SCHOOL OF ENERGY RESOURCES

Joint Minerals Committee
August 28th to 30th

UNIVERSITY OF WYOMING

School of Energy Resources

- Mark Northam, Executive Director
- Scott Quillinan, Director-Research and Operations
- Richard Horner, Director-Emerging Technologies
- Kipp Coddington, Director-Energy Policy and Economics

Disclaimer

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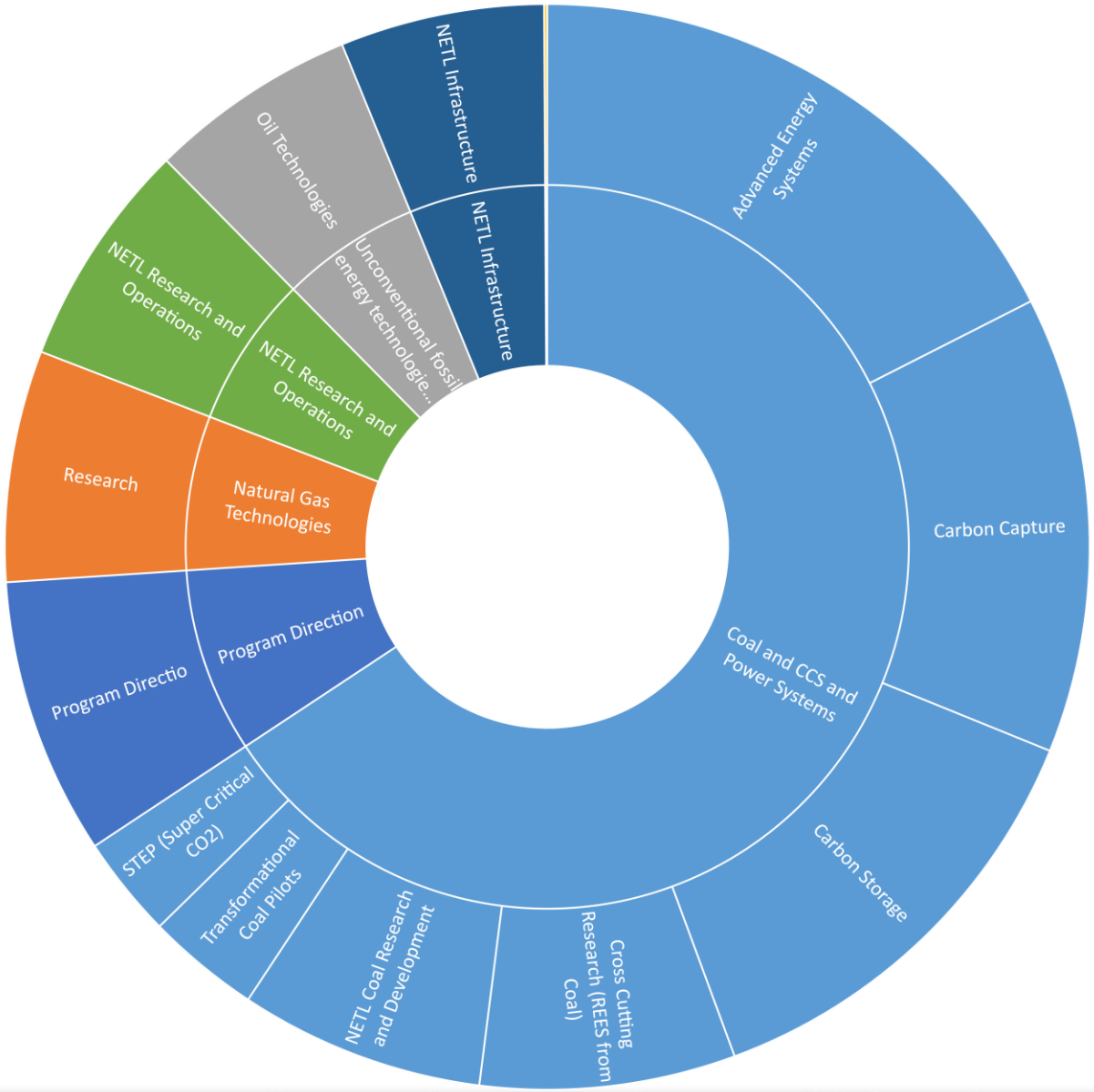
Fossil Energy Research and Development FY20



Observations from the FY20 Fossil Energy R&D budget

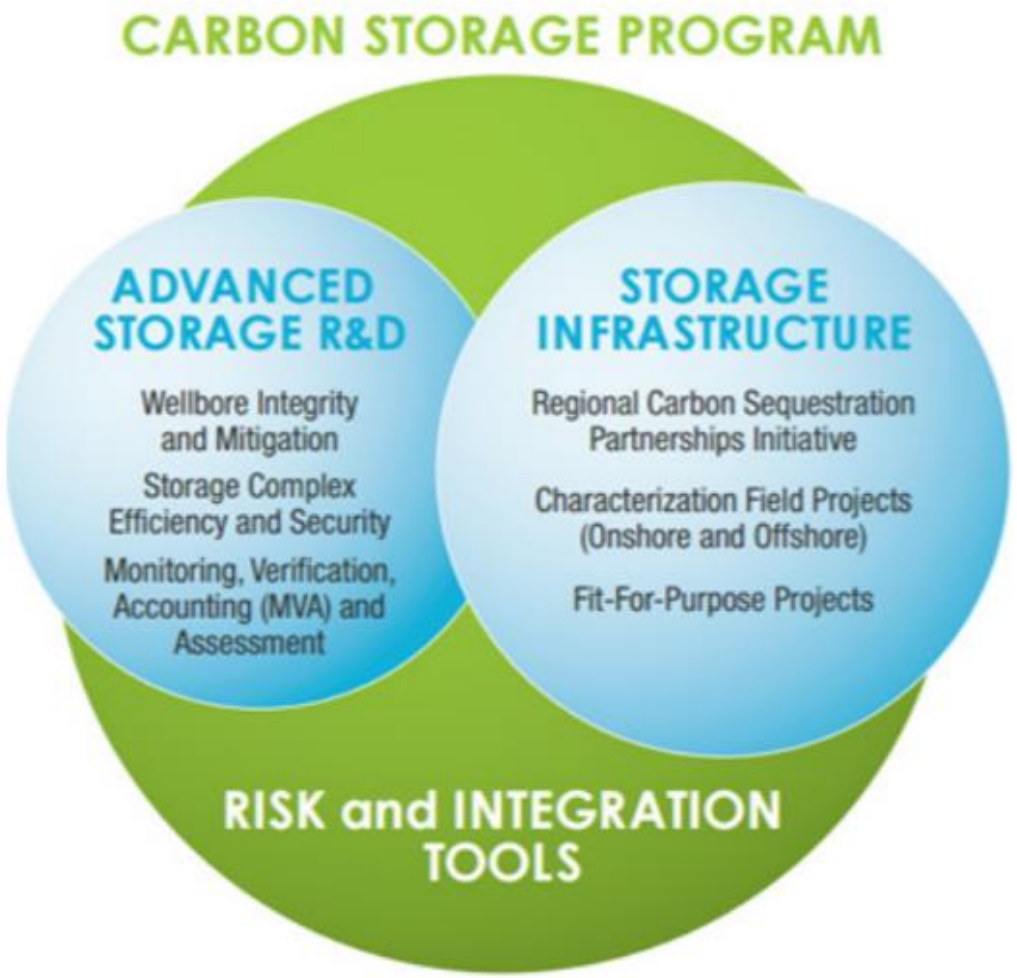
- Total budget approximately $740M
- Approximately 66% (or~$485M) will focus on coal
  - CO_2 Capture ~$100M
  - CO_2 Storage ~$100M
  - Rare earth elements in coal ~$23M
- The budget for natural gas research is growing
- The budget for unconventional resources remains steady

How long will FE R&D focus so heavily on coal?

State investments can help to unlock federal research dollars

Department of Energy Carbon Storage Initiative

- Wellbore Integrity and Mitigation
- Storage Complex Efficiency and Security
- Monitoring, Verification, Accounting (MVA), and Assessment
- Regional Carbon Sequestration Partnerships Initiative
- Characterization Field Projects (Onshore & Offshore)
- Fit for Purpose Projects



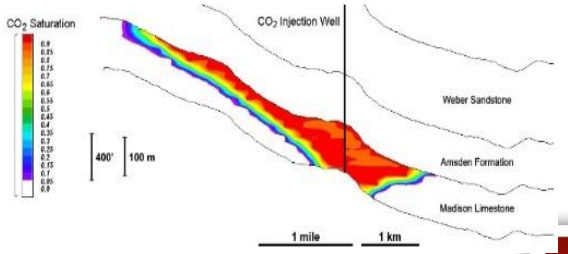
CarbonSAFE (Storage, Assurance, and Facility Enterprise)

- Projects… will address **key research gaps** in the path toward the **deployment** of carbon capture and storage (CCS) technologies, including the development of **commercial-scale** (50+ million metric tons CO_2) **geologic storage sites for CO_2 from industrial sources…**

- Projects under CarbonSAFE aim to **develop integrated CCS complexes** that are **constructed and permitted for operation in the 2025 timeframe**

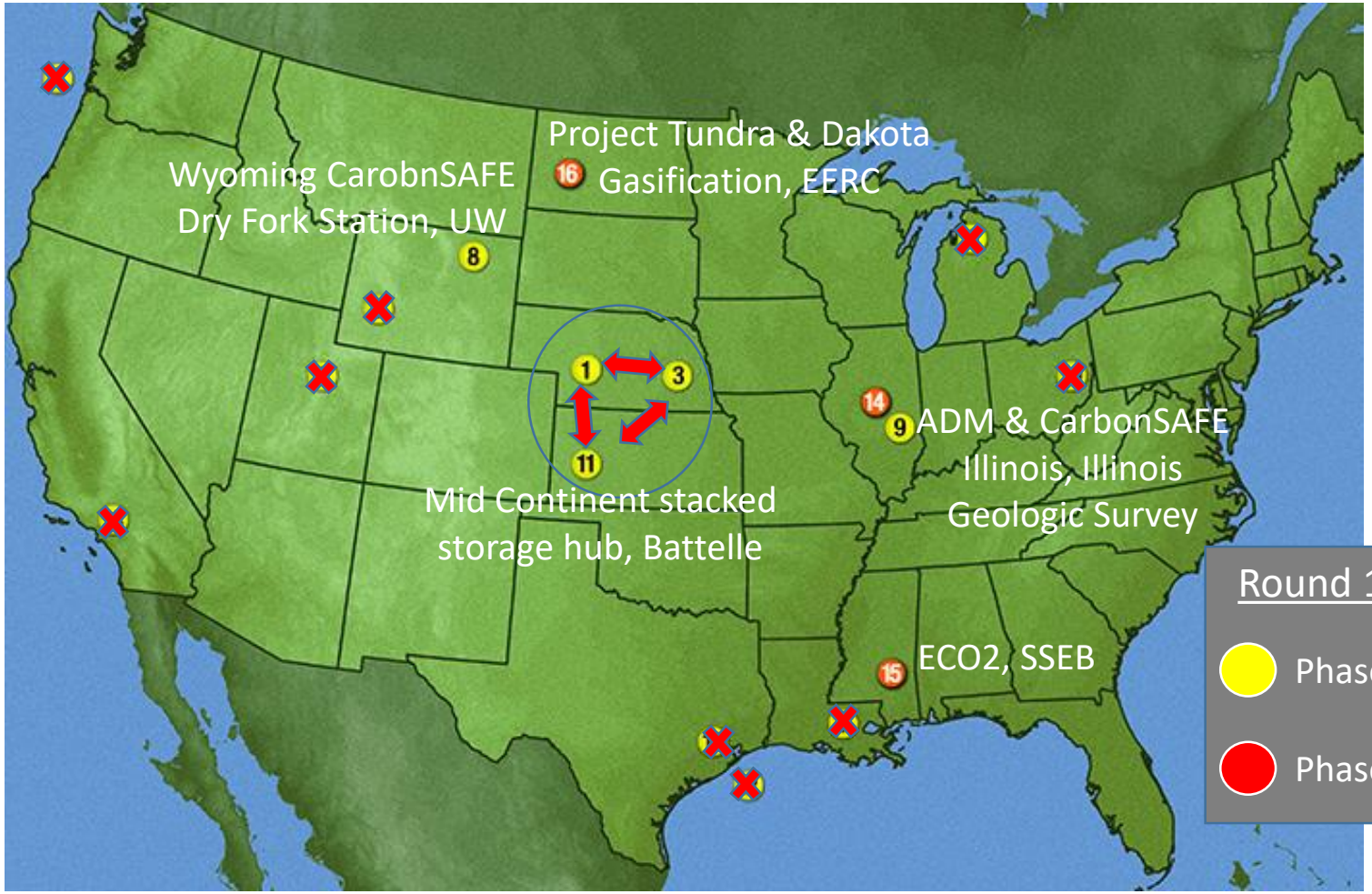
- **Get there through sequential Phases…**
  - ***Phase 1*** Integrated CCS Pre-Feasibility,
  - ***Phase 2*** **Storage Complex Feasibility,**
  - ***Phase 3*** **Site Characterization,**
  - ***Phase 4*** Permitting and Construction.

- **What about Carbon Capture?** That's a different DOE program



CarbonSAFE (Storage, Assurance, and Facility Enterprise)

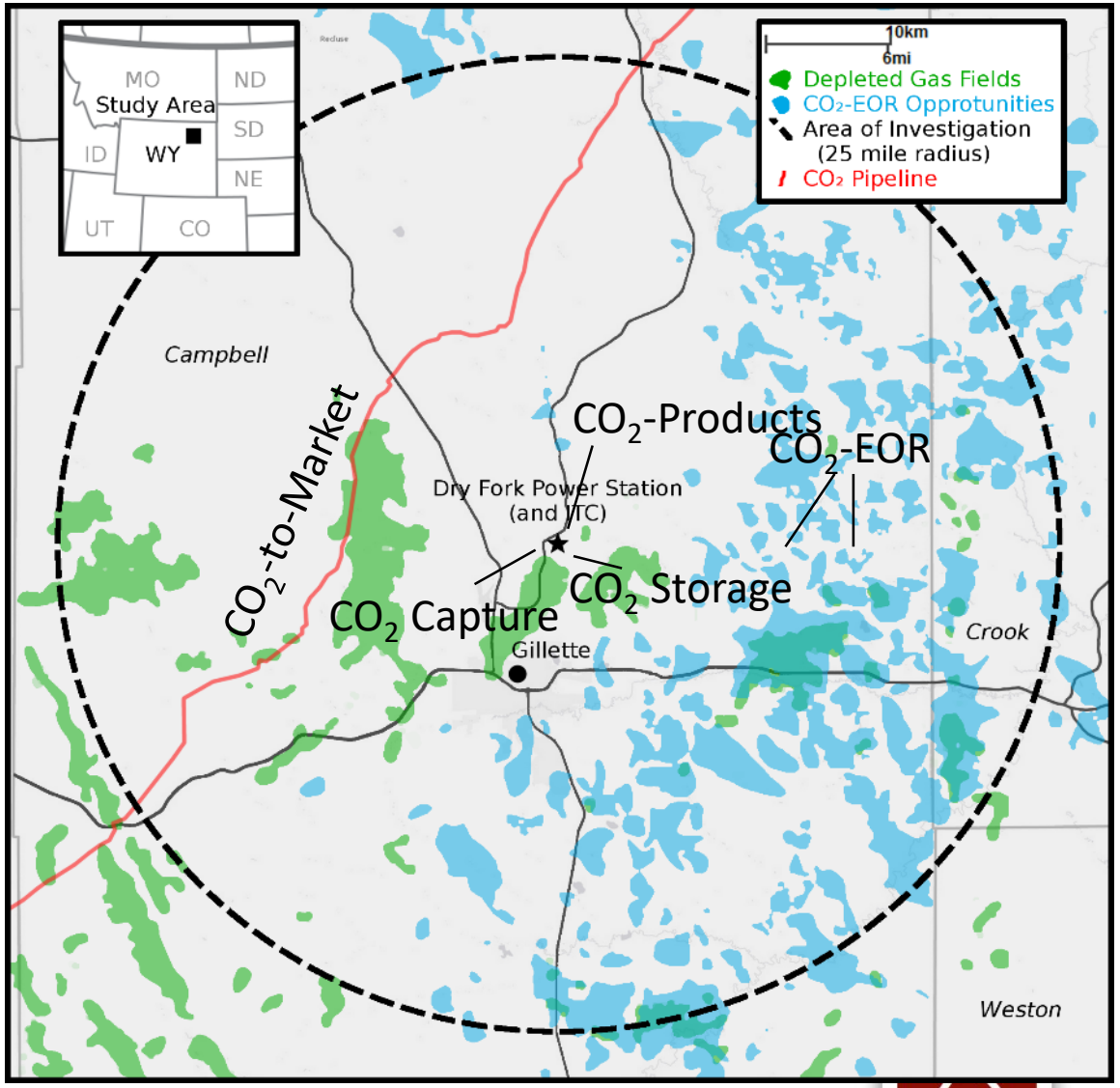
And then there were 6…..



Wyoming CarbonSAFE: Study Area

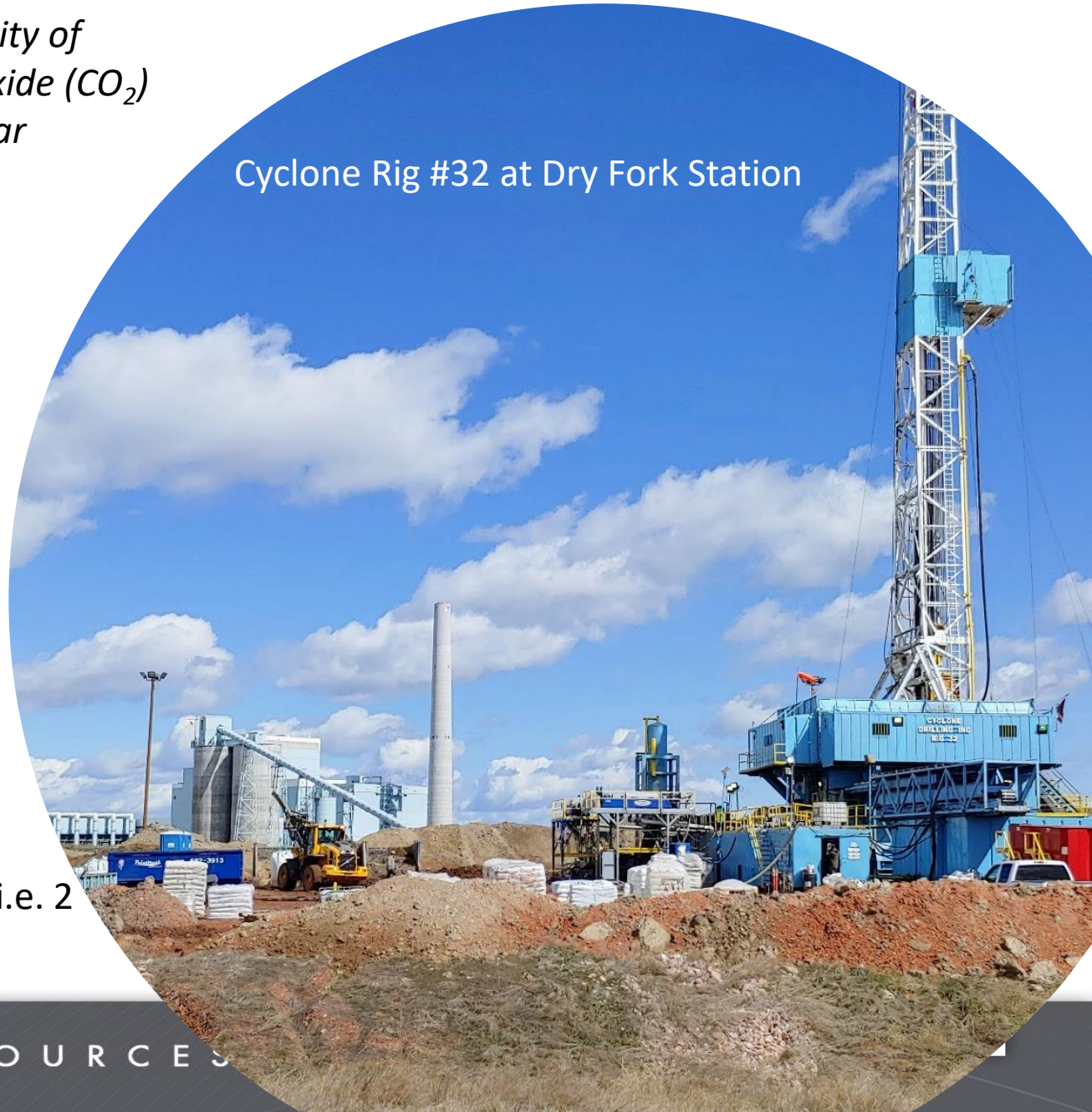
Gillette WY – Low Carbon Research Hub

- ✓ Storage: Saline reservoirs (Wyoming CarbonSAFE)
  - ➢ Located below Dry Fork Station
- ✓ Utilization: CO_2-EOR opportunities
  - ➢ Proximal EOR fields
  - ➢ Proximal to CO_2 pipeline
- ✓ Capture/Utilization: WY Integrated test Center
  - ➢ Breathe (Bangalore, India)-common fuel and petrochemical feedstock.
  - ➢ C4X (Suzhou, China) –chemicals and bio-composite foamed plastics.
  - ➢ Carbon Capture Machine (Aberdeen, Scotland) –solid carbonates and building materials.
  - ➢ CarbonCure (Dartmouth, Canada) –stronger, greener concrete.
  - ➢ Carbon Upcycling UCLA (Los Angeles, CA, USA) – CO_2 absorbing concrete replacements .
  - ➢ JCOAL & Kawasaki Heavy Industry (Japan) – CO_2 Capture
  - ➢ Membrane Technologies Research (Capture)
  - ➢ University of Kentucky (Capture)



What is a feasibility study?

Wyoming CarbonSAFE is focused on investigating the feasibility of practical, secure, permanent, geologic storage of carbon dioxide (CO_2) emissions from coal-based electricity generation facilities near Gillette, Wyoming….


Cyclone Rig #32 at Dry Fork Station

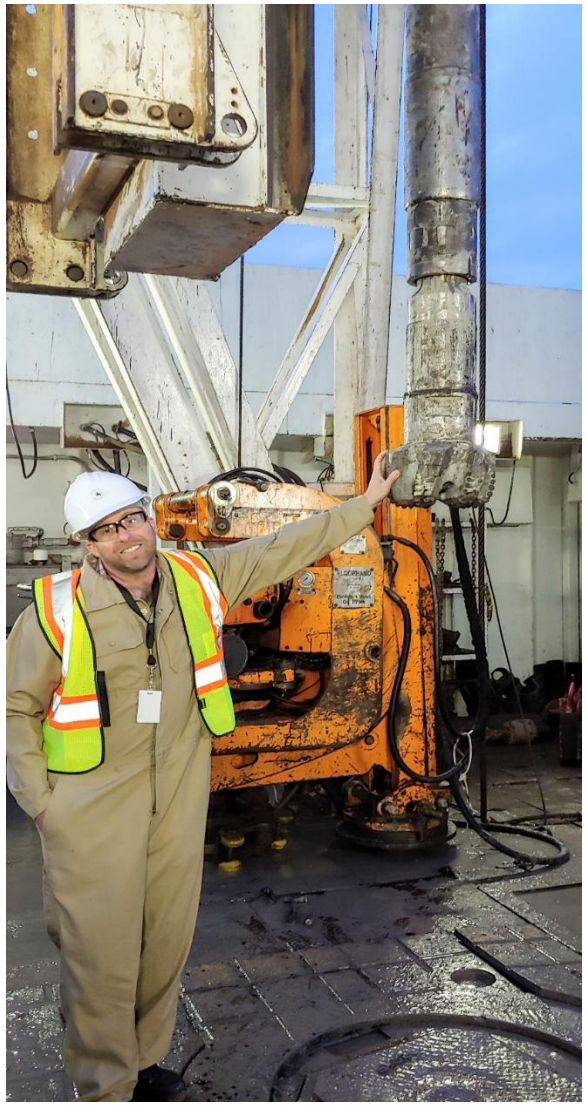
Research questions/gaps for Phase II Feasibility Study

Things we are looking for…..

- ✓ Is there sufficient volume in the subsurface to store commercial quantities of CO_2?
- ✓ Can the CO_2 be injected safely? Stored permanently?
- ✓ What are the risks/costs/policy?

[1] Commercial quantities = 50 million tons over 25 years (i.e. 2 million tons per year)

Wyoming CarbonSAFE update



- ✓ CO_2 Test Well was completed in May
- ✓ The 628 ft of core has been slabbed, cleaned and prepped for analysis
- ✓ Preliminary findings:
  - ➢ Fluid in each target formation is saline (>30,000 ppm)
  - ➢ Sufficient pore space in non-hydrocarbon bearing formations
  - ➢ Presence of thick continuous seals
- ✓ Phase III- Notice of Intent issued
  - ➢ Complete geologic characterization, assess carbon capture and permitting

Wyoming
Carbon Engineering Initiative

A Novel Integrated Solution for Making Valuable High-carbon Content Products from Powder River Basin (PRB) Coal with Near-zero Carbon Footprint

Richard A. Horner
Director Special Projects and Emerging Technology
School of Energy Resources
University of Wyoming

UNIVERSITY OF WYOMING

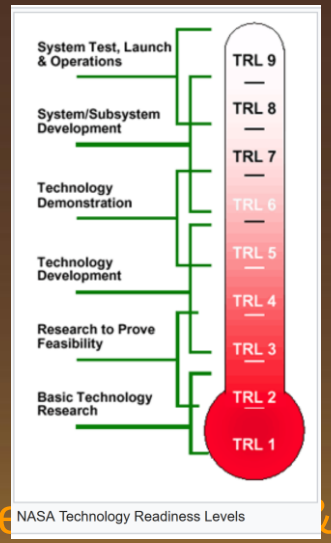
Carbon Engineering Initiative
Techno-economic Objectives

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 $116,000,000 External Investment
    - Carbon Engineering –One Time Funding : $8.8 Million

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.**

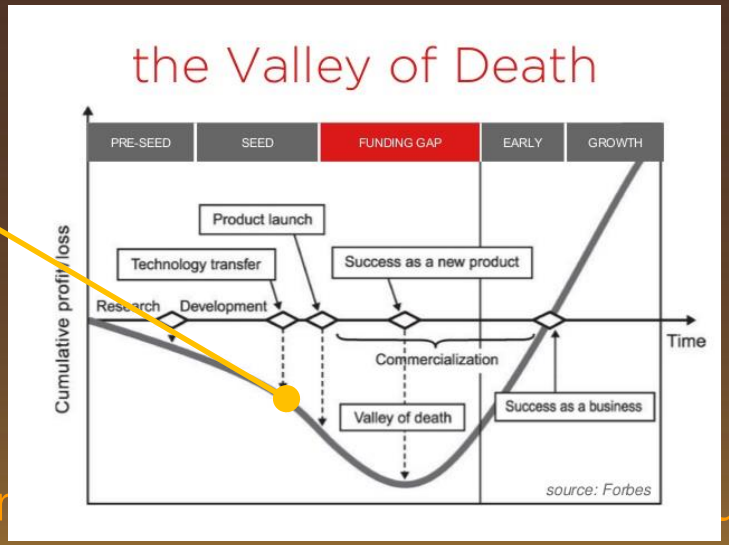


2021 - 22

2019-20

2017-18

2016

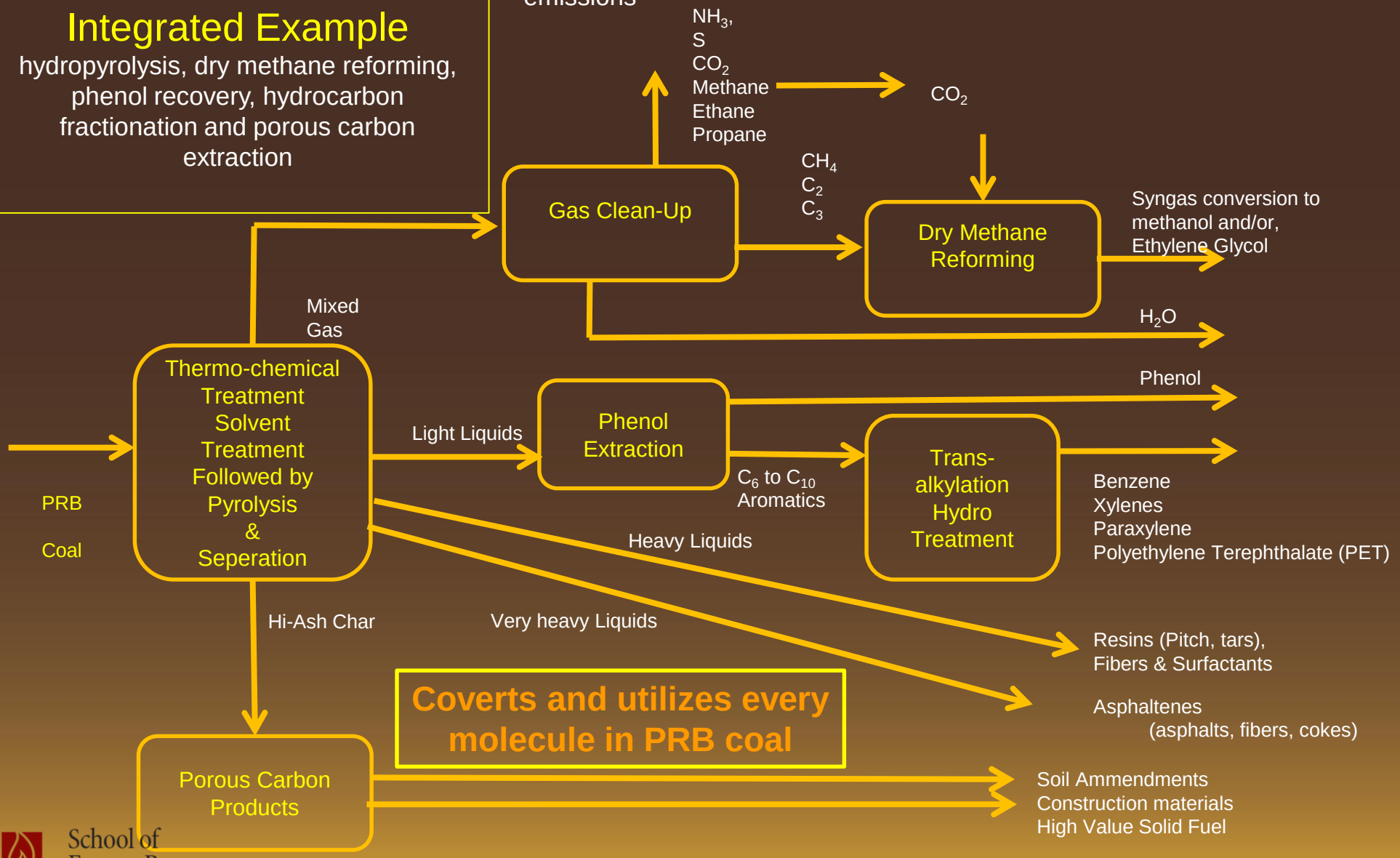


- Discre[illegible] Protected Solutions r[illegible] up to Understand Engineering Implications.

Thermo-chemical PRB Coal Conversion Integrated Example

hydropyrolysis, dry methane reforming, phenol recovery, hydrocarbon fractionation and porous carbon extraction

This is an example of how multiple technologies can be integrated into a COAL TO CARBON PRODUCT Coal Refinery with minimum CO2 emissions



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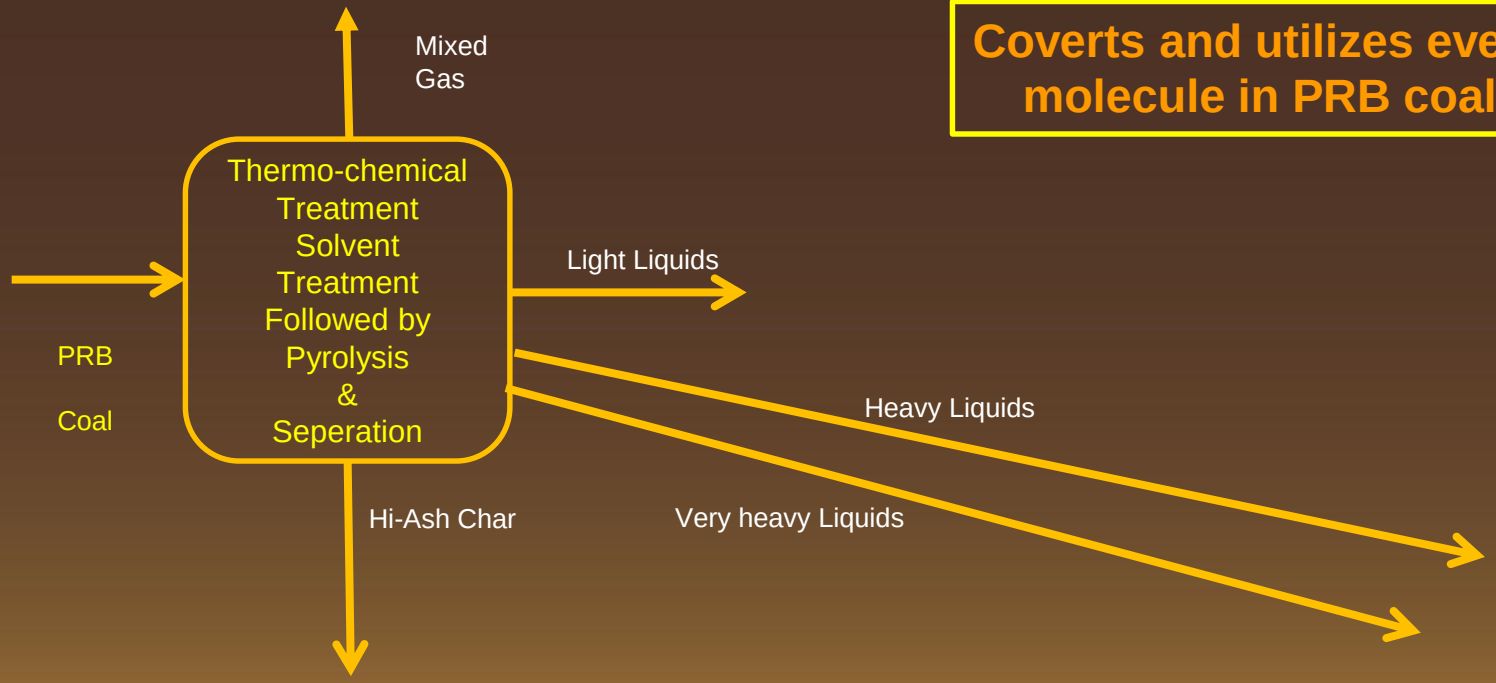
Thermo-chemical PRB Coal Conversion Integrated Example

hydropyrolysis, dry methane reforming, phenol recovery, hydrocarbon fractionation and porous carbon extraction

This is an example of how multiple technologies can be integrated into a COAL TO CARBON PRODUCT Coal Refinery with minimum CO2 emissions

Coverts and utilizes every molecule in PRB coal



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Intellectual Property

Coal Refinery - Platform Level Application

- Systems and Methods for Refining Coal into High Value Products
  - International App. No. PCT/US18/50690
  - Filed September 12, 2018
  - Published WO 2019/055529
  - Foundational level patent application
    - Combination of Solvent Extraction and Pyrolysis
    - Highly-branched, purified product distribution
  - Coordinated set of extension applications

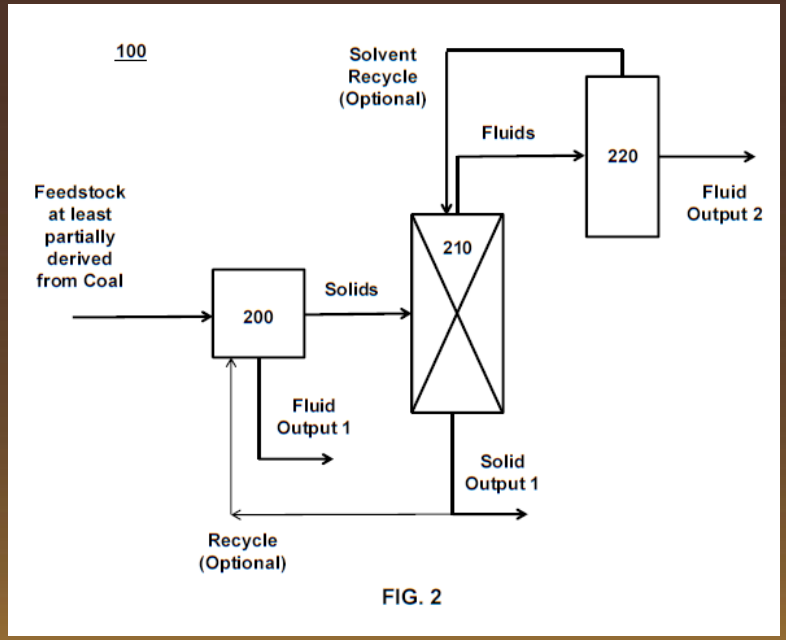

FIG. 2

Coal Refinery - IP Extensions

In Process:

Graphene Oxide from coal
Solvent Extraction of Coal to Make High Value Intermediates
High Value Molecules from Coal Using Multiple Solvent Extractions and Thermal Treatments

Carbon Engineering Initiative
Outlook

Framework for Private/Public Partnership in Place

- Three technology Companies on-board
- 4 Industrial partners engaged
- Venture Capital and Private Equity Funding around $200 million available
- State Match Required ($50 million)

Advancing 3rd Party Technology Solutions to Bring Promising Already developed technology to Wyoming

- Take Advantage of UW deep understanding of Wyoming coal behavior
- Demonstrate performance (of 3rd Party technology) on Wyoming PRB Coal
- Three (3rd Party) technologies currently being demonstrated on PRB coal.
  - Clean Coal Technologies Inc
  - Carbon Fuels LLC – DOE Award
  - Itea SpA –DOE Award
- Non exclusive technology-transfer Agreements negotiated (two complete and three more in pipeline)

Wyoming Technology Development Ecosystem

- Supporting Creation of Advanced Carbon Products Innovation Center (ACPIC)
- Identifying Site Locations in Wyoming for commercial industrial development

.....Thank you