

# Enhancing Lignite to be the Fuel of Tomorrow

Mike Holmes

VP – Research and Development

Lignite Energy Council

6/27/2023

# New Power Plant



< Activities



Visual settings



Edit

🌐 When poll is active, respond at **PollEv.com/ligniteenergy220**

📱 Text **LIGNITEENERGY220** to **22333** once to join

**If you were asked to design a new power plant, what would be most important?**

Less coal per megawatt-hour (efficiency)

Near zero emissions (environment)

Low-cost electricity (economics)



# Founding Premise

- There is no challenge regarding the use of coal as a clean, efficient fuel that has not been met by technology – nearly 90 percent of criteria pollutants from U.S. coal-based power plants are now captured or reduced through the use of technology

# Question



< Activities



Visual settings



Edit

🌐 When poll is active, respond at **PollEv.com/ligniteenergy220**

📱 Text **LIGNITEENERGY220** to **22333** once to join

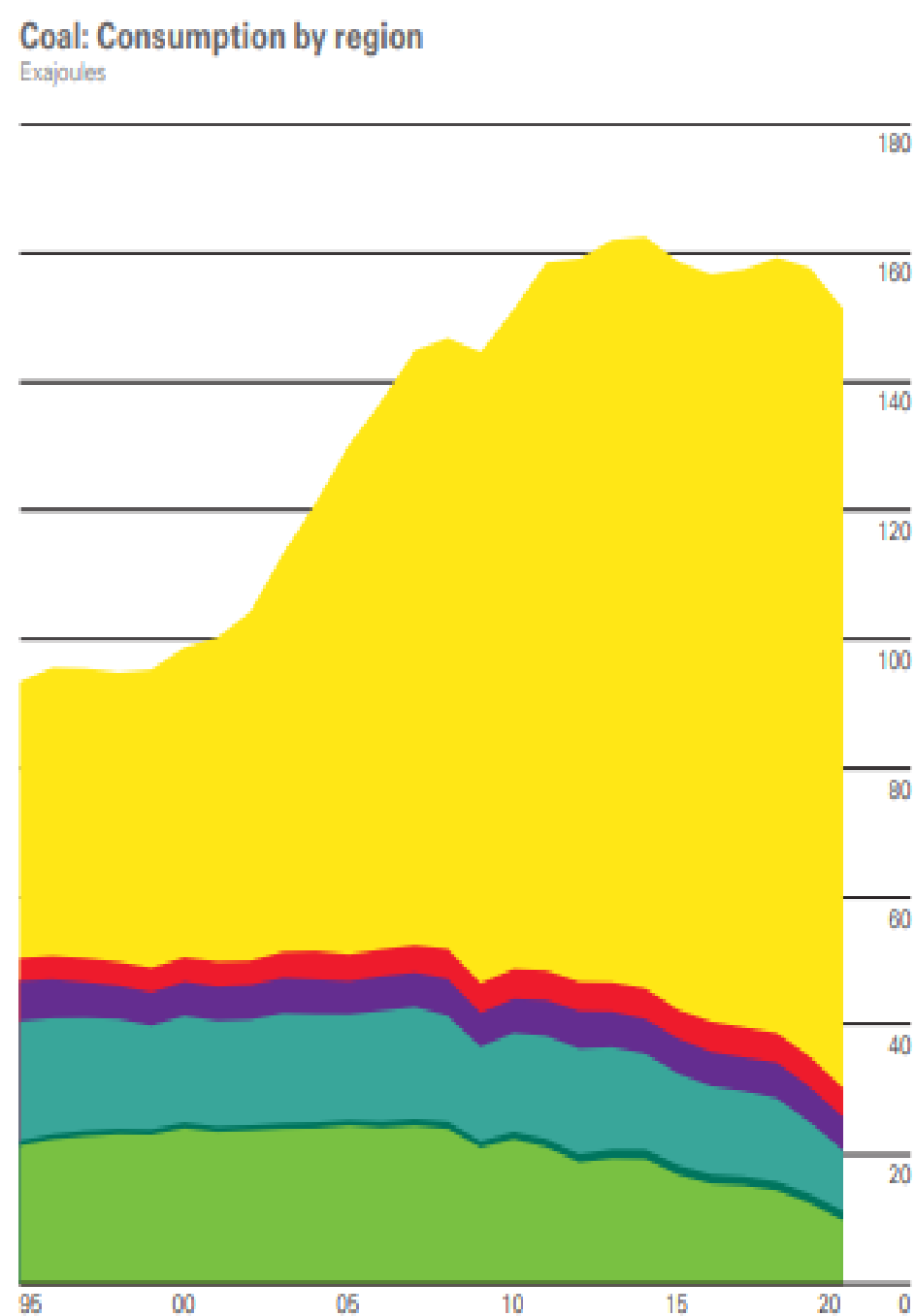
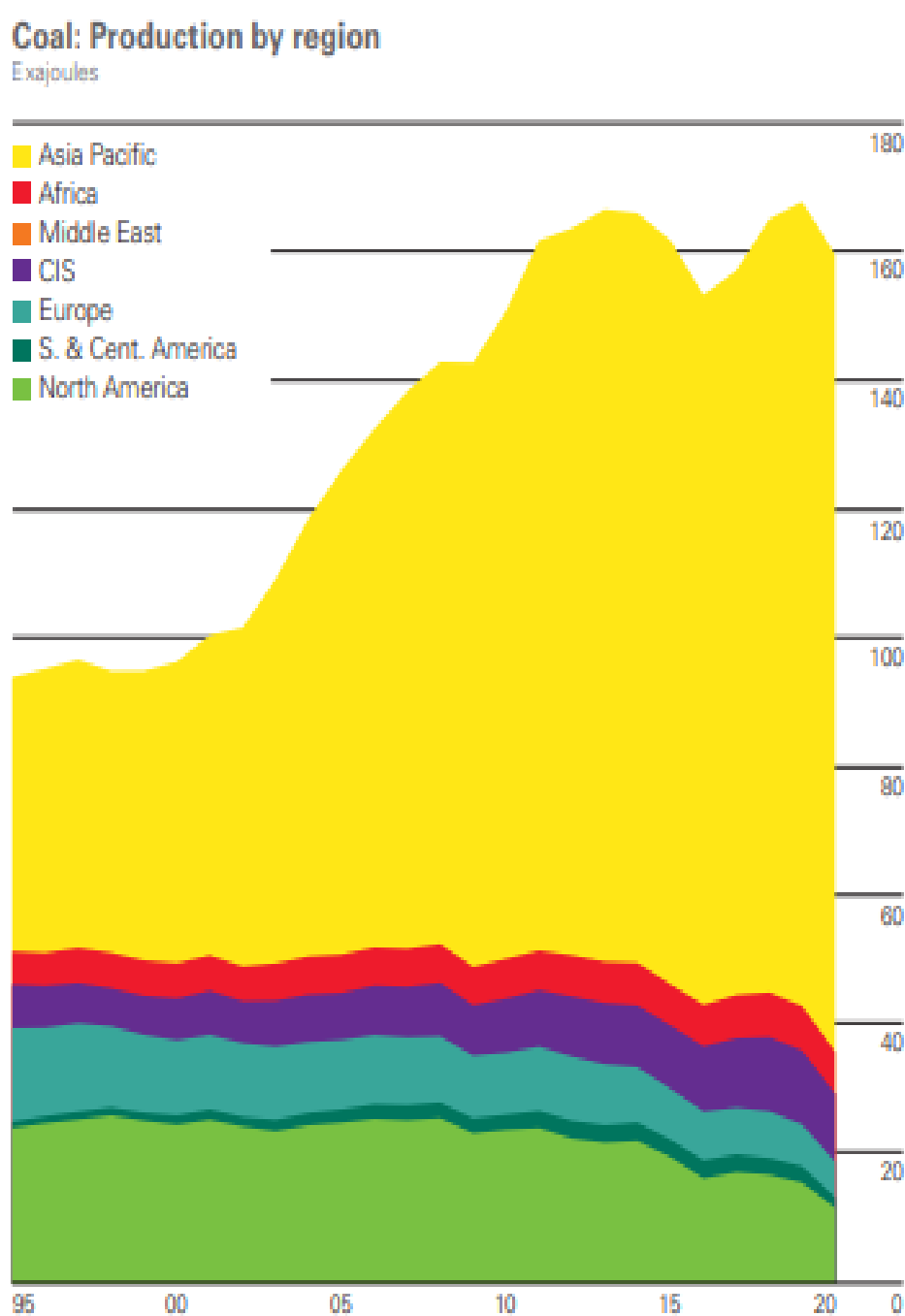
**Over the last decade coal use worldwide has??**

Decreased by 20%

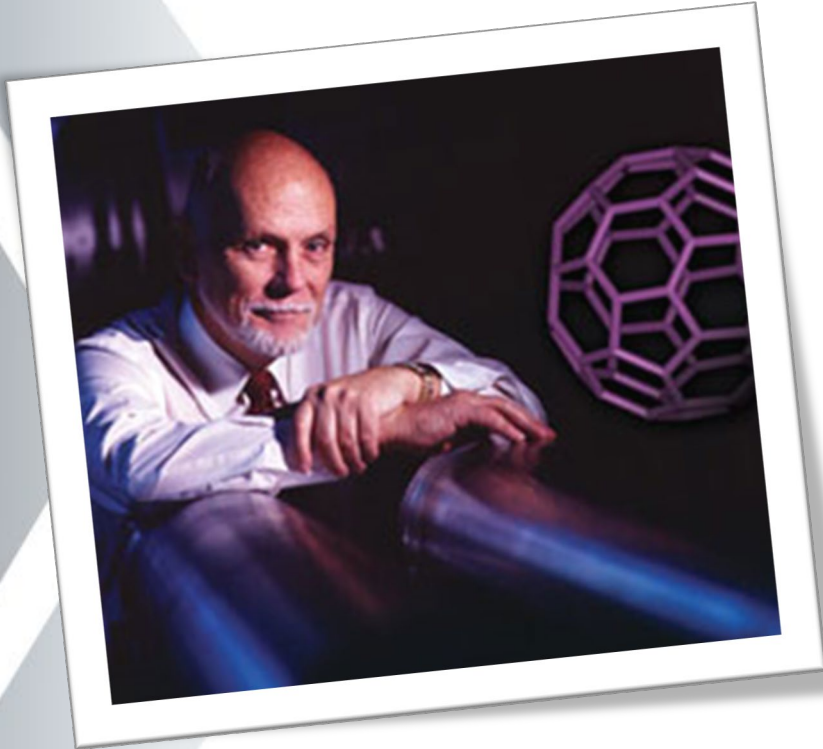
Decreased by 50%

Remained constant

Increased



# Reality Today



*"Energy may very well be  
the single most critical  
challenge facing humanity in  
this century."*

-- Nobel Laureate Richard Smalley

# The Challenge

10 terawatts (TW) of clean power on a sustainable basis and do this cheaply

Who will make the necessary scientific and engineering breakthroughs?

Can it be cheap enough to bring 10 billion people to a reasonable standard of living?

# Agenda

State-industry R&D partnership

Lignite resource

Current R&D challenges

- Solutions for Existing Plants
- Next Generation Power Plants
- Carbon Management (CO<sub>2</sub>)
- Additional Uses for Lignite

Summary

Lignite Jeopardy Game

# Glossary

- Clean Coal Technologies:
  - Defined by Congress in mid-1980s as technologies to reduce sulfur dioxide and nitrogen oxides (30 years later often refers to reduction of CO<sub>2</sub>)
  - Technologies that increase efficiencies and reduce emissions on a per unit energy basis are also clean coal technologies

# Lignite Research Council's R&D Program

**An Industry / Government Partnership**



**Public / Private Partnership**

<http://www.lignite.com/ResDev/index.htm>

<http://www.nd.gov/ndic/lrc-infopage.htm>

# Historical Successes

- Thriving with high-sodium coal  
*Optimized operation and cleanability*
- Addressing Hg and trace elements  
*Costs reduced by more than 20x*
- Meeting regulations for primary pollutants  
*Addressing potential future NOx challenges*

- Support of only US coal-to-synfuels plant  
*DGC added urea to product suite*

## A Few Highlights

- Spiritwood – industrial complex
- DryFining – coal upgrading
- Lignite mining, use, and reclamation advances through data, instrumentation & controls



Basin Electric Antelope Valley Station and DGC Synfuels Plant  
[www.dakotagas.com](http://www.dakotagas.com)

# Leveraging State Dollars



For every state dollar, six dollars is invested from industry & other sources in lignite-related R&D projects

# Future of Lignite

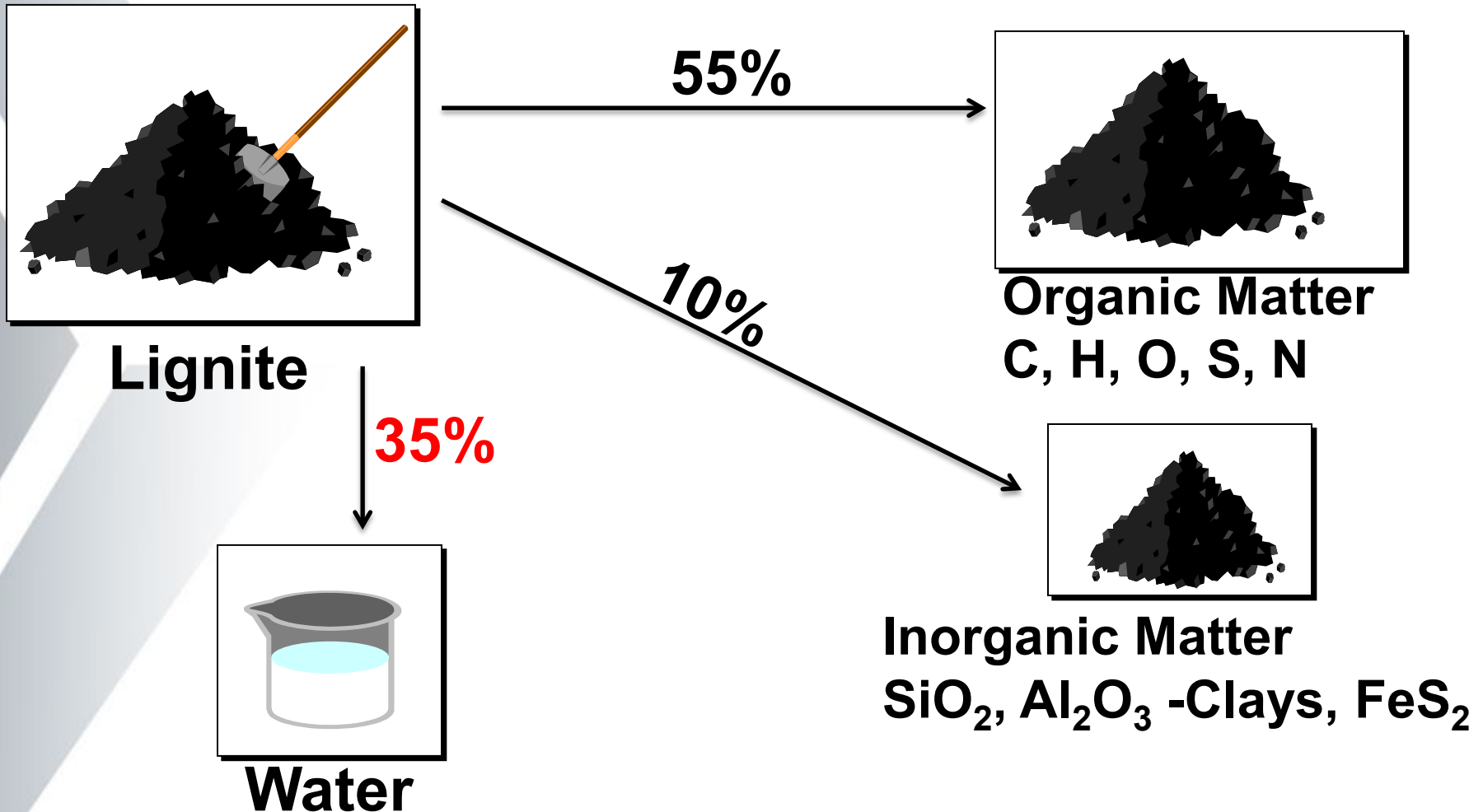
- The resource: 800-year supply of lignite



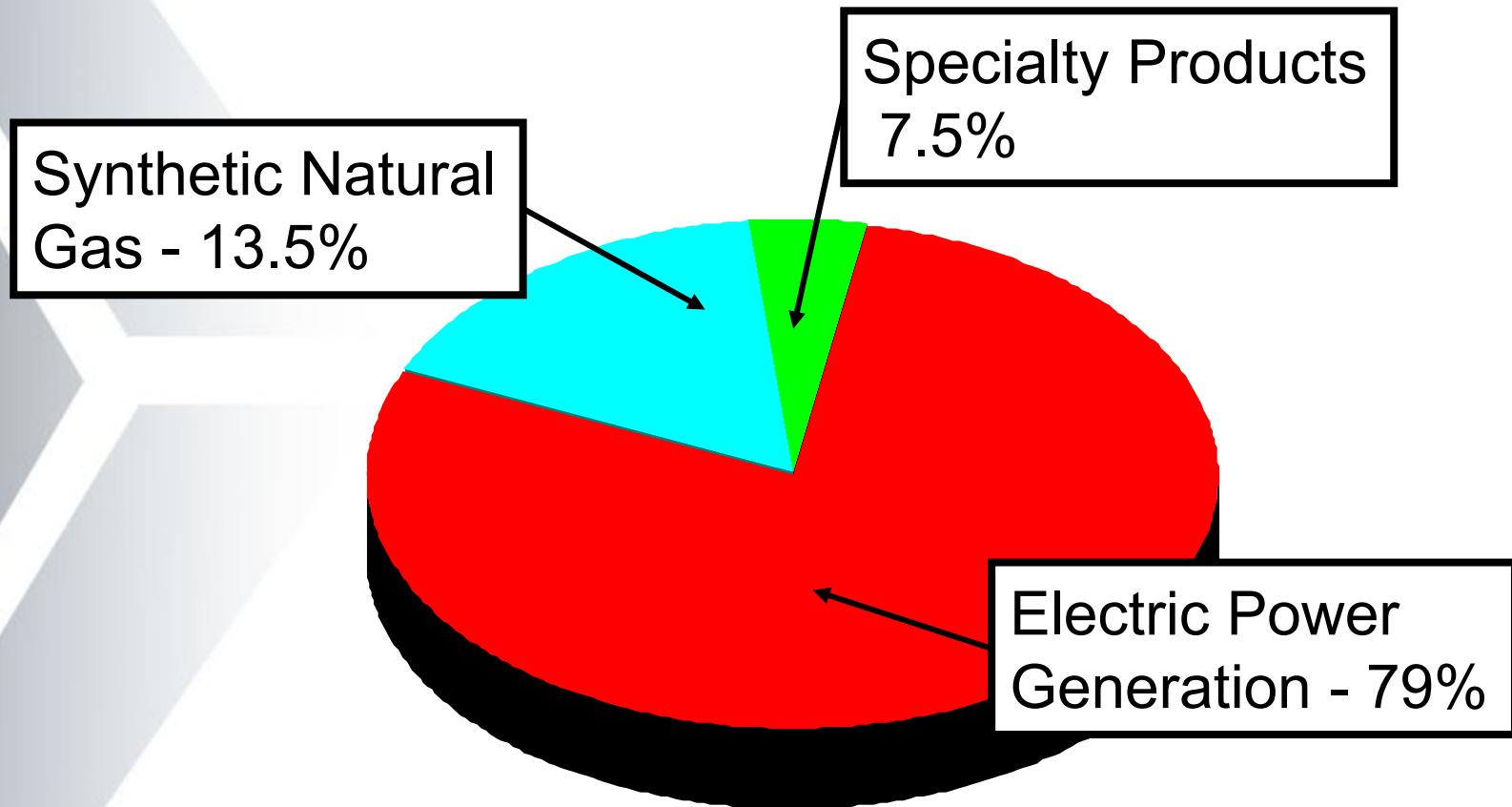
From an R&D / science perspective:

- High ash, low BTU, one-third water, high sodium
- Highly reactive for gasification purposes
- Low-cost source of carbon

# A Look at Lignite



# ND Lignite Consumption



# Coal Drying Activity

- As mined, lignite is approximately one-third moisture. This makes it uneconomical to transport by rail. However, a coal drying facility is now operational at Coal Creek Station has made transporting lignite a more economical proposition.
- The coal drying project has its roots in a simple experiment that you can simulate in the classroom.

# Coal Drying Procedure

- Weigh about 100 grams of lignite on a paper plate
- Place the coal onto a cookie sheet and place it in an oven set at its lowest temperature – 100°F or 120°F for four hours
- Reweigh the coal to determine the weight loss due to moisture and calculate the percent of moisture



# Coal Drying Procedure

## Alternative Drying Methods

- Dry the lignite using the heat from a light bulb. This method will model Coal Creek Station's use of remaining process heat from its boiler.
- Simply place the lignite in a sunny window and let it dry. Weigh the sample each day until the weight is constant for two days.

# Coal Drying Activity (Cont.)

- Coal Creek Station's pulverizes the coal prior to drying, so students can compare the rate of moisture loss and total amount of moisture lost between crushed and uncrushed coal
- Pulverized coal has greater surface area and should dry faster than coal in larger pieces

# Coal Dryer Development

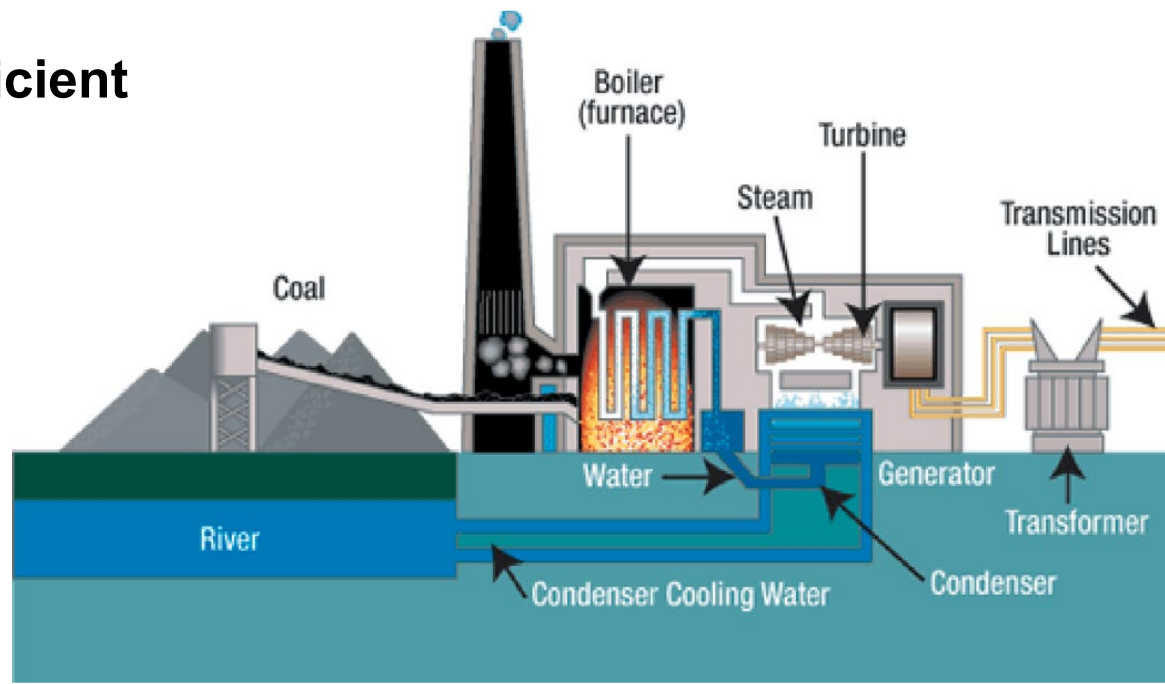
- Prototype model built adjacent to the plant (1/06)
- Used waste heat to dry the coal after it was pulverized
- Tests showed how much heat & time needed
- Eight coal dryers have been installed to dry all of the coal (operational 12/09)



# Current Energy Conversion Technologies

## Pulverized Coal-Fired Boilers

- 2400 PSI Steam; 1000°F
- Up to 600 MW/unit in ND
- 30-32% Efficient



# Current Energy Conversion Technologies



**Antelope Valley Station**

**Pulverized  
Coal-Fired  
Boilers**



**M.R. Young Station**



**Coal Creek Station**

# Current Energy Conversion Technologies

## Pulverized Coal-Fired Boilers



**Coyote Station**



**Leland Olds Station**

# Current Energy Conversion Technologies

## Fluidized bed Boiler Technology



**Spiritwood Station**

# Future Generating Technologies

Advanced  
Pulverized Coal

Oxy-fuel  
Combustion

Integrated  
Gasification  
Combined Cycle  
(IGCC)

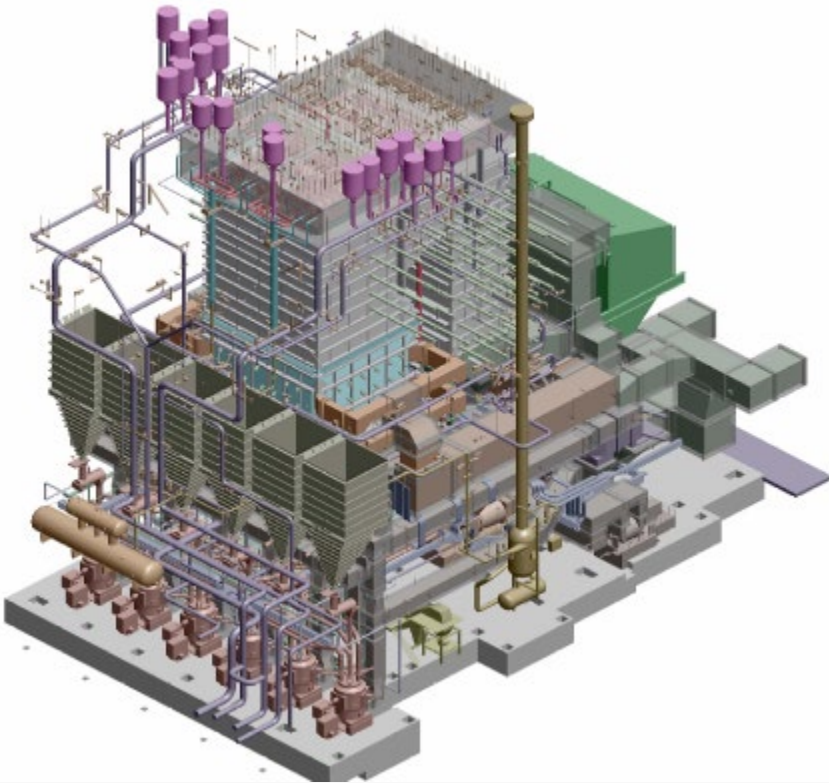
Poly-generation

Chemical Looping

Allam Cycle

# Future Generating Technologies

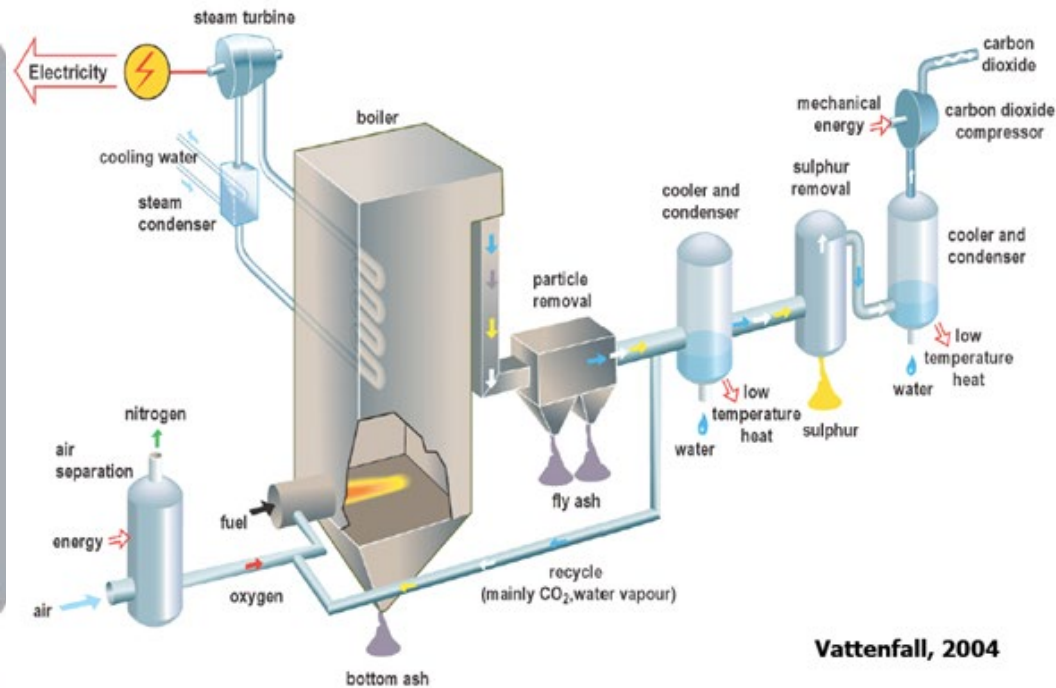
## Supercritical Pulverized Coal Power Plant



- 3500 PSI Steam; 1050°F
- Up to 1300 MW/Unit
- 35-40% Efficient

# Future Generating Technologies

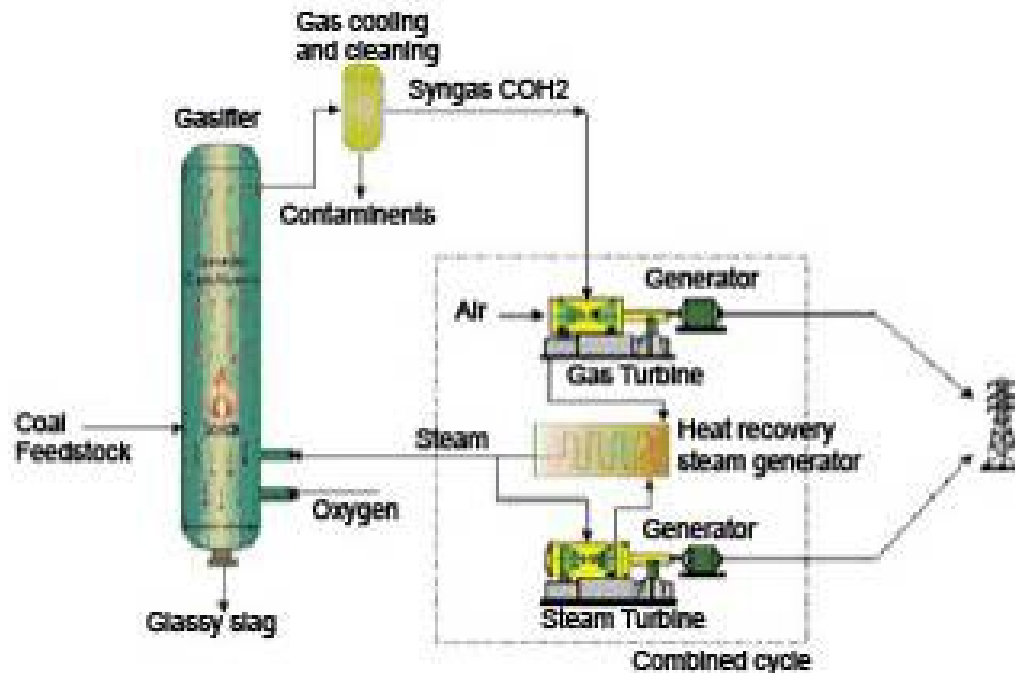
## Oxy-combustion



- Technology consideration to capture CO<sub>2</sub>
- Energy penalty ~ 1/3 (450 MW Gross yields 300 MW Net)
- First demonstrations underway in US and Europe

# Future Generating Technologies

## IGCC



- Up to 300 MW/Unit
- 40-45% Efficient
- Cost, availability & lack of lignite experience are issues

# Gasification



## Products

- Electric Power
- Synthetic Natural Gas
- Liquid Transportation Fuels
- Hydrogen
- Chemicals
- Fertilizers



## Advanced oxy-combustion system without Air Separation Unit

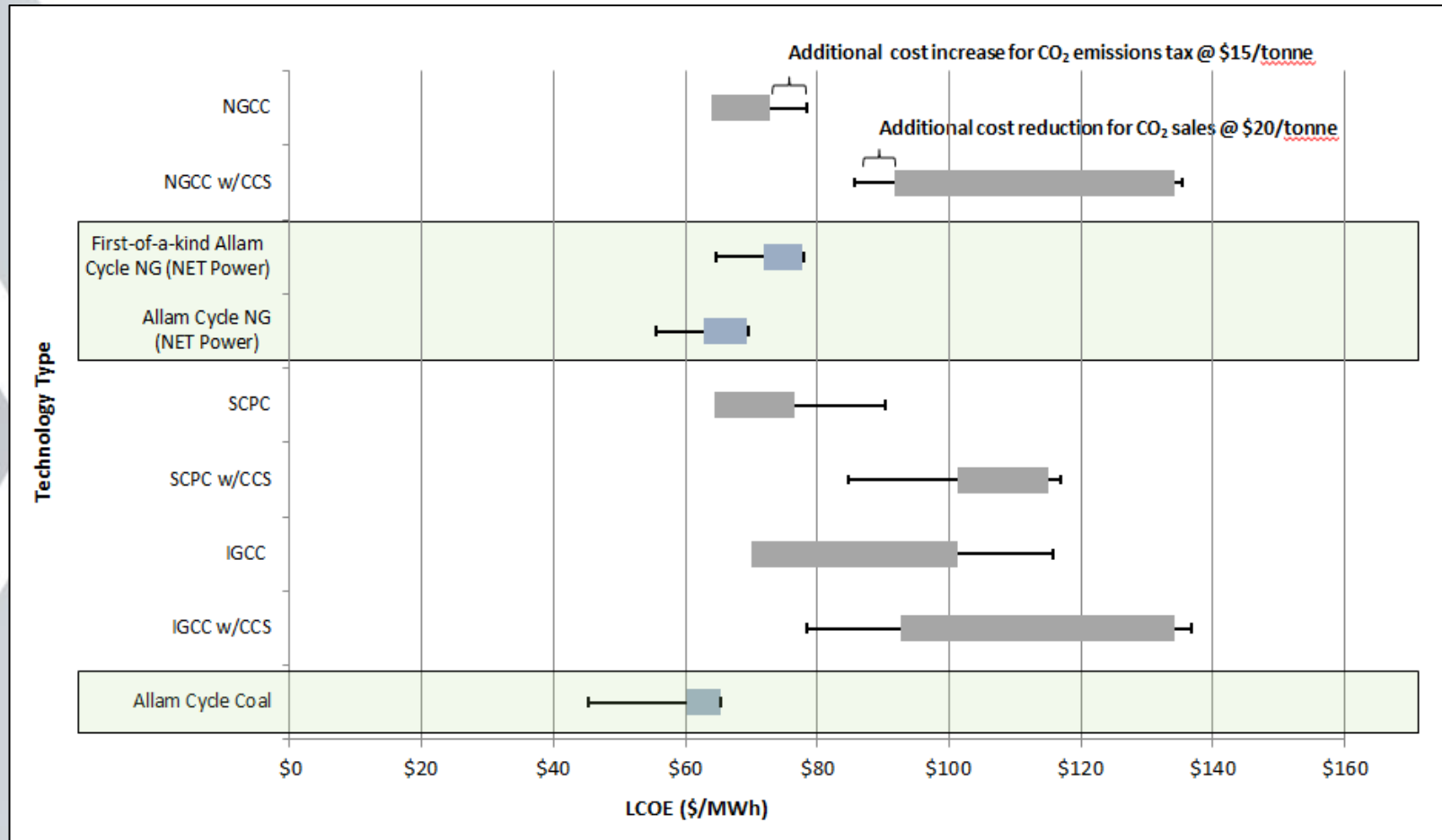
# Allam Cycle

Converts Coal to  
Syngas

Uses  
supercritical CO<sub>2</sub>  
as working fluid

Very high  
pressure  
oxycombustion

# Allam Cycle achieves clean, low-cost electricity competitive with all state-of-the-art systems

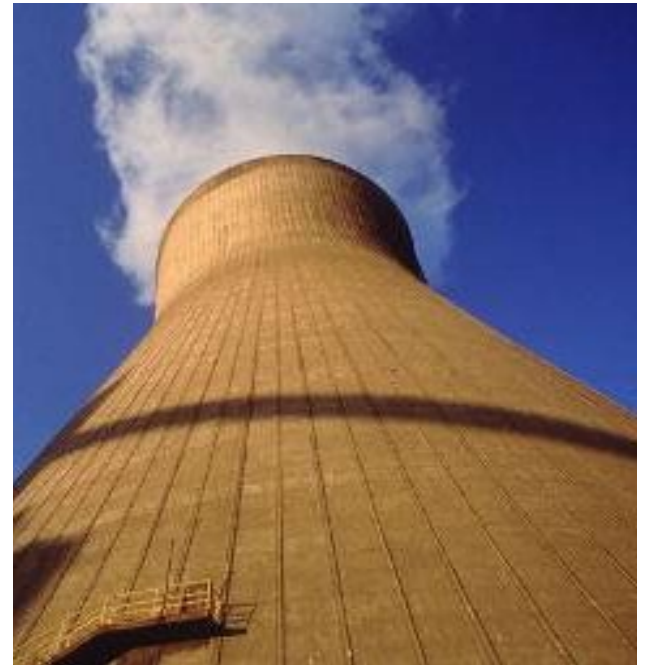


## Note:

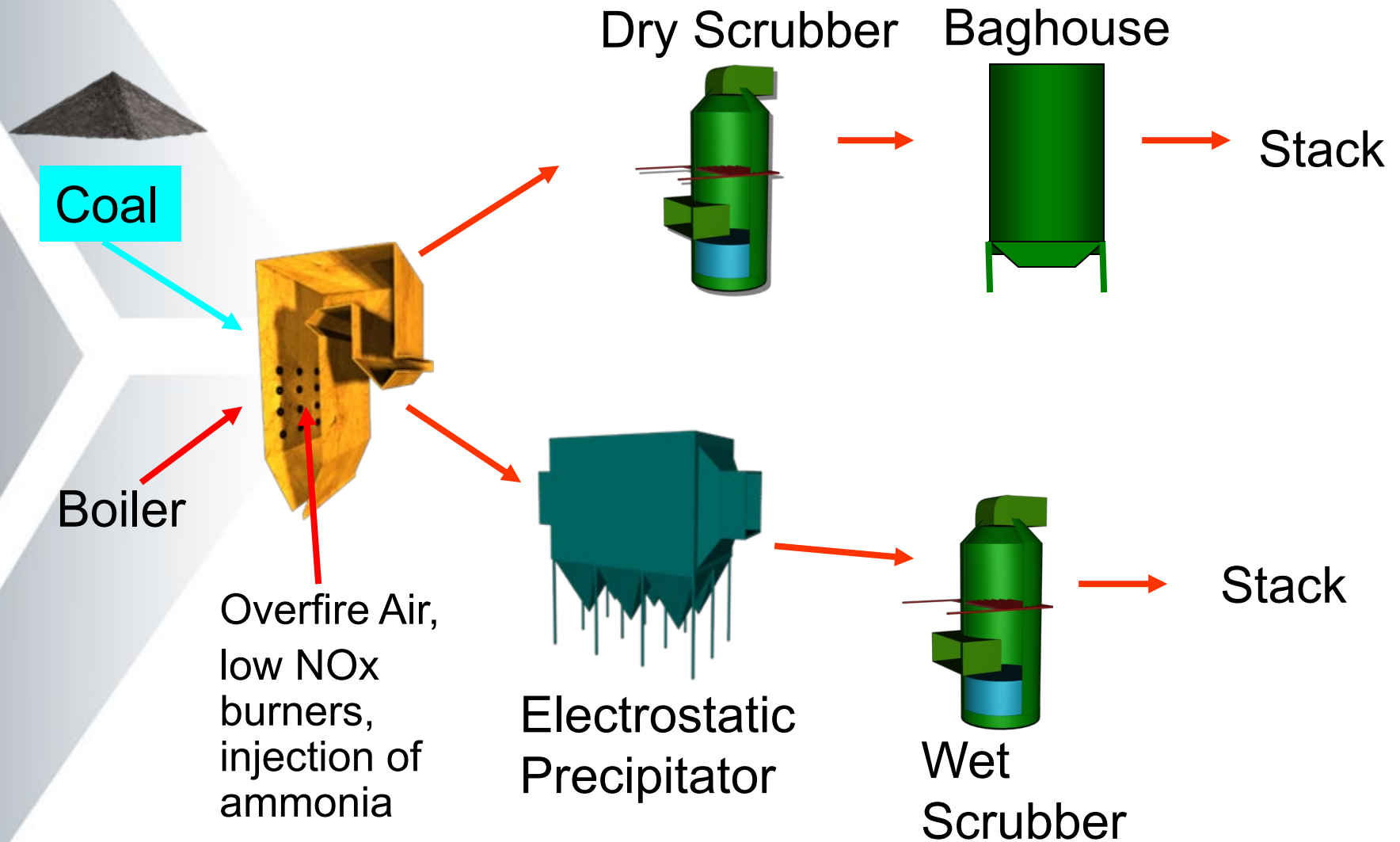
- LCOE calculated using EPRI methodology
- Assumes \$6.50/MMBtu natural gas and \$2.00/MMBtu coal
- Cost ranges represent data from several sources: EIA (2013); Parsons Brinkerhoff (2013); NETL (2012); Black & Veatch (2012)

# Emission Control Technologies

- Particulate Matter (PM) reduction >99.99%
- Sulfur Dioxide (SO<sub>2</sub>) reduction >97%
- Nitrogen Oxides (NO<sub>x</sub>) reduction >50%
- Mercury (Hg) reduction 50%-90%
- Carbon Dioxide (CO<sub>2</sub>) ??? %
  - New plants
  - Existing plants

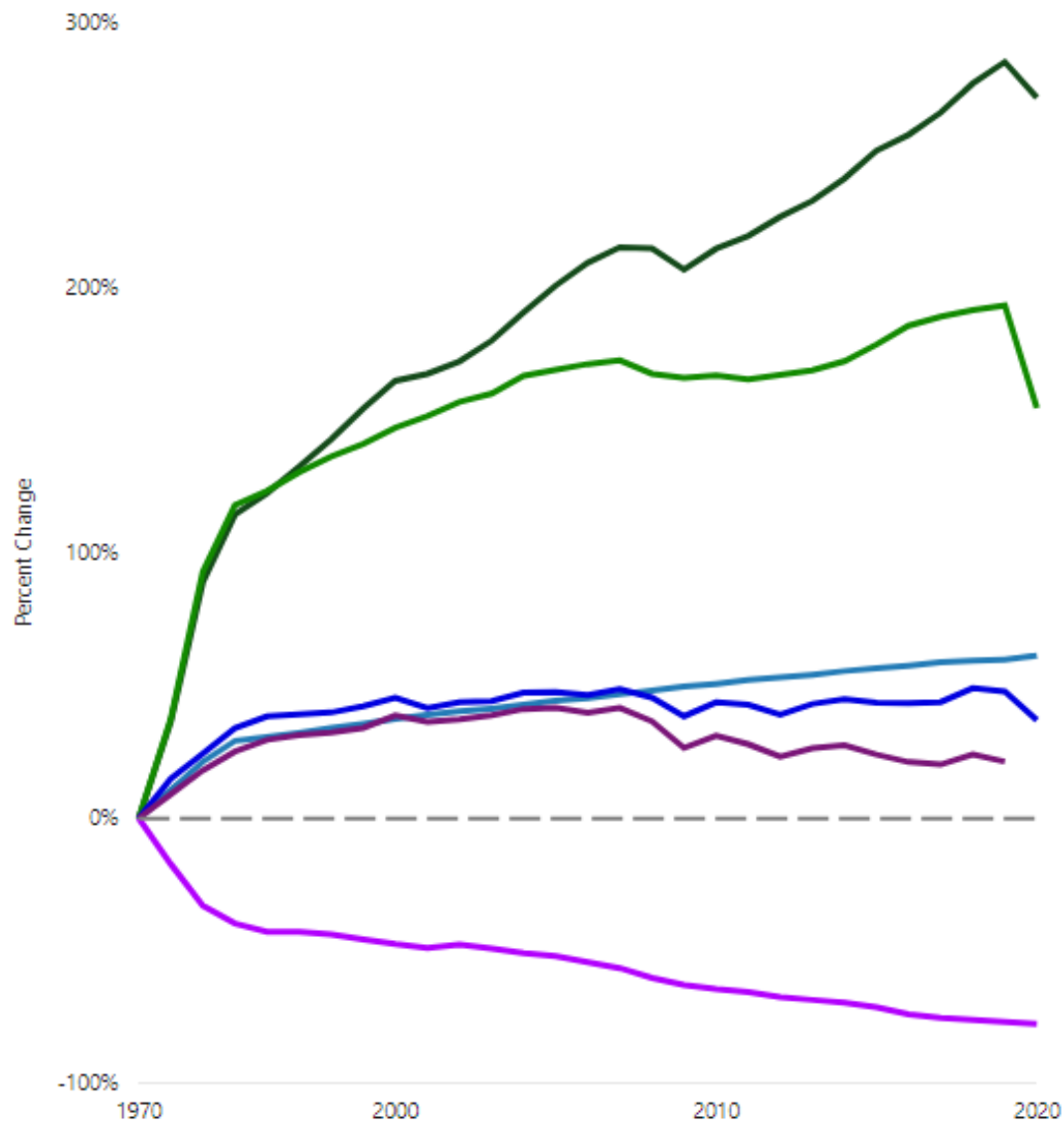


# Emission Control Technologies



# Comparison of Growth Areas and Declining Emissions

1970-2020



Source: Various



**Gross Domestic Product**



**Vehicles Miles Traveled**



**Population**



**Energy Consumption**



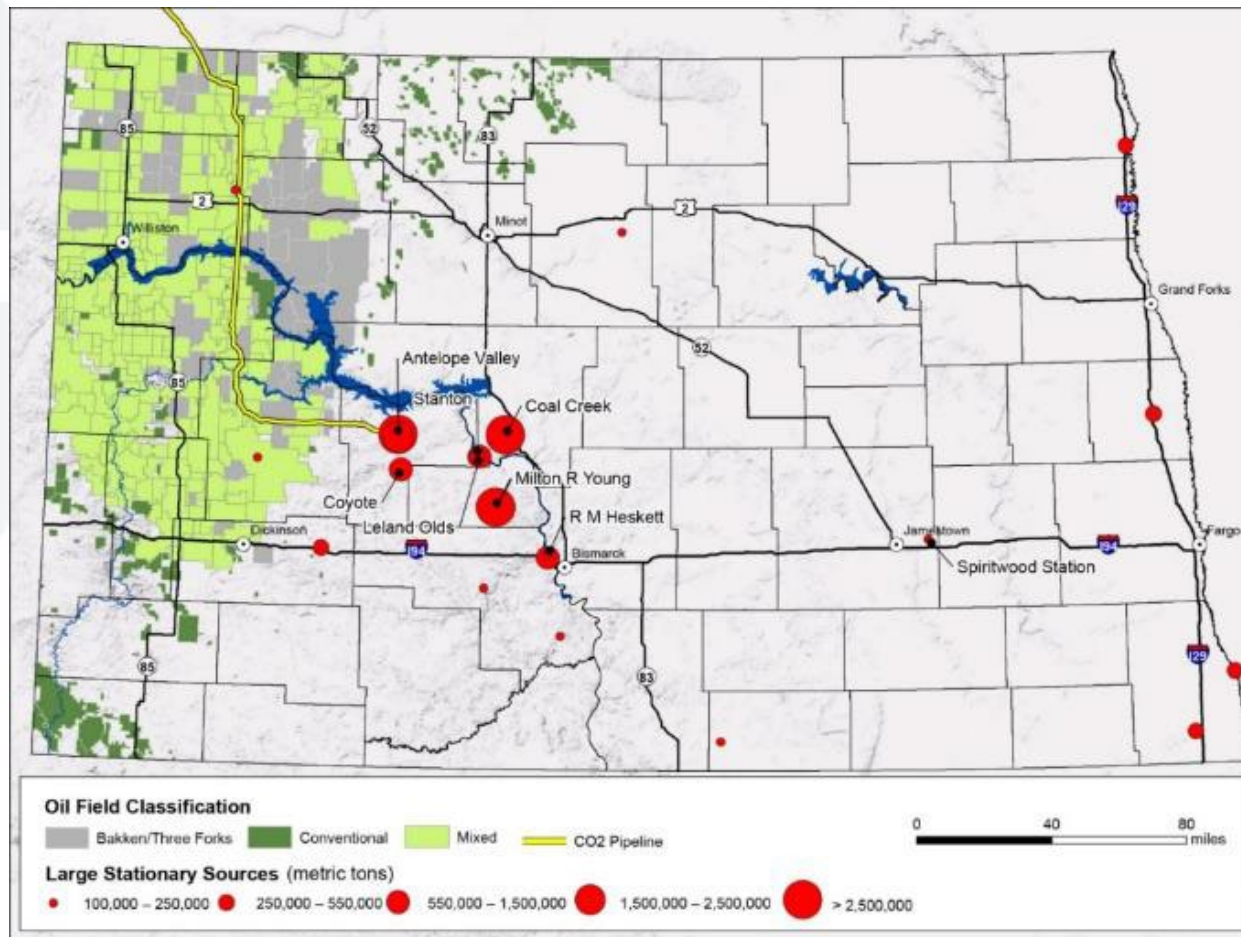
**CO<sub>2</sub> Emissions**



**Aggregate Emissions  
(Six Common Pollutants)**

# Much of the Recent Focus Has Been on Carbon Management - North Dakota is Ideally Suited

- North Dakota has an ideal situation for CO<sub>2</sub> management
  - CO<sub>2</sub> emission sources are in close proximity to CO<sub>2</sub> storage targets
  - Between 76 and 252 Gt of storage available within the state between saline formations and oil reservoirs



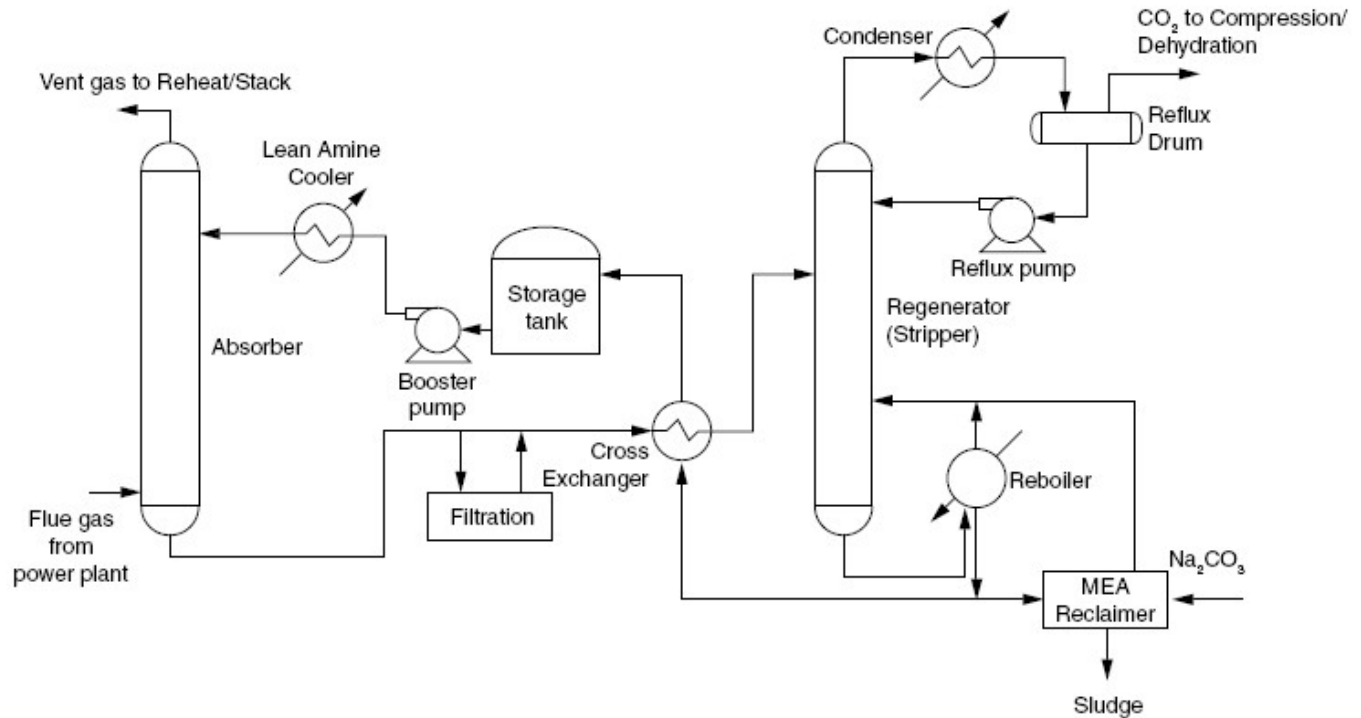
# Carbon Capture, Utilization and Storage (CCUS)



Graphic from EERC PCOR Program

# Capture Technology Overview

- Capture testing performed at Milton R Young and Coal Creek Stations over the past year
  - Primary focus in 2021 was on reducing amine losses.
- Testing has been completed, and the engineering and design work is ongoing.
  - Pre-FEED study at Coal Creek is scheduled to be completed in 2021.
  - Milton R Young FEED study scheduled to be completed this year with the report available in early 2022.

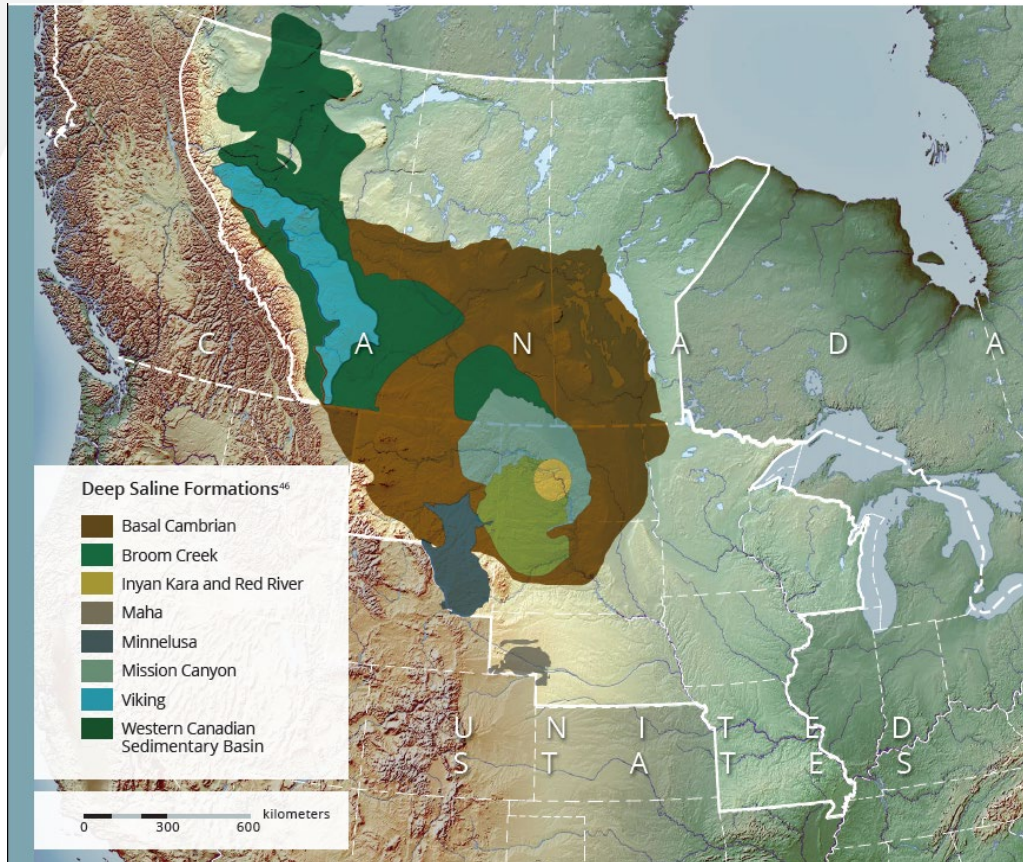


# Preliminary Front End Engineering and Design (pre-FEED) Study for a full-scale carbon dioxide capture system at Coal Creek Station (CCS2)



- Pre-FEED study is progressing well.
- All pilot system testing completed, and data analysis is ongoing.
- Economic evaluations are nearing completion.
- Geologic storage evaluated separately under Midwest Ag project.

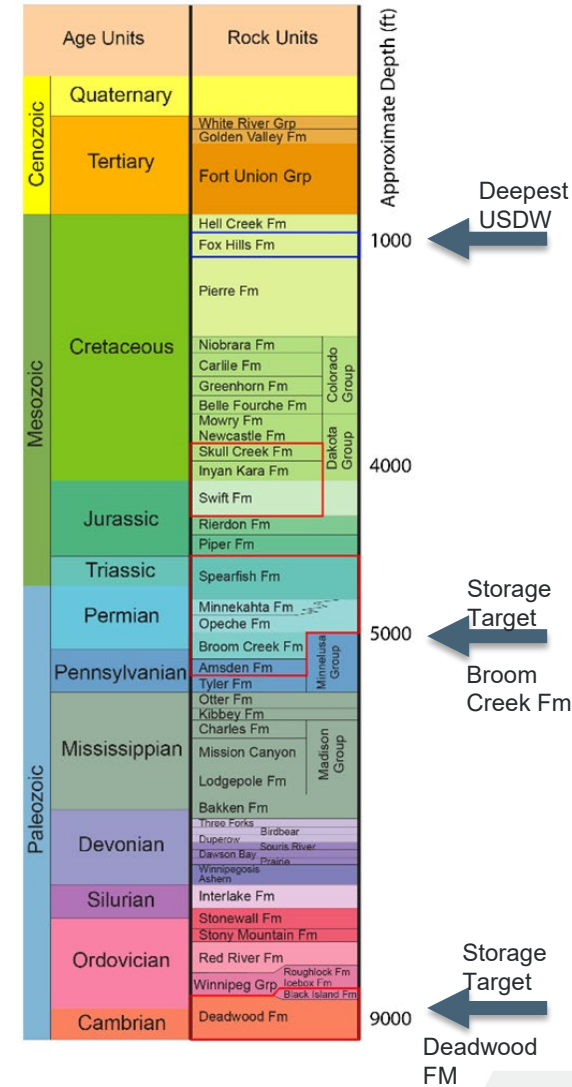
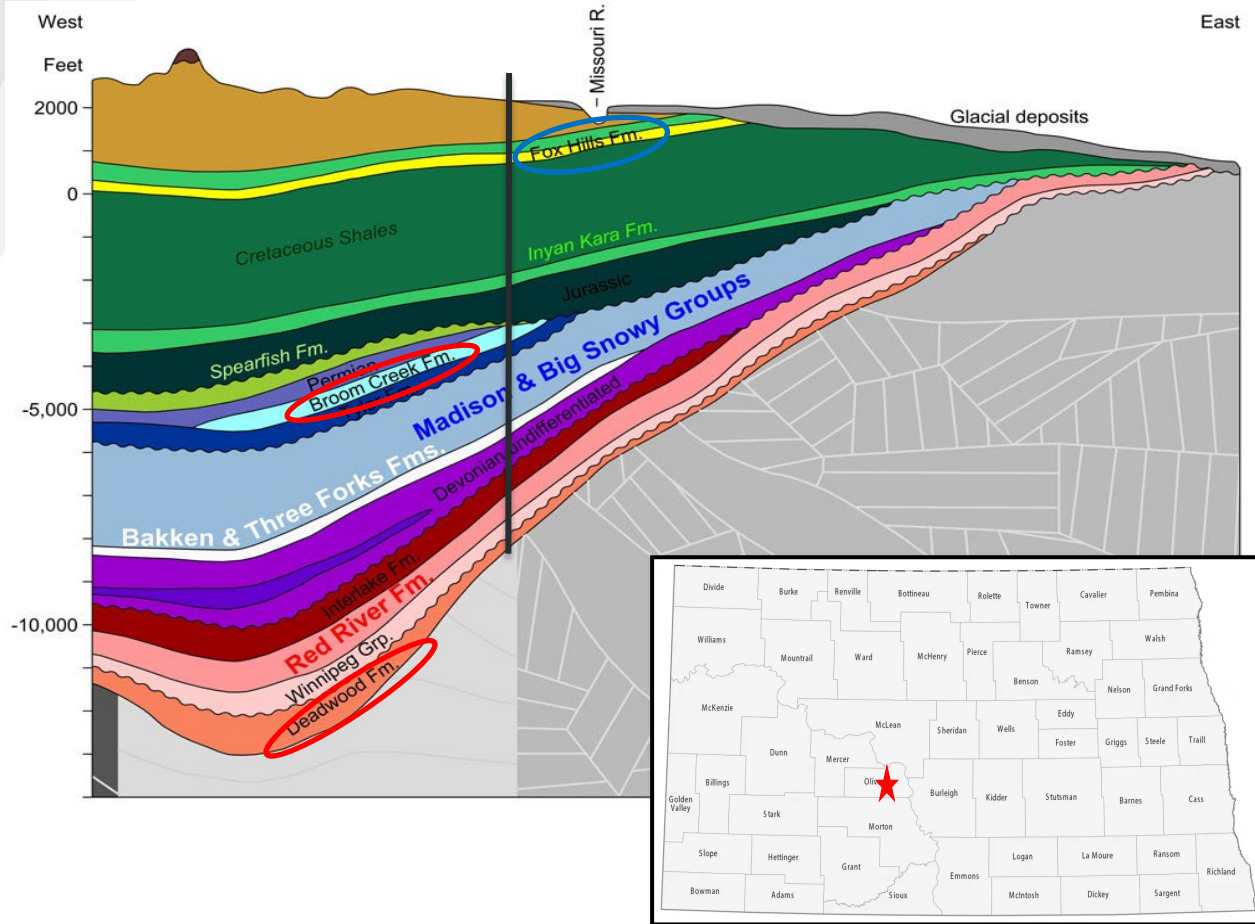
# CO<sub>2</sub> Storage Resource in the PCOR Partnership Region



Several deep saline formations throughout the PCOR region have been evaluated for CO<sub>2</sub> storage.

North Dakota formations have the ability to store between 76 billion and 252 billion tonnes of CO<sub>2</sub>.

# Project Tundra Location



Critical Challenges. Practical Solutions.

# CCUS in North Dakota Conventional Oil Fields Identified

## 201

### Conventional Oil Fields Requiring

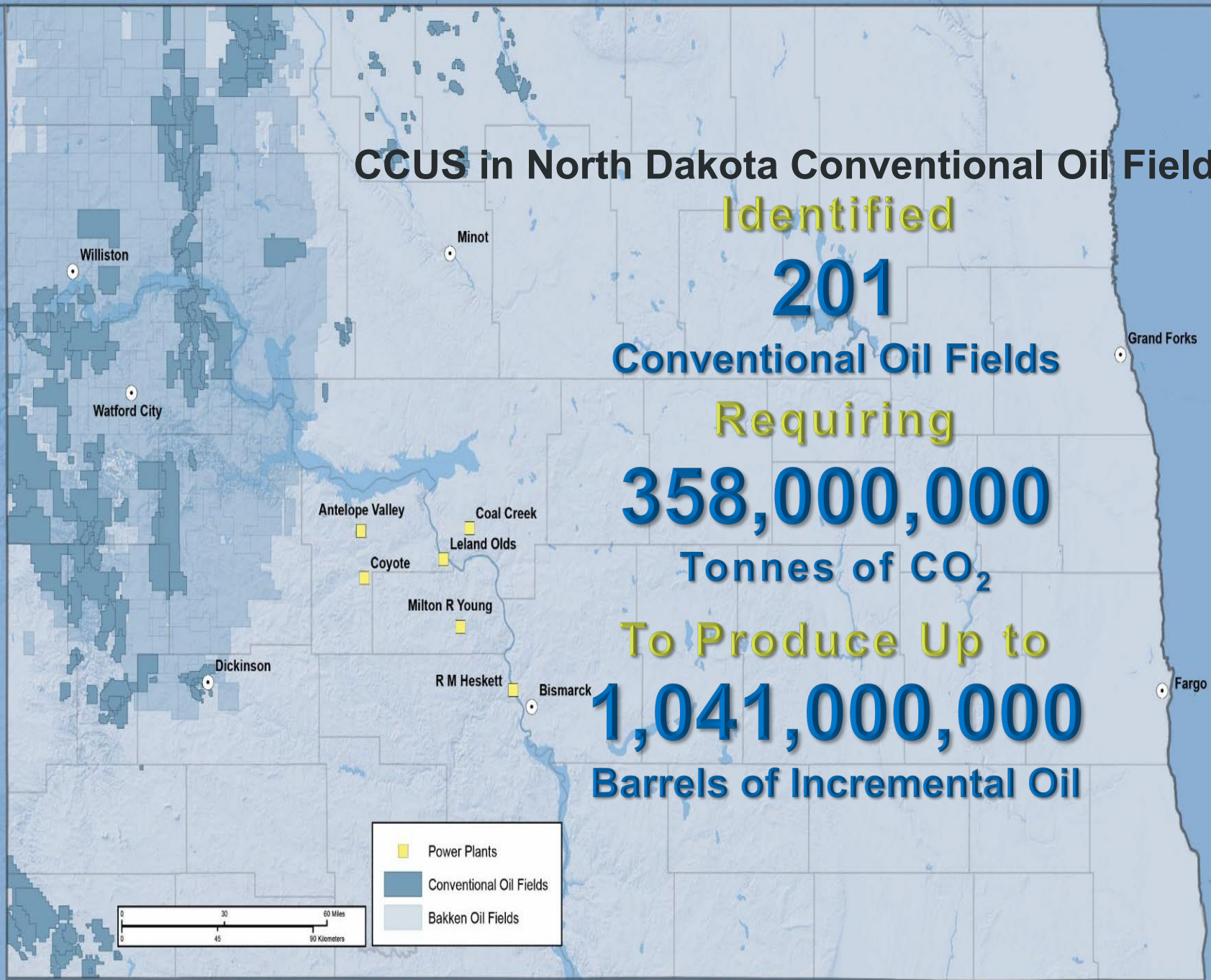
## 358,000,000

### Tonnes of CO<sub>2</sub>

### To Produce Up to

## 1,041,000,000

### Barrels of Incremental Oil



# CCUS in North Dakota Unconventional Oil Fields

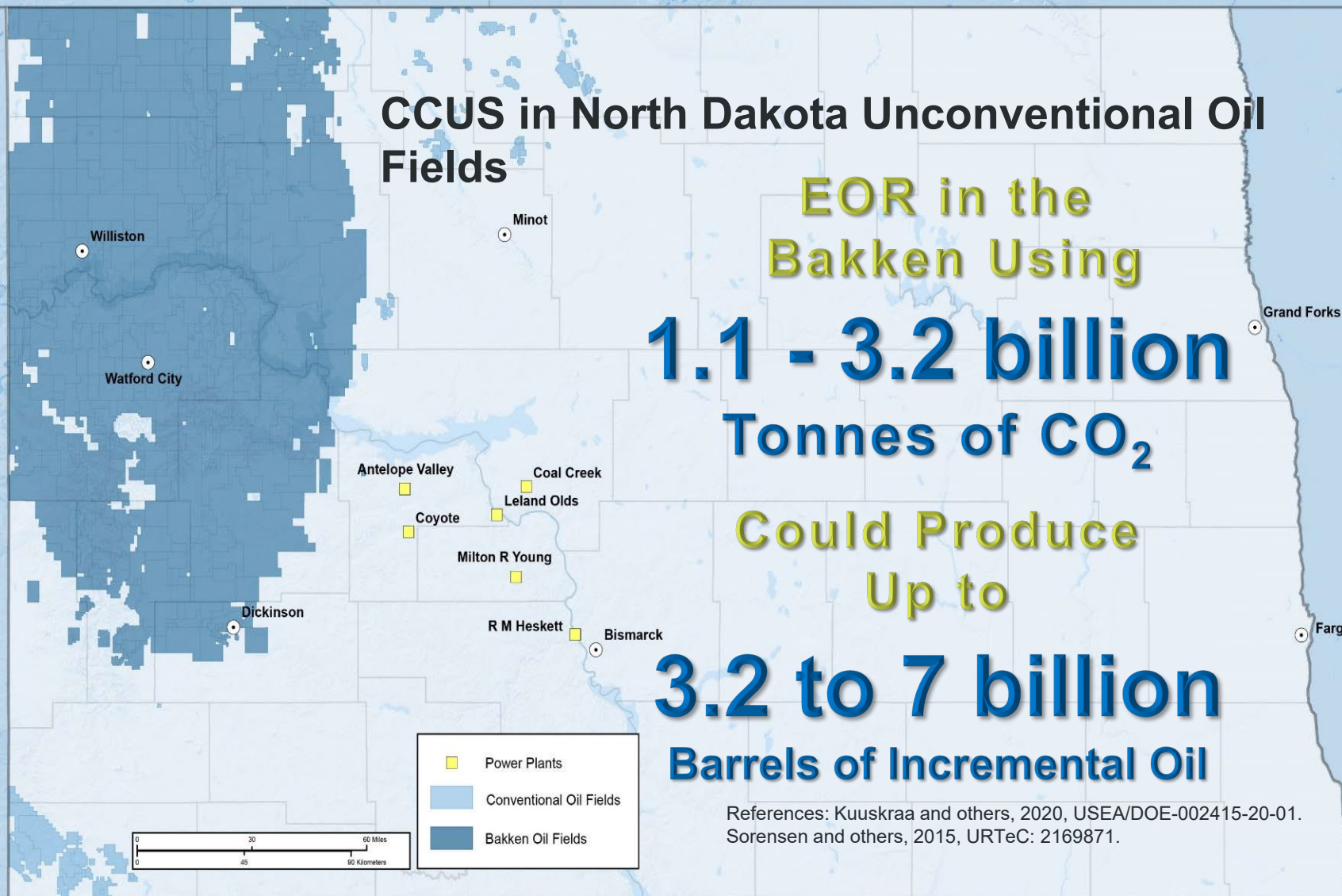
EOR in the  
Bakken Using

1.1 - 3.2 billion  
Tonnes of CO<sub>2</sub>

Could Produce  
Up to

3.2 to 7 billion  
Barrels of Incremental Oil

References: Kuuskraa and others, 2020, USEA/DOE-002415-20-01.  
Sorensen and others, 2015, URTeC: 2169871.



# North Dakota Carbon Solutions Needs

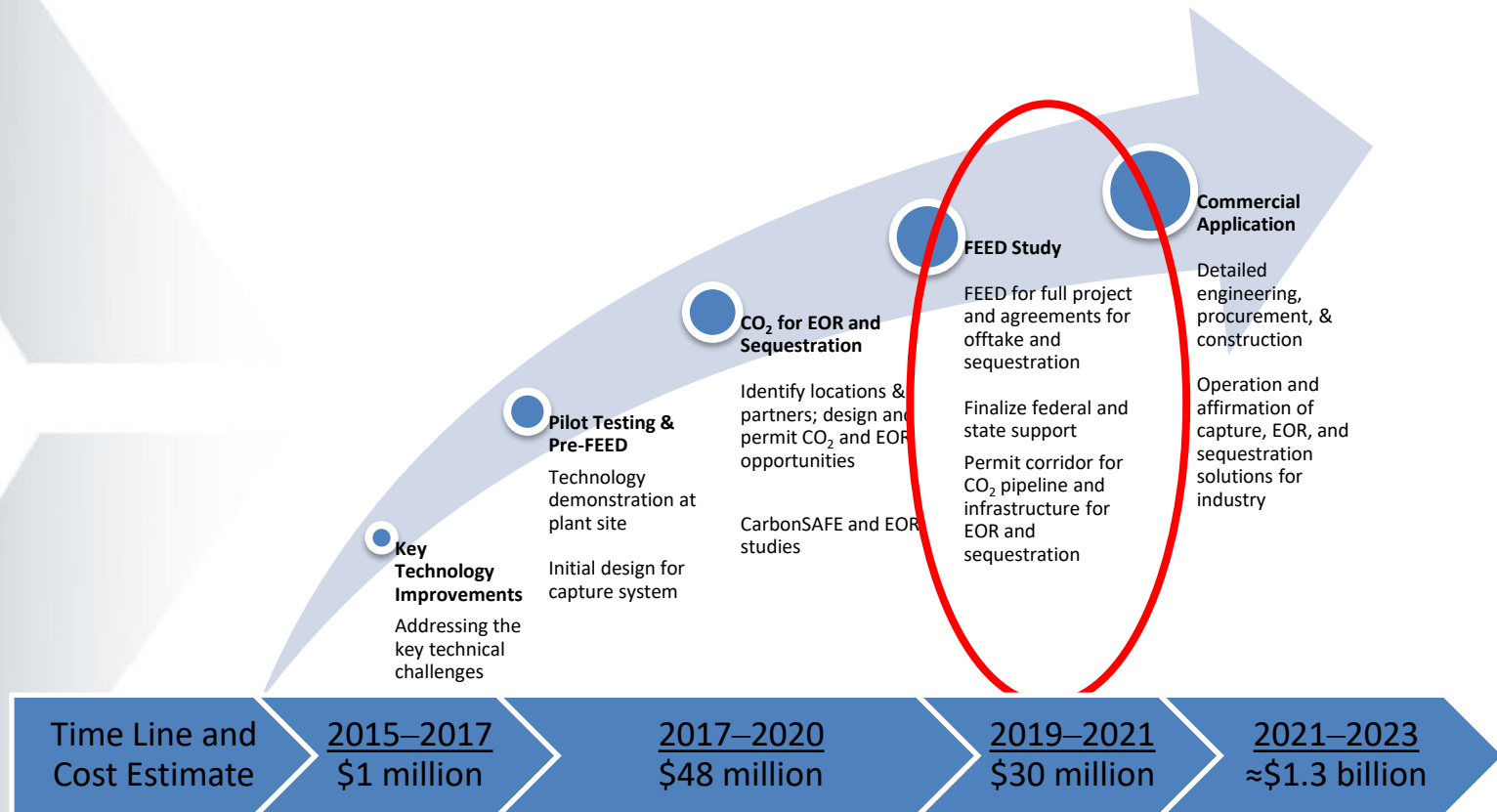


# Project Carbon Overview



- Project Carbon lays a solid foundation for Project Tundra.
- Testing of MHI solvent technology at MRY2.
  - Parametric
  - Long term
  - Solution for aerosol emissions
- Economics of CO<sub>2</sub> capture in North Dakota.
  - Cost of capture evaluation specific to MRY
  - Reducing parasitic load
  - Pre-FEED cost estimate for MRY2

# Project Tundra Road Map



# Carbonsafe - North Dakota integrated carbon storage complex feasibility study



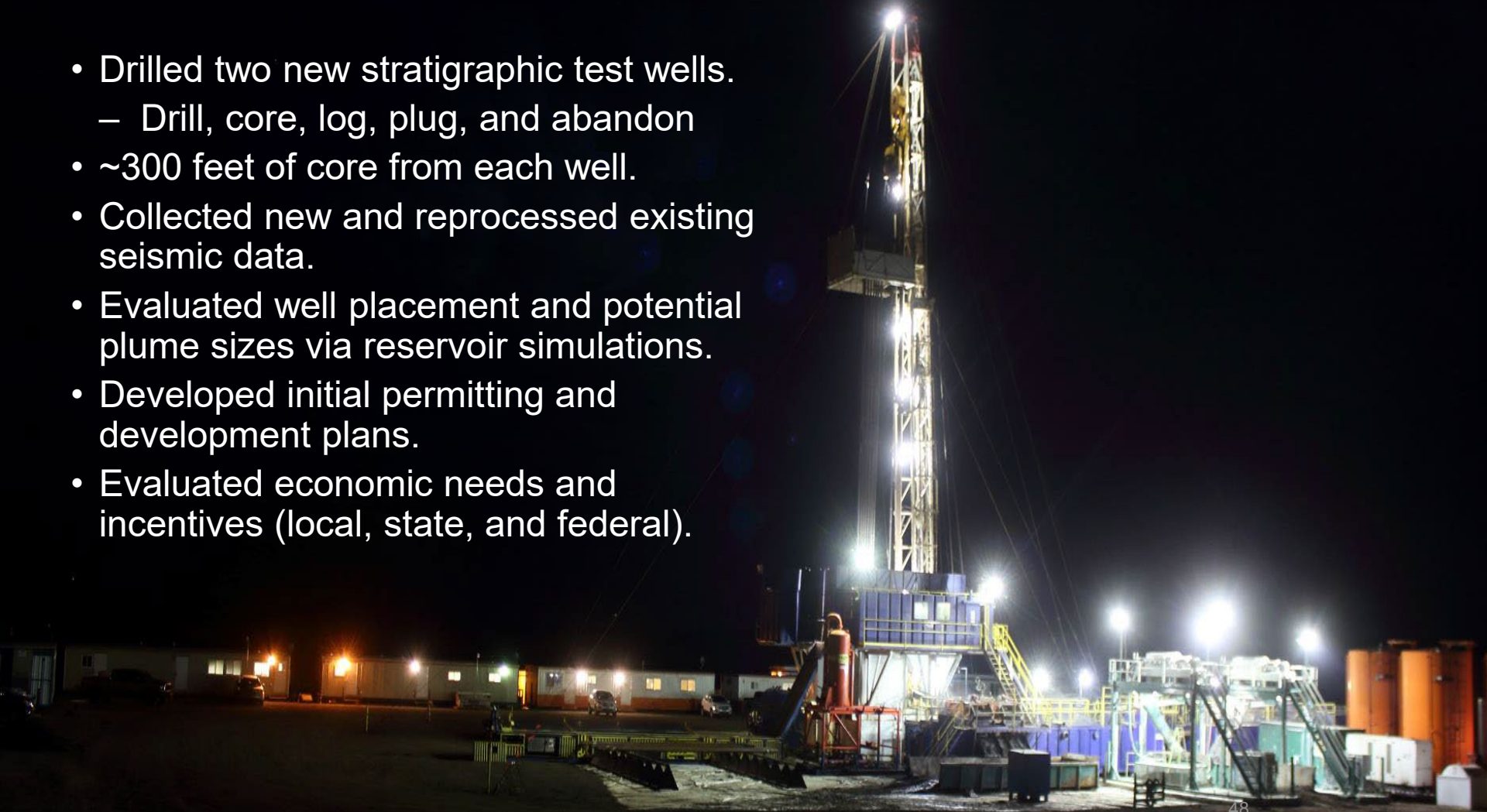
INDUSTRIAL COMMISSION OF NORTH DAKOTA  
LIGNITE RESEARCH COUNCIL

- Address technical and nontechnical challenges specific to commercial-scale deployment of a CO<sub>2</sub> storage project in central North Dakota.
- Long-term goal: develop a certified (permitted) geologic storage opportunity should a business case for CO<sub>2</sub> storage emerge.



# Major accomplishments

- Drilled two new stratigraphic test wells.
  - Drill, core, log, plug, and abandon
- ~300 feet of core from each well.
- Collected new and reprocessed existing seismic data.
- Evaluated well placement and potential plume sizes via reservoir simulations.
- Developed initial permitting and development plans.
- Evaluated economic needs and incentives (local, state, and federal).



# Carbon Management Initiatives

- Plains Carbon Dioxide Reduction Partnership (PCOR)
  - Phase I – Characterization of sources & sinks (2003-2005)
  - Phase II – Small-scale field validation tests (2005-2009)
  - Phase III – Large volume carbon storage test (2008-2017)



# Commercial Carbon Management

## Carbon Management

- SaskPower CO<sub>2</sub> capture & storage project
  - \$1.24 billion retrofit – repowering and carbon capture
  - Partnership: Gov. of Canada, Gov. of Sask., SaskPower & industry
  - Project at Boundary Dam - 150 MW Unit III (existing unit)
  - Designed to capture ~ 1 million tons CO<sub>2</sub> / year
  - Began operation in October 2014
- Petra Nova
  - 90 percent capture from 240 MW at Parish 8
  - Began commercial operation in January 2017
  - Driven by economics of enhanced oil recovery
  - Support from Texas and DOE



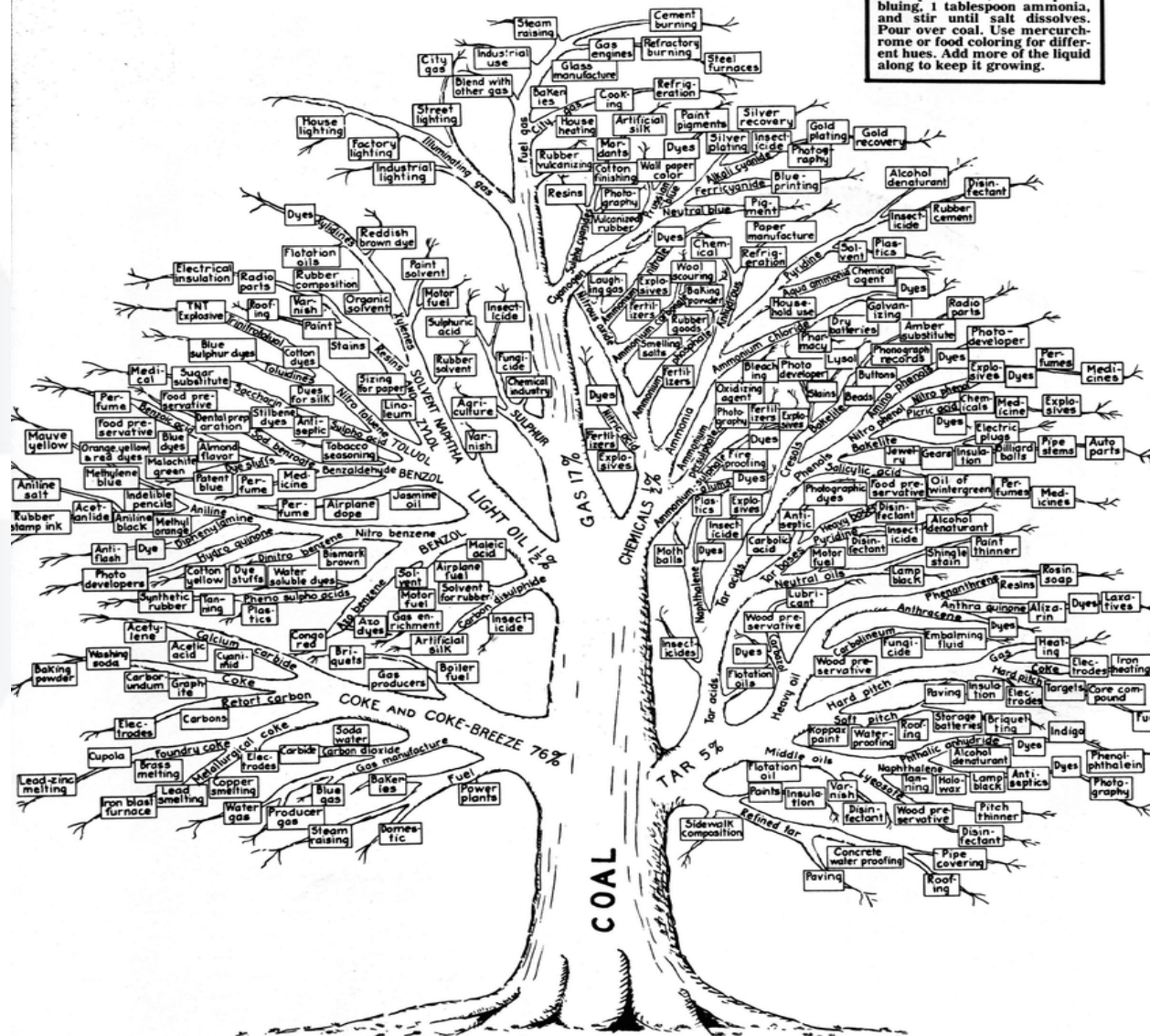
# Additional Value Opportunities for Lignite

- Diverse Product Opportunities
- Rare Earth Elements from Lignite

Showing the products obtainable from coal by carbonization in the modern by-product coke oven

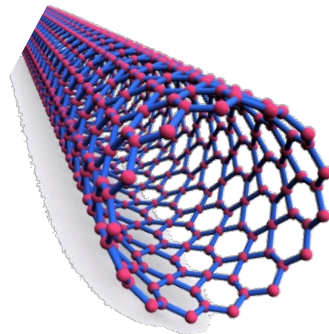
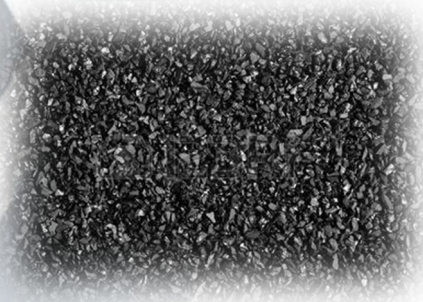
Showing the products obtainable from coal by carbonization in the modern by-product coke oven

**Depression Flower**  
Arrange coal in a bowl or flat dish. Mix 6 tablespoons water, 6 tablespoons salt, 6 tablespoons bluing, 1 tablespoon ammonia, and stir until salt dissolves. Pour over coal. Use mercurchrome or food coloring for different hues. Add more of the liquid along to keep it growing.



COMPLIMENTS OF

# Carbon Based Products



- Activated Carbon
  - Facility in final design stages in Valley City, North Dakota
- Carbon Black
  - Semi-continuous pilot unit at the EERC, proof-of-concept complete
- Carbon Fiber
  - Coal-derived pitch has unique properties
  - High value product with growing market
- Carbon Nanotubes and graphite
  - High value product with growing markets

# Coal Gasification for Fuels, Chemicals and Hydrogen

Lignite



Syngas  
 $\text{CO}_2$   
Heat



Direct or Indirect  
Liquefaction



Liquid Fuels and Additives

Gasoline  
Jet Fuel  
Diesel



EOR

Nitrogen Fertilizers



Chemicals



Electricity



# High Value Material Extraction (Rare Earth Elements)

- Pioneering work by the North Dakota Geologic Survey has led to a number of funded projects investigating recovery of high value materials from coal and byproducts:
  - Characterization study of coal and byproducts across North America
  - Rare earth element extraction from ND lignite
  - Rare earth element extraction from coal combustion byproducts
- Technology development is needed to optimize and improve economics of processes that extract and concentrate rare earth elements and other high value minerals.

1 H																	2 He	
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne	
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar	
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr	
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe	
55 Cs	56 Ba	57-71 Lanthanides		72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89-103 Actinides		104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Uub	113 Uut	114 Uuq	115 Uup	116 Uuh	117 Uus	118 Uuo
Lanthanides		57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu		
Actinides		89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr		

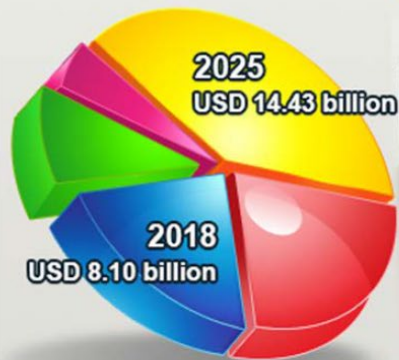
# High-value REEs and other critical metals identified by the U.S. Interior Department as “...vital to the Nation’s security and economic prosperity.”

According to the USGS 2021 Mineral Commodity Summary report, the U.S. is 100% import-reliant on REEs and other critical metals, with the bulk of imports coming from China. Chinese dominance in the REE market is due in large part to possession of a unique mineable clay resource that contains high concentrations of REEs in the form of adsorbed ions, making their extraction and refining simple and cheap versus most other REE resources. Because these REE-rich clay reserves are projected to run out in about 15 years, building a domestic REE mining, concentration, and refining industry is critically important to U.S. technology leadership, manufacturing industries, and defense.

Numerous North Dakota lignite seams contain REEs in concentrations exceeding 300 parts per million (ppm), the USGS-established threshold for an economically significant REE resource. North Dakota lignites also contain economically significant concentrations of other critical minerals including Co, Ga, Ge, and Ta. Many lignite-contained REEs and other metals are chemically bound in ways that make their extraction simpler and cheaper than extraction from traditional U.S. ore resources.

## Global Rare Earth Metals Market

Compound Annual Growth Rate **8.6%**  
(2019-2025)



➤ REEs make possible \$7 trillion in value-added products globally.

# Semplastics EHC LLC



Systematically  
Applied Research to  
Develop High Value  
Products from Coal

Artist's conception of coal building proof-of-concept design by CART



# Leonardite

Leonardite is an oxidized form of lignite, rich in humic acid.

- Existing agricultural uses
  - soil conditioner to improve moisture retention and reduce toxins
  - Animal feed additive, source of trace minerals
- Growing market in oil field fluids
  - Leonardite is used as an additive in water-based drilling fluids
- Global humic acid market was \$325.6MM in 2014 (Leonardite Production, LLC)

# Resource Recovery from a Coal Fired Power Plant to Enhance Agricultural Production in Open Field and Greenhouse Facilities

## Plant Integration:

- Waste heat used for greenhouse heating demands
- CO<sub>2</sub> & Flue gas used to enhance plant growth
- Plant water / condensate can supplement irrigation



## Updates:

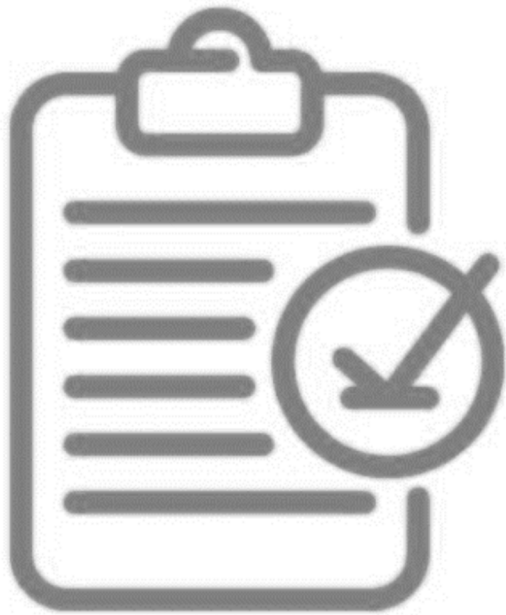
- First planting cycle complete (data analysis ongoing)
- Low and intermediate concentrations of CO<sub>2</sub> improved plant growth and highest level was antagonistic
- Second planting cycle to include varied levels of CO<sub>2</sub>





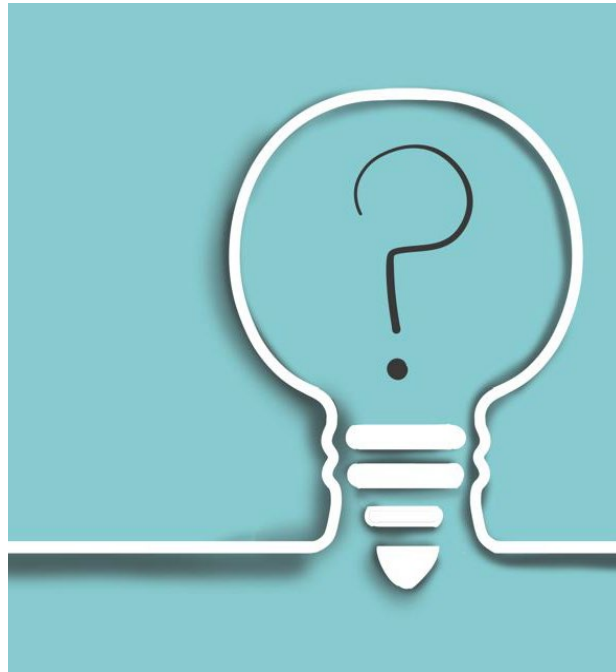
**Advanced Reclamation Strategies  
for North Dakota coal mine lands**

# Summary



- U.S. needs more sources of energy & needs to lessen dependence on foreign sources
- Lignite is a valuable source of energy & chemical products
- R&D is critical in the wise use of this abundant resource

# Questions??



# Thanks for Listening!

