Critical Challenges. Practical Solutions.

Energy & Environmental Research Center (EERC)

NORTH DAKOTA INTEGRATED CARBON STORAGE COMPLEX FEASIBILITY STUDY

DE-FE0029488

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 Technologies Integrated Review Meeting
August 26–30, 2019

Wes Peck
Principal Geologist

NORTH DAKOTA CARBONSAFE

- Address technical and nontechnical challenges specific to commercial-scale deployment of a CO_2 storage project in central North Dakota.

- Long-term goal: develop a certified (permitted) geologic storage opportunity should a business case for CO_2 storage emerge (and it is!).

NORTH DAKOTA CARBONSAFE

- U.S. Department of Energy
- NDIC Lignite Research Council
- Basin Electric Power Cooperative
- ALLETE Clean Energy
- Minnkota Power Cooperative
- BNI Energy
- North American Coal
- Prairie Public Television
- Schlumberger Carbon Services
- Computer Modelling Group, Ltd.

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

INDUSTRIAL COMMISSION OF NORTH DAKOTA
LIGNITE RESEARCH COUNCIL

BNI energy
AN ALLETE COMPANY

BASIN ELECTRIC POWER COOPERATIVE
A Touchstone Energy® Cooperative

Prairie Public

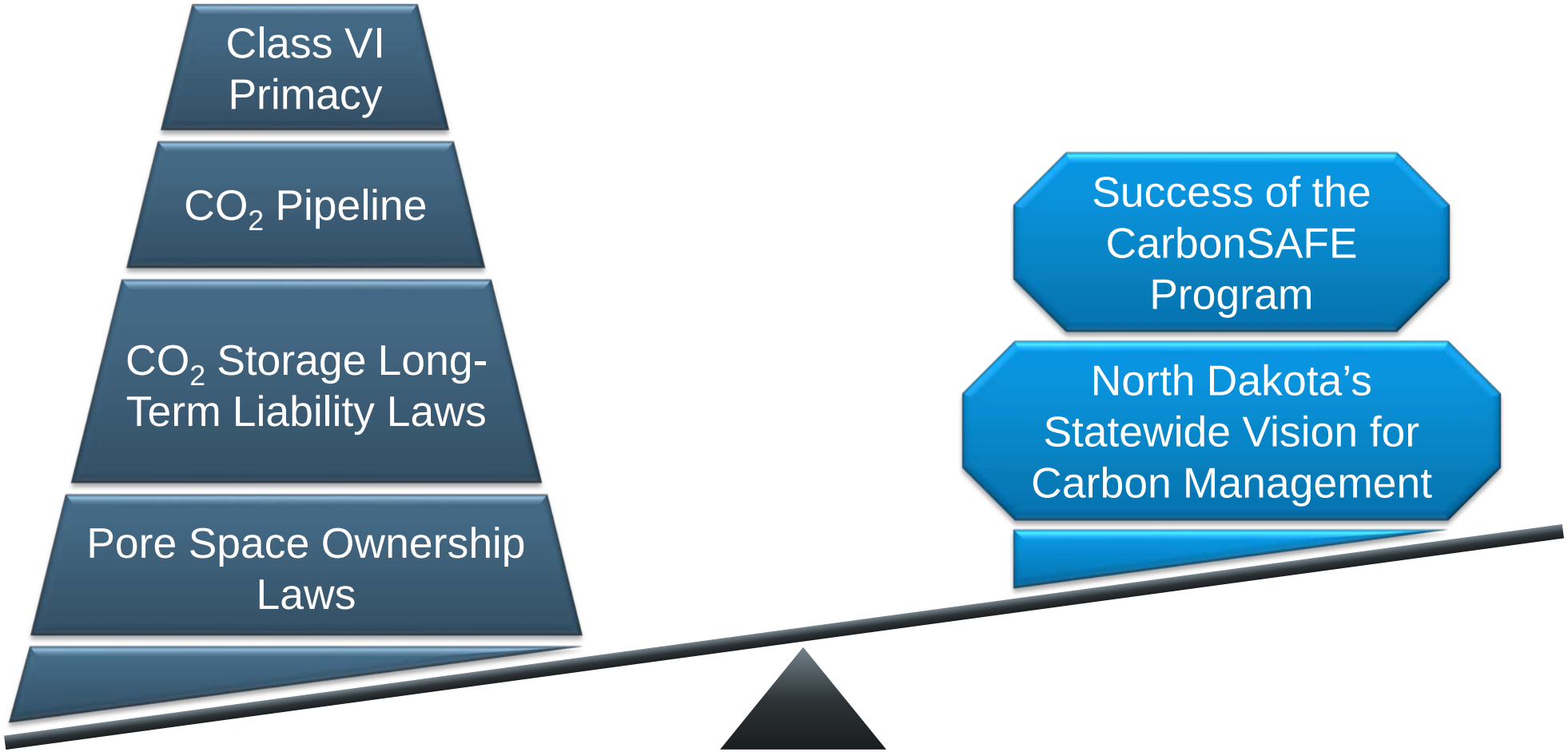
Schlumberger
Carbon Services

Minnkota Power
MPC COOPERATIVE, INC.
Your Touchstone Energy® Partner

CMG

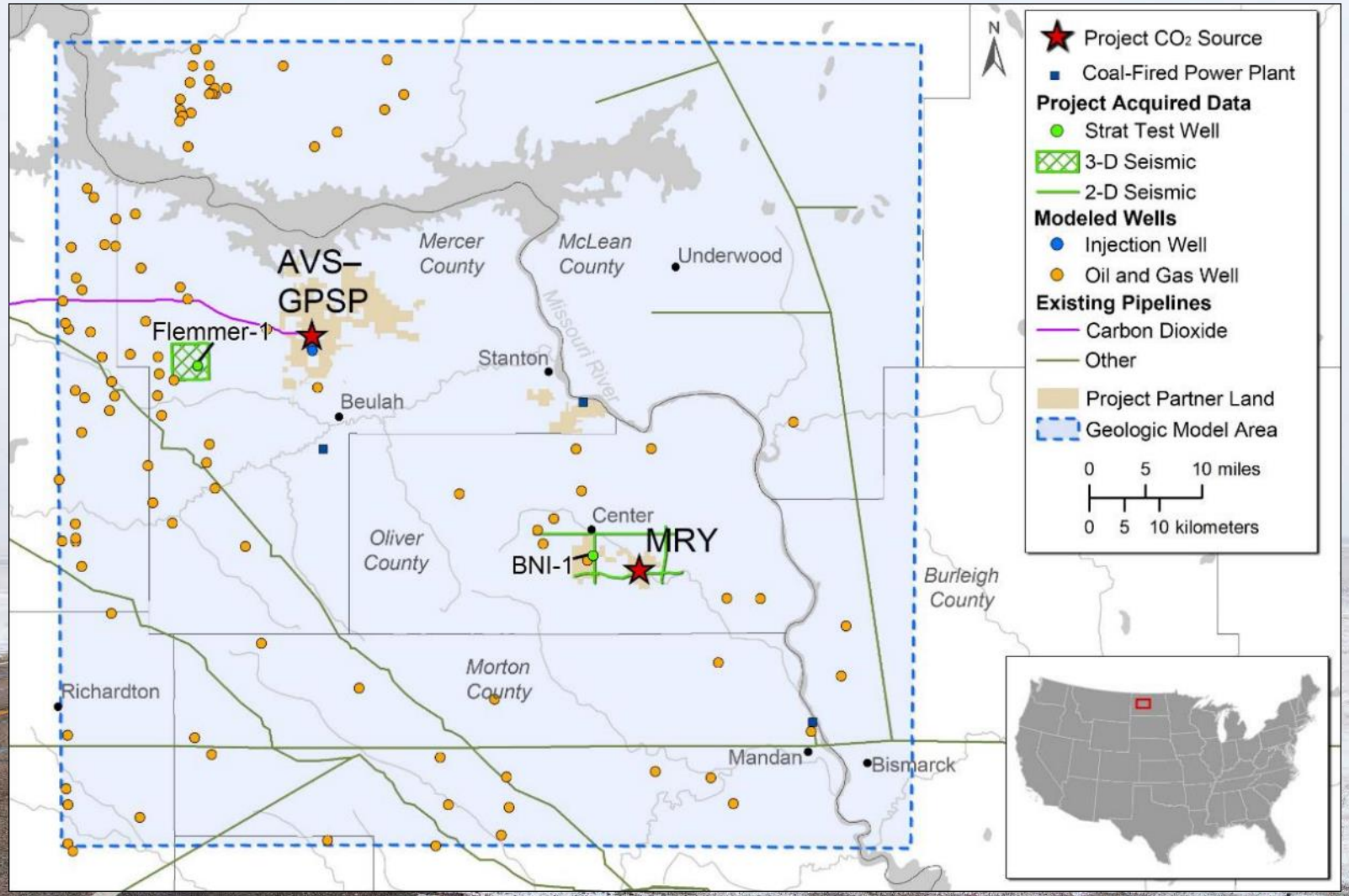
NORTHAMERICAN COAL CORPORATION

NORTH DAKOTA'S LEVERAGE



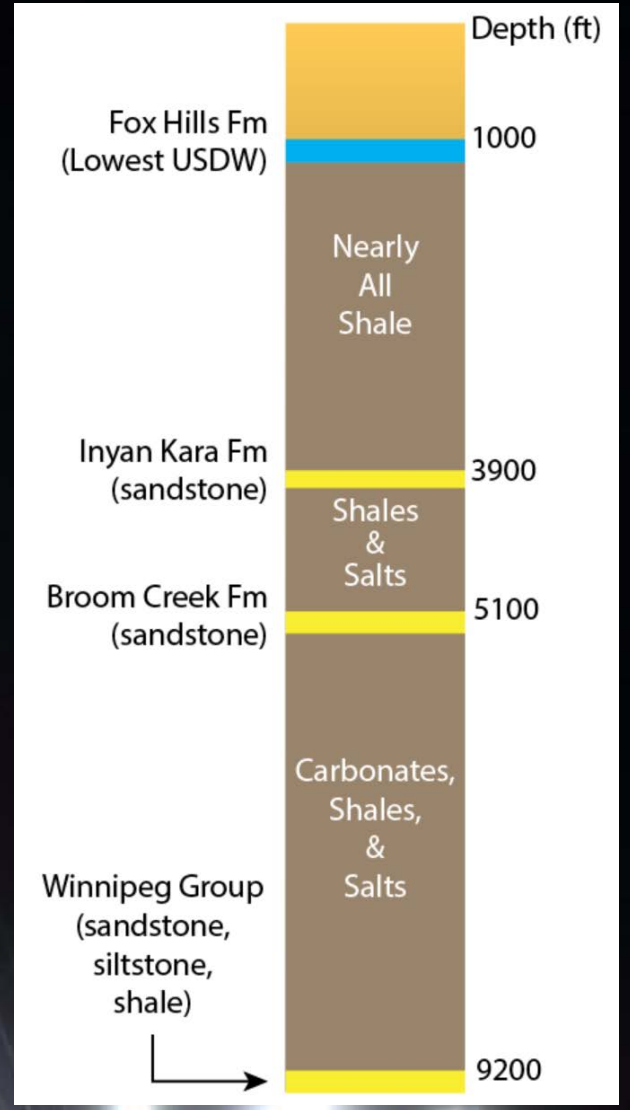
NORTH DAKOTA CARBONSAFE CO_2 SOURCE OPTIONS

PROJECT AREA



FIELD ACTIVITIES

- Drilled two new stratigraphic test wells.
  - Drill, core, log, plug, and abandon
- ~300 feet of core from each well.
  - Broom Creek (target) and Opeche Formations (seal)
- Geophysical logging and fracture test.
- Seismic source testing.
- Outreach.

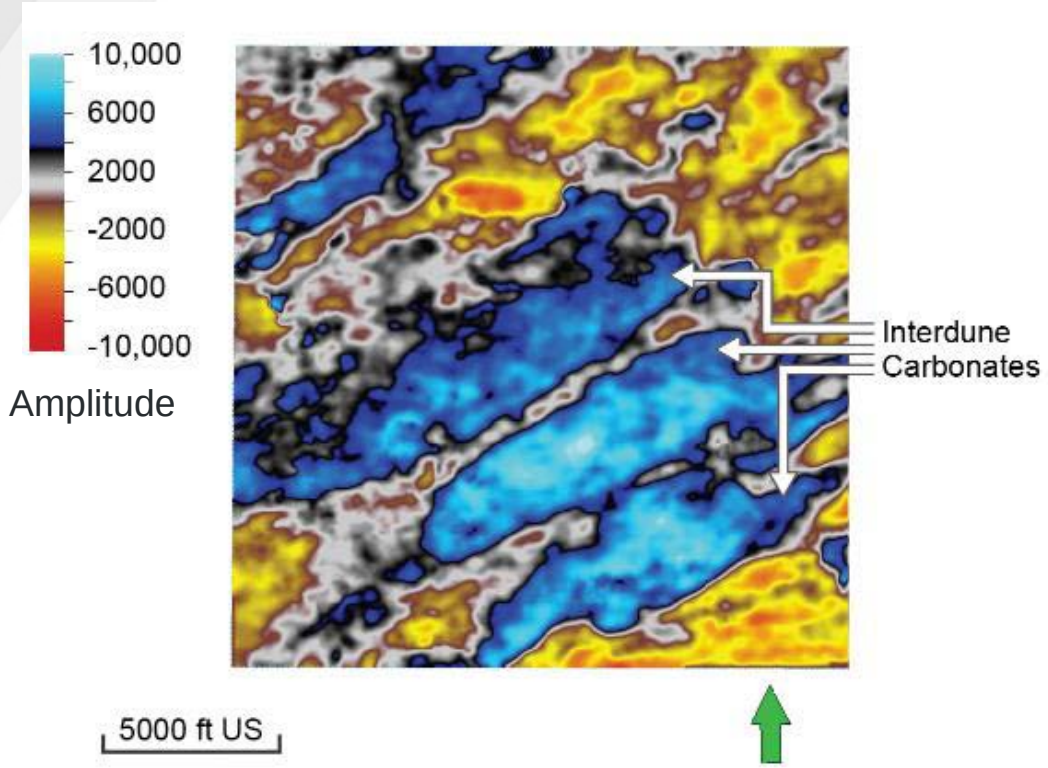


THE CORE

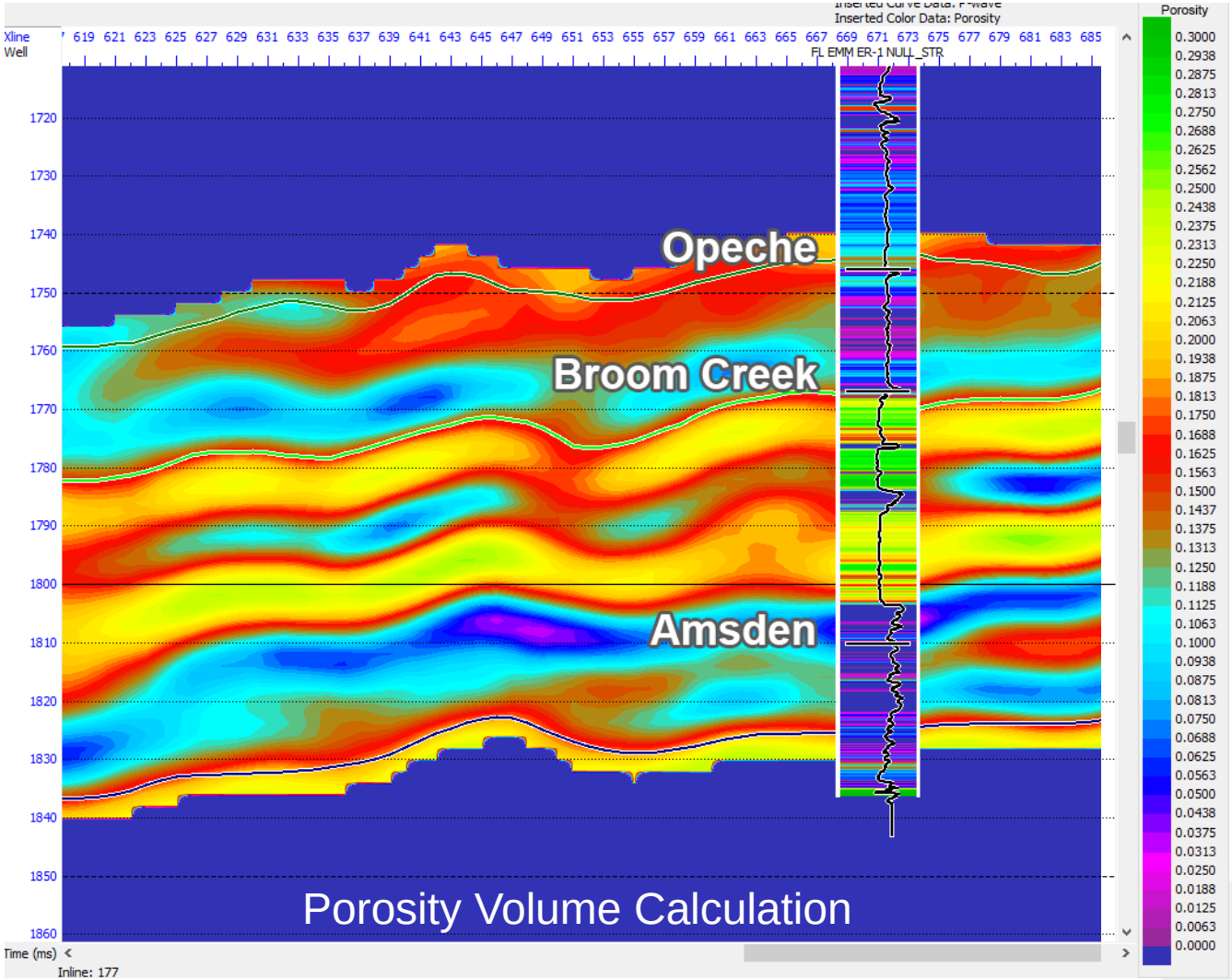
- **Flemmer-1 (east)**
- Broom Creek thickness: 263’
- Total sand thickness: 169’
  - Intervals: 53’; 34’, 65’, 17’

- **BNI-1 (west)**
- Broom Creek thickness: 273’
- Total sand thickness: 124’
  - Intervals: 89’, 19’, 16’

INTEGRATION OF SEISMIC DATA

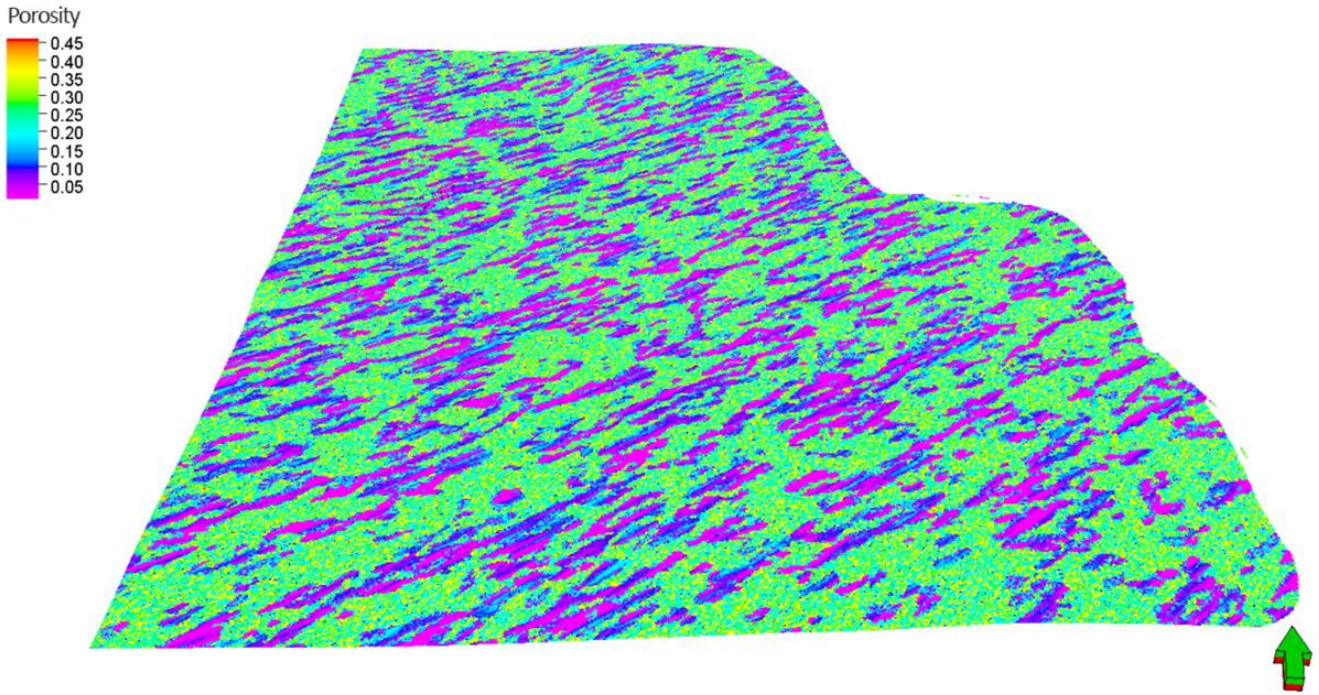


Geobody Interpretation



PETROPHYSICAL MODELING

- Porosity and permeability
  - Core analysis: three local wells and two far field wells
  - Well logs from the two strat test wells

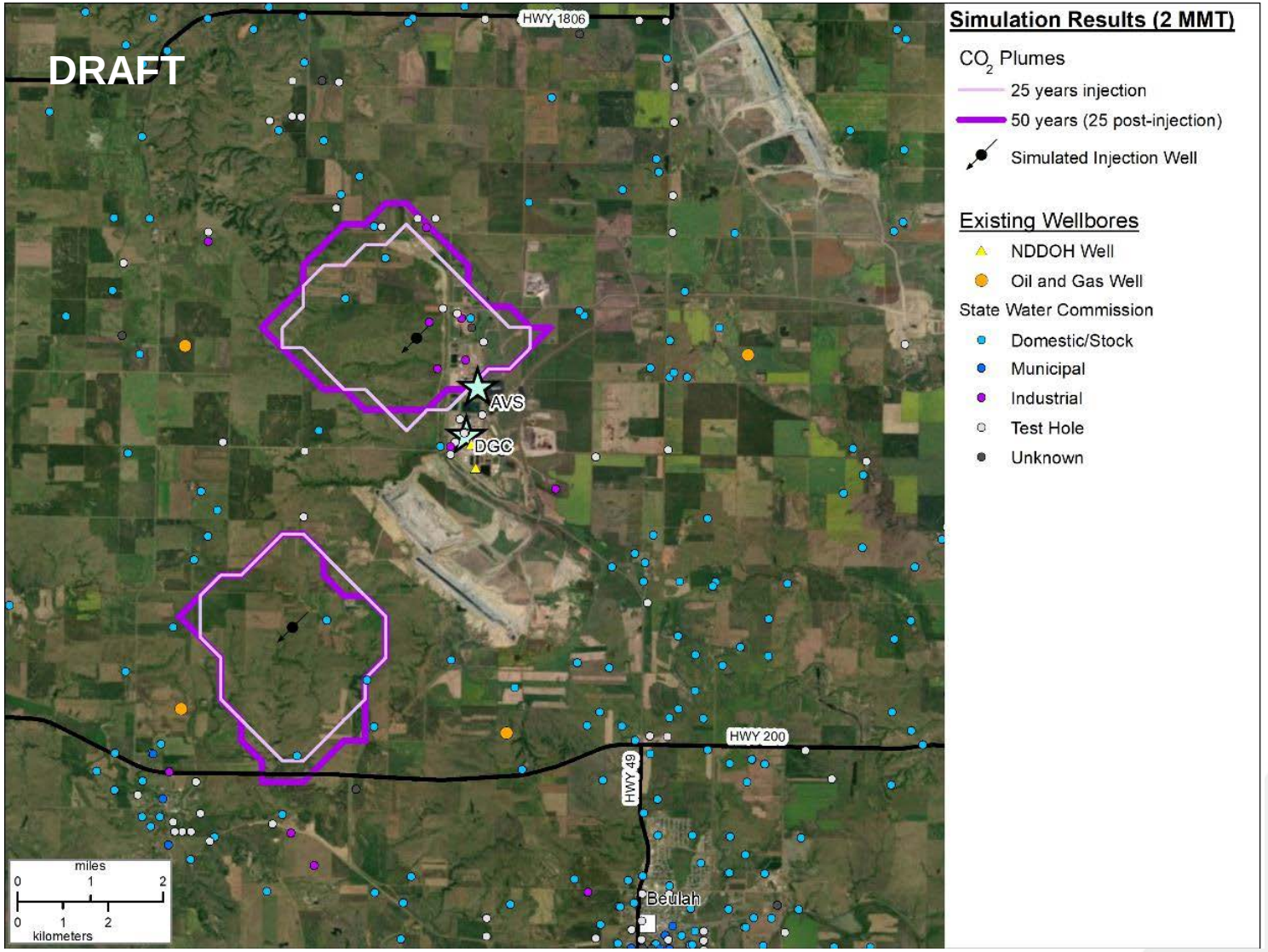


- Average porosity (%):
  - Reservoir: 26.0
  - Poor reservoir: 12.0
  - Nonreservoir: 5.0
- Average permeability (mD):
  - Reservoir: 315.1
  - Poor reservoir: 6.5
  - Nonreservoir: 0.04

NUMERICAL SIMULATION SCENARIO

Antelope Valley/Dakota Gasification

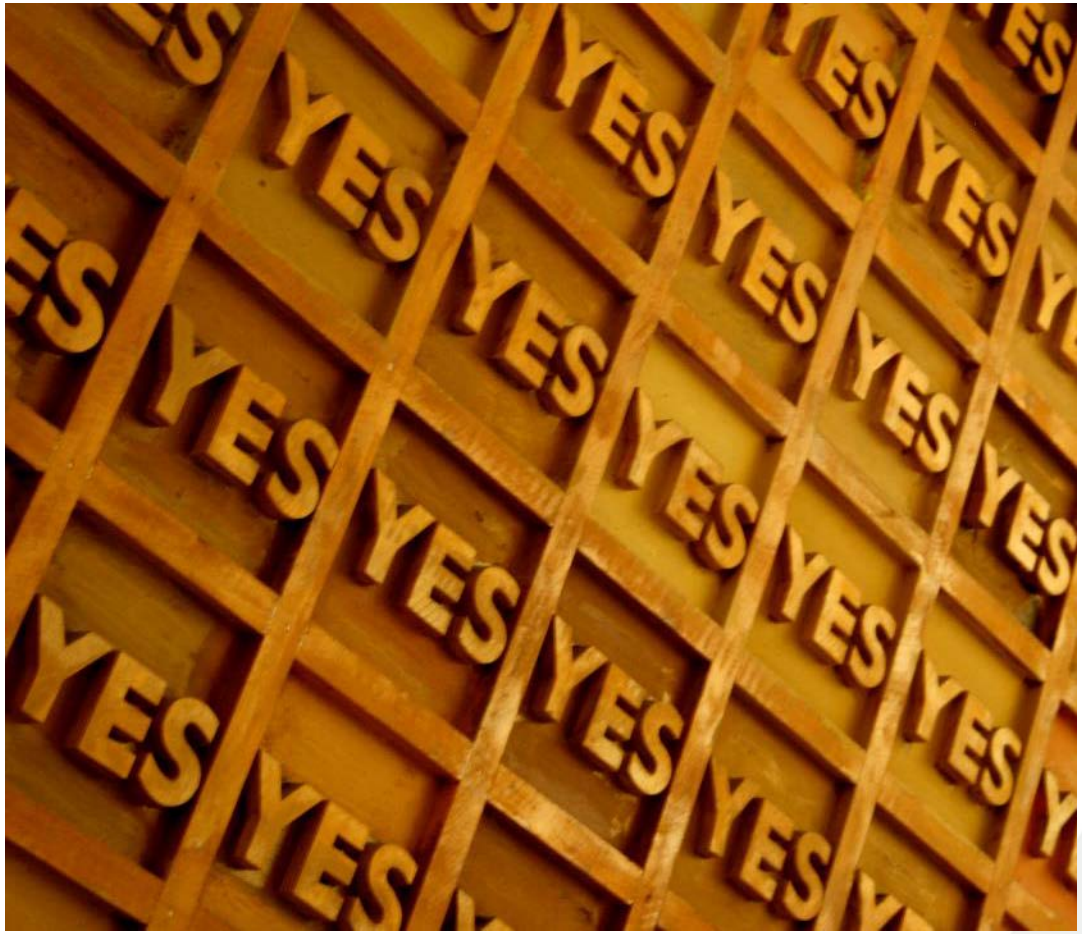
- Two injection wells
- CO_2 plume
  - 10.5 mi^2 (25 years)
  - 12.2 mi^2 (25 years postinjection)



PUBLIC OUTREACH

Foster neutral-to-positive attitudes toward the North Dakota CarbonSAFE project.

- Being factual and objective
- Serving our partners' best interests
- Courtesy and respect of the stakeholders and the community
- Transparent and proactive communication
- Consistent use of key messages



EDUCATION

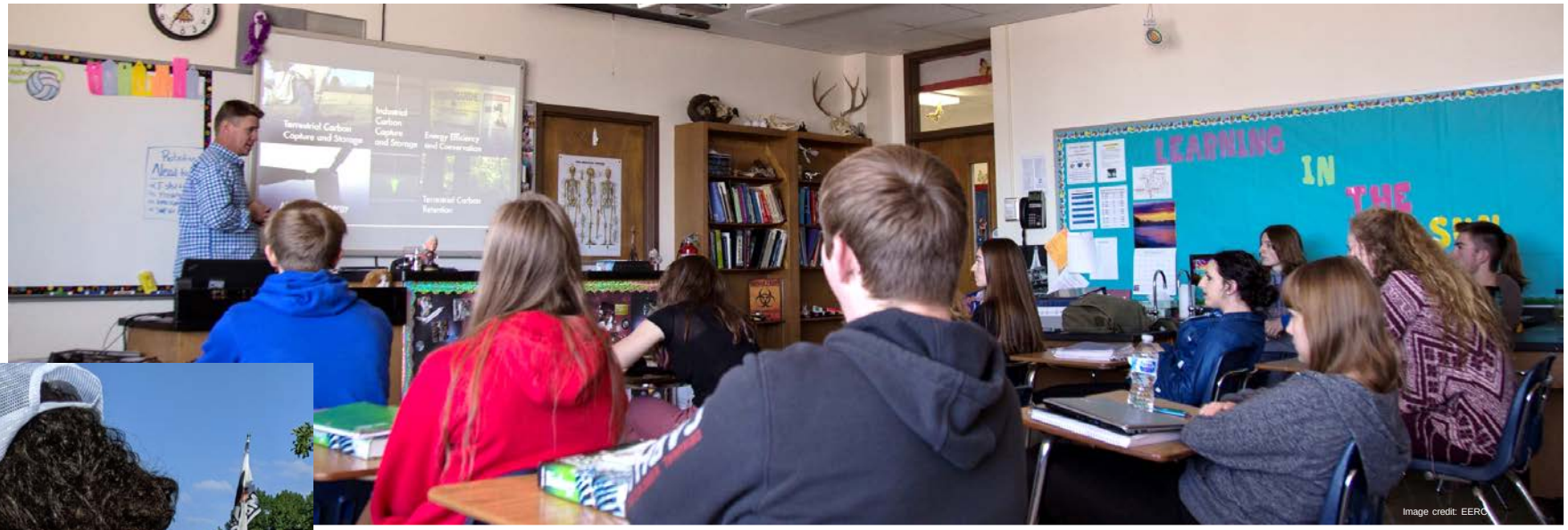


Image credit: EERC

Image credit: Prairie Public

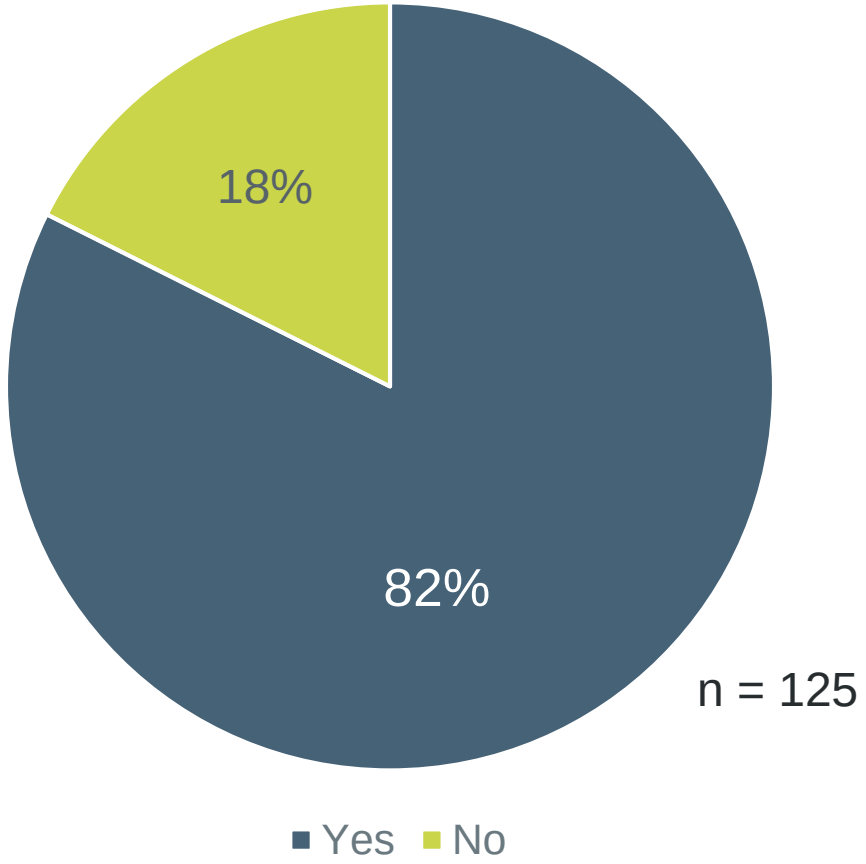
PUBLIC PERCEPTIONS OF CARBON CAPTURE, UTILIZATION, AND STORAGE

Online Survey

- Target audience: residents of Mercer and Oliver Counties
- Postcard notification to every residence in Mercer and Oliver Counties
- In mailboxes ~June 25
- Responses by August 30

Source: Minnkota Power

Before this survey, had you heard about the process of capturing CO_2 from a power plant and permanently storing it deep underground?



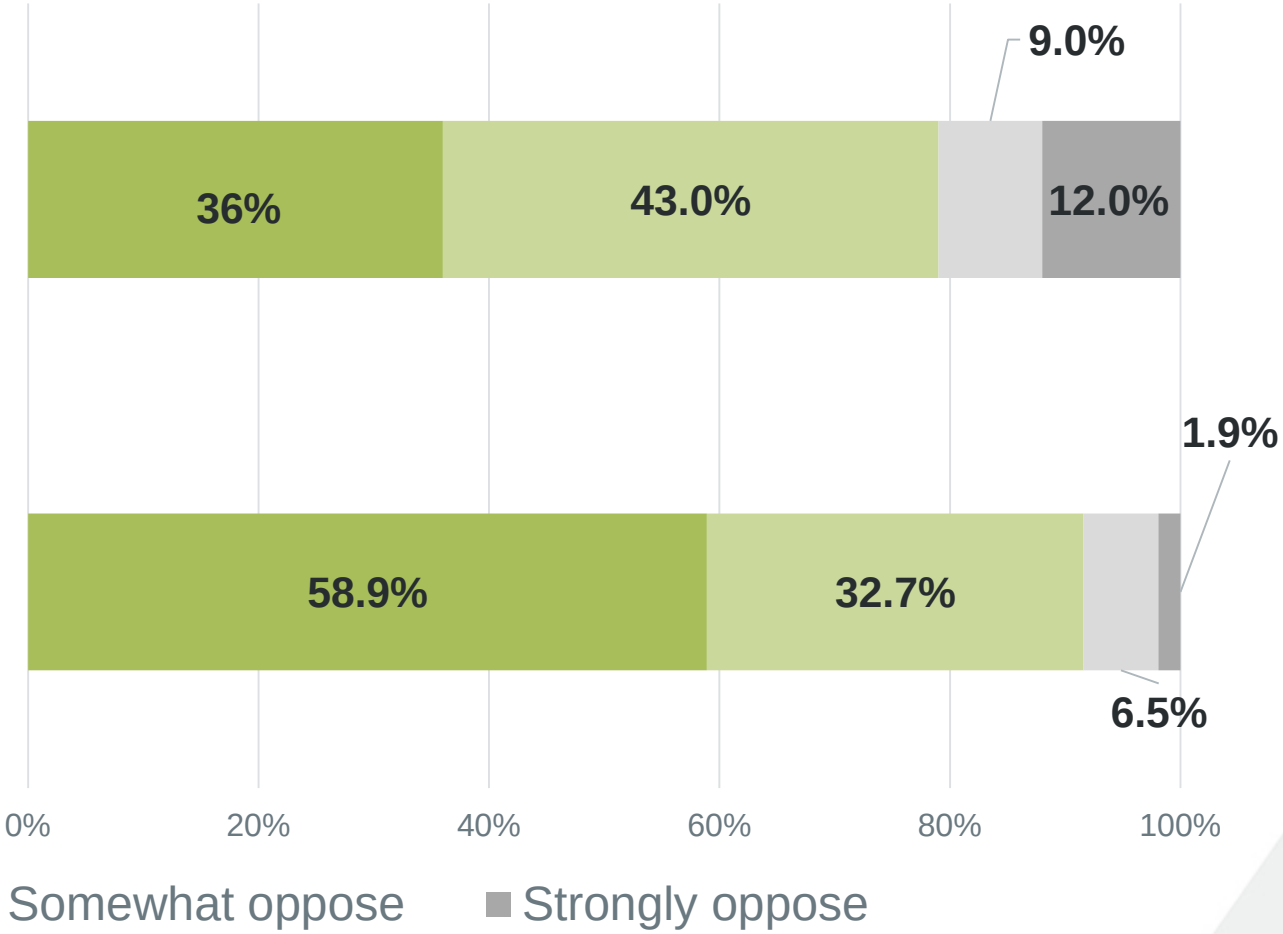
PLEASE INDICATE TO WHAT EXTENT THIS STATEMENT APPLIES TO YOU:

Do you favor or oppose projects that permanently store CO2 deep underground in North Dakota?

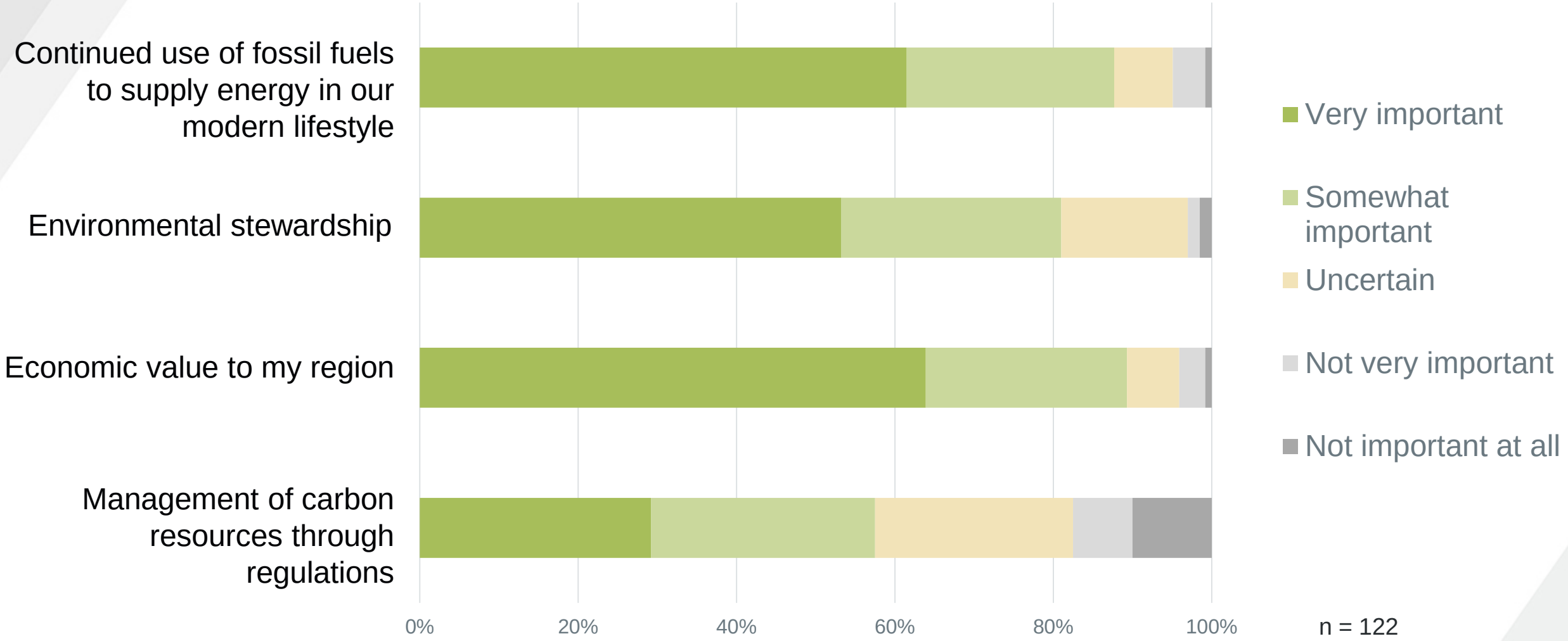
n = 100

Do you favor or oppose using CO2 to produce additional oil through enhanced oil recovery (EOR) in North Dakota?

n = 107



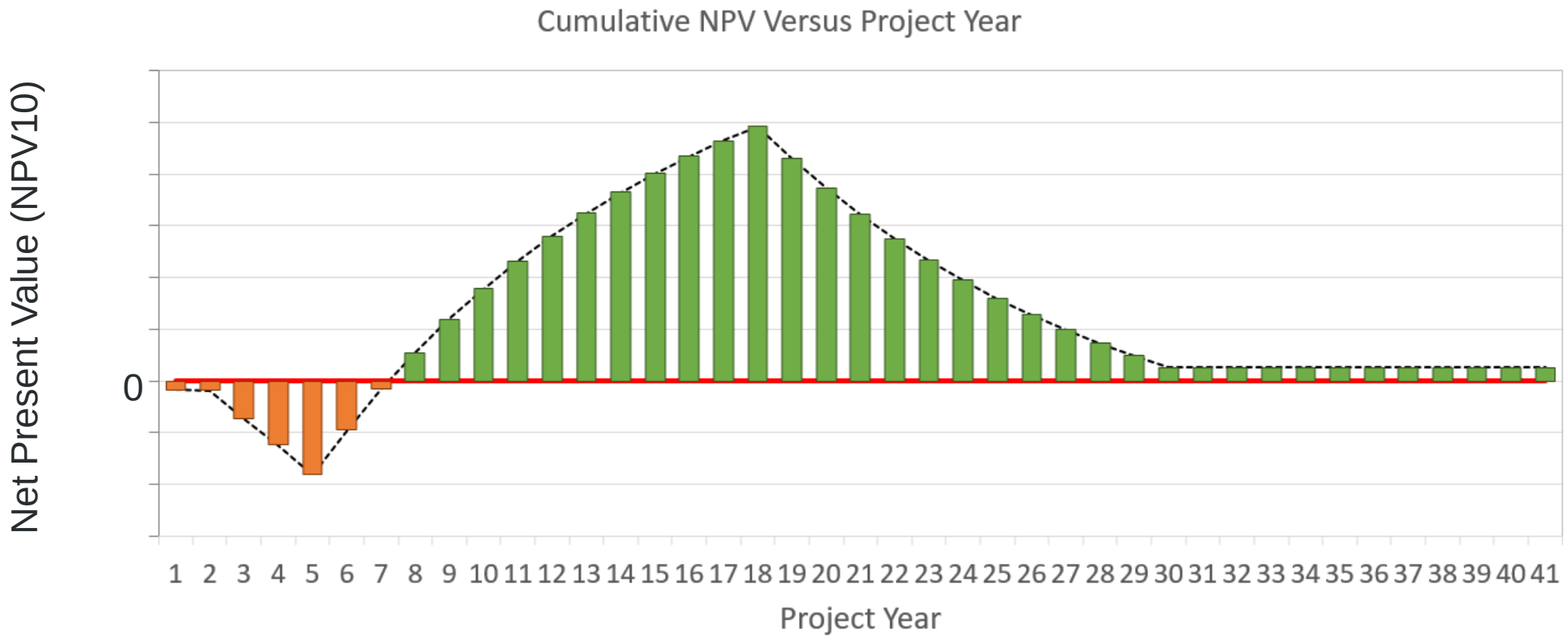
PLEASE CHOOSE THE IMPORTANCE LEVEL FOR EACH RATIONALE TO INVESTIGATE CO_2 CAPTURE AND PERMANENT STORAGE:



REGULATORY AND ECONOMIC ANALYSIS

- Evaluated state permitting requirements for implementation of Class VI injection wells.
- Exploring site access agreement options, pore space acquisition, and short-term project liability.
- Examining specific economic needs and the incentives in place to make the proposed scenarios economically feasible for the project partners.

ILLUSTRATIVE EXAMPLE OF ECONOMIC MODEL OUTPUT – CUMULATIVE NPV vs. PROJECT YEAR



SITE DEVELOPMENT PLAN

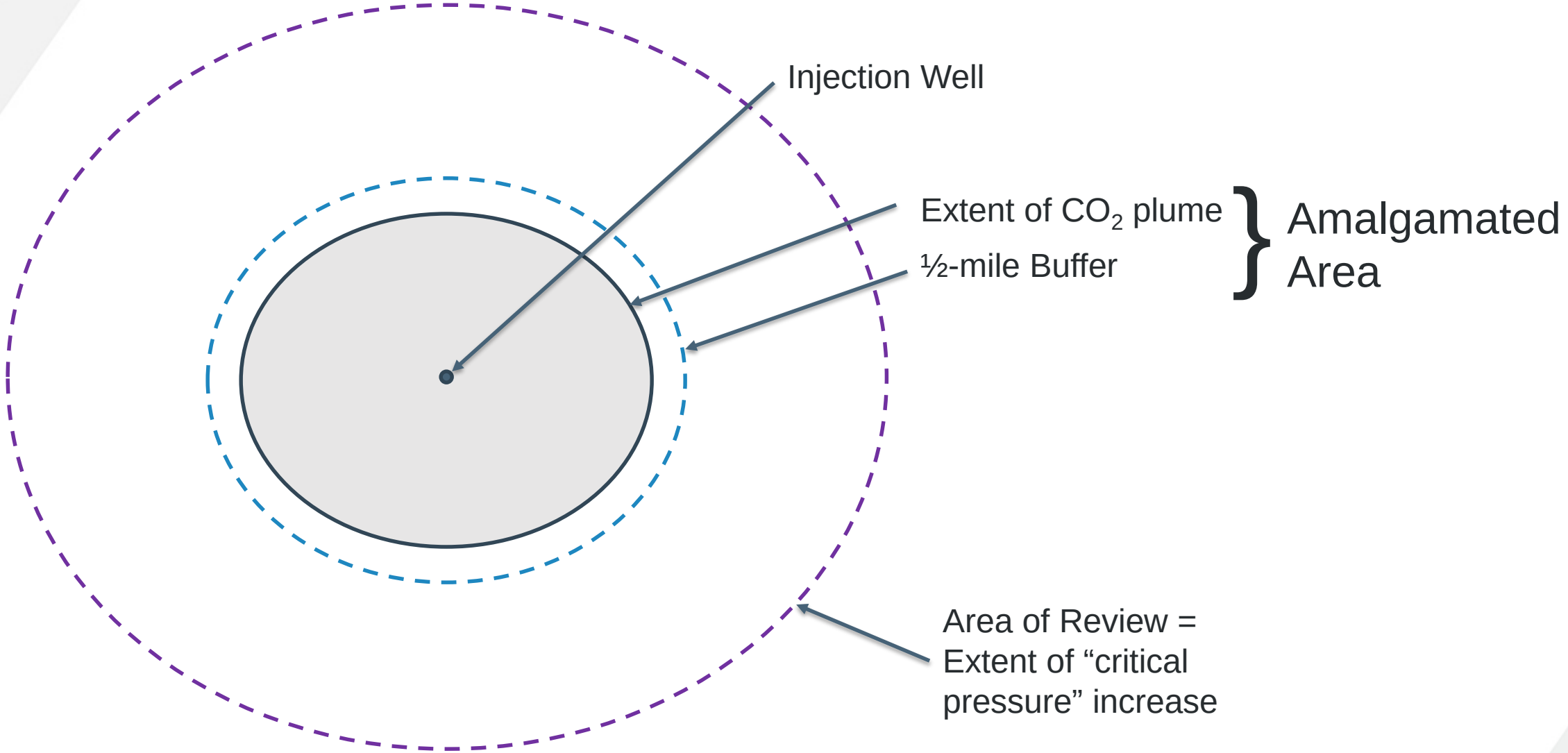
Create a detailed plan for development of an injection site within the storage complex.

- Site characterization plan
- CO_2 management strategy
- Risk assessment and mitigation strategies

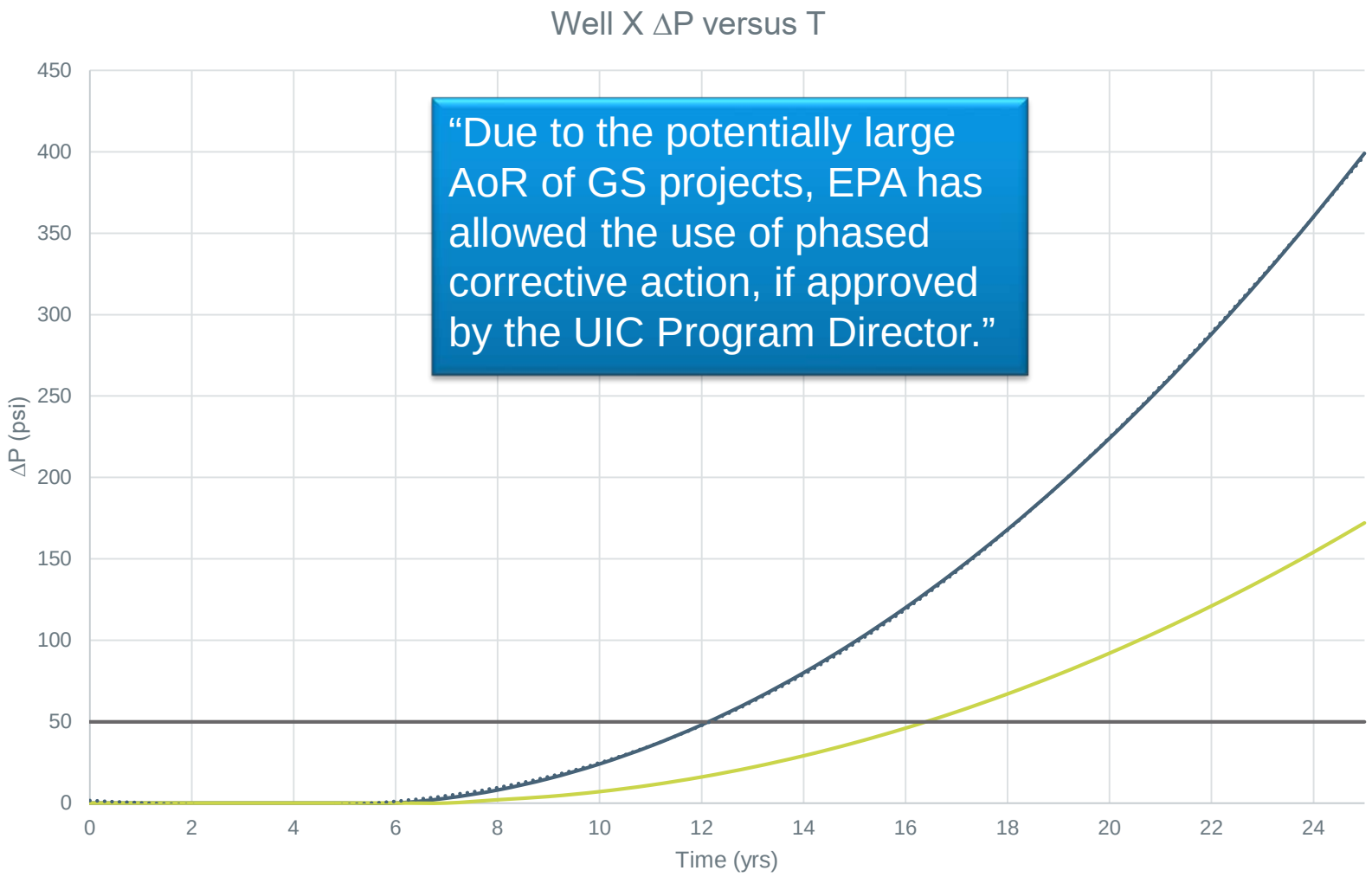
ND CLASS VI PROGRAM COMPONENTS

- Storage facility permit
- Permit to drill for injection well
- Permit to inject
- Certificate of project completion

STORAGE FACILITY CONCEPTS

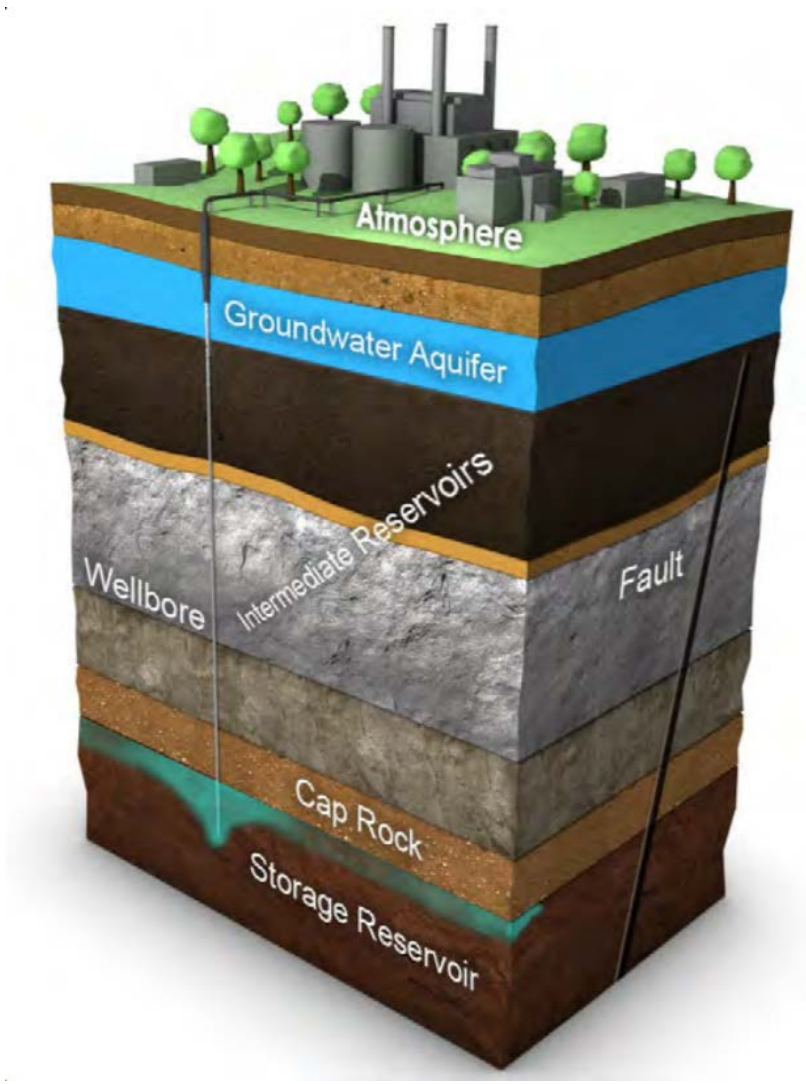


WELL PRESSURE vs. TIME CONCEPT FOR ACTION



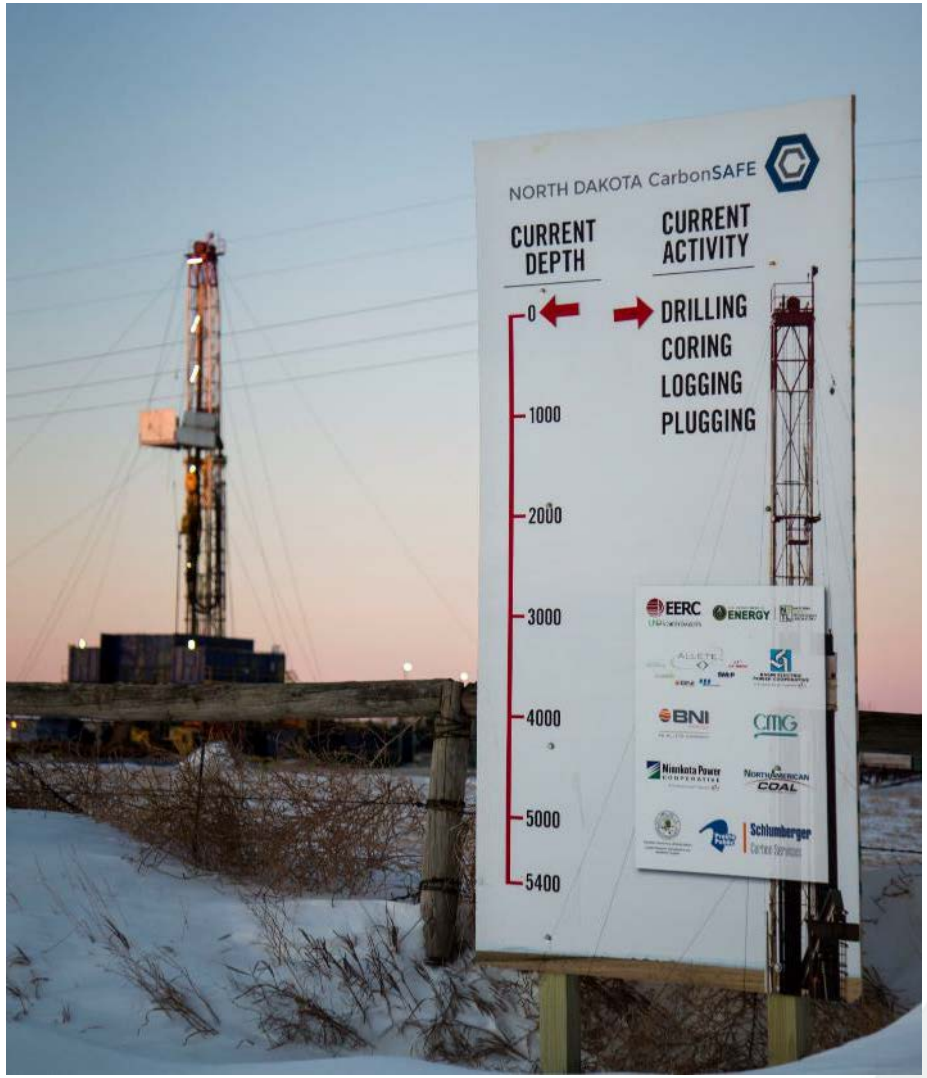
NRAP TOOL EVALUATION

1. RROM-Gen (Reservoir Reduced-Order Model – Generator) Tool, v.2017.03-1.2.1
2. REV (Reservoir Evaluation and Visualization) Tool, v.2017.03-1.2.1
3. WLAT (Wellbore Leakage Analysis Tool), v.2016.11-1.0.0.3
4. GMPIS (Ground Motion Prediction applications to potential Induced Seismicity) Tool, v.2016.11-1.0.0.3
5. NRAP-Open-IAM (open-source Integrated Assessment Model [IAM]) *BETA release for phase II of the NRAP



SITE-SPECIFIC EVALUATIONS

- Our evaluation focused on
  - Installing and running each tool.
  - Using North Dakota-CarbonSAFE data and site-specific stratigraphy.
  - Comparing NRAP tool outputs against commercial equivalents, e.g., CMG simulations (where available).
- Initial feedback has already been supplied to NETL/NRAP.



ACCOMPLISHMENTS TO DATE

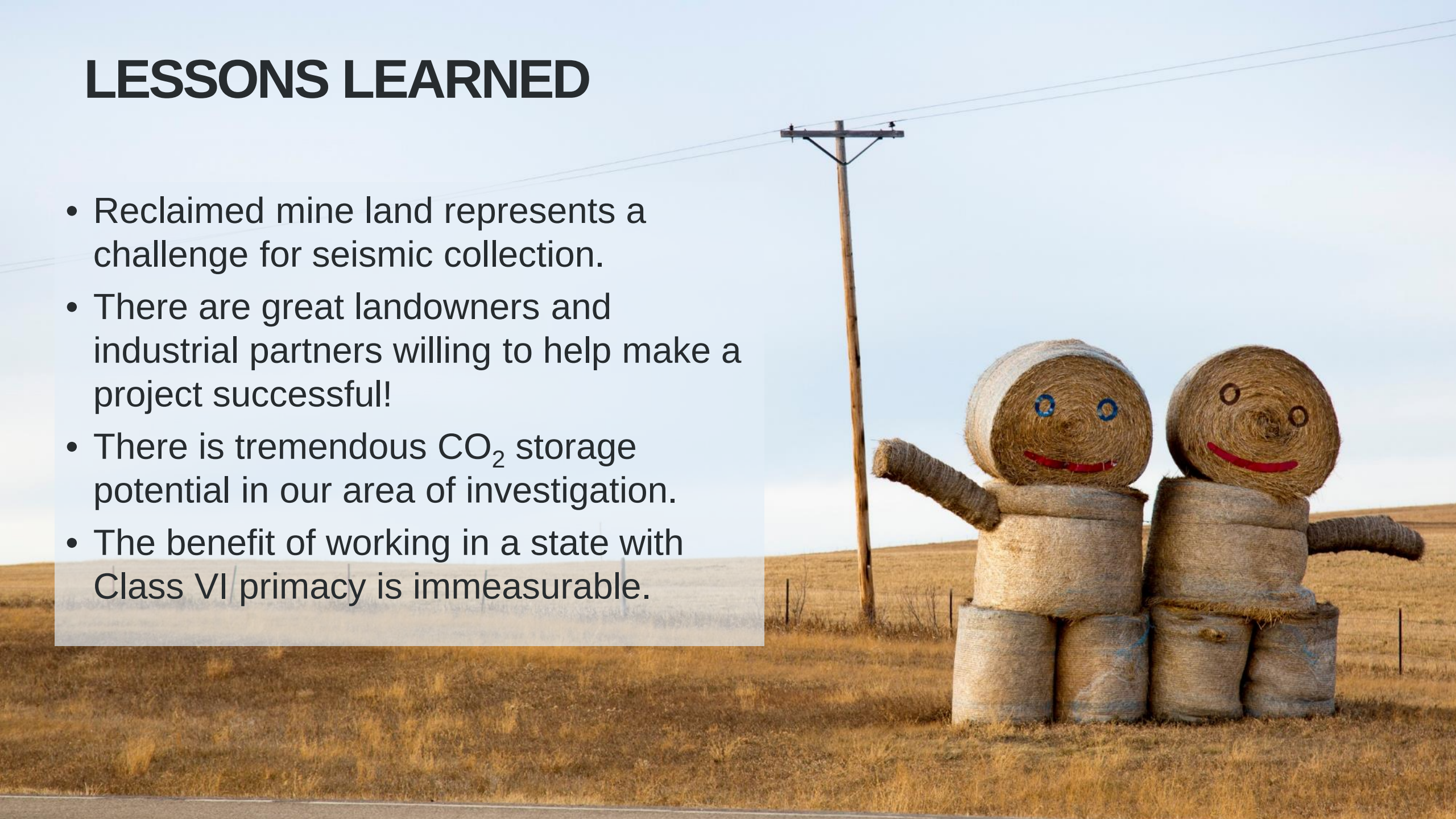
- Drilled, cored, logged, and plugged the two stratigraphic test wells.
- Retrieved water samples from the target formation.
- Completed laboratory testing of the core.
- Reprocessed legacy seismic data.
- Built geologic models and reservoir simulation models.
- Ran multiple scenarios of injection, including stack storage options.
- Monthly outreach advisory board meetings.

ACCOMPLISHMENTS TO DATE

- Held two open house events.
- Conducted public opinion survey on CO_2 storage in the region.
- Held risk assessment workshop.
- Met with state regulators to discuss pore space amalgamation concepts and potential issues.
- Began development of broad-scale business case scenarios.
- Reviewed several NRAP tools.

LESSONS LEARNED

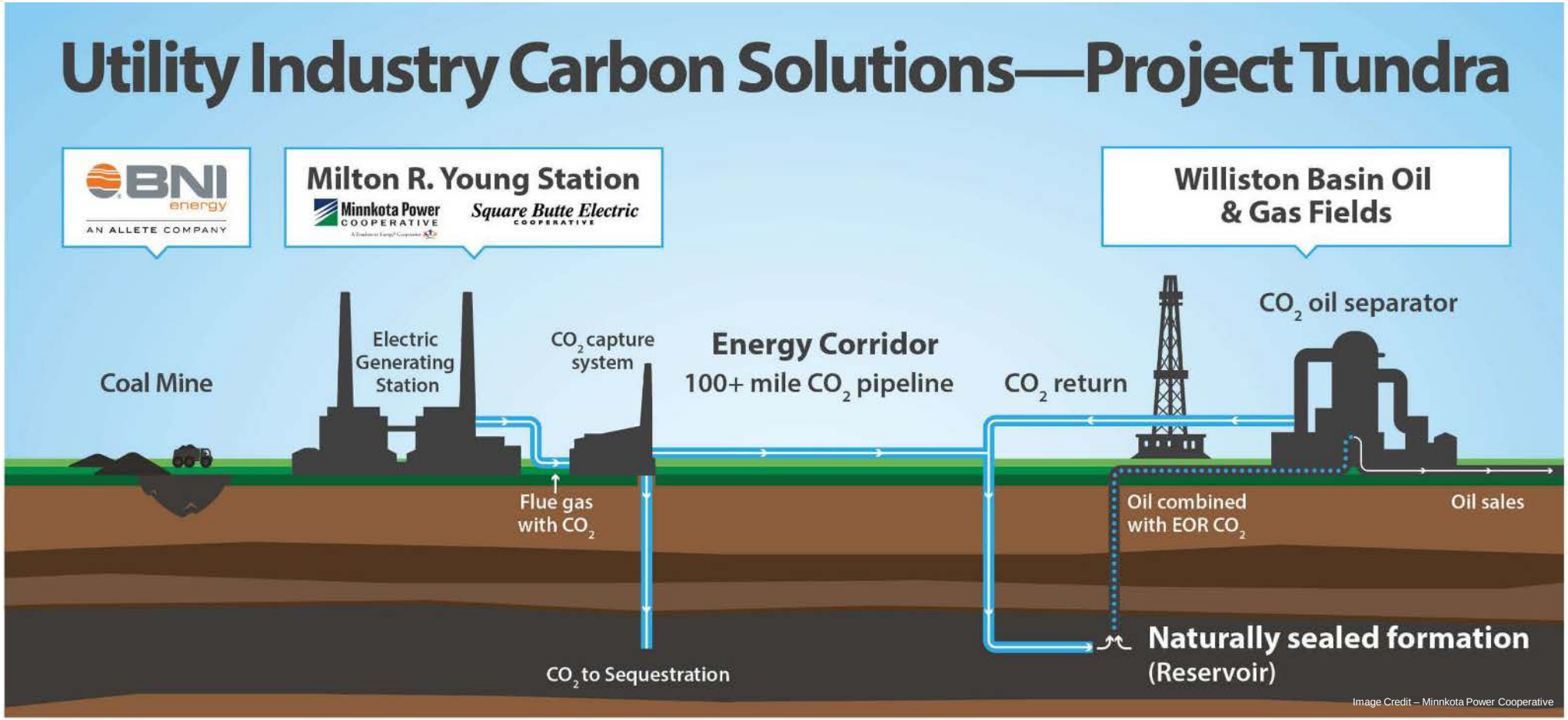
- Reclaimed mine land represents a challenge for seismic collection.
- There are great landowners and industrial partners willing to help make a project successful!
- There is tremendous CO_2 storage potential in our area of investigation.
- The benefit of working in a state with Class VI primacy is immeasurable.



SYNERGY OPPORTUNITIES

- We are not working in a vacuum. Other CCUS opportunities in the region are developing.
- Integration with future CO_2 EOR opportunities in the region.
- Contributing to public acceptance of CCUS projects.
- Building a foundation for how states can efficiently permit and oversee commercial-scale CO_2 storage projects.

Utility Industry Carbon Solutions—Project Tundra



Project Roadmap:

- Key Technology Improvements:
- Project Feasibility
- Initial Design, CO_2 for EOR and Sequestration:
- Large Pilot Testing and FEED:
- Commercial Application:

PROJECT SUMMARY

- Key findings
  - Superb reservoir properties
    - Internal baffles will aid in storage efficiency.
  - Accepting public attitude
  - Great synergy with commercial endeavors
  - Supportive state regulatory entities
- Next steps
  - Finalize site development plan
  - Finalize economic investigation
  - Complete final report

Wes Peck
Principal Geologist
wpeck@undeerc.org
701.777.5195 (phone)

Energy & Environmental Research Center
University of North Dakota
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018

www.undeerc.org
701.777.5000 (phone)
701.777.5181 (fax)

THANK YOU

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APPENDIX

BENEFIT TO THE PROGRAM

- Goals:
  - Develop and validate technologies to ensure 99% storage permanence.
  - Develop technologies to improve reservoir storage efficiency while ensuring containment effectiveness.
  - Support industry's ability to predict CO_2 storage capacity in geologic formations to within ±30%.
  - Develop best practice manuals for monitoring, verification, accounting (MVA), and assessment; site screening, selection, and initial characterization; public outreach; well management activities; and risk analysis and simulation.

- To progress toward full-scale carbon capture and storage deployment, the feasibility of a commercial-scale (50+ Mt CO_2) geologic storage complex for CO_2 must be established at one or more of the proposed sites. Activities outlined will gather data to address both the technical and nontechnical challenges associated with establishing feasibility. The results derived from implementation of the project will provide a significant contribution to DOE's Carbon Storage Program goals. Specifically, this project supports DOE Goals 1 and 2 by validating technologies that will improve reservoir storage efficiency, ensure containment effectiveness, and/or ensure storage permanence by collecting and generating fundamental geologic data from the subbasinal characterization of a potentially ideal CO_2 storage complex (Broom Creek Formation). This project also includes efforts to validate risk assessment tools developed by NRAP. Goal 3, the ability to predict CO_2 storage capacity in geologic formations to within ±30%, will be addressed by integrating characterization data derived from the proposed project into geocellular and dynamic reservoir models for a commercial-scale geologic storage complex. In addition, this project supports Goal 4 by producing information that will be useful for inclusion in DOE best practices manuals focusing on monitoring, verification, accounting, and assessment; site screening, selection, and initial characterization; public outreach; well management activities; and risk analysis and simulation.

PROJECT OVERVIEW

GOALS AND OBJECTIVES

- Describe the project goals and objectives in the statement of project objectives.
  - How the project goals and objectives relate to the program goals and objectives.
  - Identify the success criteria for determining if a goal or objective has been met. These generally are discrete metrics to assess the progress of the project and used as decision points throughout the project.

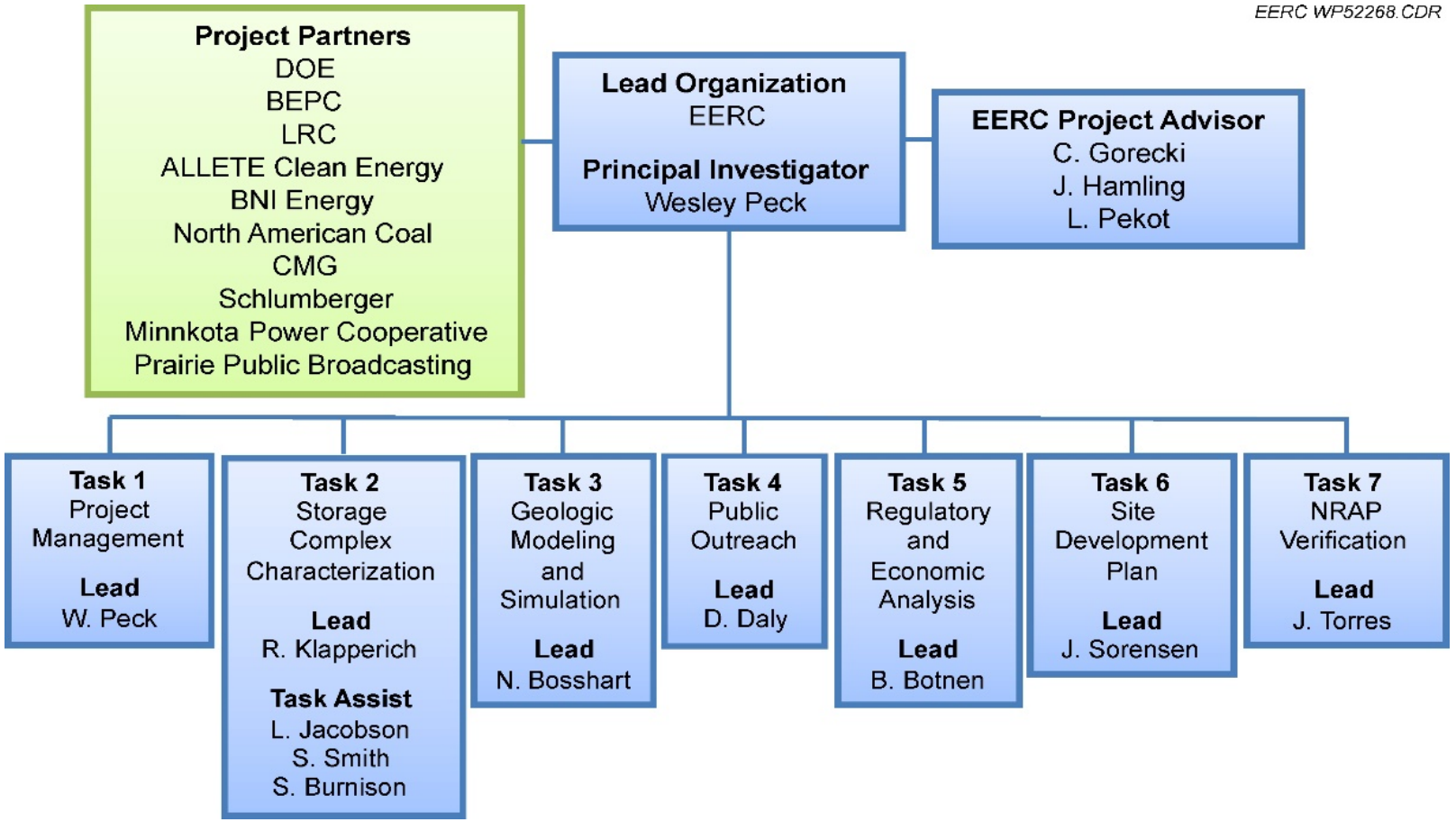
PROJECT OVERVIEW

GOALS AND OBJECTIVES

- The objective of this project is to determine the feasibility of developing a commercial-scale carbon dioxide (CO_2) geologic storage complex able to store 50+ million metric tons of CO_2 in central North Dakota safely, permanently, and economically. This objective is being met through the evaluation of two project study areas associated with two ideal geologic storage complexes located adjacent to separate coal-fired facilities in North Dakota: The Basin Electric Power Cooperative (BEPC)-owned Dakota Gasification Company (DGC) and the Minnkota-owned Milton R. Young (MRY) Station.
  - Each of the project activities will advance the state of knowledge for conducting commercial-scale CCS projects and provide lessons learned to each of these processes to help ensure the successful development of future commercial-scale projects. Furthermore, the proposed work will contribute directly to achieving DOE's goals of 1) developing and validating technologies that ensure 99% storage permanence, 2) improving reservoir storage efficiency while ensuring containment effectiveness, 3) supporting industry's ability to predict CO_2 storage capacity in geologic formations to within ±30%, and 4) developing best practices manuals.
  - This project is divided into two BPs that correspond to several project milestones. Several success criteria have been developed to help track the progress of the project and to indicate the successful completion of the project's objectives.

Task/ Subtask	Milestone Title	Planned Completion Date	Verification Method
2.2	M1 – Initiation of Well Drilling	11/30/17	Reported in subsequent quarterly report.
2.4	M2 – Completion of Seismic Reprocessing	1/31/18	Reported in subsequent quarterly report.
6.3	M3 – Risk Assessment Workshop Scheduled	2/28/18	Reported in subsequent quarterly report.
3.2	M4 – Identification of Inputs for NRAP Model(s)	9/30/18	Reported in subsequent quarterly report.
3.1	M5 – Completion of Geologic Modeling	10/31/18	Reported in subsequent quarterly report.
6.3	M6 – Updated Risk Assessment Workshop Scheduled	1/31/19	Reported in subsequent quarterly report.

ORGANIZATION CHART



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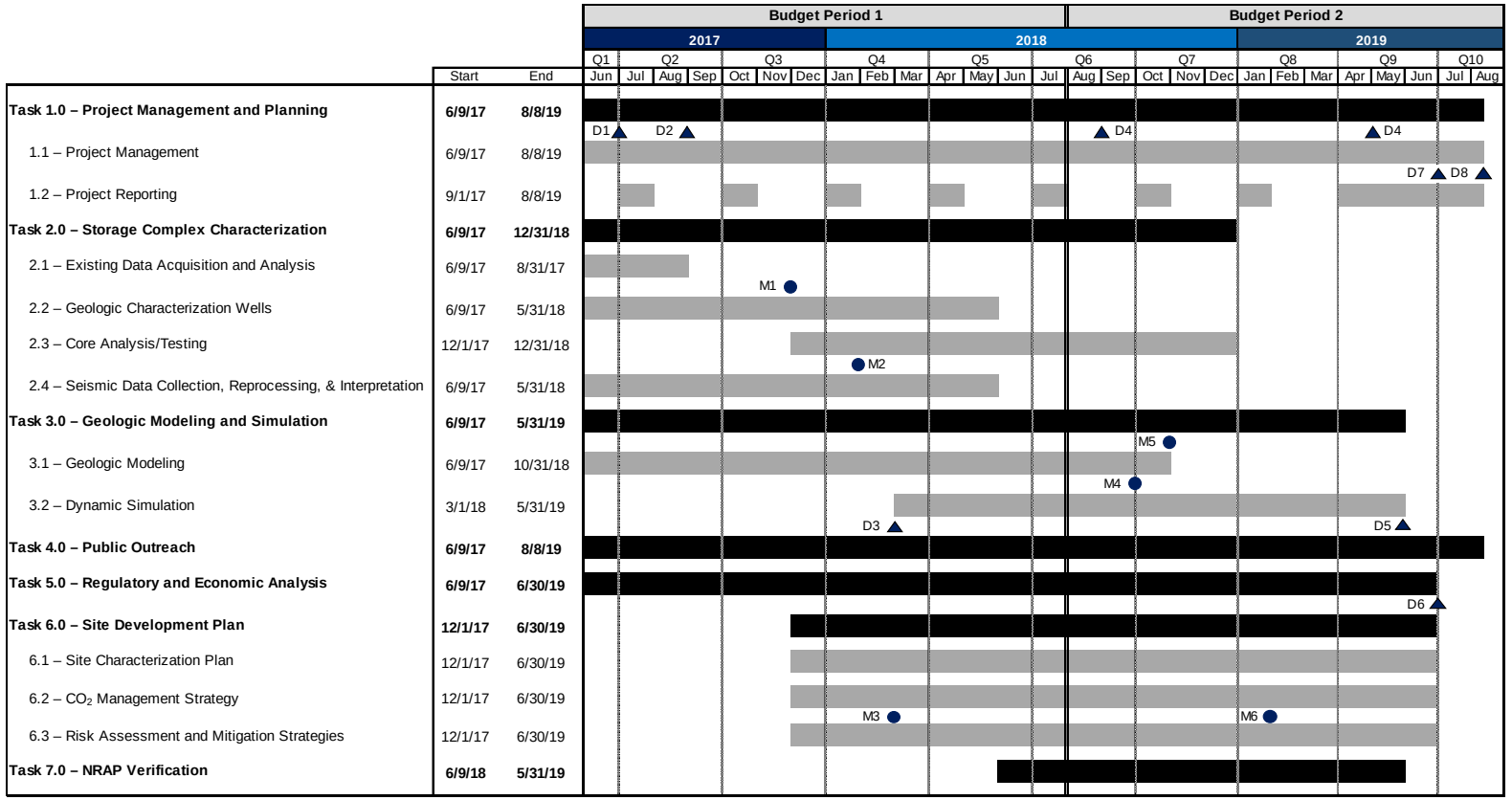

Task Duration	
Subtask Duration	

Note: Budget Period 1 ended 8/8/18.

Deliverables (D)	Milestones (M)
D1 – Project Mangement Plan (PMP)	M1 – Initiation of Well Drilling
D2 – Data Management Plan (DMP)	M2 – Completion of Seismic Reprocessing
D3 – Outreach Toolkit	M3 – Risk Assessment Workshop Scheduled
D4 – Catalog of Geologic Material	M4 – Identification of Inputs for NRAP Model(s)
D5 – Updated Outreach Plan	M5 – Completion of Geologic Modeling
D6 – Site Development Plan	M6 – Updated Risk Assessment Workshop Scheduled
D7 – Data Submitted to NETL EDX	
D8 – Final Technical Report	

ECONOMIC ANALYSIS MODELING FRAMEWORK – FOUR PROJECT PERIODS

Project Period	Years	Model Components
Project Planning and Preparation	1–5	**Costs:** Site characterization, baseline MVA, modeling and simulation, project plan, permit acquisition, subcontracts, and CO_2 pipeline(s).
CO_2 Injection (operations)	6–30	**Costs:** Capture plant/pipeline CAPEX and OPEX, storage site OPEX, MVA, pore space lease, administrative/trust funds, and 5-year permit reviews. **Financial Benefits:** 45Q and CO_2 sales.
Postinjection Site Care and Closure	31–40	**Costs:** Well plugging, pipeline decommissioning, storage site decommissioning, and PISC monitoring.
Certification of Compliance	41	**Costs:** Certificate of compliance.

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