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Critical Challenges. Practical Solutions.

Energy & Environmental Research Center (EERC)

SCALING UP TO INDUSTRIAL CCUS PROJECTS

A Regional Perspective
North Dakota, USA

CCS Technical Workshop 2020

Tokyo, Japan

January 23, 2020

John Hamling

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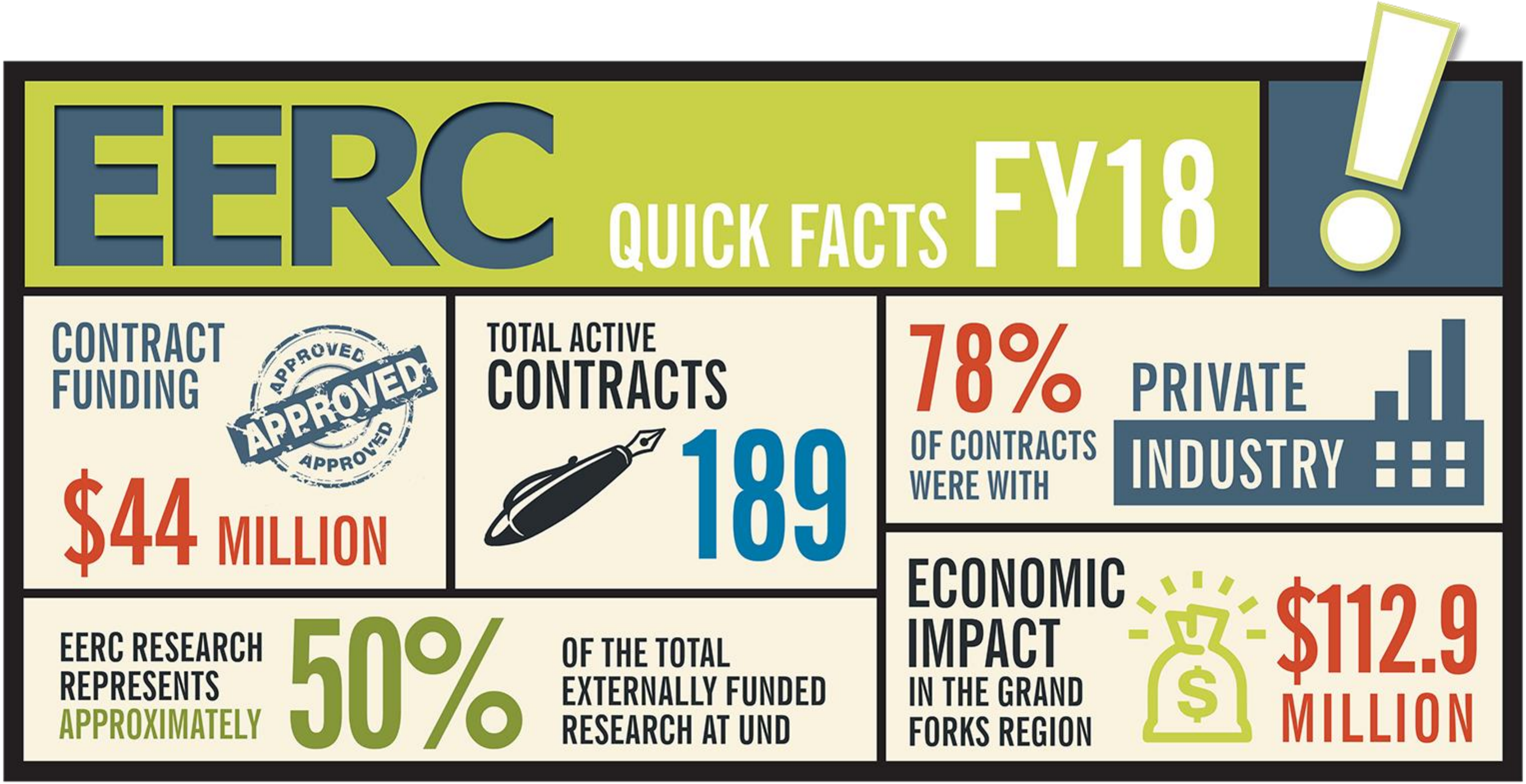
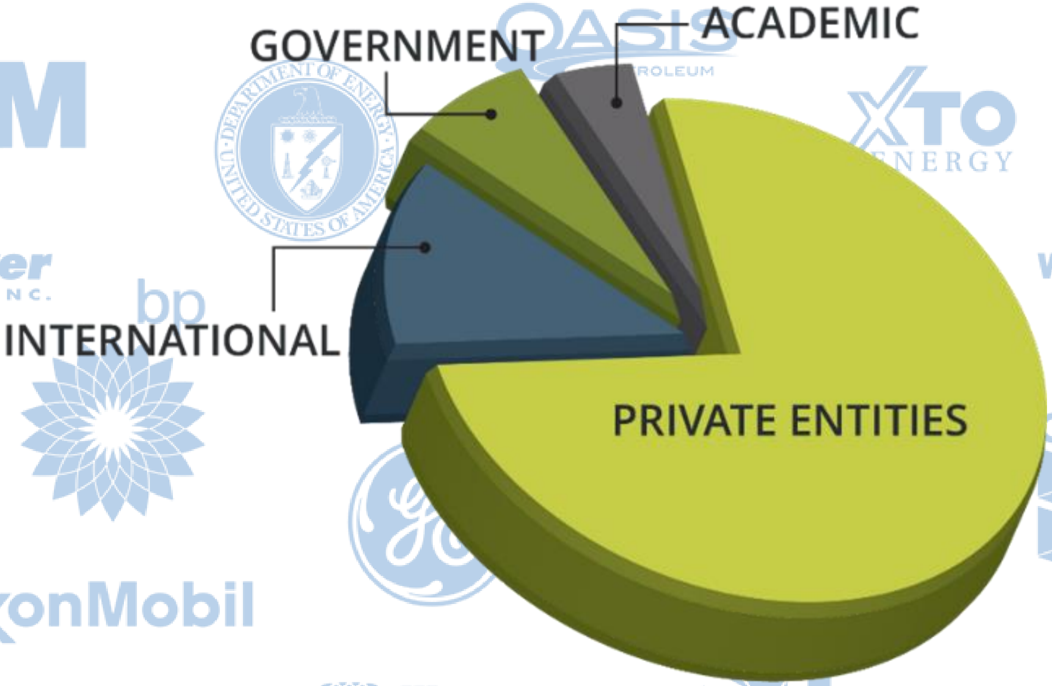
Energy & Environmental
Center


EERC
QUICK FACTS FY18
CONTRACT FUNDING
APPROVED
$44 MILLION
TOTAL ACTIVE CONTRACTS
189
78%
OF CONTRACTS WERE WITH
PRIVATE INDUSTRY
EERC RESEARCH REPRESENTS APPROXIMATELY
50%
OF THE TOTAL EXTERNALLY FUNDED RESEARCH AT UND
ECONOMIC IMPACT
IN THE GRAND FORKS REGION
$112.9 MILLION


WATER USE MINIMIZATION TECHNOLOGY
FUELS OF THE FUTURE
MOBILE LABORATORIES
FUEL PROCESSING
HIGH-BAY TECHNOLOGY DEMONSTRATION
NATIONAL CENTER FOR HYDROGEN TECHNOLOGY
CHEMICAL STORAGE
LABORATORIES
OFFICES
IN-HOUSE FABRICATION SHOP
TECHNOLOGY DEMONSTRATION
DISCOVERY HALL MEETING AREA
254,000 SQ FT OF FACILITIES

WORKING AROUND THE GLOBE

MORE THAN 1300 CLIENTS IN 53 COUNTRIES



CLIENT-FOCUSED

THIS IS HOW WE WORK

INDUSTRY

STATE ENTITIES

GOVERNMENT
(U.S. and others)

EERC VISION

TO LEAD THE WORLD IN
DEVELOPING SOLUTIONS
TO ENERGY AND ENVIRONMENTAL
CHALLENGES.

A STATE OF ENERGY

Population – ~760,000 (~70,000 square miles)

CO_2 emissions – 34th – ~56 million tonnes per year

Total Energy Production 6th

- Oil – 2nd
- Natural gas – 10th
- Coal – 8th
- Wind – 10th
- Ethanol – 10th

Agricultural products

- 19 – top three

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Image Credit – Steve Shook[1]

A RESOURCE MANAGEMENT PHILOSOPHY

Mission to promote and prudently develop North Dakota's oil, gas, fossil, and renewable energy resources.

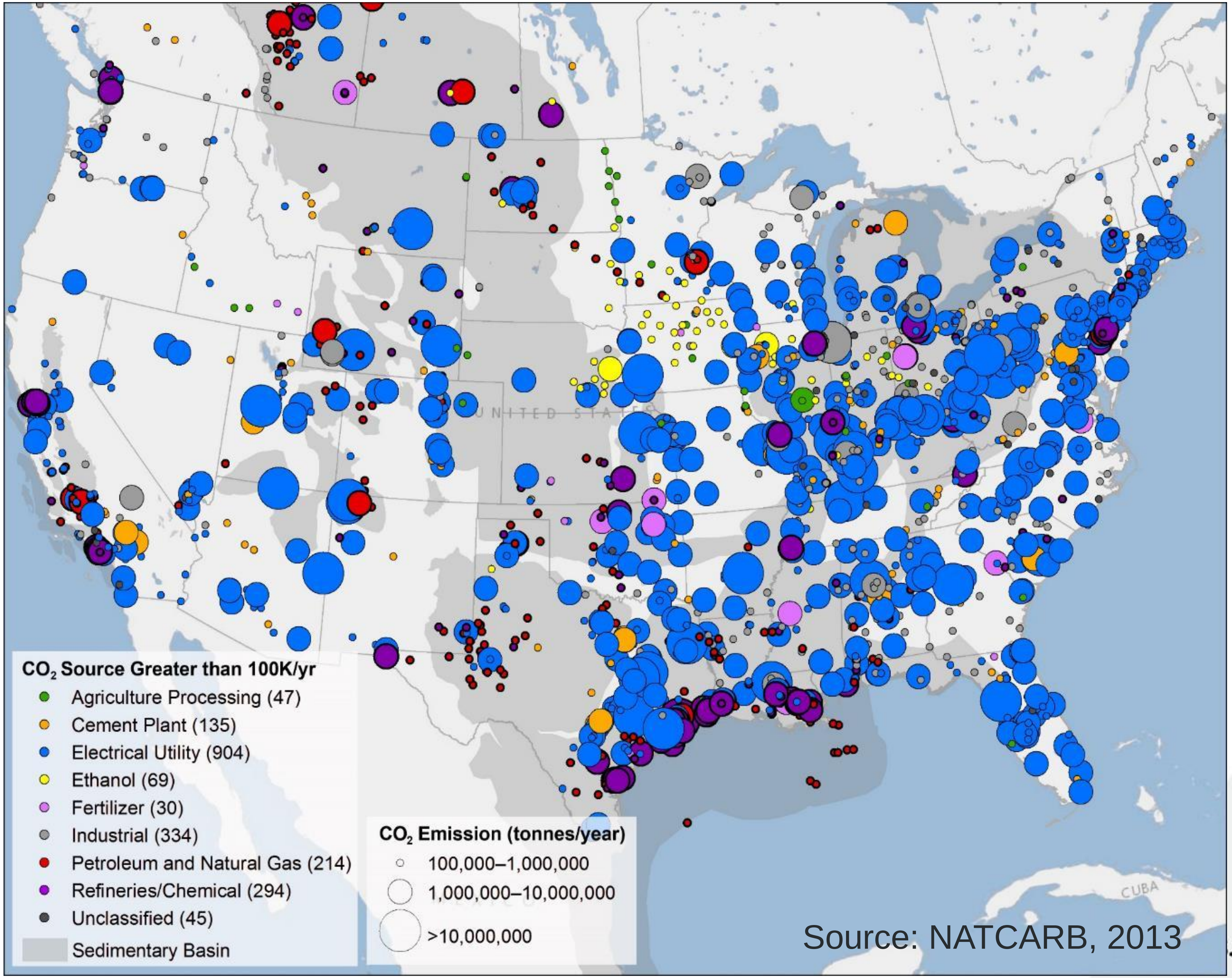
"Public interest to promote geologic storage of carbon dioxide..."

Carbon capture, utilization, and storage (CCUS) is a key to leveraging a tremendous endowment of fossil energy to provide secure, reliable, affordable, safe, clean energy.

Public accustomed to energy industry and the role it plays.

CO_2 POINT SOURCES WITH EMISSIONS GREATER THAN 100,000 METRIC TONS/YEAR

Many industrial sources of anthropogenic CO_2 are in proximity to sedimentary basins that provide the opportunity for geologic CO_2 storage.



Source: NATCARB, 2013

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REGIONAL POTENTIAL

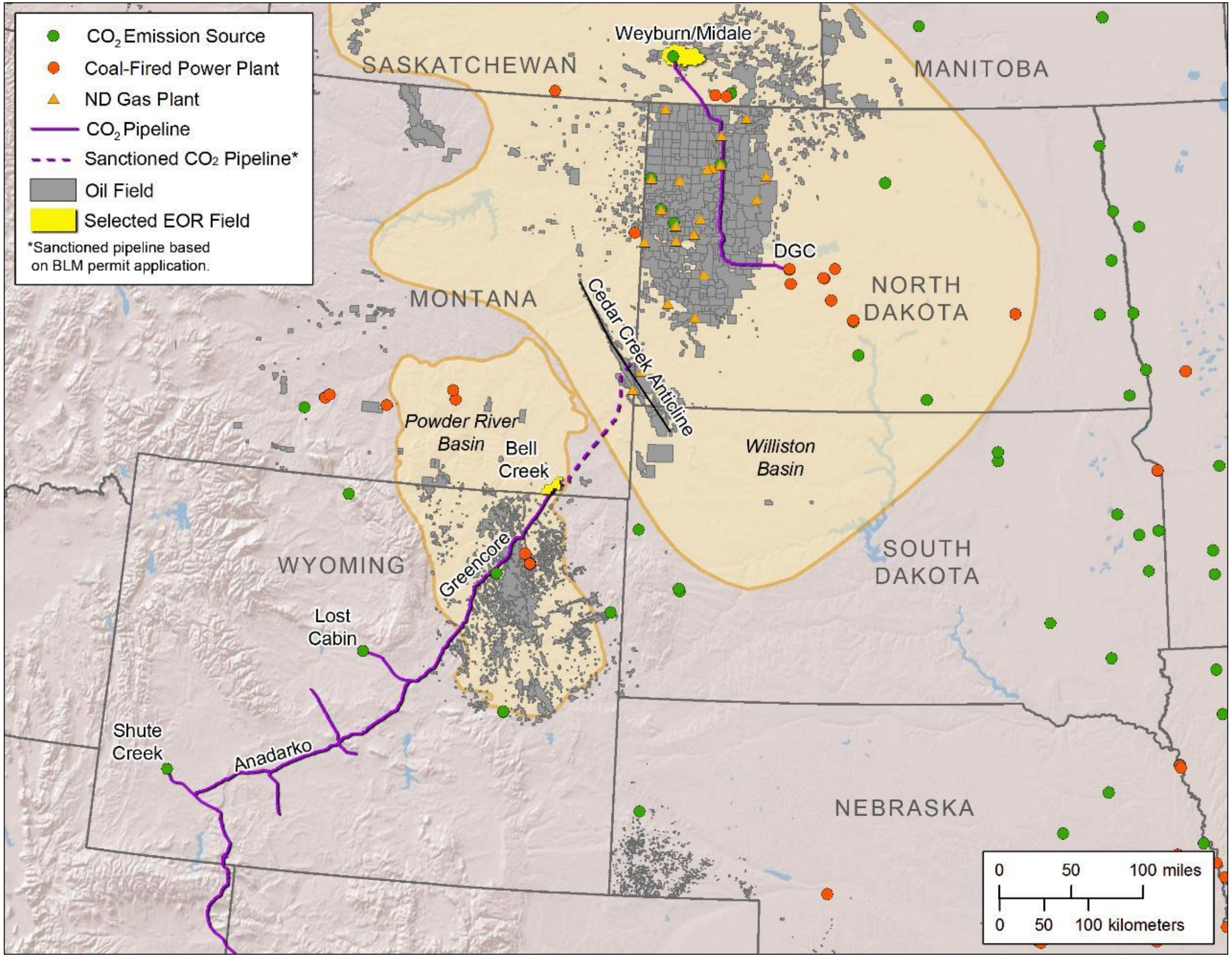
A Prolific Oil-Producing Region in North America

- Conventional
- Unconventional
- Stacked horizons
- Residual oil zones (ROZs)?

Abundant Anthropogenic CO_2 Sources Proximal to Enhanced Oil Recovery (EOR) and Storage Opportunities

Growing CO_2 Transportation Network

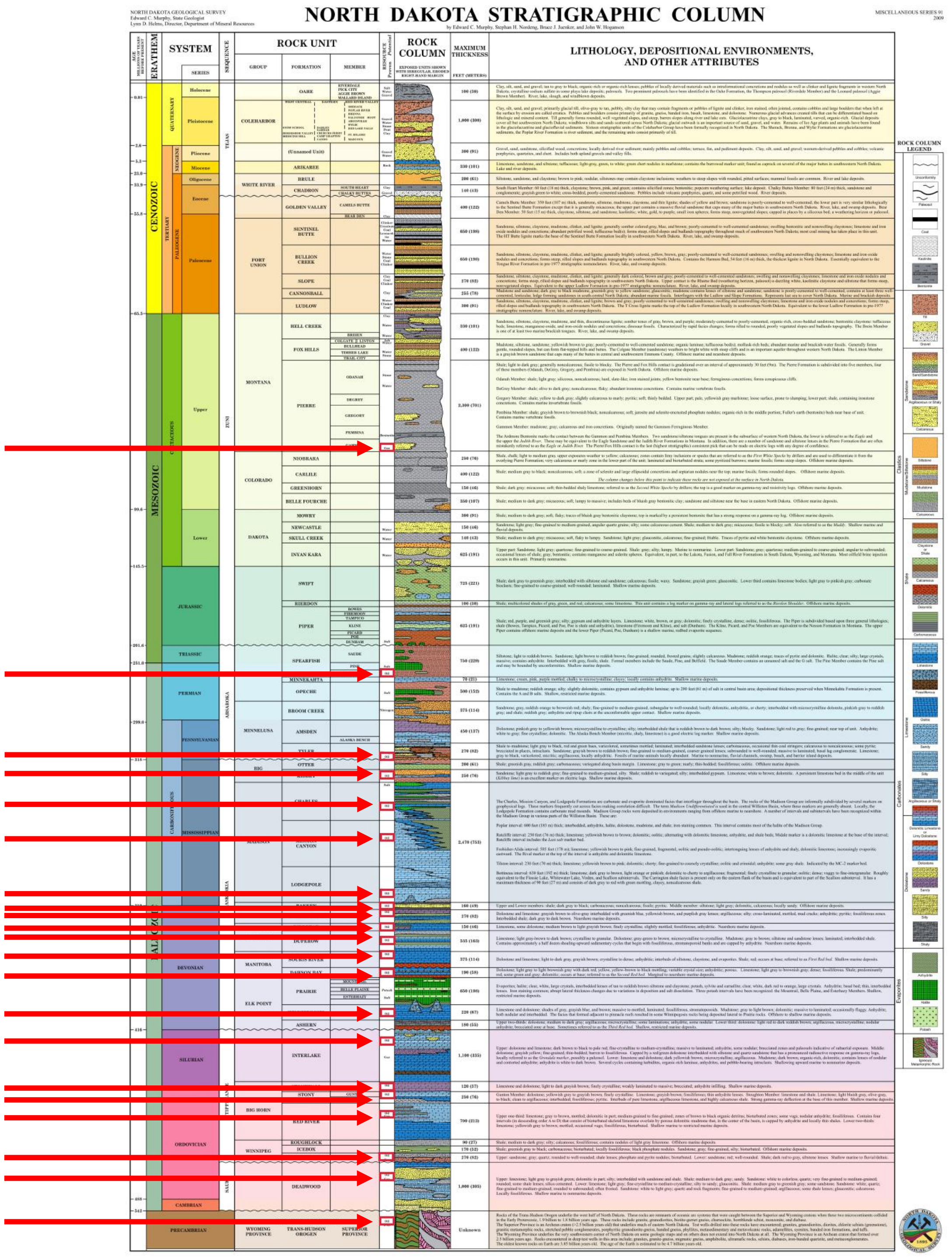
Massive CO_2 Storage Potential in Deep Saline Formations

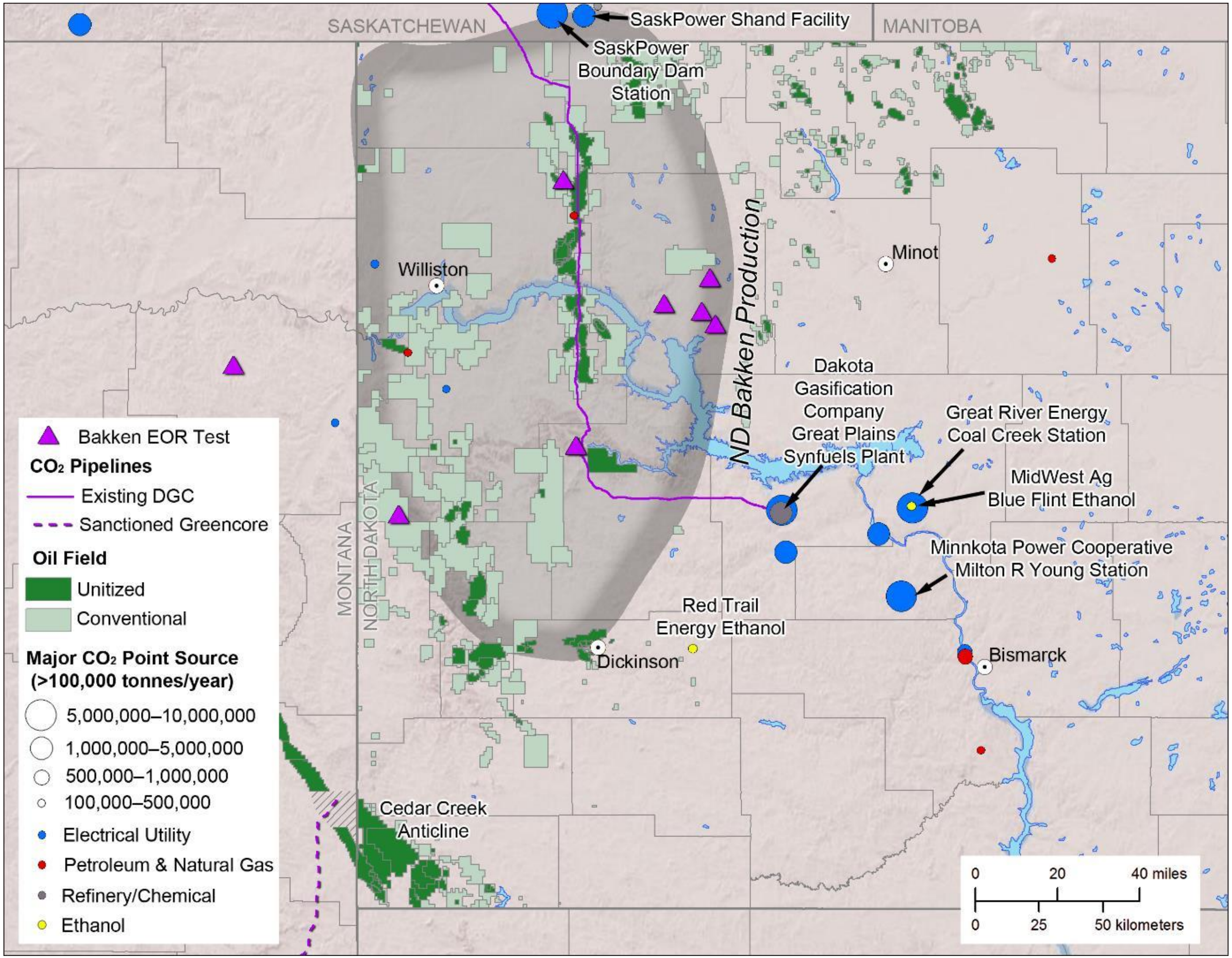


GEOLOGY

21 hydrocarbon-bearing formations; several contain multiple producing horizons.

Multiple potential unconventional source rock formations.





ENORMOUS EOR OPPORTUNITY

86 conventional unitized fields:

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

200+ conventional fields

- **>1 Bbbl of incremental oil**
- **>358 million metric tons of CO_2 needed**

Conventional + Bakken Petroleum System:

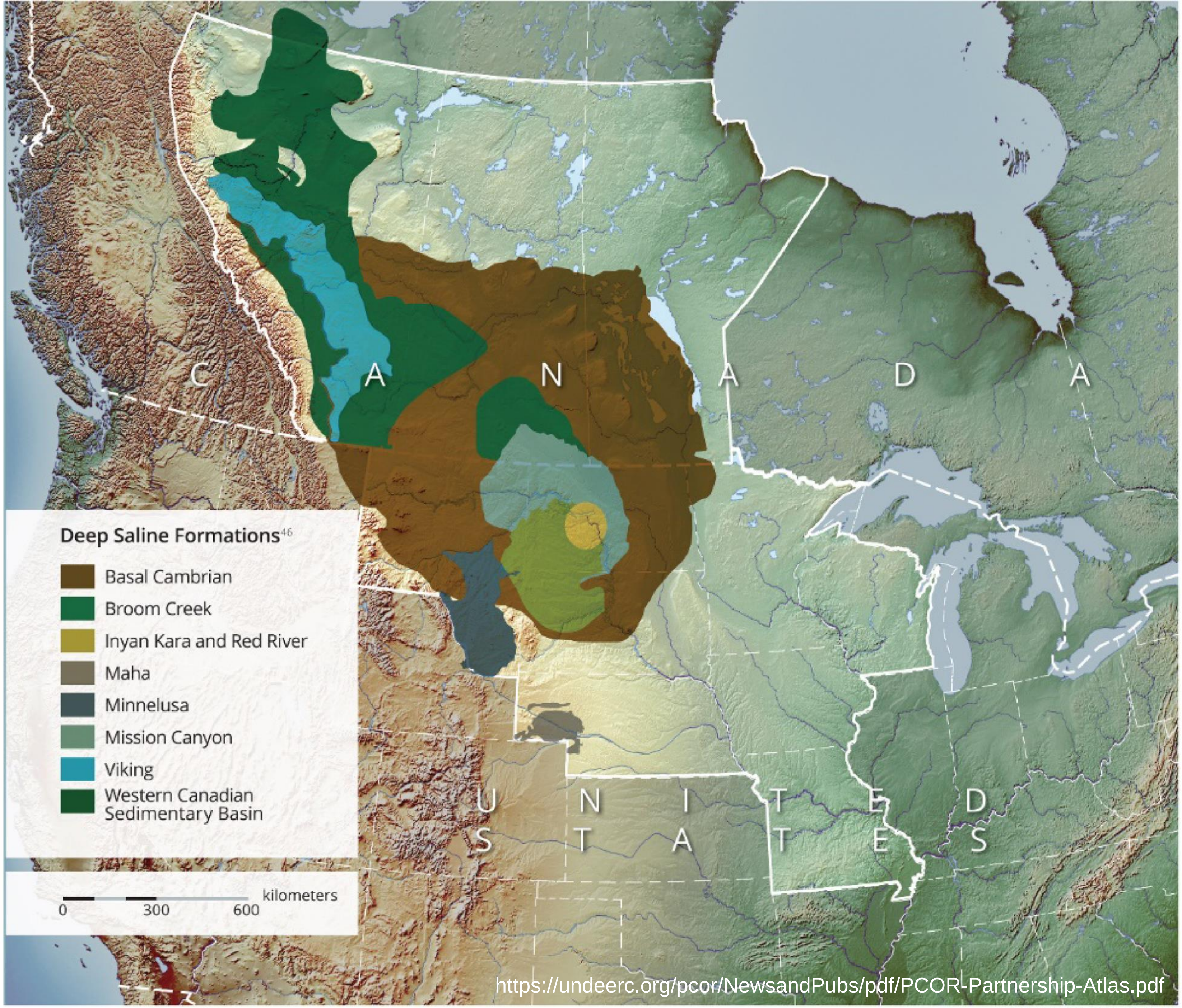
- **4 Bbbl–7.6 Bbbl of incremental oil**
- **2 Btons–3.8 Btons of CO_2 needed**

…or more

ENORMOUS DEDICATED STORAGE POTENTIAL IN DEEP SALINE FORMATIONS

More than 330 GT of storage potential,

100+ billion tonnes in ND alone.



https://undeerc.org/pcor/NewsandPubs/pdf/PCOR-Partnership-Atlas.pdf

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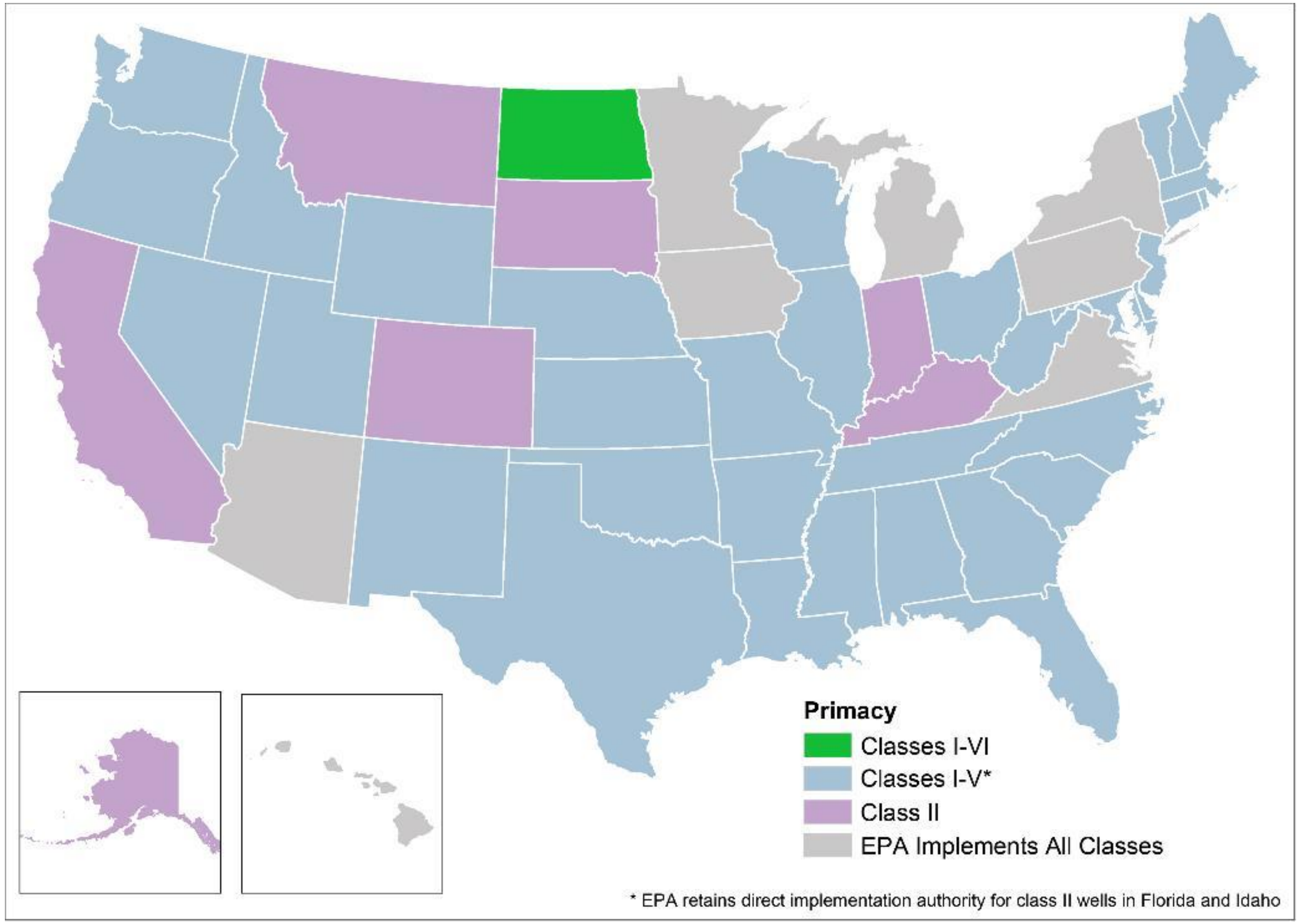
UNDERGROUND INJECTION CONTROL

NORTH DAKOTA'S GOT CLASS! I, II, III, IV, V, AND VI



Class I	Class II	Class III	Class IV	Class V	Class VI
ND Dept of Health	NDIC Oil & Gas Division	ND Geological Survey	ND Dept of Health	ND Dept of Health	NDIC Oil & Gas Division
Hazardous and nonhazardous fluids (industrial and municipal wastes).	Brines and other fluids associated with oil and gas production.	Fluids associated with solution mining of minerals.	Hazardous or radioactive wastes. This class is banned by EPA.	Nonhazardous fluids into or above a USDW and are typically shallow.	Injection of carbon dioxide for long-term storage.

PRUEDENT REGULAITONS THAT ENABEL CCUS
Codified in North Dakota Law

CHAPTER 38-22 CARBON DIOXIDE UNDERGROUND STORAGE

38-22-01. Policy. It is in the public interest to promote the geologic storage of carbon dioxide. Doing so will benefit the state and the global environment by reducing greenhouse gas emissions. Doing so will help ensure the viability of the state's coal and power industries, to the economic benefit of North Dakota and its citizens. Further, geologic storage of carbon dioxide, a potentially valuable commodity, may allow for its ready availability if needed for commercial, industrial, or other uses, including enhanced recovery of oil, gas, and other minerals. Geologic storage, however, to be practical and effective requires cooperative use of surface and subsurface property interests and the collaboration of property owners. Obtaining consent from all owners may not be feasible, requiring procedures that promote, in a manner fair to all interests, cooperative management, thereby ensuring the maximum use of natural resources.

ANCILLARY REGULATORY MECHANISMS FACILITATE INDUSTRIAL CCUS

Carbon dioxide storage facility administrative fund ($0.01/ton): administrative costs associated with regulating storage facilities.

Carbon dioxide storage facility trust fund ($0.07/ton): cost of long-term monitoring.

<u>Certificate of Project Completion – Release of Bond – Transfer of Title and Custody</u>

State issues certificate of project completion (all criteria met – at least 10 years postinjection)

- Releases responsibility, regulatory requirements, and bonds
- Transfer of title and custody to storage facility and stored CO_2 state
- State oversees/responsible for monitoring and managing the storage facility until such time as federal government assumes responsibility (assures site access/confidence)

State retains all authority to regulate future mineral and UIC activities

- protection from recapture of incentives.

State issued determination of storage (facilitate trading and incentive programs)

INCENTIVES

45Q Tax Credits

- Projects beginning construction before January 1, 2024, can claim credits for 12 years after operations begin.
- Tax credits claimed by the taxpayer capturing the emissions or transferred to operators of CO_2 EOR projects.
- Tax credit for CO_2 stored in a qualified EOR project

  (10-year ramp up to a maximum of $35/tonne in 2026).
- Tax credit for CO_2 stored in a saline formation

  (10-year ramp-up to a maximum of $50/tonne in 2026).

West Coast LCFS Markets

- Credits trading up to $213 per ton.
- Stacked with 45Q

North Dakota CCUS Incentives

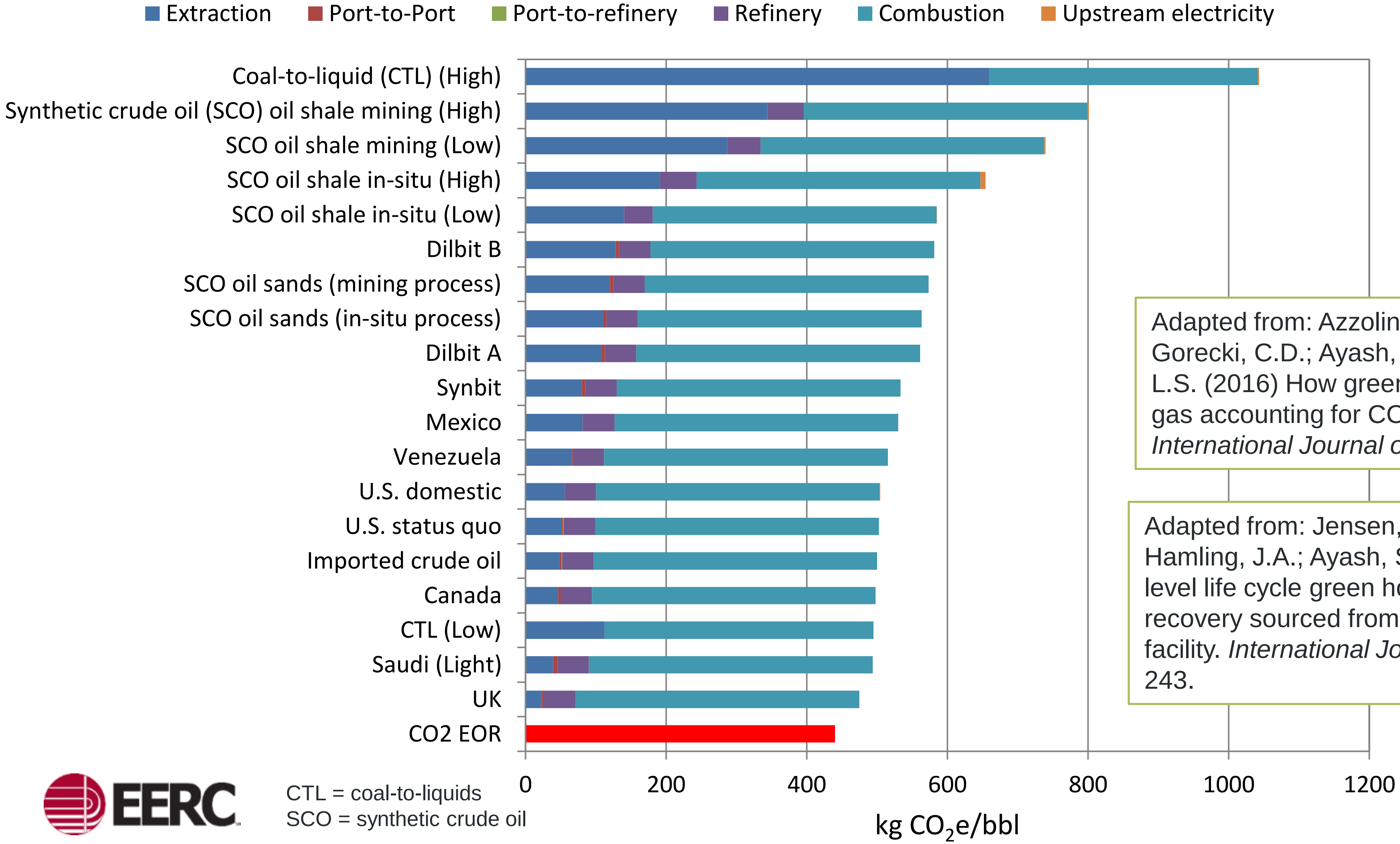
- Coal conversion tax: tax reduction with CO_2 capture (up to 50%)

- No sales tax on capture-related infrastructure
- No sales tax on CO_2 sold for EOR

- No sales tax on construction of pipeline.
- Property tax-exempt for 10 years (equipment)

- No sales tax on CO_2 EOR infrastructure
- 0% extraction tax for 20 years for tertiary incremental recovery
- Production tax still applies

LIFE CYCLE ANALYSIS RESULTS INDICATE EOR WITH CAPTURED CO_2 FROM ANTHROPOGENIC SOURCES RESULTS IN LOWER-CARBON-INTENSITY OIL



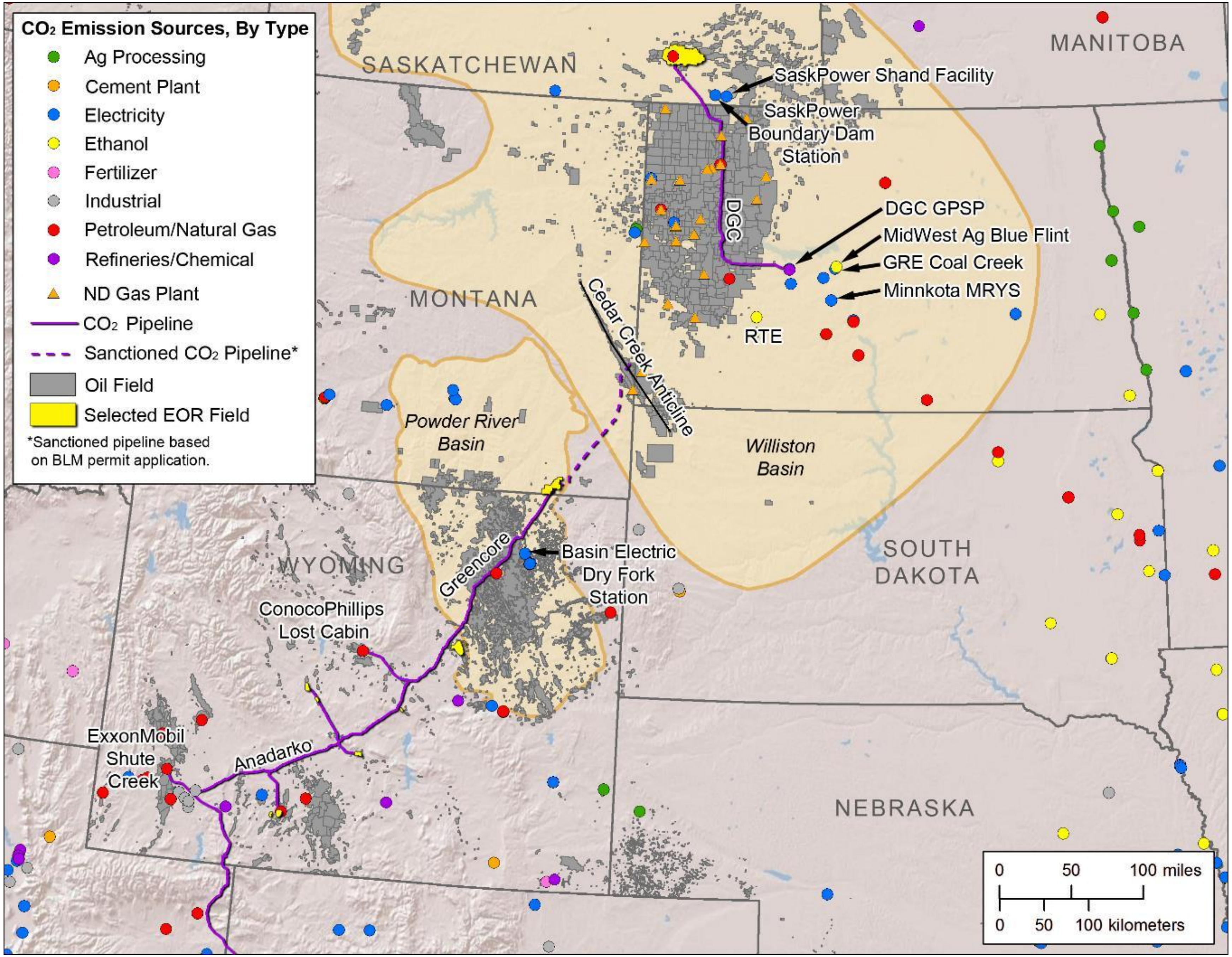
Adapted from: Mangmeechai, A., 2009, *Life Cycle Greenhouse Gas Emissions, Consumptive Water Use and Levelized Costs of Unconventional Oil in N. America*. Dissertation, Carnegie Mellon University: Pittsburgh, PA.

Adapted from: Azzolina, N.A.; Peck, W.D.; Hamling, J.A.; Gorecki, C.D.; Ayash, S.C.; Doll, T.E.; Nakles, D.V.; and Melzer, L.S. (2016) How green is my oil? A detailed look at greenhouse gas accounting for CO_2-enhanced oil recovery (CO_2-EOR) sites. *International Journal of Greenhouse Gas Control*, 51:369–379.

Adapted from: Jensen, M.D.; Azzolina, N.A.; Schlasner, S.M.; Hamling, J.A.; Ayash, S.C.; Gorecki, C.D.; (2018) A screening-level life cycle green house gas analysis of CO_2-enhanced oil recovery sourced from Schute Creek natural gas-processing facility. *International Journal of Greenhouse Gas Control*, 78:236–243.

CTL = coal-to-liquids
SCO = synthetic crude oil

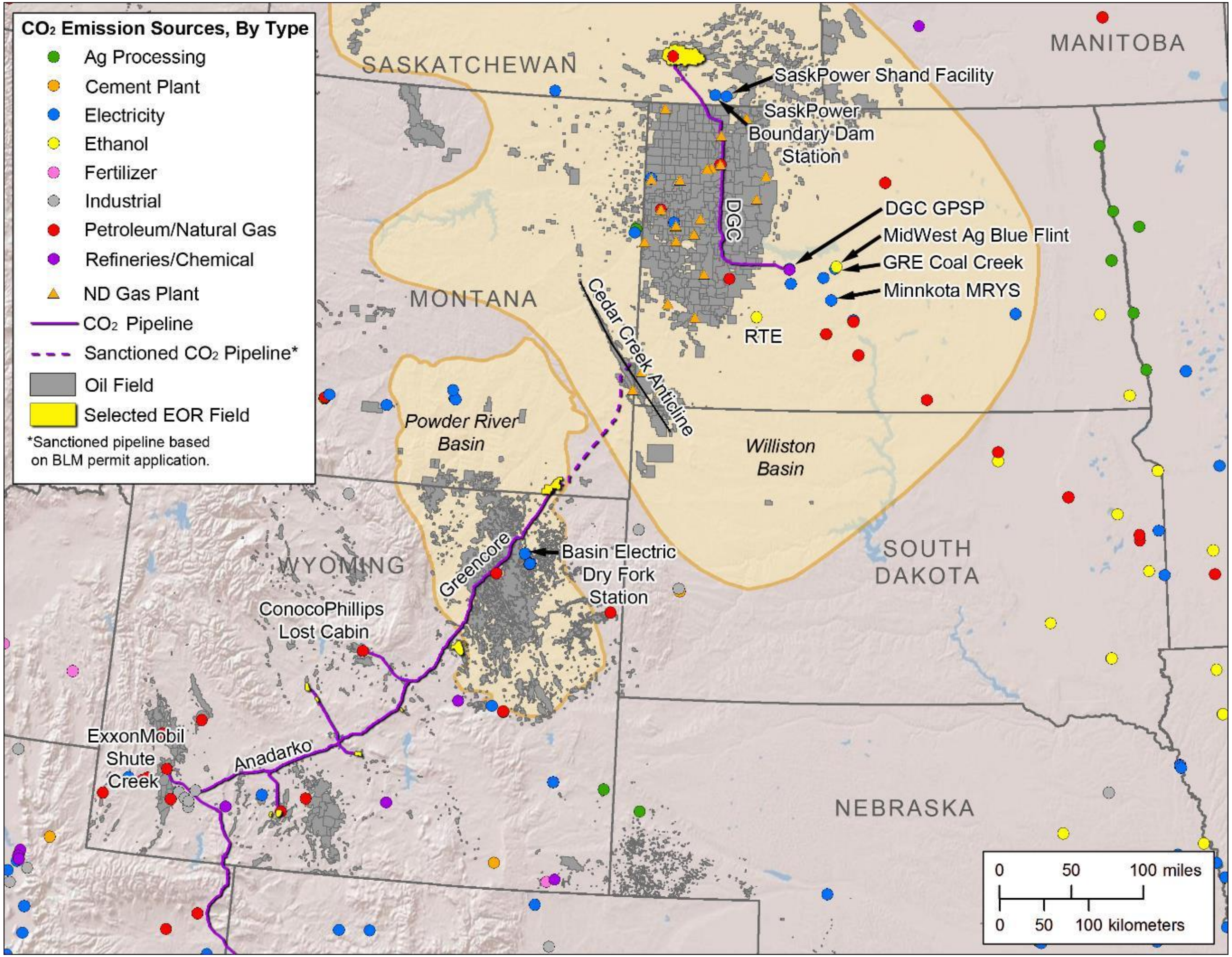
ENGAGED PARTNERS



Commercial Industrial CCUS Projects

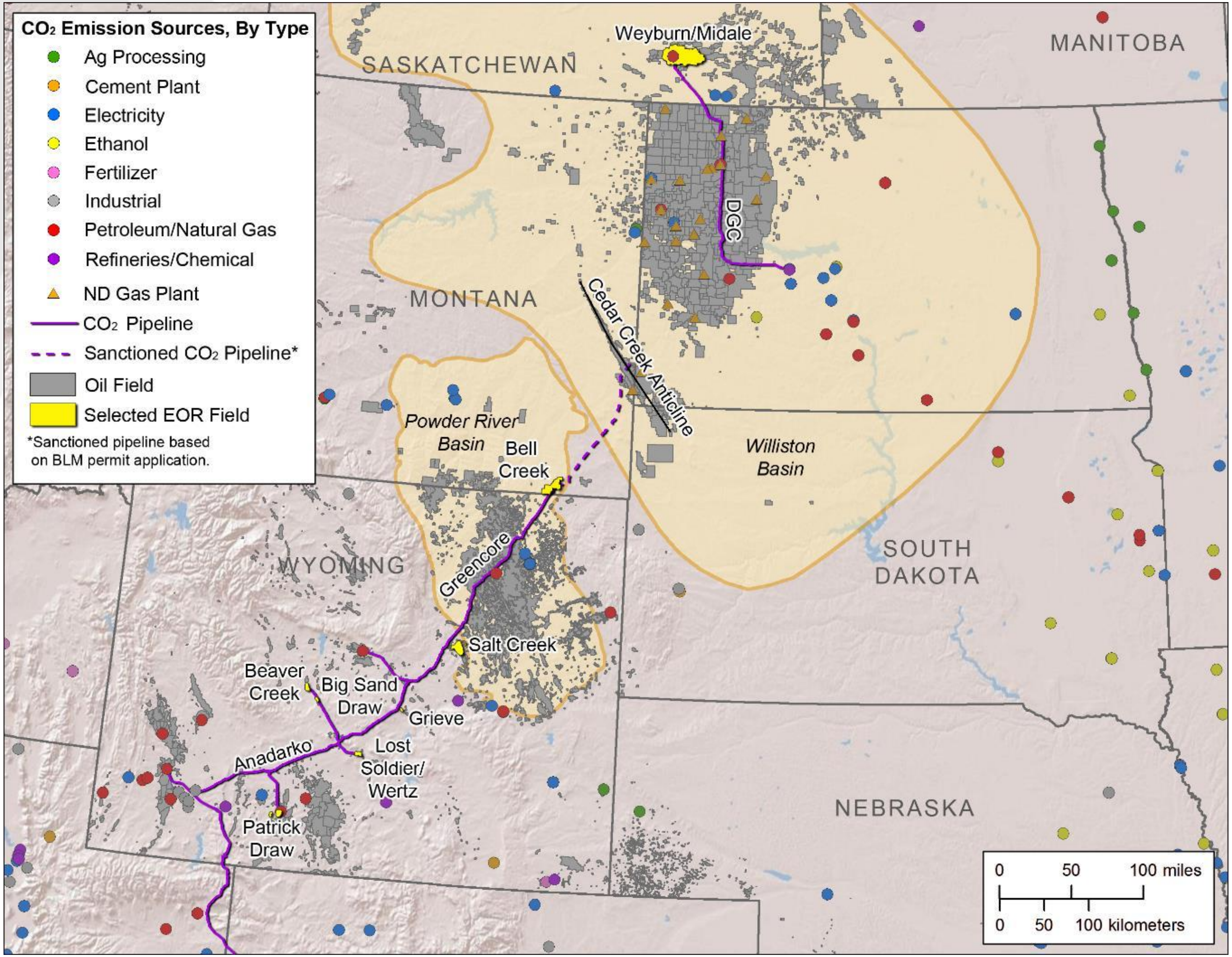
- Basin Electric Power Cooperative, Dakota Gasification Company Great Plains Synfuels (commercial)
- Basin Electric Power Cooperative Ammonia Process Liquefaction Plant (commercial)
- SaskPower Boundary Dam Carbon Capture Project (commercial)
- Exxon Mobil Shute Creek Natural Gas Processing (commercial)
- ConocoPhillips Lost Cabin Natural Gas Processing (commercial)
- Shell Quest CCS Facility* (commercial) – Alberta, Canada

*not pictured.



Announced Industrial CCUS Projects

- Red Trail Energy – **Richardton Ethanol Facility** (precommercial/FEED)
- Minnkota Power Cooperative **Project Tundra** – Milton R. Young Station (precommercial/FEED)
- Basin Electric Power Cooperative Dry Fork Station (precommercialization/FEED)
- Great River Energy **CCS^2** - Coal Creek Station (feasibility)
- Midwest AgEnergy – Blue Flint Ethanol Facility (feasibility)
- SaskPower Shand Power Station (feasibility)



CO_2 Transportation Network

DGC line (commercial)

- 205-mile 14” - 12”

Greencore Pipeline (commercial)

- 232-mile long 20”
- (725 MMscf/day)
- Anadarko CO_2 pipeline interconnect

Greencore Pipeline Expansion (sanctioned)

- 110-mile expansion to Baker, MT, and Cedar Creek Anticline

North Dakota Industrial Sources Line(s) (conceptual)

DGC Food-Grade Truck Facility (commercial)

RED TRAIL ENERGY, LLC

North Dakota Ethanol Production

Reduced Carbon Intensity of North Dakota Ethanol Production Through Geologic CO_2 Storage

Incentive Programs

- Low-carbon fuel standard (LCFS) programs (~$200/tonne)
- 45Q ($50/tonne)

Image Credit: Red Trail Energy

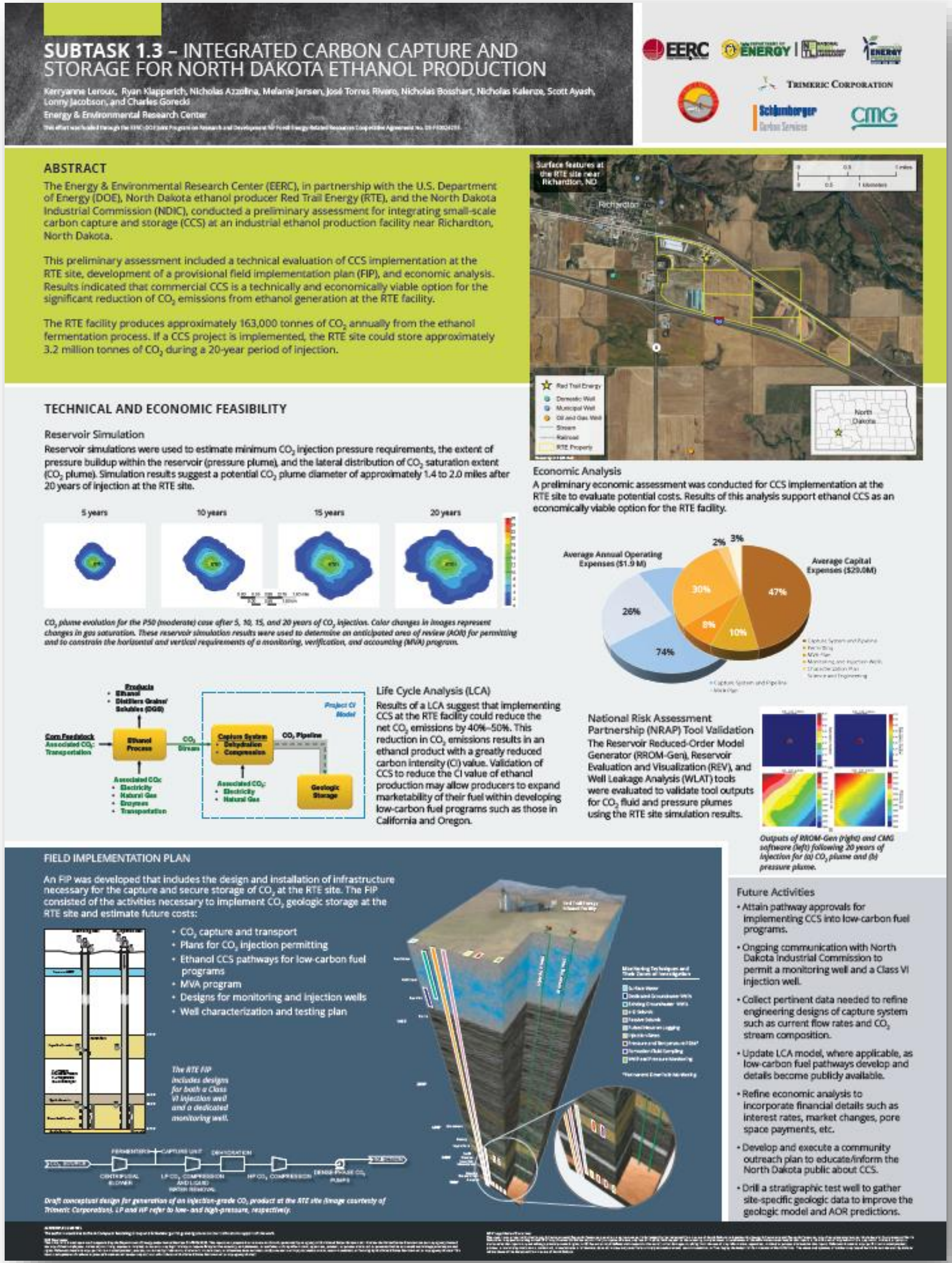


Image Credit: Energy & Environmental Research Center

Operated by Minnkota Power Cooperative, the Young Station is a mine-mouth generating station that uses lignite coal supplied from the adjacent BNI Coal mine. Unit 2, a 455-megawatt unit that began commercial operation in 1977, is the target for Project Tundra.

Project Tundra is in the advanced research and design phase. If the project moves ahead, construction will commence in 2022-2023

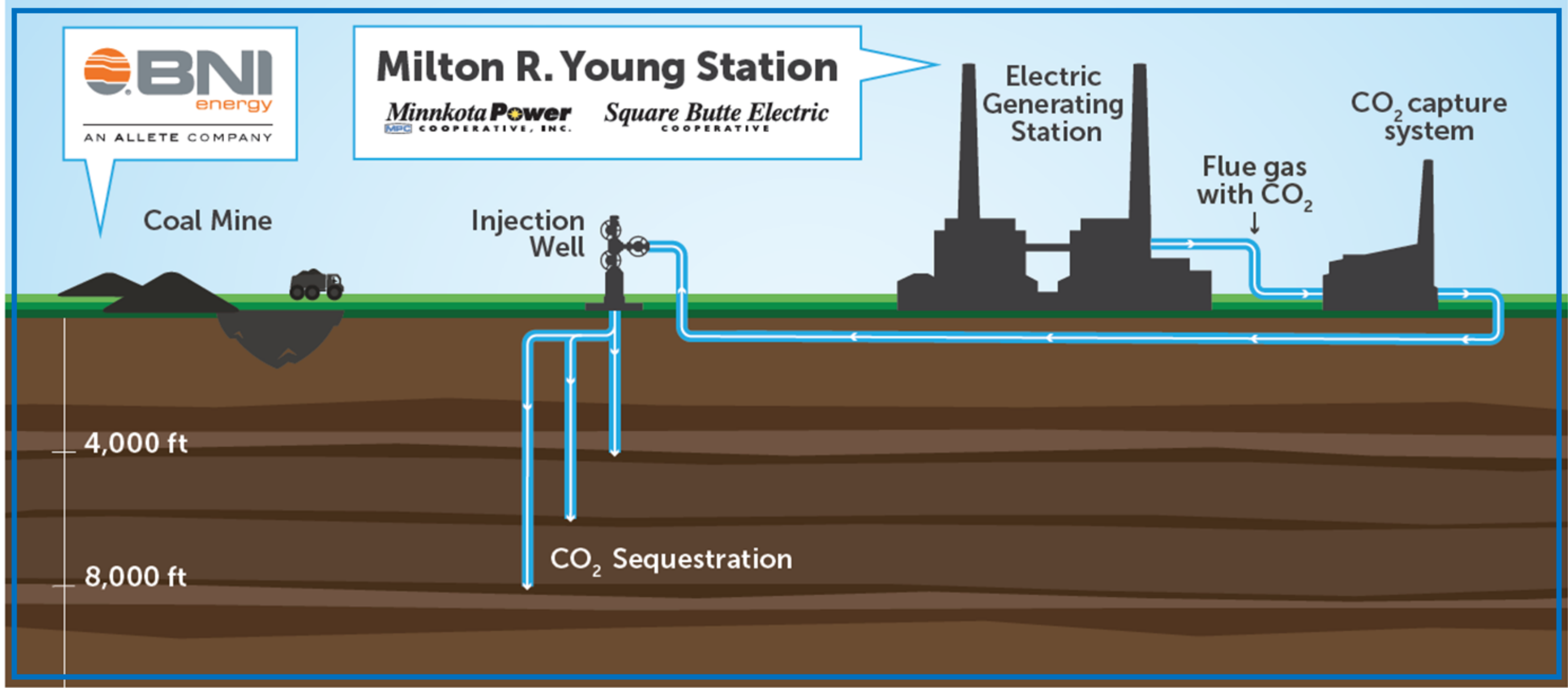
Precommercial:

Front-end engineering and design (FEED)

90% postcombustion CO_2 capture (~4 million tons per year).

Preparing to pursue federal and state permits required to build CO_2 capture facility and store CO_2 in deep geologic formations.

Exploring ND EOR opportunities.



NORTH DAKOTA CarbonSAFE

U.S. DEPARTMENT OF ENERGY | NATIONAL ENERGY TECHNOLOGY LABORATORY

ALLETE clean energy

BASIN ELECTRIC POWER COOPERATIVE
A Touchstone Energy® Cooperative

BNI energy
AN ALLETE COMPANY

Minnkota Power Cooperative, Inc.
Your Touchstone Energy® Partner

CMG

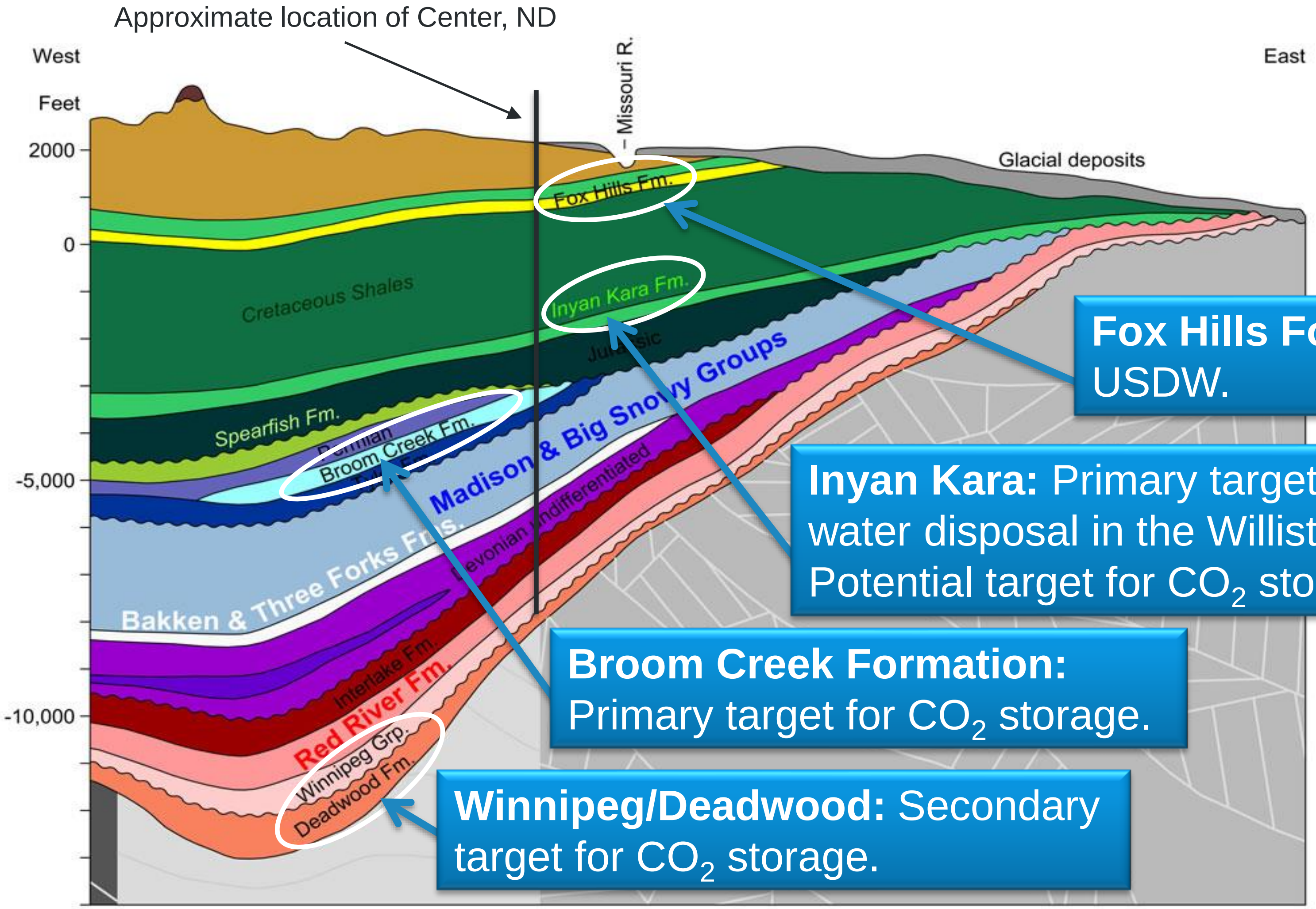
Prairie Public

North American Coal Corporation

Schlumberger


Image Credit – EERC

CARBONSAFE ZONES OF FOCUS



Fox Hills Formation: Lowest USDW.

Inyan Kara: Primary target for produced water disposal in the Williston Basin. Potential target for CO_2 storage.

Broom Creek Formation: Primary target for CO_2 storage.

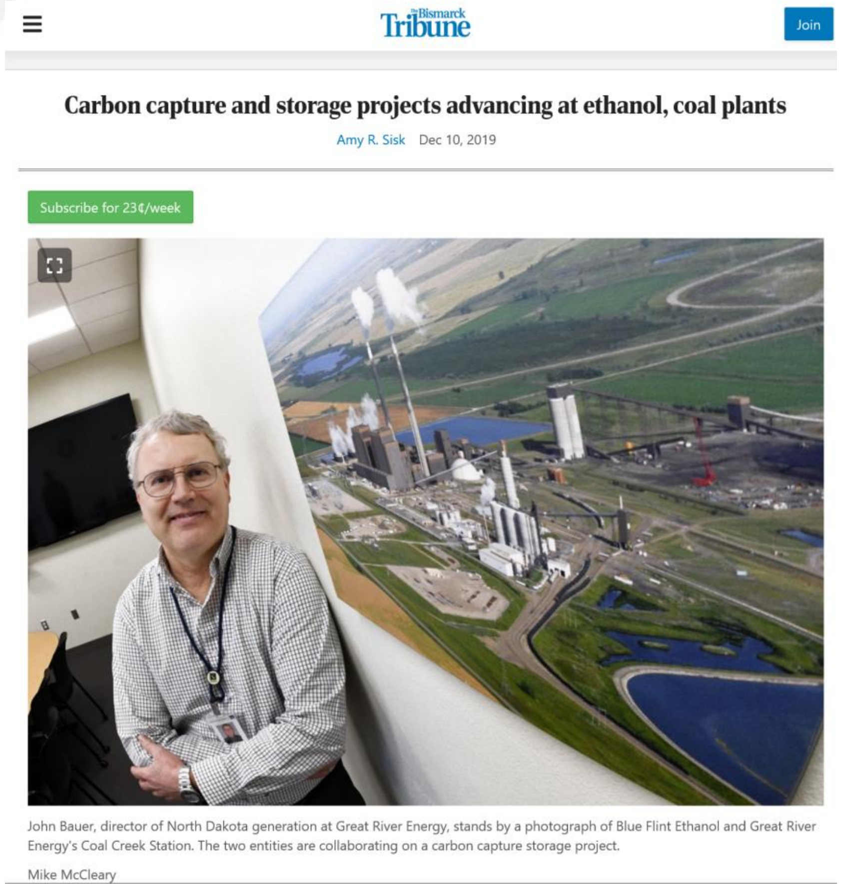
Winnipeg/Deadwood: Secondary target for CO_2 storage.

STEPS & TIMELINE TO IMPLIMENT INDUSTRIAL PROJECTS

DRIVERS FOR INDUSTRIAL CCUS

OBSTACLES FOR INDUSTRIAL CCUS

ENABLERS OF INDUSTRIAL CCUS



≡ The Bismarck Tribune Join

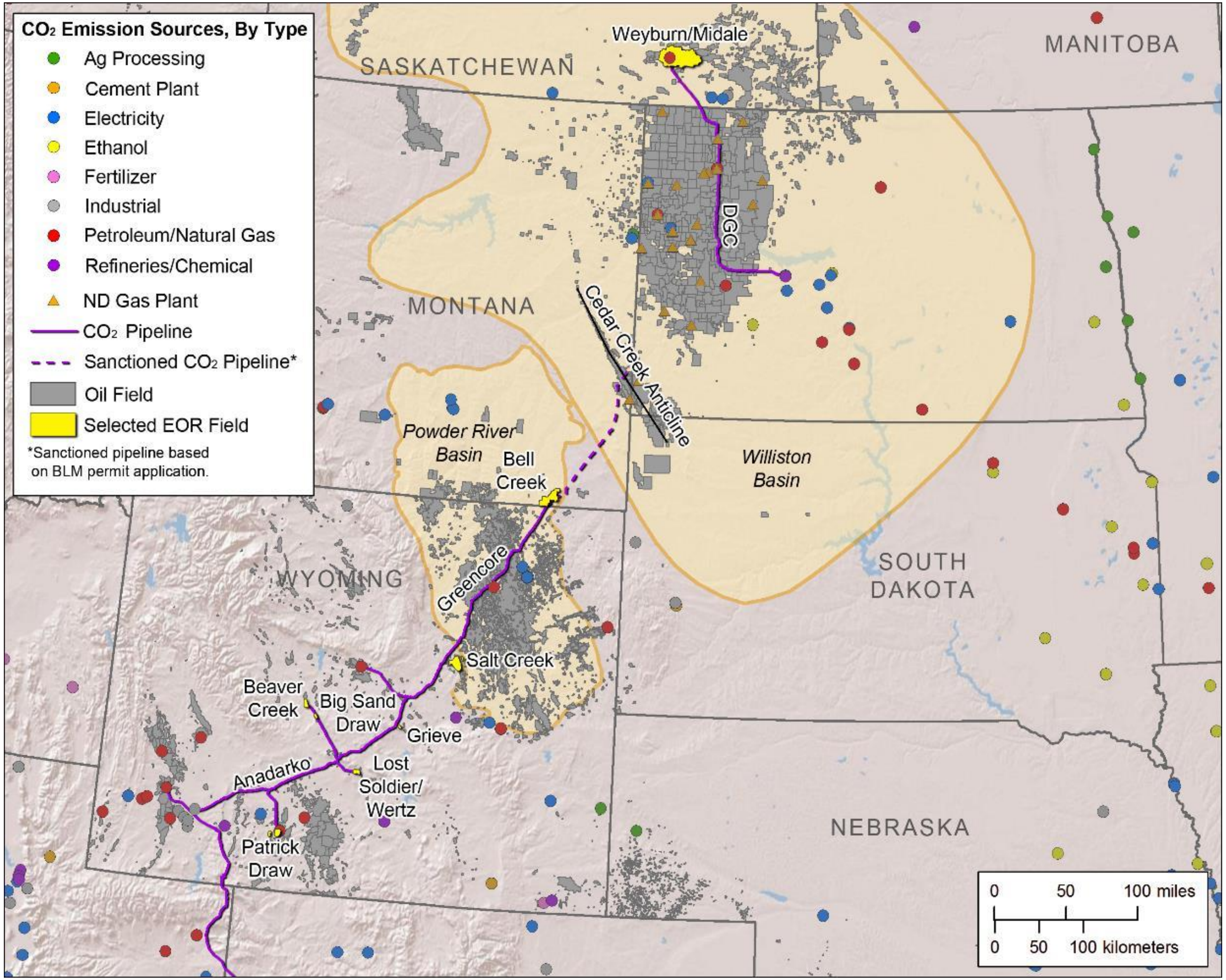
Carbon capture and storage projects advancing at ethanol, coal plants

Amy R. Sisk Dec 10, 2019

Subscribe for 23¢/week

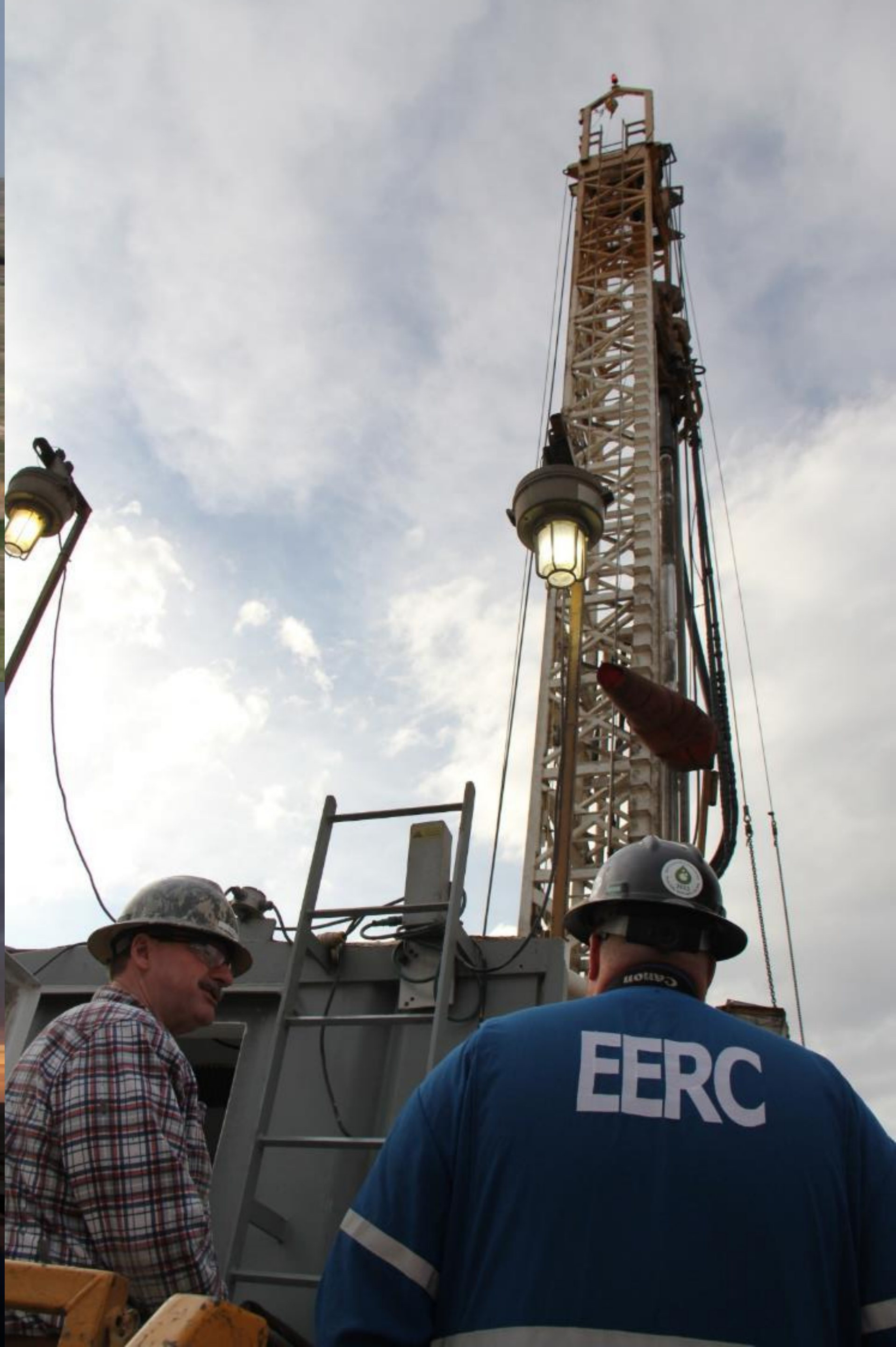
John Bauer, director of North Dakota generation at Great River Energy, stands by a photograph of Blue Flint Ethanol and Great River Energy's Coal Creek Station. The two entities are collaborating on a carbon capture storage project.

Mike McCleary



NORTH DAKOTA

BRINE EXTRACTION AND STORAGE TEST



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GEOLOGIC CO_2 STORAGE

CONSIDERATIONS FOR INDUSTRIAL PROJECTS

- Buoyant fluid
- Large volumes = large footprint
- Transportation
- Access to pore space
  - Leasing, unitization/amalgamation, trespass
- Regulatory compliance
- Assuring permanence for incentives or credits
  - Conformance and storage efficiency

Because of a host of technical, social, regulatory, environmental, and economic factors, brine disposal tends to be more accessible and generally quicker, easier, and less costly to implement compared to dedicated CO_2 storage.

ACTIVE RESERVOIR MANAGEMENT (ARM)

TWO COMPLEMENTARY COMPONENTS

ARM Test

- Reduce stress on sealing formation
- Geosteer injected fluids
- Divert pressure from leakage pathways
- Divert pressure from CO_2 plume
- Reduce area of review (AOR) and amalgamated area
- Improve injectivity, capacity, and storage efficiency
- Validate monitoring techniques, and forecast model capabilities

Brine Treatment Test Bed

- Alternate source of water
- Reduced disposal volumes
- Salable products for beneficial use

Brine extraction can enable dedicated CO_2 storage and improve the geologic CO_2 storage potential of a site.

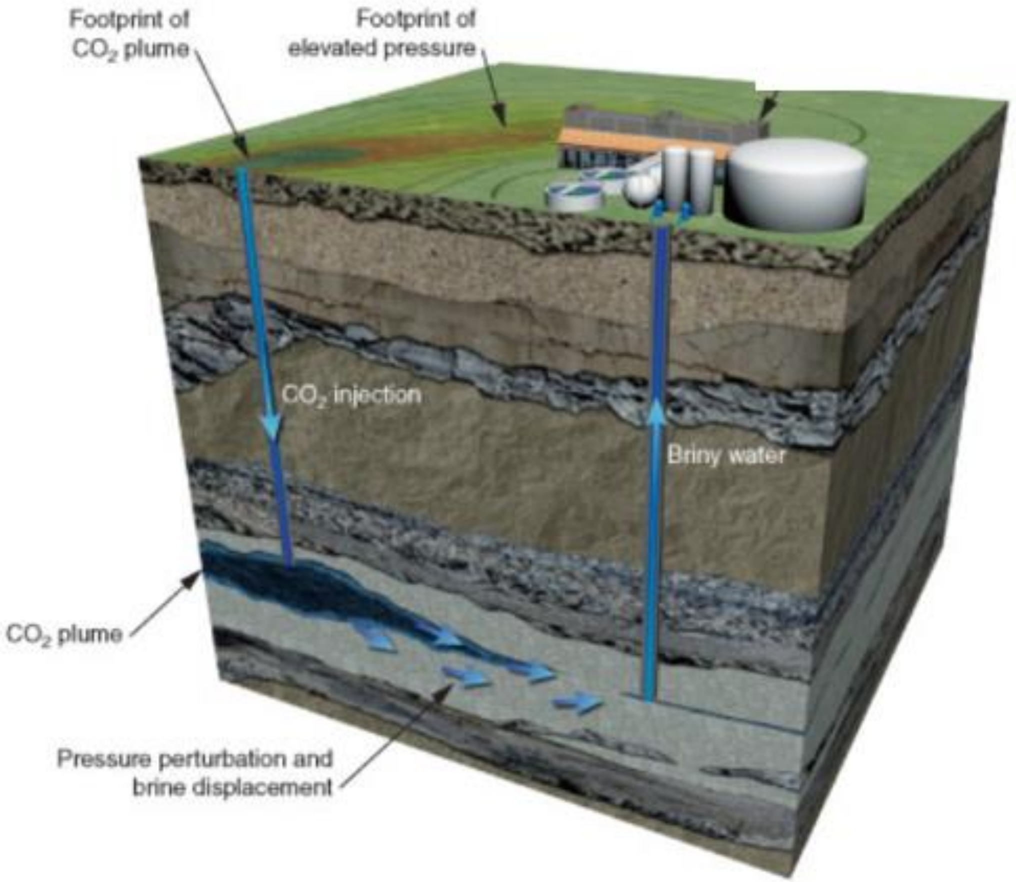


Illustration modified from Lawrence Livermore National Laboratory https://str.llnl.gov/Dec10/aines.html

HOW ARM CAN ENABLE COMMERCIAL GELOGIC CO_2 STORAGE

A HYPOTHETICAL EXAMPLE

- Collaboration with Thomas Buscheck (Lawrence Livermore National Laboratory)
  - Model developed and calibrated for CO_2 storage in a continuous, open saline reservoir
    - ♦ Developed, in part, with data provided by the ND BEST project for SWD operations injecting into Inyan Kara Formation

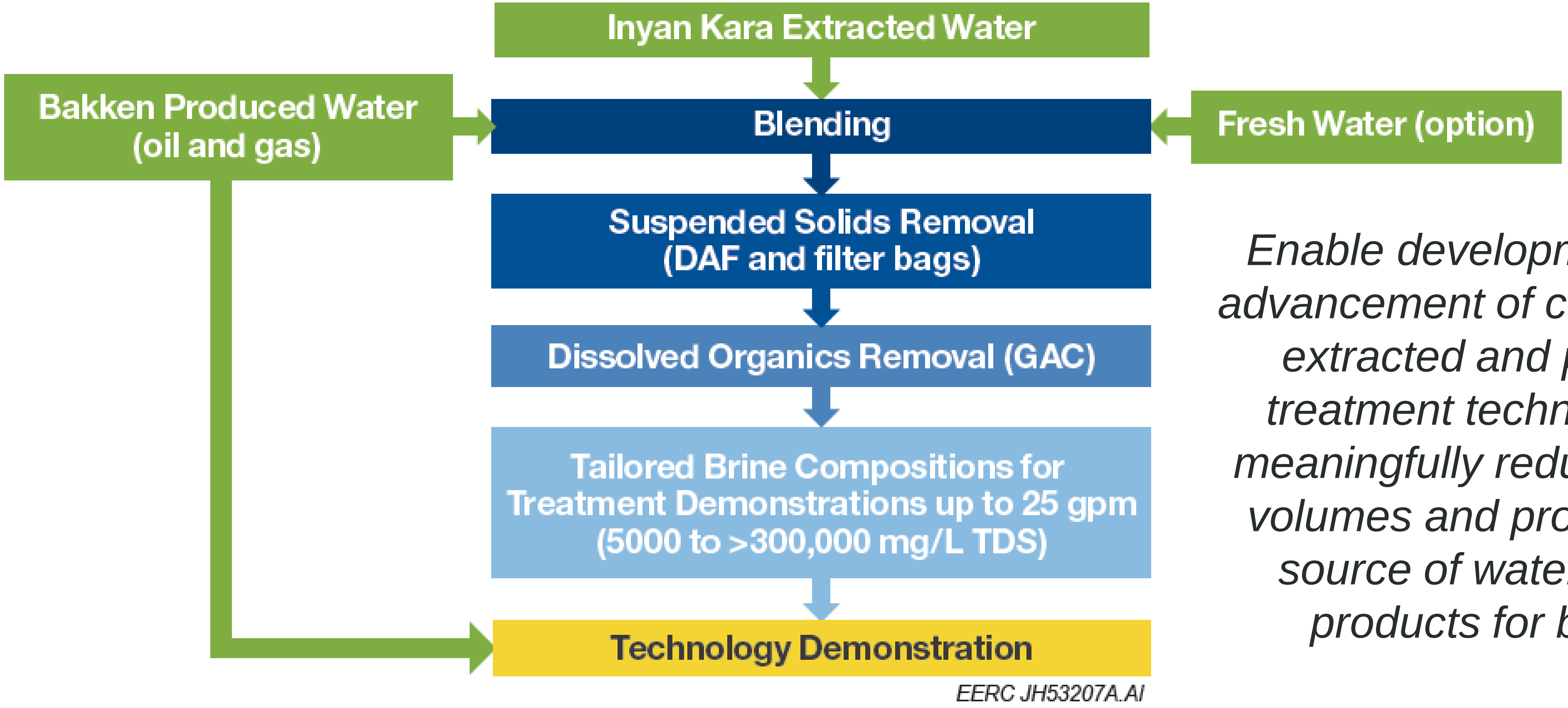
- Modeled scenario
  - Inject 2.0 MT/year of CO_2 from October 1, 2008, to March 1, 2019, with concurrent SWD
  - Six brine extraction wells (~11,000 bpd/well) with reinjection >12 miles away
    - ♦ >95% reduction in AOR
      - From 249 km^2 to 9 km^2
        - Area within reservoir with pressures 75 psi or more above the original reservoir pressure at the end of the injection period
    - ♦ > 90% reduction in postinjection monitor period
      - From 26 years to 2 years
        - Time for reservoir pressure to decline to less than 75 psi above original reservoir pressure at the injection well following injection period

Results summarized from: Task 4: Active Reservoir Management (FEW-0191) presented by Thomas Buscheck of Lawrence Livermore National Lab at the U.S. Department of Energy National Energy Technology Laboratory, Addressing the Nation’s Energy needs Through Technology innovation – 2019 Carbon Capture, Utilization, Storage, and Oil and Gas Technology Integrated Review Meeting, August 26-30, 2019

ACCOMPLISHMENTS

ACTIVE RESERVOIR MANAGEMENT

BRINE TREATMENT TECHNOLOGY DEVELOPMENT AND TEST FACILITY



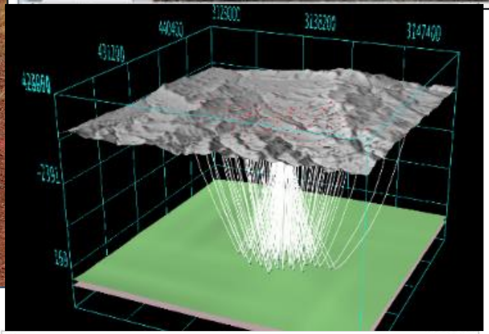
Enable development, testing, and advancement of commercially viable extracted and produced water treatment technologies that can meaningfully reduce brine disposal volumes and provide an alternate source of water and/or salable products for beneficial use.

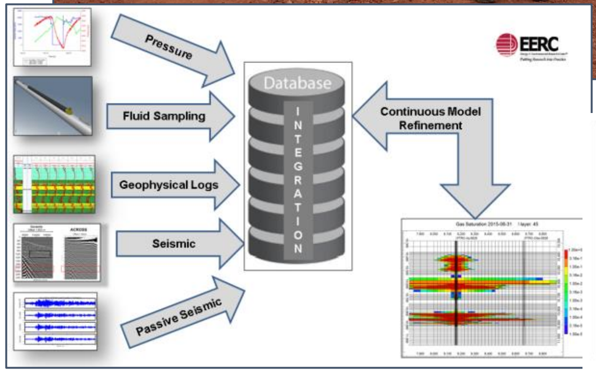
ACCOMPLISHMENTS

BRINE TREATMENT DEVELOPMENT FACILITY

COST-EFFICIENT MONITORING

- Intelligent, adaptive, scalable, strategic
- Fast automated processing/quicker integration
  - Improve interpretations and performance forecasts
  - Actionable results that inform operational decisions
  - Integrated with autonomous operation
- Low environmental and operational impact
  - Autonomous, remote sensing, no umbilical, site access
- Viable long term (10–100 years postinjection!!!)
  - Cost effective, robust, reliable, site access, highly trainable
- Understood and effectively communicated
  - Public and regulatory acceptance
  - Deterministic





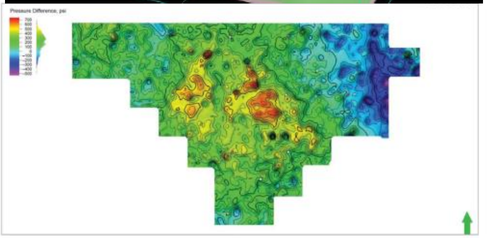
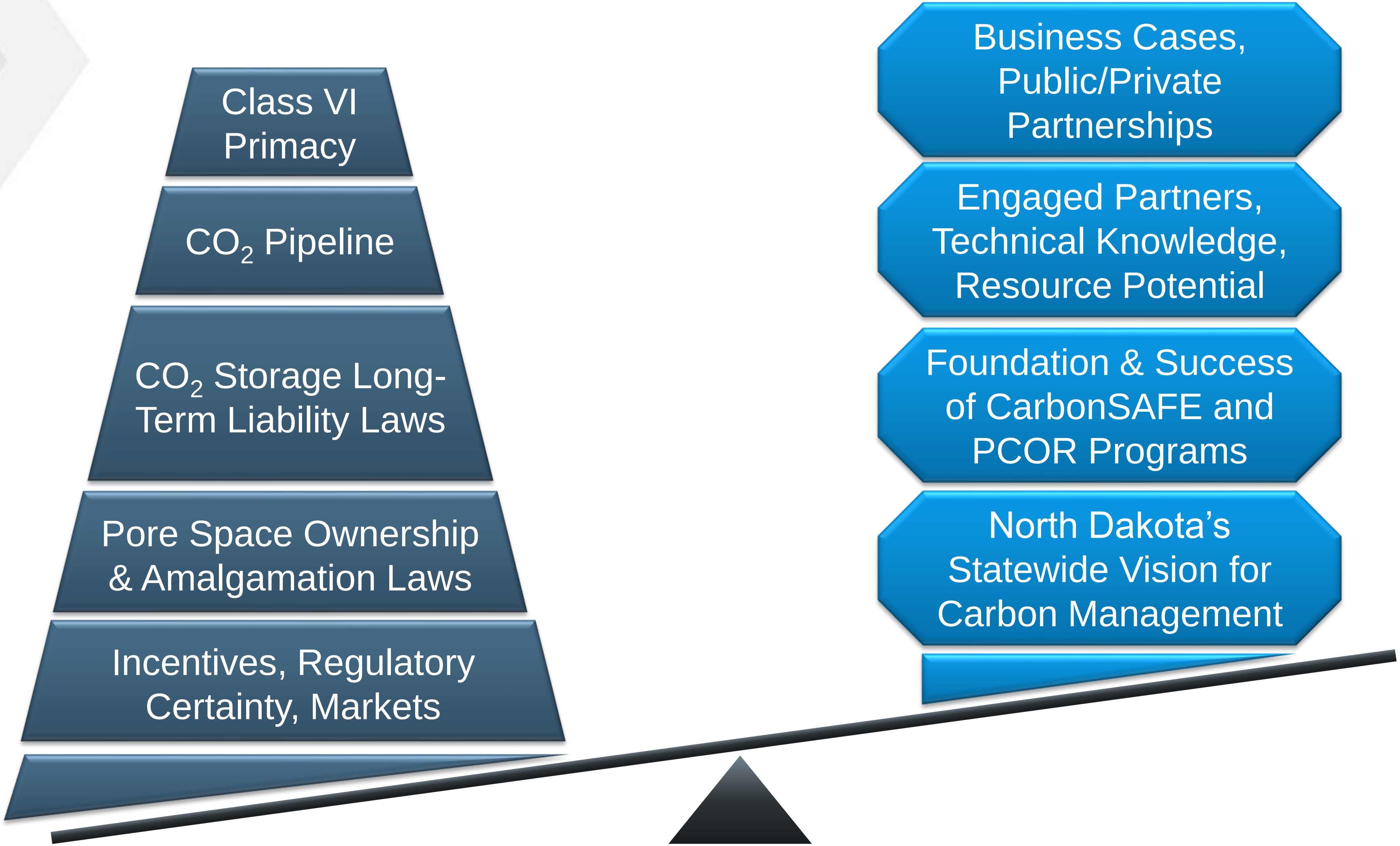


Fig. 14. Reservoir pressure differences between September 2015 and December 2016 inverted from measured InSAR data.


Class VI Primacy
CO_2 Pipeline
CO_2 Storage Long-Term Liability Laws
Pore Space Ownership & Amalgamation Laws
Incentives, Regulatory Certainty, Markets
Business Cases, Public/Private Partnerships
Engaged Partners, Technical Knowledge, Resource Potential
Foundation & Success of CarbonSAFE and PCOR Programs
North Dakota's Statewide Vision for Carbon Management

Credit: https://www.projecttundrand.com/young-station

QUESTIONS & DISCUSSION

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THANK YOU

Critical Challenges. Practical Solutions.

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