Critical Challenges. Practical Solutions.

Energy & Environmental Research Center (EERC)

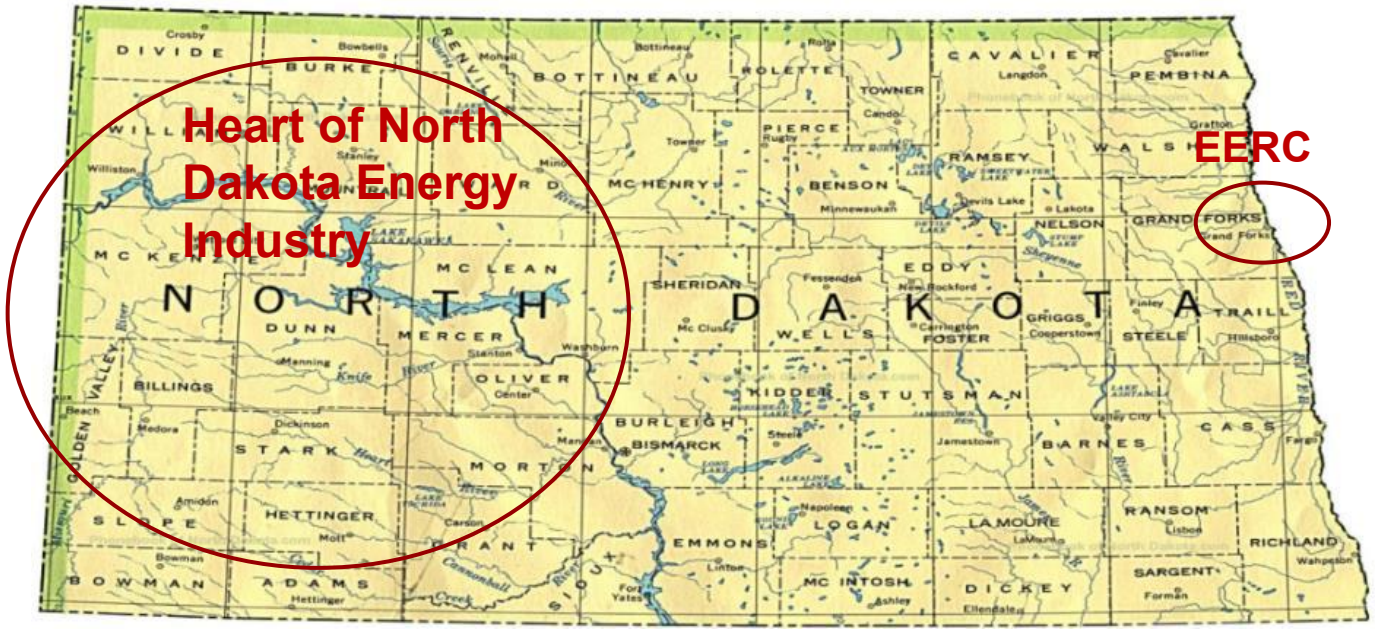
Kentucky Enhanced Oil Recovery Potential

KOGA's 88th Annual Meeting
Campbell House Hotel, Lexington, KY
June 26, 2025

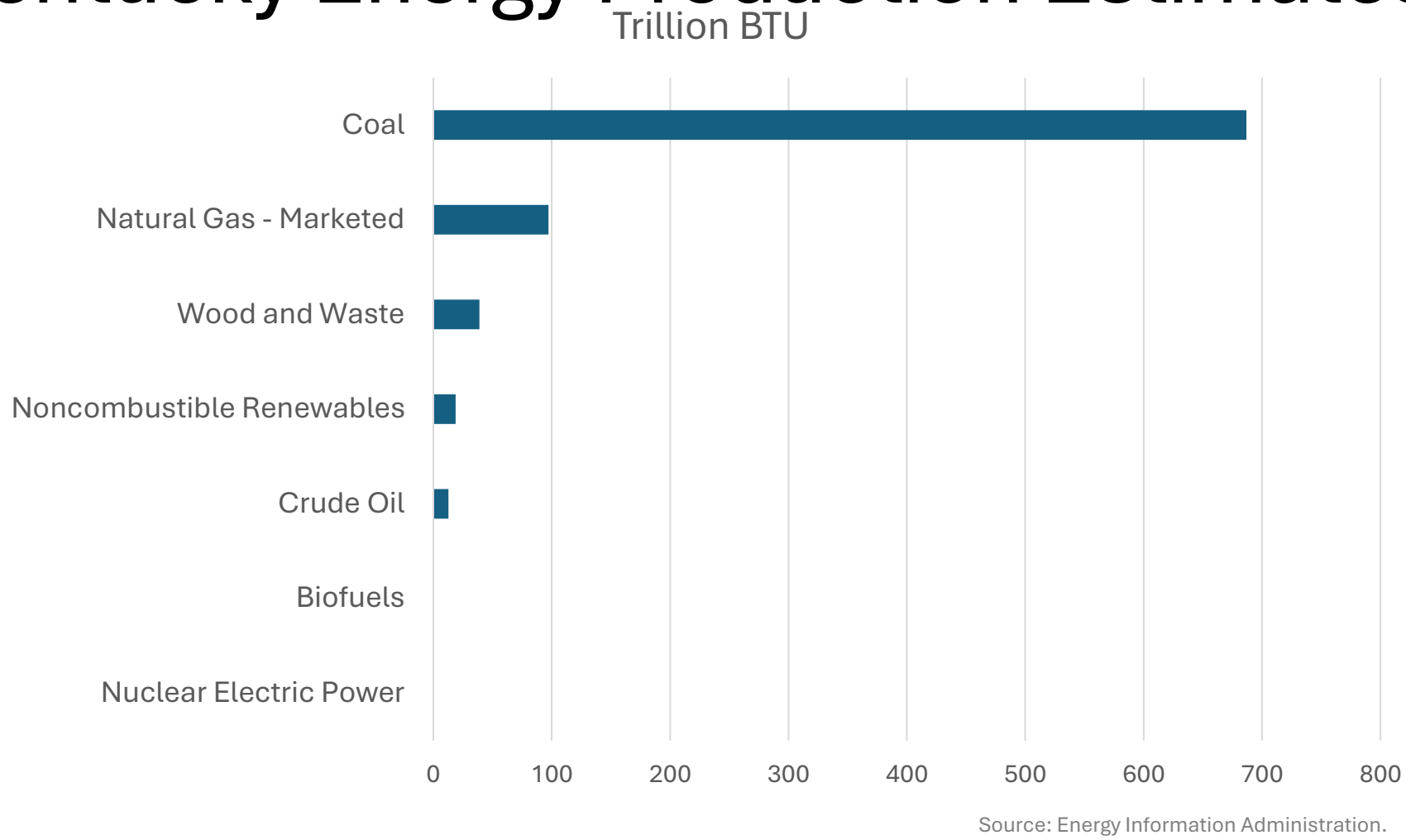
Charles Gorecki
CEO

Energy & Environmental Research Center (EERC)

- Nonprofit branch of the University of North Dakota
- Over 250 employees focused on energy and environmental solutions
- More than 254,000 square feet of state-of-the-art laboratory, demonstration, and office space

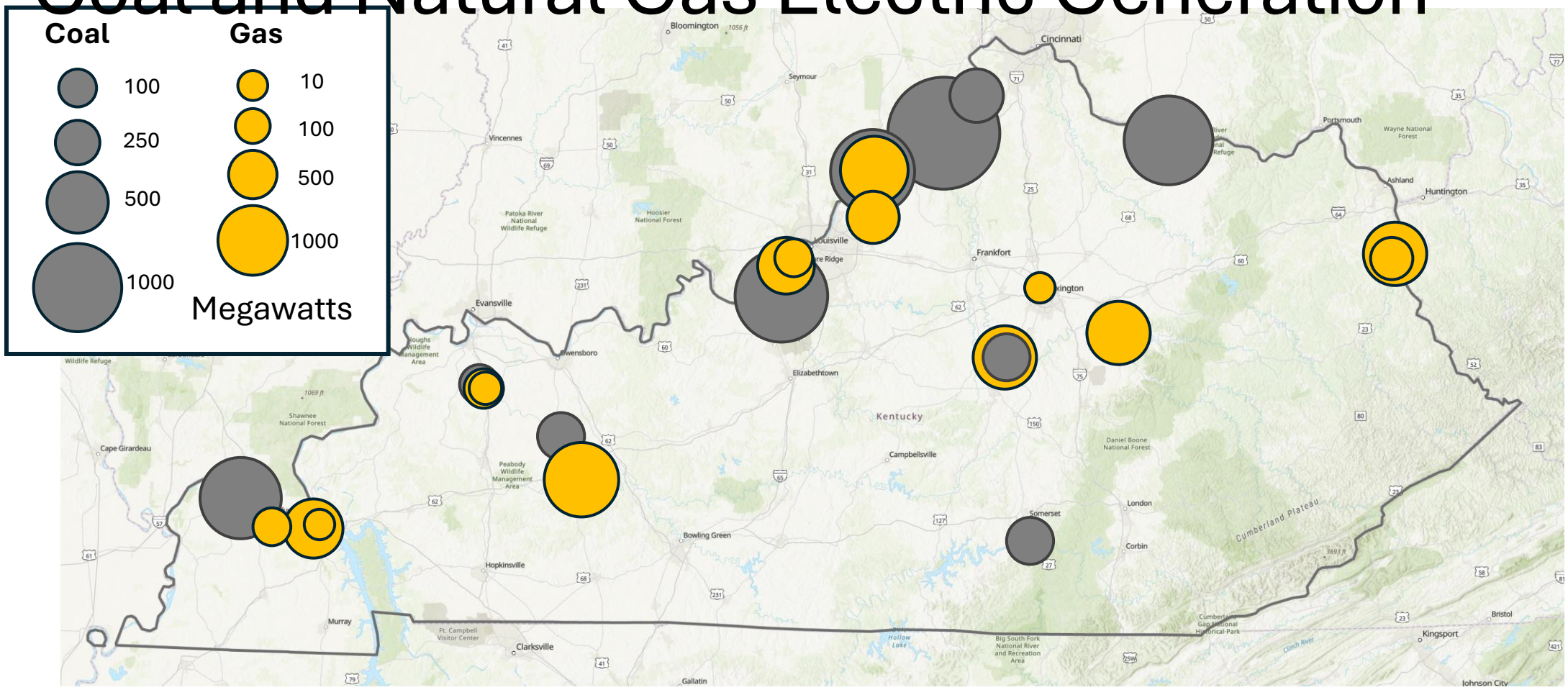


Kentucky Energy Production Estimates, 2022

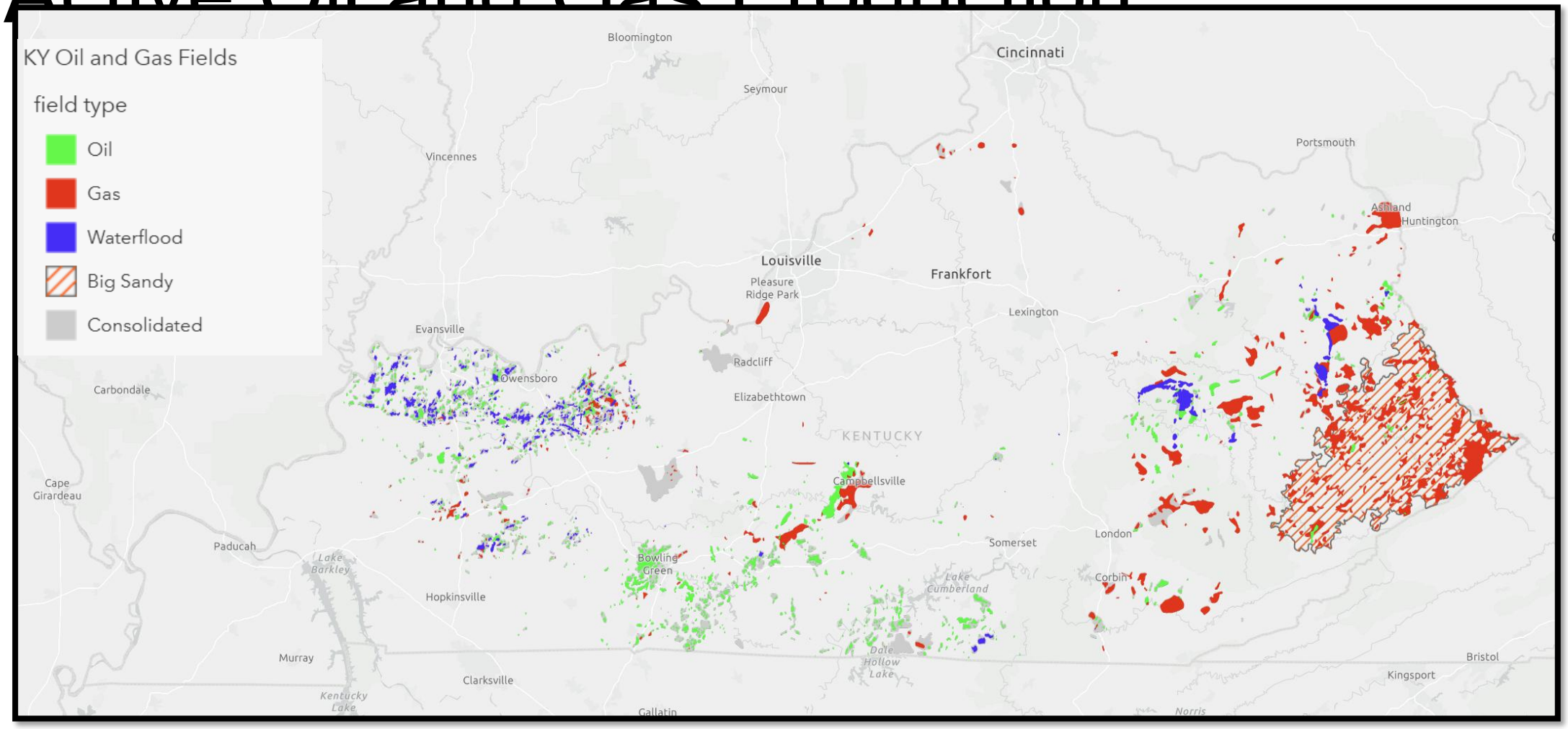


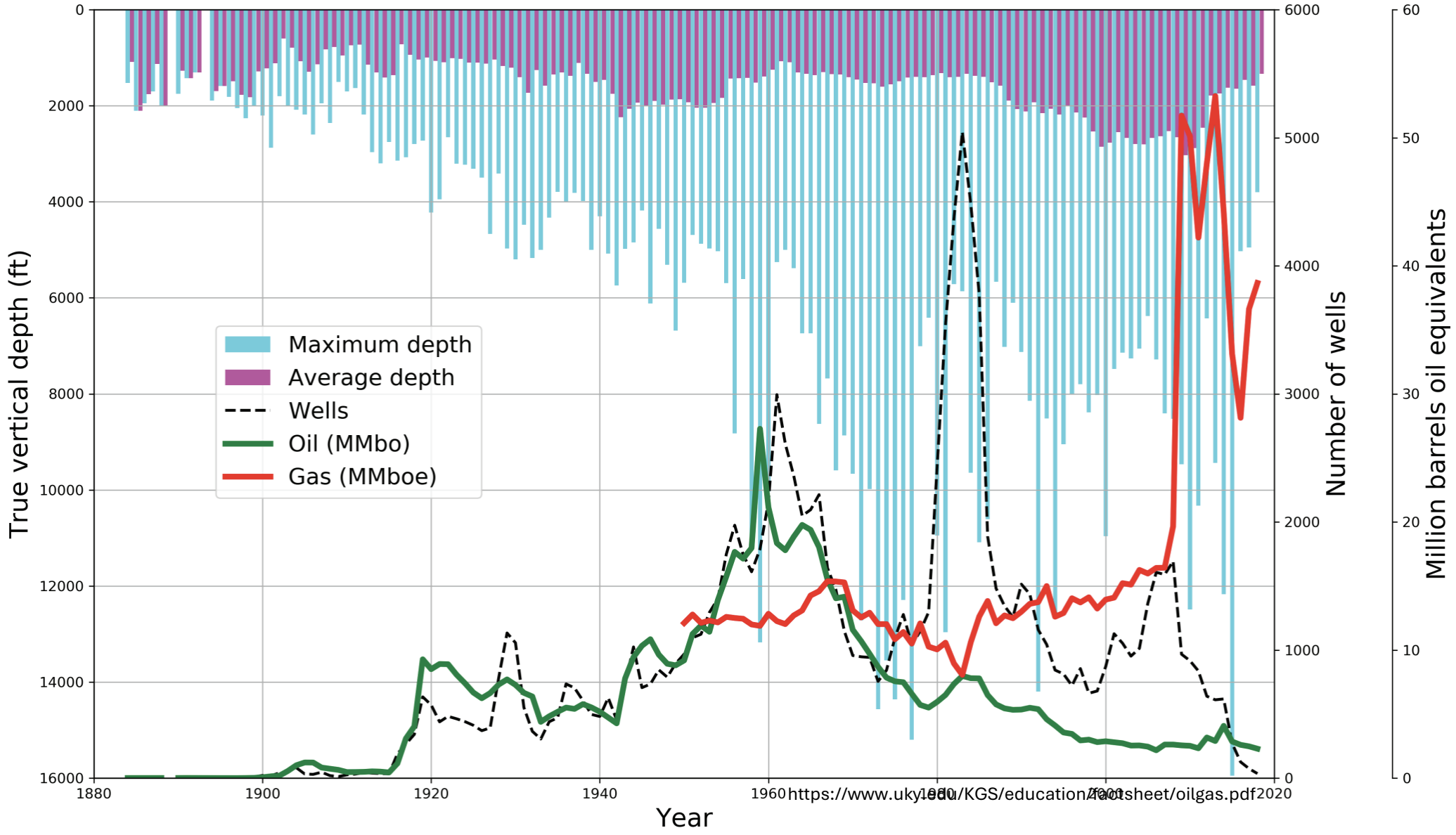
Source: Energy Information Administration.

Coal and Natural Gas Electric Generation

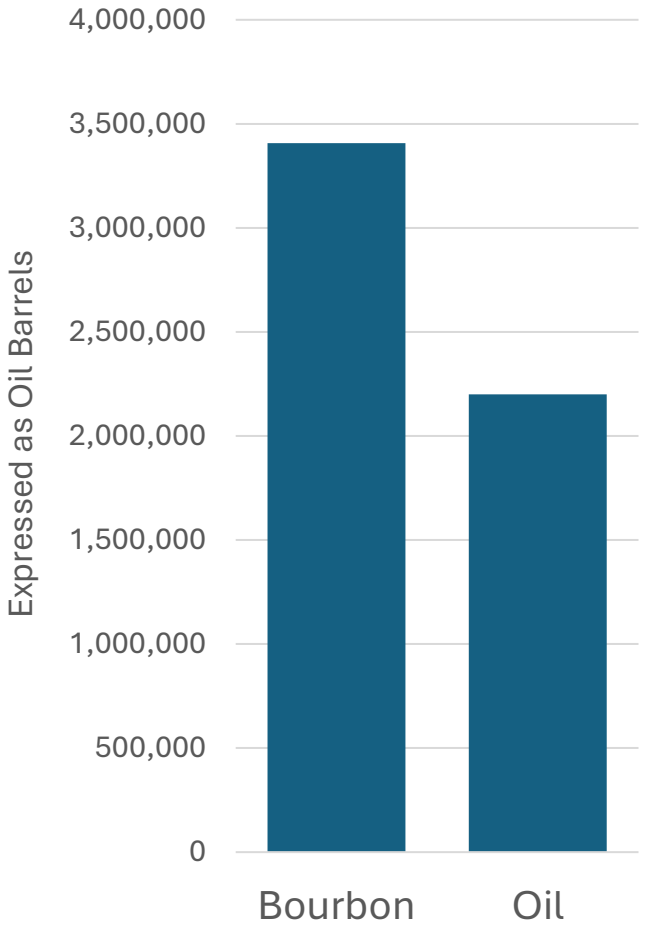


Active Oil and Gas Production




Maximum depth
Average depth
Wells
Oil (MMbo)
Gas (MMboe)
True vertical depth (ft)
Number of wells
Million barrels oil equivalents
Year
0
2000
4000
6000
8000
10000
12000
14000
16000
1880
1900
1920
1940
1960
1980
2000
2020
https://www.uky.edu/KGS/education/factsheet/oilgas.pdf

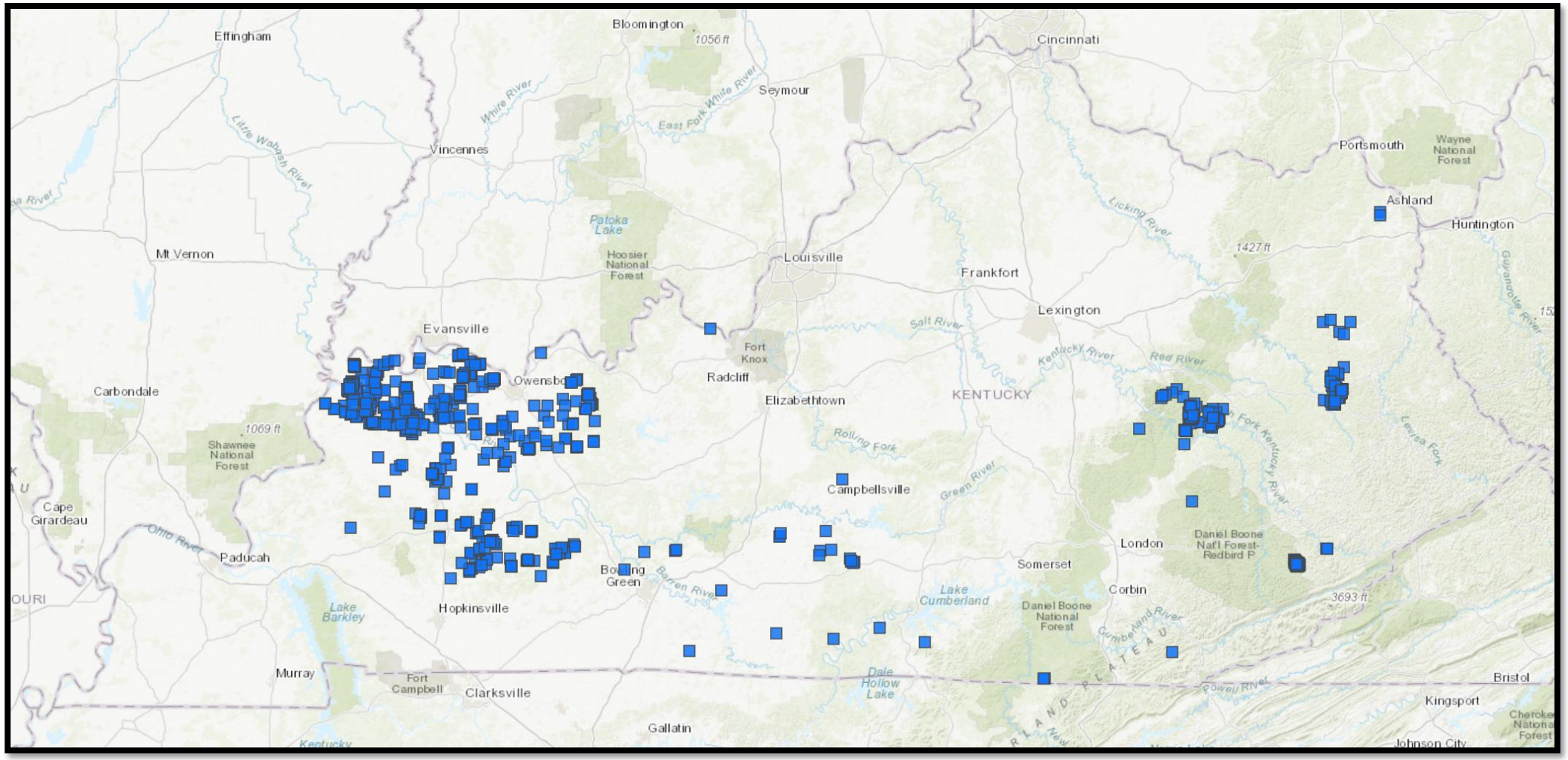
2022 Production Oil versus Bourbon



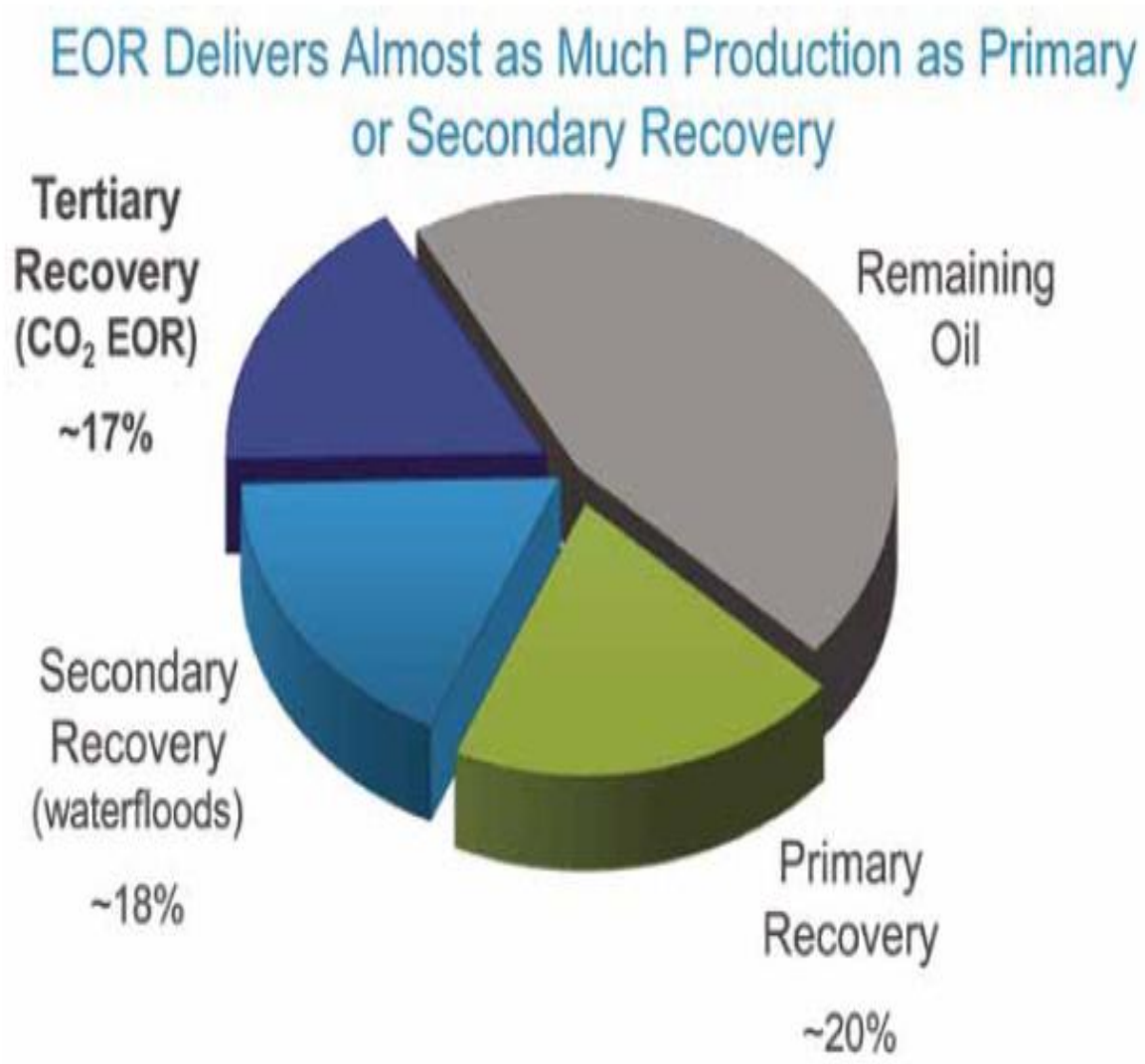
Oil Barrel = 42 gallons
Bourbon Barrel = 53 gallons

Source: www.nbcnews.com.

Distribution of Active Enhanced Recovery Water Injection



Stages of Oilfield Maturity



EOR Using CO_2 – How It Works

- Carbon dioxide (CO_2) dissolves in oil, lowers oil viscosity, and swells the oil, thereby allowing oil to flow more freely.
- CO_2 injection repressures the reservoir, thereby reestablishing a drive mechanism.
- A portion of the injected CO_2 will be produced with the oil and water, separated at the surface, and recycled to be used again in the

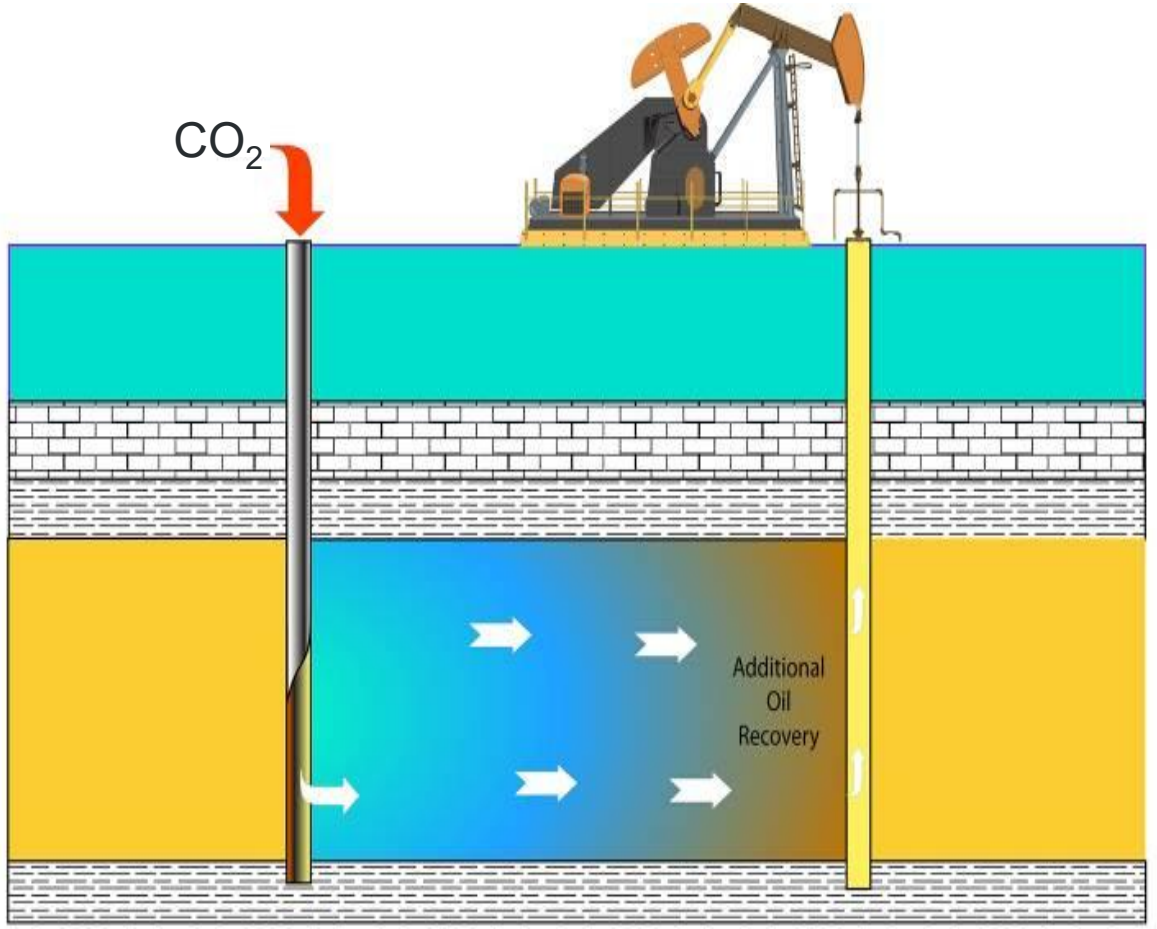
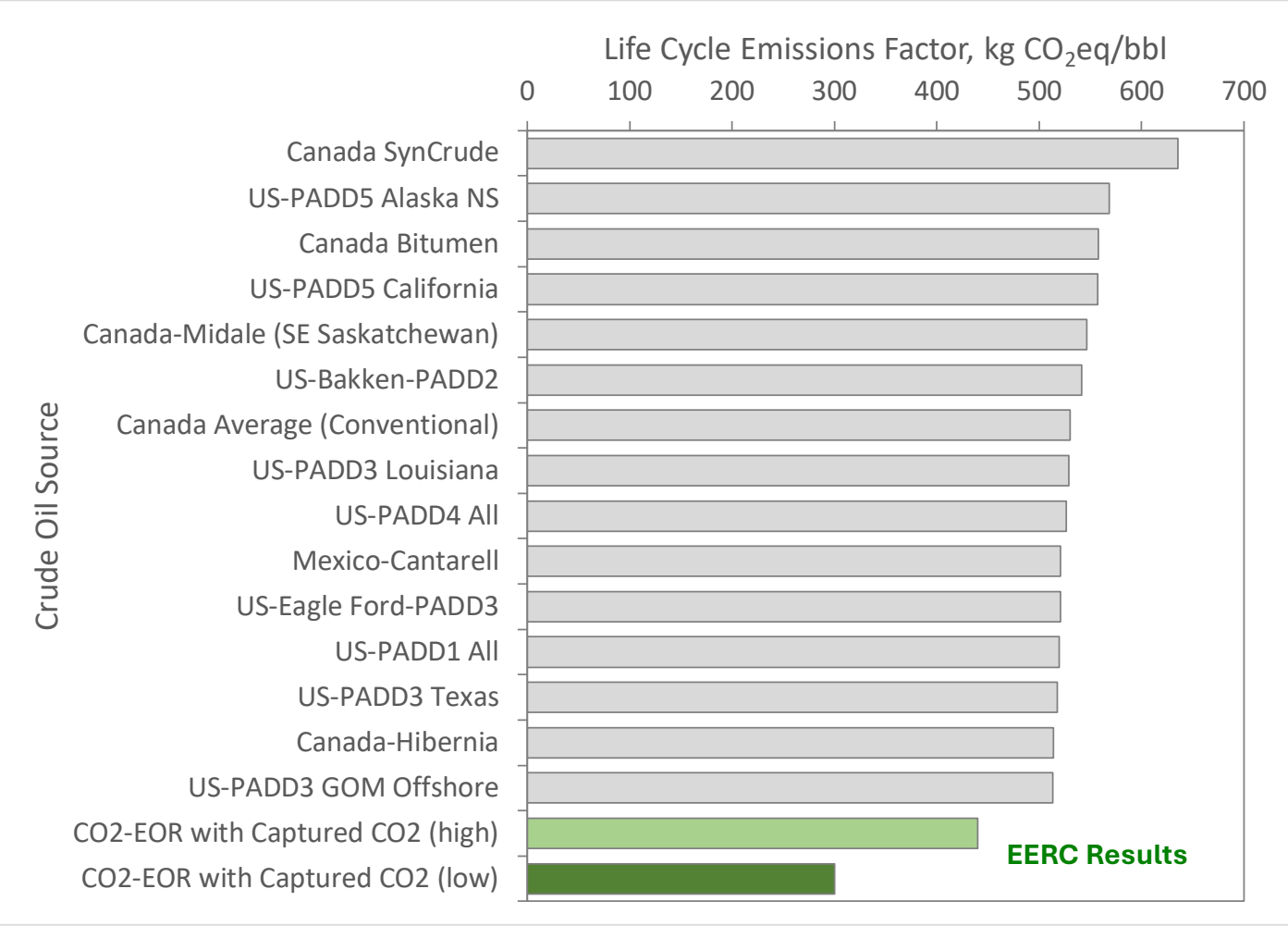


Image shows “Injector–Producer Pair” EOR scheme.

A “huff ‘n’ puff” in a single well is another common EOR scheme.

CO_2 EOR Produces Lower Carbon-Intensity Oil



Adapted from: Cooney, G., Jamieson, M., Marriott, J., Bergerson, J., Brandt, A., and Skone, T.J., 2017, Updating the U.S. life cycle GHG petroleum baseline to 2014 with projections to 2040 using open-source engineering-based models: Environ. Sci. Technol., v. 51, p. 977–987.

Three Immiscible CO_2 EOR Pilot Tests

Big Sinking (1988–1993)

- 1300-ft injection depth
- 240 wells with 390 cyclical gas injection treatments
- 1.2 Mcf/bbl
- Incremental recovery of 180,000 bbl during the 5-year effort
- Utilized CO_2, N_2, and rich gas

Sugar Creek (2009–2010)

- 1850-ft injection depth
- 7300 tons injected during the 1-year test
- 20–30 tons/day
- 10-bopd increase over preinjection rates
- ~3200 bbl of incremental oil
- Early breakthrough at neighboring wells

Euterpe (2010–2011)

- 1860-ft injection depth
- Single-well cyclic injection
- 3–4-week soak time
- 80 tons injected
- 2.7-bopd increase (200%)

Conclusions: Immiscibility between CO_2 and oil will be the prevailing condition in most Kentucky reservoirs (approximately 90%) and limit CO_2 EOR effectiveness.

2020 Investigation by the Kentucky Geological Survey

Evaluation of Geologic CO_2 Sequestration Potential and CO_2 Enhanced Oil Recovery in Kentucky

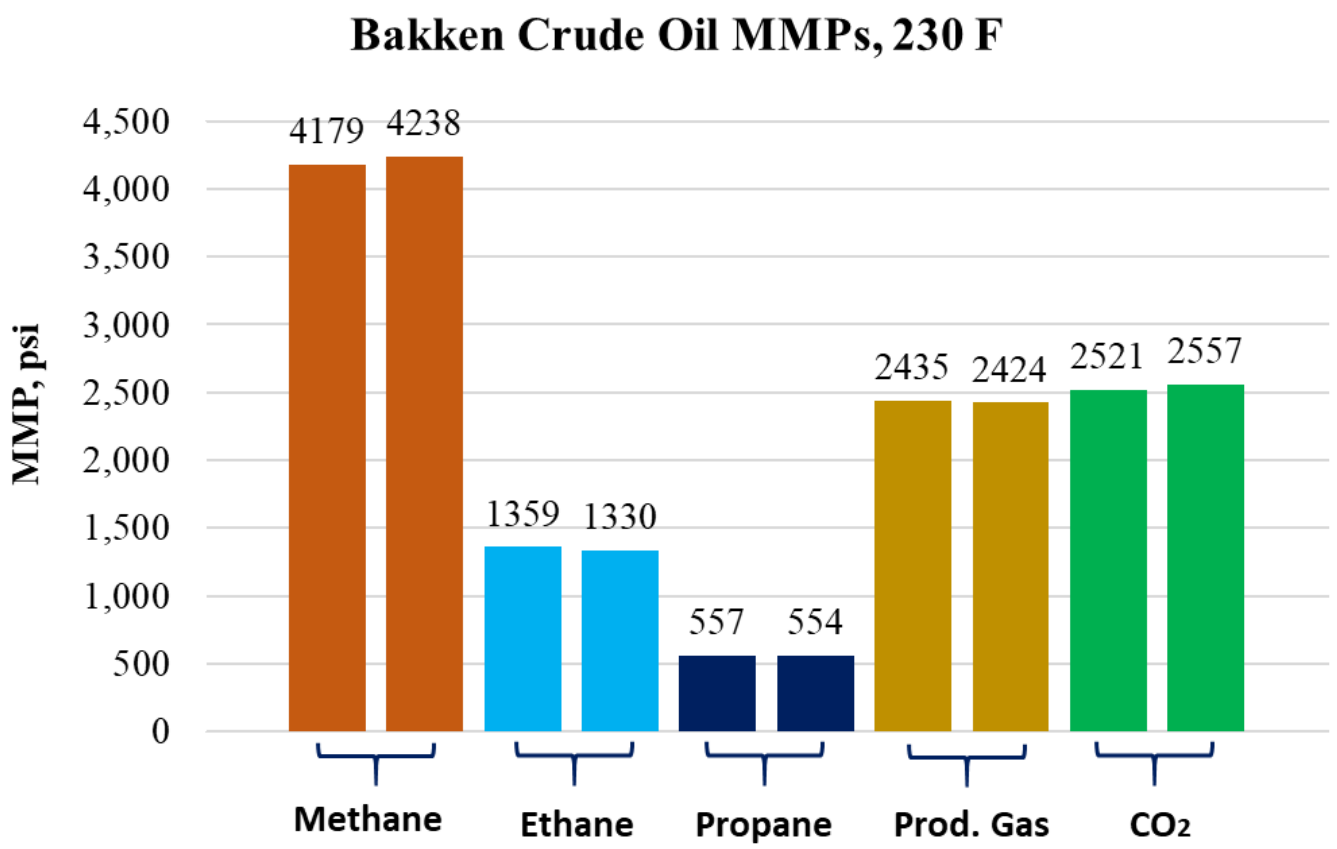
Thomas M. Parris,
Stephen F. Greb,
Brandon C. Nuttall

- Examined 70 reservoirs in 51 oil fields.
- Most reservoirs were well below the calculated minimum miscibility pressures.
- 53% of the fields could be pressured to miscible or near-miscible conditions (800–1200 psi).
- No reported forecast of incremental oil recovery.

https://kgs.uky.edu/kgsweb/olops/pub/kgs/Energy/RI21_12/RI21_12_Chapter2.pdf.

What Goes On at MMP?

Minimum Miscibility Pressure of Various Solvents



Minimum miscibility pressures (psig) at 230°F:

- Methane: 4718–4238
- Ethane: 1359–1330
- Propane: 557–554
- Produced Gas: 2435–2424
- CO_2: 2521–2557

NGLs' Ability to Dissolve Crude Oil*

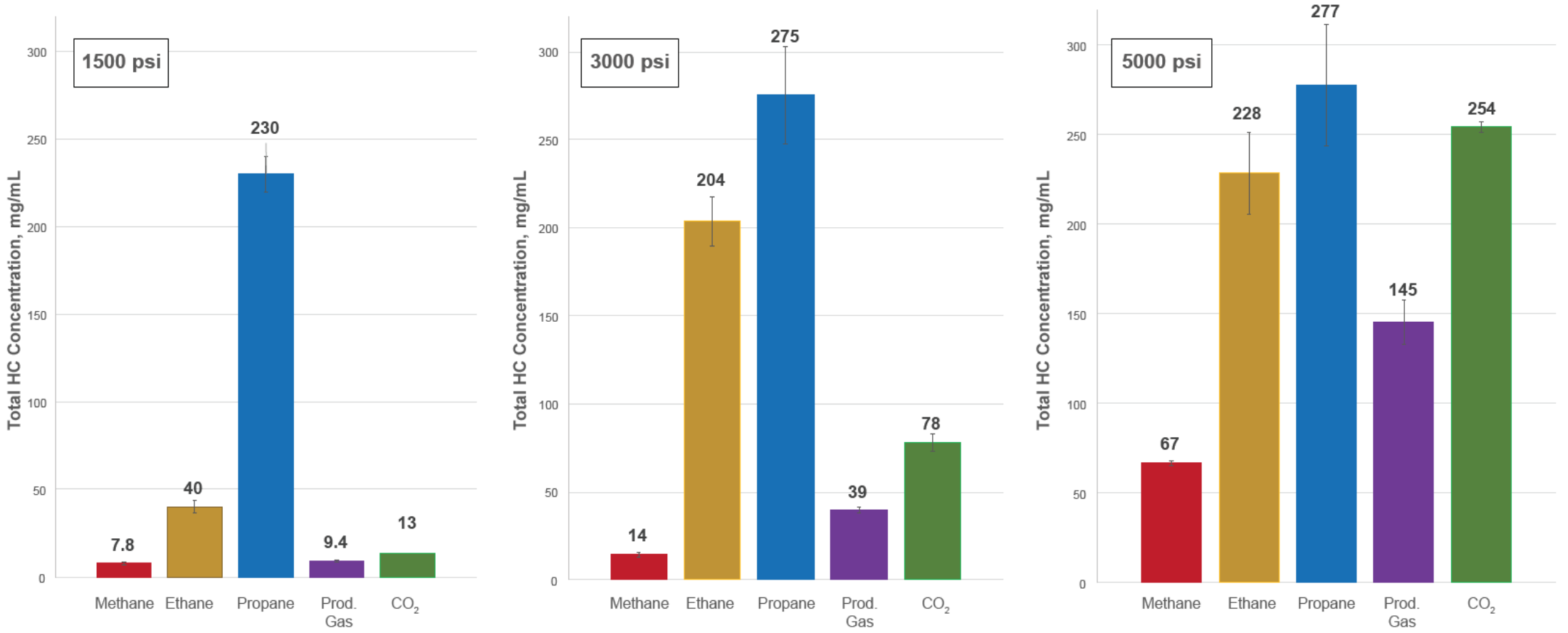


Figure 2: Effect of pressure on the abilities of CO_2 and hydrocarbon gases to dissolve bulk crude oil at the 230°F reservoir temperature.

*As reflected in Laboratory Investigations of CO_2 and Produced Gas EOR and Sorption Potential in the Bakken Petroleum System, EERC, September 2024.

IRS Section 45Q and State Incentives

U.S. Federal 45Q Tax Credits

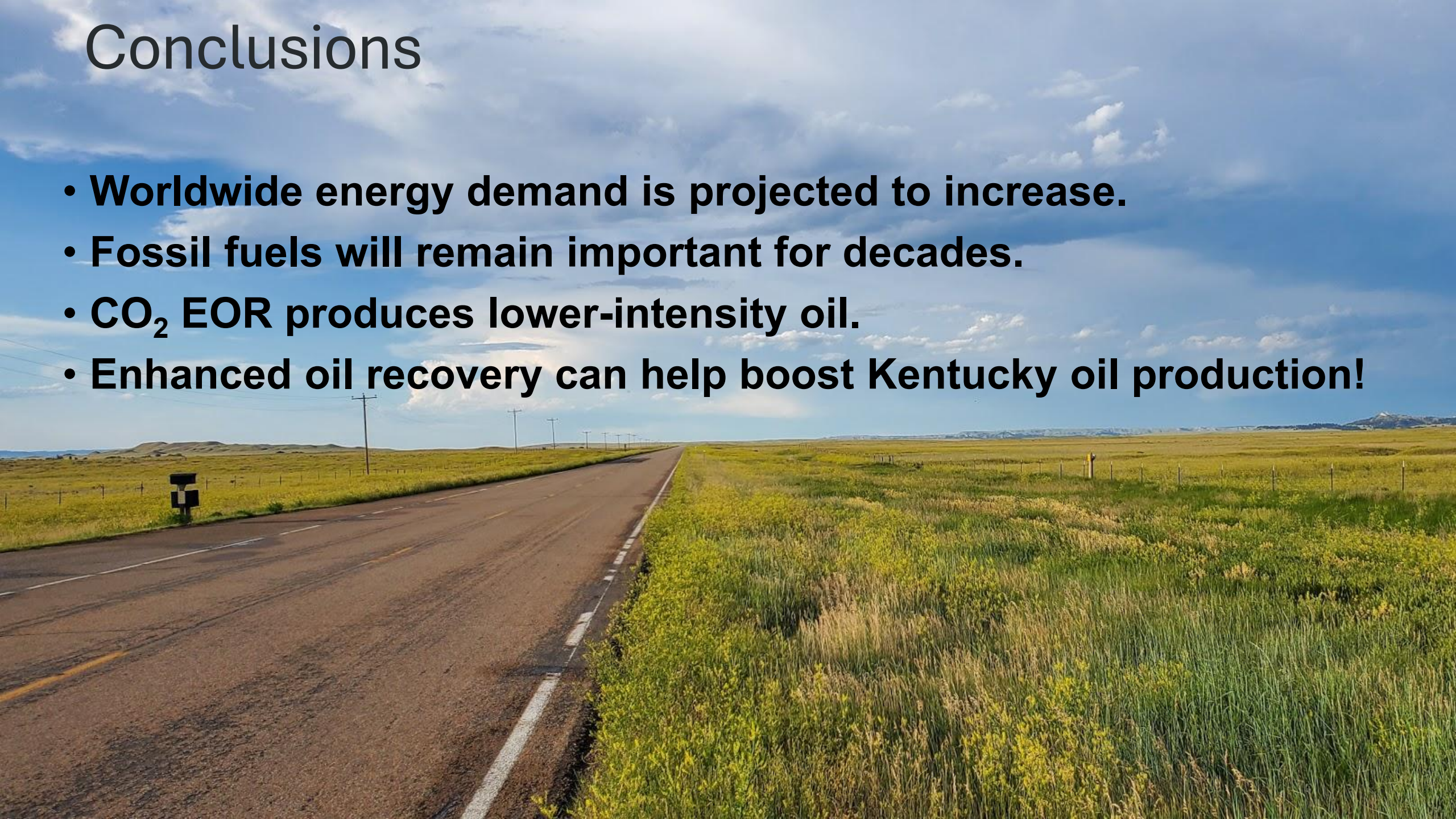
- **$85/tonne** tax credit for CO_2 stored in a **saline formation**
- **$60/tonne** tax credit for CO_2 stored in a **EOR project**
- **$180/tonne** tax credit for CO_2 stored in saline formation as a result of DAC
- **$130/tonne** tax credit for CO_2 stored in a EOR project as a result of DAC

North Dakota EOR Tax Incentives

- No sales tax on CO_2 sold for EOR
- No sales tax on CO_2 capture or pipeline infrastructure
- Property tax-exempt for 10 years
- No sales tax on CO_2 EOR infrastructure
- 0% extraction tax for 20 years for CO_2 E

Image Credit – EERC

Conclusions



- **Worldwide energy demand is projected to increase.**
- **Fossil fuels will remain important for decades.**
- **CO_2 EOR produces lower-intensity oil.**
- **Enhanced oil recovery can help boost Kentucky oil production!**

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THANK YOU

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Big Sinking Field (eastern Kentucky) CO_2 EOR Test 1988–1993

Conclusions of the first test:
The cyclic CO_2 program was successfully applied to 240 wells with 390 treatments performed. The overall efficiency was 1.2 Mcf/bbl, resulting in an incremental recovery of 180,000 bbl during the 5-year effort.

Conclusions of a second test:

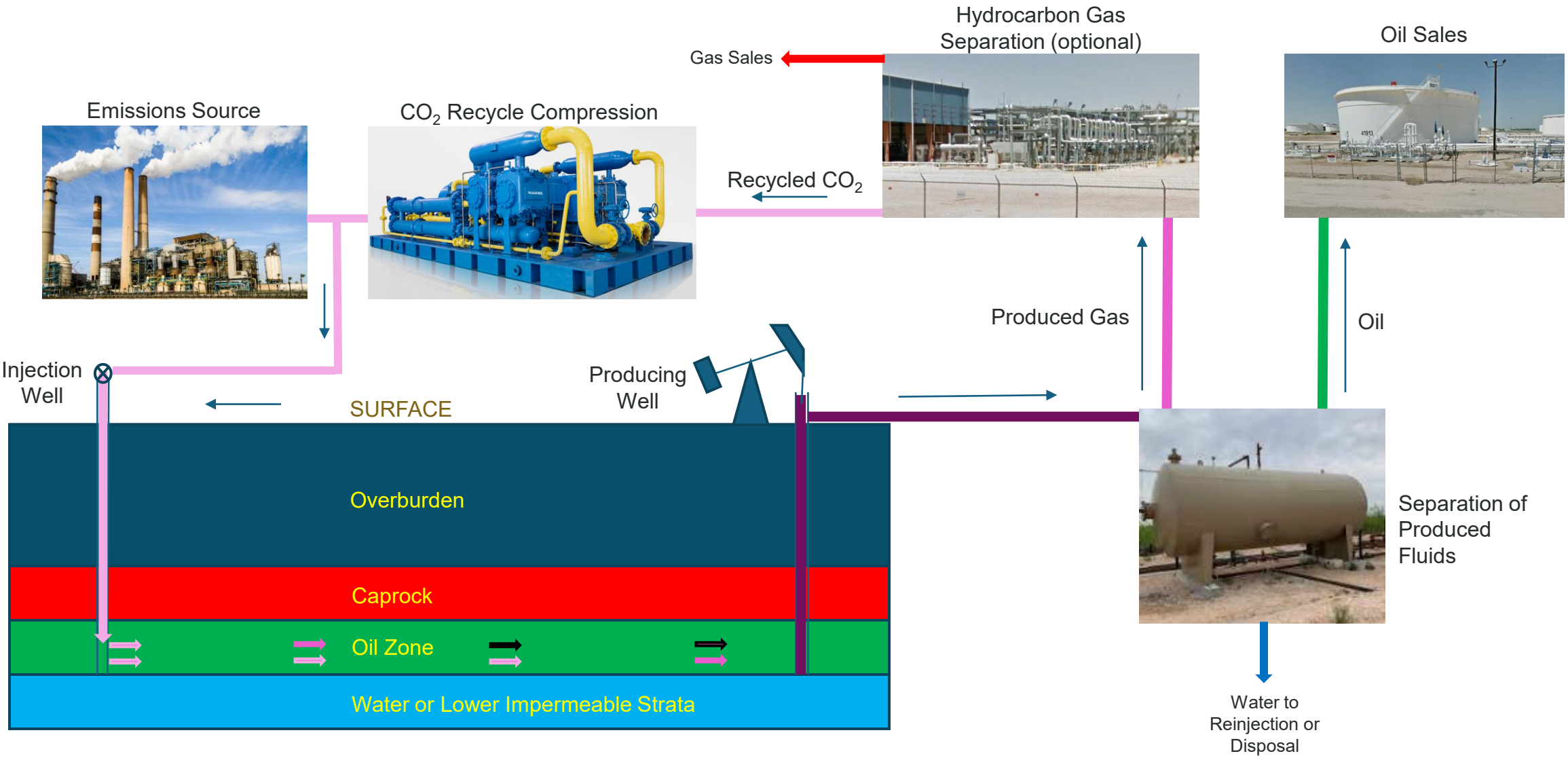
- N_2/CO_2 and rich gas were both shown to be effective in recovering additional oil.
- Significant improvement in the cyclic recovery cost from CO_2 to rich gas was shown, dropping 80% on the fourth cycle with rich gas on the same lease.
- While the N_2/CO_2 mixture showed a higher recovery efficiency than the rich gas, the rich gas recovery showed a significant reduction in cost per recoverable barrel.
- Longer soak times are needed for the exhaust gas and rich gas recoveries than pure CO_2 cycles.

Immiscible CO_2 application

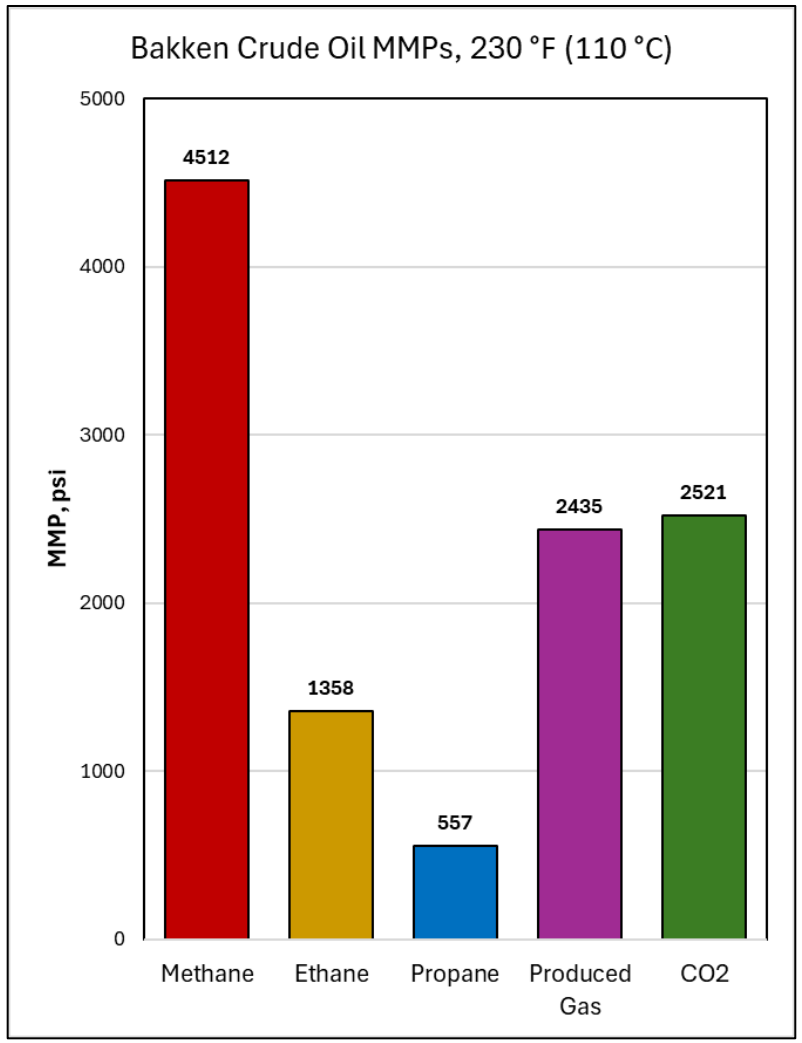
Reservoir properties:

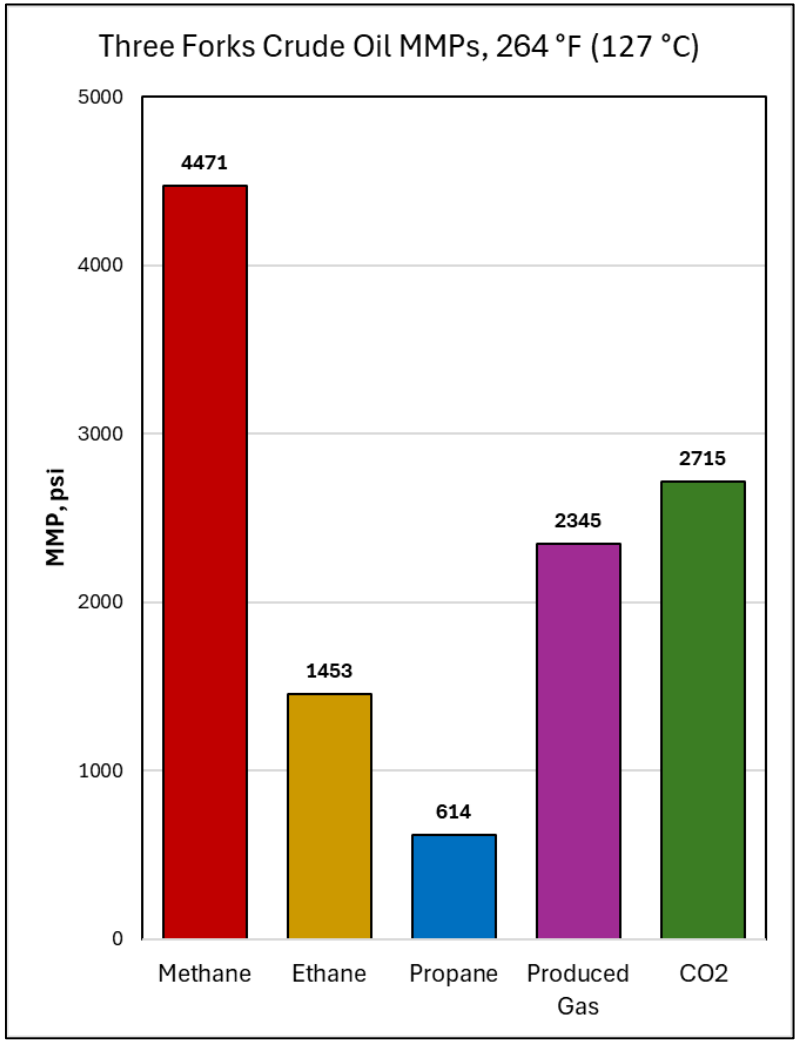
- Depth (ft): 1300
- Thickness (ft): 60
- Porosity (%): 13
- Water saturation (%): 50
- Permeability (mD): 19
- BHP (psi): 150
- Temperature (°F): 68
- Oil gravity (°API): 38
- Produced gas–oil ratio: 1500:1
- Produced water-oil ratio: 10:1
- Average well spacing (acres): 8

CO_2 EOR: Closed-Loop System for Permanent CO_2 Storage



Miscibility Pressure Based on Various Solvents*





Properties of solvents:

1. Ability to dissolve bulk crude oil: propane, ethane, CO_2, produced gas, methane

2. Pressure required to dissolve heavier hydrocarbons (C20–C36):

Propane:	≥ 1500 psig
Ethane:	≥ 3000 psig
CO_2:	≥ 5000 psig
Produced gas:	> 5000 psig
Methane:	no ability

3. Viscosity of remaining crude oils after exposure:

Propane: Little change
Ethane: Moderate change
CO_2, produced gas, methane: Much higher

*As reflected in Laboratory Investigations of CO_2 and Produced Gas EOR and Sorption Potential in the Bakken Petroleum System, EERC, September 2024