
EERC
Critical Challenges. Practical Solutions.

DEVELOPMENTS IN CO_2, ETHANE, AND RICH GAS EOR: A WILLISTON BASIN PERSPECTIVE

CO_2 & ROZ Conference

Carbon Management Workshop

Midland, Texas

December 4, 2017

John Hamling, Principal Engineer, Oilfield Operations

Critical Challenges. Practical Solutions.

DISCLAIMER

A STATE OF ENERGY PRODUCTION

Sixth in overall U.S. energy production :

- Second in oil
- Sixth in coal

CCUS is key for continuing to provide energy in a clean, affordable, reliable manner.

Image Credit – Steve Shook[1]

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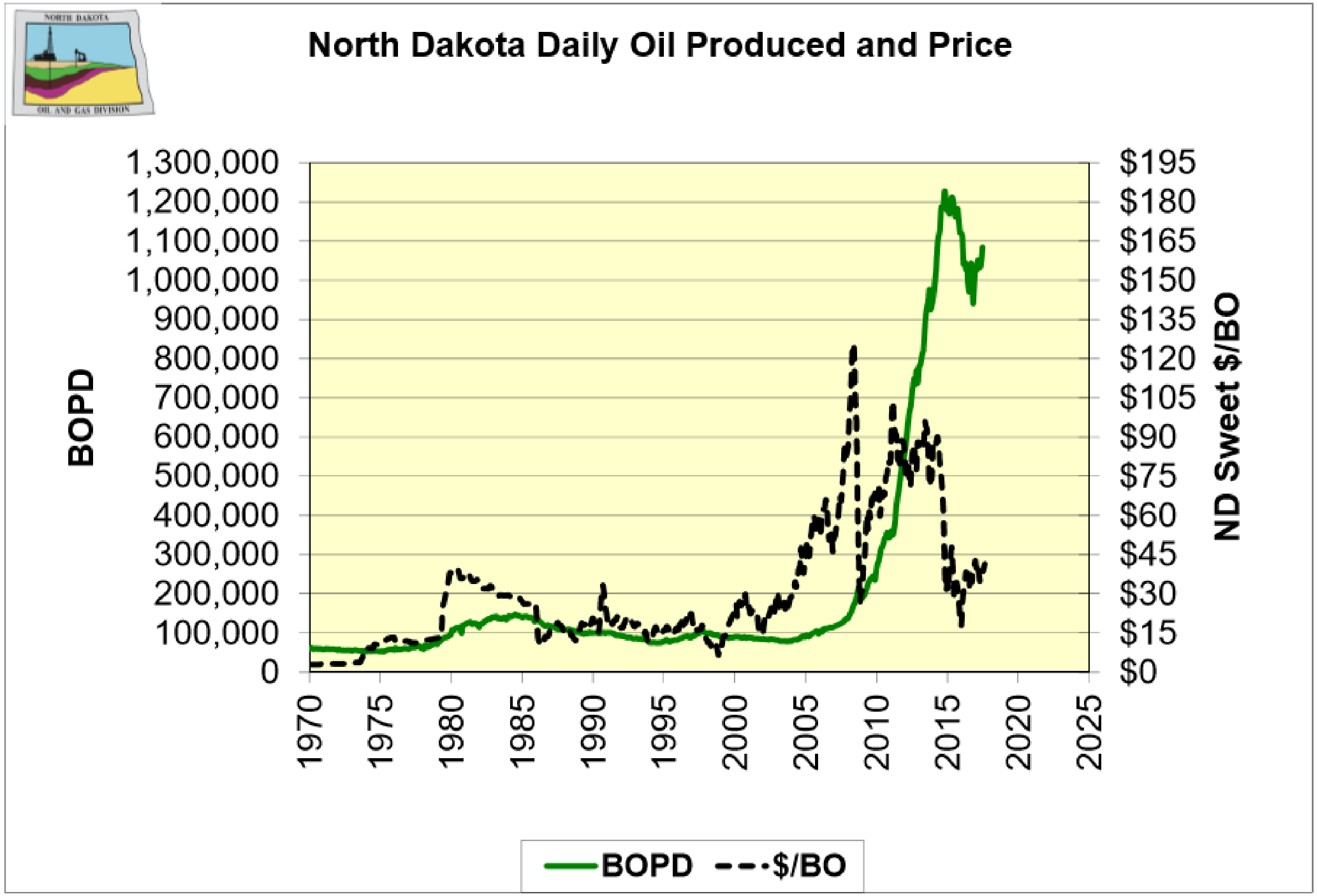
Wells

- 14,080 active
  - 2056 conventional
  - 12,024 Bakken/Three Forks
- 1498 inactive (+$50 for 90 days)
- 863 DUC (+$55 for 90 days)
- 1950 permitted (+$60 for 90 days)
- 13,154 increase density (approved 10/30/2017)
- **31,545 total**
- **55,000–65,000 estimated final**

Estimated $125 billion* in economic investment from wells and oil and gas gathering, processing, and transportation infrastructure (~$150,000 per capita)

**Does not include investments in housing and infrastructure made by private firms and state–local–federal government*



Well economic investment and production information presented by:
The North Dakota Department of Mineral Resources to
the Western North Dakota Energy Association on 11-02-2017:
https://www.dmr.nd.gov/oilgas/presentations/WDEA110217_.pdf

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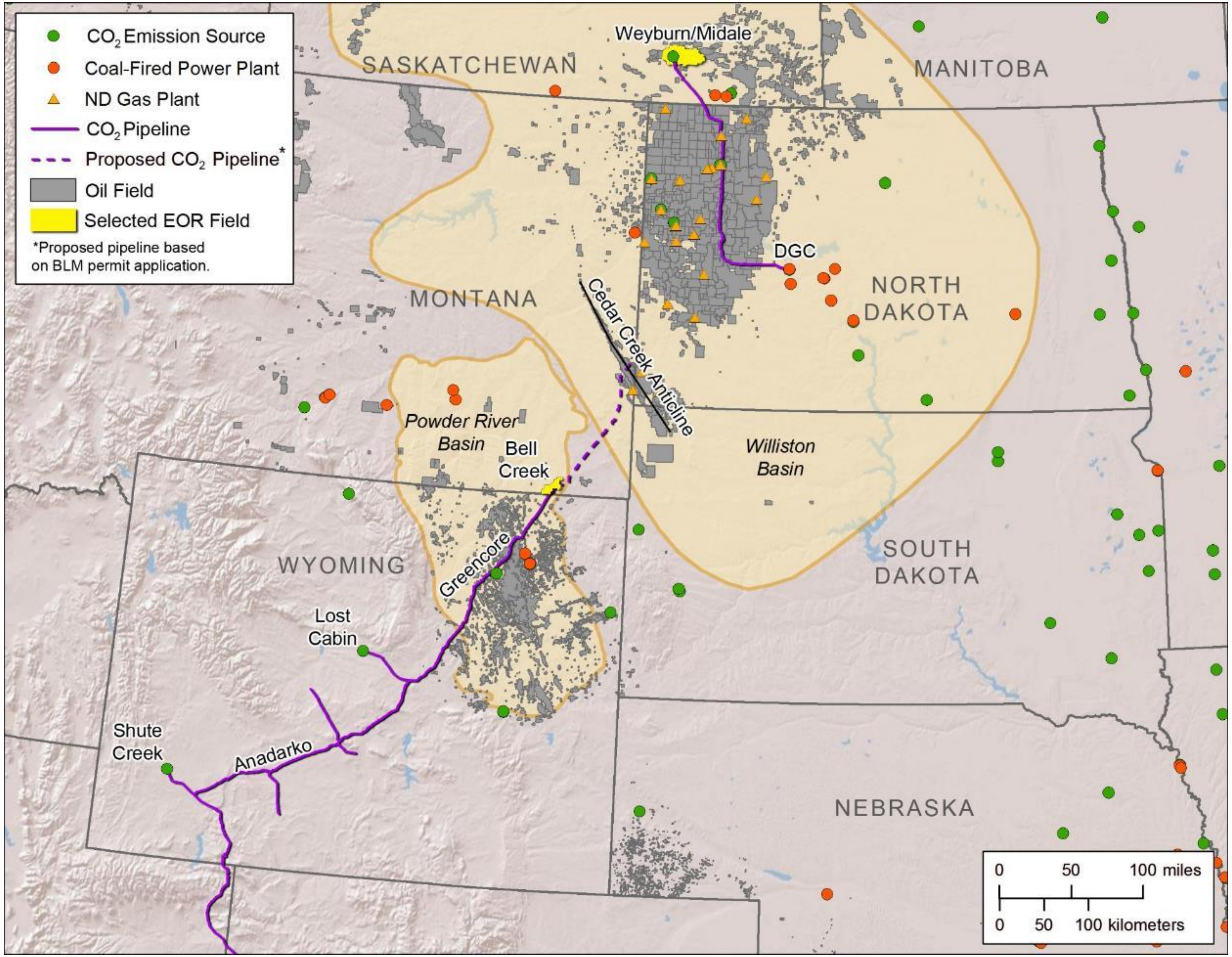
WILLISTON BASIN CCUS POTENTIAL

The Williston Basin is one of the most prolific oil-producing regions of North America.

- **Conventional**
- **Unconventional**
- **ROZs?**
- **Stacked horizons**

An abundance of anthropogenic CO_2 sources.



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IDEAL OPPORTUNITIES

MORE POWER = MORE CO_2


Image Credit – Basin Electric Power Cooperative

Image Credit – EERC


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Image Credit – NACCO Industries


Image Credit – EERC

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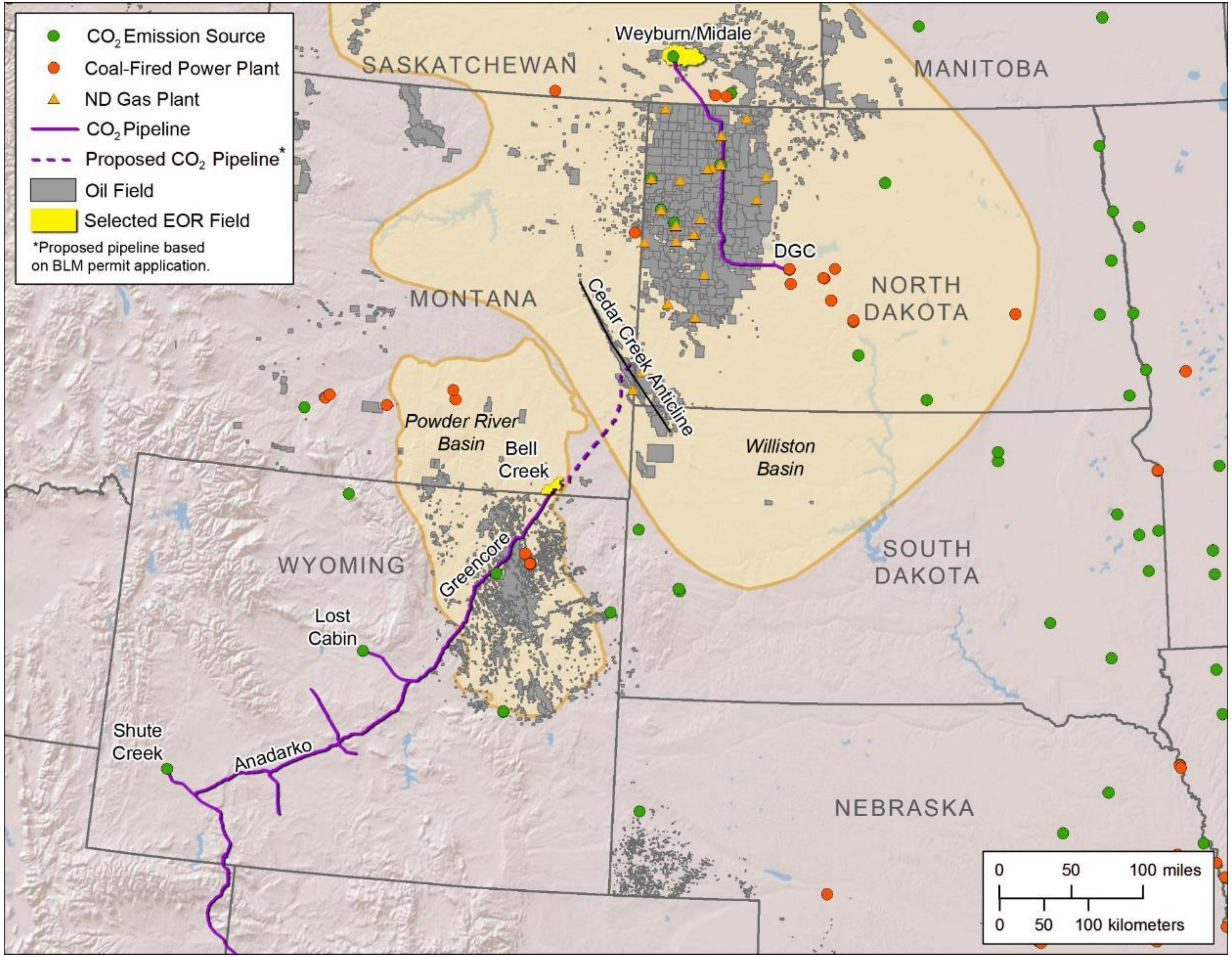

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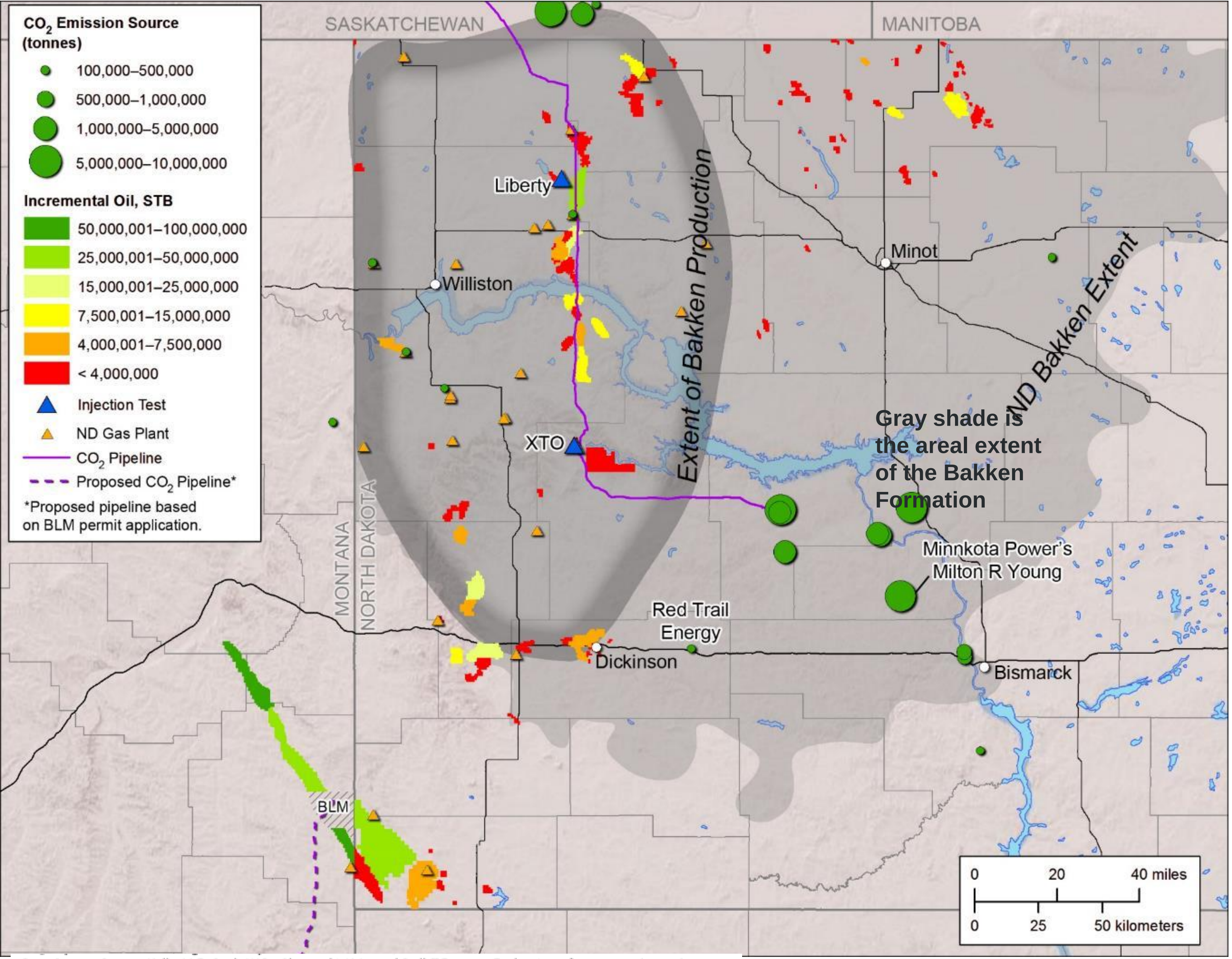
Current Status of North Dakota's Class VI Primacy Application

- EPA has reviewed all comments received and is currently preparing responses to the comments.
  - EPA Region VIII will be responding to comments

Slide copied and modified from a presentation given by NDIC

- EPA's response to comments will be published in the final rule approving North Dakota's Class VI primacy application
- The goal is for North Dakota primacy approval to be published in the Federal Register in January 2018.

NORTH DAKOTA EOR OPPORTUNITIES



-Data Source: Burton-Kelly, M.E., Peck, W.D., Glazewski, K.A., and Doll, T.E., 2014, Evaluation of near-term (5-year) potential for carbon dioxide enhanced oil recovery in conventional oil fields in North Dakota: Final report for Kadrmas, Lee & Jackson, EERC Publication 2014-EERC-07-07, Grand Forks, North Dakota, Energy & Environmental Research Center, July.

In 86 conventional unitized oil fields identified as EOR targets with near-term potential:

- **280 to 630 million bbl of incremental oil**
- **47 to 283 million metric tons of CO_2 needed**

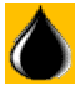
UNCONVENTIONAL BAKKEN AND THREE FORKS

OOIP Estimates

300 Bbbl
(Flannery and Kraus, 2006)

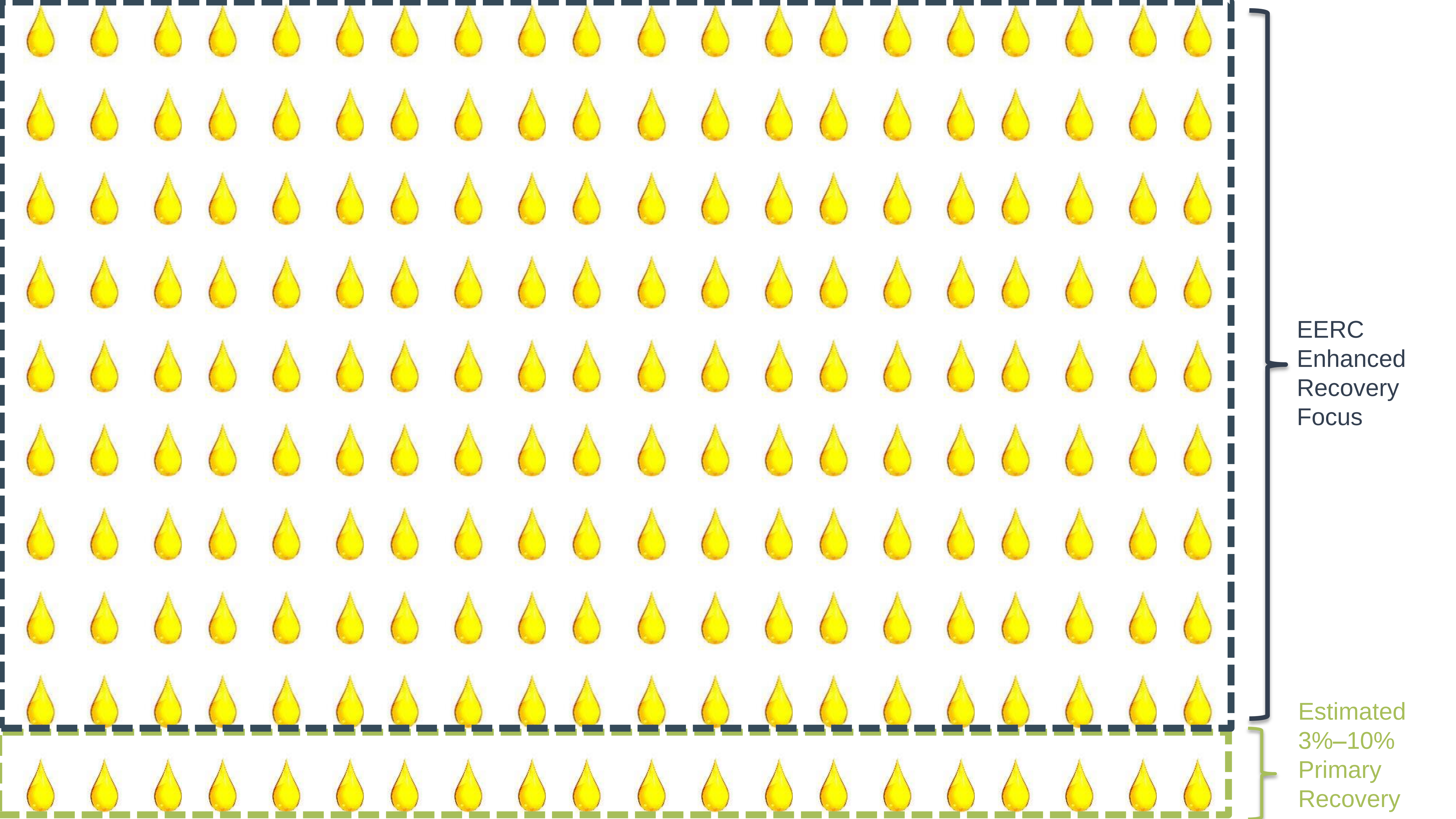
900 Bbbl
(Continental Resources, 2011)

Technically Recoverable Reserve Estimates



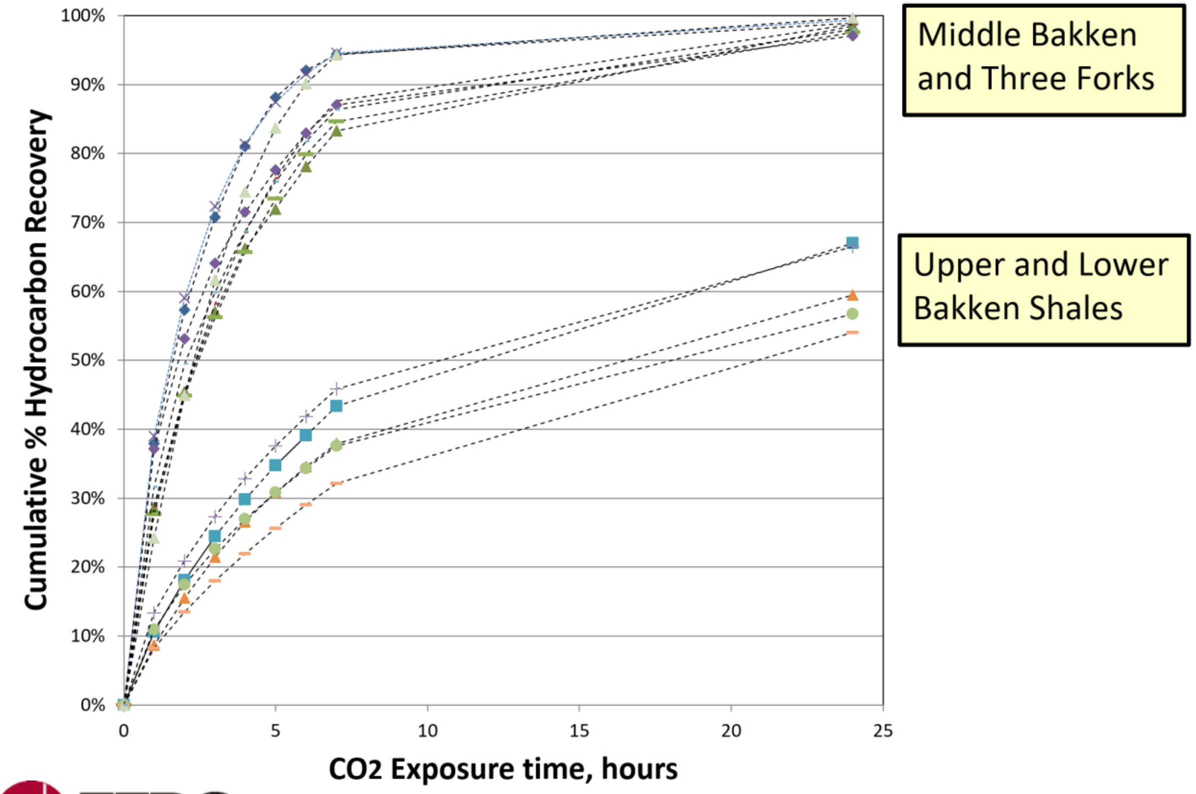
7.4 Bbbl
(USGS, 2013)

24 Bbbl
(Continental Resources, 2011)


EERC Enhanced Recovery Focus
Estimated 3%–10% Primary Recovery

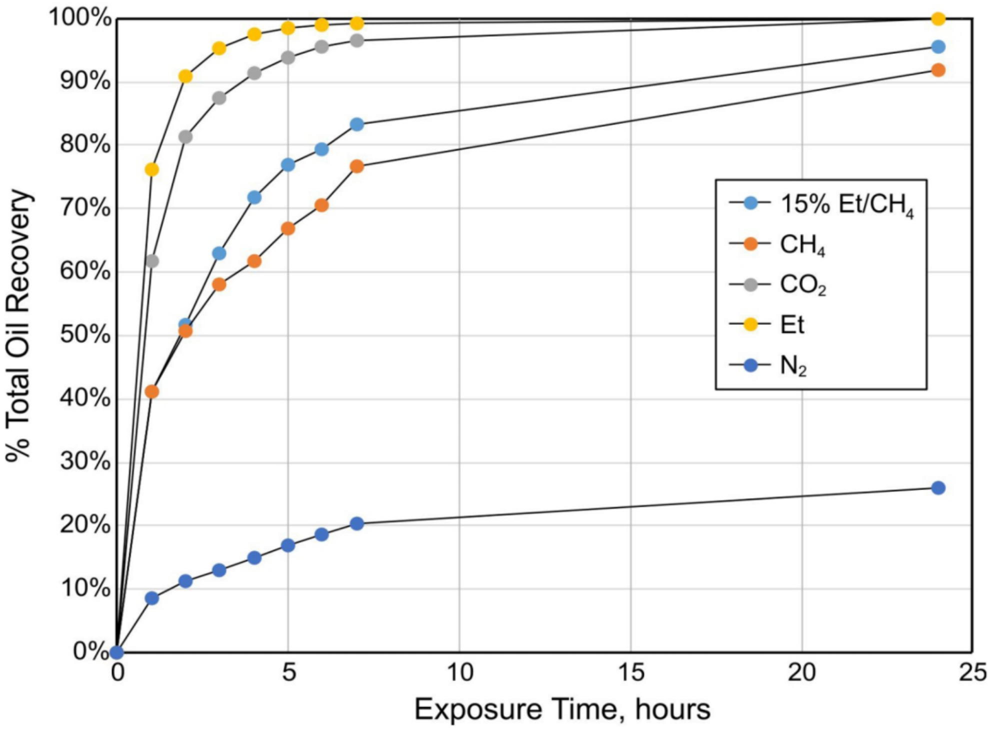
BAKKEN EXTRACTION (LABORATORY)

Laboratory CO_2 Recovery of oil Hydrocarbons from a single McKenzie County well. (5000 psi, 110 C, well 24123)



Oil recovery from a Middle Bakken laminated zone rod show different recoveries, even though all fluid pressures are above their MMP (except N2).

(110 C, CH4 and N2 at 6000 psi, other fluids at 5000 psi)



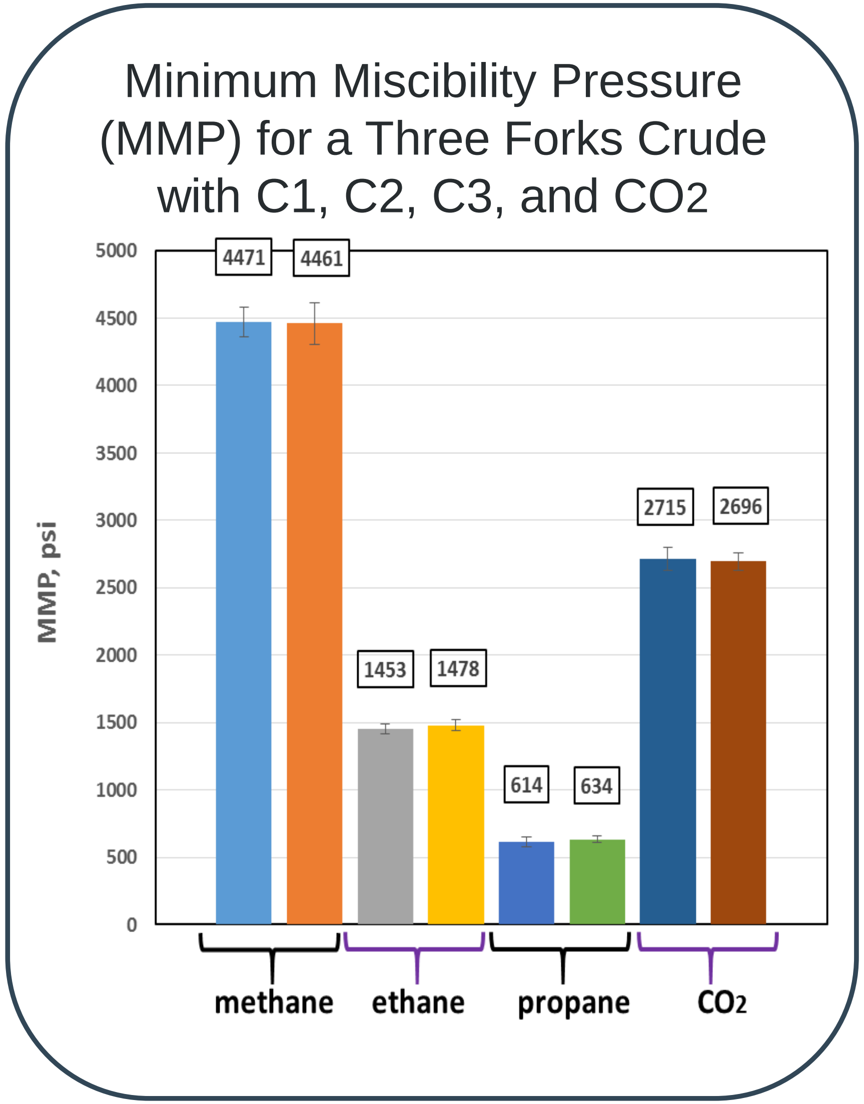
CO_2 and Produced Gas Experiments to support EOR projects: Pure CO_2, C1, C2, C3, and their mixtures.

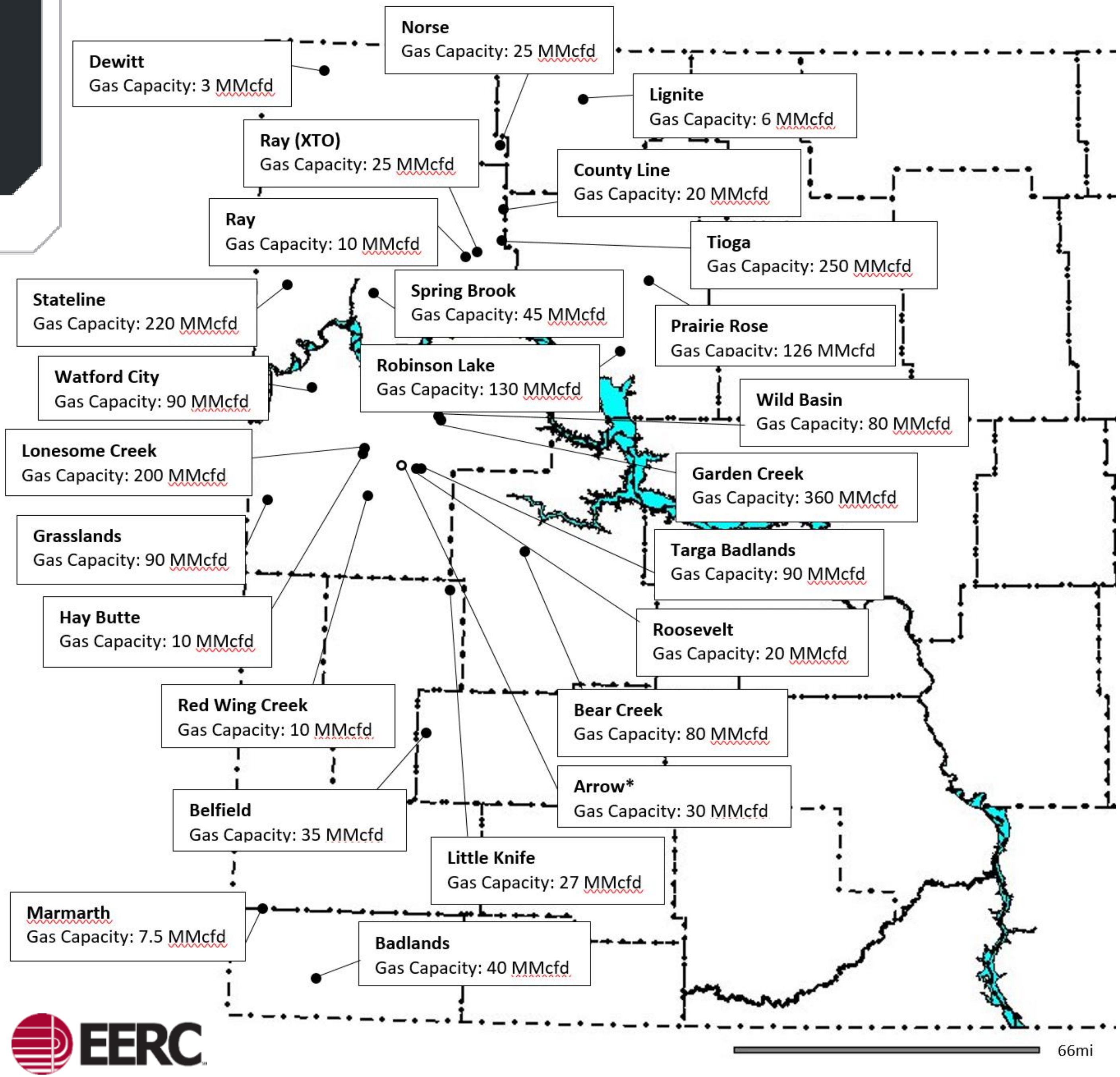
- *Effects on MMP.*

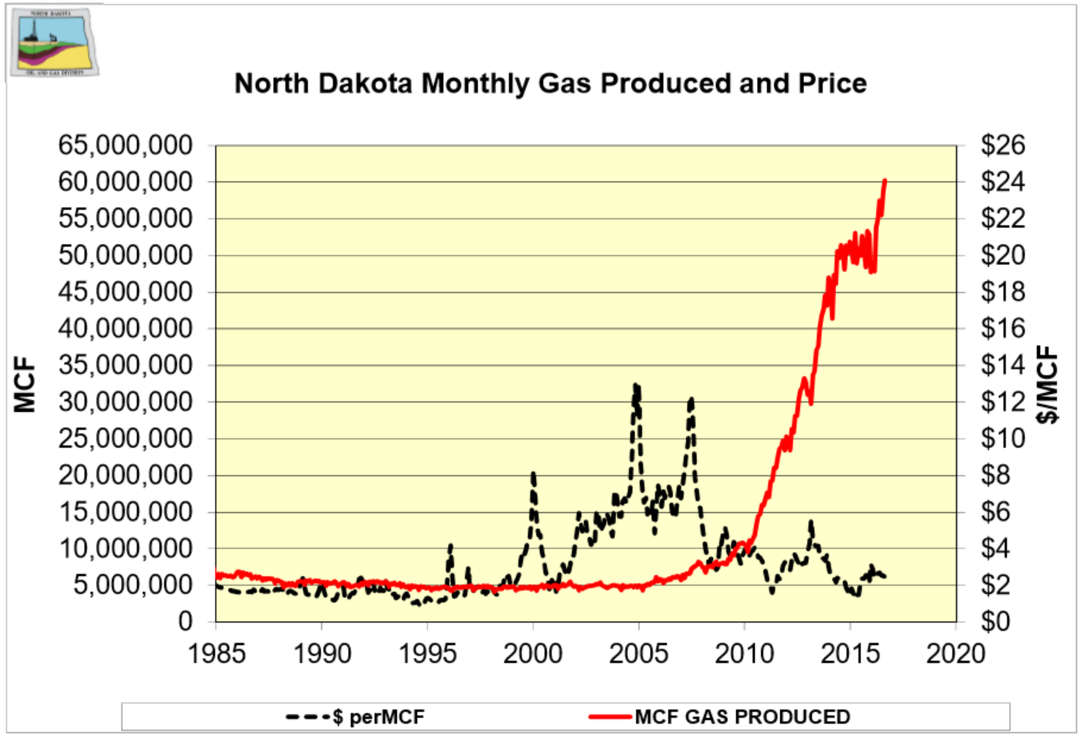
- *Ability to solvate low- and high-MW hydrocarbons into the "miscible" phase (and effects on residual nonproduced crude composition and viscosity). (C2 is better than CO_2, but both are better than C1. C3 in progress.)*

- *Ability to mobilize oil from Middle Bakken, Three Forks, and Upper and Lower Shales (C2 often better than CO_2, both better than C1. C3 in progress).*

- *Ability to swell crude oil (planned).*







- Estimated ND gas-processing capacity (2017) = 2054 MMcfd
- Estimated ND average gas production (Sept. 2017) = 1942 MMcfd
- Calculated average ethane production = 388.5 MMcfd*

*Ethane production calculated based on assumption that raw gas entering processing is composed of 20% ethane by volume.

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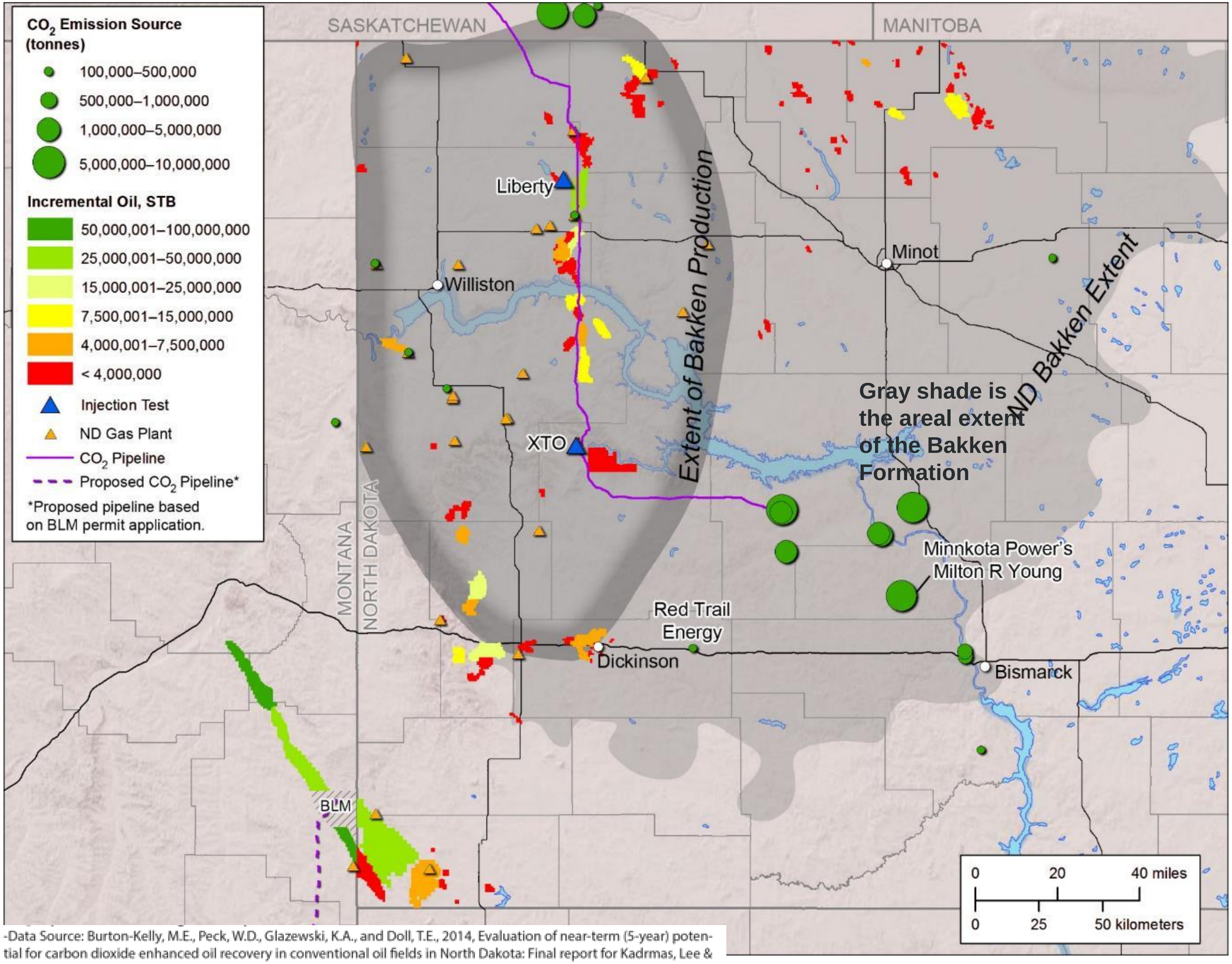

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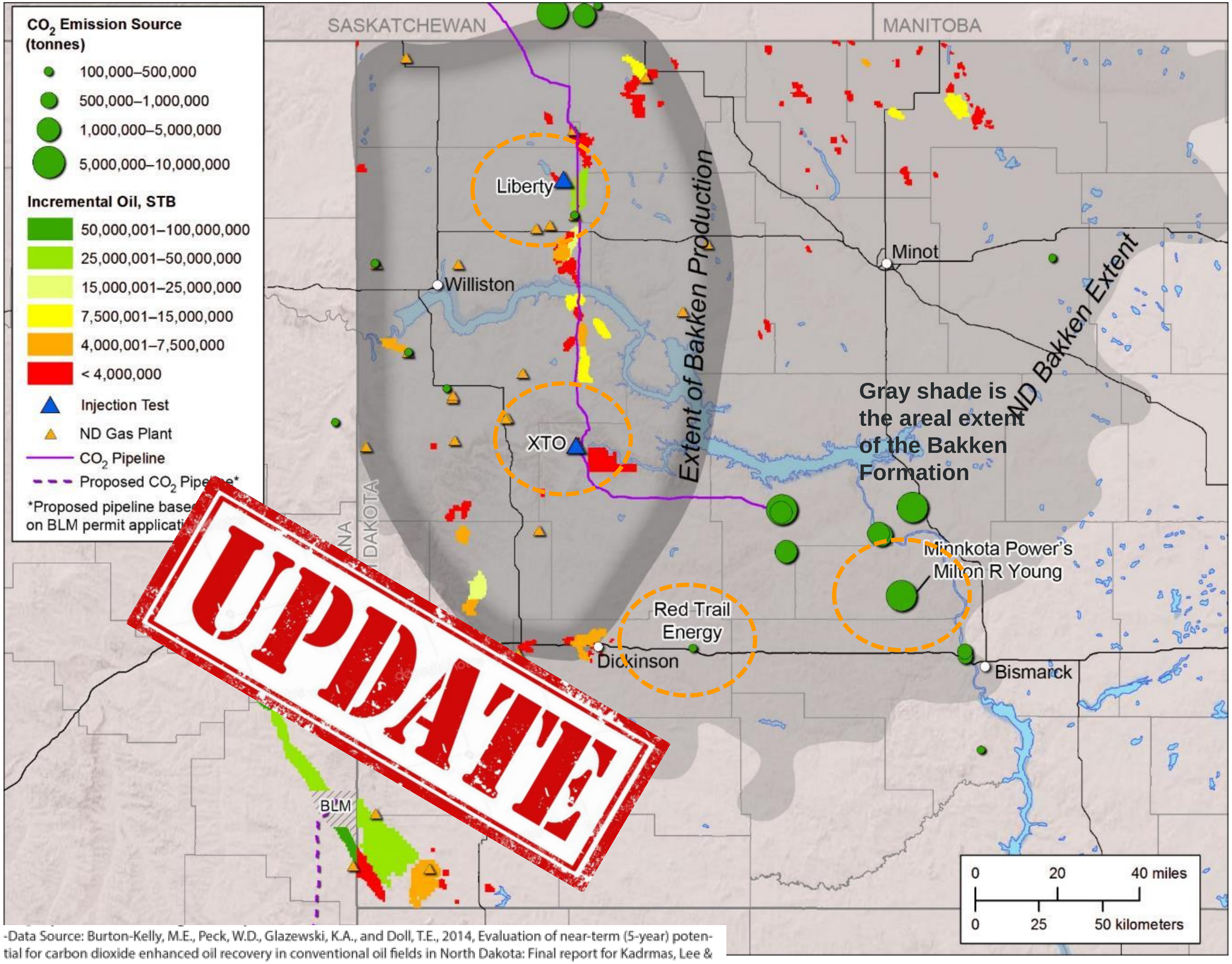
- **47 to 283 million metric tons of CO_2 needed**

- **Conventionals combined with Bakken:**
  - **4–7.6 Bbbl of incremental oil**
  - **2–3.8 Btons of CO_2 needed**



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NORTH DAKOTA EOR OPPORTUNITIES

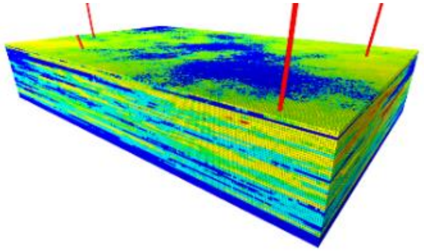
Two new unconventional EOR tests

- **XTO injection test**
- **Liberty rich gas EOR pilot**

Two CO_2 capture retrofit and business case studies:

- **Red Trail Energy (ethanol)**
- **Milton R. Young Station (455-MW coal-fired unit)**

BAKKEN CO_2 STORAGE AND ENHANCED RECOVERY PROGRAM – FIELD INJECTION TEST



XTO ENERGY

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TEST CONCEPT AND HYPOTHESIS

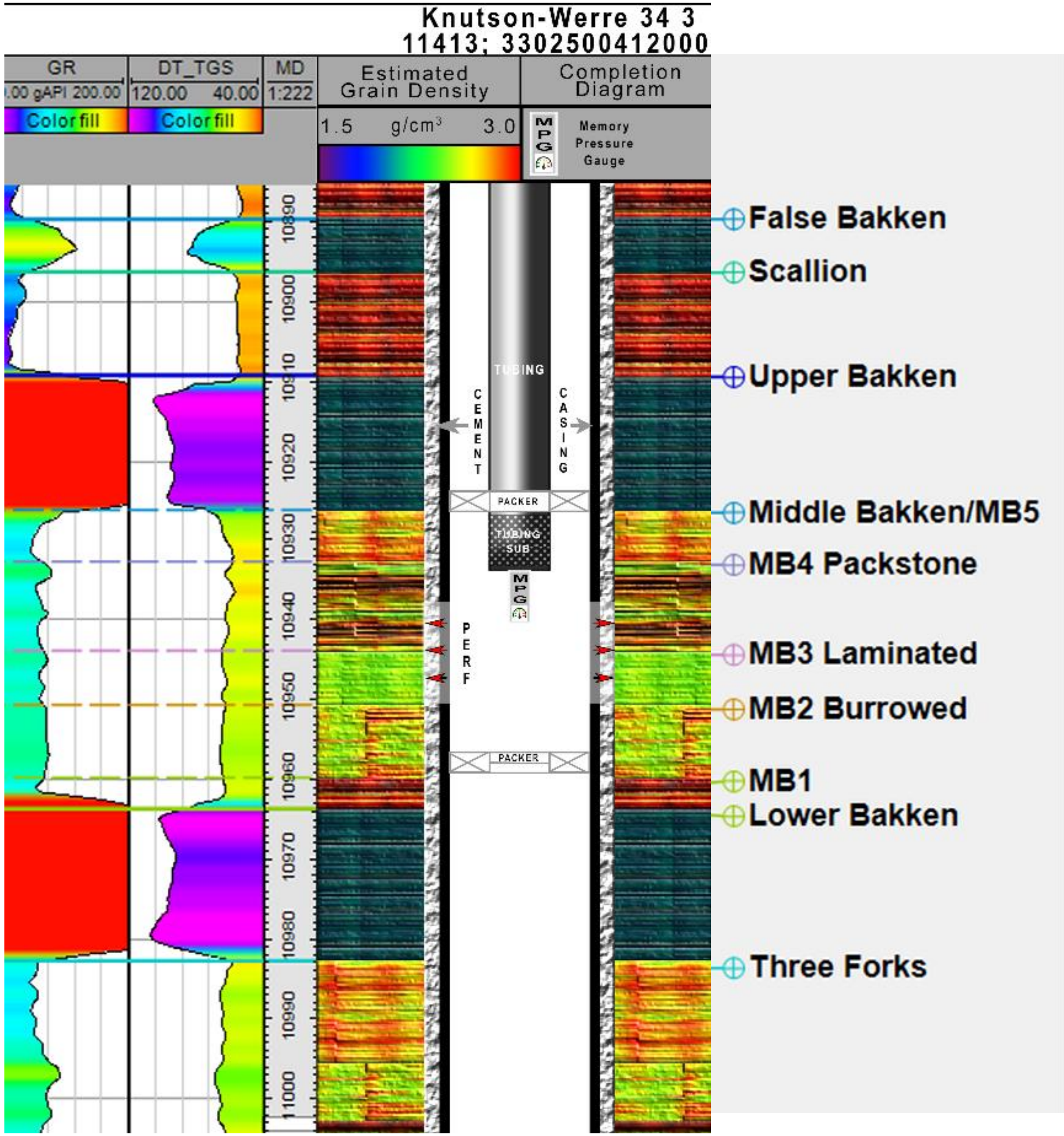
Past pilot-scale CO_2 injection tests into horizontal, hydraulically fractured Bakken wells have shown little to no effect on oil mobilization.

- CO_2 likely moved so quickly through fractures that it did not have enough contact time, or became too dispersed, to interact with stranded oil in the matrix.

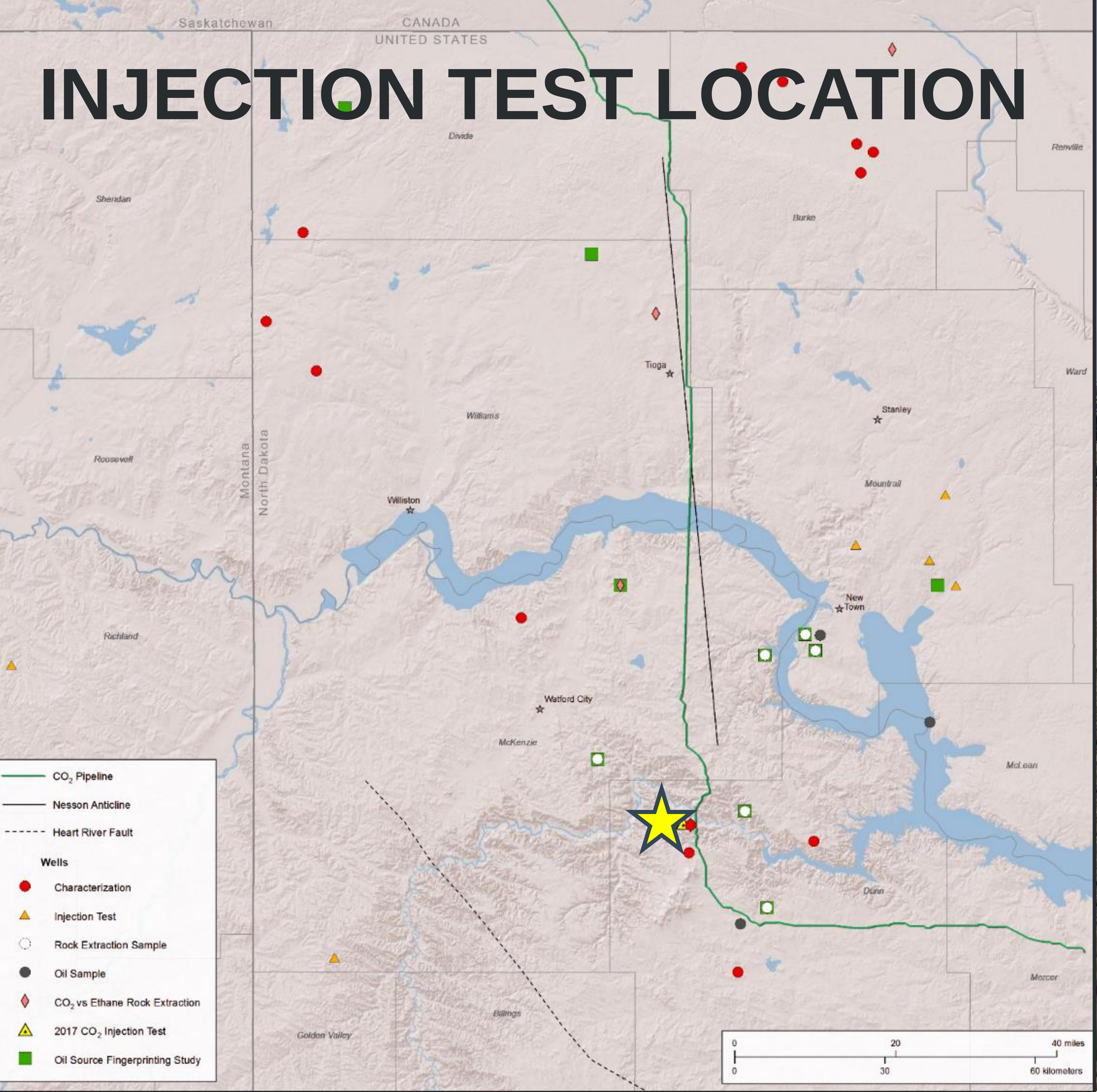
Hypotheses to be tested in a vertical well:

1. CO_2 can be injected into an unstimulated Bakken reservoir.
2. The injected CO_2 can interact with the in-place fluids, resulting in subsequent mobilization of hydrocarbons and storage of CO_2.

Additional objective: inform injection rates and CO_2 volumes needed for future pilot-scale tests.

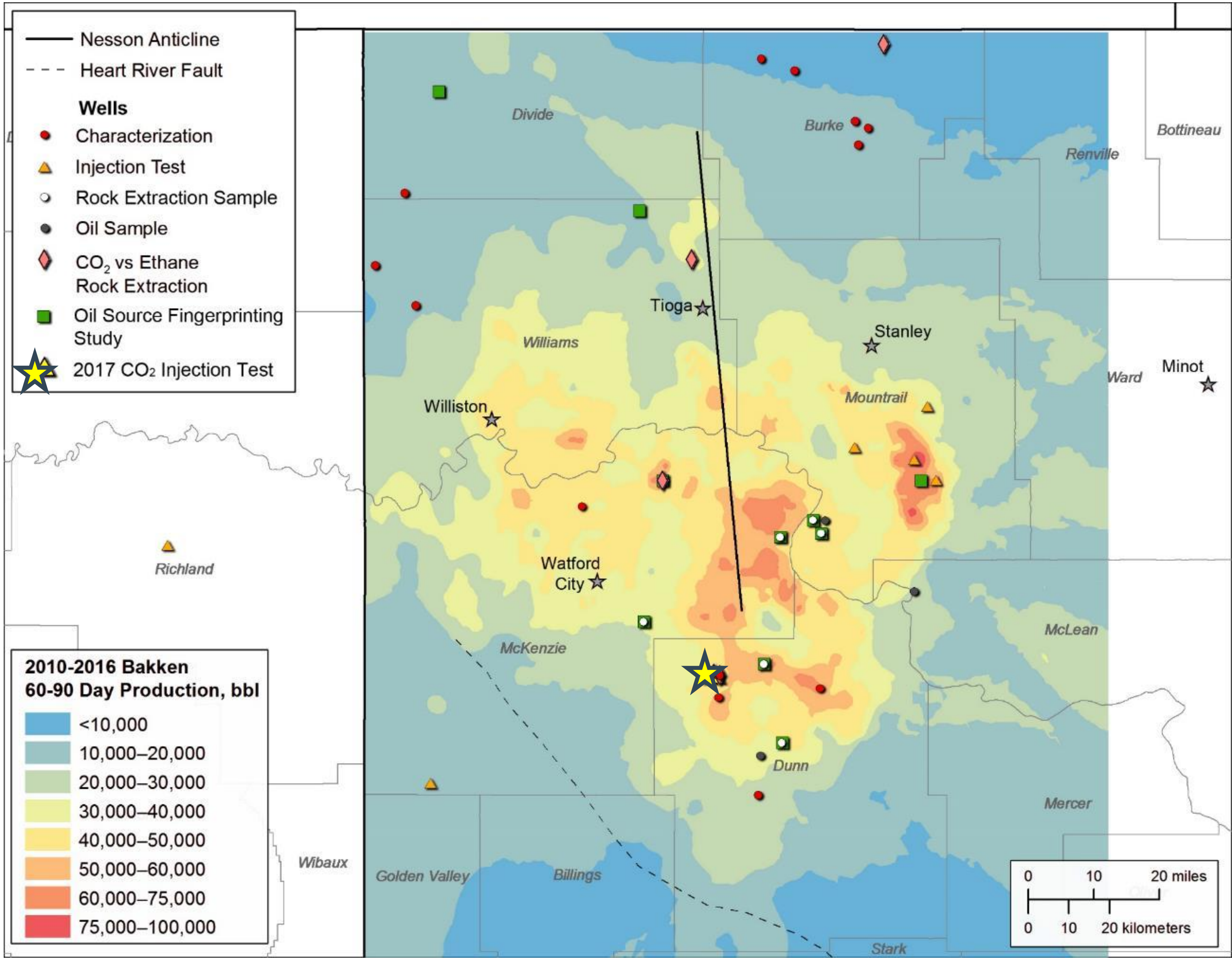


INJECTION TEST LOCATION



INJECTION TEST LOCATION

- Knutson-Werre 34-3 well.
- Owned and operated by XTO Energy.
- Vertical well originally completed in the Duperow Fm, below the Bakken, in 1985.
- Located in one of the more highly productive areas of the Bakken.



WELL PREPARATION WORK

BOTTOMHOLE PRESSURE AND TEMPERATURE GAUGES

- Bottomhole gauges were installed to monitor pressure and temperature during all major stages of the test (pretest baseline, injection, soak, flowback).

BRING IN THE CO_2

- Praxair
- Collect (Swab) pre-test oil sample
- "Pretest" injection in April 2017
- "Main" injection June 2017

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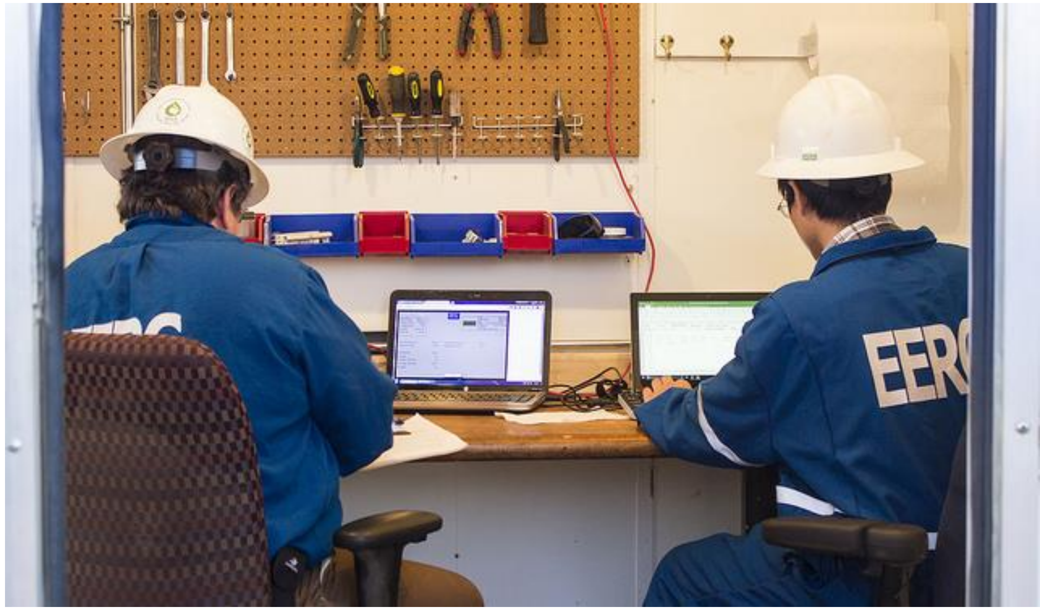
ON-SITE DATA COLLECTION AND MONITORING

- Real-time monitoring of bottomhole pressure (BHP) and bottomhole temperature (BHT).



LESSONS LEARNED FROM THE "PRETEST" CO_2 INJECTION

- Maximum BHP achieved was 9113 psi.
- BHT was 255°F.
- Minimum injection rate of the equipment was 4.5 to 5 gallons/minute.
- Tubing held up to the injection pressure.
- Downhole gauges worked very well!
- Fluid influx into the well is low but consistent.
- Informed CO_2 volume and rate for main test

MAIN INJECTION TEST

- Injection started on June 24
- Completed on June 28
- Main test included:
  - Tube filling and pressure building (16 hours)
  - Two periods of cyclic injection (16 and 32 hours)
  - One period of continuous injection (32 hours)
  - Shut-in period for pressure falloff data (4 hours)

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MAIN INJECTION TEST STATISTICS

- Initial BHP ~7500 psi
- Stable injection rates between 6 and 12 gpm
- Maximum BHP ~9480 psi
- BHP during continuous injection ~9400 to ~9470 psi
- Temperature ranged from 251° to 257°F

Day	Date	Total Cum [gal]	Cum Mass [tons]	Period
1	24-Jun	2236.7	10.4	Filling
1	24-Jun	50.8	0.2	BHP from 8200 to 8600
1	24-Jun	207	1.0	Cyclic inj- Part 1
2	25-Jun	1160.5	5.4	Cyclic inj- Part 1
2	25-Jun	904.5	4.2	Cyclic inj- Part 2
2	26-Jun	1009.4	4.7	Cyclic inj- Part 2
3	26-Jun	1752.6	8.1	Cont. Inj
4	27-Jun	11131	51.8	Cont. Inj
5	28-Jun	2806.2	13.0	Cont. Inj
		TOTAL	**98.9**	**tons of CO_2 injected**

SOAK AND FLOWBACK

- Soak period lasted for 9 days.
- Pressure and temperature were monitored.
- The view was enjoyed…
- Flowback ➔ 5 day shut in ➔ Flowback

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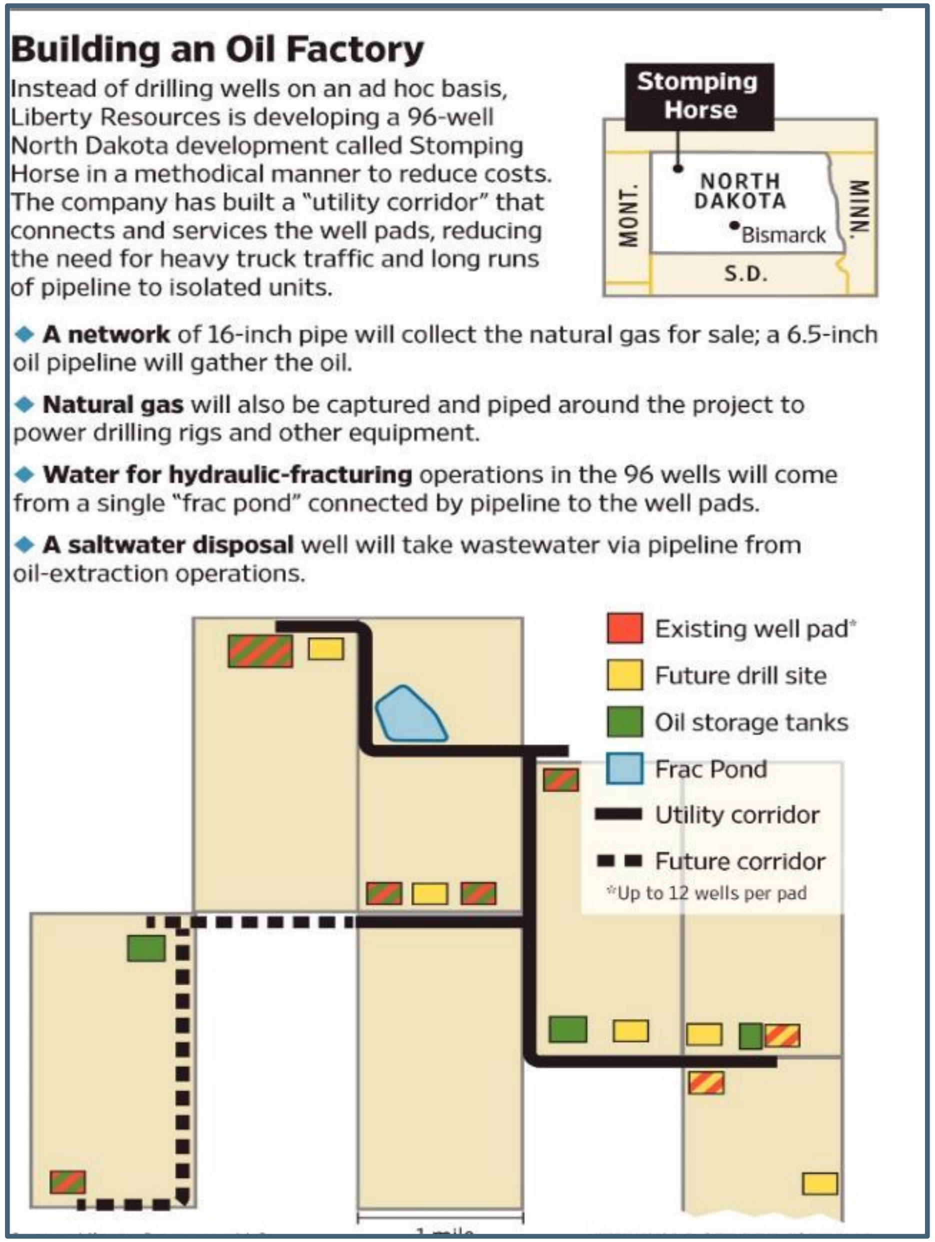
CO_2 INJECTION TEST KEY RESULTS

- No oil production prior to injection.
- Injected 100 tons of CO_2 over 4 days into unstimulated Middle Bakken reservoir.
- After 2 weeks of soaking, oil flowed to surface.
- Composition of the oil shifted toward lower-molecular-weight hydrocarbons after the injection.
- This is evidence that CO_2 penetrated the matrix and mobilized oil.
- Provided rate, pressure, and performance parameters to aid in the design of future pilots

STOMPING HORSE OIL FACTORY

- Liberty approached the EERC in December 2016 to explore leveraging state and federal funding with their Oil Factory project
  - Located at their Stomping Horse complex in Williams County, North Dakota
  - A methodical, structured approach to oilfield development
  - Designing a system of well sites, rather than site-by-site
  - Maximizing field and DSU productivity, ***<u>including the use of rich gas for EOR</u>***
  - Minimizing environmental impact



PROJECT OBJECTIVES

- Determine the ability of various rich gas mixtures (methane, ethane, propane) to mobilize oil in a Bakken reservoir.
- Determine the changes in gas and fluid compositions over time in both the reservoir and the surface infrastructure environments, assessing how those changes affect reservoir and process facility performance.
- Optimize future commercial-scale tight oil EOR design and operations using data generated in the lab, validated numerical modeling and simulation, and in the field.
- Establish the effectiveness of selected monitoring techniques for reservoir surveillance and injection conformance monitoring.
- Determine effectiveness of a cyclic multiwell huff & puff (CMWHP) concept and other conformance control practices.

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THOUGHTS ON THE FUTURE OF THE BAKKEN

- The potential size of the prize for EOR is enormous!
- Widespread deployment is perhaps a decade away, largely due to a lack of commercially available CO_2, but rich gas may be a way to bridge that gap.
- Rich gas is readily available, and capture of anthropogenic CO_2 in the Williston Basin has momentum.
- Results of field and laboratory tests have shown tremendous promise; a portfolio of projects like these is needed to enable proliferation of EOR, advance the science, validate the results
- There are several uncertainties and challenges that yet need to be addressed including conformance, accessing stranded hydrocarbons, the role of fractures, recovery factors and utilization rates, recovery mechanisms, potential to store CO_2 and reduce carbon intensity of produced oil.


THANK YOU!

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