MAXIMIZING OIL RECOVERY EFFICIENCY AND SEQUESTRATION OF CO_2 WITH "GAME CHANGER" CO_2-EOR TECHNOLOGY

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BACKGROUND

1. Status and Outlook for CO_2-EOR
2. "Game Changer" CO_2-EOR Technology
   - Increasing Oil Recovery Efficiency
   - Expanding CO_2 Storage Capacity
3. "Early Application" of CO_2-EOR
4. Summary

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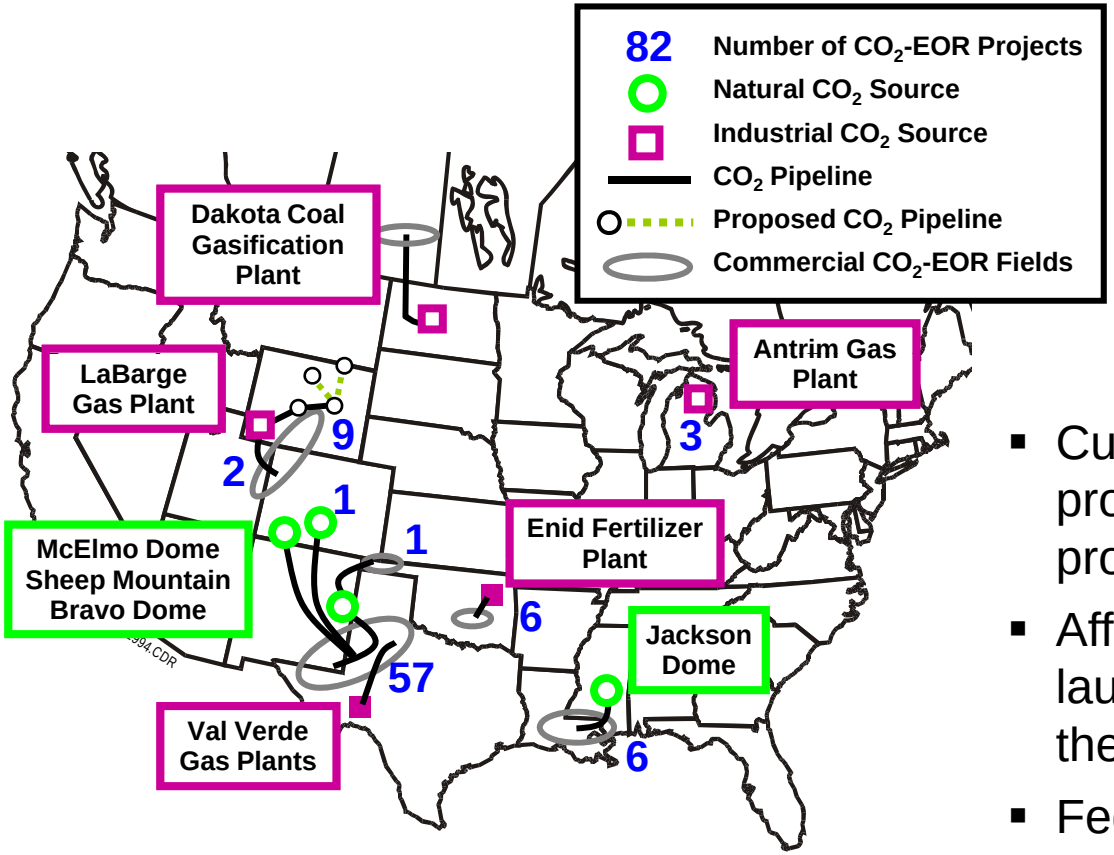
U.S. CO_2-EOR ACTIVITY



- Currently, 82 CO_2-EOR projects provide 237,000 B/D of production
- Affordable natural CO_2 launched CO_2-EOR activity in the 1980's
- Federal tax credits (Sec.43) and state severance tax relief still encourage CO_2-EOR

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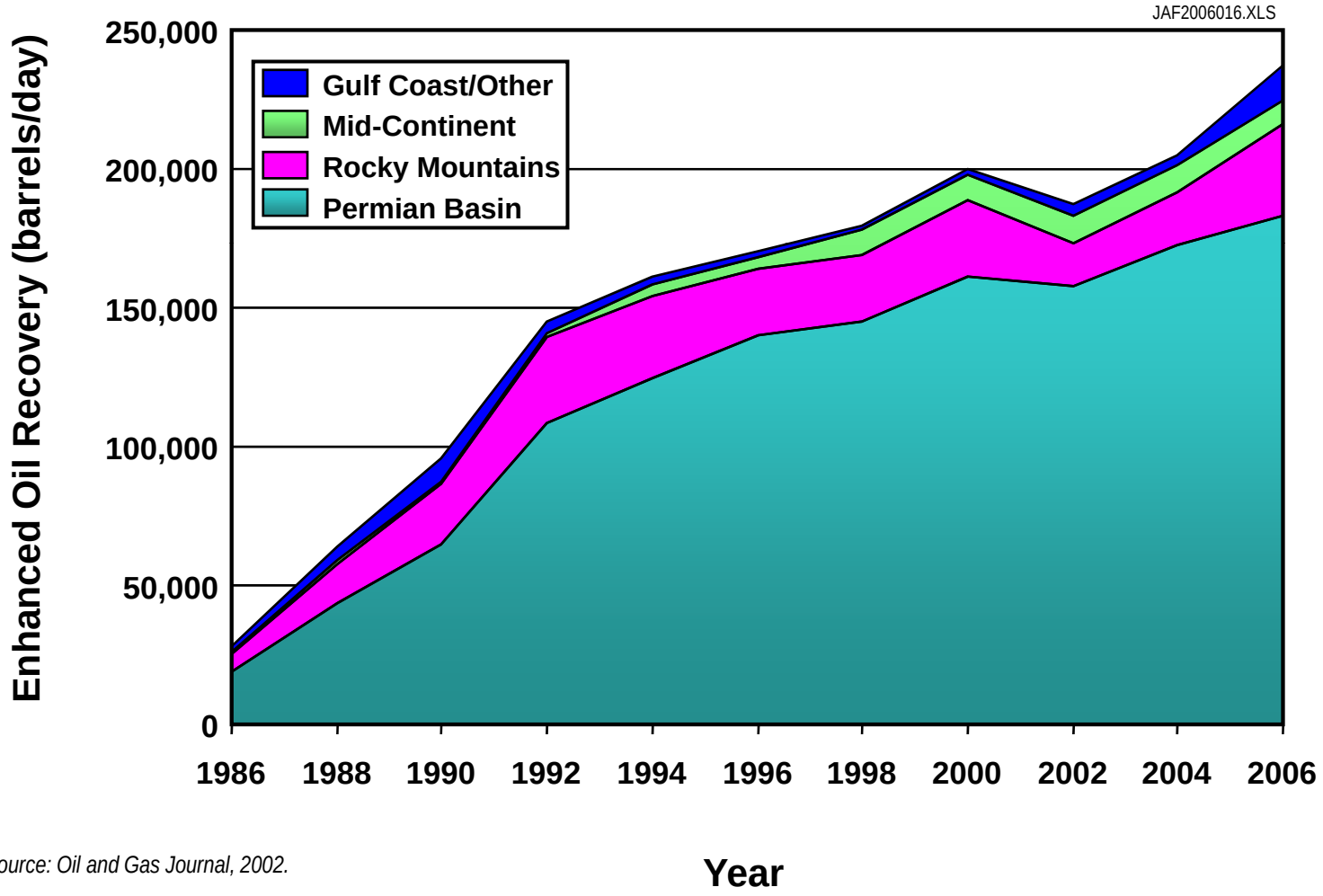
GROWTH OF CO_2-EOR PRODUCTION IN THE U.S.



Source: Oil and Gas Journal, 2002.

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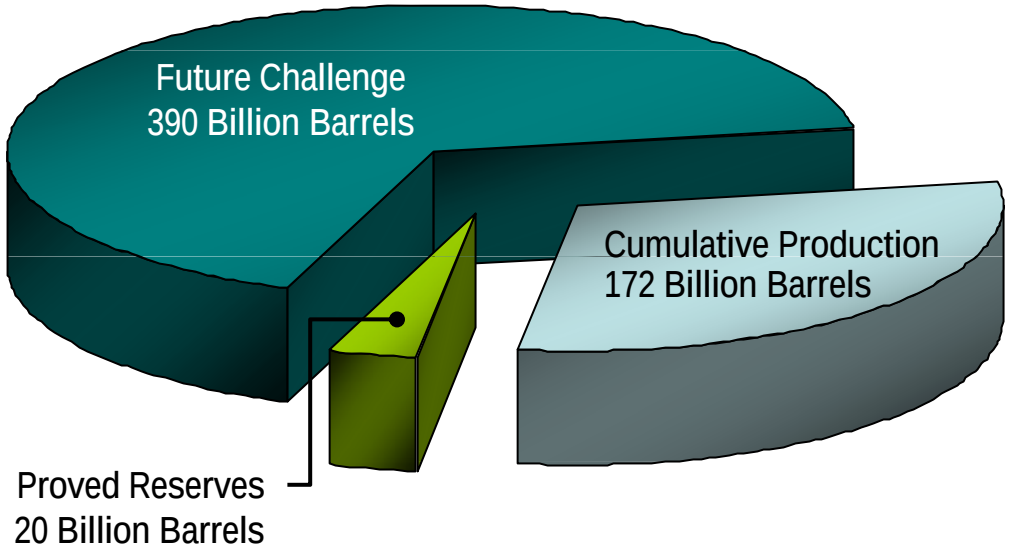
LARGE VOLUMES OF DOMESTIC OIL REMAIN "STRANDED" AFTER PRIMARY/SECONDARY OIL RECOVERY

Original Oil In-Place: 582 B Barrels*

"Stranded" Oil In-Place: 390 B Barrels*



*All domestic basins except the Appalachian Basin.
Source: Advanced Resources Int'l. (2005)

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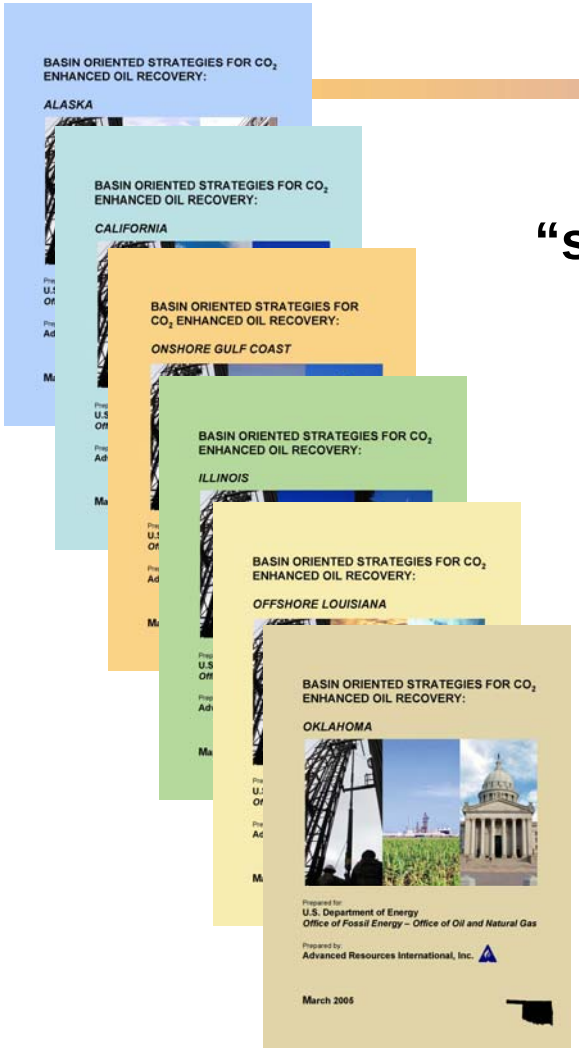
OUTLOOK FOR CO_2-EOR



Recently completed "basin studies" of applying "state-of-the-art" CO_2-EOR in the U.S. indicate:

- Nearly 89 billion barrels of technically recoverable resource,
- From 4 to 47 billion barrels of economically recoverable resource.

Results are based on applying streamline reservoir simulation to 1,581 large oil reservoirs (two thirds of U.S. oil production).

Available on the U.S. DOE web site.
http://www.fe.doe.gov/programs/oilgas/eor/Ten_Basin-Oriented_CO2-EOR_Assessments.html

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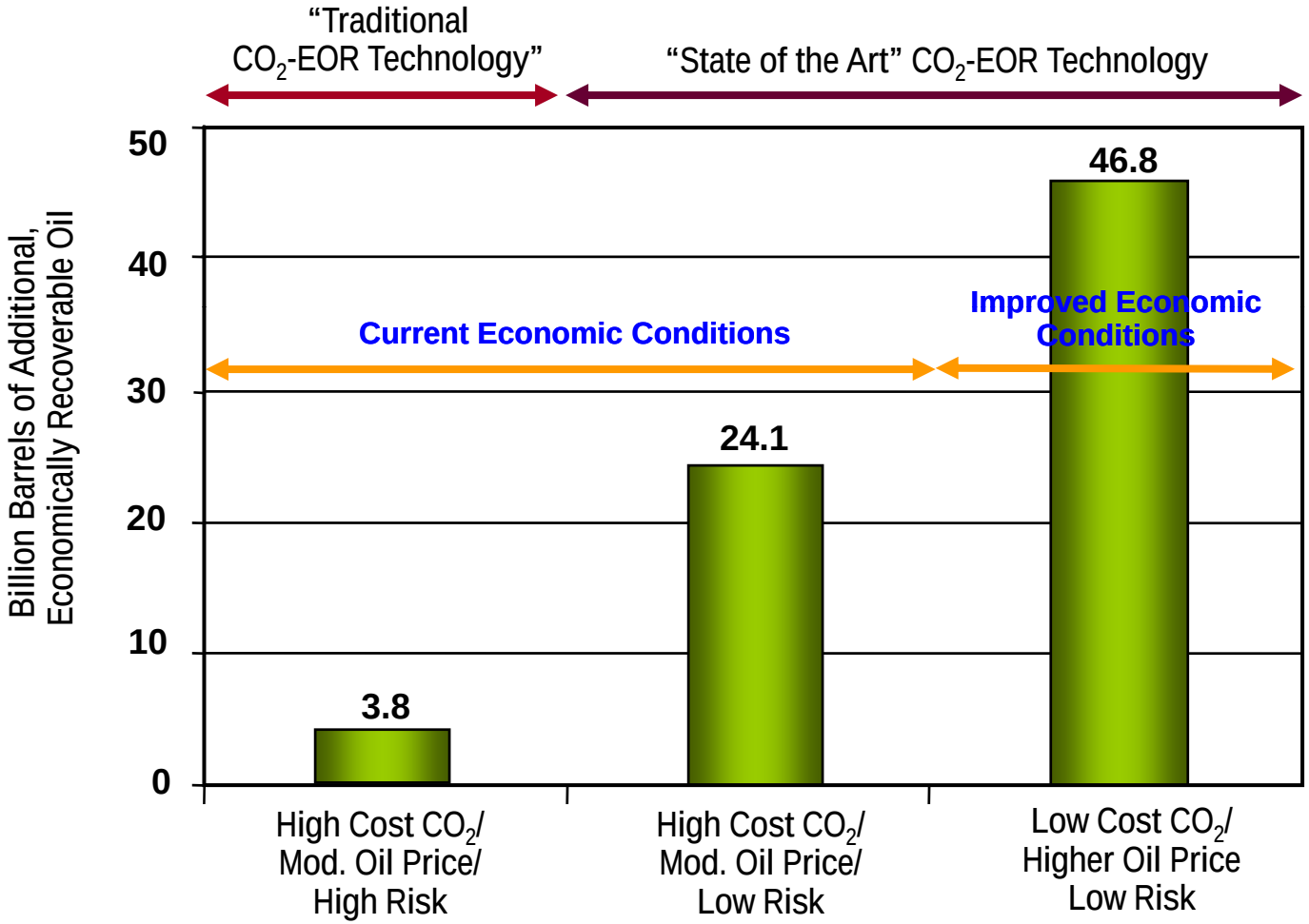
ECONOMICALLY RECOVERABLE RESOURCES FROM CO_2-EOR



Assumptions:
- CO_2 Costs ($/Mcf): High = 5% oil price; Low = 2% oil price.
- Oil Price ($/Barrel): Moderate = $30; High = $40.

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"NEXT GENERATION" CO_2-EOR TECHNOLOGY

Gravity-stable laboratory core floods can recover essentially all of the residual oil. Reservoir modeling and selected field tests also show that high oil recovery efficiencies are possible with innovative applications of CO_2-EOR.

Process designs that improve CO_2 contact with the reservoir can facilitate high oil recovery efficiencies.

So far, except for a handful of cases, the actual performance of CO_2-EOR has been less than optimum:

- **Geologically complex reservoir settings**
- **Lack of "real time" information on performance**
- **Limited process control capacity**

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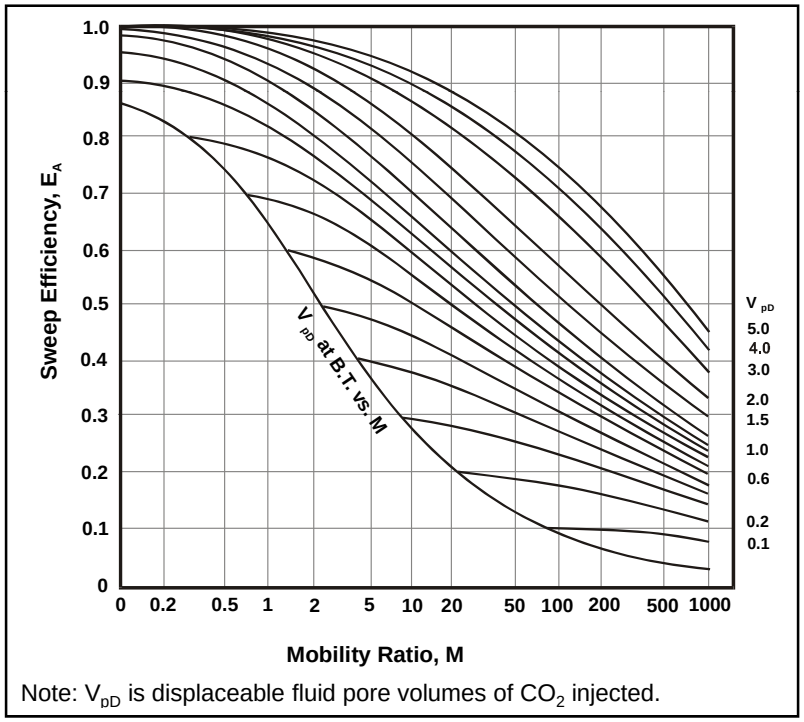
LIMITATIONS OF PAST PERFORMANCE

Because of high CO_2 costs and lack of information and process control, the great majority of past-CO_2 floods have used insufficient volumes of CO_2.

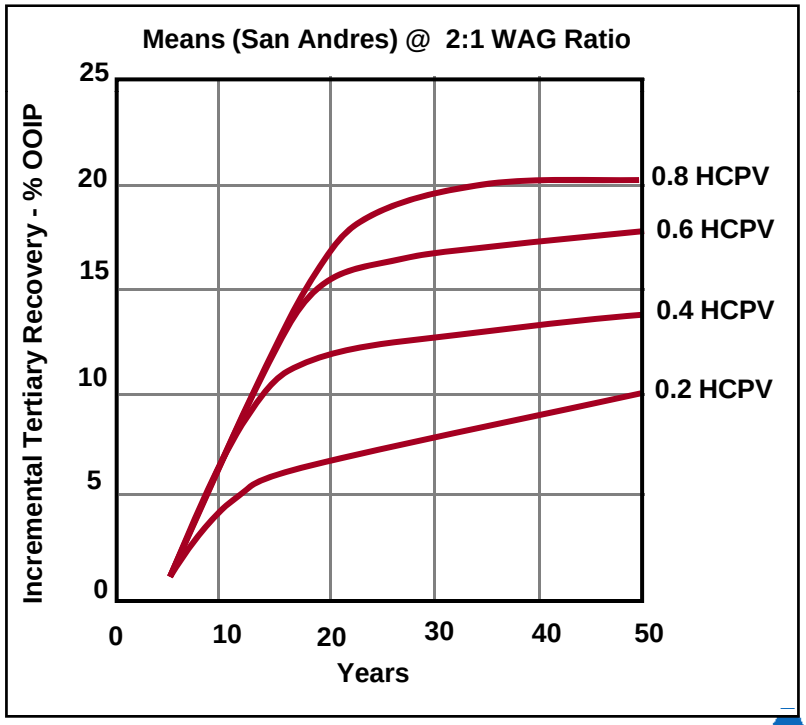
Sweep Efficiency in Miscible Flooding



Note: V_{pD} is displaceable fluid pore volumes of CO_2 injected.

Source: Claridge, E.L., "Prediction of Recovery in Unstable Miscible Displacement", SPE (April 1972).

Injected CO_2 vs Oil Recovery



Source: SPE 24928 (1992)

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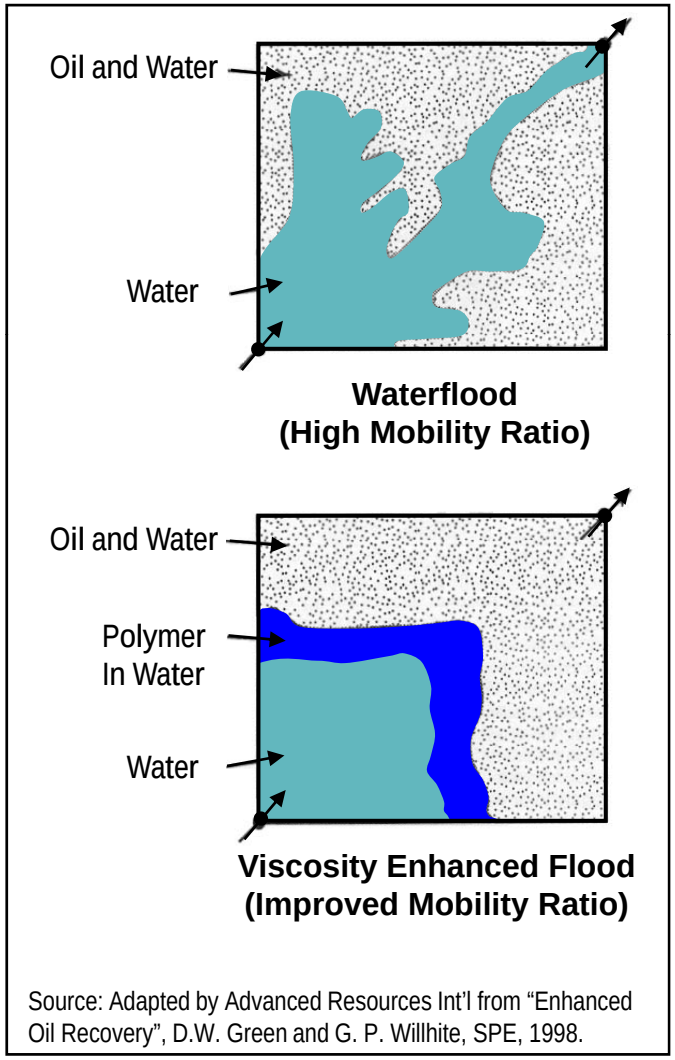
LIMITATIONS OF PAST PERFORMANCE



Source: Adapted by Advanced Resources Int'l from "Enhanced Oil Recovery", D.W. Green and G. P. Willhite, SPE, 1998.

In many CO_2 floods, the injected CO_2 achieved only limited contact with the reservoir:

- **Viscous fingering**
- **Gravity override**

Addition of viscosity enhancers could help improve the mobility ratio and reservoir contact.

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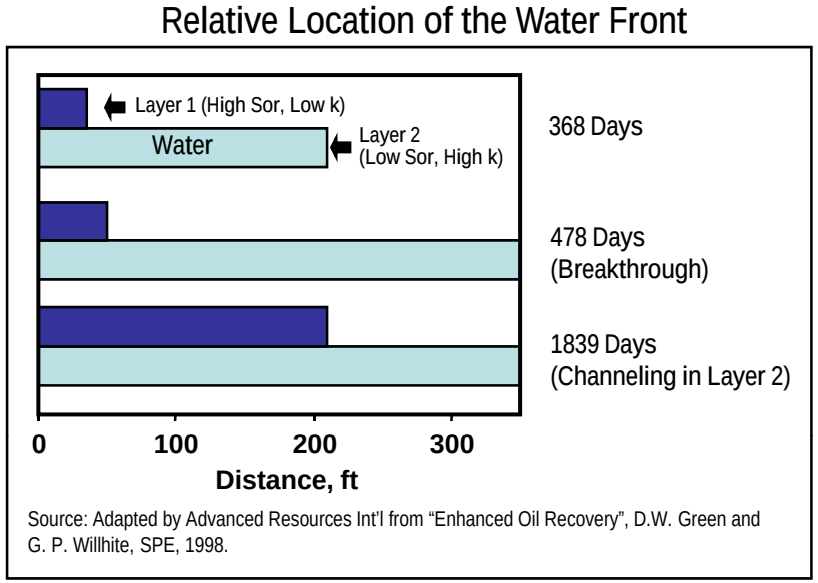
REVIEW OF PAST PERFORMANCE



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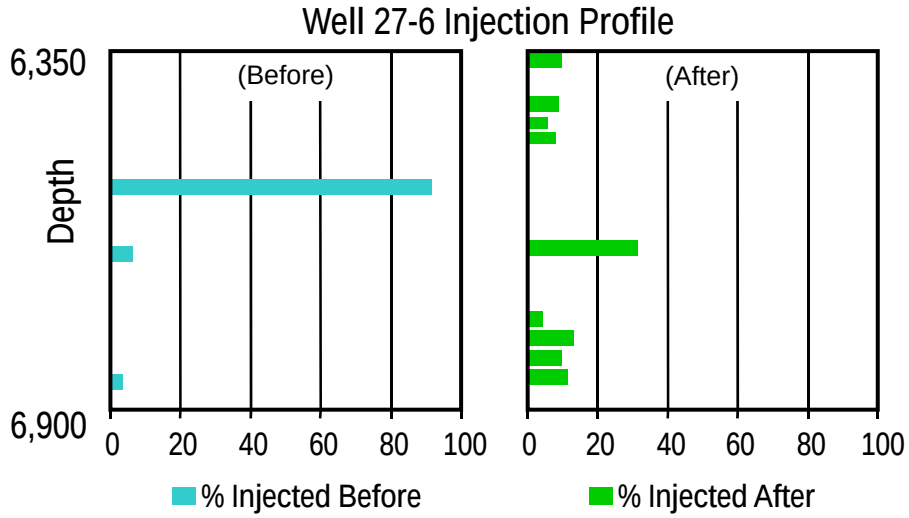

Source: "SACROC Unit CO_2 Flood: Multidisciplinary Team Improves Reservoir Management and Decreases Operating Costs", J.T. Hawkins, et al., SPE Reservoir Engineering, August 1996.

A major barrier is the inability to target the injected CO_2 to reservoir strata with high residual oil saturation.

The figures show:

- **Higher oil saturation/lower permeability portion of the reservoir is inefficiently swept;**
- **CO_2 channeling can be mitigated with well workover.**

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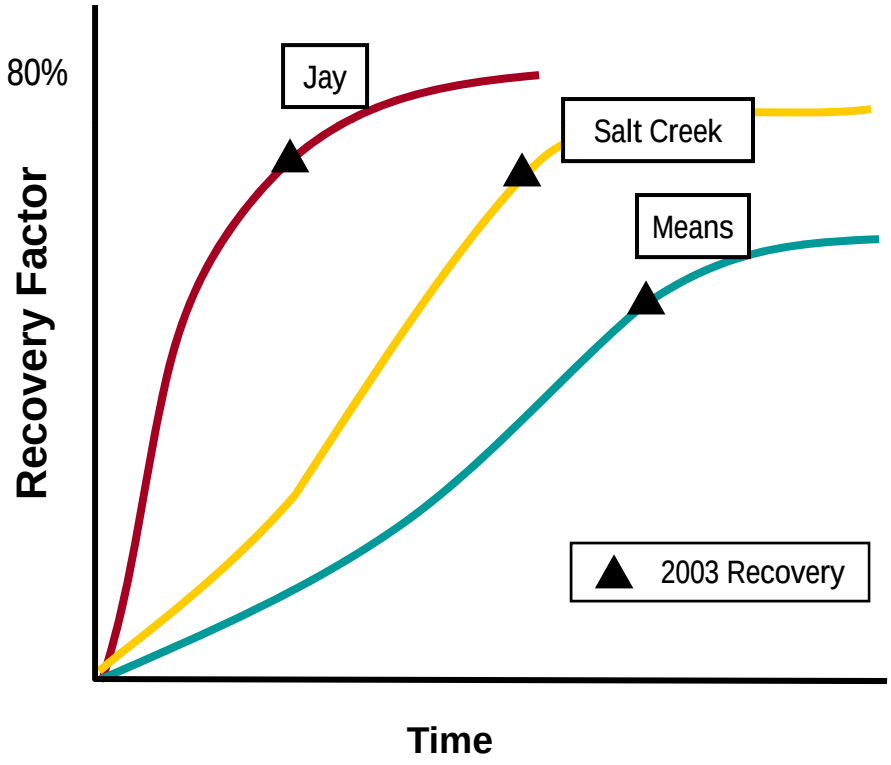
ARE HIGHER OIL RECOVERY EFFICIENCIES ACHIEVABLE?

Example Carbonate Field Oil Recovery Efficiencies



Source: Three ExxonMobil Oil Fields, SPE 88770 (2004)

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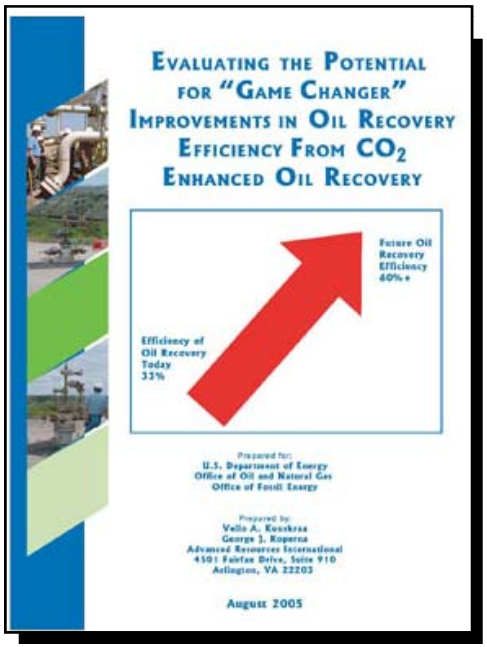
"GAME CHANGER" CO_2-EOR TECHNOLOGY

The DOE report, ***"Evaluating the Potential for "Game Changer" Improvements in Oil Recovery Efficiency from CO_2-Enhanced Oil Recovery":***



- Reviews performance of past CO_2-EOR floods.
- Sets forth theoretically and scientifically possible advances in technology for CO_2-EOR.
- Examines how much "game changer" CO_2-EOR technology would increase oil recovery and CO_2 storage capacity.

Available on the U.S. DOE web site.
http://www.fe.doe.gov/programs/oilgas/publications/eor_co2/Game_Changer_Document.pdf

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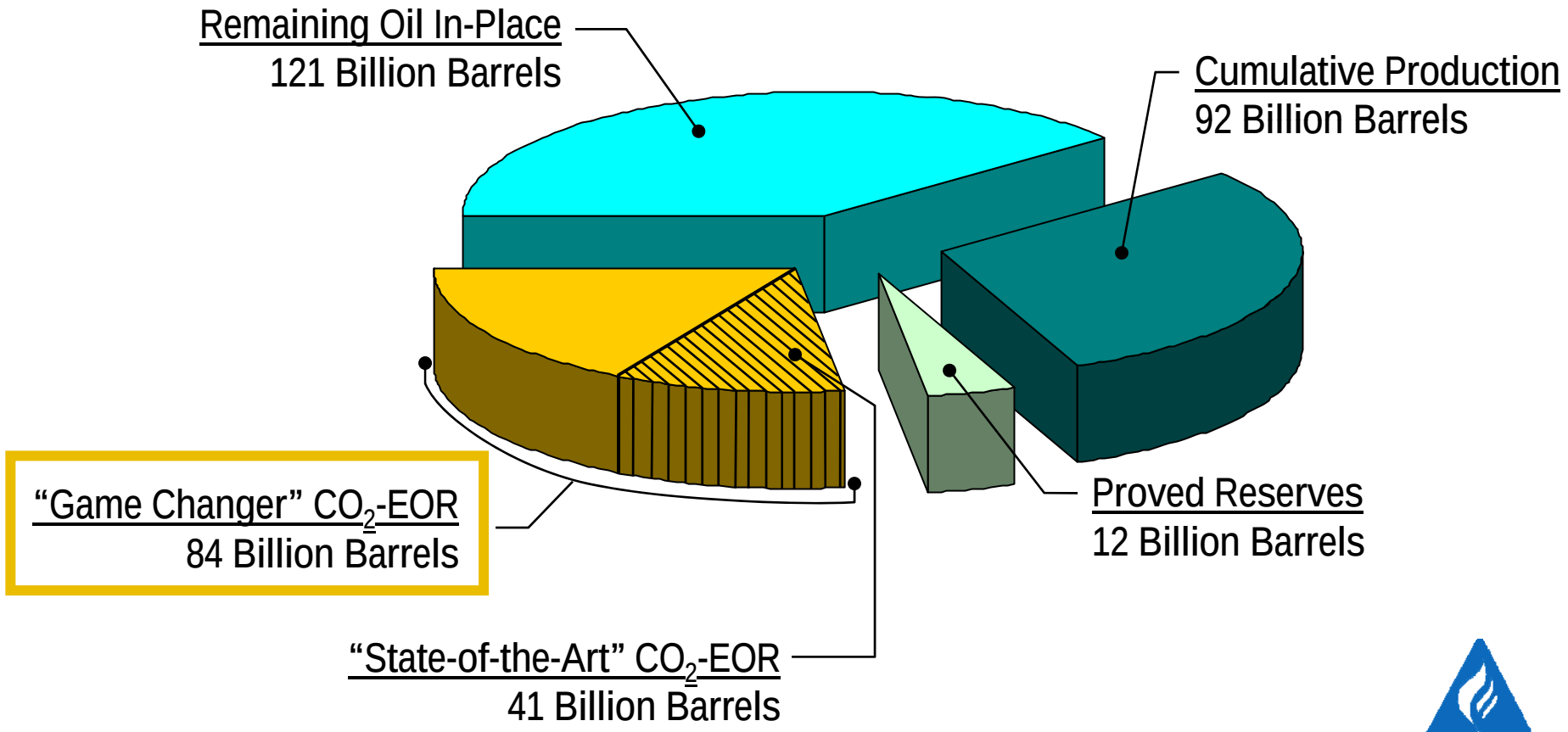
"GAME CHANGER" CO_2-EOR TECHNOLOGY (Cont'd)

- **Innovative Flood Design and Well Placement**
- **Viscosity and Miscibility Enhancement**
- **Increased Volume of CO_2 Injection**
- **Flood Performance Diagnostics and Control**
  - Inter-disciplinary technical teams
  - 4-D seismic
  - Instrumented observation wells
  - Zone-by-zone performance information

ACHIEVING 60+% OIL RECOVERY EFFICIENCY WITH "GAME CHANGER" CO_2-EOR TECHNOLOGY

Original Oil In Place: 309 Billion Barrels
(Six U.S. Basins/Areas)



Source: Advanced Resources International, 2005

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INTEGRATING CO_2-EOR AND CO_2 STORAGE

Expanding CO_2 Storage Capacity: A Case Study. Large Gulf Coast oil reservoir with 340 million barrels (OOIP) in the main pay zone.

Another 100 million barrels (OIP) in the underlying 130 feet of residual oil zone and an underlying saline reservoir 195 feet thick.

- Main Pay Zone:
  - Depth - - 14,000 feet
  - Oil Gravity - - 33°API
  - Porosity - - 29%
  - Net Pay - - 325 feet
  - Initial Pressure - - 6,620 psi
  - Miscibility Pressure - - 3,250 psi
- Primary/Secondary Oil Recovery: 153 million barrels (45% of OOIP)

Theoretical CO_2 storage capacity: 2,710 Bcf (143 million tonnes)

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INTEGRATING CO_2-EOR AND CO_2 STORAGE (Cont'd)

State-of-the-Art. Vertical wells; 1 HCPV of CO_2 (purchased and recycled CO_2); @ 1:1 WAG.

Alternative Design.

- Gravity-stable CO_2 injection with horizontal production wells.
- Targeting main pay zone, plus residual oil zone and underlying saline reservoir.
- Injecting continuous CO_2 (no water); continuing to inject CO_2 after completion of oil recovery.
- Instituting rigorous diagnostic and monitoring.

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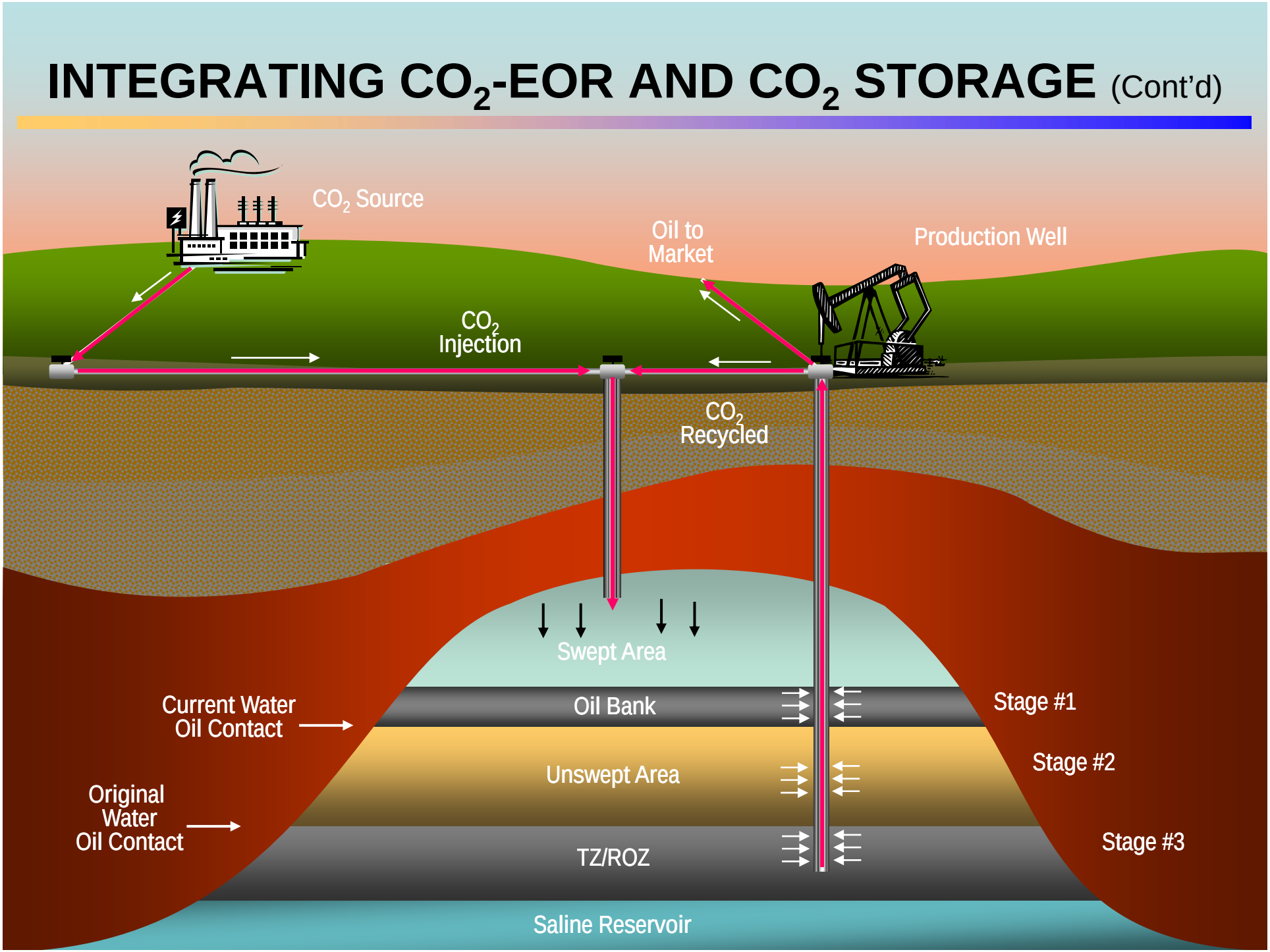
INTEGRATING CO_2-EOR AND CO_2 STORAGE (Cont'd)



INTEGRATING CO_2-EOR AND CO_2 STORAGE (Cont'd)

With alternative CO_2 storage and EOR design, much more CO_2 can be stored and more oil becomes potentially recoverable.

The additional oil produced is "GREEN OIL".

	"State of the Art"	"Next Generation"
	(millions)	(millions)
CO_2 Storage (tonnes)	19	109
Storage Capacity Utilization	13%	76%
Oil Recovery (barrels)	64	180
% Carbon Neutral ("Green Oil")	80%	160%

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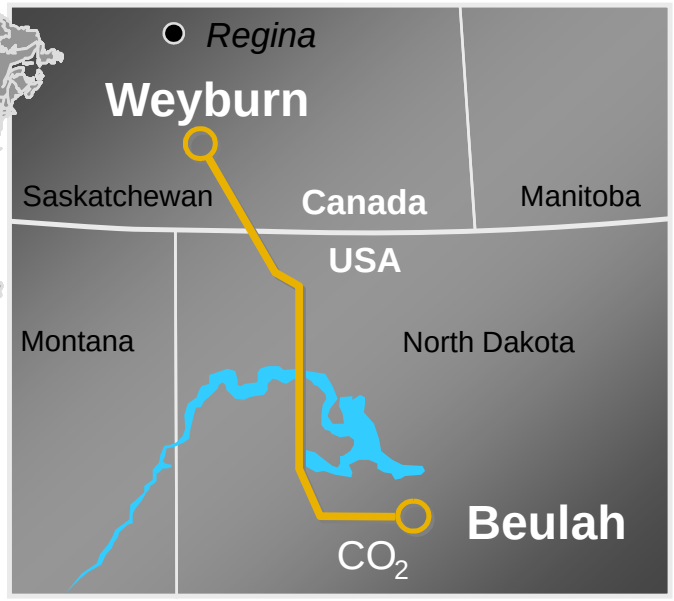
Weyburn Enhanced Oil Recovery Project

(An Operating Project Maximizing Oil Recovery and CO_2 Storage)



- Largest CO_2 EOR project in Canada:
  - OOIP 1.4 Bbbls
  - 155 Mbbls incremental
- Outstanding EOR response
- World's largest geological CO_2 sequestration project
  - 2.4 MMt/year (current)
  - 7 MMt to date
  - 23 MMt with EOR
  - 55 MMt with EOR/sequestration

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"EARLY APPLICATION" OF CO_2-EOR

Improving Revenues and Profits: A Case Study. Large, 2.4 billion barrels (OOIP) Permian Basin oil reservoir.

- Depth - - 5,200
- Gravity - - 33° API
- Porosity - - 12%
- Net Pay - - 141 ft.
- Initial Pressure - - 1,850 psi
- Miscibility Pressure - - 1,500 psi

First produced using traditional sequence - - primary, then secondary and finally CO_2-EOR.

Next produced with "early application" CO_2-EOR design - - primary, then CO_2-EOR (skipping the waterflood).

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"EARLY APPLICATION" OF CO_2-EOR (Cont'd)

The economic value of this oil reservoir (after primary recovery) is much higher under "early application" of CO_2-EOR.

	Traditional Sequence (After Primary Recovery)	"Early Application" (After Primary Recovery)
	(Million)	(Million)
Gross Revenues (NPV @ 10%)	$9,300	$19,000
Oil Recovery (Barrels/Years)	1,060 (53 yrs)	1,040 (28 yrs)
Water Production (Barrels)	3,900	1,500

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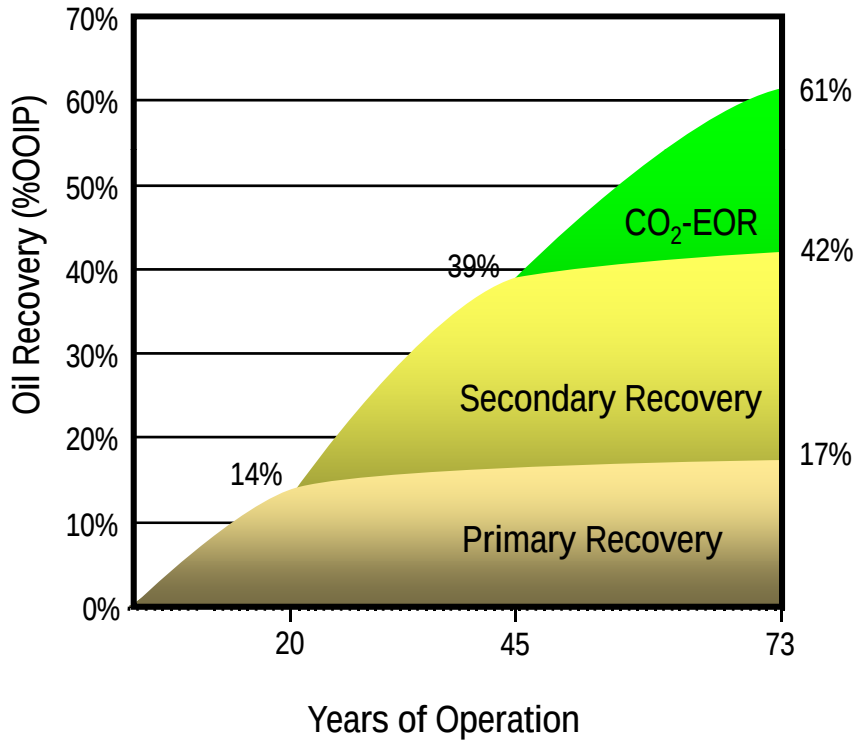
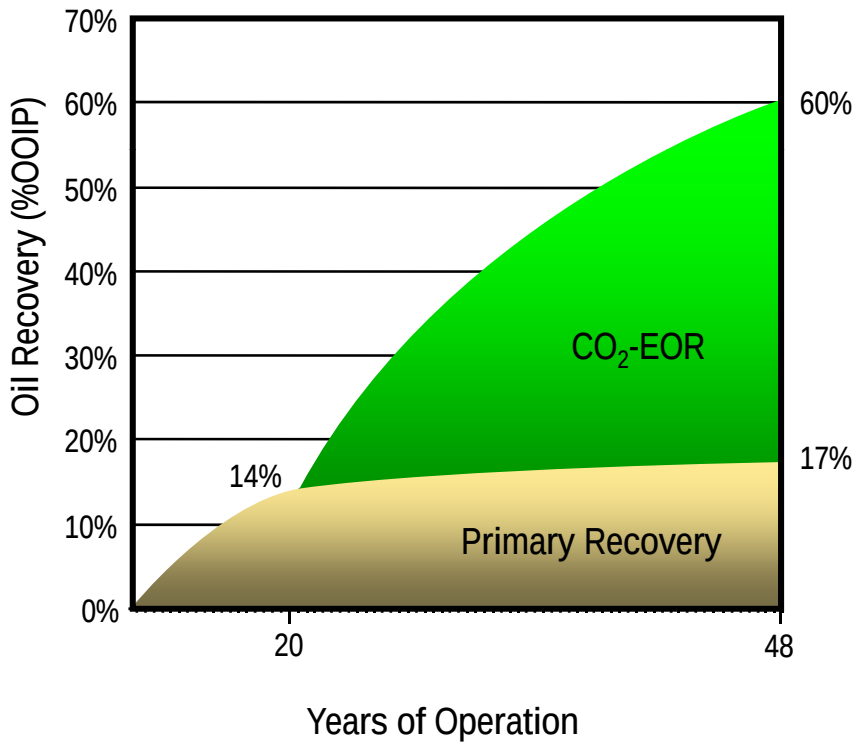
"EARLY APPLICATION" OF CO_2-EOR (Cont'd)

Traditional Sequence



"Early Application"



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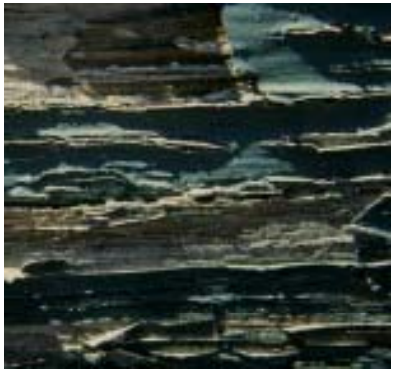

SUMMARY

1. CO_2 enhanced oil recovery, while still an emerging industry, has the potential to add significant volumes of future oil supply, in the U.S. and worldwide.
2. Thirty years of experience shows that CO_2-EOR is a technically sophisticated and challenging process, but one that can be successful if "managed and controlled", not just "operated".
3. "Game Changer" CO_2-EOR technologies, incorporating scientifically possible but not yet fully developed advances, could significantly increase oil recovery efficiency.

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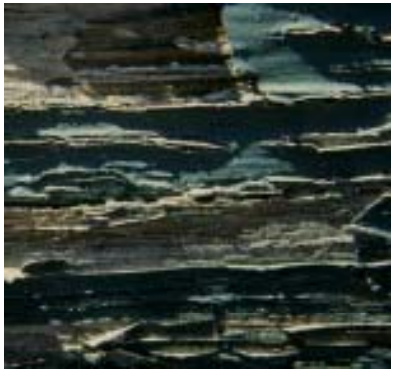

SUMMARY (Cont'd)

4. "Early application" of CO_2-EOR technology can significantly increase the economic value of the remaining oil resource.
5. Wide-scale application of CO_2-EOR is constrained by lack of sufficient "EOR-Ready" CO_2 supplies. A mutually beneficial link exists between CO_2-EOR and new industrial sources of CO_2.
6. Under a "carbon constrained world", productively using industrial CO_2 emissions for CO_2-EOR will become a winning strategy.

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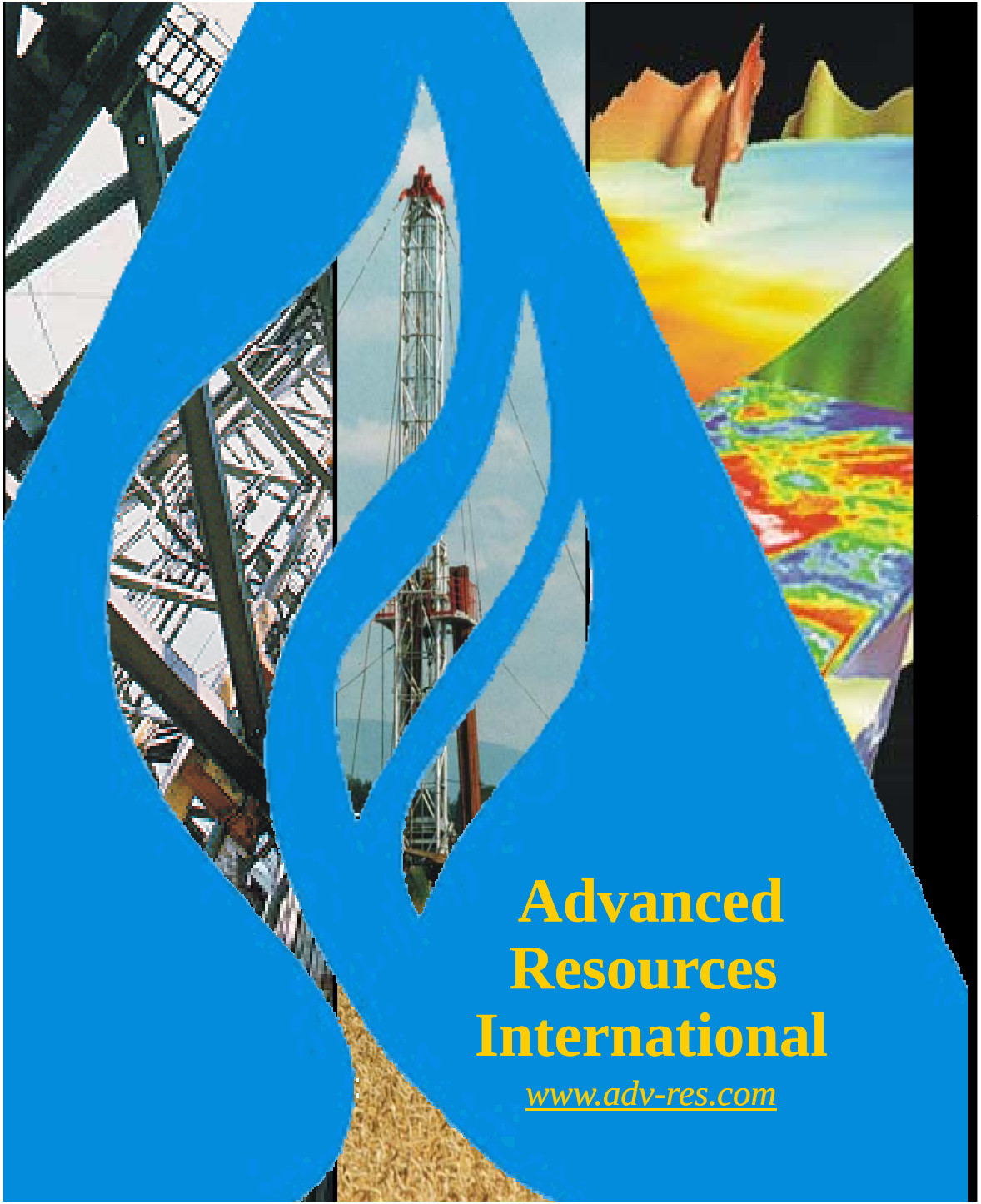

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