Energy & Environmental Research Center (EERC)

EERC RESEARCH PRIORITIES AND EVALUATION OF SALT FORMATIONS FOR SUBSURFACE STORAGE

72nd Annual Propane Gas Association Annual Meeting & Convention

June 22, 2022

Josh Stanislowski

Director of Energy Systems Development

ENERGY & ENVIRONMENTAL RESEARCH CENTER (EERC)

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

MULTIDISCIPLINARY TEAM

DIVERSE EXPERTISE

AND CAPABILITIES TO IMPACT THE WORLD

OUR FACILITIES

254,000 SQ FT OF FACILITIES

THE FUTURE: A CARBON-CONSTRAINED WORLD

Microsoft will be carbon negative by 2030

Jan 16, 2020 | Brad Smith - President

FINANCIAL TIMES

Shell yields to investors by setting target on carbon footprint

Cutting emissions to be linked to executive pay in industry first

-Dec. 2018

SIEMENS

Intends to **cut the carbon footprint** of its operative business **in half by 2020** and become **climate neutral by 2030.**

-Aug. 2018

The Guardian US edition

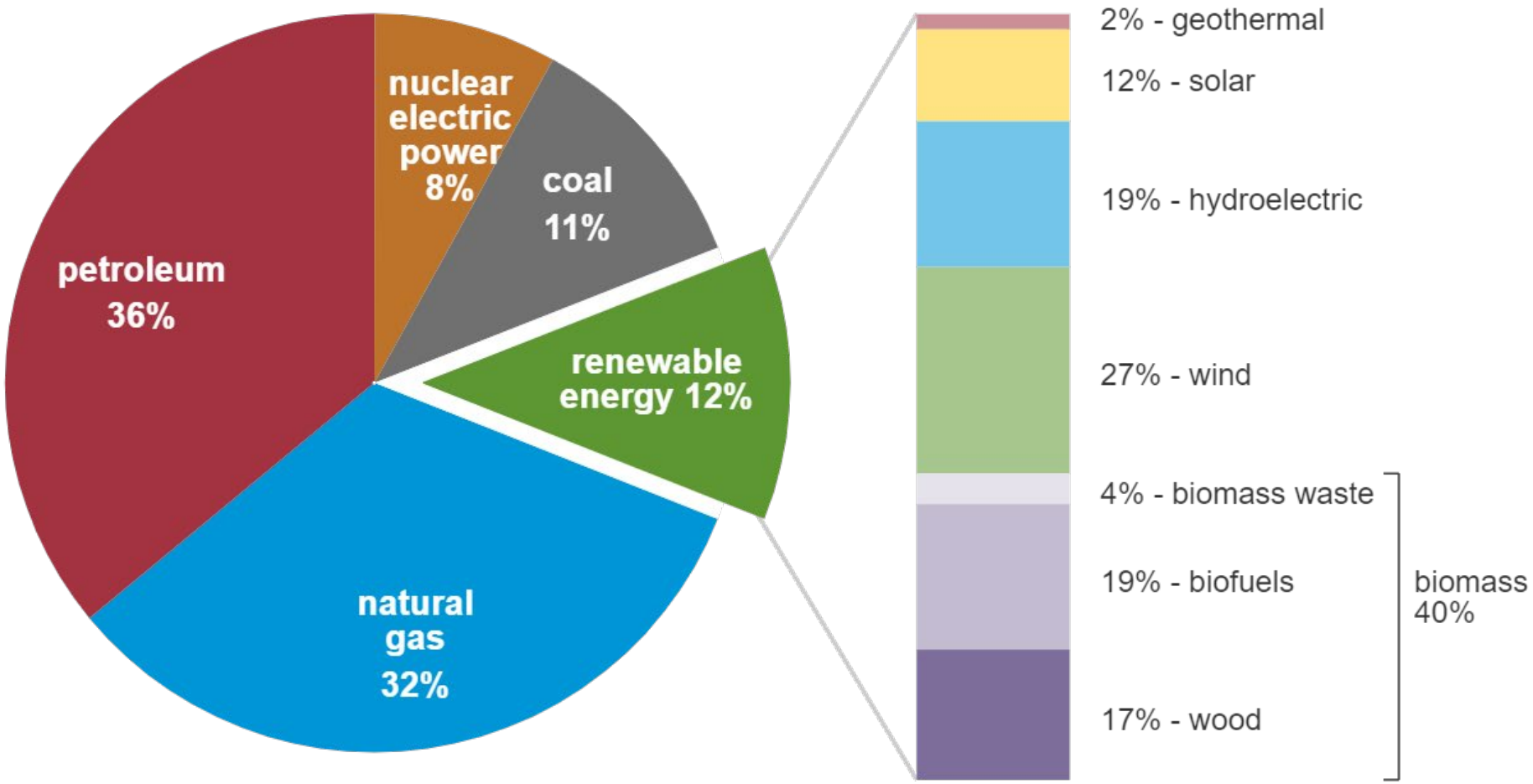
Food and drinks companies respond to consumer pressure on climate change

-Aug. 2014

U.S. primary energy consumption by energy source, 2021

total = 97.33 quadrillion British thermal units (Btu)

total = 12.16 quadrillion Btu



Source: U.S. Energy Information Administration, *Monthly Energy Review*, Table 1.3 and 10.1, April 2022, preliminary data

Note: Sum of components may not equal 100% because of independent rounding.

NEVER BEFORE HAS THE FUTURE OF NORTH DAKOTA'S ECONOMY BEEN SO TIED TO ENERGY R&D

ENERGY AND MINING

Workers, communities fear closing North Dakota's largest coal plant will destroy their way of life

The Minnesota-based Great River Energy announced this month it plans to shutter Coal Creek Station in North Dakota, which turns lignite from Falkirk Mine into electricity, in 2022.

Written By: April Baumgarten | May 17th 2020 - 6am.

Fourth-generation coal miner Grace Kerzmann stands Wednesday, May 13, near the Coal Creek Station power plant south of Underwood, N.D. Michael Vosburg / Forum Photo Editor

UNDERWOOD, N.D. — For the past five years, fourth-generation lignite coal miner Grace Kerzmann could be found driving giant trucks, the ones with wheels roughly double her height, around Falkirk Mine near Underwood.

ENERGY AND MINING

Gov. Doug Burgum calls for North Dakota to be carbon neutral by 2030

Speaking before hundreds of oil industry operators and executives, the Republican governor advocated for a path to retain the core place of the state's fossil fuel industries while dramatically reducing their carbon footprint.

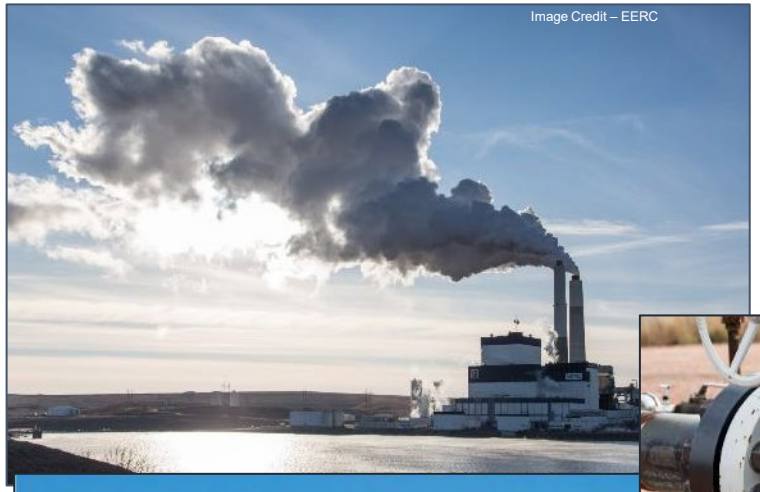
Written By: Adam Willis | 6:30 pm, May 12, 2021

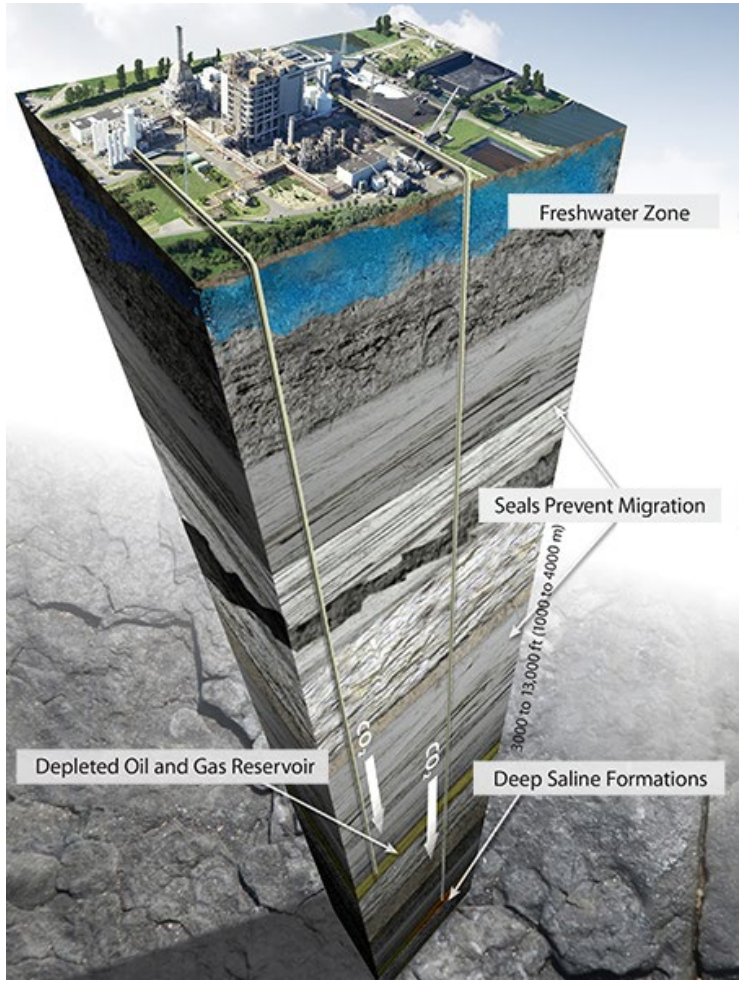
North Dakota Gov. Doug Burgum. Mike McCleary / Bismarck Tribune

BISMARCK — Speaking to oil industry operators and executives, Gov. Doug Burgum announced a goal Wednesday, May 12, to get North Dakota to carbon neutrality by

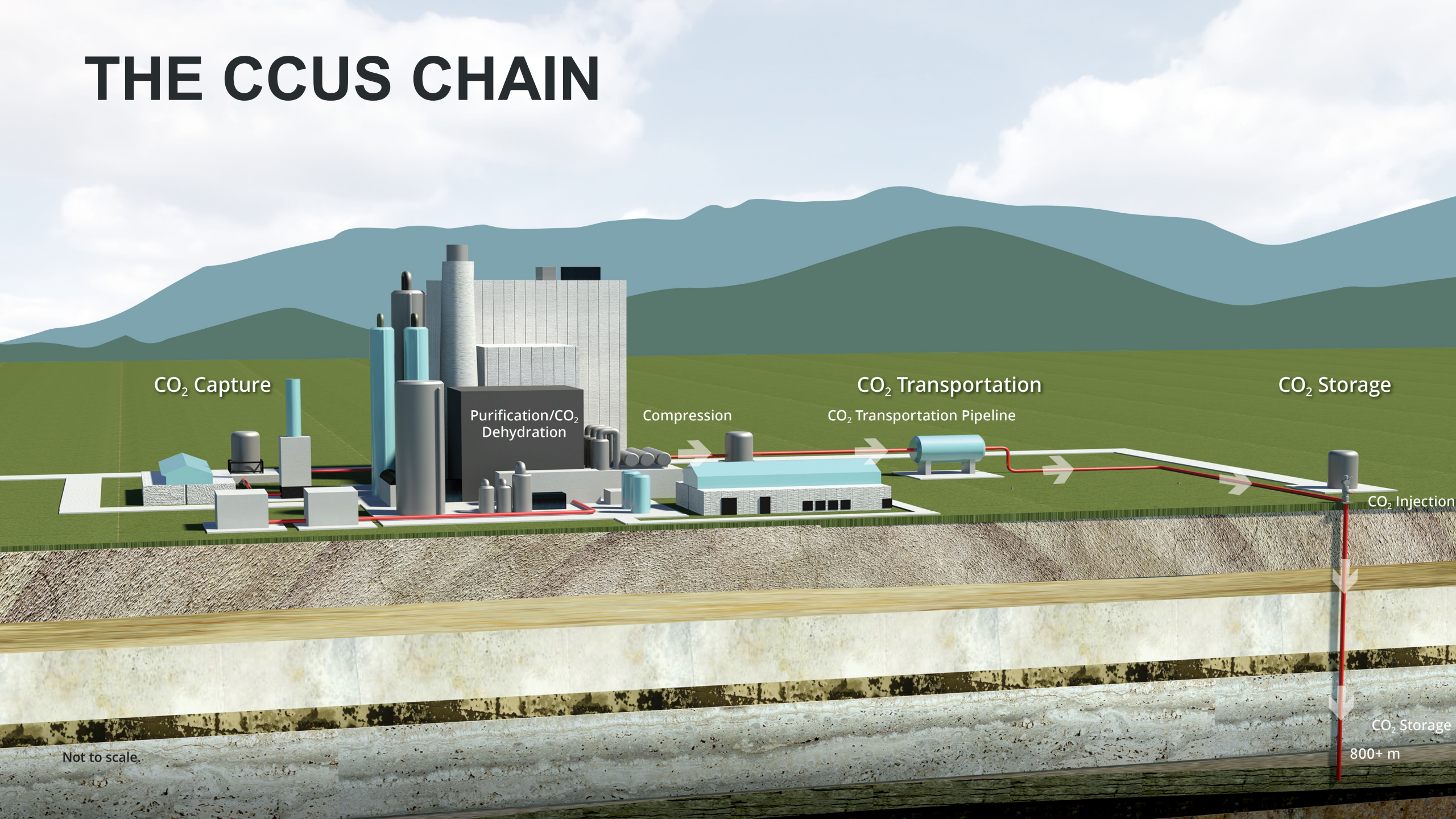
Grand Forks Herald
GrandForksHerald.com

CO_2 CAN BE MANAGED





THE CCUS CHAIN



FULL-SCALE CAPTURE PROJECTS

Coal Creek Station

Milton R. Young Station

RED TRAIL ENERGY – ETHANOL

LOW CARBON FUEL STANDARD

~200,000 tons of CO_2 annually

RED TRAIL ENERGY L.L.C. RICHARDTON, ND

GREAT SEAL STATE OF NORTH DAKOTA

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

TWO UIC CLASS VI GEOLOGIC CO_2 STORAGE FACILITY PERMITS ISSUED UNDER STATE PRIMACY

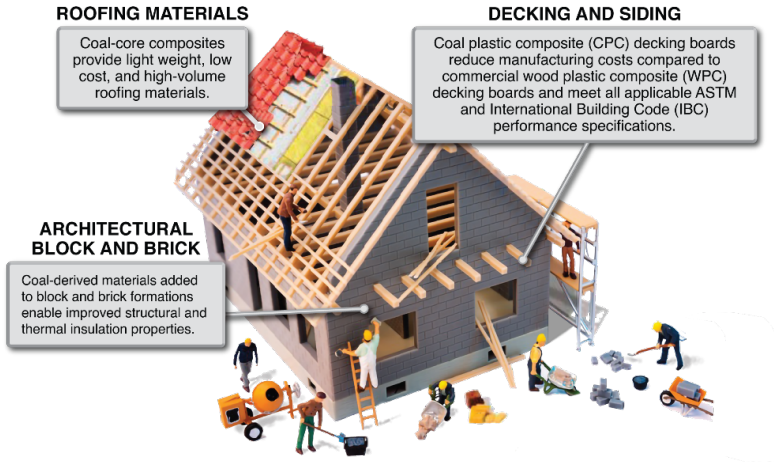
RED TRAIL ENERGY, L.L.C.
RICHARDTON, ND
RTE

PROJECT TUNDRA

COAL-DERIVED HIGH-VALUE CARBON MATERIALS

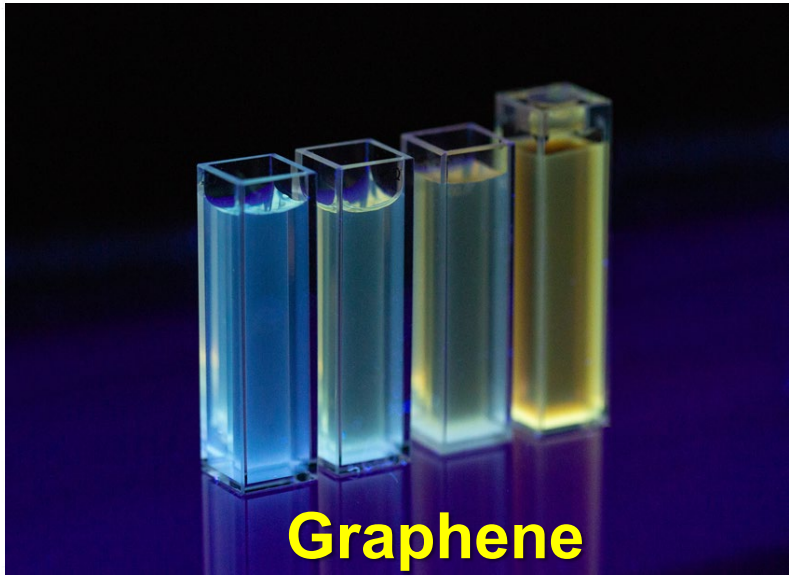
High-End Applications:

- Next-generation energy storage
- Military applications
- Transformative lightweight electrical and optical devices



Carbon-Based Home

Synthetic Graphite



CRITICAL MINERALS

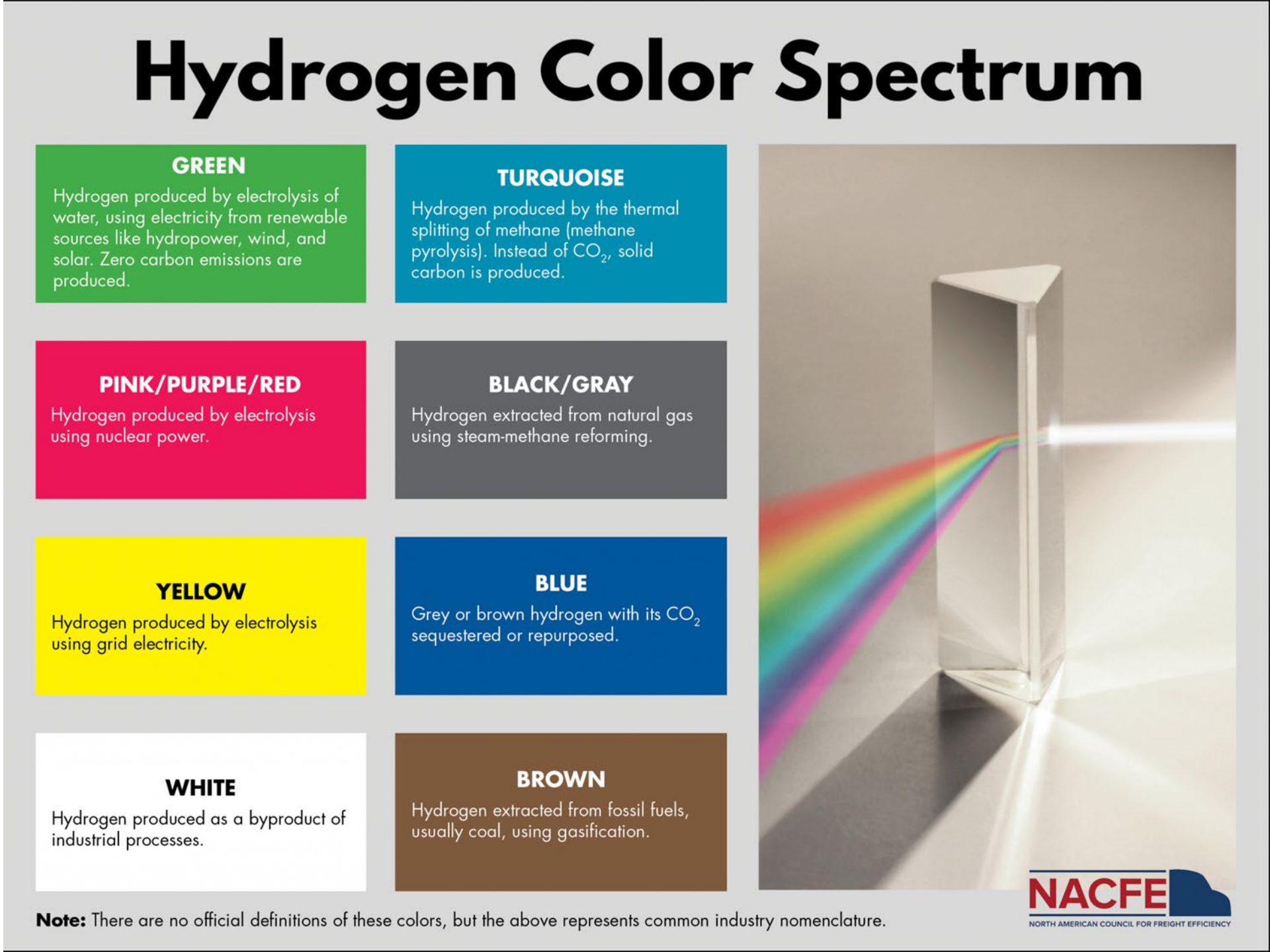
Rare-earth elements (REEs) and platinum group elements (PGEs) are CRITICAL for our state and national security priorities.

COLORS OF HYDROGEN

- Unofficial definitions have been developed for hydrogen, based on the production method.

Image from:

https://nacfe.org/wp-content/uploads/2020/12/Hydrogen-Color-Spectrum-HiRes-2.png



Source: H2@Scale | Department of Energy

HYDROGEN OPPORTUNITIES IN NORTH DAKOTA

Hydrogen and Power Production

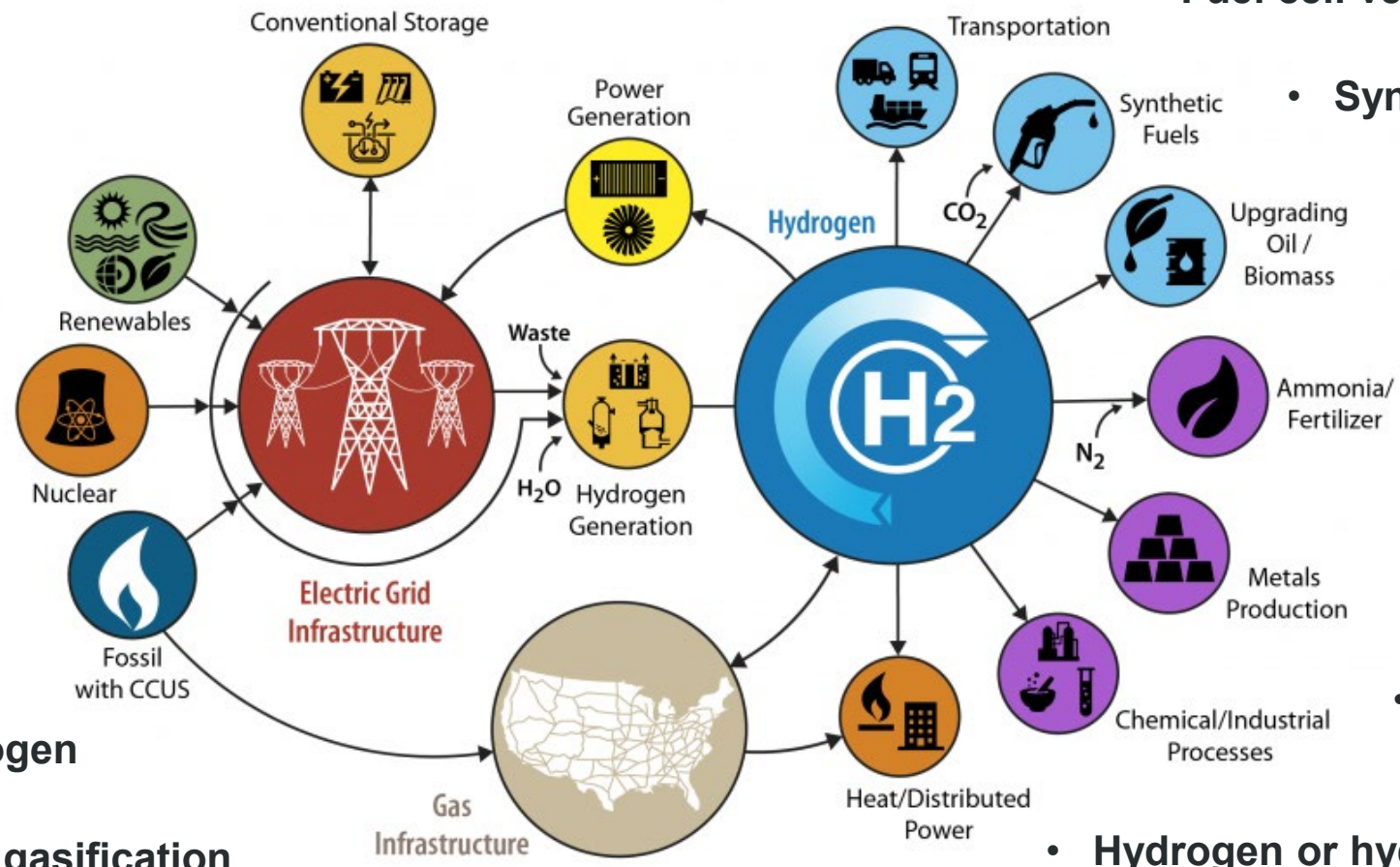
Electrolysis-Based Hydrogen Production

Fossil and Renewable Power Production

- Coal
- Natural gas
- Wind
- Hydro

Syngas-Based Hydrogen Production

- Coal and biomass gasification
- NG reforming/pyrolysis



- Pipelines inter- and intrastate

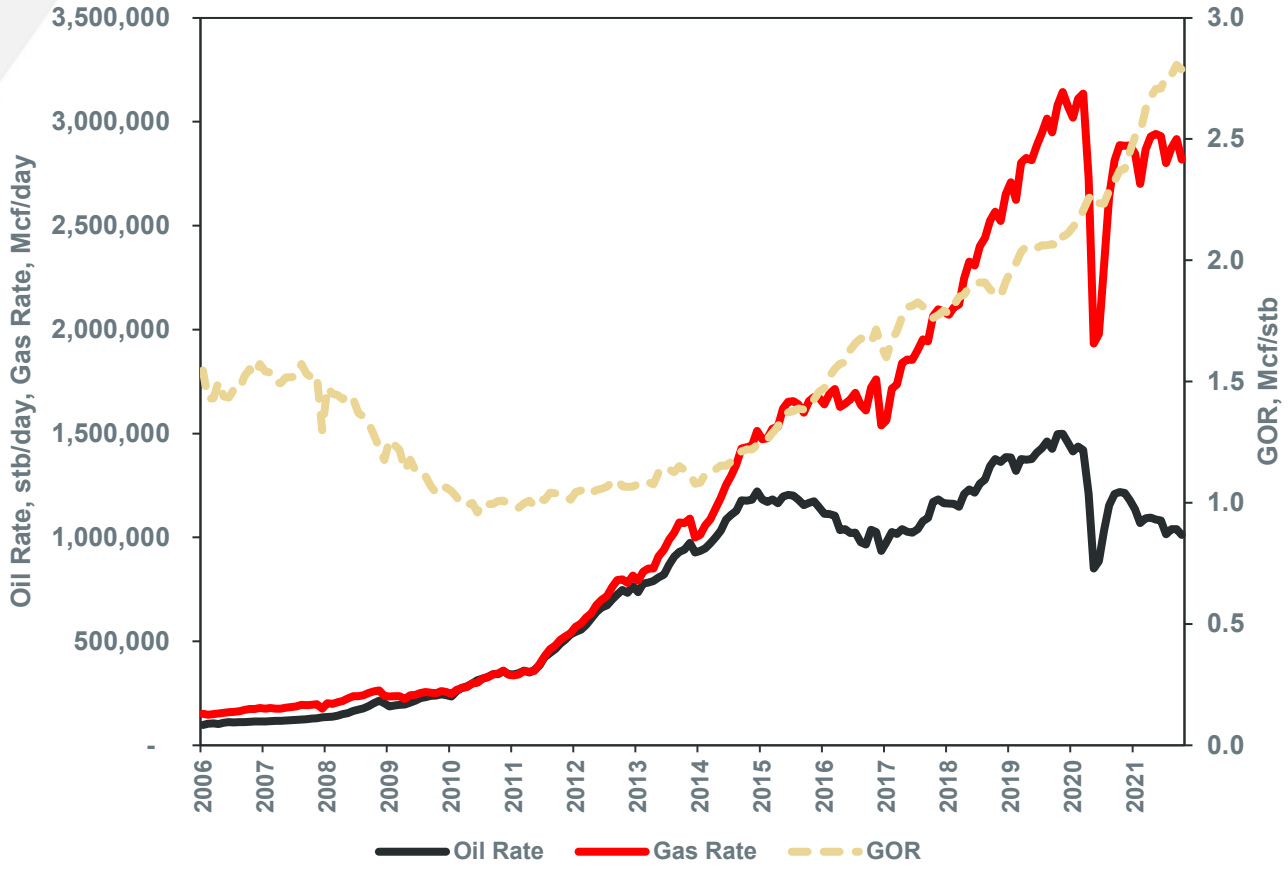
Hydrogen Uses

- Fuel cell vehicles
- Syngas conversion to fuels
- Refining: petroleum and renewable oil
- Fertilizer manufacture
- REEs and critical minerals manufacture
- Petrochemical manufacture
- Hydrogen or hydrogen–NG mix for industry or building applications

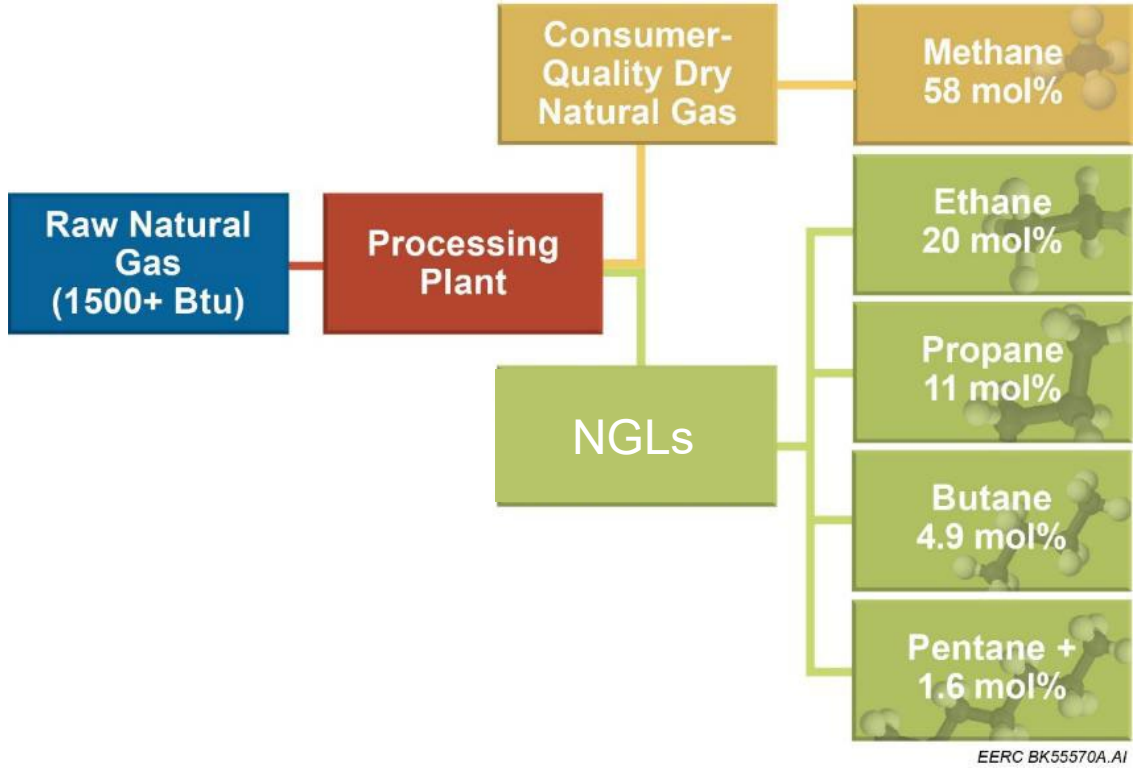
Salt Cavern Storage Project Update

NORTH DAKOTA GAS PRODUCTION

With continued increases in oil production, the gas-to-oil ratio (GOR) is expected to follow a similar trend.

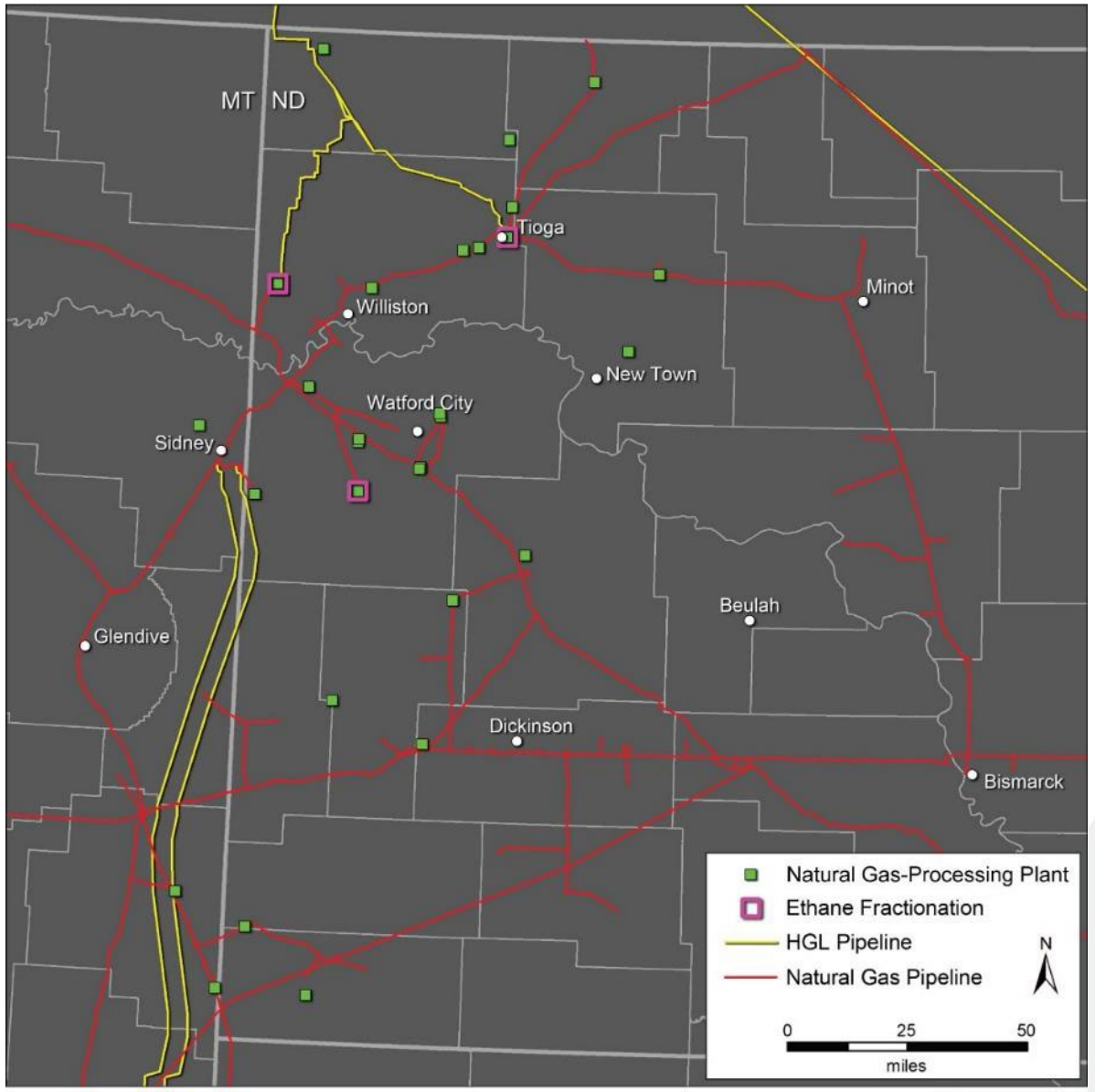


Natural gas liquids (NGLs) are present in as much as 35% of processed gas in North Dakota.



NORTH DAKOTA–MONTANA GAS PROCESSING AND PIPELINES

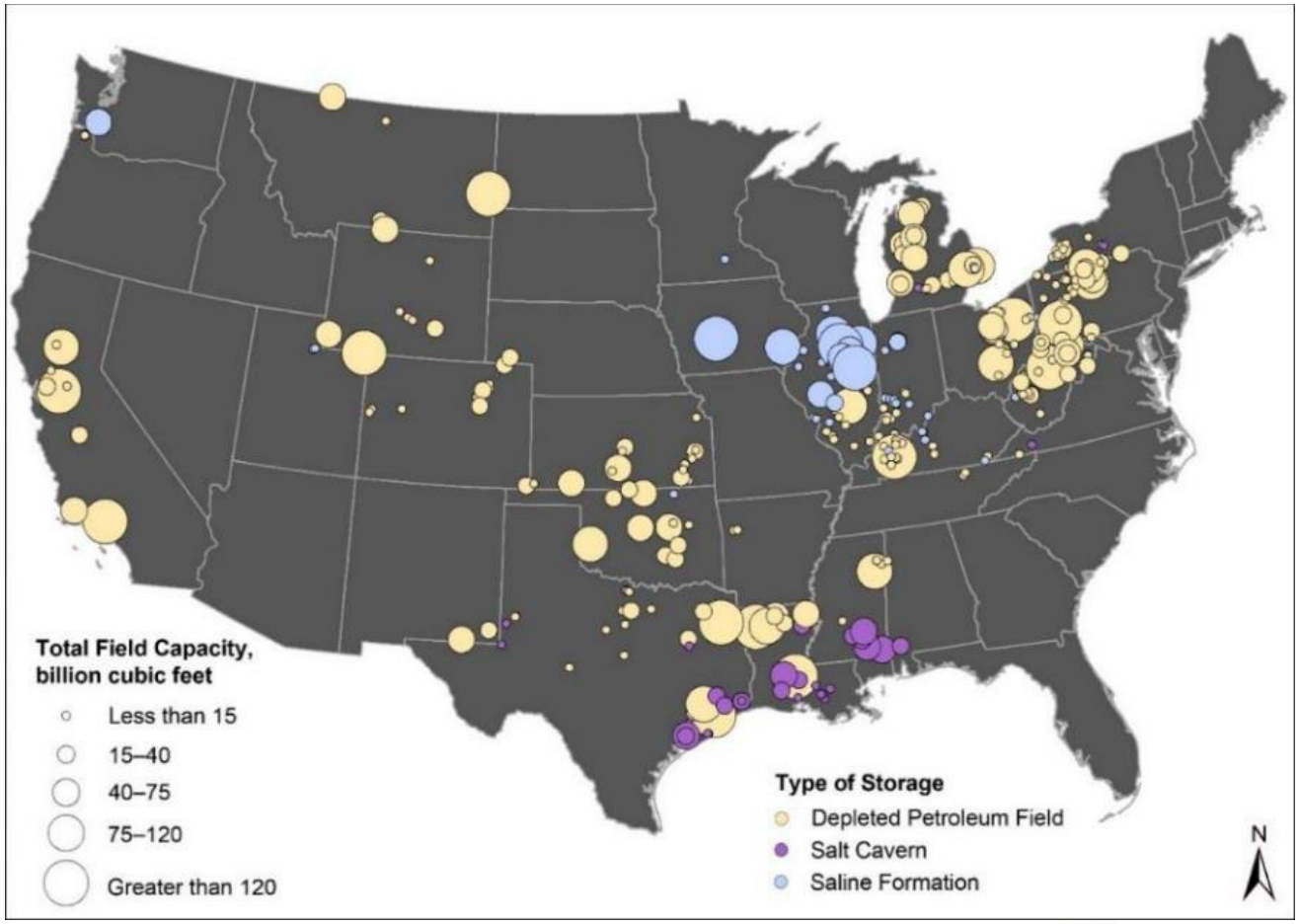
- Increasing oil/gas production in North Dakota has resulted in significant investment in gas transportation infrastructure.
- Ethane and NGLs/HGLs (hydrocarbon gas liquids) are captured at three processing/ fractionation plants in the region.
- HGL pipelines deliver product to Canadian and U.S. markets.
- **Gas storage could provide commercial opportunities for North Dakota:**
  - NGL/HGL storage
  - Hydrogen storage
  - Temporary storage of produced gas

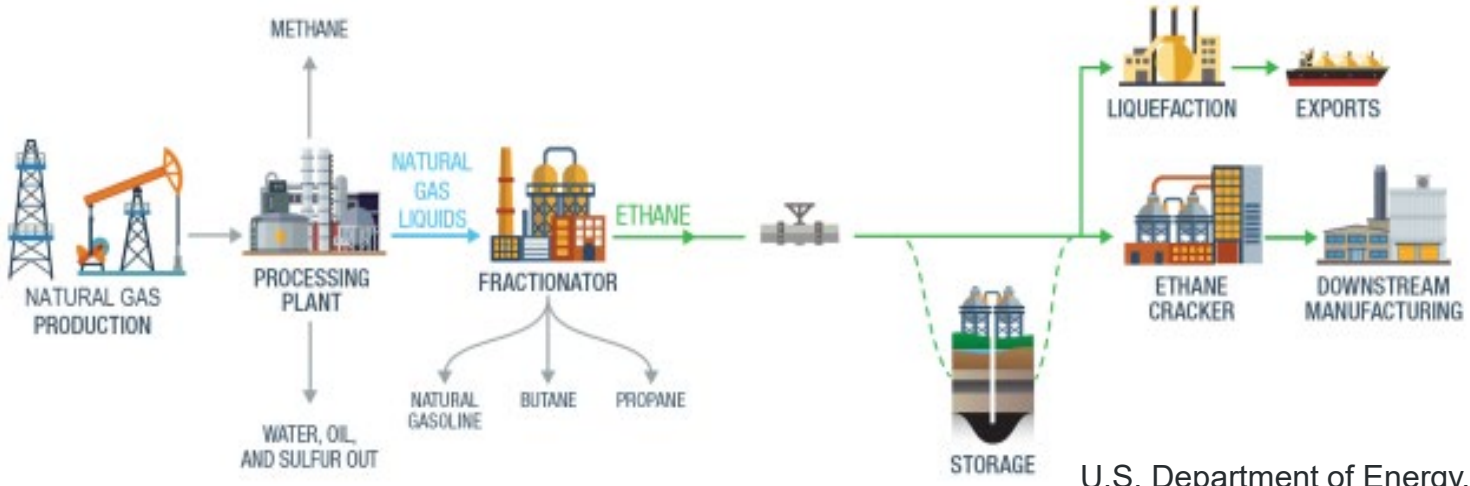


EERC SS59850.AI

GAS STORAGE

- Natural gas storage is a proven technology that began in 1915.
- Typically, gas storage is used to supplement energy demands associated with seasonal heating needs.
- Over 300 gas storage locations in the United States are active.
- **Salt cavern storage of NGLs is a critical element for petrochemical development.**





U.S. Department of Energy, 2018

COMMON GAS STORAGE TARGETS

Benefits of salt cavern storage:

- Allows for high injection and withdrawal rates.
- High sealing capacity of the salts limits gas migration.
- Lower gas cushion than saline aquifers or depleted oil and gas reservoirs.

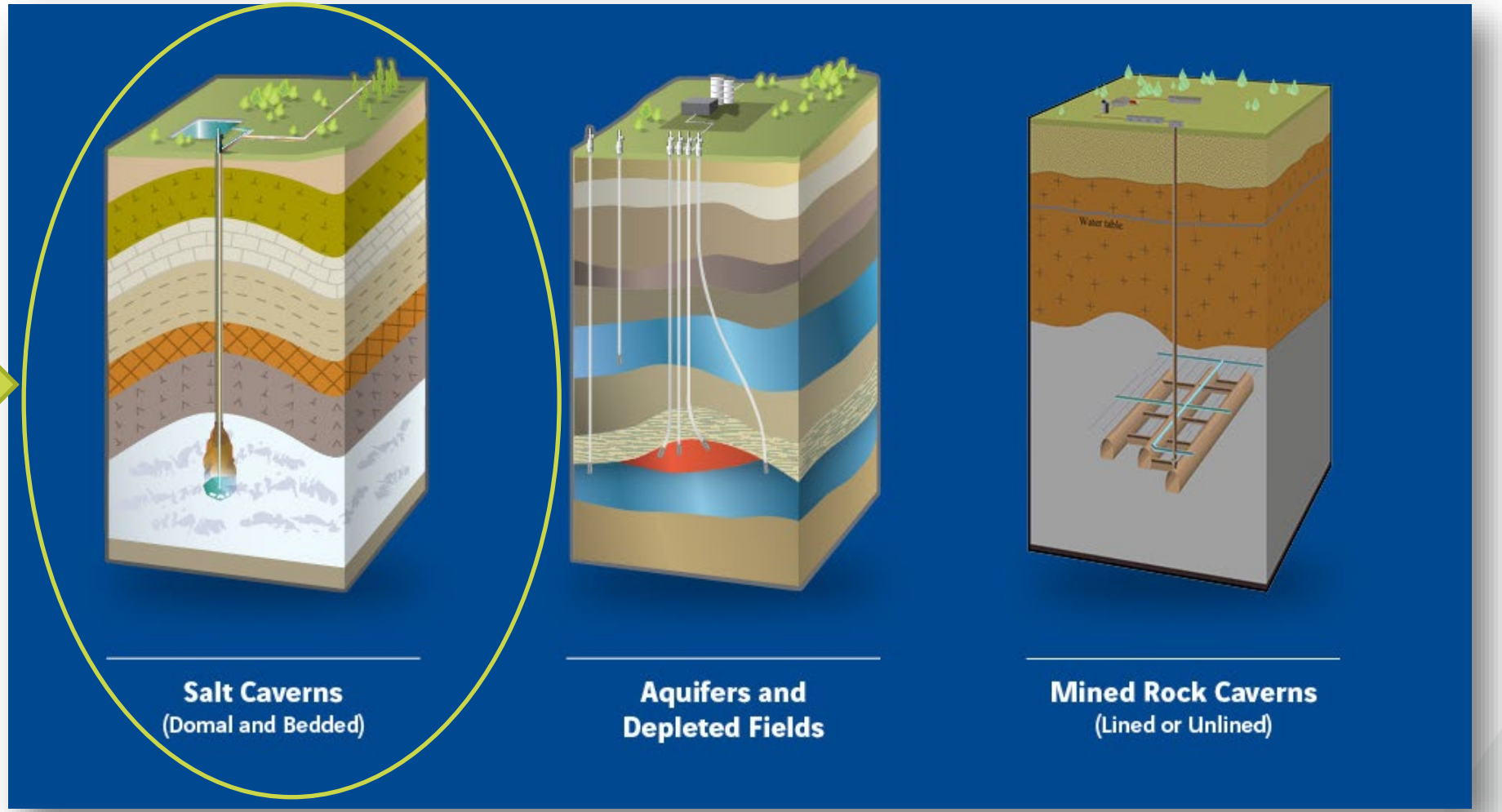
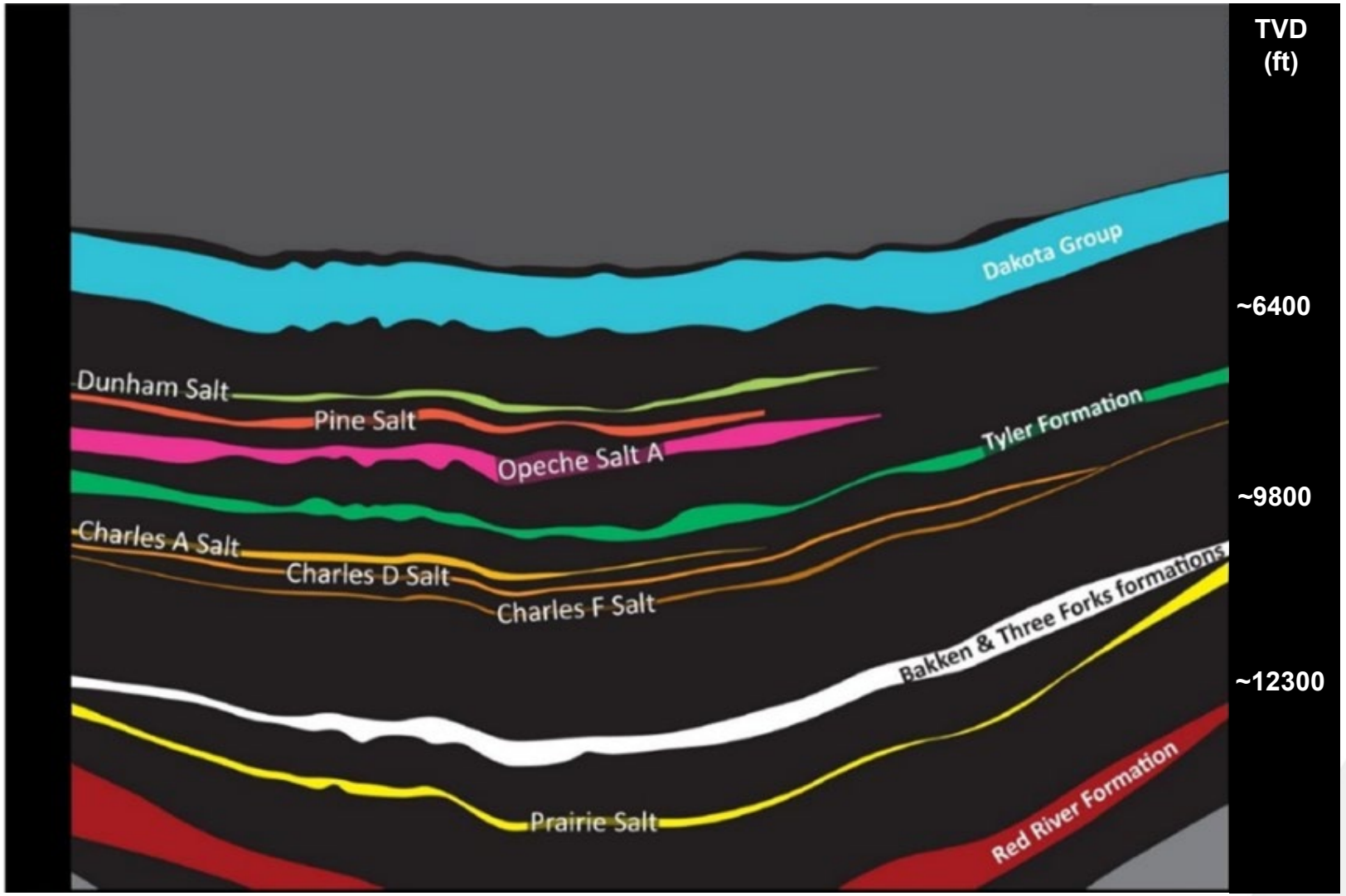


Image from Geostock Sandia: https://www.entrepose.com/en/geostock-sandia/expertise/

NORTH DAKOTA'S SUBSURFACE SALT DEPOSITS

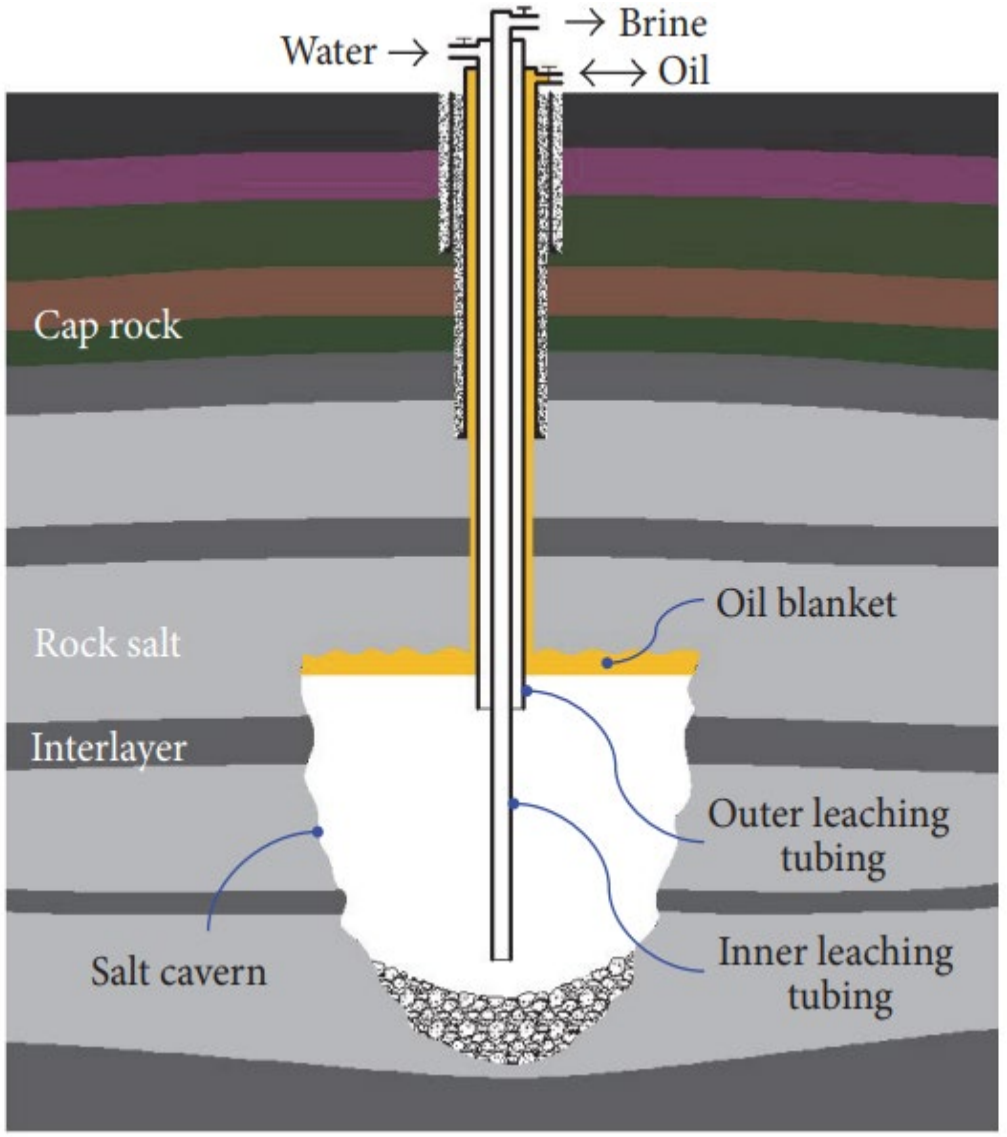
- North Dakota has several subsurface salt formations with potential for cavern development.
- Critical criteria for cavern development in the salts include thickness, depth (temperature <180°F), and extent.



(Extracted and modified from Nesheim and LeFever, 2009)

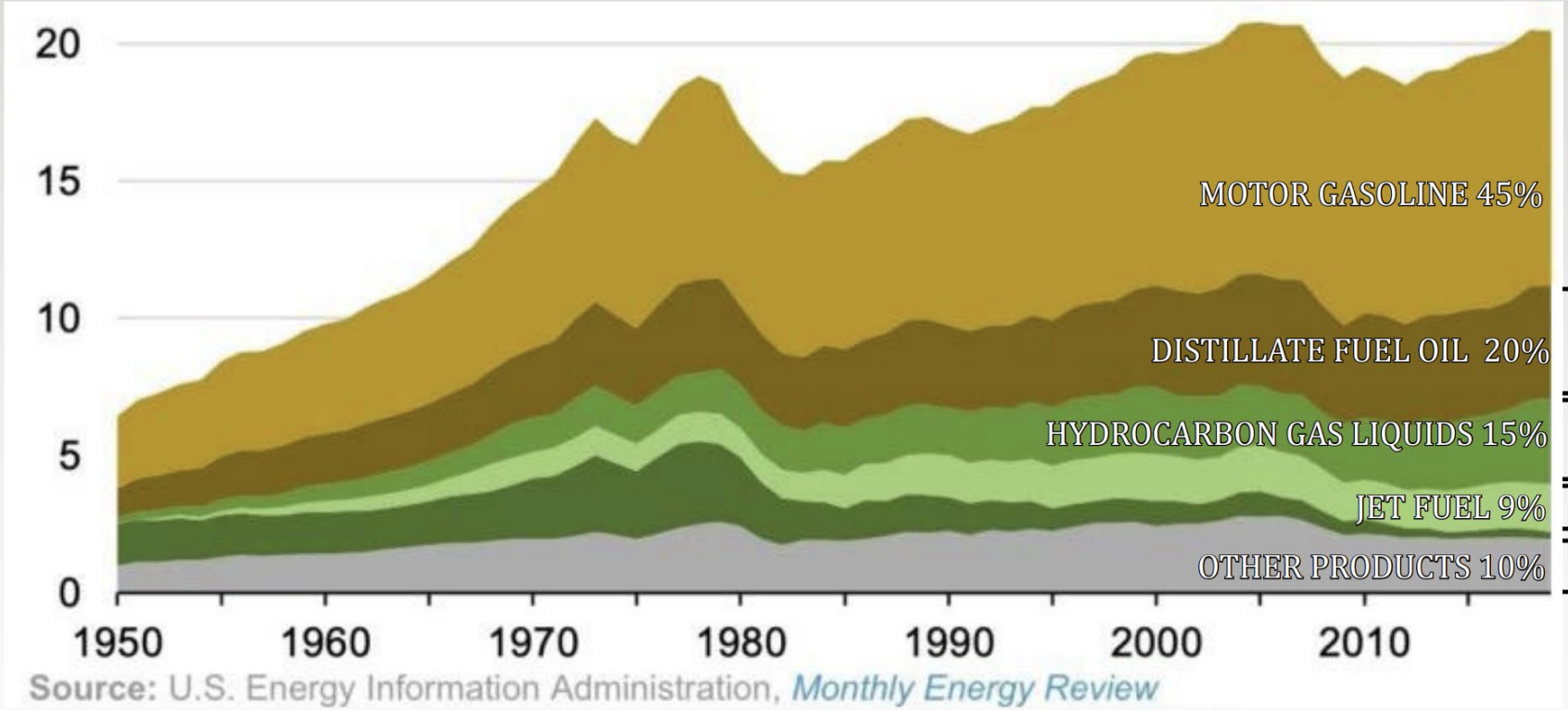
CAVERN DEVELOPMENT/OPERATION

- Caverns are created by injecting fresh or saline water into salt formations and producing salt to the surface. The process is referred to as ***solution mining.***
- Upon completion of the cavern, brine used in the development is displaced to the surface with NGLs.
- Commonly, this brine is stored on the surface for future on-demand NGL recovery.
- Caverns are commonly operated using constant pressure through the injection of brine for retrieval of NGLs.
  - Geomechanical stability is promoted using this constant pressure technique as pressure cycling is minimized.



U.S. Consumption of Petroleum Products by Type

Millions of Barrels Per Day



Source: U.S. Energy Information Administration, *Monthly Energy Review*

DIESEL FUEL is used to distribute necessities such as food and medical supplies and is the dominant fuel used by modern agricultural equipment to feed the world.

HYDROCARBON GAS LIQUIDS are used as feedstock for making other petroleum products and petrochemicals. Petrochemicals are used to make thousands of essential products, medical supplies and pharmaceuticals, tech gadgets and even renewable energy infrastructure.

JET FUEL is absolutely essential not only for fueling commercial and private jets, but the aircraft used by our military forces to defend our freedoms.

The more than 6,000 **"OTHER"** petroleum-based products include synthetic rubber, asphalt, road oil, lubricants, wax, crayons, cosmetics, paint thinner, petroleum coke and much more!

- Gasoline represents just **45%** of U.S. petroleum consumption.
- Natural gas/hydrocarbon liquids are used to make multiple products, including plastics, synthetic rubber, cooking and heating fuel, antifreeze, detergents, and paints and resins, among other products.

Figure Source: Illinois Petroleum Resources Board

PRIOR EERC WORK – FALL 2020

Study Objectives

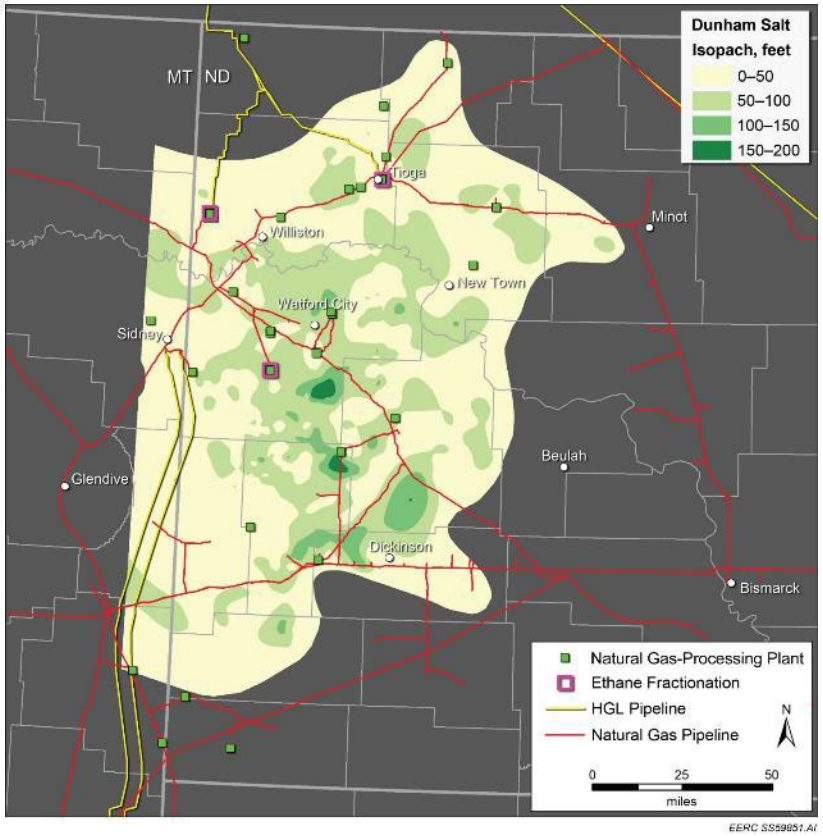
- Identify a regional extent within western North Dakota where infrastructure and required resources are collocated with salt formations that may be suitable candidates for construction of storage caverns.
- Describe the methods used to construct and operate salt caverns for gas/liquids storage.
- Estimate the size of caverns that could be constructed in North Dakota salts, and assess stability, given realistic cavern dimensions, by conducting limited geomechanical simulations.
- Develop estimated costs for selected key surface equipment components of a salt cavern storage facility.

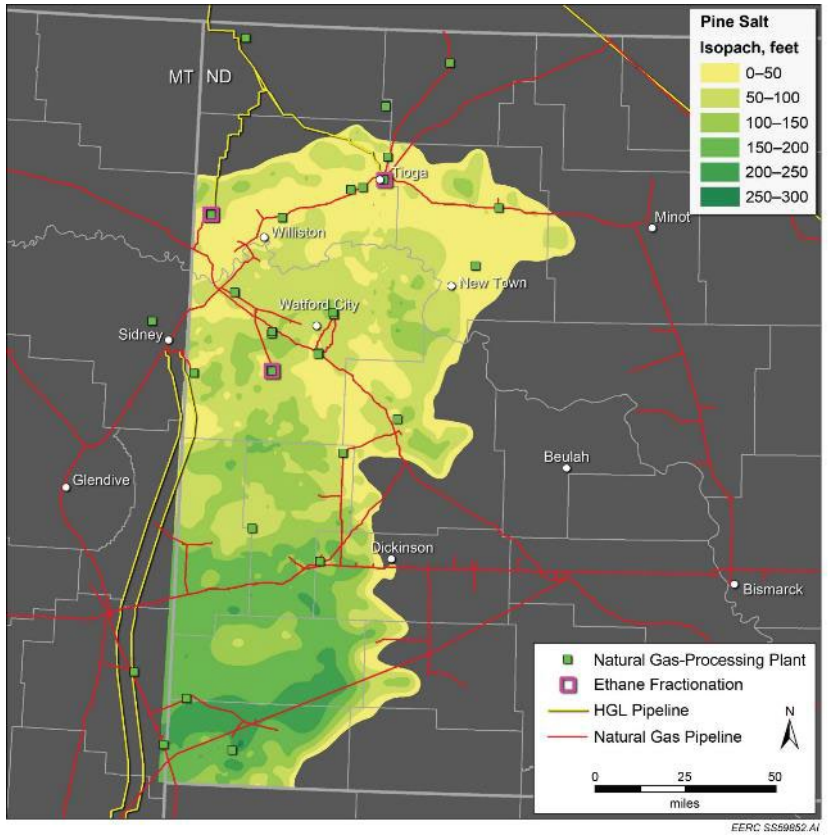
GEOLOGICAL REVIEW

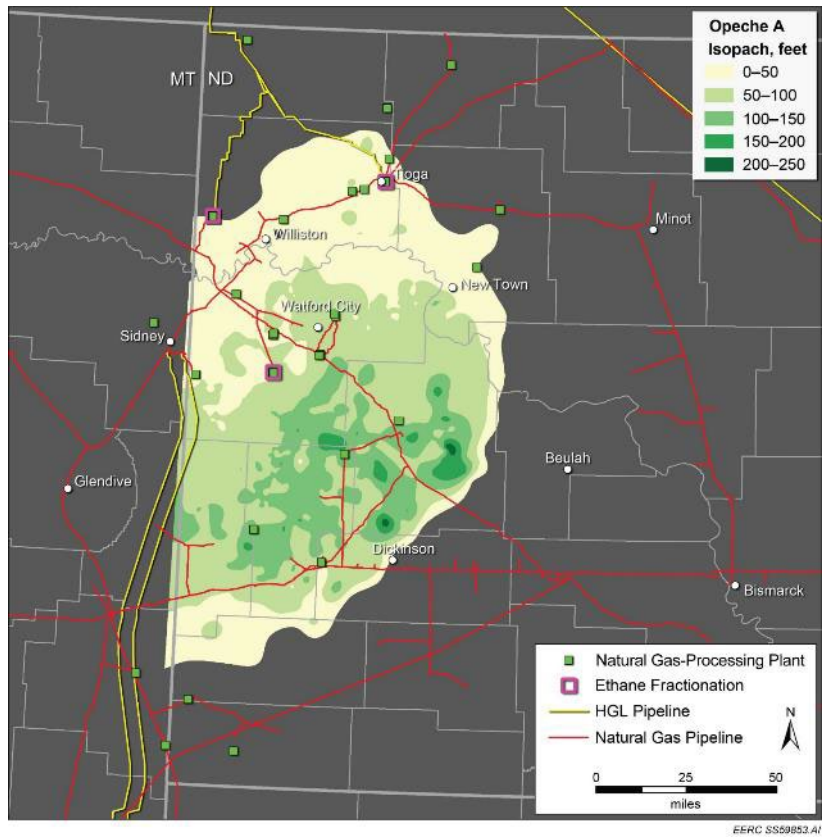
Candidate Salts

- Dunham Salt – thickness <200 ft max., depth <6800 ft
- Pine Salt – thickness <300 ft max., depth <7200 ft
- Opeche A Salt – thickness <250 ft max., depth <7400 ft

Images show extent, thickness, and proximity to regional infrastructure.







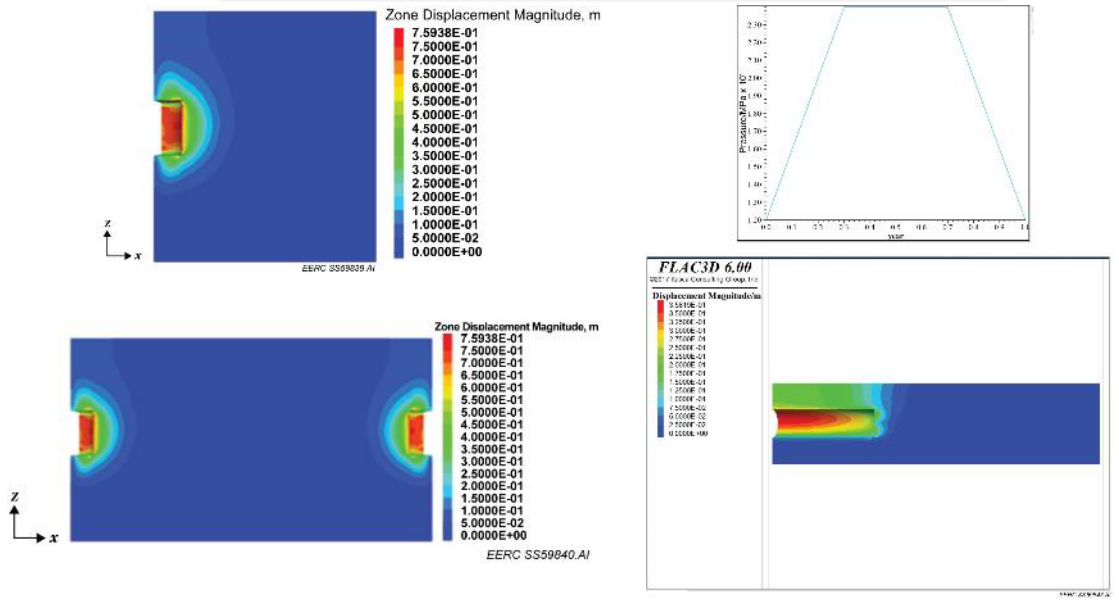
GEOMECHANICAL STABILITY OF SALT CAVERNS

- The geomechanical properties of the salt beds and the overlying rocks are important for understanding:
  - Optimal cavern sizes.
  - Cavern roof stability.
  - Potential for salt creep.

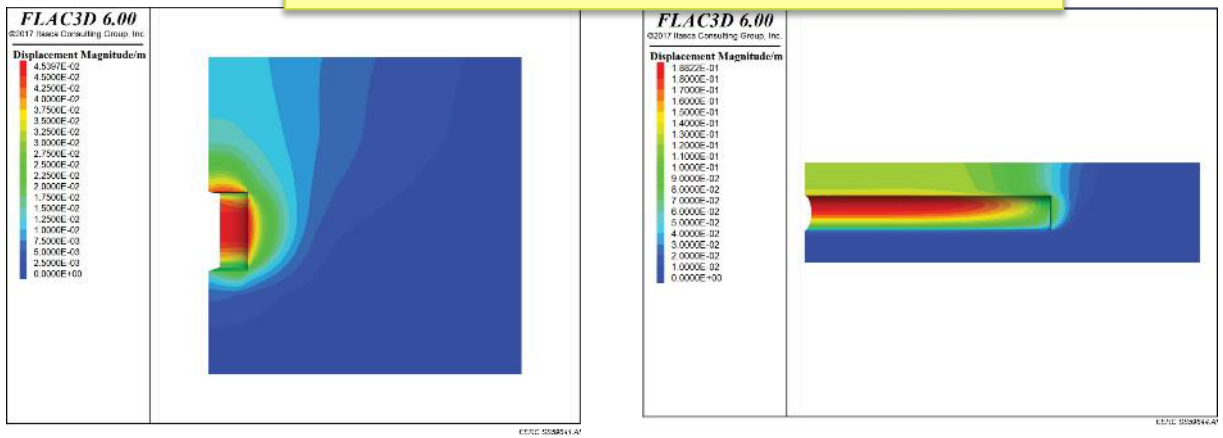
- Simulations of mechanical stability were performed for multiple cavern geometries under cyclic and constant pressure scenarios.

- Effects of temperature were evaluated in select simulations.

Simulation Performed under Cyclic Pressure



Simulation Performed under Cyclic Pressure



KEY FINDINGS FROM THE 2020 STUDY

- Several salt beds were identified as potential candidates for salt cavern development and NGL storage.
- Preliminary simulation results suggest the development of small caverns is achievable in North Dakota salt beds. The use of multiple caverns was found to be a viable design approach with suitable geomechanical stability.
- Preliminary engineering assessments were performed to evaluate major equipment/component needs and associated cost; however, additional work is needed to further refine the operational needs and costs.
- Additional site-specific data (rock samples) are needed.

Image from BusinessGreen

EERC'S CURRENT EFFORTS

2021 Legislative Assembly

- Section 14 of Senate Bill 2014 states: "Pursuant to the continuing appropriation under section 57-51.1-07.3, the industrial commission shall use up to $9,500,000, or so much of the sum as may be necessary, from the oil and gas research fund to contract with the energy and environmental research center for an underground energy storage study."

Project Goal:

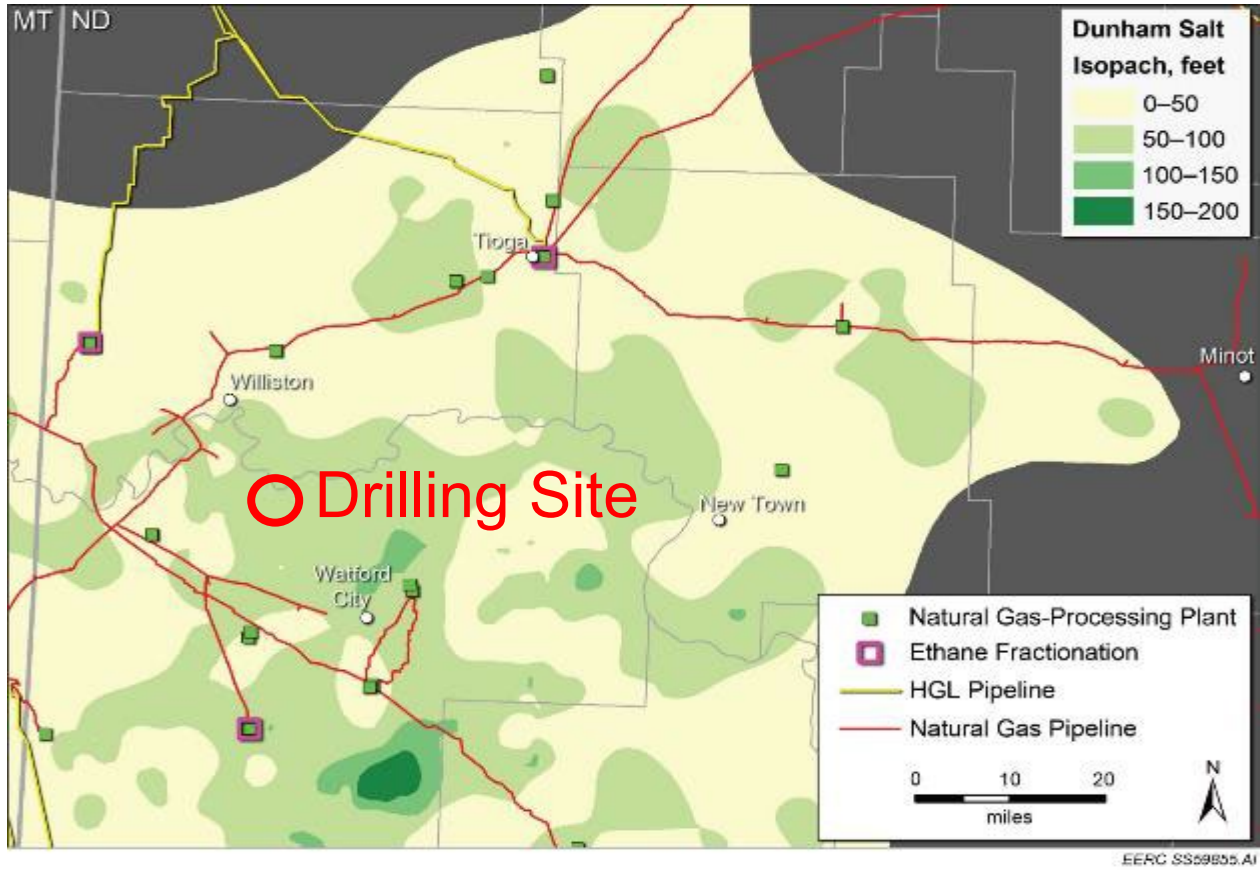
- The EERC is using field-, laboratory-, and modeling-based efforts to validate the depth, thickness, and geologic/geomechanical suitability of North Dakota salt formations for cavern development.

North Dakota
Industrial Commission

PROJECT OBJECTIVES

- Detailed assessment of the presence, depth, and composition of targeted salt formations via drilling of a stratigraphic test well and collection of core from each salt formation.
- In-depth rock characterization followed by modeling and simulation to assess:
  - The detailed composition of the salt zones.
  - The sealing potential of overlying and underlying geologic strata.
  - Geomechanical stability of the salt zones and overlying formations.
- Site-specific engineering design recommendations for future cavern development pilot studies.
- Detailed engineering studies to match potential storage needs/future demand with cavern storage potential.

GEOLOGICAL REVIEW



SITE SELECTION, DRILLING, AND CORE COLLECTION

- Site has been secured southeast of Williston, and drilling has commenced.
- NESET Consulting Service is providing general contracting services and will work closely with the EERC team through the well-planning to site closure process.
- Key activities:
  - Site preparation
  - Drilling
  - Coring
  - Logging
  - Well abandonment and site closure

CORE TESTING AND INTERPRETATION

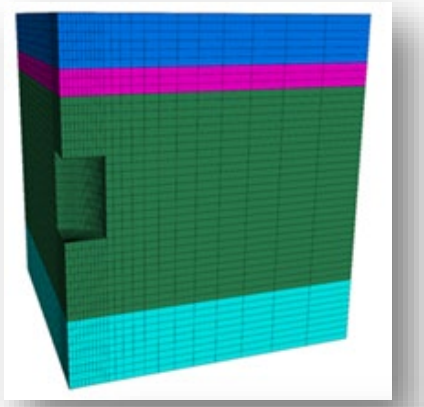
Routine analyses to identify the bulk characteristics of the formations including:

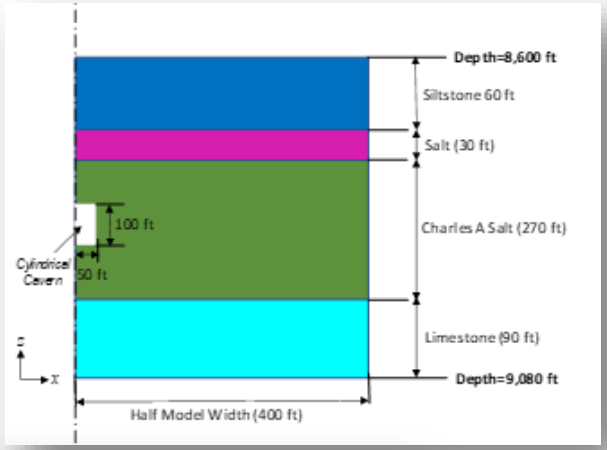
- Composition, thickness, porosity, and permeability.
- Geomechanical competency of the overlying and underlying sealing formations.
- Geomechanical properties of the salt intervals.
- Dissolution properties of the salts encountered.

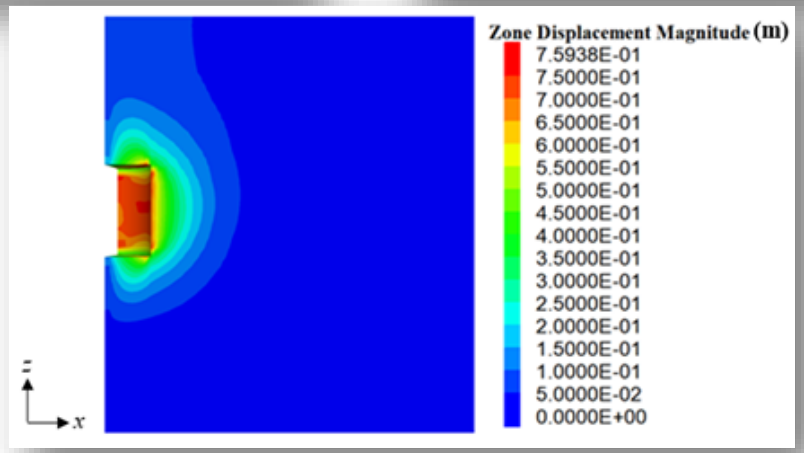
GEOLOGIC AND GEOMECHANICAL MODELING

- Based on site-specific data generated through the drilling, logging, and core-testing process.
- Geologic models will be developed to help interpret the subsurface geologic characteristics and evaluate regional structural and stratigraphic trends that may impact cavern development.
- Geomechanical modeling will incorporate information derived from geologic modeling, wireline logging, formation testing, and laboratory data sets and will inform the overall cavern dimensions and operational stability.

CAVERN SIZE AND GEOMECHANICAL STABILITY







ENGINEERING ANALYSIS AND DESIGN

- Detailed engineering design and analysis will be performed to identify surface equipment needs; design specifications; brine handling, use, and disposal practices; and monitoring needs.
- Advisement is being sought from external engineering teams with expertise in developing and operating salt caverns used for hydrocarbon storage.

PROJECT STATUS

- Site was selected and core drilling began in late May 2022.
- Drilling expected to be completed by the end of June 2022.
- Preliminary findings available by the end of 2022.
- Project complete by June 2023.
- If successful, next steps would be to conduct a demonstration project.

PROJECT DELIVERABLES

- A final report that includes:
  - A summary of the key findings from the site-specific geological investigation.
  - Site-specific cavern design and engineering considerations based on the successful drilling and coring of a well.
  - Key lessons learned from the pilot projects for future development efforts.
  - An implementation plan highlighting the viability of storing hydrocarbon gases and hydrogen in engineered salt caverns.
- Rock cores from our most promising targets for salt cavern development.

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THANK YOU

Critical Challenges. Practical Solutions.

EERC | UND UNIVERSITY OF NORTH DAKOTA

Critical Challenges. Practical Solutions.