
December 7, 2021



WYOMING
ENERGY
AUTHORITY

Wyoming Energy Strategy and CCUS Status

Midland CO₂ Conference

Dr. Glen Murrell

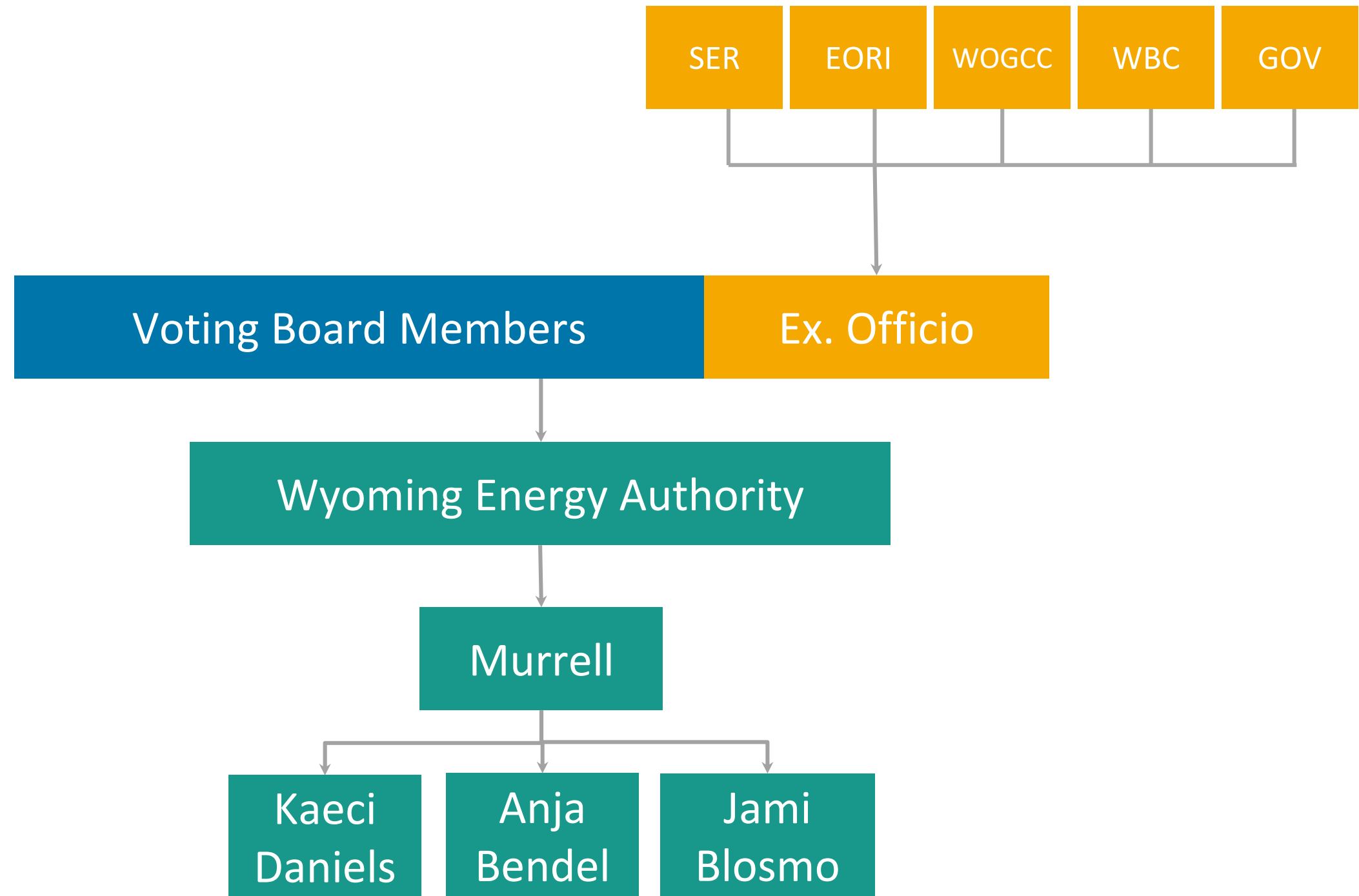
WEA

VISION

WEA advances Wyoming's energy strategy by driving data, technology, and infrastructure investments.

MISSION

WEA supports and promotes Wyoming's energy sector by implementing the state's energy strategy; delivering positive economic impact and jobs for Wyoming, fostering an environment for the sustainability and growth of Wyoming's economy, and ensuring Wyoming continues to power the nation.



Core Activities



Advocacy

Using evidence based reasoning to determine and advocate for the optimal policy, technology and economic solution.

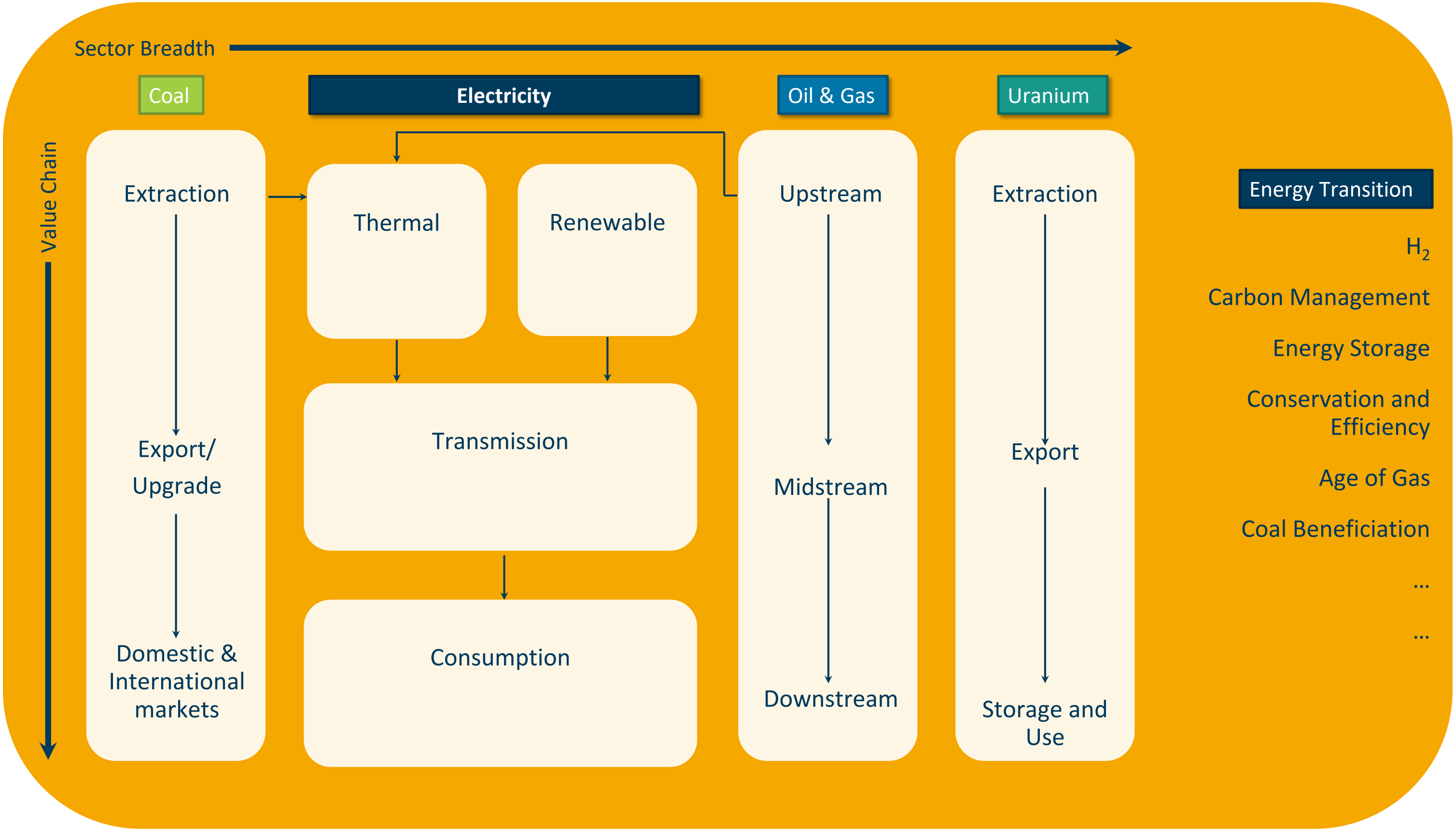
Coordination

Providing a framework for cohesive and coordinated development efforts.

Promotion

Informing and educating the public and key stakeholders on policy, technology and development opportunities

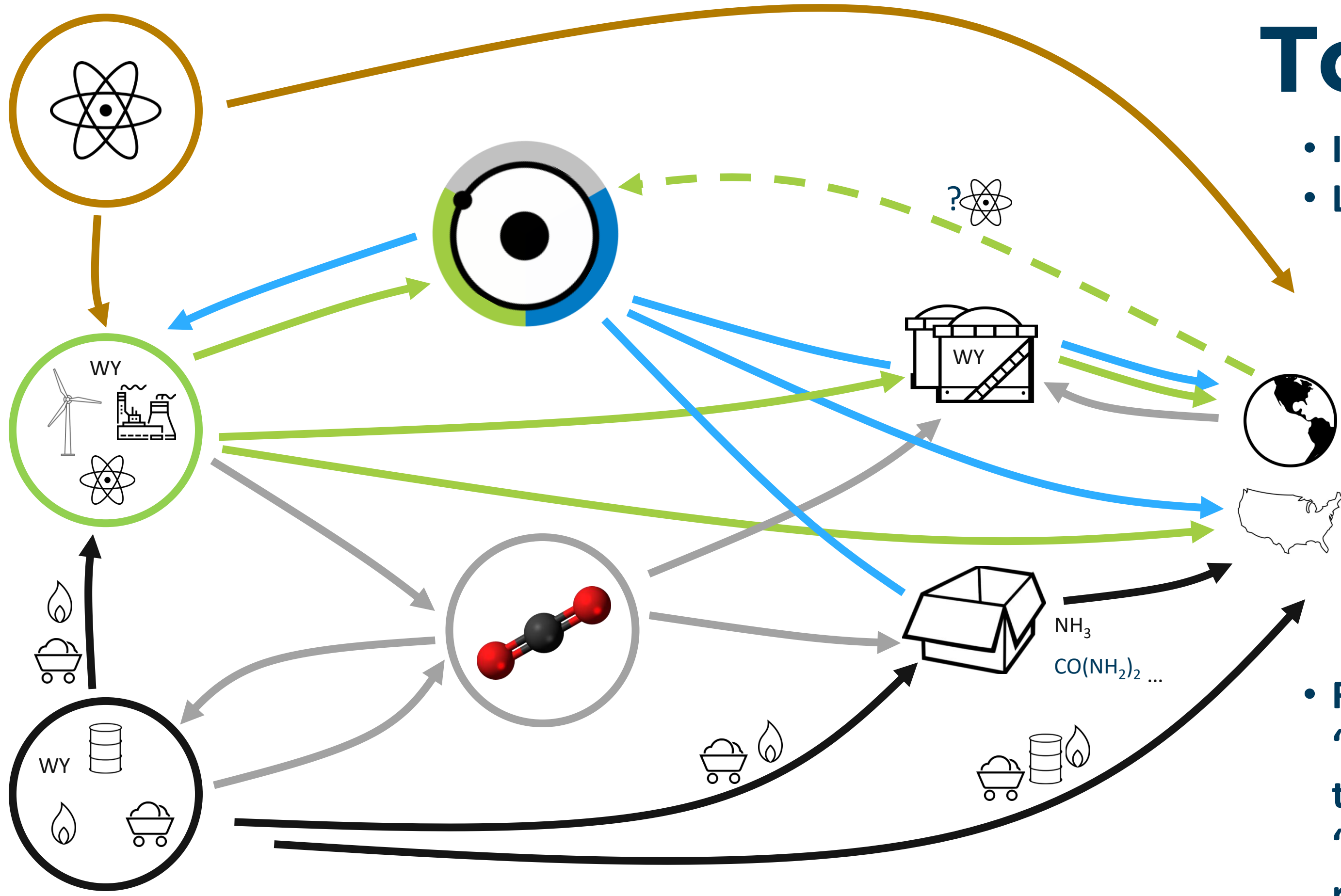
Scope



... plus, non-energy extractives, like Trona, Bentonite, precious metals....

Tomorrow?

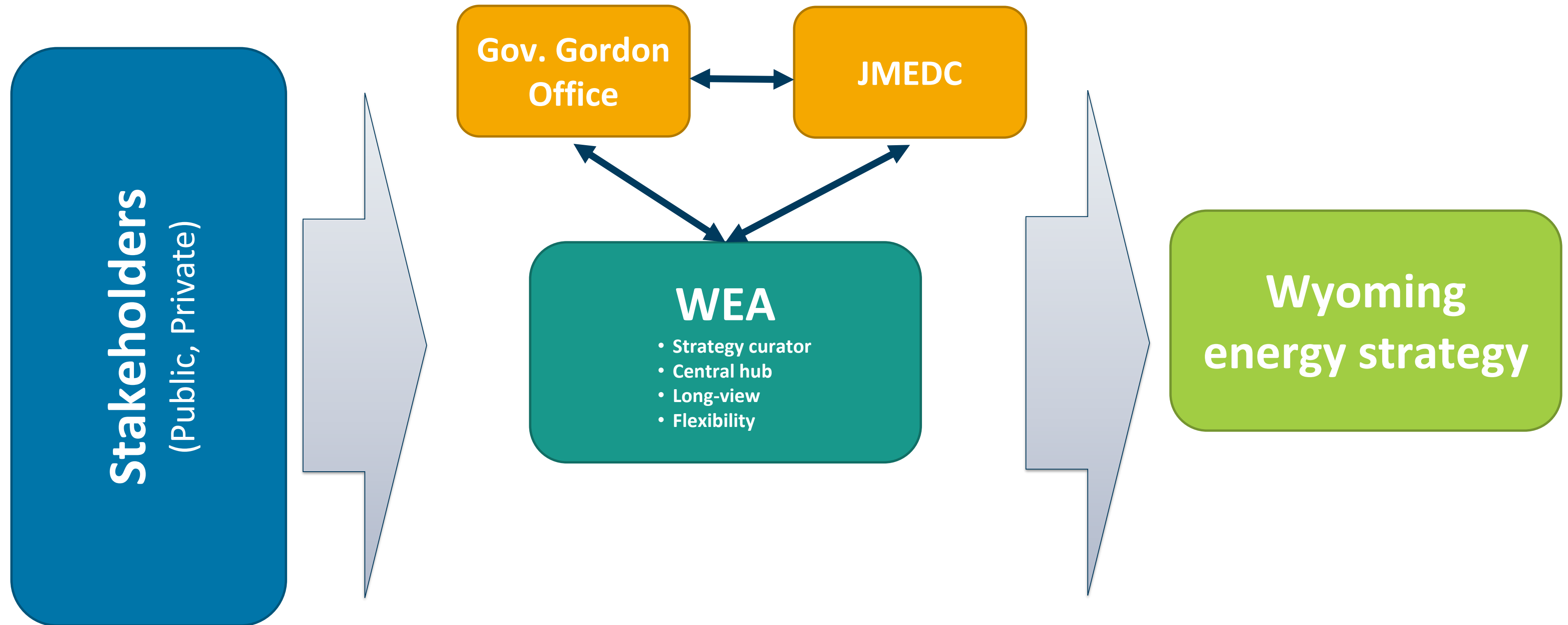
- Integrated energy economy
- Low-carbon intensity



- From: 'extract-transport-consume', to 'extract-upgrade-store-reuse'

Wyoming Energy Strategy

"...develop, administer, update and communicate the Wyoming energy strategy."



Wyoming Energy Strategy



Wyoming Energy

- **7,717 trillion BTU (~\$14.5B in product value) in 2018**
- **3rd largest producer in USA. If Wyoming were a country it would be ~13th largest, and roughly equivalent to Norway, Kazakhstan or the U.A.E.**
- **Coal @ \$12t is cheaper than dirt: 40lb of top soil is \$1.78 (~7.5X value)**
- **Oil @ \$35bbl is cheaper than water: 1 Gallon of water is ~\$1 (~\$42 bbl)**
 - *Constituent product value (e.g. gasoline, diesel, jet fuel,...) is ~\$80bbl*
- **Gas @ \$2Mcf is cheaper than air: 80 cf tank refill ~\$5 (~30X value)**
- **Electricity @ 10c/KWh is simply darn cheap: \$1 worth of electricity could boil a kettle of water 50 times**

ABUNDANCE = CHOICE

...and people are choosing low-emissions energy

...and their Governments are responding

Our North Star

EMPOWERING OUR NATION WITH A NET-ZERO ENERGY MIX

“...today, I challenge you to join me in making Wyoming net negative in CO₂ emissions. We have to take the lead, and not look back..... ,

*As we actively and thoughtfully collaborate with industry environmental groups, entrepreneurs, local communities, and others to produce our way to net negative carbon emissions, literally. Not by regulating away our past, **but by innovating our way to the future.**”*

- Gov. Gordon, State of the State address, March, 2, 2021

Strategic Opportunities

Heritage Projects



**CCUS deployment +
decarbonized products**
Hydrogen + H₂ products
Demand creation
— *old and new markets*

Electrification



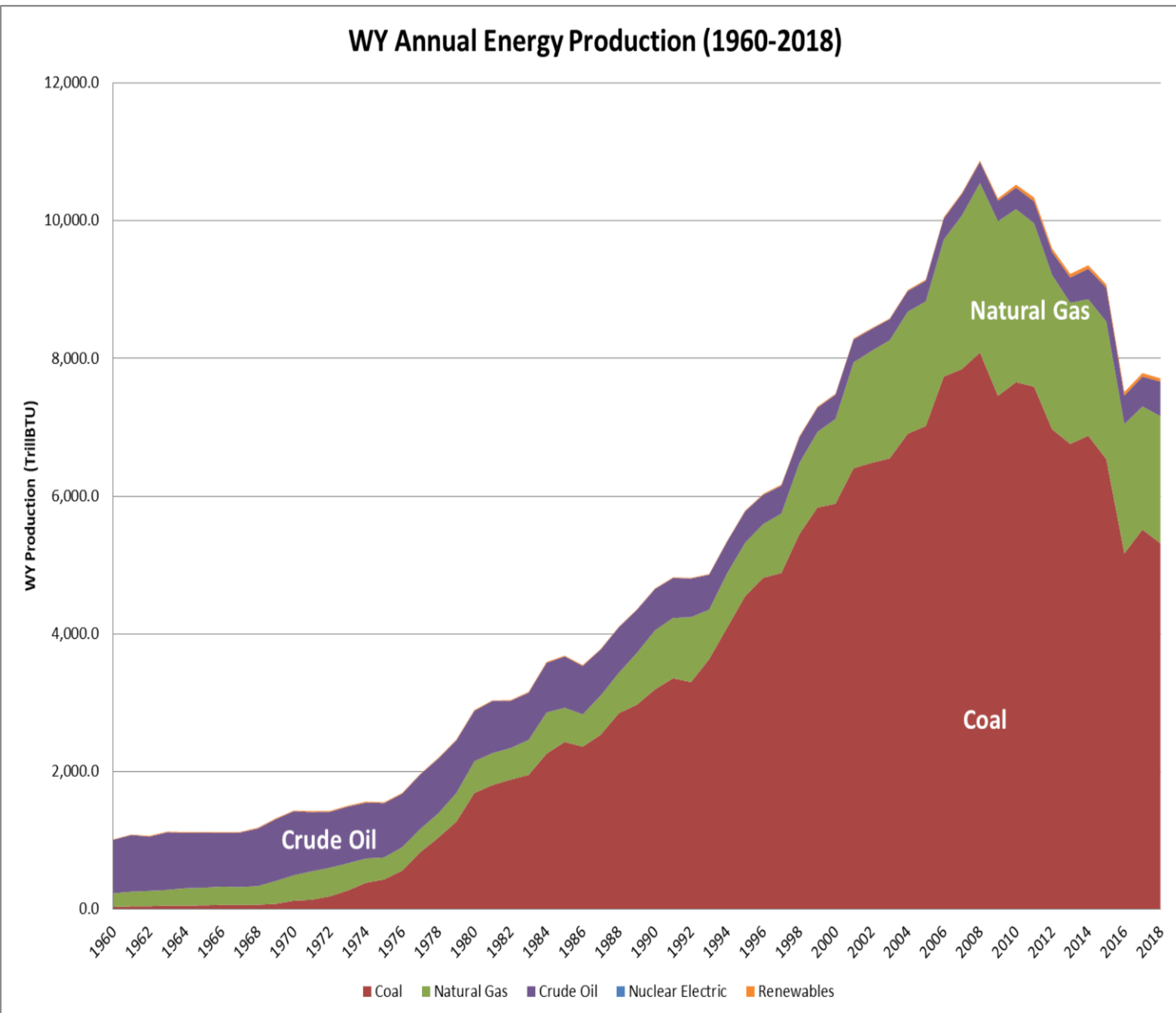
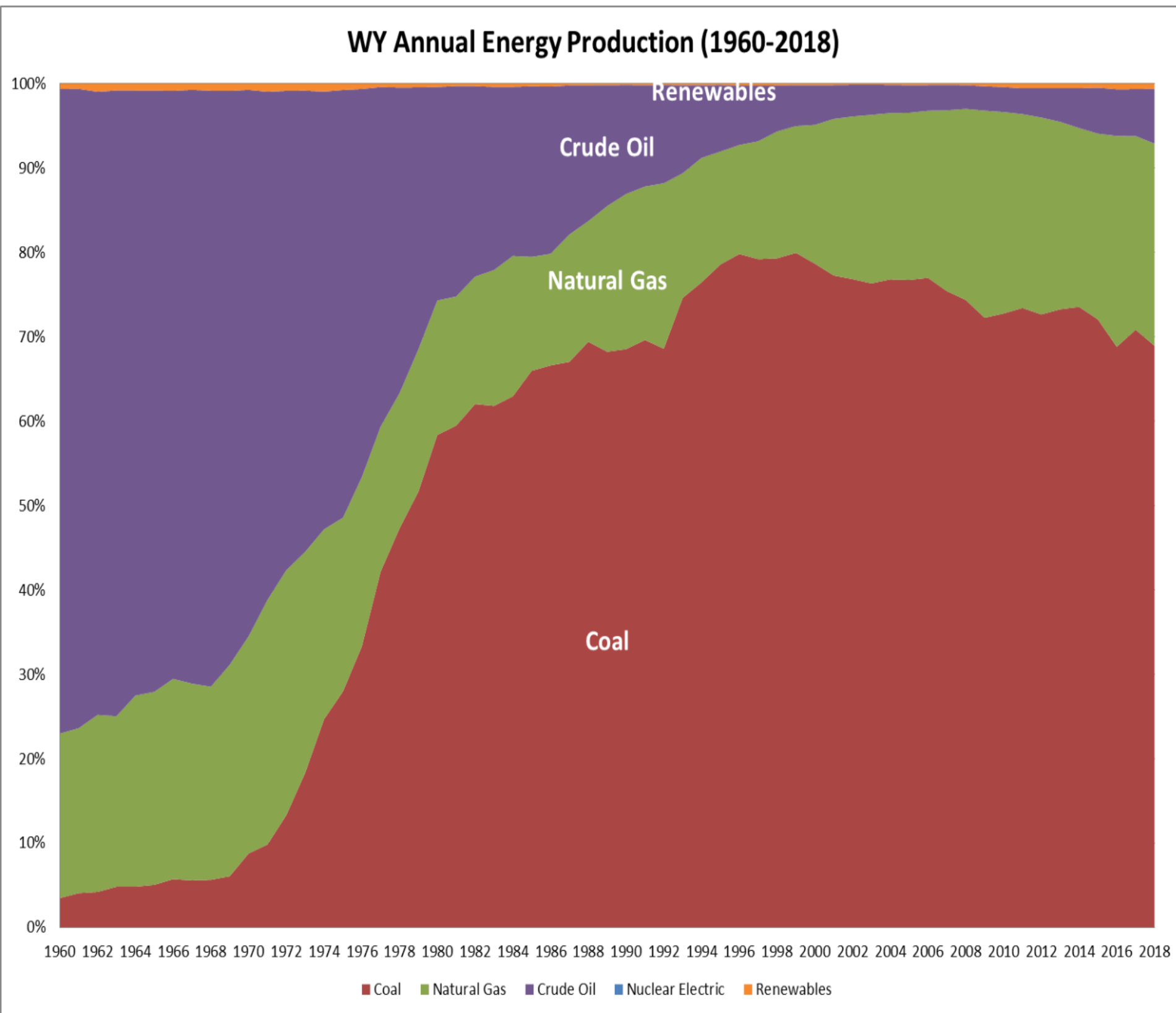
**Storage, transmission &
resiliency**
Value-added electricity
- *Green data centers, crypto mining,
Renewables based Direct Air Capture
(DAC)*
**Retail evolution — EV,
conservation/efficiency**
**Repurposed
Infrastructure**

Energy Evolution



Advanced nuclear tech
— *SMR, Thorium salt*
REE and CM
Carbon engineering
Non-linear value chains

The Challenge

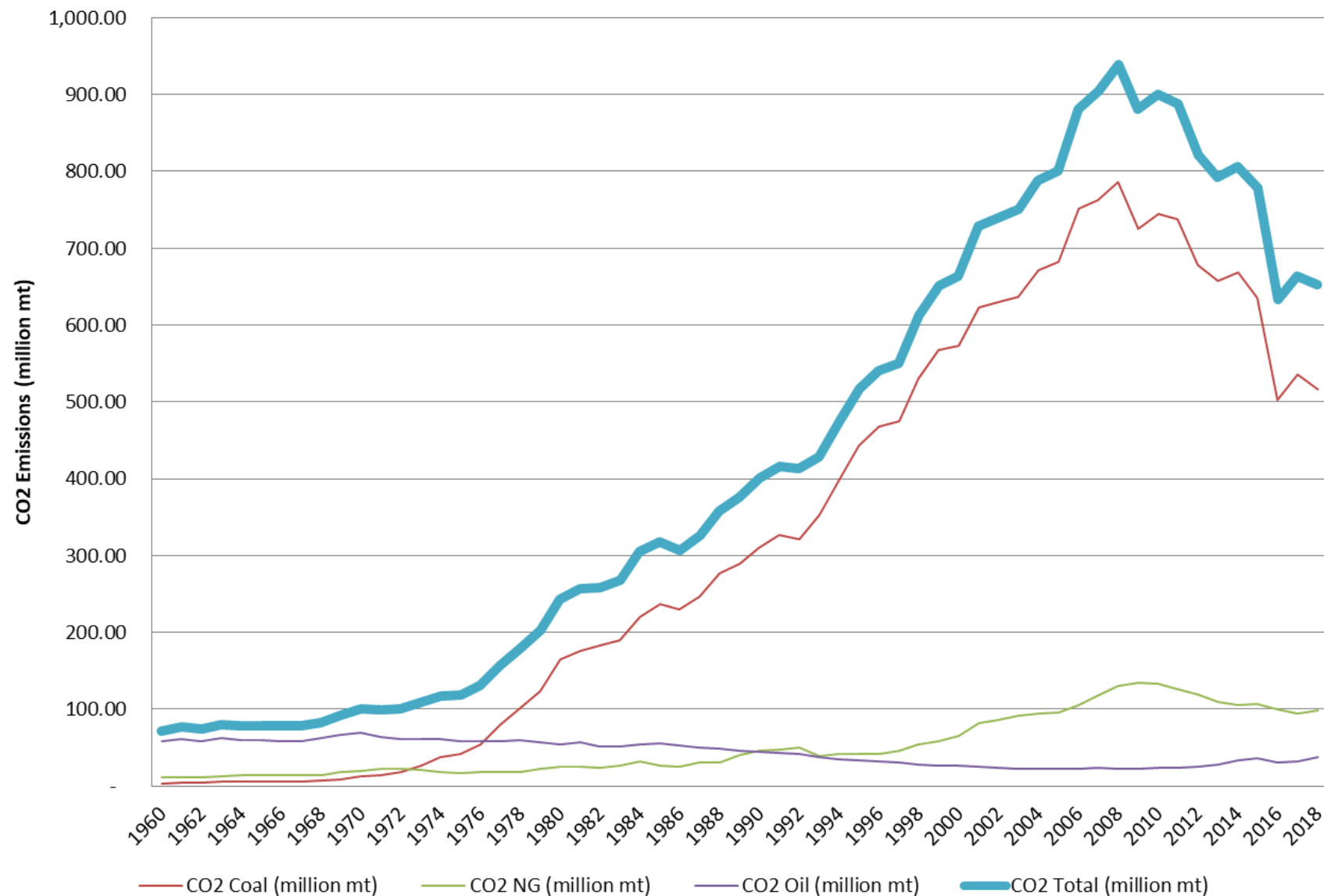


The Challenge

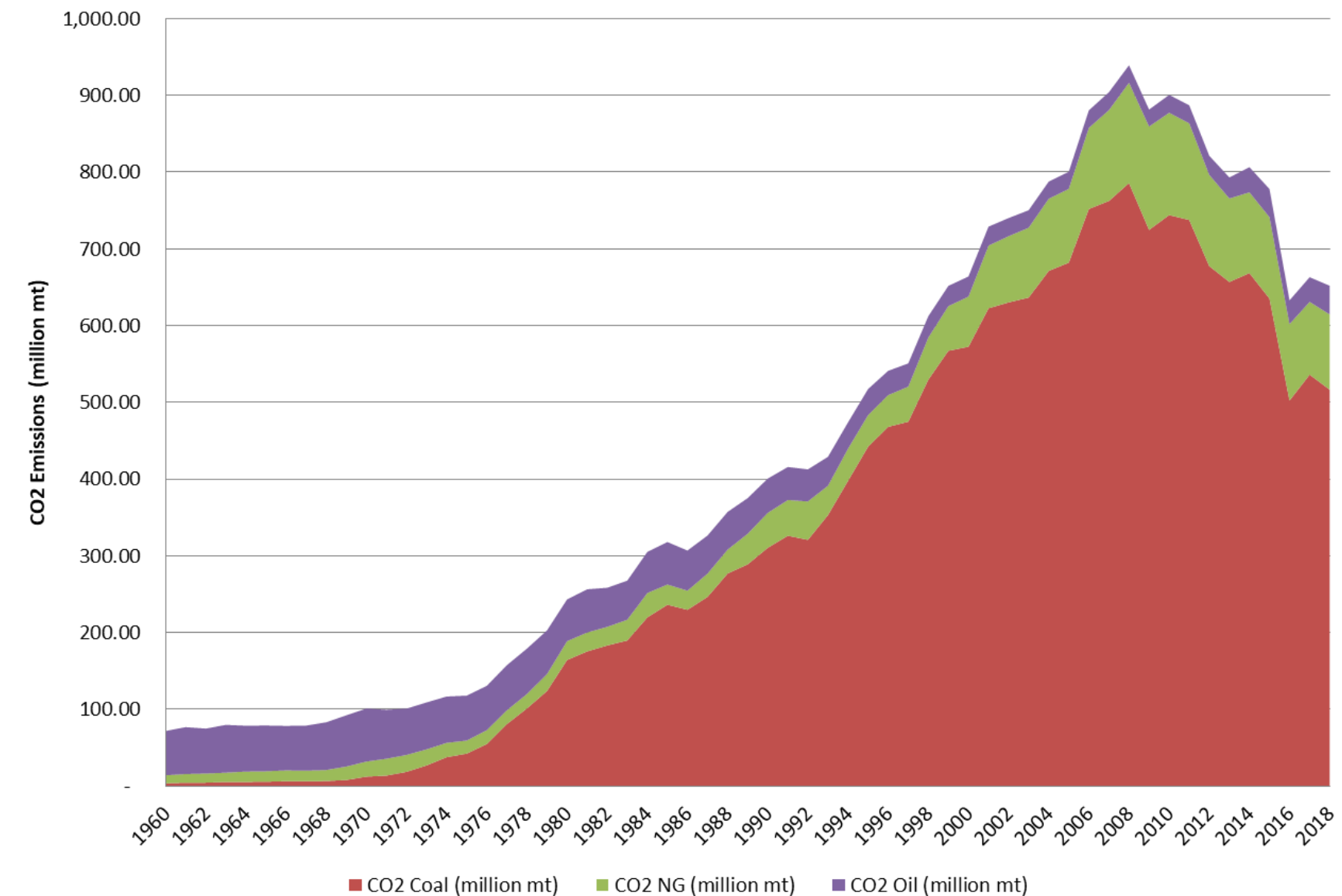
mt = metric ton

- WY's emissions are dominated by our Energy production. Internal (S1&2) CO₂ footprint ~90 mill. mt/yr (mostly due to electricity generation). Full (S1,2&3) emissions peaked in 2008 (940 mill. mt/yr), corresponding to peak in coal production. Has since declined 30% to **525 million mt in 2019**

WY Annual CO₂ Emissions (from Hydrocarbon sources)
(1960-2018)



WY Annual CO₂ Emissions (from Hydrocarbon sources)
(1960-2018)



Key Initiatives

Hydrogen

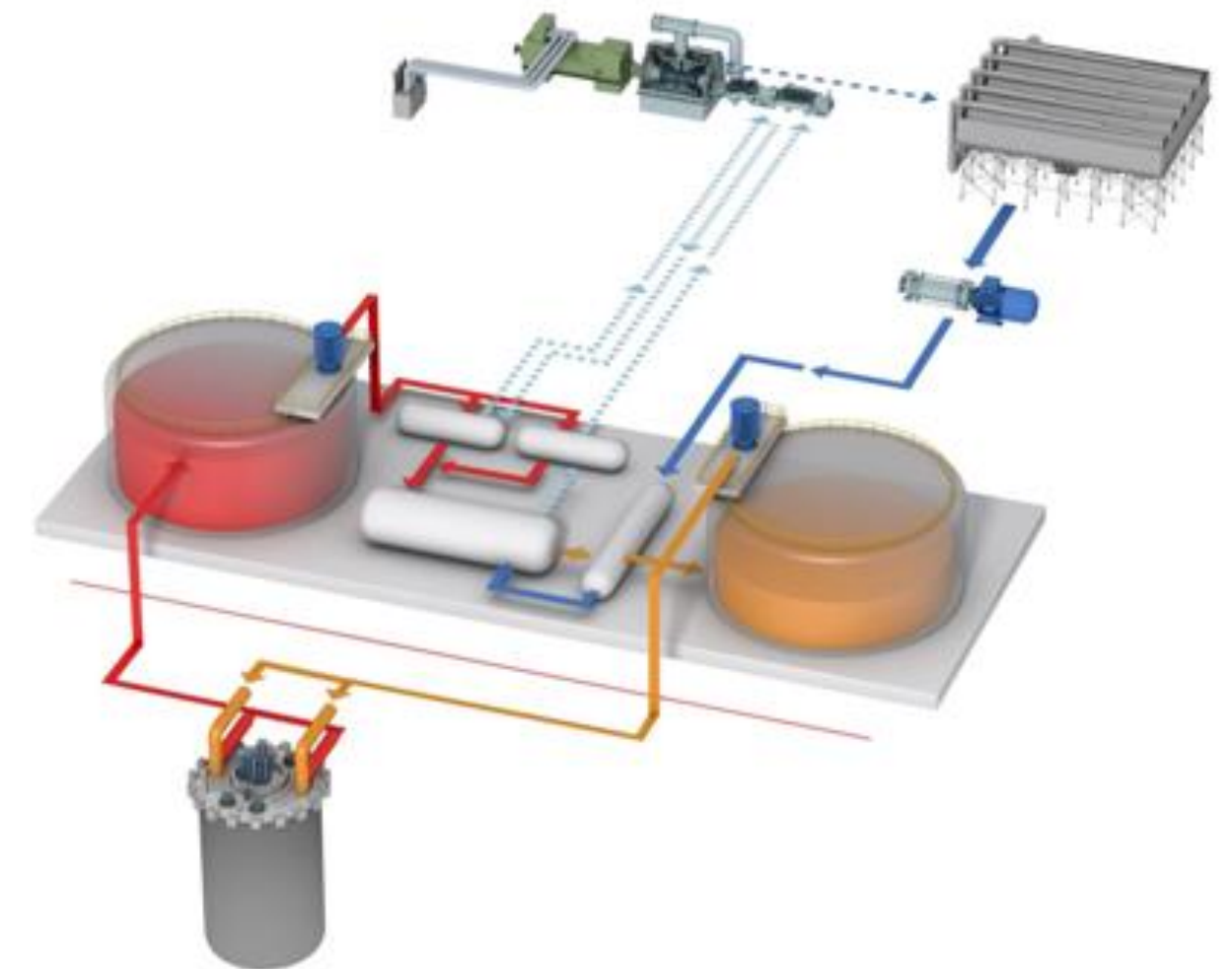
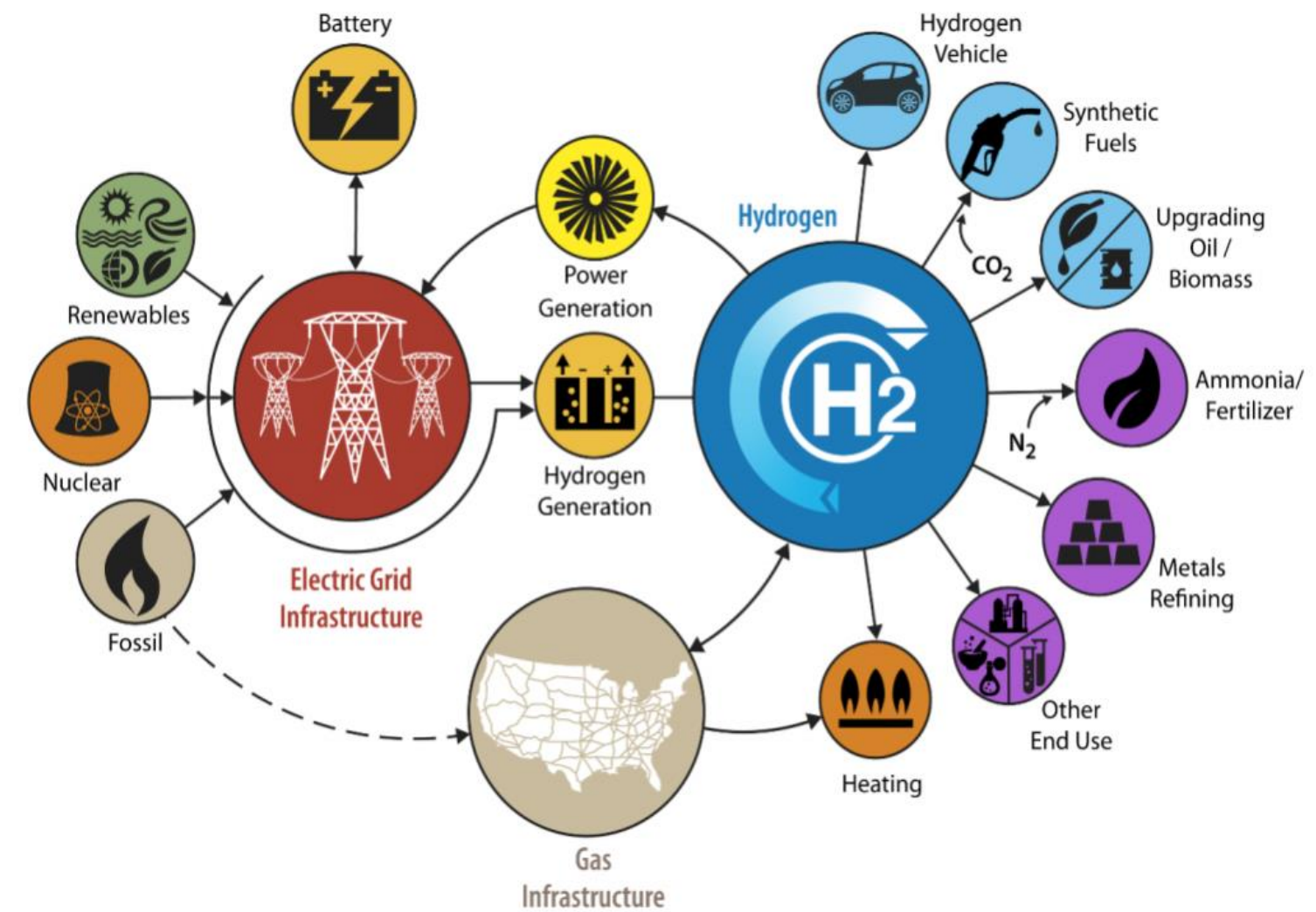
- SER COE
- WEA Hydrogen RFP

Sequestration

- Pre-permit Class VI wells
- Public/Private commercialization of CCUS

Advanced Nuclear

- Value-chain development
- Education



Why Sequestration?

- *Wyoming has an existing **CO₂ management infrastructure** already, which could be connected up to other CO2 pipeline systems*
- *Wyoming has abundant **reservoir storage capacity***
- *Wyoming has **Class VI primacy***
- *Wyoming established a strategic **pipeline corridor initiative***
- *It has a head start on many **policy reqs.***
- *It benefits **ALL CO2 emission sources** including H2*
- *It would remove a great deal of uncertainty, liability and CAPEX from any emitters consideration*

Why Hydrogen?

- *Wyoming has the greatest abundance of natural feedstock for Hydrogen production in the country (NG, Coal, Renewables)*
- *Its geographical location is favorable*
- *It has all the ancillary export infrastructure in place*
- *It has an existing substantial CO₂ management infrastructure already*
- *It has an existing Hydrogen manufacturing industry*
- *It has a head start on many policy needs*
- *It aligns with the Wyoming Energy Strategy and other economic initiatives in the state – “All-of-the-above”, “Net-Zero”, “Value-added”, “energy and economic diversification”, “innovate to the future”*

Hydrogen Energy Earthshot

“Hydrogen Shot”

“1 1 1”

\$1 for 1 kg clean hydrogen
in 1 decade

Launched June 7, 2021



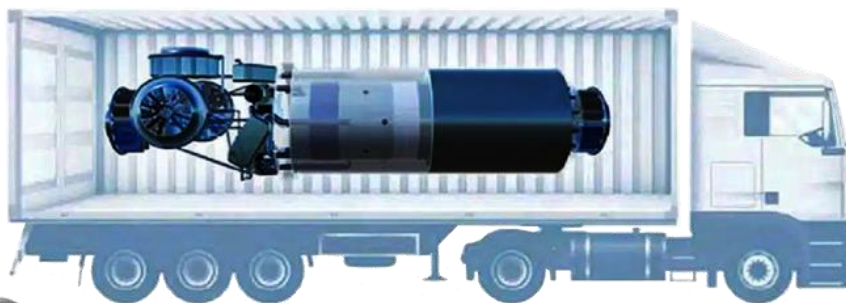
Why Advanced Nuclear?

- *Wyoming will host new TerraPower Sodium demonstration reactor*
- *Wyoming has long-standing Uranium mining history and established ancillary energy infrastructure (transmission)*
- *Wyoming has considerable existing logistic and supply chain presence*
- *Integrates well with low-emissions energy economy*
- *Potential to provide niche solutions to industrial energy/emissions challenges*
- *It aligns with the Wyoming Energy Strategy and other economic initiatives in the state – “All-of-the-above”, “Net-Zero”, “Value-added”, “energy and economic diversification”, “innovate to the future”*

Nuclear Reactor Demonstration Timeline



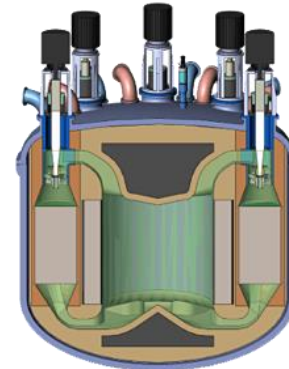
MARVEL DOE
2022-2023



Project Pele Microreactor DoD
2023-2024



DOME Test Bed NRIC
2023-2024



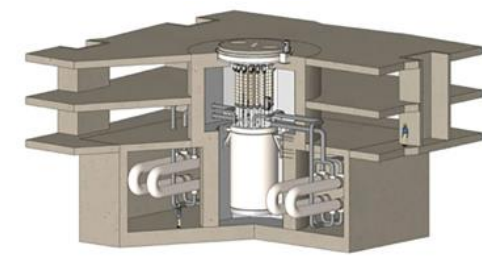
MCRE Southern Co. & TerraPower
2025



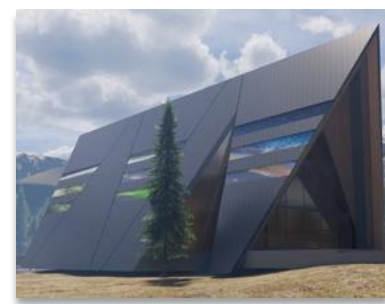
LOTUS Test Bed NRIC
2024



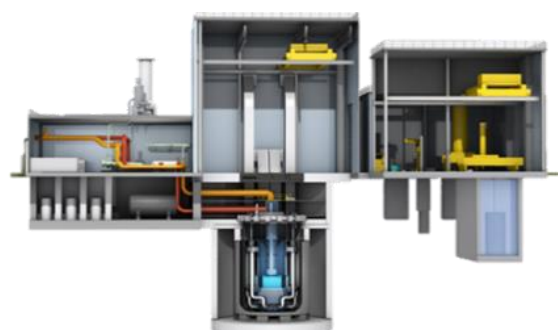
NRIC National Reactor Innovation Center



Hermes Kairos
2026

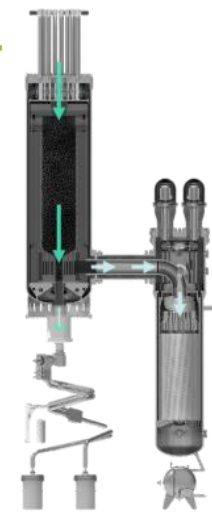


Aurora Oklo Inc. TBD



Sodium Reactor TerraPower & General Electric
2028

Xe-100 X-energy
2027



SMR UAMPS & NuScale
2029



2030

Business Sensitive

IDAHO NATIONAL LABORATORY

Advanced Reactor Technologies

- Enhanced passive safety
- Versatile applications due to range of sizes and ability to integrate with future energy needs
- Reduced cost by enabling factory fabrication
- Based on decades of research and development at DOE national laboratories

SIZES

SMALL

1 MW to 20 MW

Micro-reactors

*Can fit on a flatbed truck.
Mobile. Deployable.*

MEDIUM

20 MW to 300 MW

Small Modular Reactors

Factory-built. Can be scaled up by adding more units.

LARGE

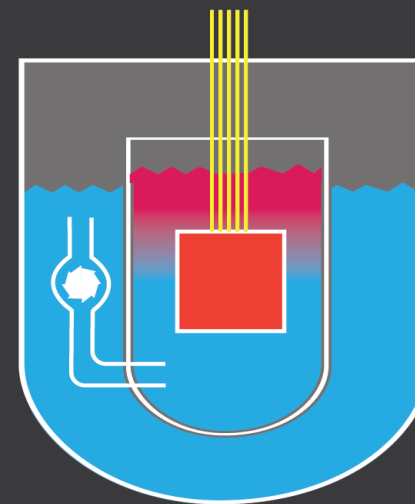
300 MW to 1,000 + MW

Full-size Reactors

Can provide reliable, emissions-free baseload power

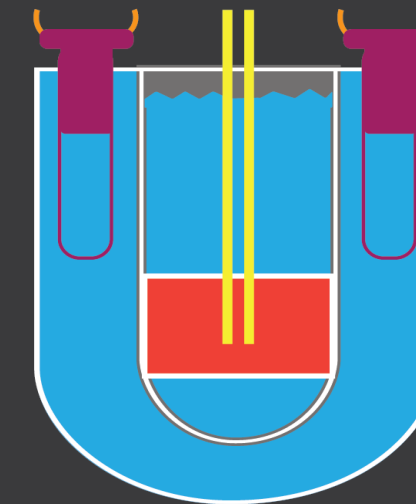
Advanced Reactors Supported by the U.S. Department of Energy

TYPES



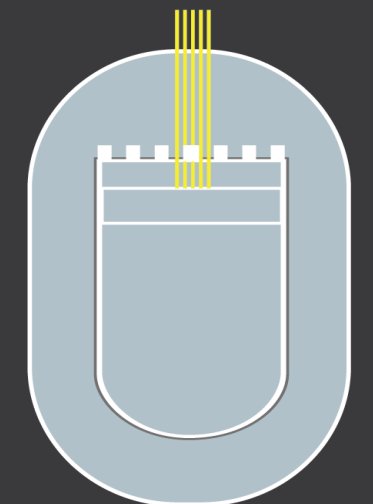
MOLTEN SALT REACTORS –

Use molten fluoride or chloride salts as a coolant. Online fuel processing. Can re-use and consume spent fuel from other reactors.



LIQUID METAL FAST REACTORS -

Use liquid metal (sodium or lead) as a coolant. Operate at higher temperatures and lower pressures. Can re-use and consume spent fuel from other reactors.

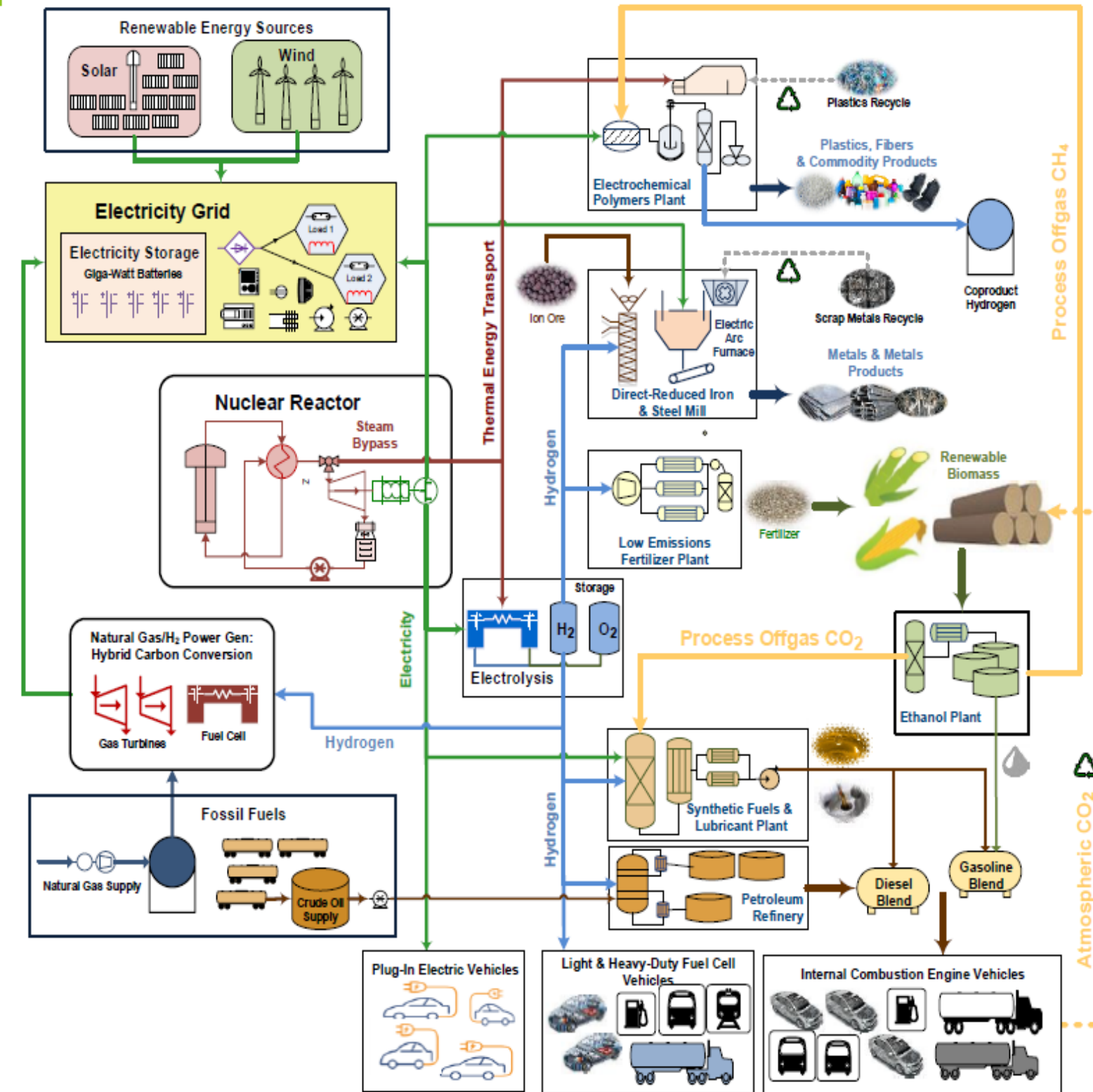


GAS-COOLED REACTORS –

Use flowing gas as a coolant. Operate at high temperatures to efficiently produce heat for electric and non-electric applications.

There is a role for nuclear with coal, natural gas, and wind & solar in Wyoming

- **Clean Power- East and West**
 - Zero-emissions fossil fuels
 - Wind
 - Nuclear
 - Energy Storage for Power Arbitrage
- **Carbon Conversion to High Value Product**
 - Natural Gas to Polymers and Hydrogen
 - Coal to carbon materials and rare-earths
 - Iron ore reduction and steel production
 - Minerals Processing
 - Fertilizers
 - Hydrogen for transportation systems
 - Hydrogen for emerging markets
 - Fabrication Shops



CCUS Status

Public Sector

CarbonSAFE

Integrated Test Center - MTR

Pipeline Corridor Initiative

Class VI Primacy¹

ARP Capture Project (\$200m)

ARP Sequestration Hub (\$25m)

WEA CCUS RFP (\$10m)

Sequestration as a Service

State assumption of long-term stewardship

State based accreditation framework

Private Sector

Rocky Mountain Power REOI

XOM Shute Creek

H2 + CCUS (6 projects)

Industrial Source CCUS

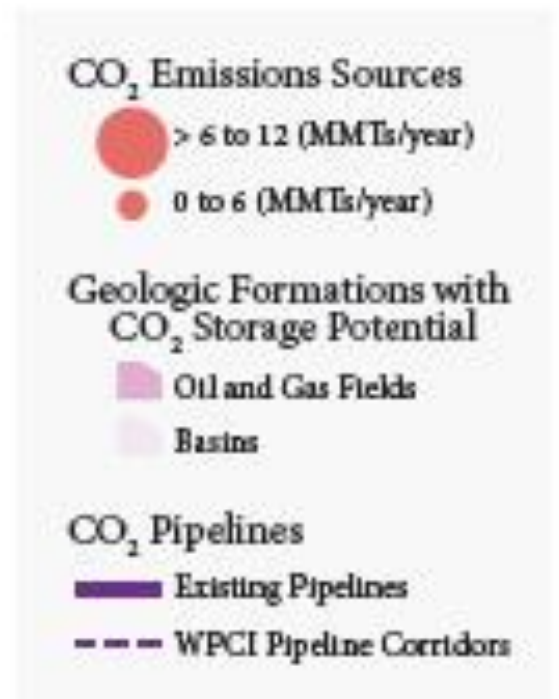
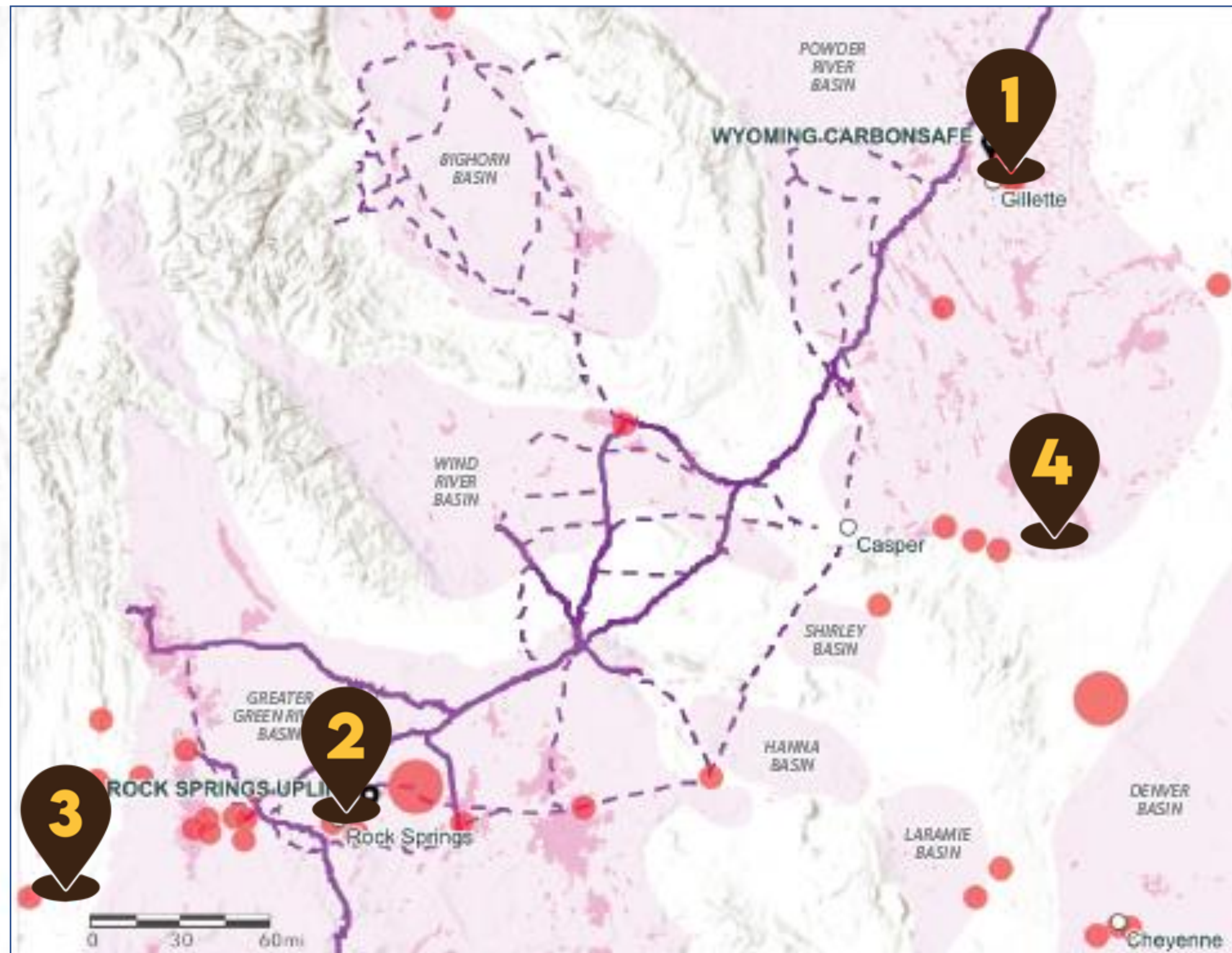
CO₂ Import + Sequestration

¹ First application submitted last week

UW Highlighted CCUS Projects

Carbon Capture and Storage (CCS) projects in Wyoming

1. Wyoming CarbonSAFE Project at Dry Fork Station
2. Rock Springs Uplift-Regional CCUS Hub
3. Depleted Gas Fields (Fold and Thrust)
4. Project Blue Bison (Blue Hydrogen)
5. Plains CO₂ Reduction Partnership (PCO₂R)-Regional effort



Wyoming CarbonSAFE: CO₂ Source and Capture

1. Wyoming:

- ✓ CCUS legal Framework
- ✓ Statewide CO₂ transportation network
- ✓ Class VI Primacy (pending)



**BASIN ELECTRIC
POWER COOPERATIVE**
A Touchstone Energy® Cooperative

2. Dry Fork Station:

- ✓ Built in 2007, on-line in 2011
- ✓ 385 MW Coal-fired plant
- ✓ 3.3 Million tons of CO₂/year
- ✓ Operating life span through 2070

3. Wyoming Integrated Test Center:

- ✓ Commercial-Scale Front-End Engineering Study for MTR's Membrane CO₂ Capture Process (DE-FE0031846)
- ✓ UKY-CAER Heat-Integrated Transformative CO₂ Capture Process for Pulverized Coal Power Plants (DE-FE0031583)
- ✓ Novel Next Generation Sorbent System for Post-Combustion CO₂ Capture – TDA Research, Inc. (DE-FE0031734)
- ✓ Kawasaki Heavy Industries and JCOAL novel solid technology



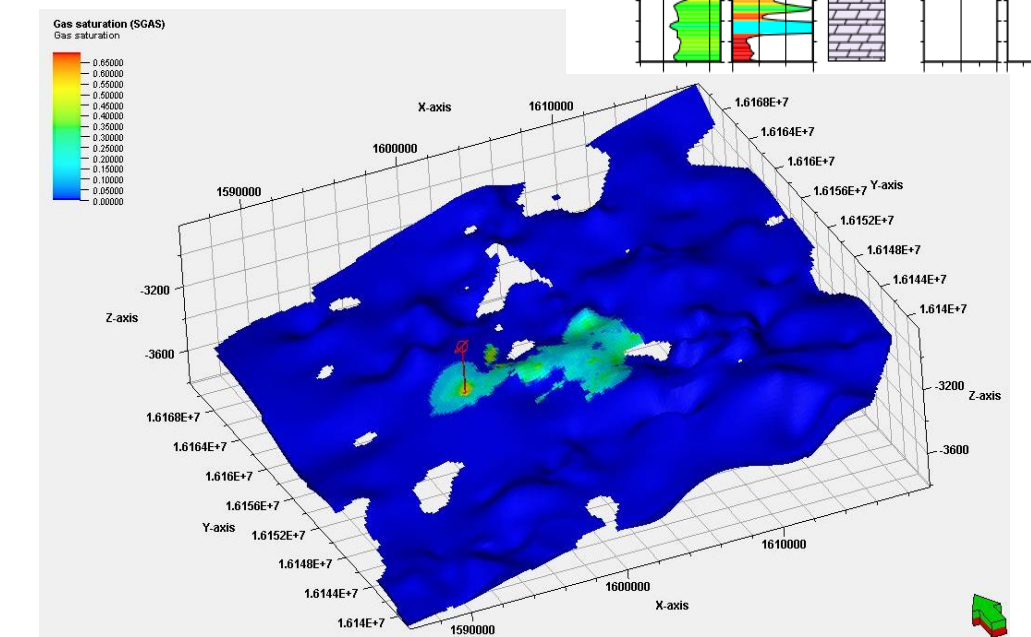
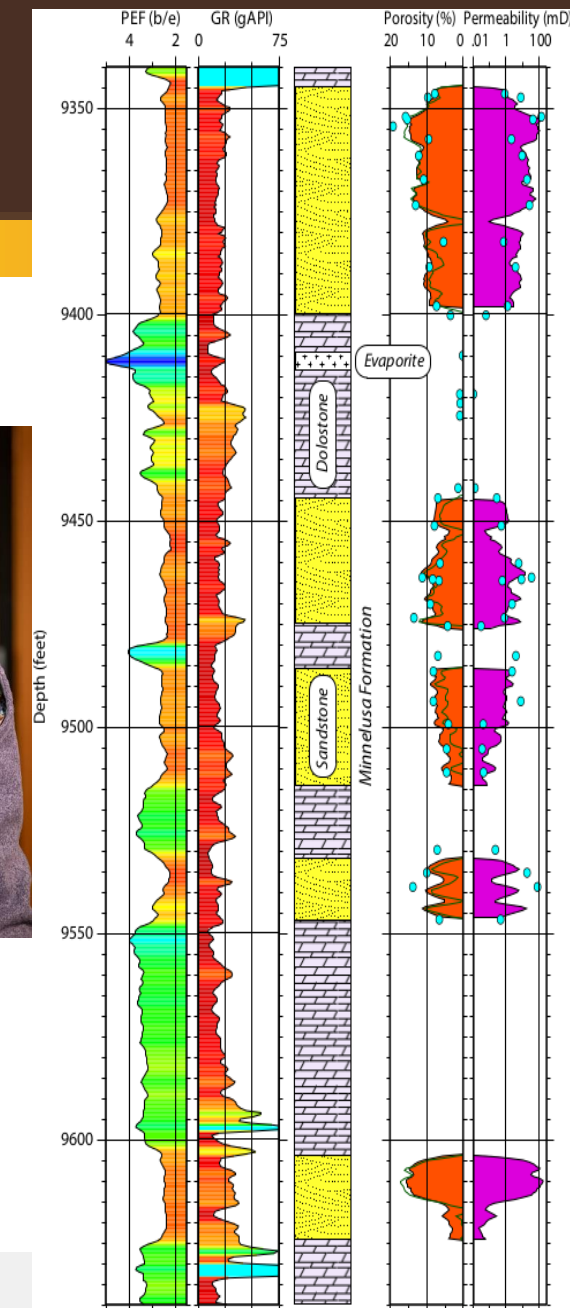
**WYOMING
INTEGRATED
TEST CENTER**



Wyoming CarbonSAFE

Work completed to date:

- Geologic characterization: *Stratigraphic test well, 3D seismic, geologic modeling, risk analysis*
- Monitoring network: *Soil and water baselines established*
- Legal and regulatory analyses: *Model pore space leasing agreements, model CO2 off-take, Environmental Information Volume (EIV)*
- Economic modeling: *Web-based tool*
- Public Outreach: *Workshops, webpages, webinars, public presentations*



University of Wyoming Integrated Hydrogen/CCUS Projects

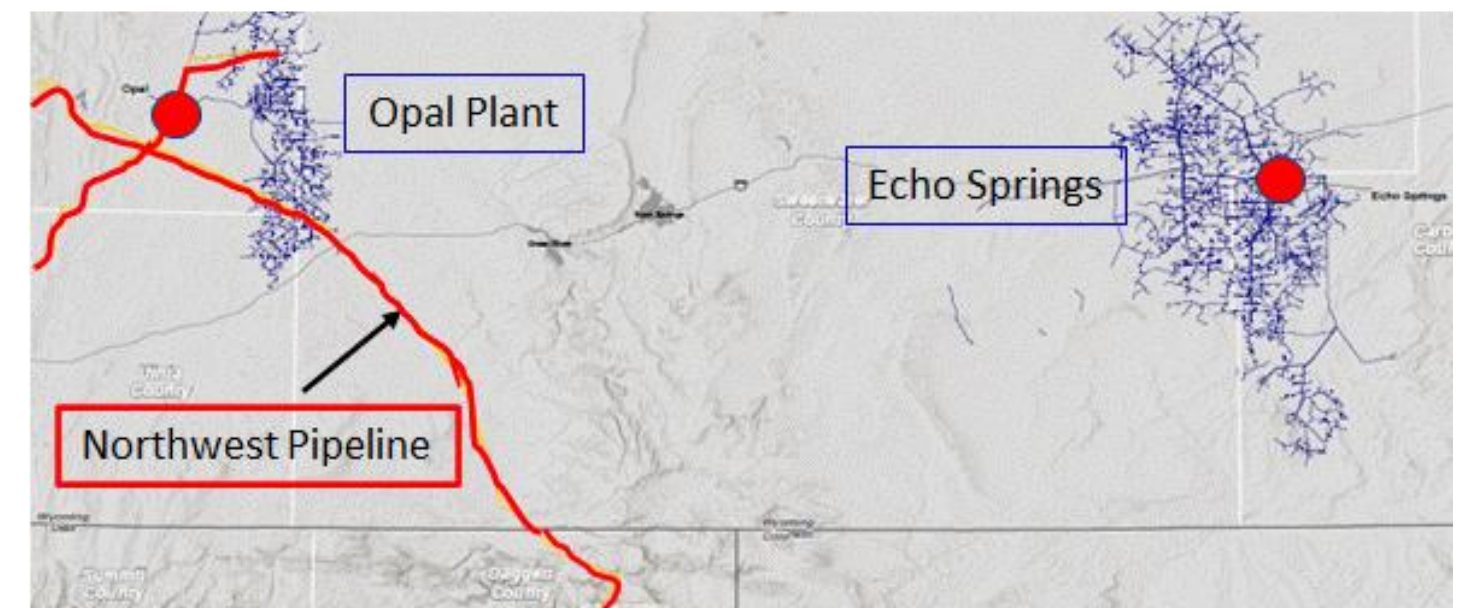
Initial engineering of the CO₂ capture unit of TEP *Blue Bison* ATR Plant

- Led by Tallgrass MLP Operations LLC (TEP), funded by the DOE
- FEED-type study on retrofitting an autothermal reforming (ATR) plant near Douglas, Wyoming with carbon capture that utilizes existing natural gas infrastructure
- Commercial scale system to separate and store 1.66 MT/year of CO₂ Sized for 220 MMSCFD of Operational goal of operations by 2025, with commercial H₂ sales/distribution via pipeline

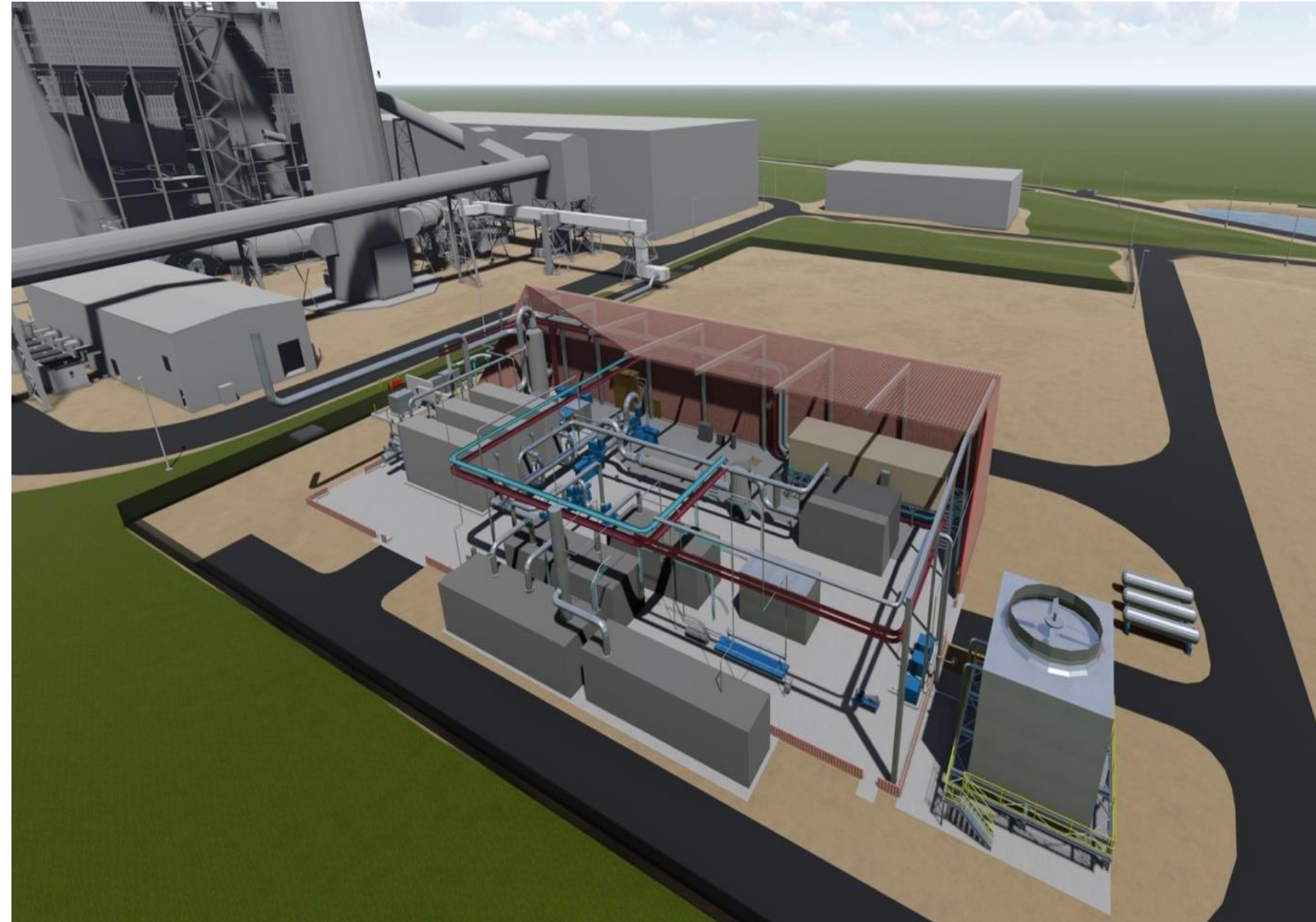


Williams Wyoming Hydrogen Hub: Feasibility Study of Green Hydrogen Generation and Transport in SW Wyoming

- Led by Williams Companies Inc., funded by the WEA
- Green hydrogen feasibility with regional CCUS and water resource assessments
- Utilizes existing assets (land and power facilities) with a goal of lowering the carbon impact of existing business



Membrane Technology and Research



- MTR has a successful CO₂ capture research portfolio spanning more than a decade.
- 160-180 ton per day of liquid CO₂ product system will be located in the large test bay.
- \$64 million total project cost.
- Kickoff meeting for Construction and Operation Phase November 5, 2021.
- Will capture approximately 70% of the CO₂. The most economical rate for \$/tonne captured.



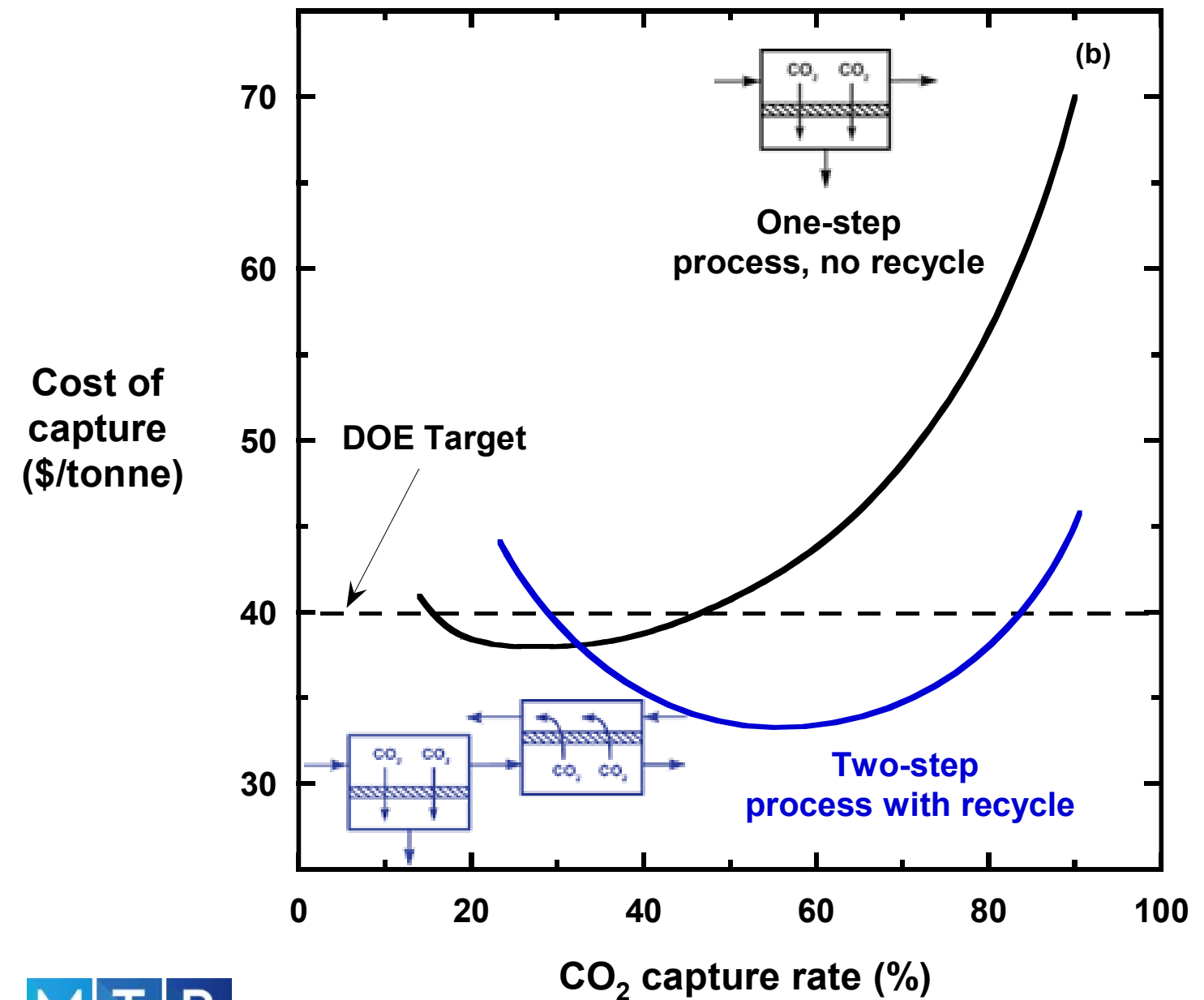
ITC

WYOMING
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TEST CENTER

Membrane Technology and Research (MTR)

MTR is completing a FEED study at Basin Electric's Dry Fork Station. Publicly shared CO₂ capture cost curve:

Tested at NCCC, TCM, and possibly WYITC. Obviously a very compact solution.



[https://netl.doe.gov/projects/files/Scale-Up%20and%20Testing%20of%20Advanced%20Polaris%20Membrane%20CO₂%20Capture%20Technology%20\(FE0031591\).pdf](https://netl.doe.gov/projects/files/Scale-Up%20and%20Testing%20of%20Advanced%20Polaris%20Membrane%20CO2%20Capture%20Technology%20(FE0031591).pdf)

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CONTACT US

ADDRESS

325 W 18th Street

Suite 1

Cheyenne, Wyoming 82001

PHONE NUMBER

307-635-3573

WEBSITE

www.wyoenergy.org

EMAIL ADDRESS

glen.murrell@wyo.gov

