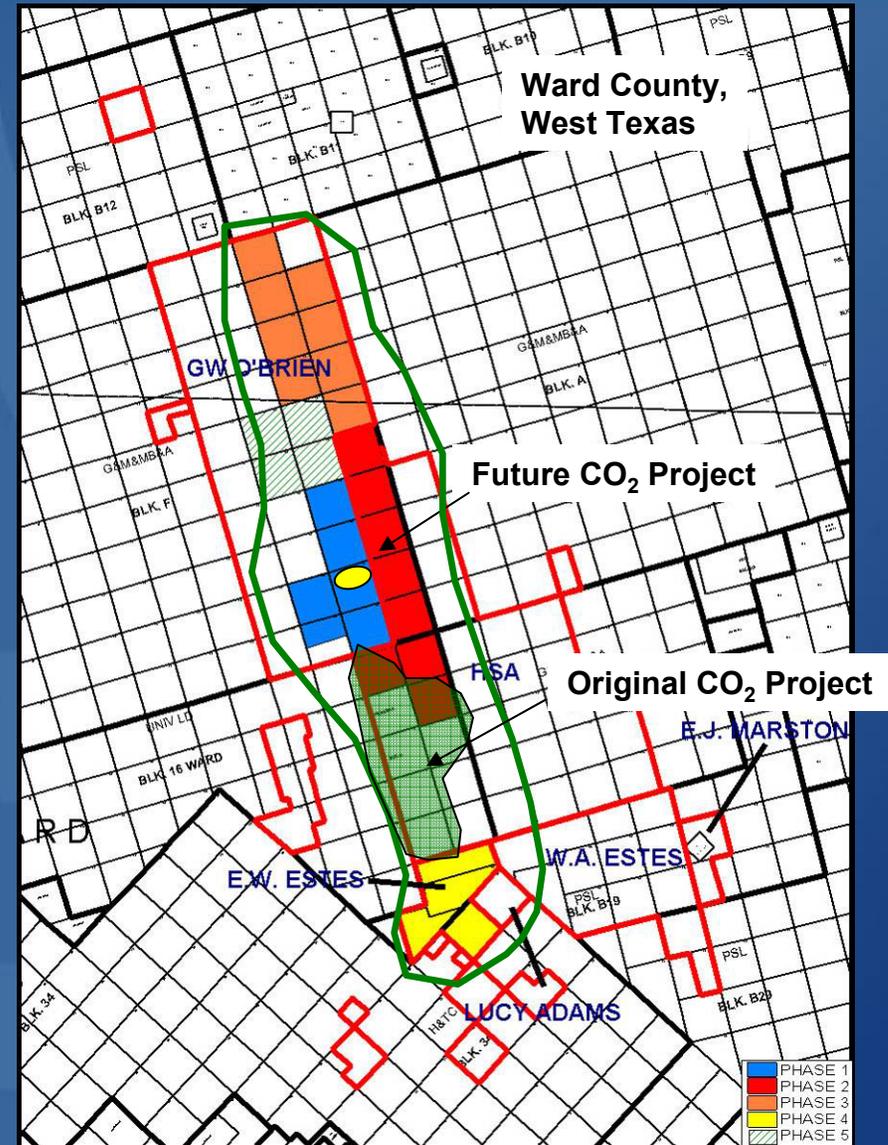


Original CO₂ Project

- ◆ March 1989 to June 2003
- ◆ Injection: 2.7 million tonnes
- ◆ 400 wellbores
- ◆ Performance studies ongoing

Future CO₂ Flood

- ◆ Startup May 2007
- ◆ 26 sections planned
- ◆ 645 mmbo OOIP target
- ◆ Injection: 14 million tonnes
- ◆ 4D Seismic monitoring
- ◆ Observation Wells



Production - CO₂ Recovery



New plants are more efficient

WOG Dry Trail Plant

- ◆ Original plant 40 mmscfpd
- ◆ Expanding to 80 mmscfpd with second parallel plant
- ◆ Membrane Technology
- ◆ Smaller footprint
- ◆ Lower Capital
- ◆ Reduced installation time
- ◆ Improved energy efficiency
- ◆ Reliability: 95%+



Plant I – Ryan-Holmes



Plant II – Membranes

New Generation of CO₂ Separation



Design evolution



- 5" x 41"
- 1979



- 12" x 41"
- 1992



- 12" x 41"
- 1998

Relative Diameter	1	2.40	5.5
Gas Capacity	1	5	17.5
Relative Footprint	1	0.39	0.24
Relative Skid weight	1	0.41	0.18

Courtesy NATCO Company 11

- *Recover Stranded Oil*
- *Way Forward For Power Generation*

WHITING

World Oil Demand



73 million barrels of Crude Oil per day

	Population (Millions)	Oil* Consumption (Millions / Day)	Consumption Rate (bbls / Capita)
U.S.	293	20.7	25.8
China	1,299	6.4	1.8
India	1,075	2.5	.8

Demand for oil will continue to increase

World Oil Supply



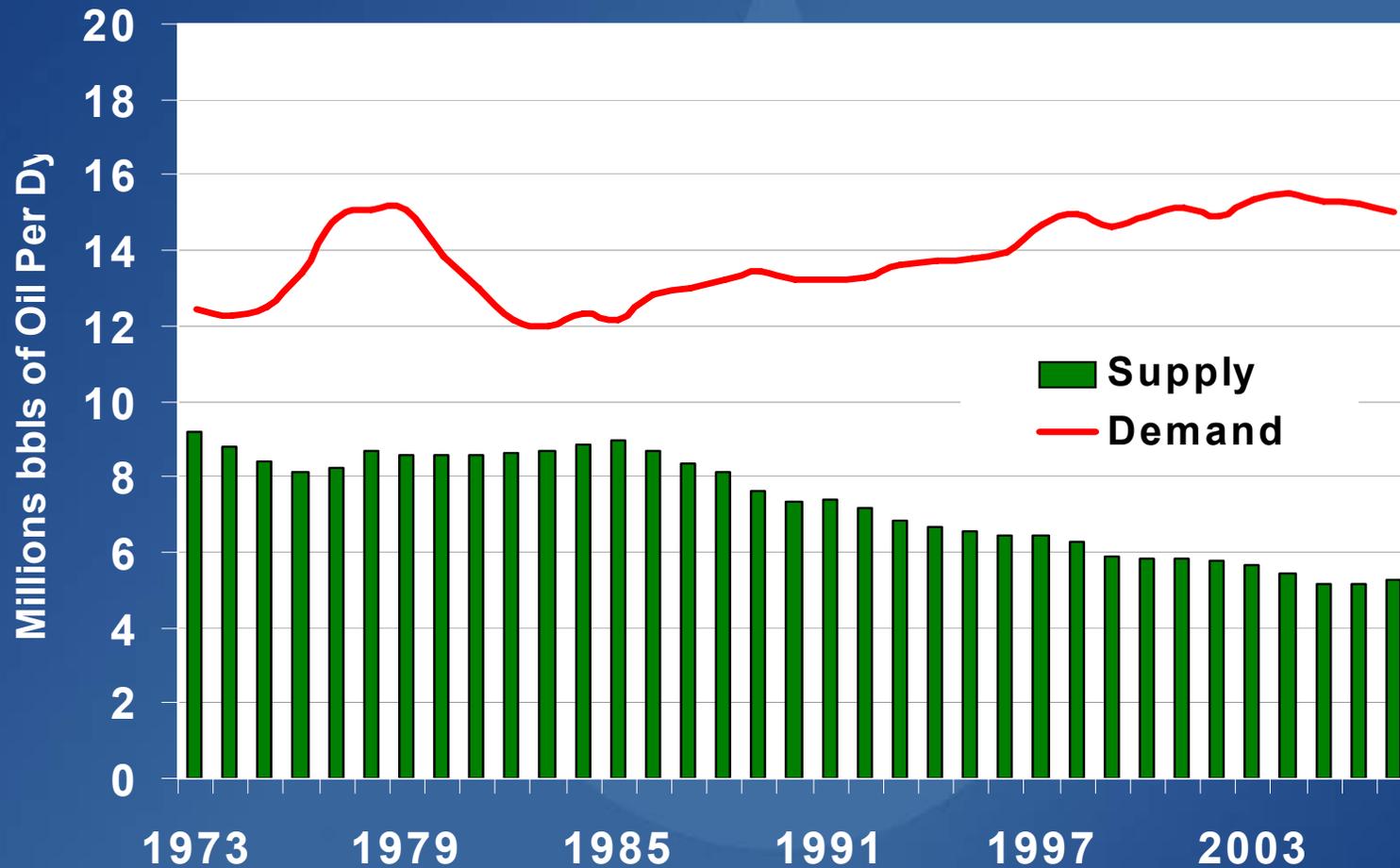
Struggling to move above 73 million bbls per day



U.S. Oil Supply and Demand



U.S. Purchases 600 million \$ of crude oil per day

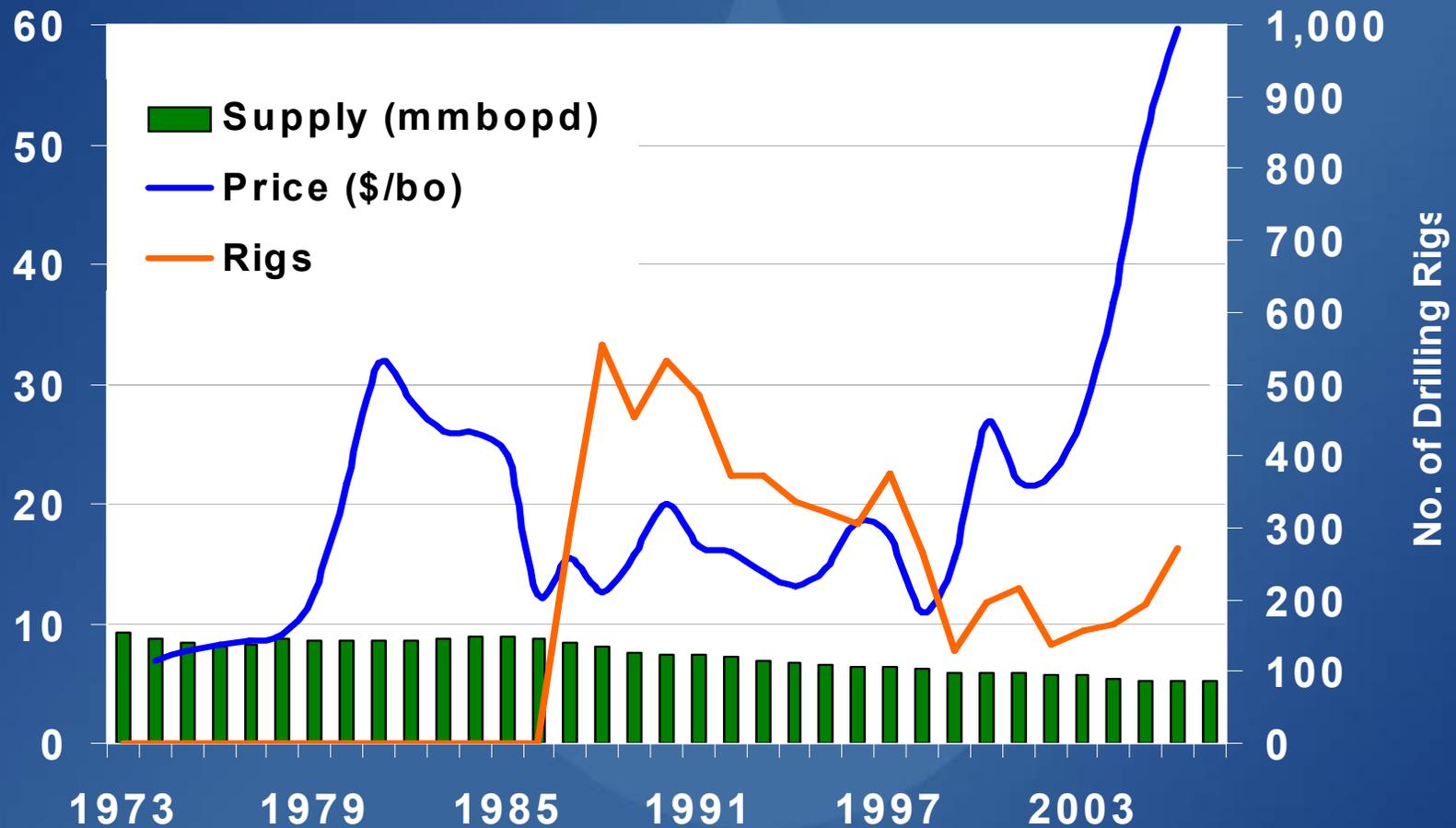


Source: EIA, U.S. Crude Oil Production and Consumption

U.S. Oil Drilling Results



Impact of drilling has been minimal

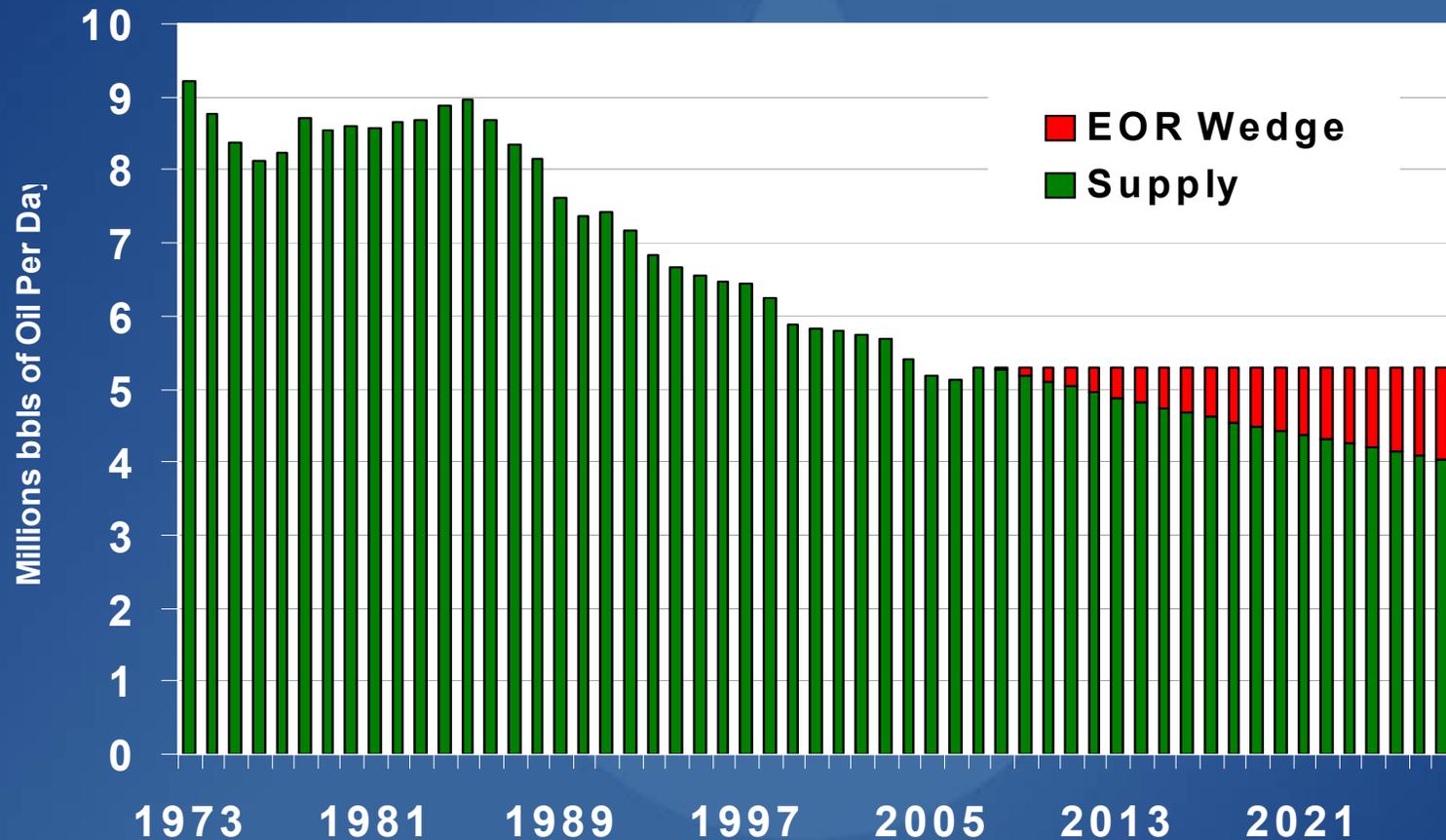


Source: EIA

Recovering Stranded Oil

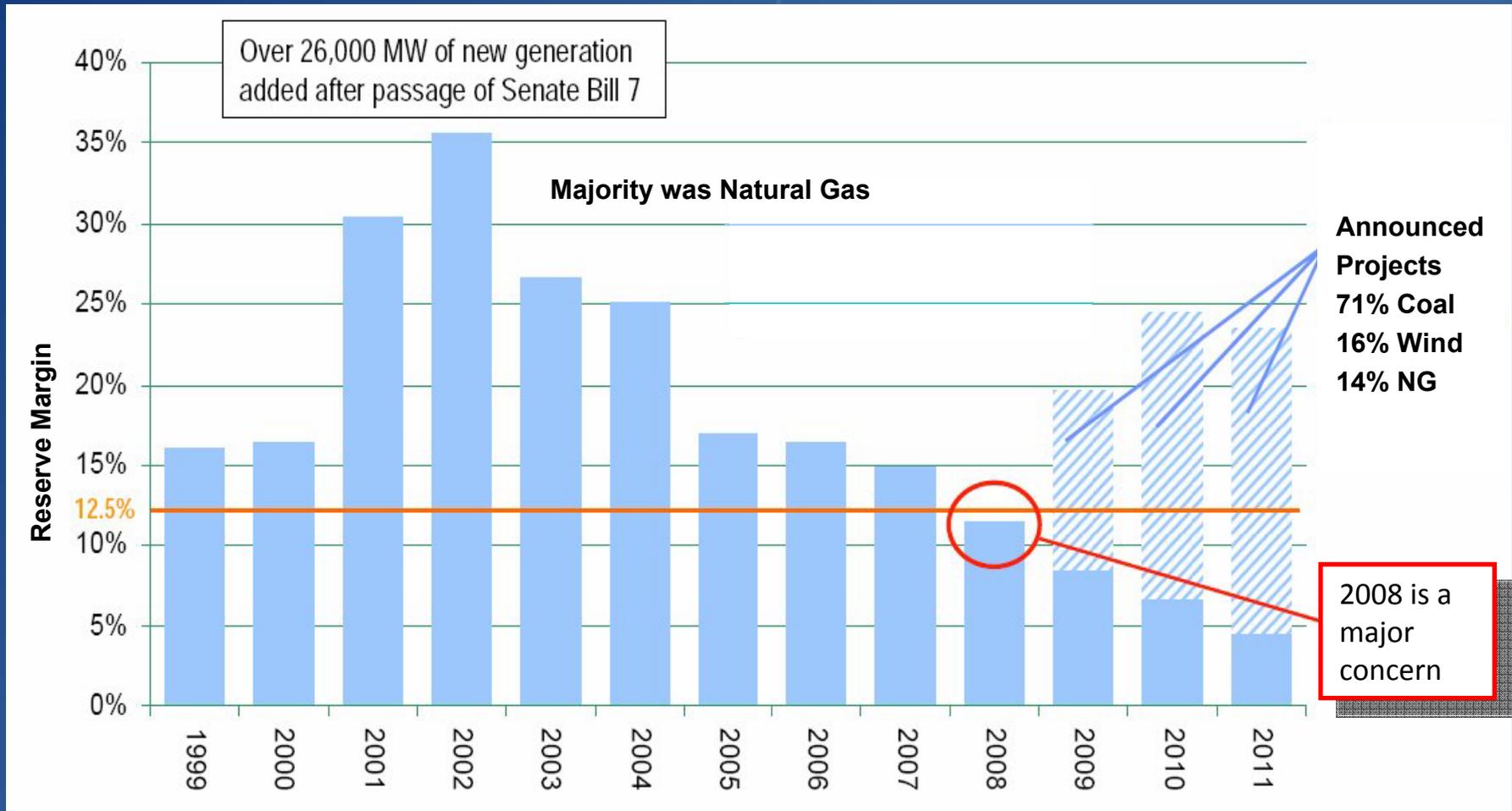


Impact of EOR could be significant. Arresting decline would add 25 billions barrels of Oil



Source: EIA

Texas Power Situation – ERCOT Reserve Margins

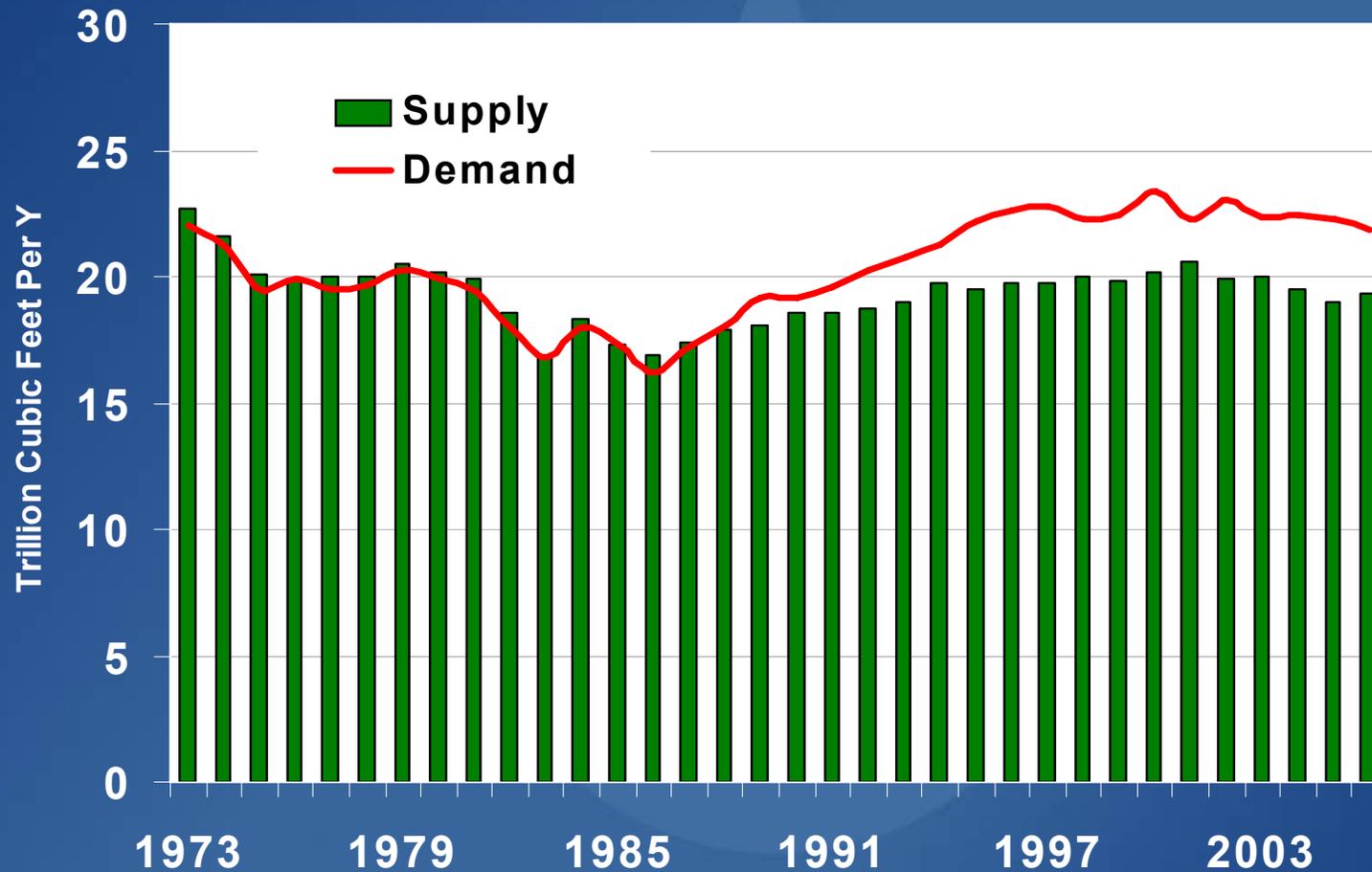


Source: EIA

U.S. Gas Supply and Demand



Ongoing Imbalance

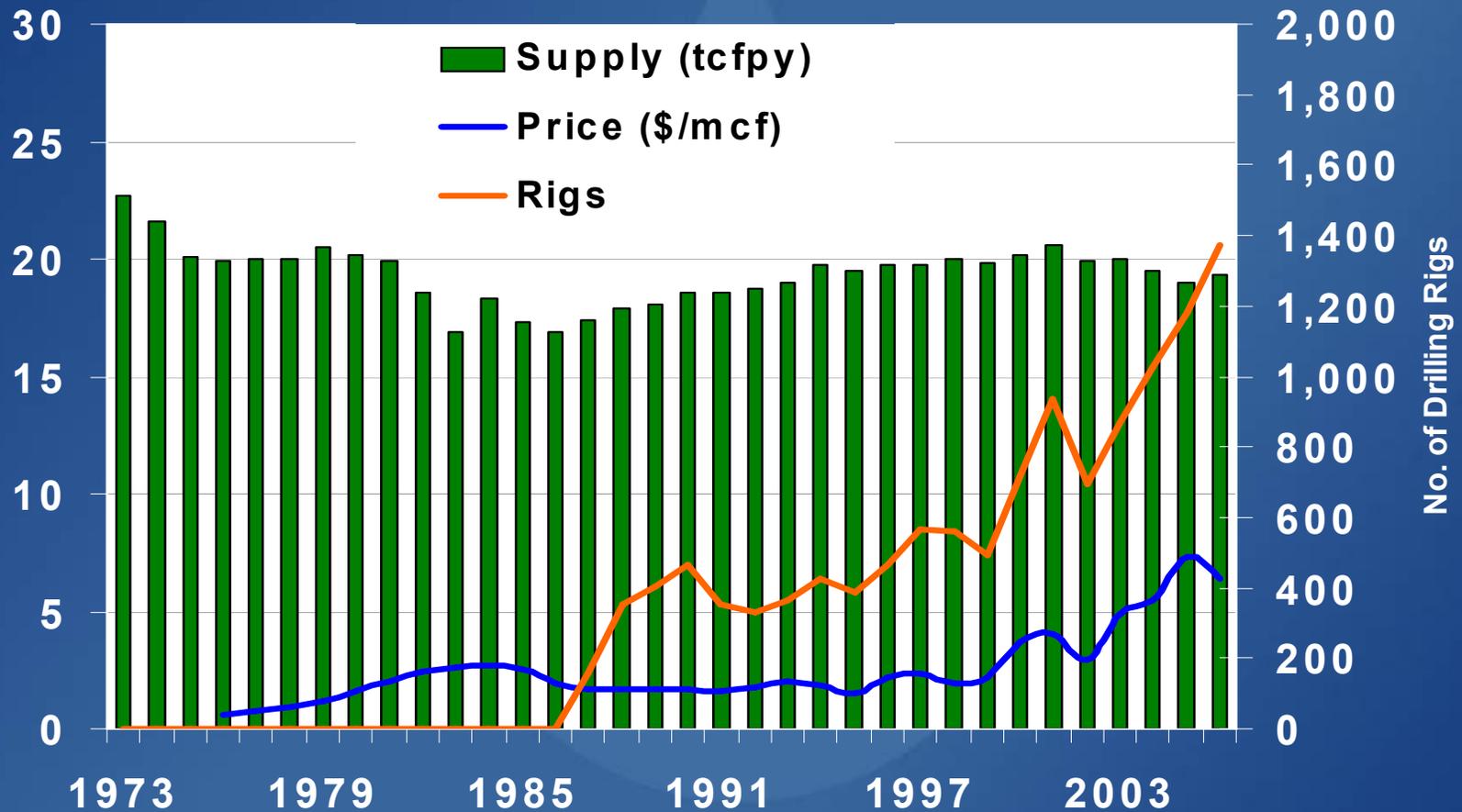


Source: EIA

U.S. Gas Drilling Results



Impact of drilling has been minimal

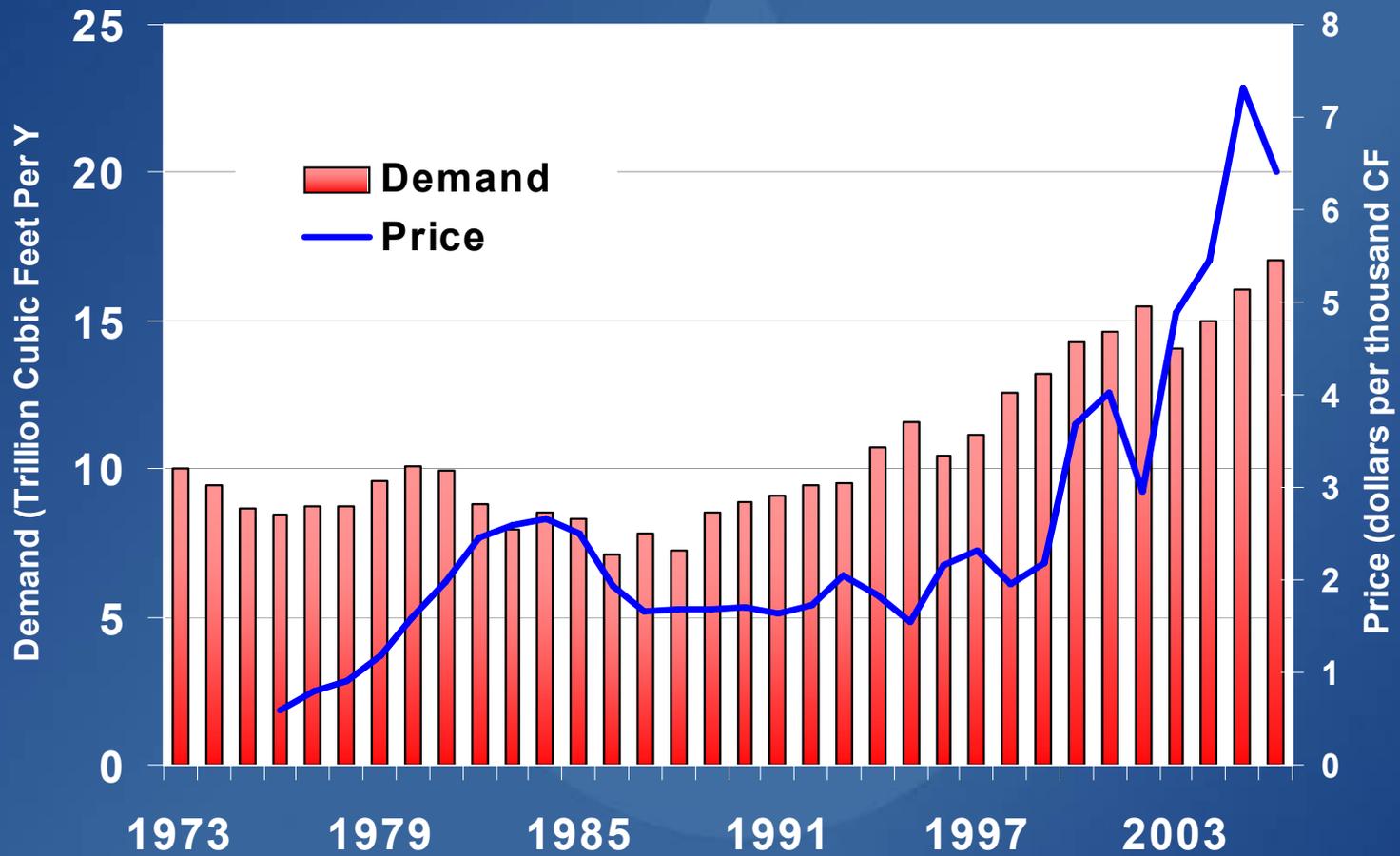


Source: EIA

U.S. Gas Demand - Power Generation



Gas is now an expensive fuel for power generation



Source: EIA

Comparison of Generating Options



Plant	Scrubbed Coal \$/mwh	IGCC With CCS \$/mwh	Gas Combined Cycle \$/mwh
Capital	18.43	29.59	8.77
O&M	7.28	9.07	3.28
Fuel	13.81	15.16	50.14
Total	39.51	53.82	62.19
CO2 Value			
Commodity		(10.56)	
Emission Credit		(3.70)	
Net Cost		39.55	

Assumptions: Coal \$31.22/ston, CO₂ \$.60/mcf, EC \$4.00/tonne , NG \$7.00/mmbtu

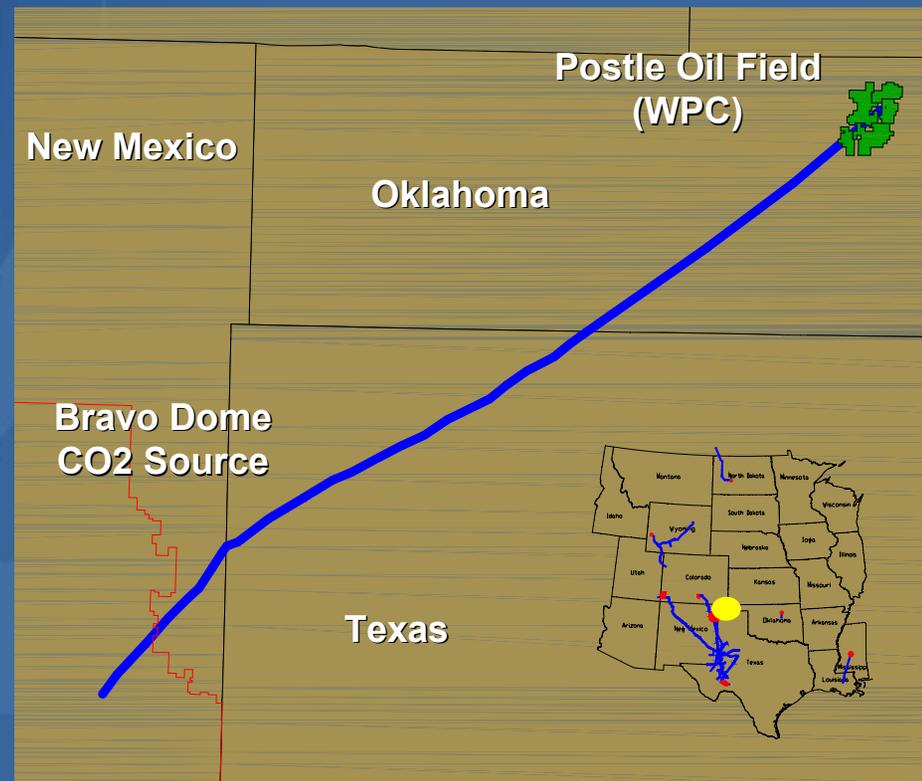
- **EOR Experience**
 - **CO₂ Transportation**
 - **CO₂ Injection**
 - **CO₂ Management**
 - **Regulations**
 - **CO₂ Capture**
- **EOR Benefits**
 - **Recover stranded oil**
 - **Lowers cost of power generation**
- **Close the economic gap – Cap and Trade, tax credits (wind), etc.**

Back Up

WHITING

Whiting Transpetco Pipeline

- ◆ 12 “ diameter
- ◆ 121 miles long
- ◆ Built in 1994
- ◆ No major incidents
- ◆ 99% + up-time



No technological barriers. Right-a-way is the challenge

The CO₂ Flood Process



Injected CO₂ does remain in the reservoir

