Western States Coal Strategies Forum
Moab, UT
20-22 November 2019

Power Production, Transmission and Partnerships

- Working Group Session 2.1

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Waypoints Wyoming

Projects and Partners

- University of Wyoming
  - School of Energy Resources
  - Center for Energy Policy and Research
- Wyoming Infrastructure Authority
  - Wyoming Integrated Test Center
- Campbell County Wyoming
- Energy Capital Economic Development
  - Carbon Products Innovation Center

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Overview

- Coal's Reliabilty Attributes
  - What defines a reliable and secure fuel?
    - ❑ Abundant
    - ❑ Affordable
    - ❑ High Energy Density
    - ❑ Transportable
    - ❑ Low Cost Storage
    - ❑ Dispatchable

So what…?!?

If there are no mines mining it and no plants burning it…then the attributes that make coal a reliable fuel just don't matter.

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Business

Coal Slump Sends Mining Giant Peabody Energy Into Bankruptcy

By Tiffany Kary, Tim Loh, and Jim Polson
April 13, 2016, 12:41 AM MDT *Updated on April 13, 2016, 5:22 PM MDT*

Casper Star Tribune:

Two coal mines in Wyoming closed and sent 700 workers home Monday afternoon after their owner filed for bankruptcy, the latest blow to a region that has been battered by an economic downturn in the fossil fuel sector.

Source: S&P Global Market Intelligence

U.S. coal companies that salvaged unwanted assets left by a wave of bankruptcy that swept over the sector in 2015 and 2016 are now seeking the aid of the bankruptcy court themselves.

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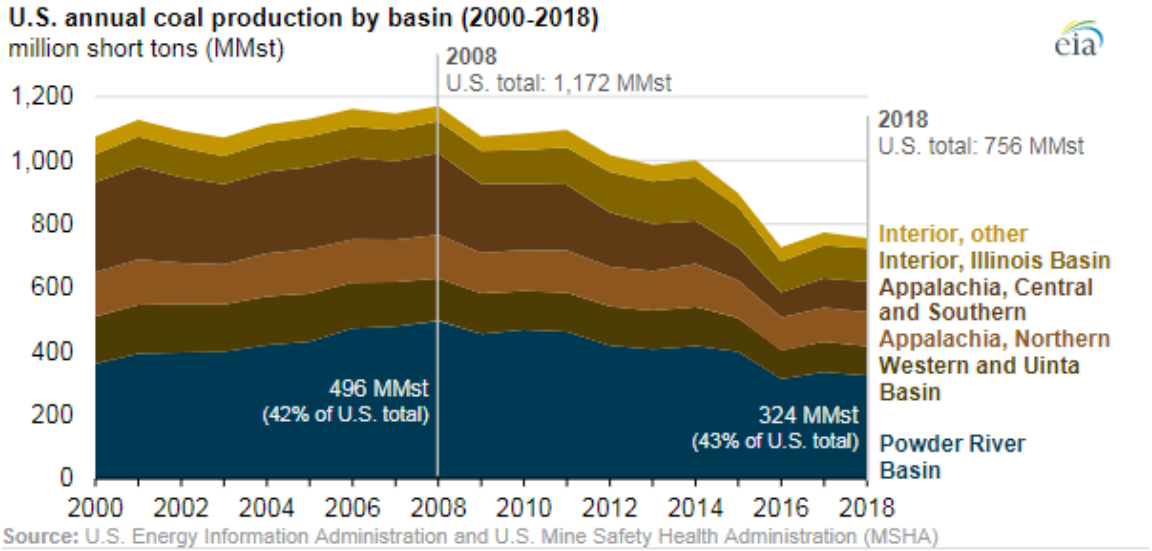
Summary of conditions

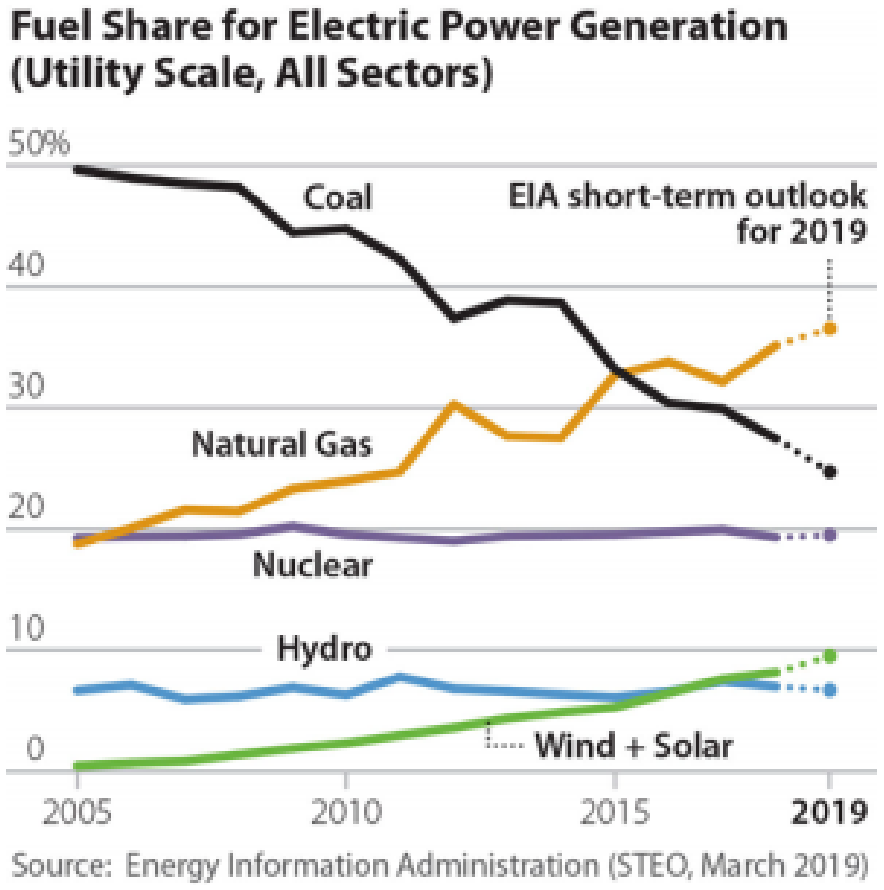
- Demand declining and this will continue
- Overcapacity increasing
- Prices remain flat or declining
- Costs rising, margins falling



More than 40% of coal produced in the United States comes from 16 mines in the Powder River Basin (PRB), a mining region primarily located in northeast Wyoming and southeast Montana. Four companies collectively own more than half of those PRB mines, and those 10 mines produced 87% of the Basin's coal in 2018. Two of those companies, Cloud Peak and Blackjewel, filed bankruptcy this year. The two other companies, Peabody and Arch Coal, are proposing a joint venture that involves some of the PRB mines.

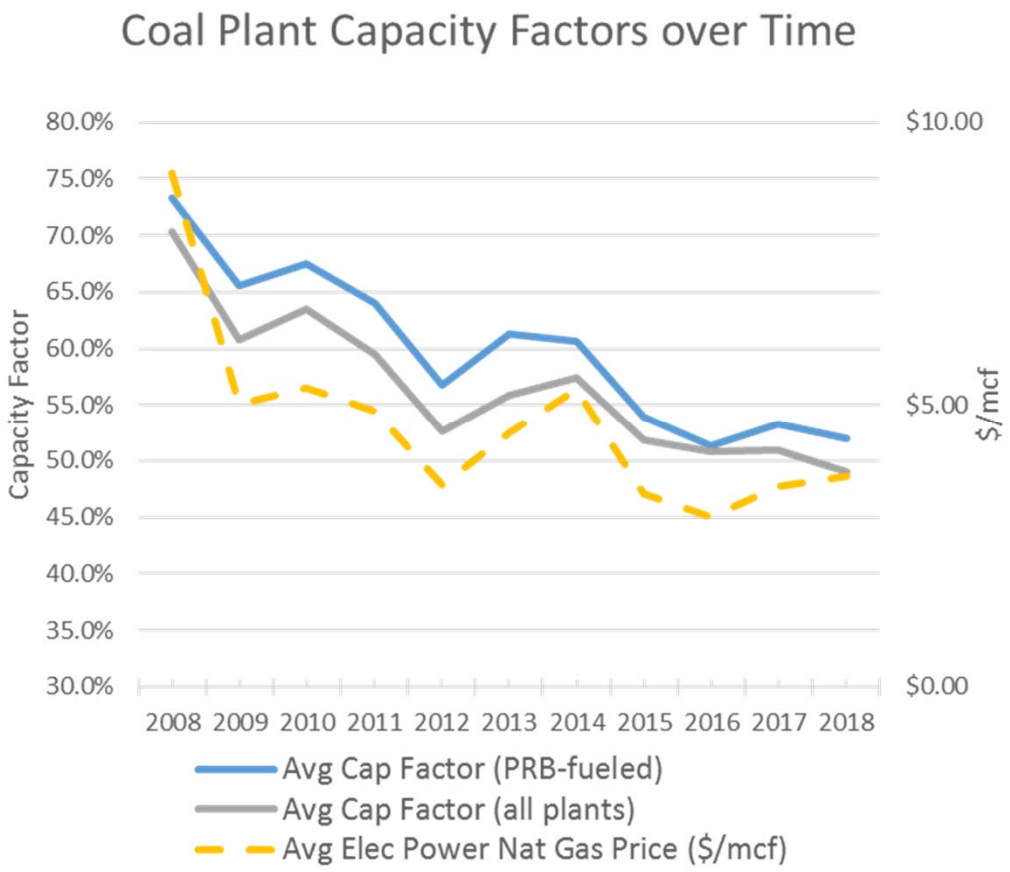
Shift away from coal continues unabated

This is not a temporary outcome – it is a structural change in the generation sector.



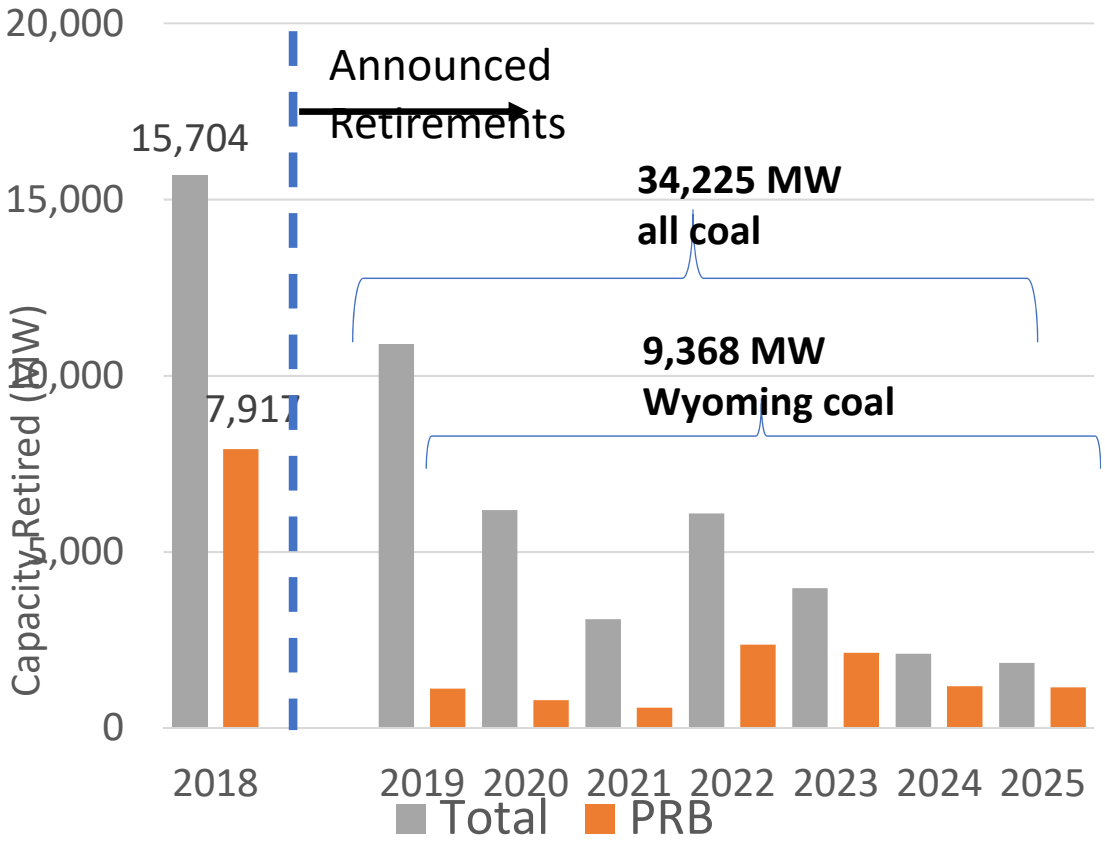
Coal Use Trend in Generation Sector:

- Capacity factors of all plants nation-wide, and all PRB-fueled plants have declined by 40% since 2008.
  - Natural gas prices have declined by about 60%.
- Reduced operation has forced closure of nearly 30% of plants nationally, and 17% of PRB-fueled plants since 2008.



Retirements will continue:

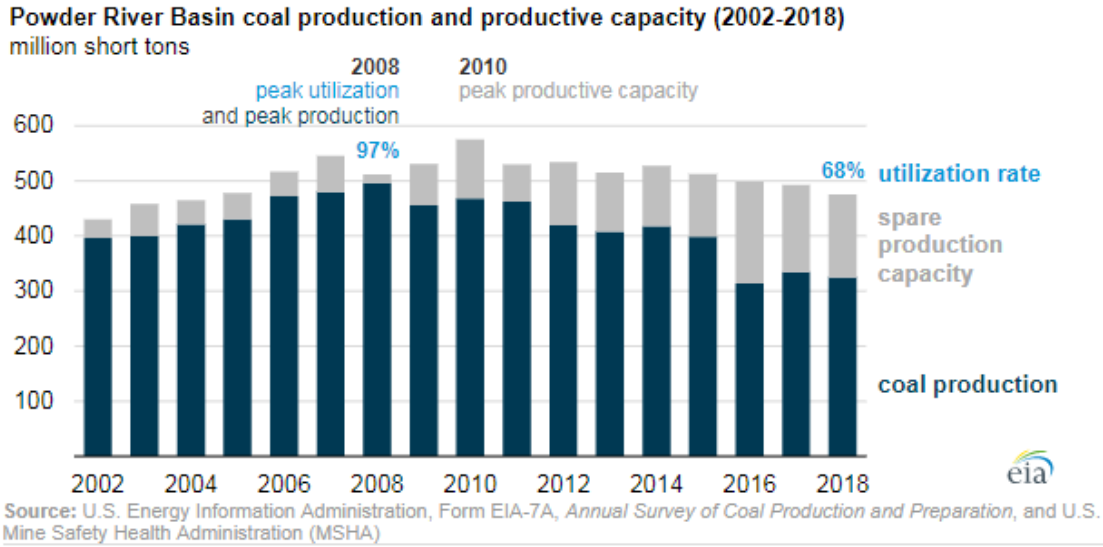
Current estimates (which grow monthly)



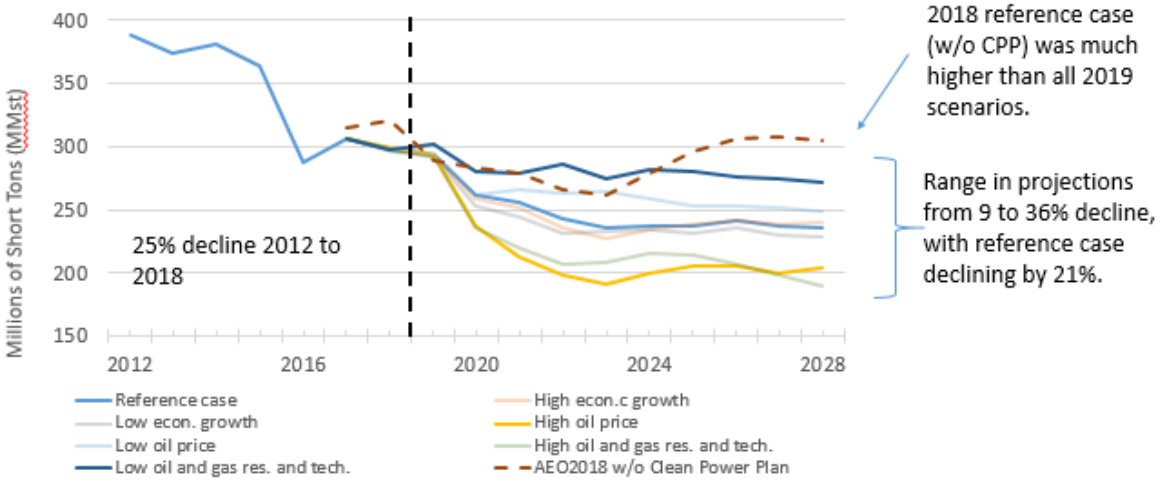
Source: Author's dataset, EIA, IEEFA, various press sources.

Current Problem: Overcapacity in PRB

- Lack of price impact from Blackjewel closures suggests overcapacity a real problem.
- Overcapacity results in reduced economies of scale/higher operating costs.
- Cutthroat competition: too many mines chase too few customers, lowering prices.
- Overcapacity increases likelihood of closure, increasing uncertainty and reducing access to needed investment => Higher costs.



Wyoming PRB Production Projections (2019-2028)



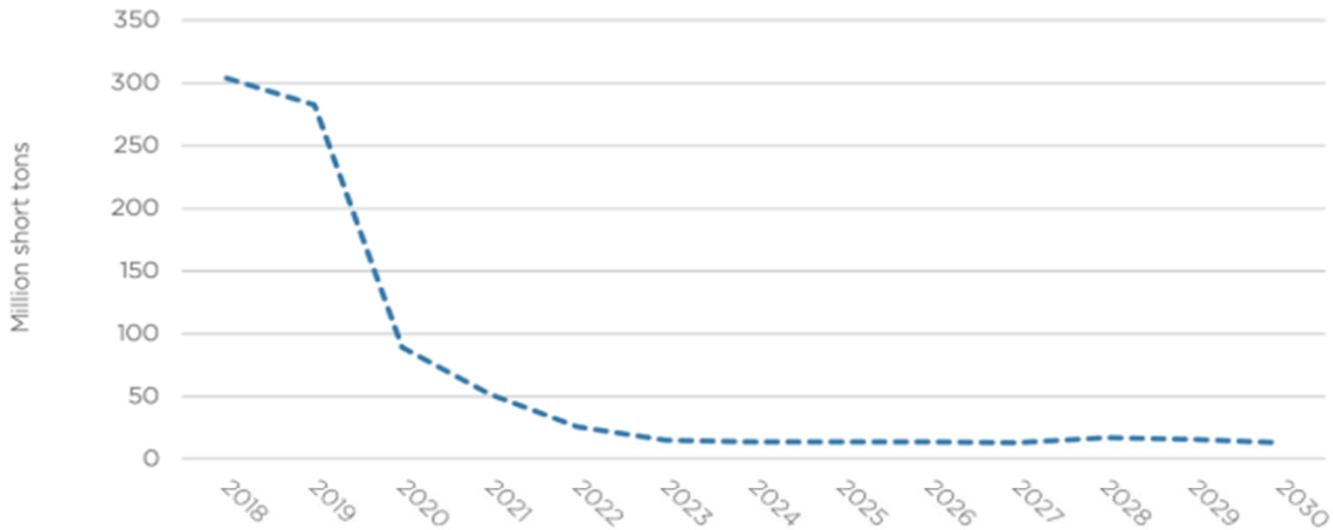
Source: EIA Annual Energy Outlook 2019 (assumes no change in current regulations)

If politics really comes into play

bituminous coal from surface mines that is burned at power plants in the United States. EIA projects that coal produced elsewhere in the western United States would experience a similarly dramatic and rapid decline.

FIGURE 6: POWDER RIVER BASIN COAL PRODUCTION UNDER EIA $25/TON SCENARIO

Figure 6: Powder River Basin Coal Production under EIA $25/ton Scenario



Source: U.S. Energy Information Administration

The EIA projections for the $25/ton Carbon Price Scenario also show a collapse in coal production from the midwestern and southeastern United States, although not quite as rapid as in the western region. Coal production from Northern Appalachia (accounting for 16 percent of current US production and comprised of: PA, OH, MD, and Northern

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Deja vu all over again…

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Drivers of coal decline (in order)

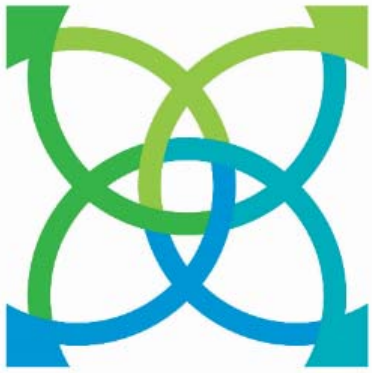
Cost Competitiveness

- Natural gas
- Aging Fleet
- Renewables
- Regulation Uncertainty

Coal squeezed out of markets

Consumer Preferences

- Preference for cleaner and cheaper fuels



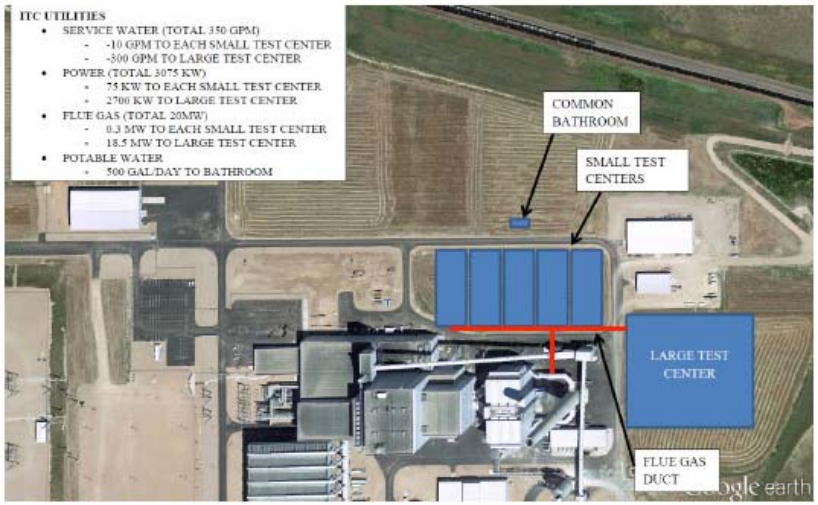
Next Generation Technology for Today's Energy

Jason Begger, Executive Director
Wyoming Infrastructure Authority

Dry Fork Station (Basin Electric Power Coop) & Wyoming Integrated Test Center (WY-ITC)

Dry Fork Station

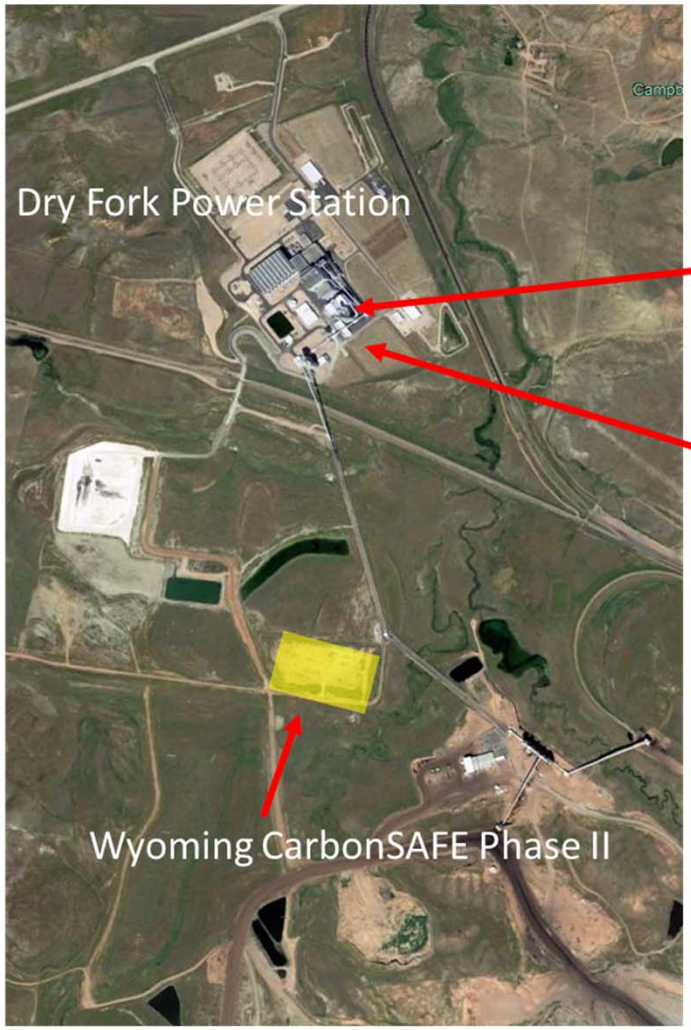
- ✓ Built in 2007
- ✓ 385 MW Power Plant
- ✓ 3.3 Million tons of CO_2/year

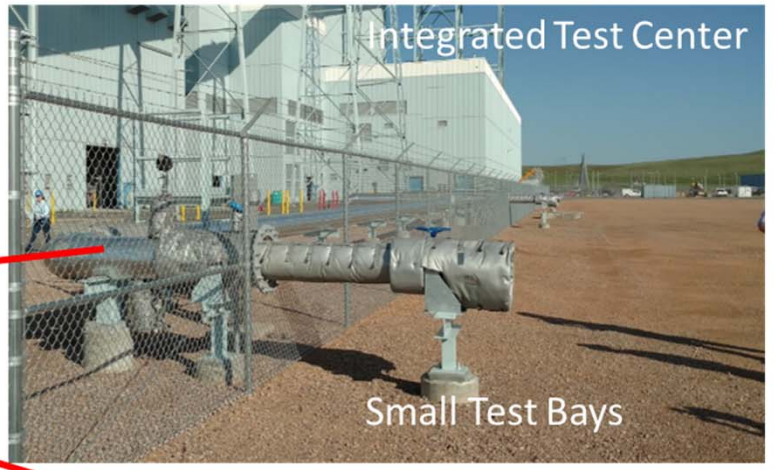


ITC WYOMING INTEGRATED TEST CENTER

WY-ITC

- ✓ Completed fall 2017
- ✓ Test CO_2 capture/CCUS technologies
- ✓ $20 Million public/private investment
- ✓ NRG COSIA Carbon XPRIZE ($20M global competition to develop breakthrough technologies for CO_2 emissions)





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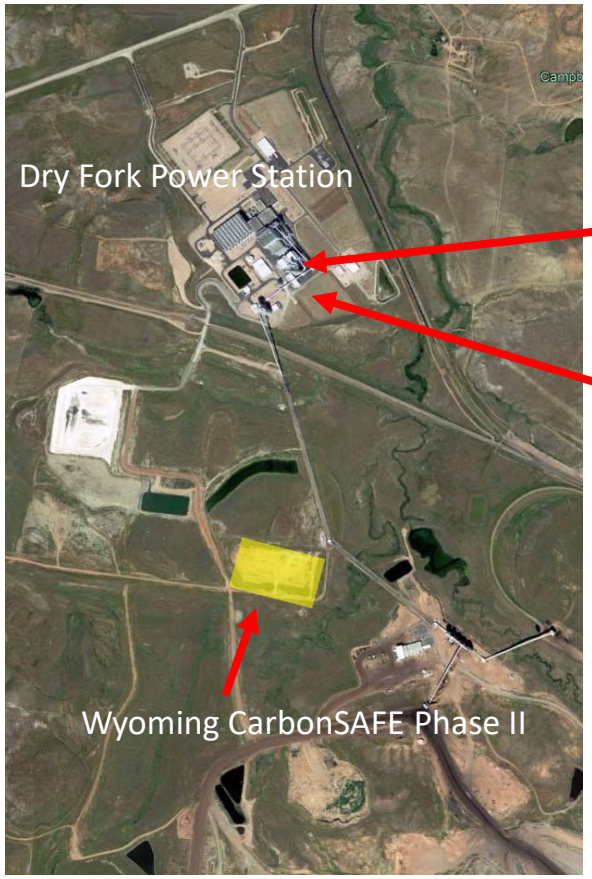
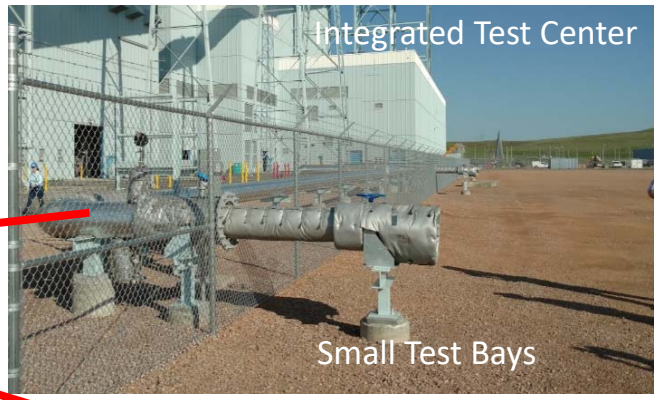
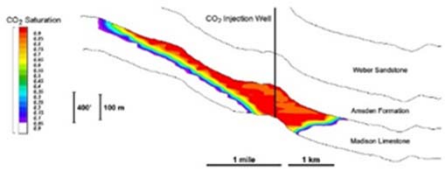
CarbonSAFE Wyoming: Study Area





CarbonSAFE (Storage, Assurance, and Facility Enterprise)

- Projects will address **key research gaps** in **commercial scale** (50+ million metric tons CO_2) CCUS deployment
- CarbonSAFE projects aim to **develop integrated CCS complexes** that are **constructed and permitted for operation in the 2025 timeframe**
- Get there through four (4) sequential Phases:
  - ***Phase 1*** Integrated CCS Pre-Feasibility
  - ***Phase 2*** **Storage Complex Feasibility**
  - ***Phase 3*** Site Characterization
  - ***Phase 4*** Permitting and Construction



TDA Research

- TDA – based in Wheat Ridge, CO
- Skid-based Hybrid membrane/sorbent test system
- Finalizing permitting, lease and insurance
- Testing began November 2019

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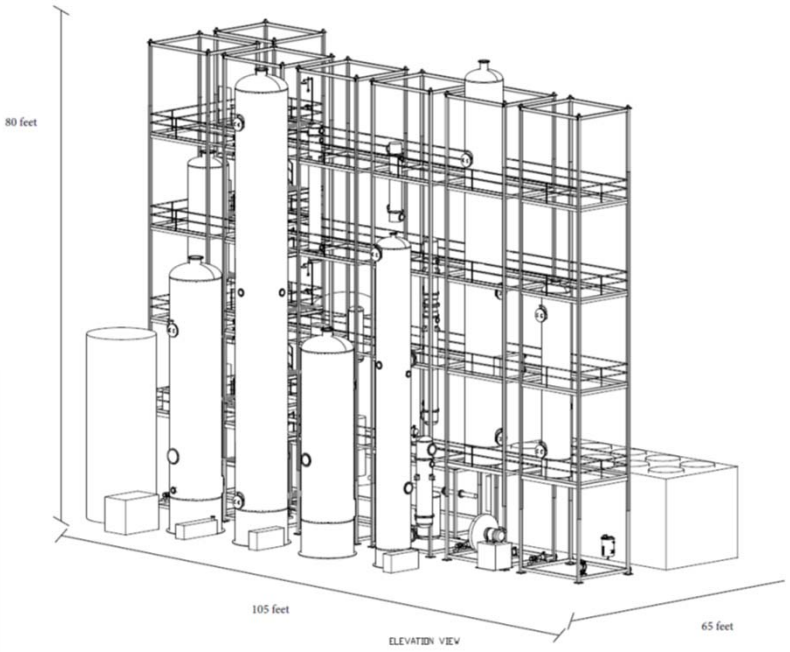
Membrane Technology and Research

- MTR has a successful CO_2 capture research portfolio.
- Has received initial phase 1 funding from U.S. DOE.
- Partnering with Wyoming ITC for phase 2 application for design and permitting and phase 3 operation.
- 200 tons per day of liquid CO_2 product system will be located in the large test bay.

Photo Credit: NETL

University of Kentucky



- UK has a solvent based CO_2 capture system.
- Has received initial phase 1 funding from U.S. DOE.
- Partnering with Wyoming ITC for phase 2 application for design and permitting and phase 3 operation.

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Photo Credit: UK

JCOAL – KHI

- July 2016 – State of Wyoming - JCOAL (Japan Coal Energy Center) MOU
- April 2017 – WY delegation meetings in Japan
- Sept. 2017 – JCOAL/UWSER conference in Gillette
- March 2018 – WY delegation meetings in Japan
- April 2018 – Announcement of JCOAL-KHI (Kawasaki Heavy Industries) test at ITC – dry sorbent, fixed bed technology
- May 2018 – Japan Ministry of Environment, JCOAL and KHI trip to Gillette
- August 2018 – Feasibility trip to Gillette
- December 2018 – Met with US based EPC firms
- February 2019 –Wyoming permitting trip
- April 2019 – Washington, DC meetings

XPRIZE competition

Breathe (Bangalore, India) – Led by Dr. Sebastian Peter, the team is producing methanol, a common fuel and petrochemical feedstock, using a novel catalyst.

Carbon Capture Machine (Aberdeen, Scotland) – Led by Dr. Mohammed Imbabi, the team is producing solid carbonates with applications to building materials.

C4X (Suzhou, China) – Led by Dr. Wayne Song and Dr. Yuehui Li, the team is producing chemicals and bio-composite foamed plastics.

Dimensional Energy (Ithica, NY, USA) – Led by Jason Salfi, the team is using artificial photosynthesis to produce environmentally responsible polymers and chemical intermediaries for industrial partners.

Carbon Upcycling UCLA (Los Angeles, CA, USA) – Led by Dr. Gaurav Sant, the team is producing building materials that absorb CO_2 during the production process to replace concrete.

XPRIZE is a temporary tenant of the ITC and at the completion of the competition, the space will be available to new testers.

COMING SOON!
Advanced Carbon Products Innovation Center

- Coal-to-Products
- Platform to demonstrate processes at a pre-commercial scale
- Six test bays
- Coal provision and preparation for developers

Carbon Engineering Initiative
Techno-economic Objectives

Investigate and develop technology solutions for the conversion of Wyoming coal into chemical & engineered products in a sustainable and environmental friendly way:

- Primary Objective is to SELL More PRB Coal – Commodity volume and profit rather than small volume specialties and economic rent.
- Make products that command price premiums over the btu value of Wyoming coal.
- Develop New Diversified Economic Development Opportunities That Advantage Wyoming's vast Mineral Wealth.
- Investment to date – all State Money over the last 4 years:
  - **By end June 2019 = $11.9 million**
  - **FY 2019-20 funding = $4.45 million (State) and $1 million Private Sector**
  - **FY2021-22 (Aspirational) =**
    - Carbon Engineering - Matching Funds : State $23,300,000 to Attract $116 Million External Investment
    - Carbon Engineering –One Time Funding : $8.8 Million

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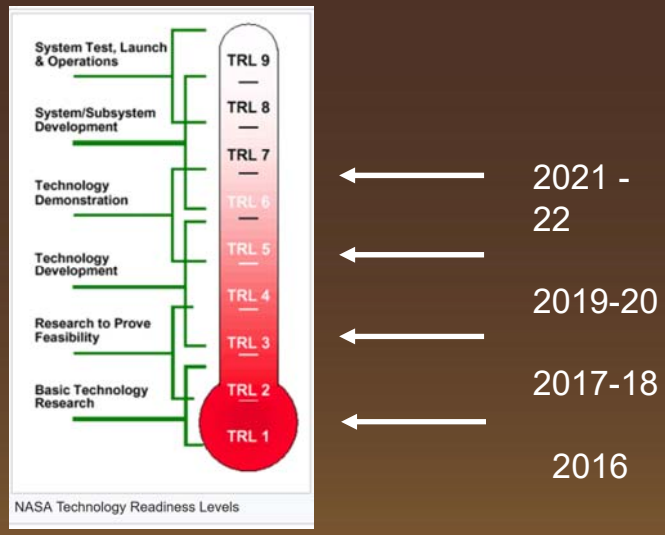
Carbon Engineering Initiative
Current Reality

- Innovative New-coal Conversion Processes & Product Opportunities Have Been Proven in the Laboratory.
- Preliminary Techno-economic Appraisal Shows Good Returns if a Coal Refinery was Built in Wyoming.
  - **Technology Readiness Level (TRL) Achievements Reveal Significant Latent Value can be Realized if Further Investments in Carbon Engineering are Made.**

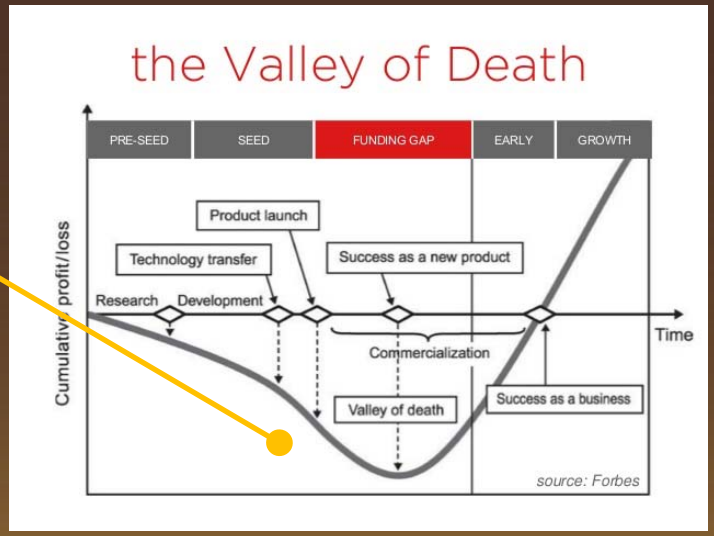


2021 - 22

2019-20

2017-18

2016



- Discrete Patented & Protected Solutions need to be Integrated & Scaled-up to Understand Engineering Implications.

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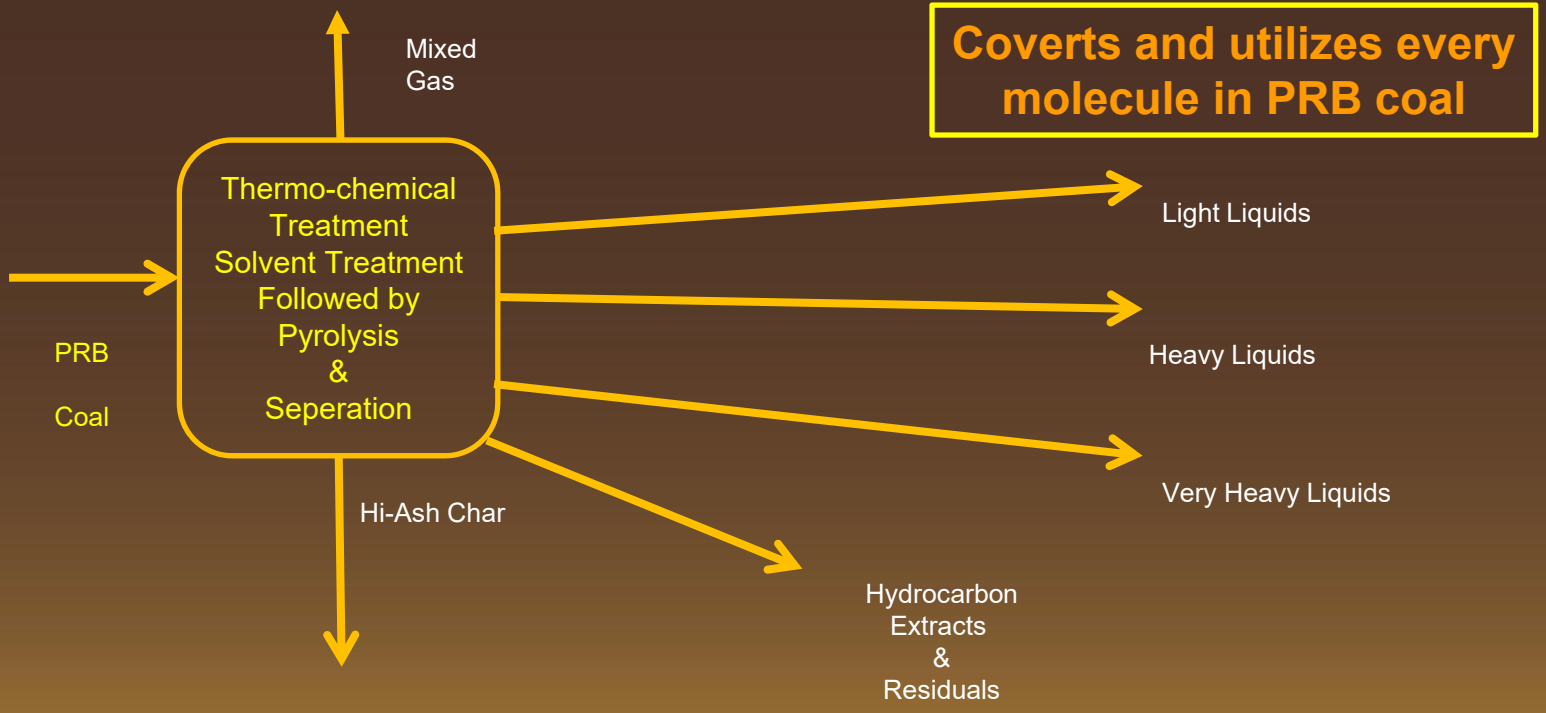
Thermo-chemical PRB Coal Conversion Technology Platform

This is an example of a primary technology platform that can produce different intermediate feedstocks for conversion into derivative products



Coverts and utilizes every molecule in PRB coal

School of Energy Resources

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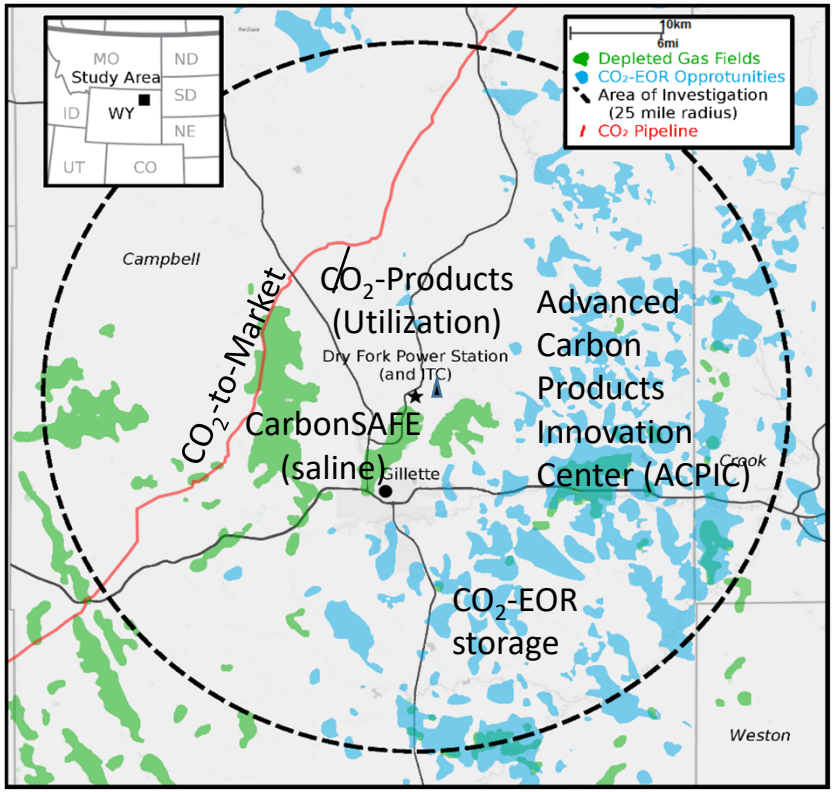
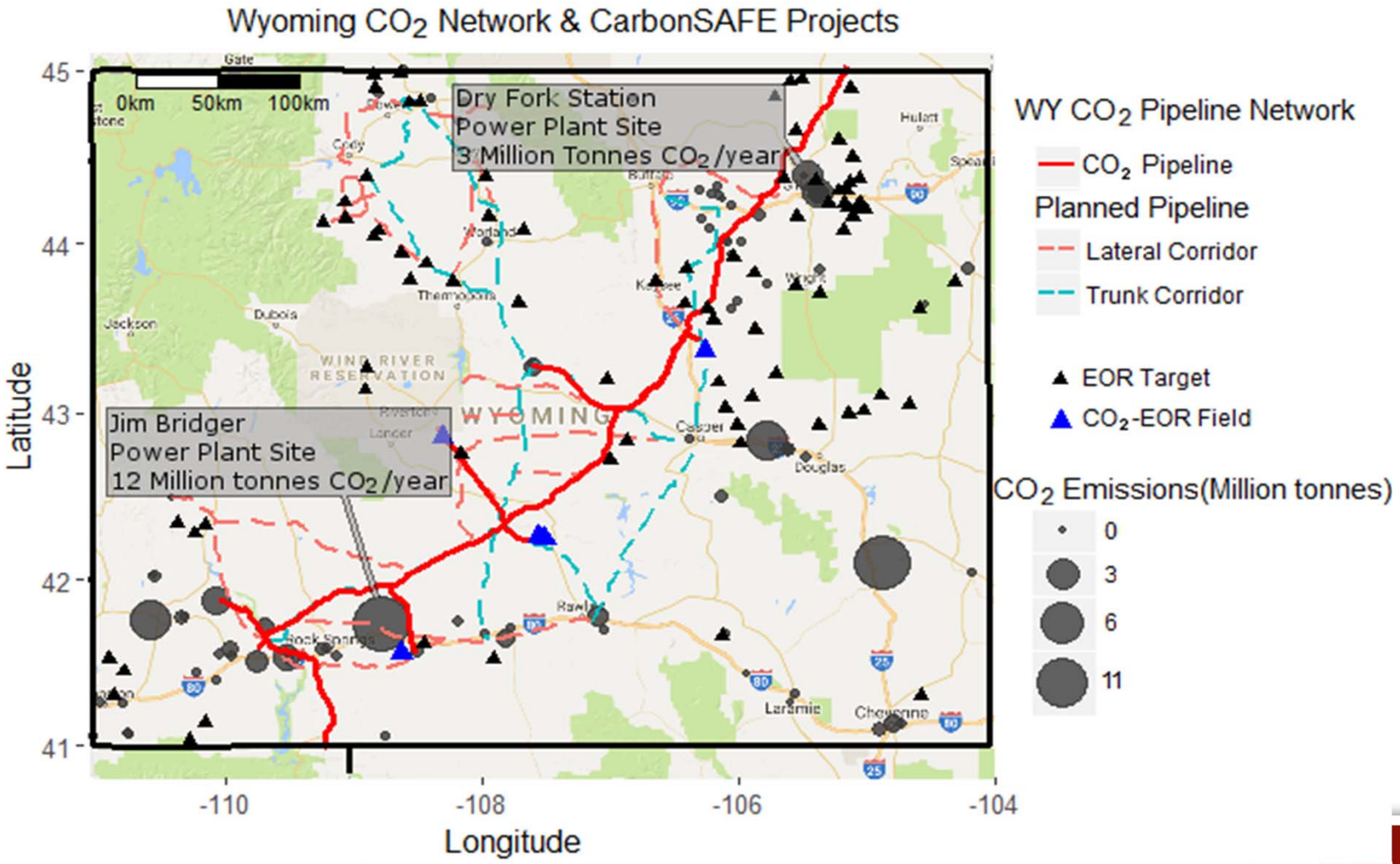
Creation of a Carbon Ecosystem

- Coal Production and Power Generation
- CCUS @ Integrated Test Center
- Sequestration @ CarbonSAFE
- CO_2 to Market (WIA & Pipeline Corridors)
- CO_2 to Enhanced Oil Recovery
- Coal to Products @ ACPIC
- Regional Deployment of CCUS



Creation a Carbon Ecosystem



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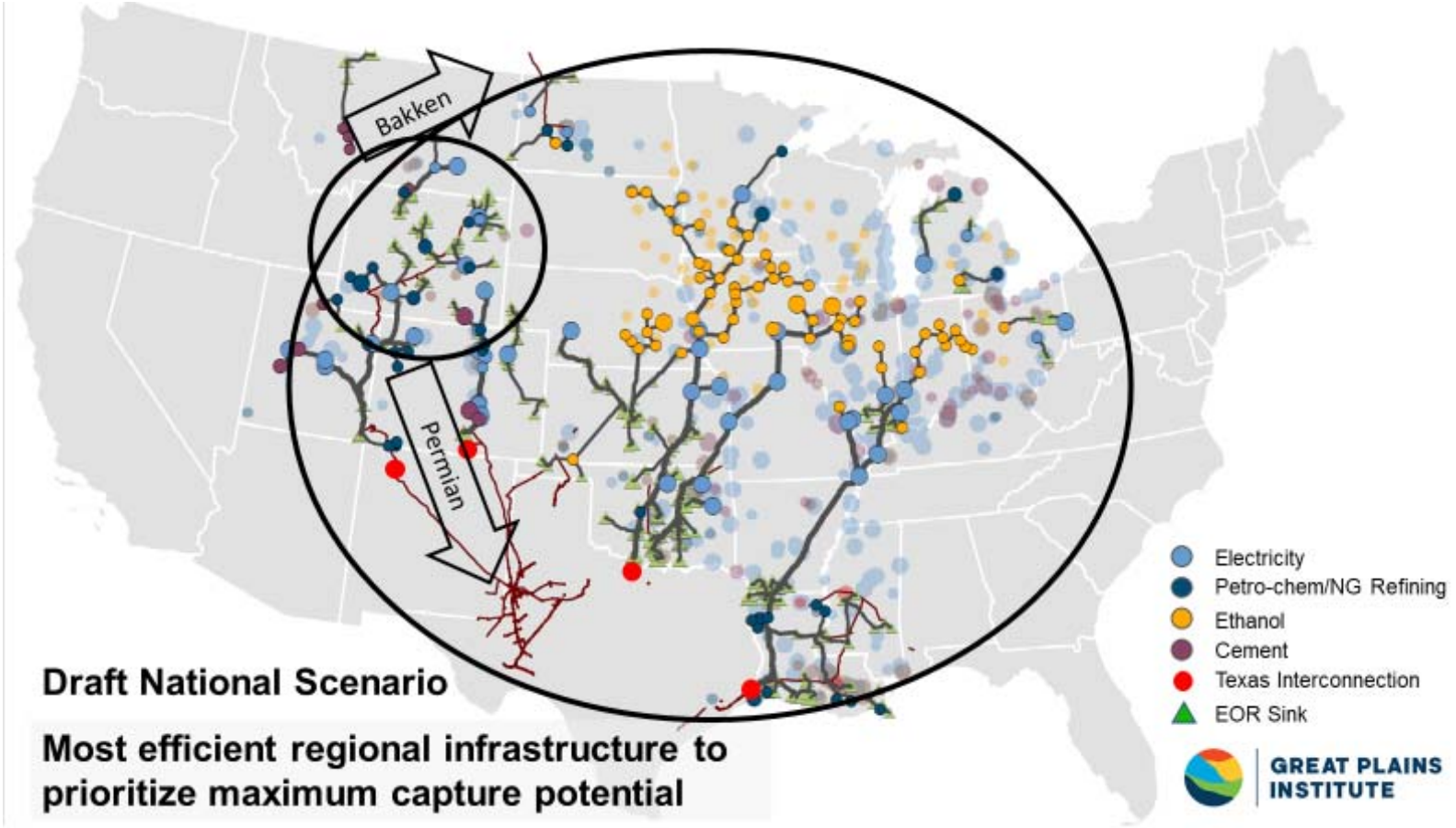

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***Not* the end…the beginning.**

Thank you!

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