Industry Experience with CO2 for Enhanced Oil Recovery

Workshop on California Opportunities for CCUS/EOR

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June 27, 2012

Chevron Has Significant Operations with CO_2 EOR Projects

- Chevron installed the first large-scale CO_2 miscible EOR flood in the Permian basin at the SACROC project in 1972.
- Chevron presently operates 6 floods and injects roughly 450 MMCFPD of CO_2.
- Chevron produces about 30,000 BOPD from its CO_2 EOR projects, which represents about ~10% of all CO_2 EOR production in the US.
- Chevron operates large-scale recycle compression & natural gas liquids recovery plants to support CO_2 EOR projects.

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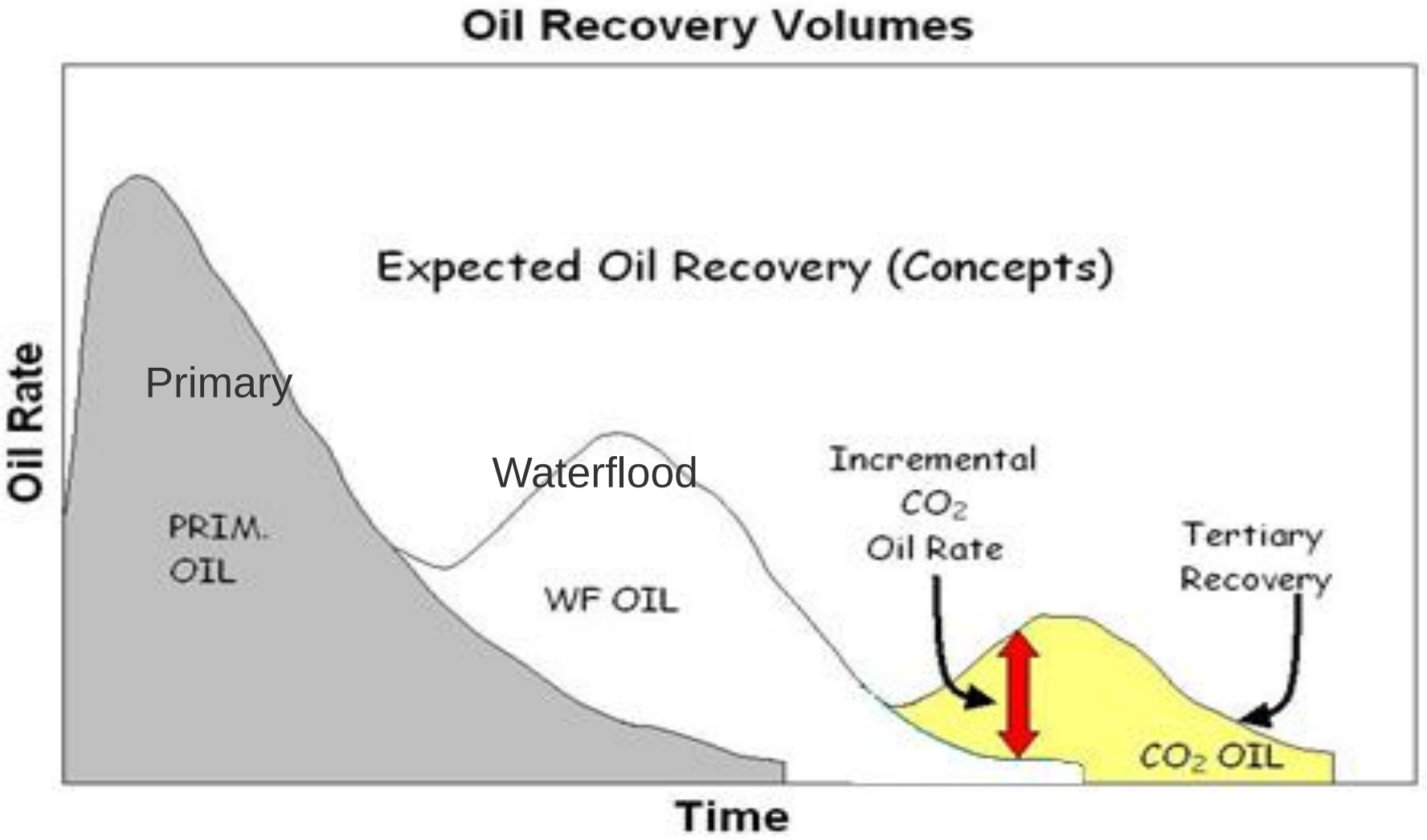
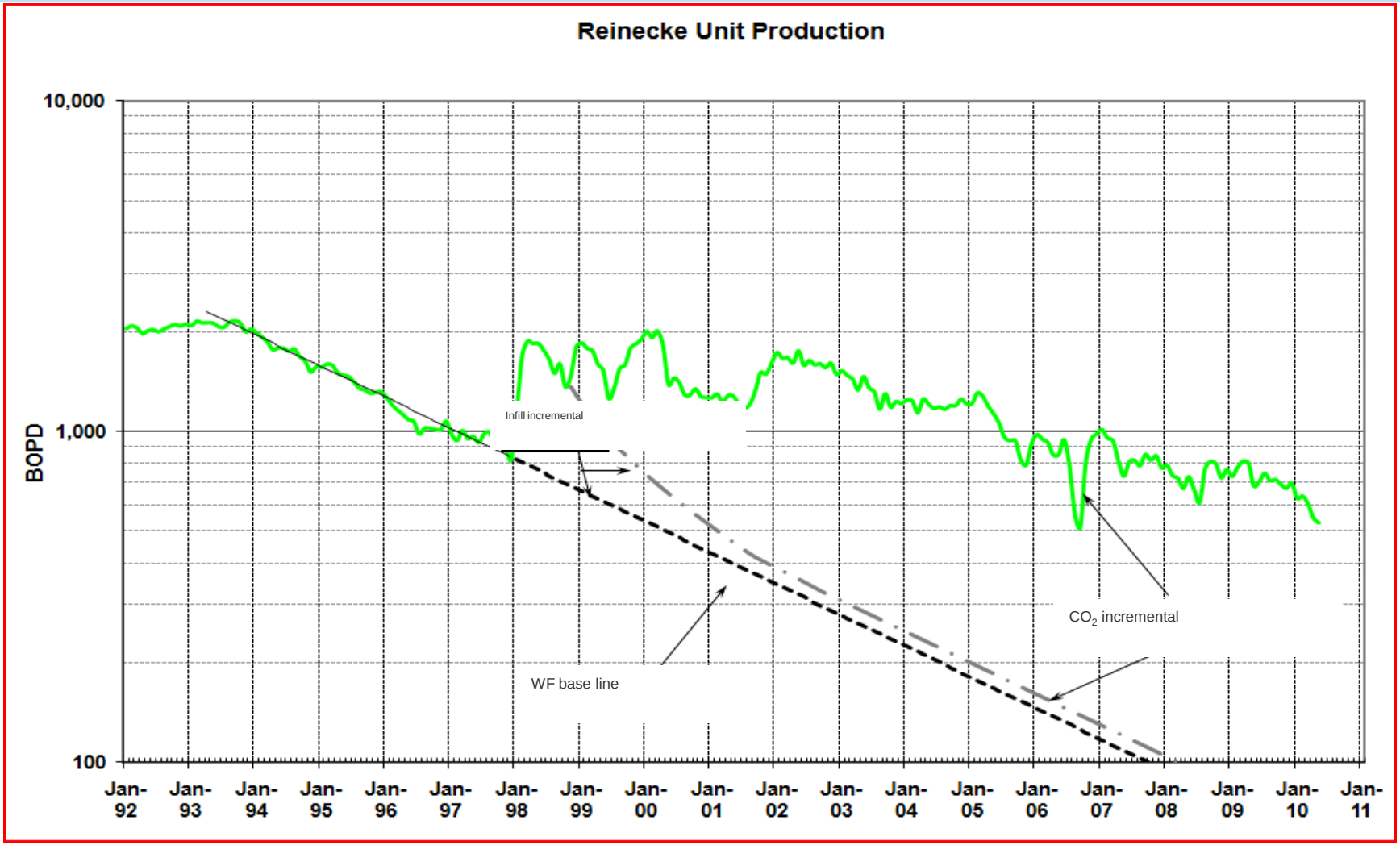
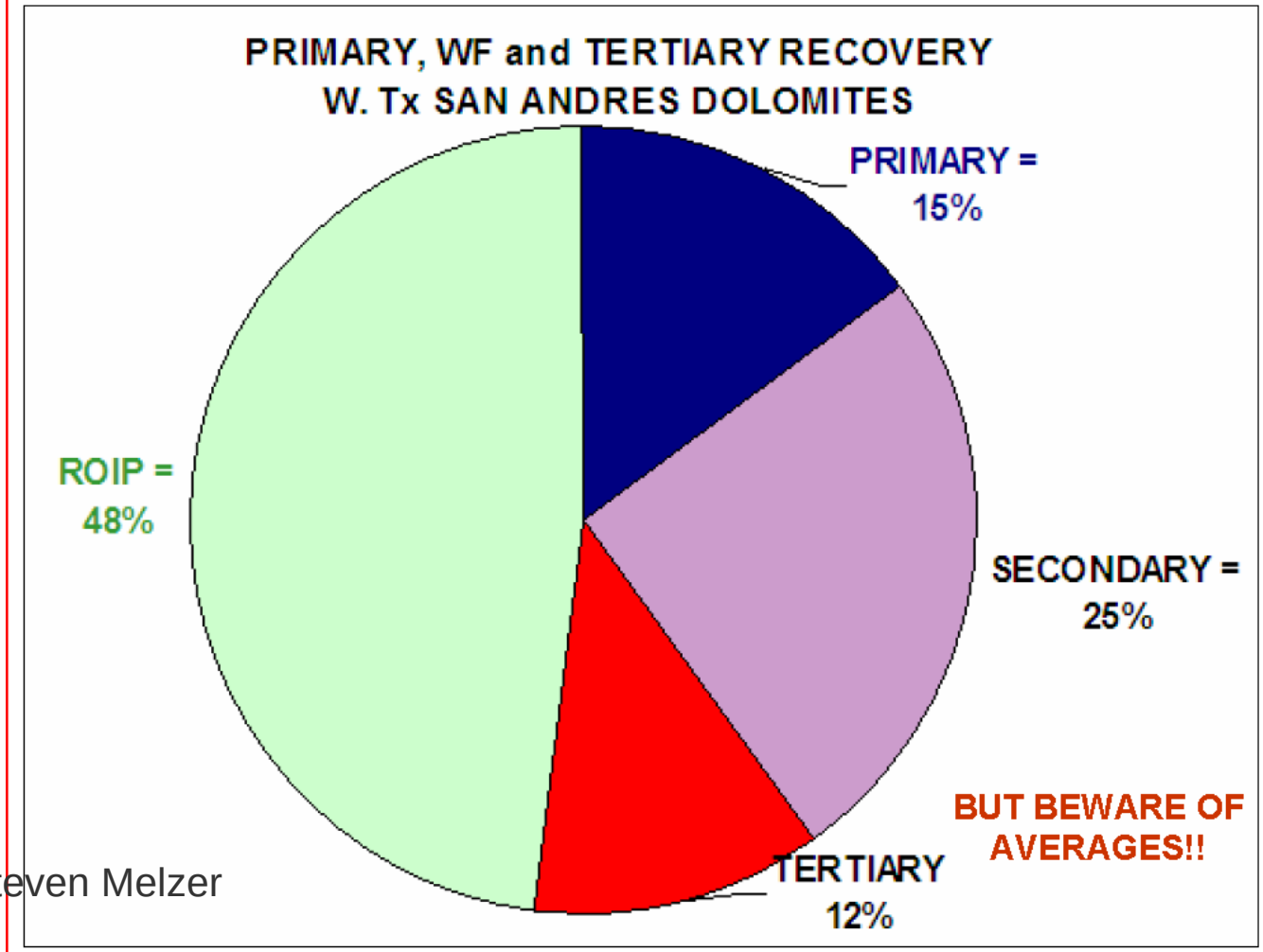
Enhanced Oil Recovery: Comes after the "Easy Oil" has already been produced



Reinecke Unit: Production Decline Averted



Comparison of Oil Recovery due to various stages in Life of an Oilfield



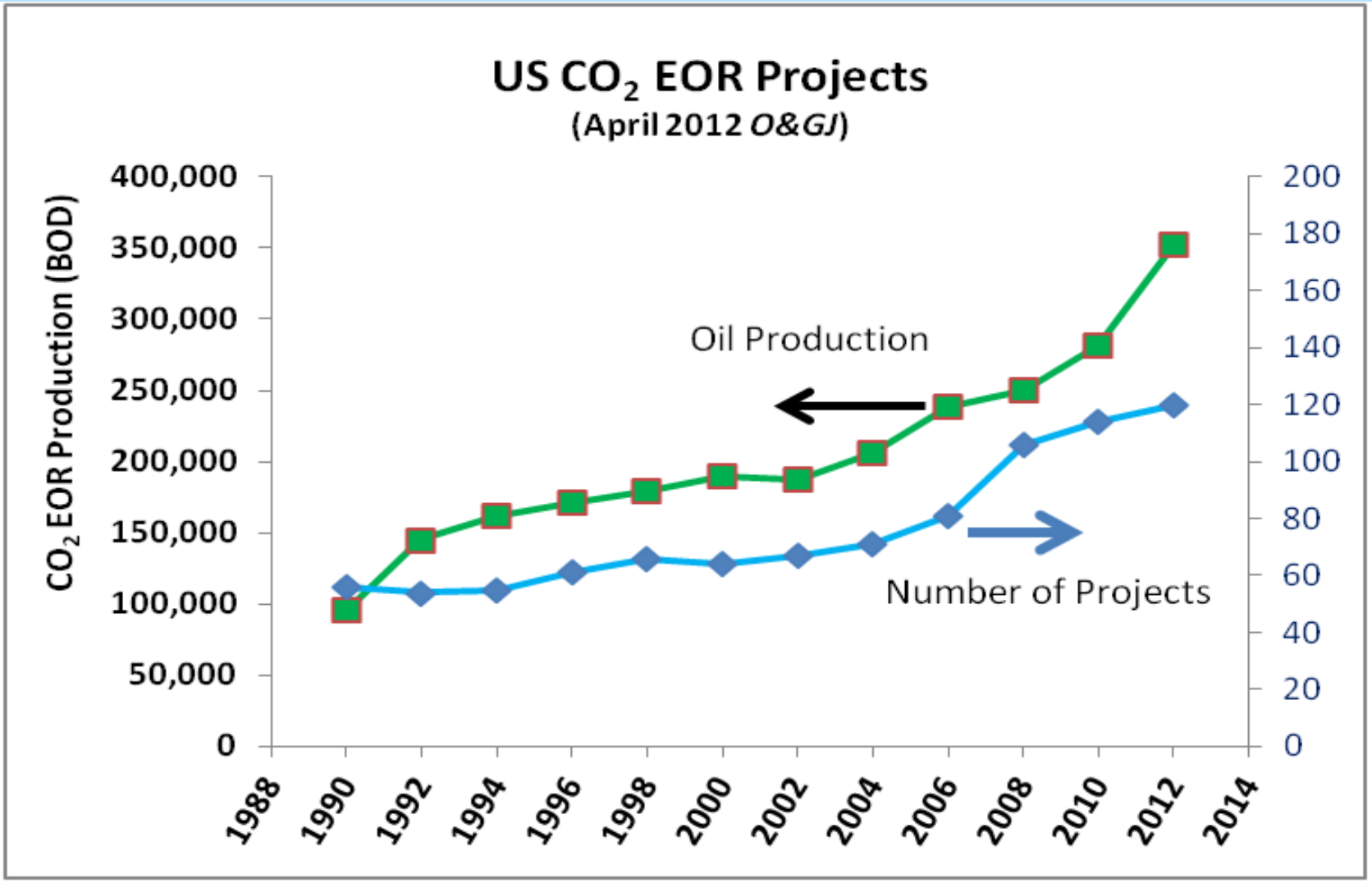
Source: Steven Melzer

History of CO2 EOR

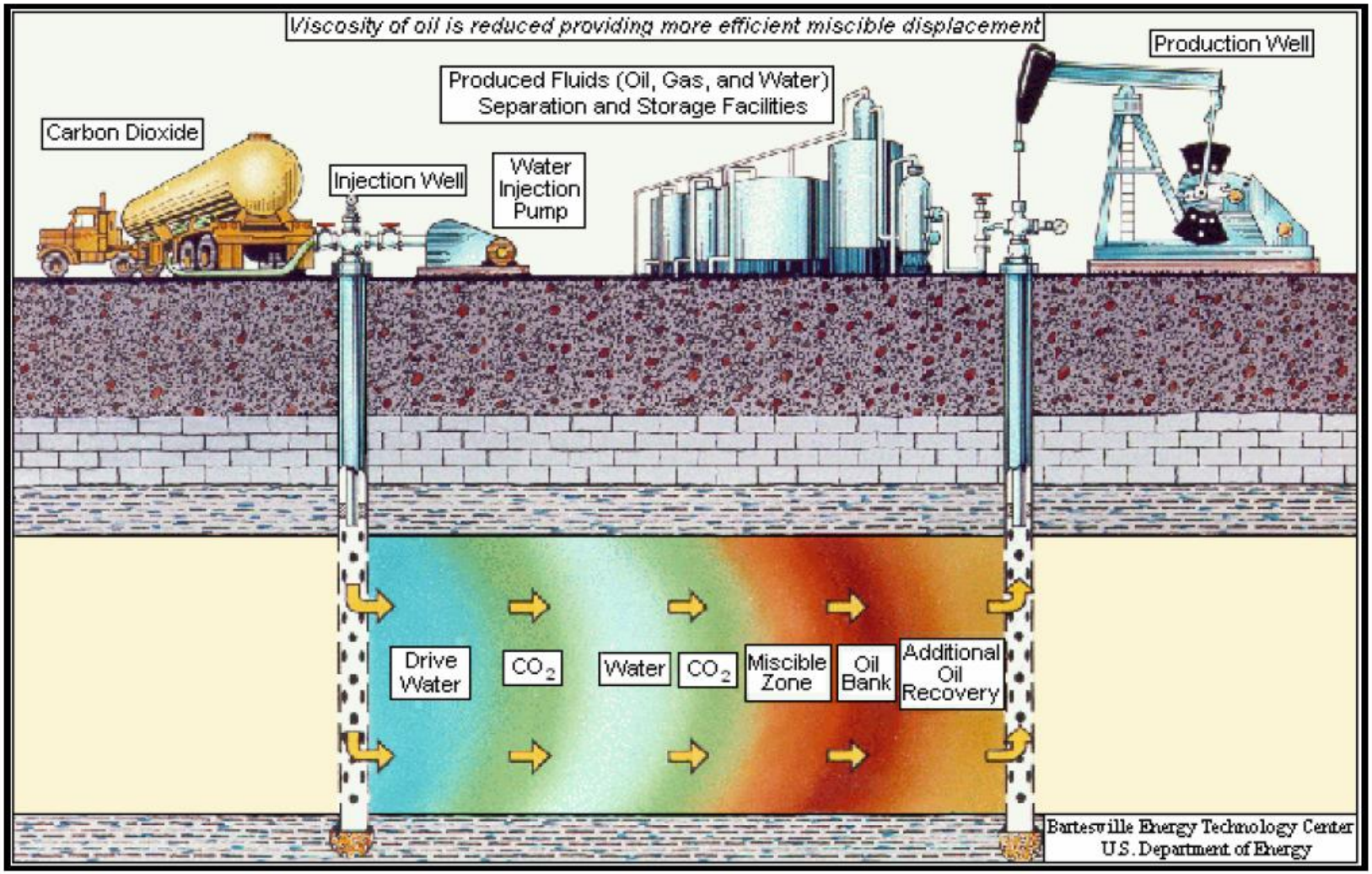
- First large scale demonstrations in early 1970s:
  - SACROC (1972) was a Chevron project
- Since then, projects implemented in multiple countries: Canada, Hungary, Turkey, Trinidad, France & Russia.
- Under consideration for fields in North Sea, UAE, Indonesia, Saudi Arabia & Abu Dhabi.

- Current Status in US
  - 120 projects
  - Accounts for 350,000 bbls of oil per day in production
  - CO2 supply ~ 3 billion cubic feet per day
  - Significant growth in the Gulf Coast & Permian Basin
  - 42 Billion barrels of recoverable reserves in the US

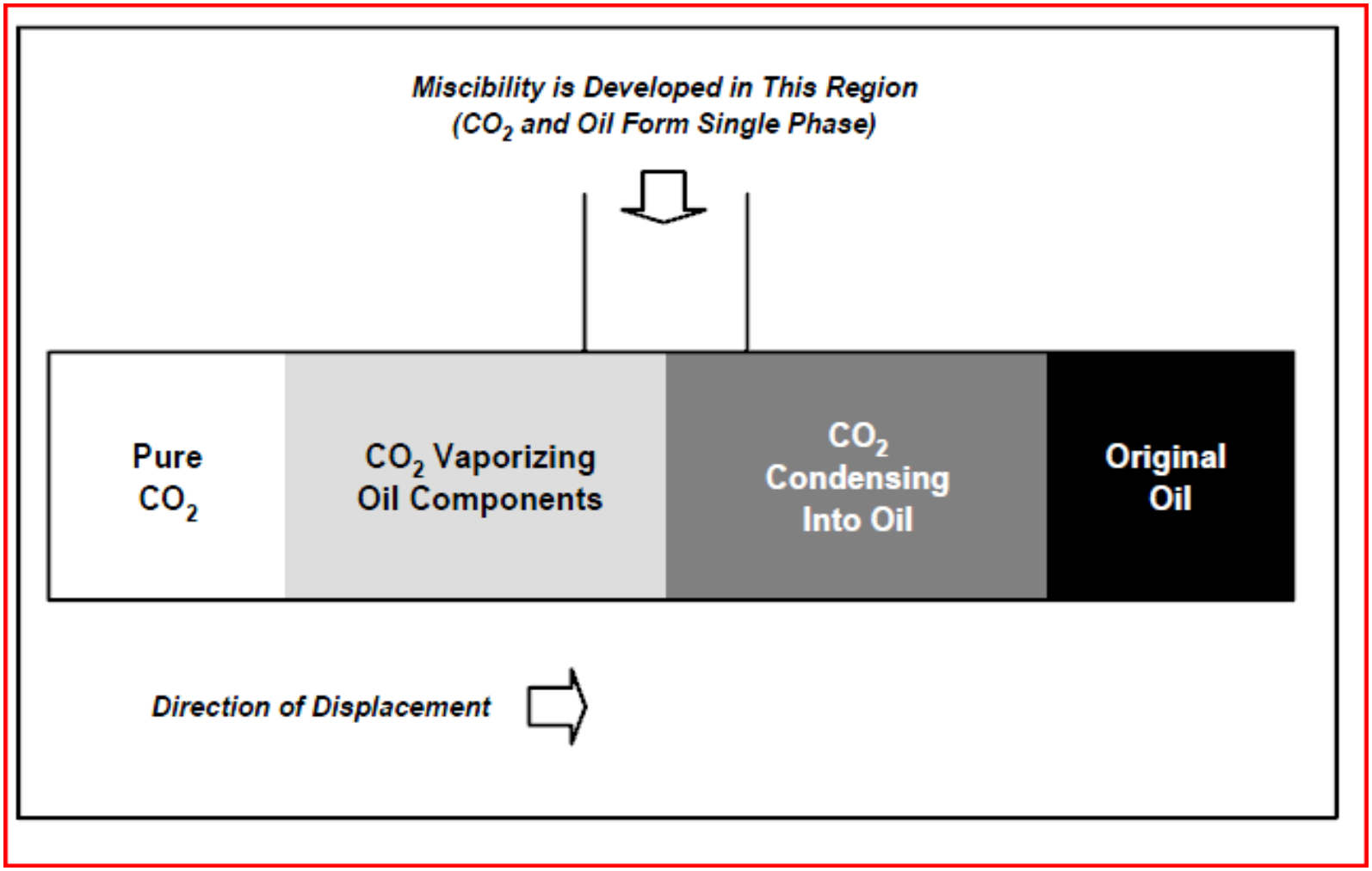
CO2 EOR Projects



THE COMPONENTS OF CO_2 FLOODING



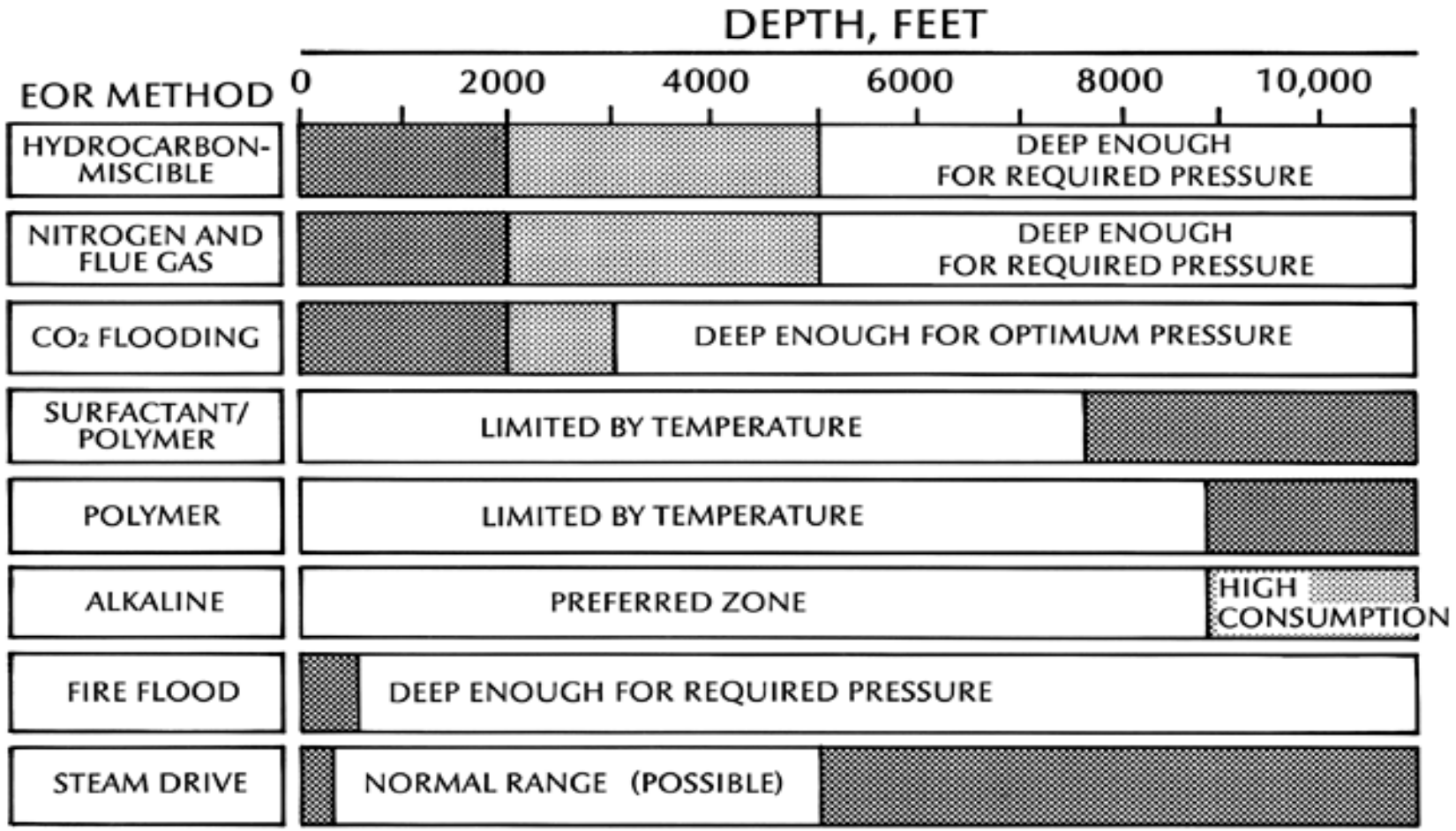
Schematic Showing the CO2 EOR Process



Chevron's EOR Laboratory in Richmond, CA

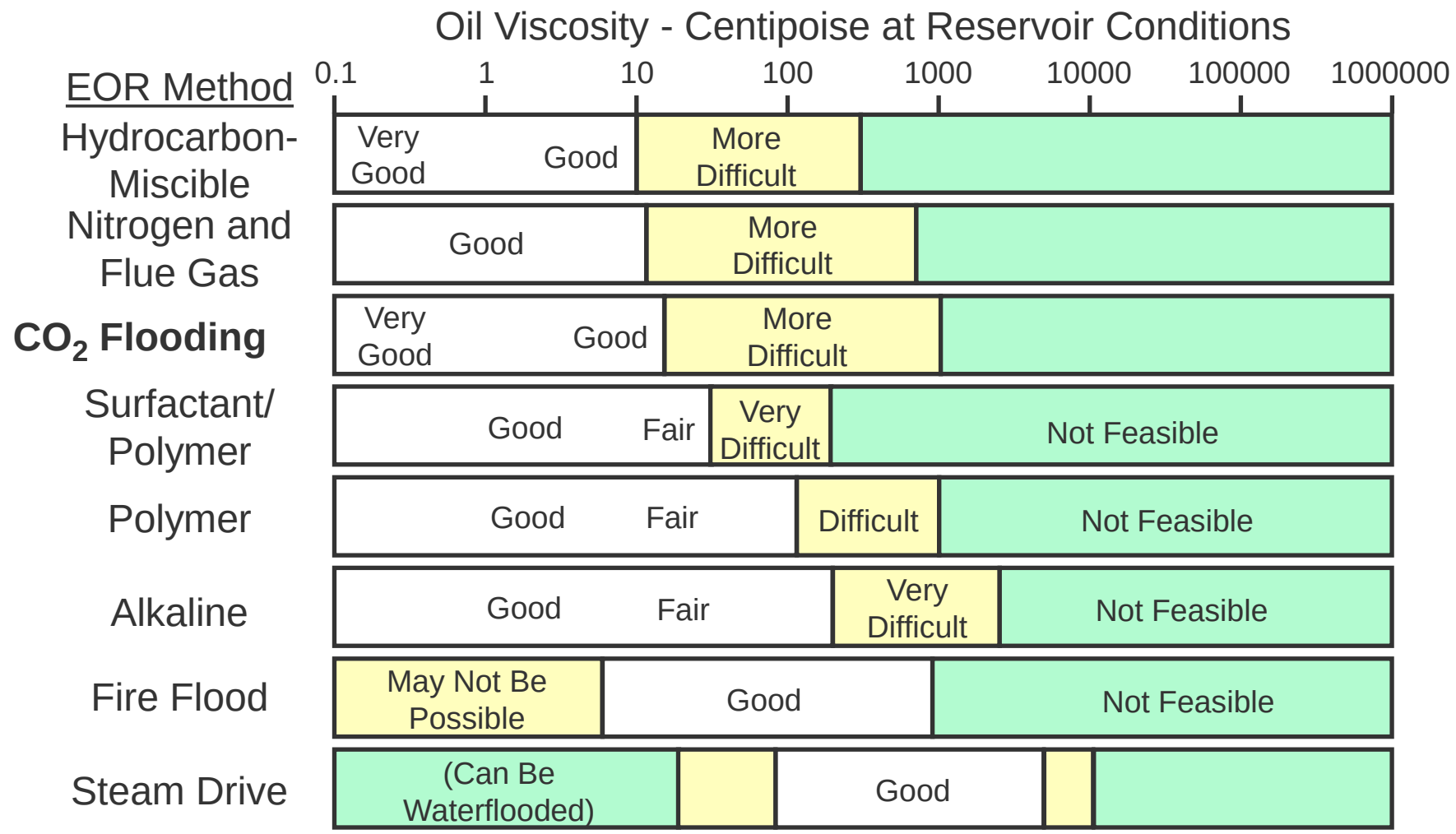
Chevron Miscible Gas EOR Laboratory Capability --- Slimtube/Coreflood System

Comparison of Optimal Depth for Various EOR Methods: CO2 is best for reservoirs > 3000 ft



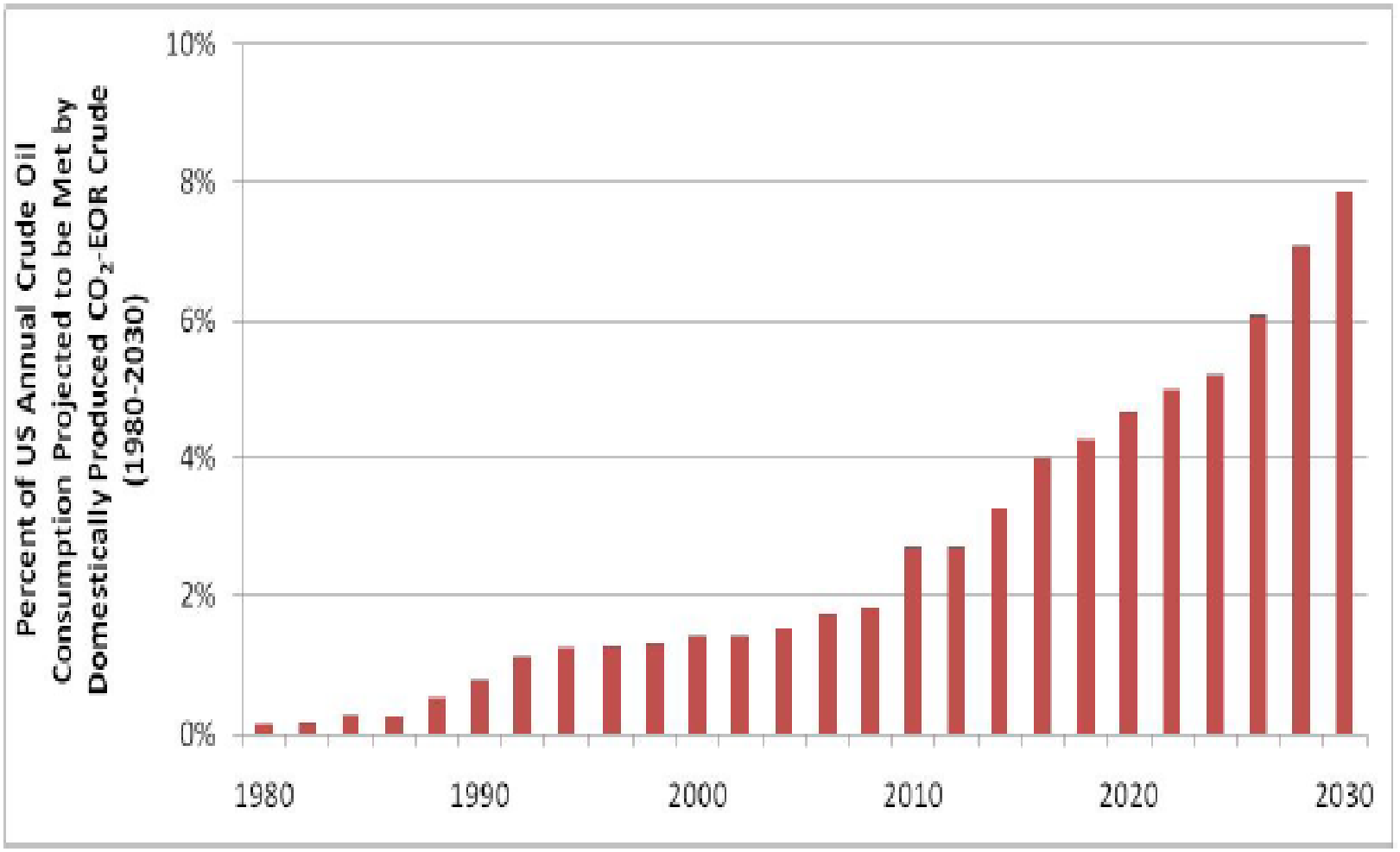
Source: Larry Lake

Comparison of Optimal Oil Viscosity for Various EOR Methods: CO2 is best for low viscosity oil

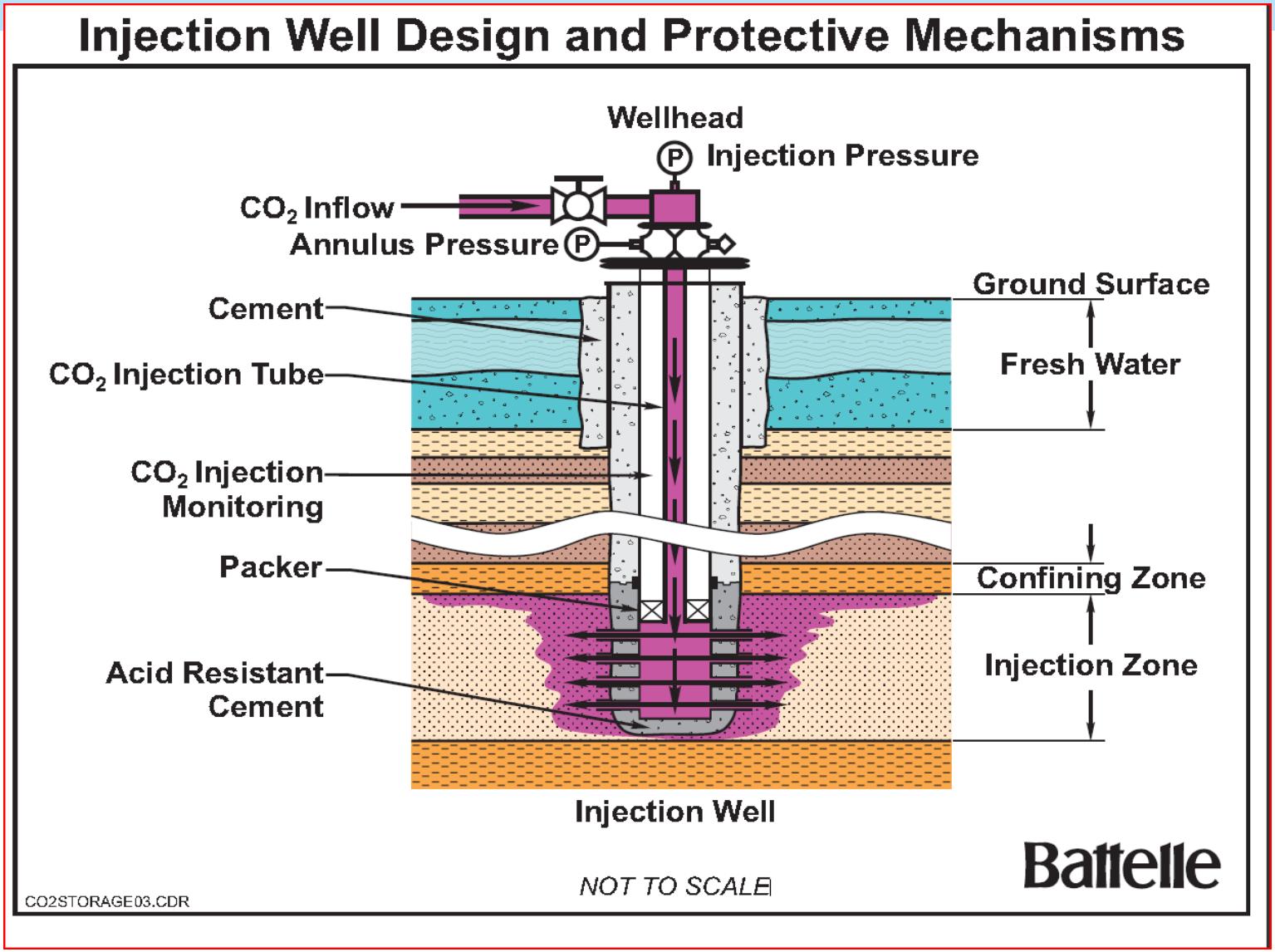


Source: Larry Lake

CO2 EOR is expected to continue to grow in the US: Forecast from US DOE (EIA)



Injection Well Design for CO2 EOR



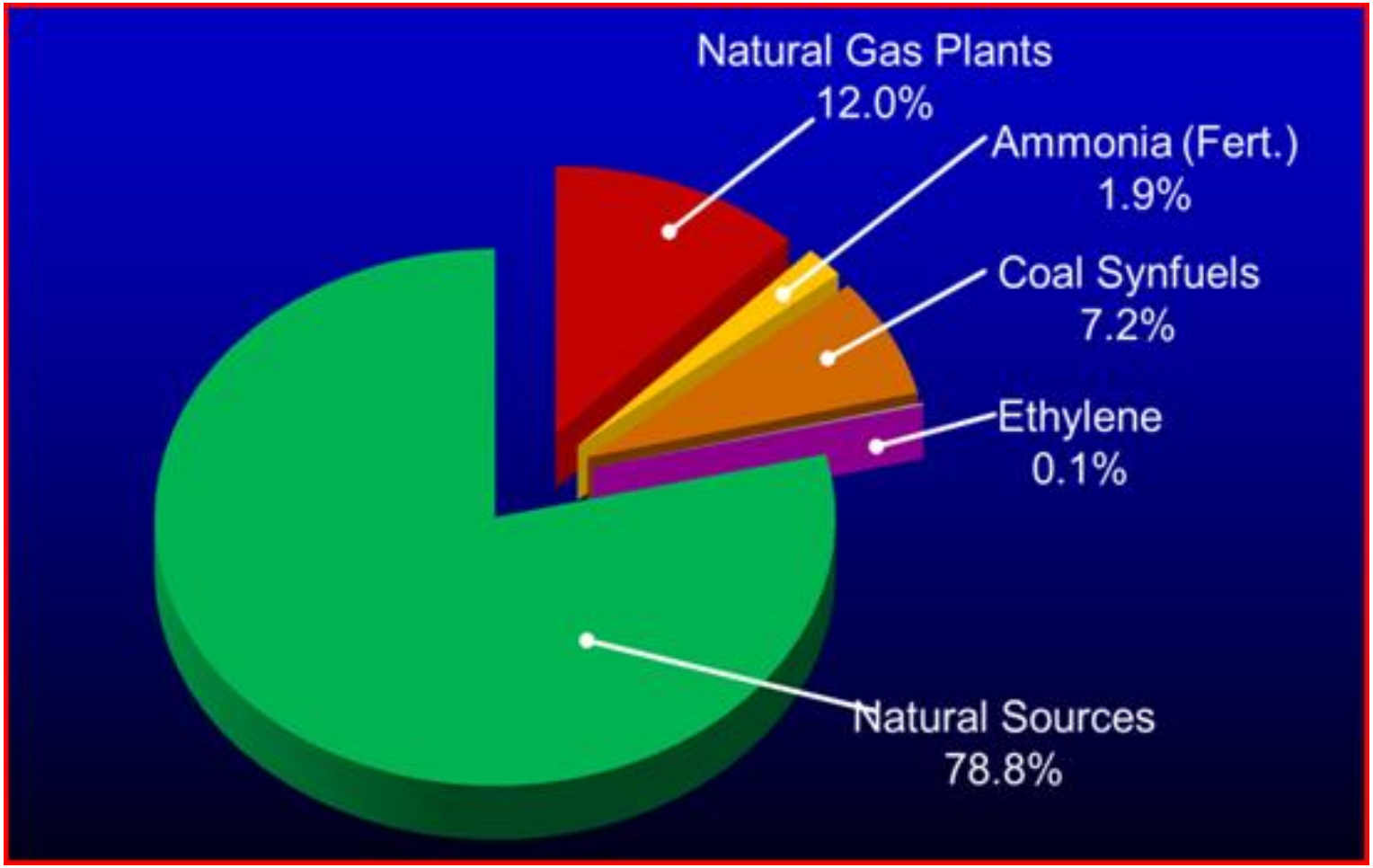
Characteristics of CO2 Enhanced Oil Recovery Projects

- Considered a “tertiary” process: typically applied after waterflooding
- Incremental recoveries due to CO2 can range from 8% to18% with an average of 12%.
- Critical issue: need inexpensive source of CO2. This has historically been an issue in California.

- Criteria for Appropriate Reservoirs for CO2 Flooding:
  - Greater than 2000 feet deep
  - Producing “light” oil, that is, oil with an API gravity > 25 degrees
  - Pressure that has been maintained through waterflooding
  - Homogenous reservoir –so that the CO2 does not channel through” thief zones

CURRENT CO_2 SOURCES, PIPELINES

Source of North American CO_2 Deliveries for EOR



Sources of Carbon Dioxide for EOR

- Naturally Occurring CO2 reservoirs
- Natural Gas Separation Plants
- Ammonia Plants – Texas & Oklahoma
- Ethanol Plants –Kansas
- Ethylene Plants - Alberta
- Coal Gasification
  - North Dakota (providing CO2 to Weyburn)
  - Texas Clean Energy Project (planned)
  - California: Hydrogen Energy (planned)
- Potential Sources:
  - Refineries
  - Power Plants (post combustion capture)

Picture of a CO2 Pipeline

California Oil Basins

California CO2 Injection Pilots

Field	Basin	Started	Stopped
East Coyote	Los Angeles	1982	1984
Huntington Beach	Los Angeles	1981	1982
Wilmington (various projects)	Los Angeles	1981	1987
Ventura	Ventura	1988	1988
North Coles Levee	San Joaquin	1981	1984
Lost Hills	San Joaquin	2000	2001
Elk Hills	San Joaquin	2005	2005

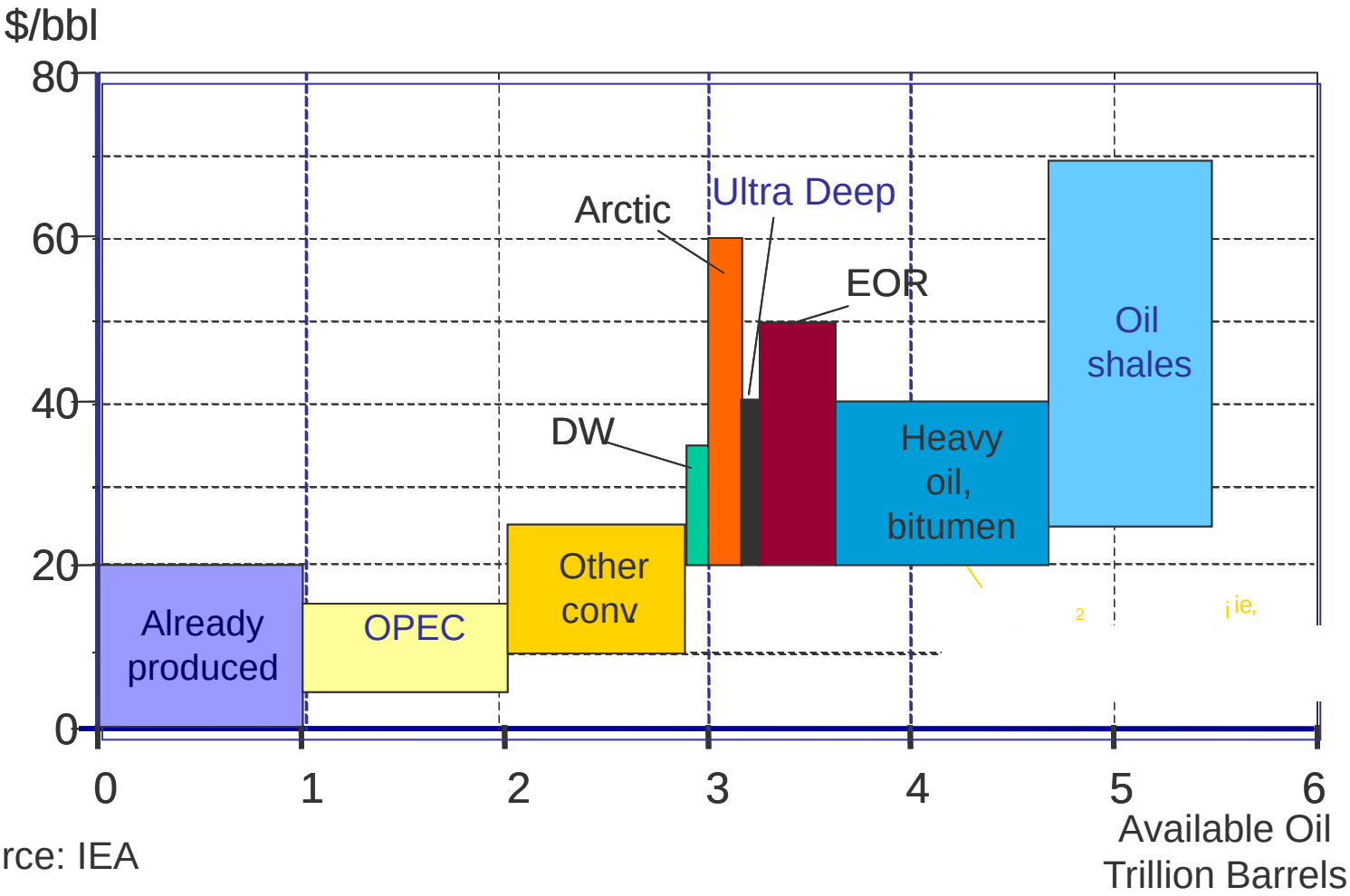
Concluding Remarks

- ✓ CO2 EOR is a proven technology: the industry has had 35+ years of experience with no major incidents.
- ✓ CO2 EOR has become the leading EOR method in the world. It has the potential to add lessen the US dependence on foreign oil.
- ✓ Oil companies are motivated to closely monitor the fate of the CO2 they inject- it is a valuable commodity that they purchase.
- ✓ CO2 EOR cannot be applied to all fields. For example, it cannot be applied to “heavy” oil fields such as those in Kern county.
- ✓ A critical factor for a successful CO2 EOR project is access to an inexpensive source of CO2.

Backup

Oil Resources…

But costly to produce, and may be CO2 intensive



Source: IEA

Potential for Worldwide Unconventional Oil Production

Option	MM bbl/d	Key Location
CO2 EOR	3-6	USA
Oil Sands	4-5	Canada
Ultra-Heavy Oils	4-5	Venezuela
Syngas- to- liquids from remote natural gas	2-3	Middle East
Syngas-to-liquids from coal or biomass	1-2	China & USA

Source: SFA Pacific