Breaking It Down: Carbon Capture, Utilization & Storage Technologies

NARUC-WIEB Carbon Capture, Utilization, and Storage Workshop

FRIDAY, SEPT. 18, 2020| 1 – 2 PM ET

SPEAKERS

- **Dr. Holly Krutka,** Executive Director, School of Energy Resources, University of Wyoming
- **Jason Begger,** Wyoming Energy Authority
- **Scott Quillinan,** Director of Research, School of Energy Resources, University of Wyoming

Carbon Capture Technology Overview

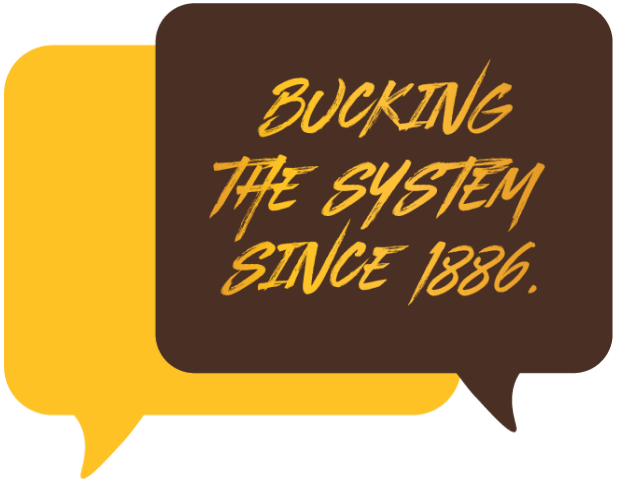
Holly Krutka, PhD
Executive Director
UW School of Energy Resources

Prepared for the NARUC-WIEB CCUS
September 18, 2020

THE WORLD NEEDS MORE COWBOYS.

SER's Mission:

Energy-driven development for Wyoming



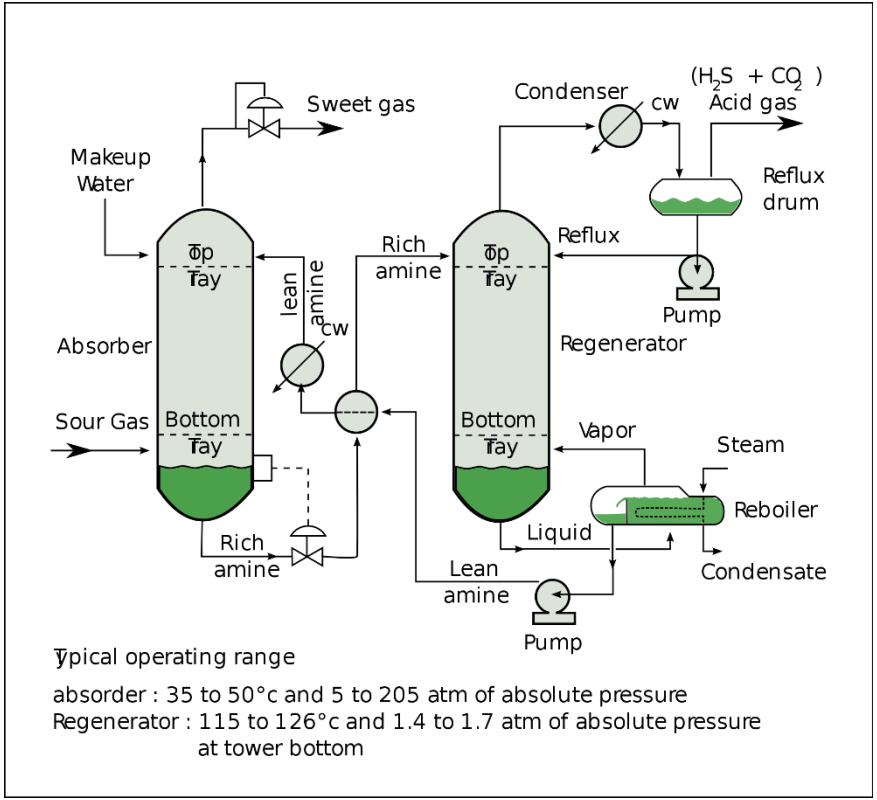
Carbon Capture Technology Overview

THE WORLD NEEDS MORE ADVENTUROUS SPIRIT.

Post-Combustion: Aqueous Amines

Process Overview:

- Used in many industries to strip acid gases
- Solvent is used repeatedly
- Reacts with CO_2 in Absorber
- Releases purified CO_2 in Regenerator



Post-Combustion: Petra Nova

- Technology provider: Mitsubishi Heavy Industries
- Completed on schedule, on budget
- Designed for 90% capture rate
- Demonstrated capture rate of **92.4%**
- First of a kind on a coal-fired power plant
- Next of a kind will be less expensive
- $190 million from DOE

Image credit: www.nrg.com/case-studies/petra-nova.html

Post-Combustion: In Development

- DOE has a robust CO_2 capture program aimed at reducing overall cost in terms of $/ton
- Novel technologies advancing
  - Advanced amines
  - Non-aqueous liquids
  - Solid adsorbents
  - Membranes
  - Novel concepts and hybrid systems

Sources: NETL, Cost and Performance Baseline for Fossil Energy Plants, Revision 3, July 2015; NETL Cost and Performance Baseline for Fossil Energy Plants, September 2019.

Image credit: https://netl.doe.gov/sites/default/files/netl-file/20CCUS_Ackiewicz.pdf

Pre-Combustion: Overview

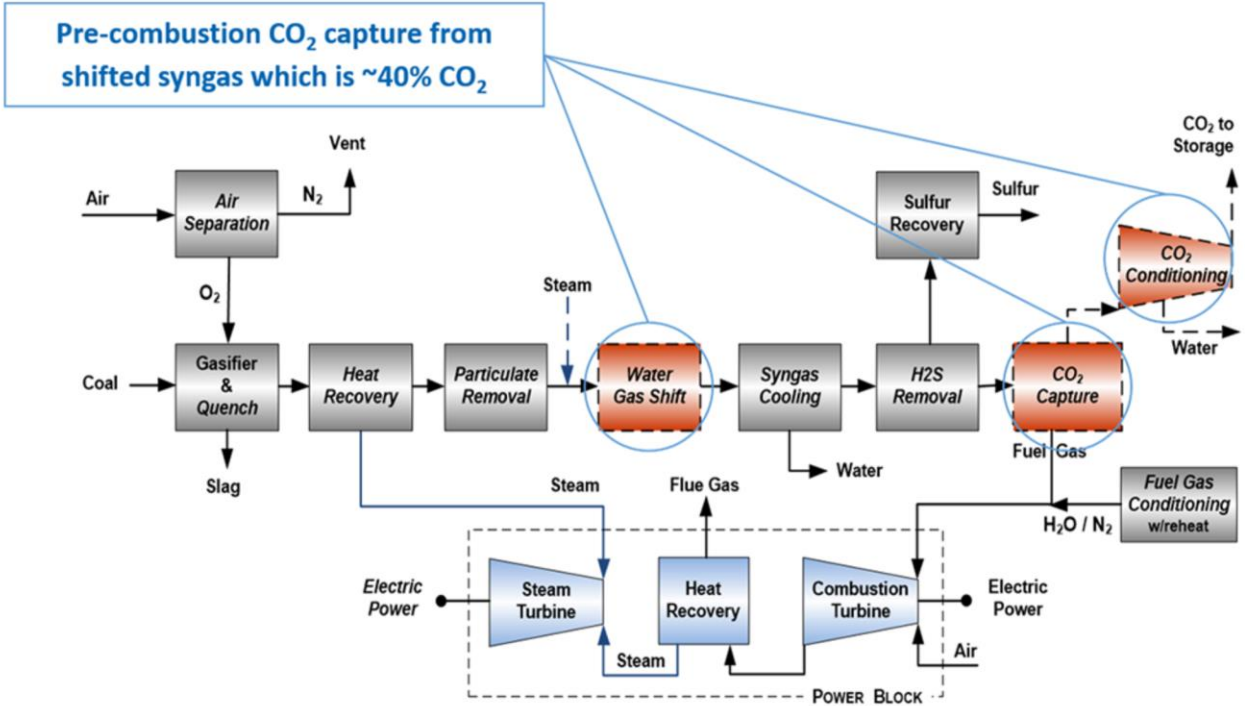


Image credit: https://netl.doe.gov/coal/carbon-capture/pre-combustion

Advanced Systems: Overview

Programs:
- CoalFIRST
- Large-pilot

Select Technologies:
- Allam Cycle
- Chemical looping
- Pressurized oxy-combustion
  - Staged, pressurized oxy-combustion
  - Flameless, pressurized oxy-combustion

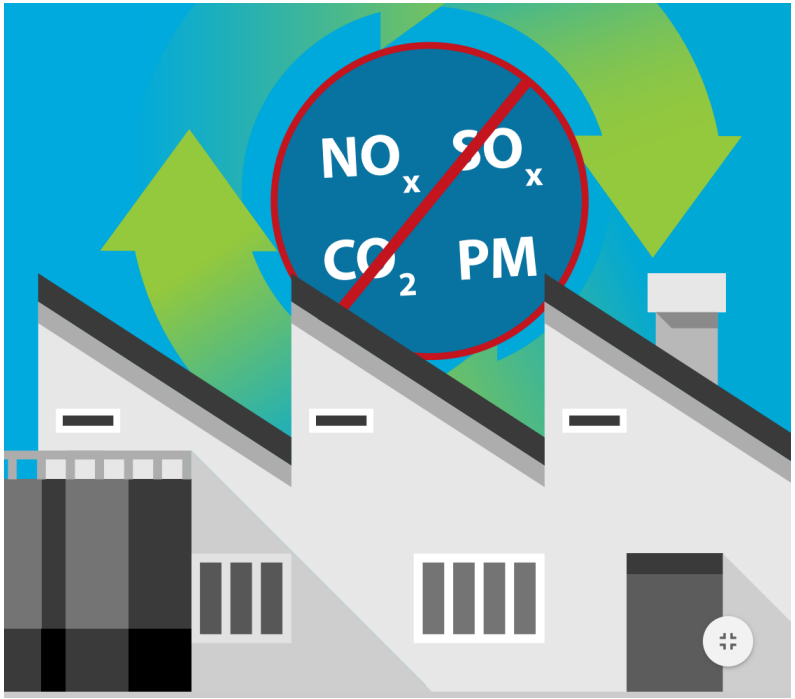
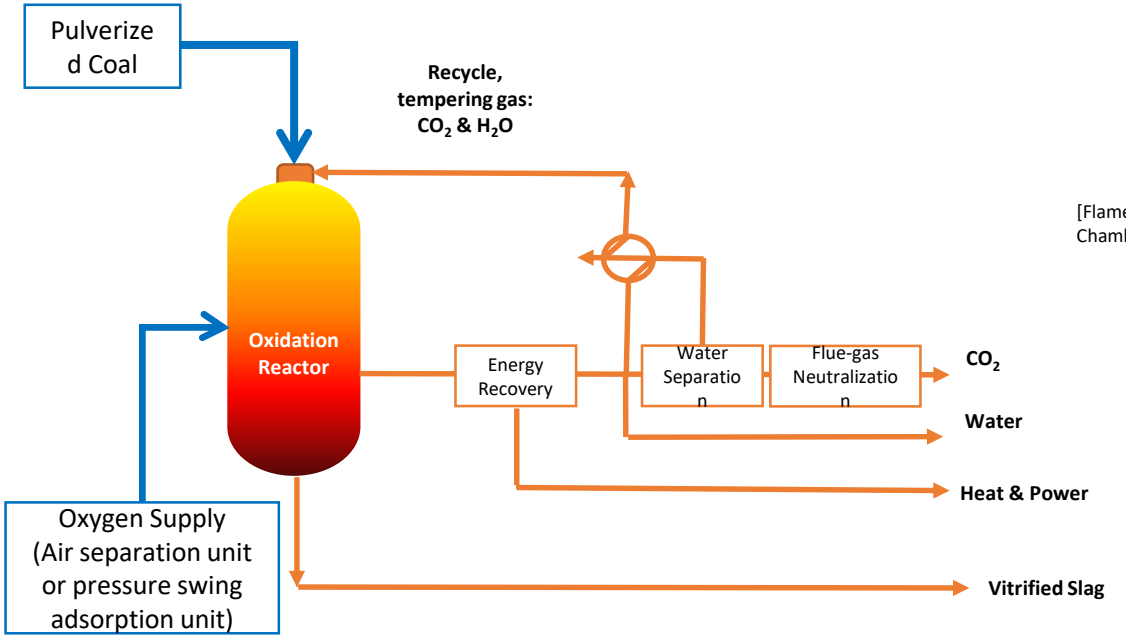
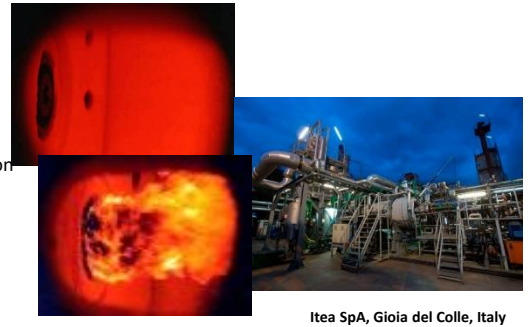


Image credit: netl.doe.gov/sites/default/files/netl-file/Coal-Fired%20Plants%20of%20the%20Future%20Infographic.pdf

A Novel Approach to Fossil Fuel Consumption: Flameless Pressurized Oxy-combustion



[Flameless Combustion Chamber]



Itea SpA, Gioia del Colle, Italy demonstration facility (5MWth)

Session 25: FPO-focused presentation, Richard Horner

Wyoming Background

- Mineral industry maintains a strong social license to operate
- Largest coal producer in the country
- Largest coal mines in the world by volume and the related infrastructure
- Extremely low mining costs
- PRB coal offers lower upstream methane emissions
- Class VI well primacy
- Supportive state and local governments
- Proactive communities that are demonstration-ready
  - Wyoming Integrated Test Center
  - Wyoming Innovation Center facility
  - Upton shovel-ready industrial park

Carbon Capture Technology Overview

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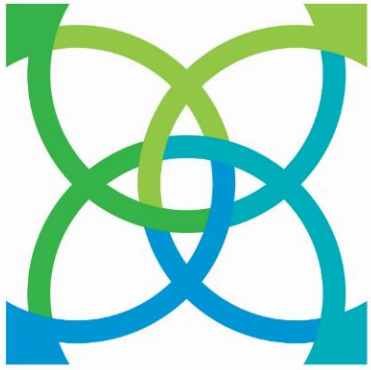

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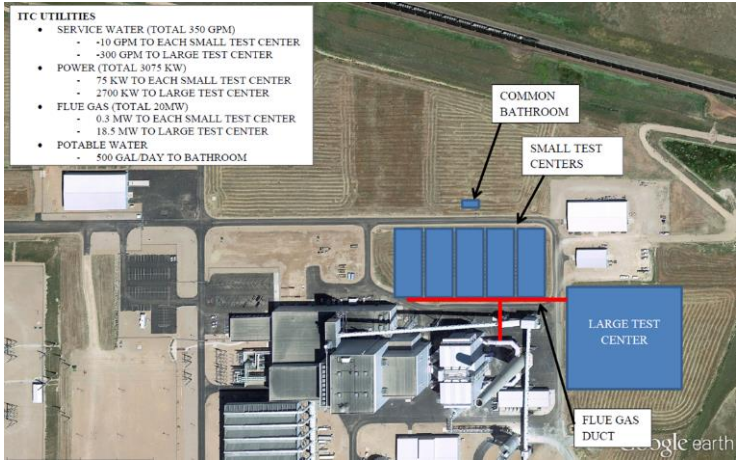
Powering the Nation, Fueling Innovation

What exactly is the ITC?

- Only facility of this size in the western hemisphere
- Supplied with 20 MW equivalency of flue gas from the Dry Fork Power Station
- Simple design keeps costs low, provides flexibility for researchers and quick turnaround time
- Designed for maximum flexibility and scalability for testing – not a laboratory



Credit: Basin Electric Cooperative

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ITC Partners

- State of Wyoming - $15 million
- Basin Electric – Host at Dry Fork Station
- Tri-State G&T - $5 million
- National Rural Electric Cooperatives Association - $1 million
- Wyoming Infrastructure Authority – Managing Entity
- Black Hills Corp. and Rocky Mountain Power providing technical expertise and in-kind contributions

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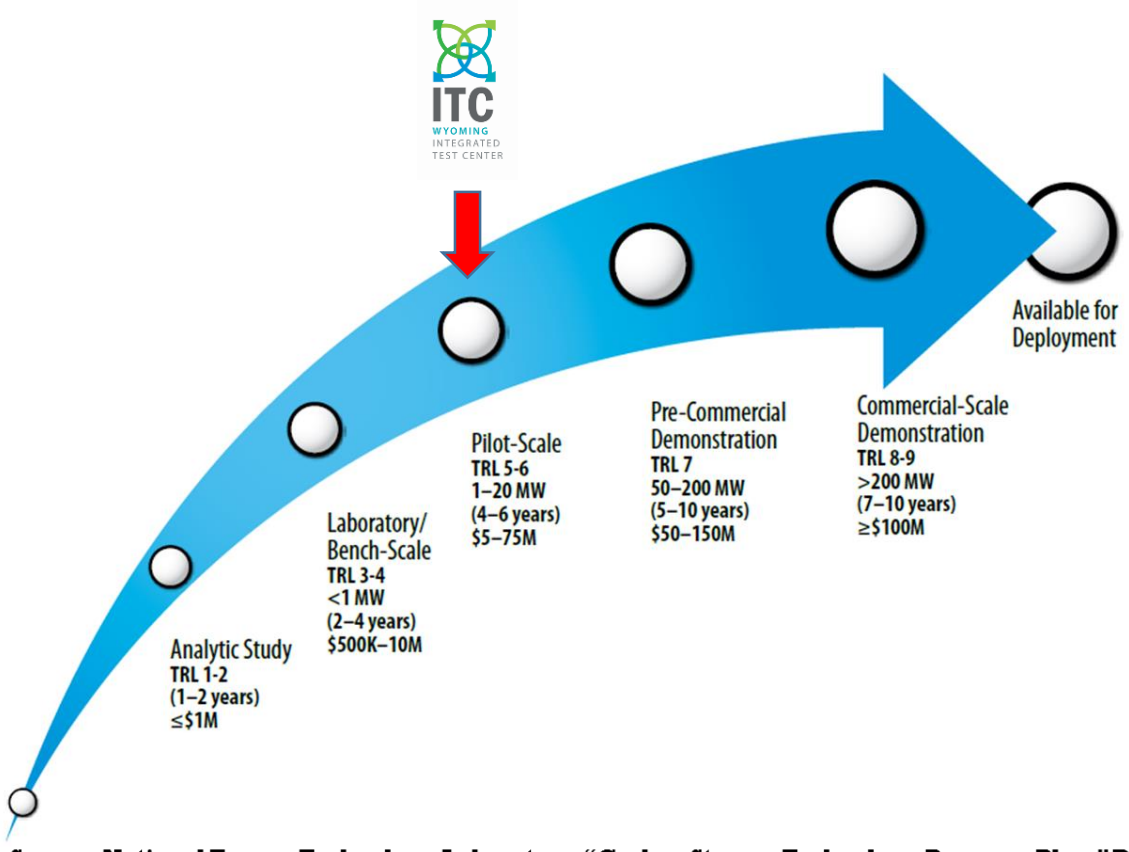
BASIN ELECTRIC POWER COOPERATIVE
A Touchstone Energy® Cooperative

TRI-STATE G&T
A Touchstone Energy® Cooperative

National Rural Electric Cooperative Association
A Touchstone Energy® Cooperative

R&D Timeline



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Source: National Energy Technology Laboratory, "Carbon Storage Technology Program Plan," December 2014

The Integrated Test Center

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Phase 1 of CCUS

Capturing CO2

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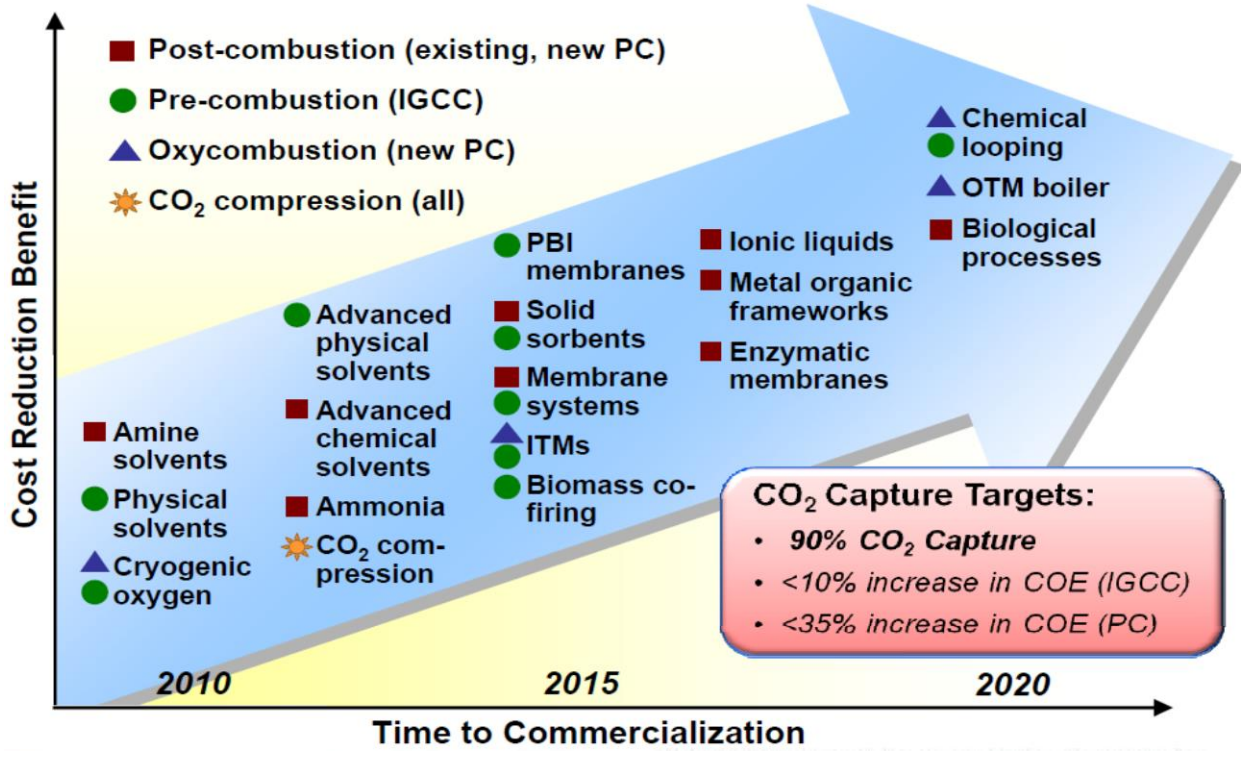
Phase 1 of CCUS

CO2 Capture



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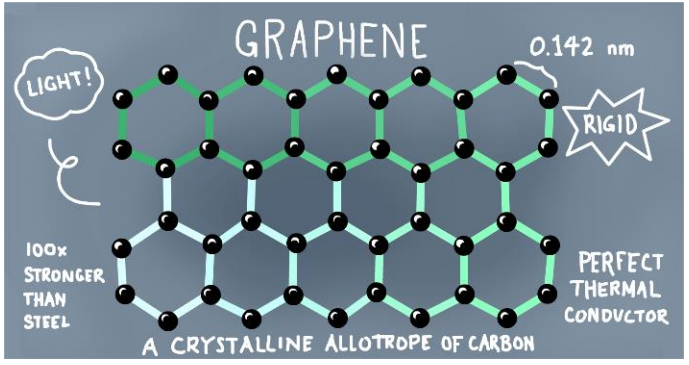
Phase II of CCUS

What do we do with the CO2?

1. Geologic Sequestration
   - EOR
   - Permanent sequestration
2. **CO2 Conversion/Utilization**
   - **Conversion to other products**



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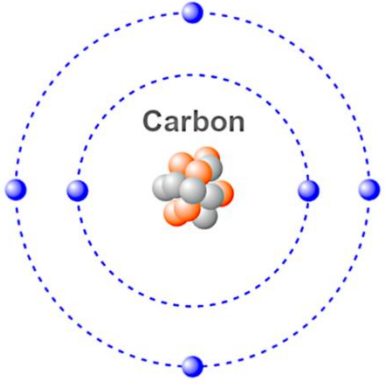
What is carbon?

- Diamonds
- Graphite
- Present in all living organisms
  - Tree – 50%
    - Absorb carbon dioxide, expel oxygen
  - Humans – 18%
    - Absorb oxygen, expel carbon dioxide
    - Absorb carbon through diet – e.g. carbohydrates
- Fossil energy
  - Hydrocarbons



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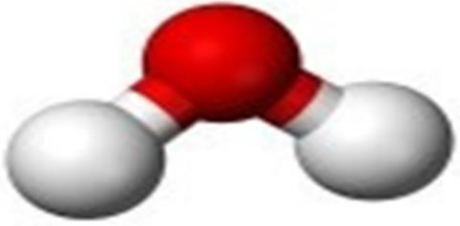
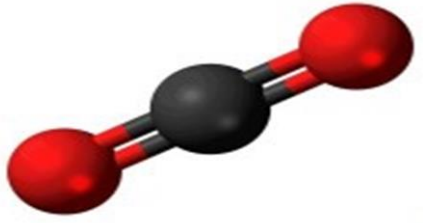
What's the issue?

When hydrocarbons are burned, the hydrogen is consumed and water and carbon dioxide are formed.



Water



Carbon Dioxide

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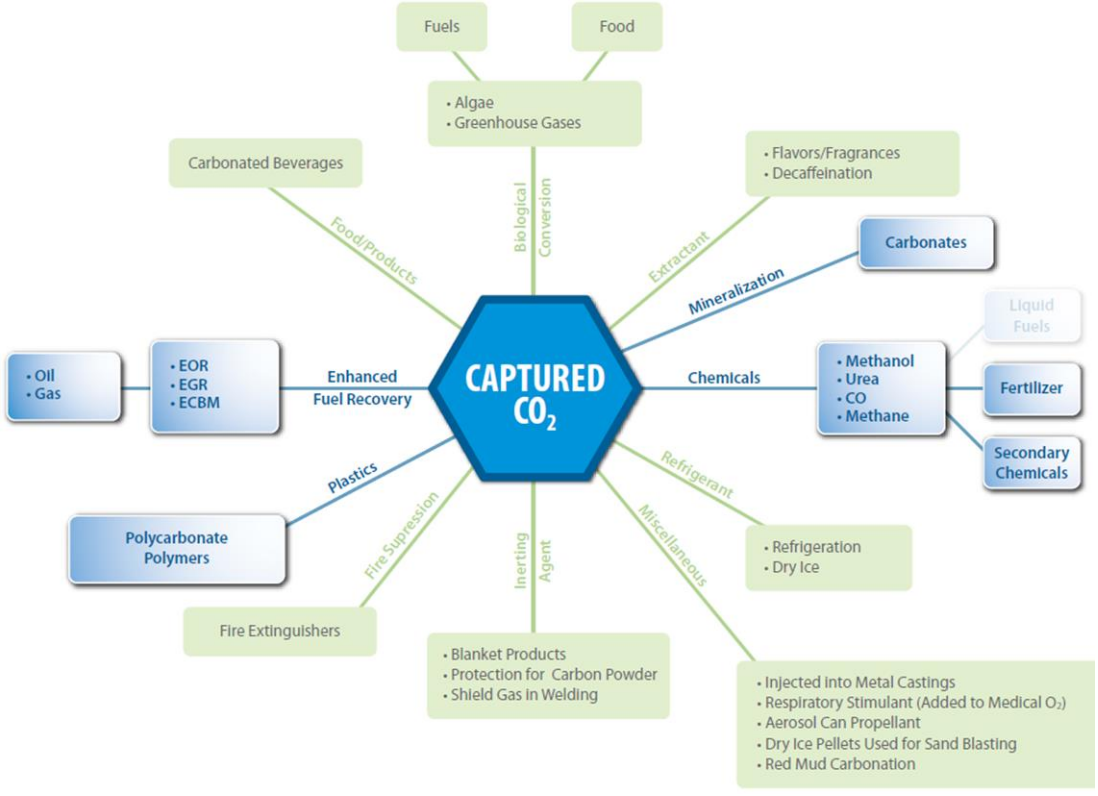
Phase II of CCUS

CO2 Conversion/Utilization



Source: National Energy Technology Laboratory, "Carbon Storage Technology Program Plan," December 2014

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XPRIZE Foundation

"The $20M NRG COSIA Carbon XPRIZE will challenge the world to reimagine what we can do with CO_2 emissions by incentivizing and accelerating the development of technologies that convert CO_2 into valuable products."

- In September 2015 announced Carbon XPRIZE competition with NRG and COSIA
- Two tracts
  - Natural gas
  - Coal
- Three rounds of competition per tract
  - 1 – Technical Papers – up to 15 teams will move on
  - 2 – Small scale, laboratory testing – up to 5 teams will share $2.5 million prize
  - 3 – Real world, larger scale – grand prize of $7.5 million

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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) – Based out of the University of Aberdeen, 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, New York, US) – CEO Jason Salfi is using photocatalysis to convert CO2 to fuel.

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.

JCOAL – GreenOre

- June 2019 – Wyoming Infrastructure Authority, JCOAL (Japan Coal Energy Center), Columbia University MOU.
- November 2019 – ITC site visit
- November 2019 – Agreement reached to proceed with test skid

A slag carbonation pilot plant owned by the JV between GreenOre and Baotou Steel Group (China), commissioned Spring 2019.

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Questions?

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Geologic storage of CO2: Characterization and permitting

Scott Quillinan, Director-Center for Economic Geology Research, University of Wyoming
September 18th, 2020

Western Interstate Energy Board

NARUC Subcommittee on Clean Coal and Carbon Management

Carbon Capture, Utilization & Storage Workshop

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Disclaimer

Acknowledgment: This portion of the presentation is based upon work supported by the Department of Energy under Award Number DE-FE0031624.

Points of Discussion

- DOE Carbon Storage Assurance Facility Enterprise
- Primer on CO2 Storage
- Class VI Underground Injection Control
- Case Study-Wyoming CarbonSAFE

Department of Energy's CarbonSAFE Program

Carbon Storage Assurance Facility Enterprise (CarbonSAFE)

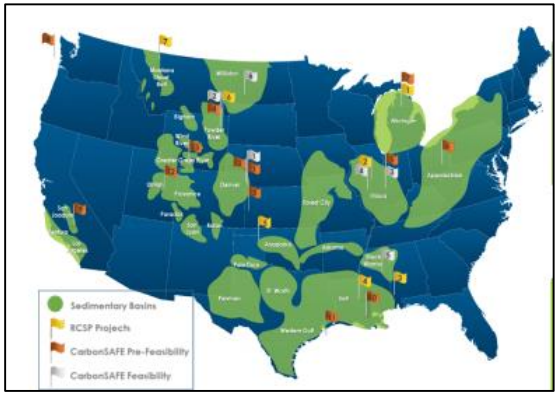
CarbonSAFE Objectives

⇒ Address the R&D knowledge gaps and develop the technologies needed to nationally deploy commercial scale (50+ million metric tons) CO_2 storage.

⇒ Understand the development of a CCUS storage complex from the feasibility study through the point of injection.

⇒ Improve understanding of commercial-scale project screening, site selection, geologic characterization, modeling, and monitoring.

⇒ Address both the technical and non-technical challenges associated with characterization, permitting, and monitoring of a geologic storage complex.



Phase I: Integrated CCS Pre-Feasibility
18-month initiative

- Formation of a team; development of a feasibility plan; and high-level technical evaluation of the sub-basin and potential CO_2 sources
- Thirteen projects funded

Phase II: Storage Complex Feasibility
2-year initiative

- Data collection; geologic analysis; analysis of contractual and regulatory requirements; subsurface modeling; risk assessment; evaluate monitoring requirements; and public outreach
- Six projects funded

Phase III: Site Characterization and CO_2 Capture Assessment
3-year initiative

- Detailed site characterization; obtain Underground Injection Control (UIC) Class VI Permit to construct; CO_2 Capture Assessment; NEPA approvals

Phase IV: Permitting and Construction of Storage Complex
2.5-year initiative

- Obtain UIC Class VI permit to inject; drill and complete injection and monitoring wells; develop risk and mitigation plans
- Subject to future funding

https://netl.doe.gov/node/9667

Department of Energy's CarbonSAFE Program

*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 Dry Fork Station Gillette, Wyoming….*

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)

https://www.youtube.com/watch?v=UoYnC4h7_Dg&feature=youtu.be

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Wyoming CarbonSAFE Program

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

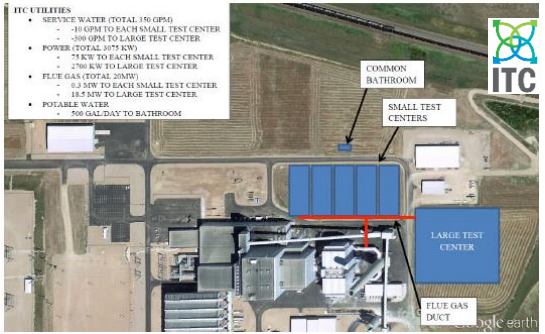
Dry Fork Station

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

BASIN ELECTRIC POWER COOPERATIVE
A Touchstone Energy® Cooperative

WY-Integrated Test Center (ITC)

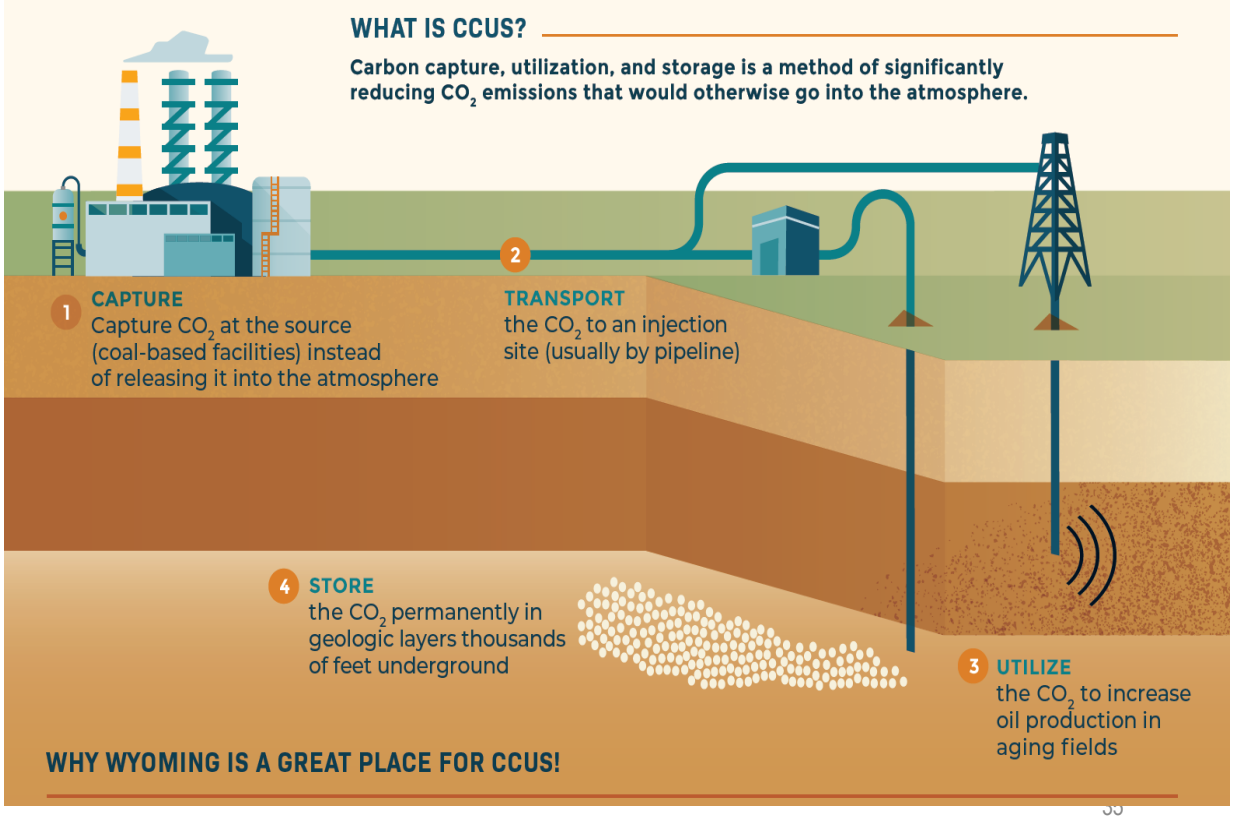
- ✓ Completed fall 2017
- ✓ Test CO_2 capture/CCUS technologies
- ✓ $20 Million public/private investment
- ✓ NRG COSIA Carbon XPRIZE ($20M global competition to develop breakthrough technologies for CO_2 emissions)



Carbon Capture, Use, and Storage Primer

CO2 Enhanced Oil Recovery: Utilizes CO_2 to extract 30-60% more of the reservoirs oil reserve

Saline Aquifer Geologic Storage: CO_2 storage in deep, pressurized, formations that contain only salt water



Overview of Class VI wells

"**The minimum criteria for siting** must be located in areas with a **suitable geologic system**, including an **injection zone** that can receive the total anticipated volume of carbon dioxide and **confining zone(s)** to contain the injected carbon dioxide stream and displaced formation fluids [40 CFR 146.83]."

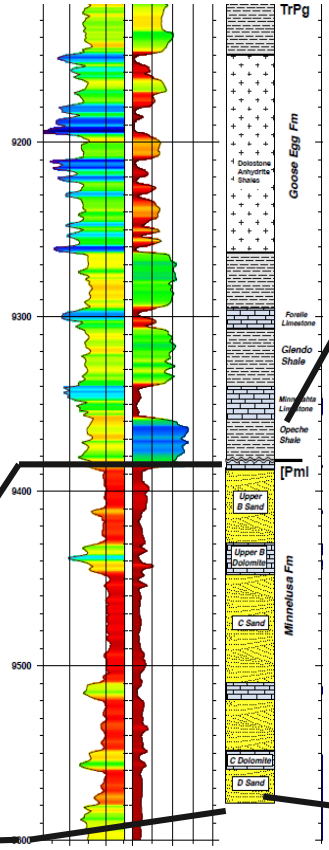
"Beginning with the permit application and continuing through the life of the project, owners or operators must submit materials related to:

- Site characterization and pre-injection logging and testing;
- AoR modeling and corrective action;
- Well construction and operation;
- Financial responsibility demonstrations;
- Testing and monitoring during the injection and post injection phases;
- Well plugging and site closure, including non-endangerment demonstrations; and
- Emergency and remedial response."

Suitable geologic system

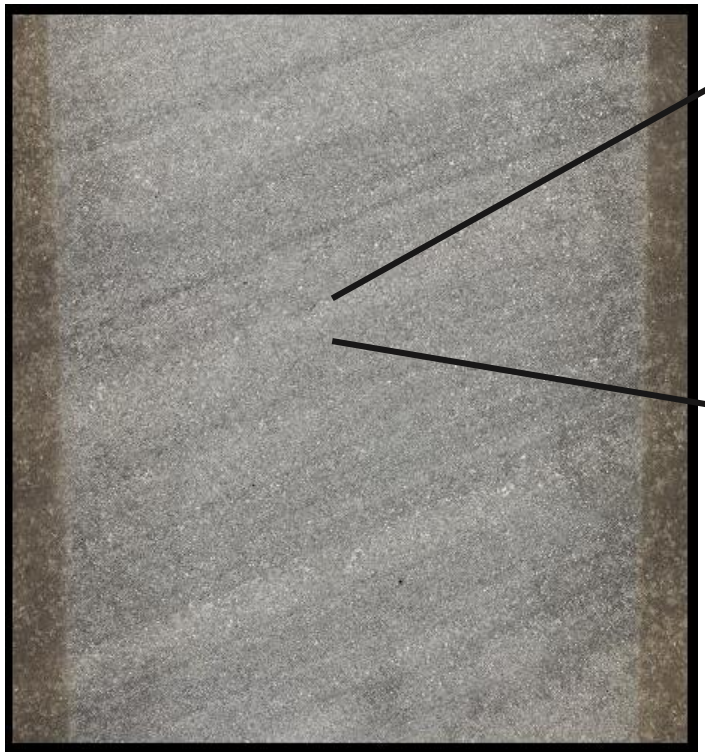
Examples from Wyoming CarbonSAFE

Age	Formation/Member	
Recent		alluvium and stream terraces
Paleocene		Fort Union Formation
		Lance Formation
		Fox Hills Sandstone
Upper Cretaceous		Pierre (Lewis) Shale
		Niobrara Formation
		Carlile Shale
		Belle Fourche Shale
		Mowry Shale
		Muddy Sandstone
Lower Cretaceous		Skull Creek Shale
		Fall River (Dakota) Formation
		Lakota Formation
		Morrison Formation
Upper Jurassic	Upper Sundance	Redwater Shale member
	Lower Sundance	Hulett Sandstone member
		Stockade Beaver Shale member
		Canyon Springs Sandstone member
Middle Jurassic		Gypsum Spring Formation
Triassic		Spearfish Formation
Permian	Goose Egg Formation	Ervay Salt member
		Minnekahta Limestone
		Opeche Formation
Pennsylvanian		Minnelusa Formation
Mississippian		Madison Limestone

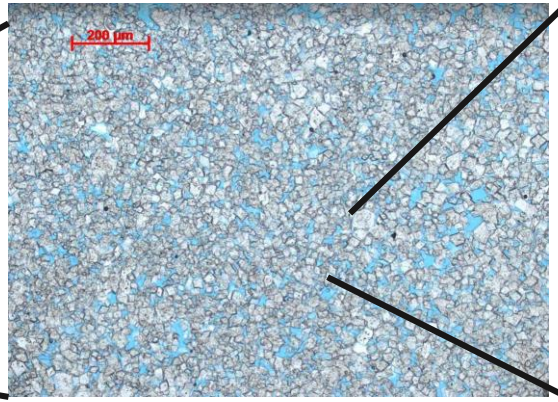


Injection Zone: Reservoir Rock

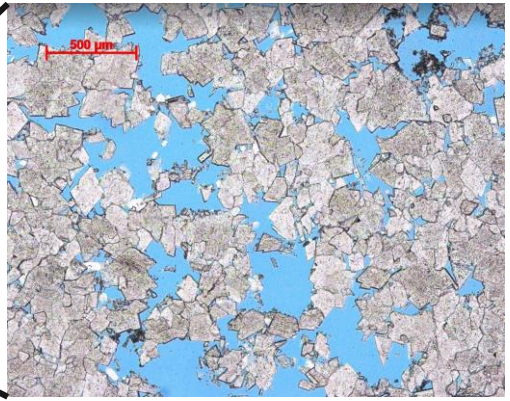
Examples from Wyoming CarbonSAFE



The rock…



The rock, but closer…



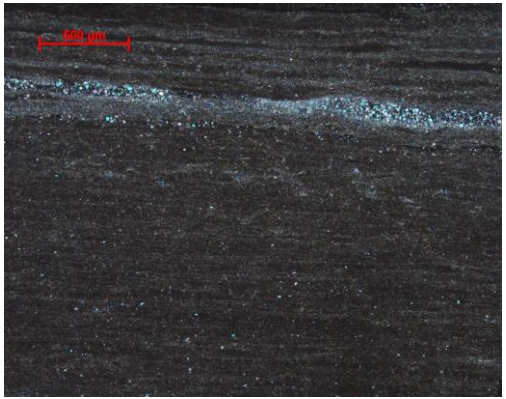
The rock, but even closer…

Porosity-Rock's ability to hold fluid

Permeability-Rock's ability to allows fluid to flow within the rock matrix

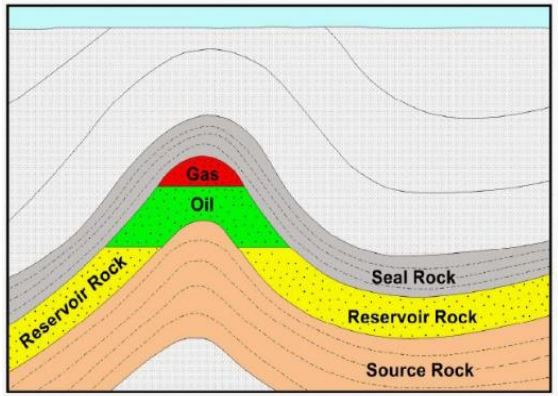
Confining Zone(s)

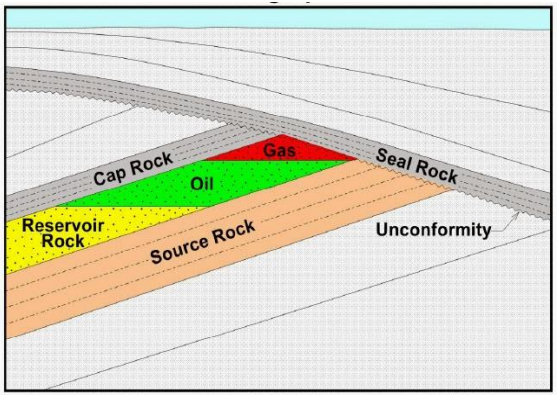
The seals…..



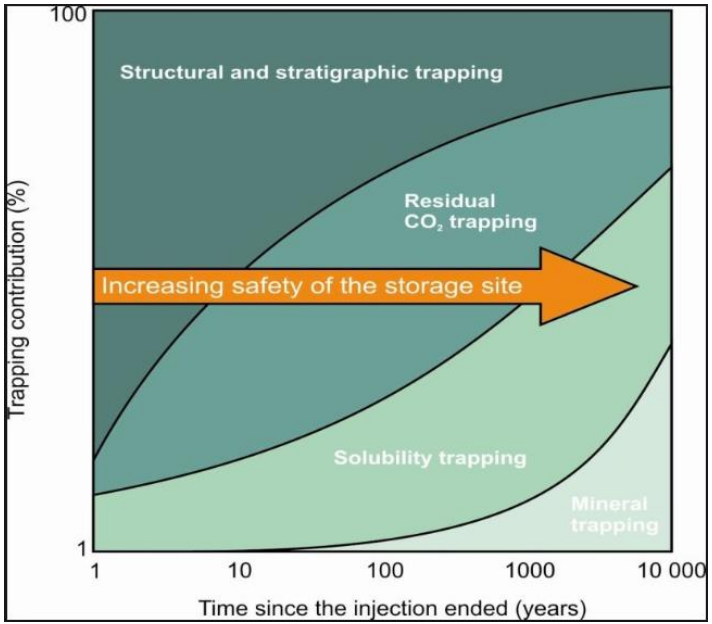
Reservoir

The traps…





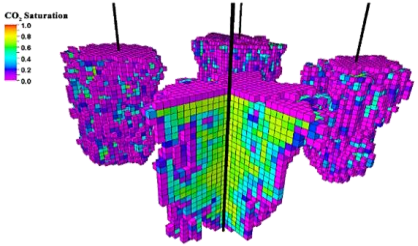
Mineralization…



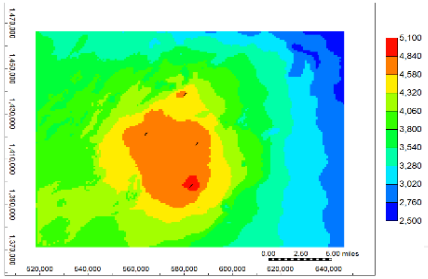
Calculating the area of review (AOR)

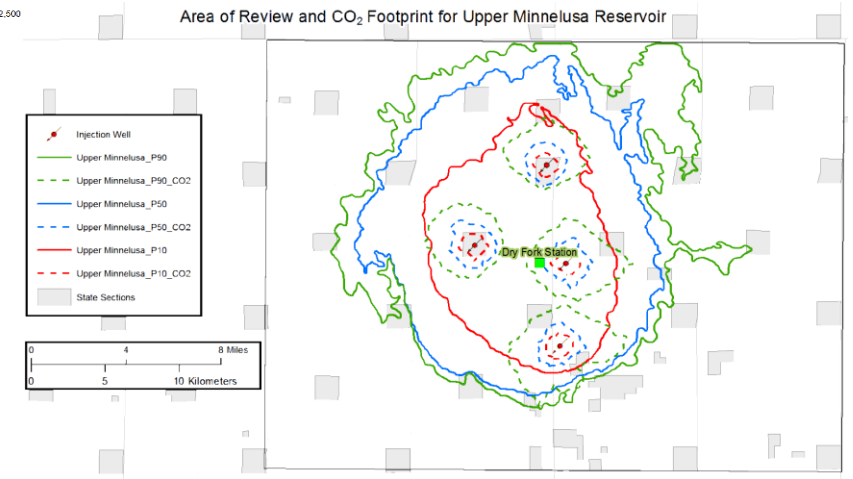
Example from Wyoming CarbonSAFE

Revised Numerical Simulations Of CO_2 Injection



Simulated Pressure Response



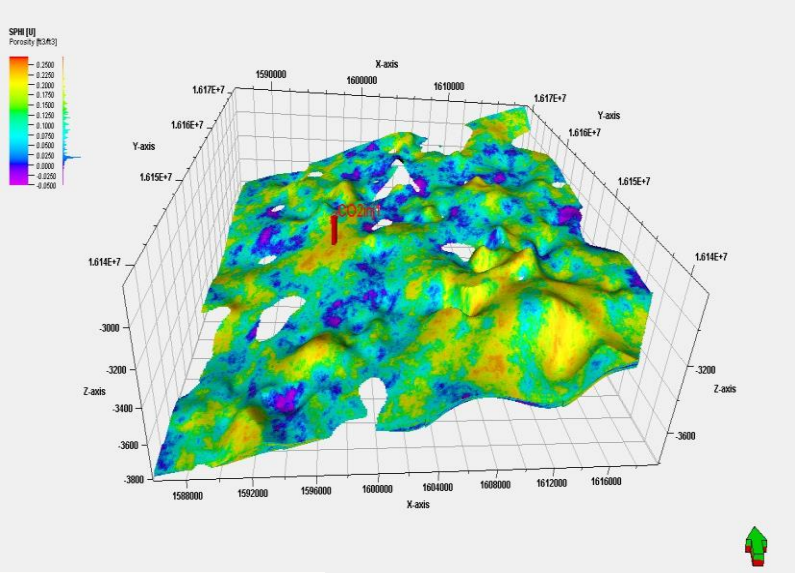


- **Area of Review: "**the region surrounding the geologic sequestration project where **USDWs may be endangered by the injection activity**. The area of review is delineated using computational modeling that accounts for the physical and chemical properties of all phases of the **injected carbon dioxide stream and displaced fluids**, and is based on available site characterization, monitoring, and operational data as set forth in 40 CFR 146.84.2"

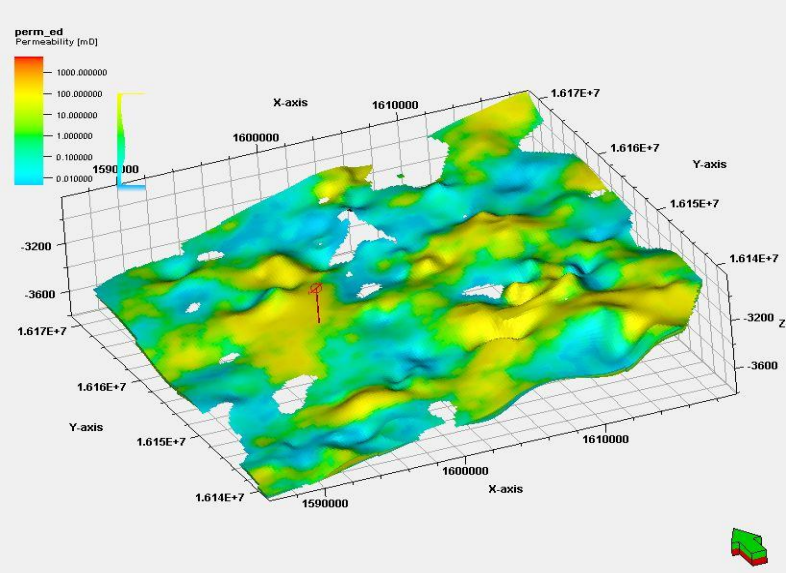
Understanding geologic heterogeneity

Example from Wyoming CarbonSAFE

The porosity varies a lot across formation (0.01% to 27%).



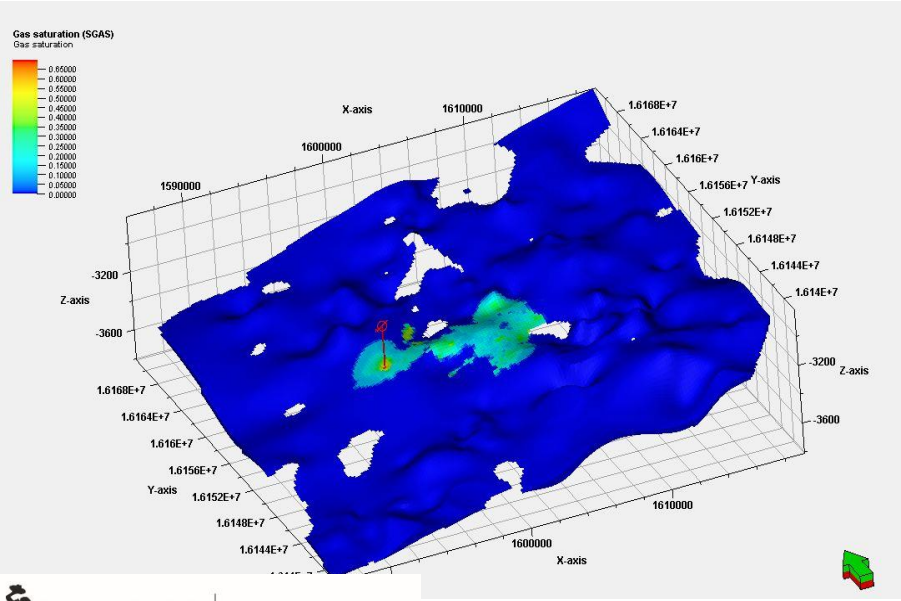
The permeability also varies a lot across formations (0.004 to 100 mD).

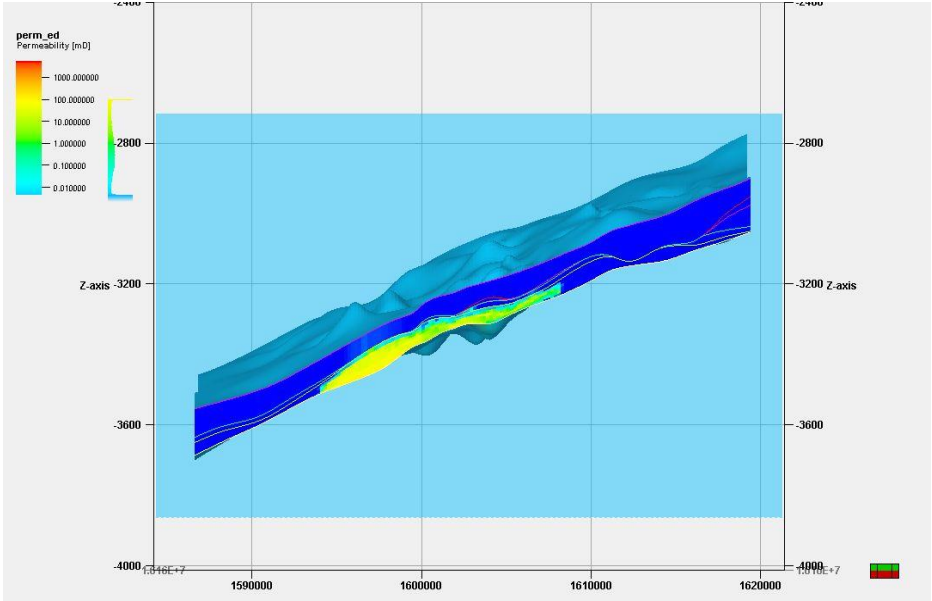


Understanding geologic heterogeneity

Example from Wyoming CarbonSAFE

The distribution of CO2 plume after 50 years injection. The expanding CO2 is about 1.5 miles from the injection well. It is completely contained in formation.



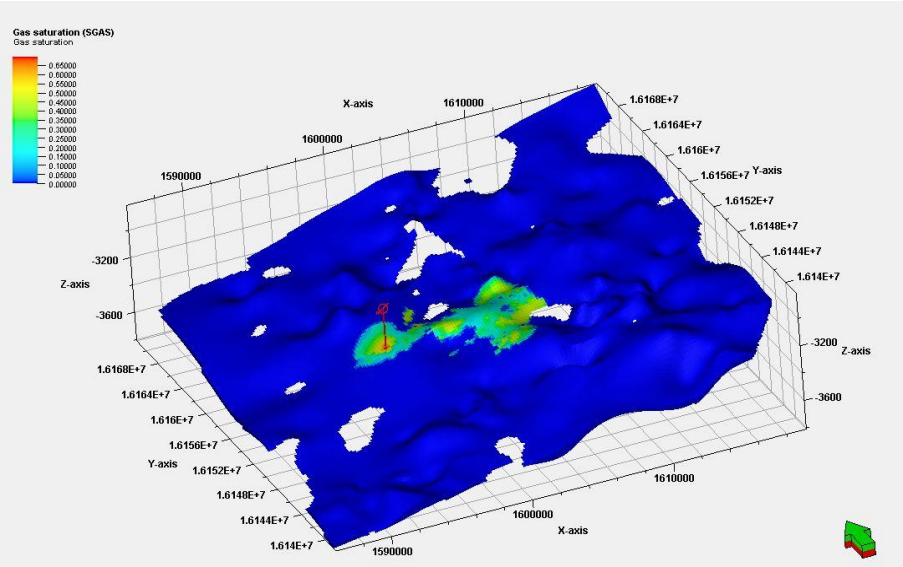


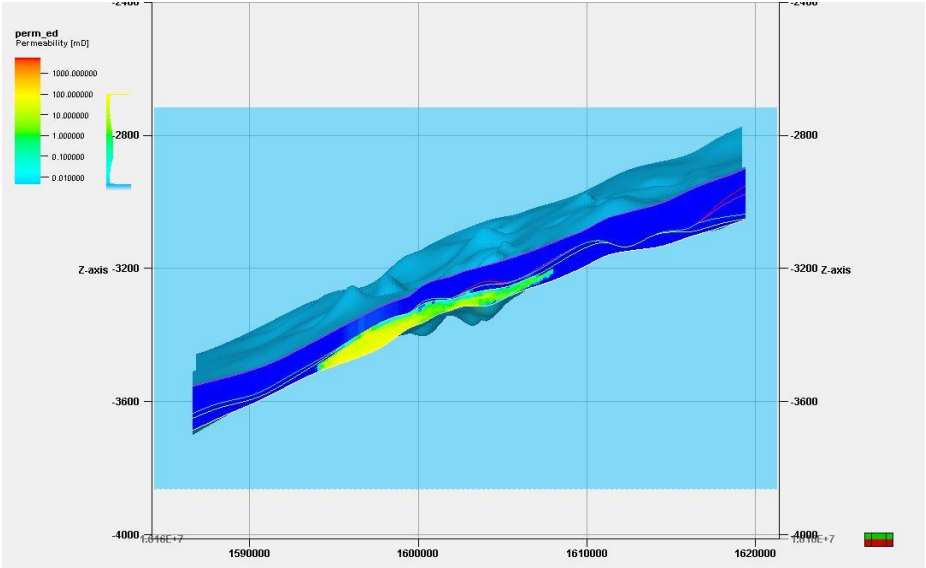
UW School of Energy Resources

Understanding geologic heterogeneity

Example from Wyoming CarbonSAFE

The distribution of CO2 plume after 50 year of post injection. The expanding CO2 only occurs at upper dip direction. The saturation of the CO2 decreases slightly through post injection time, and the reservoir pressure is reduced significantly after 10 year of post injection.

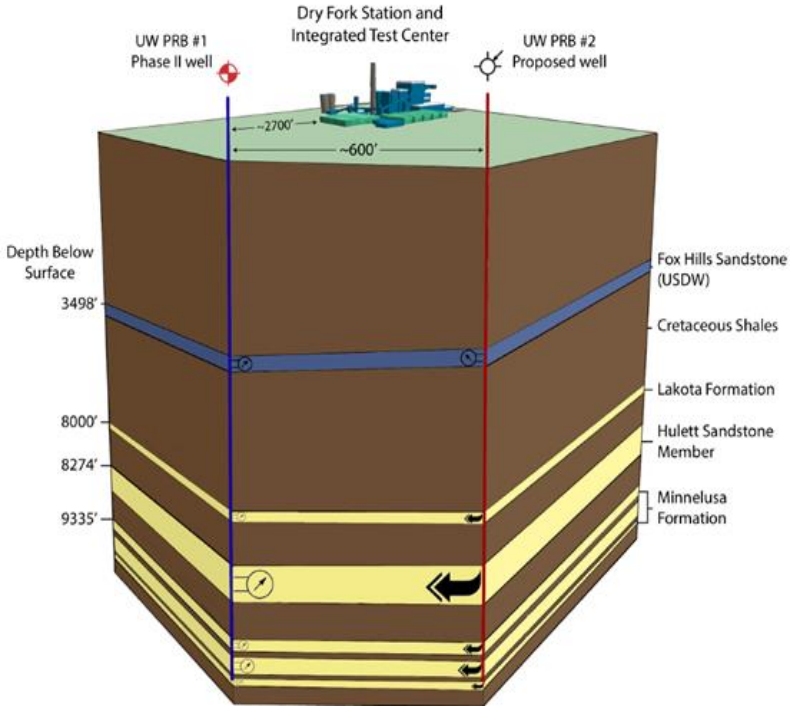




What's next for Wyoming CarbonSAFE

Example from Wyoming CarbonSAFE

- Commercial-scale subsurface injection testing and monitoring
- Finalize geologic characterization
- Prepare and file Class VI permits
- Integrate this project with a separately funded CO_2 capture study
- Conduct the required NEPA analyses for commercialization of the site



Geologic storage of CO2: Characterization and permitting

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Western Interstate Energy Board

NARUC Subcommittee on Clean Coal and Carbon Management

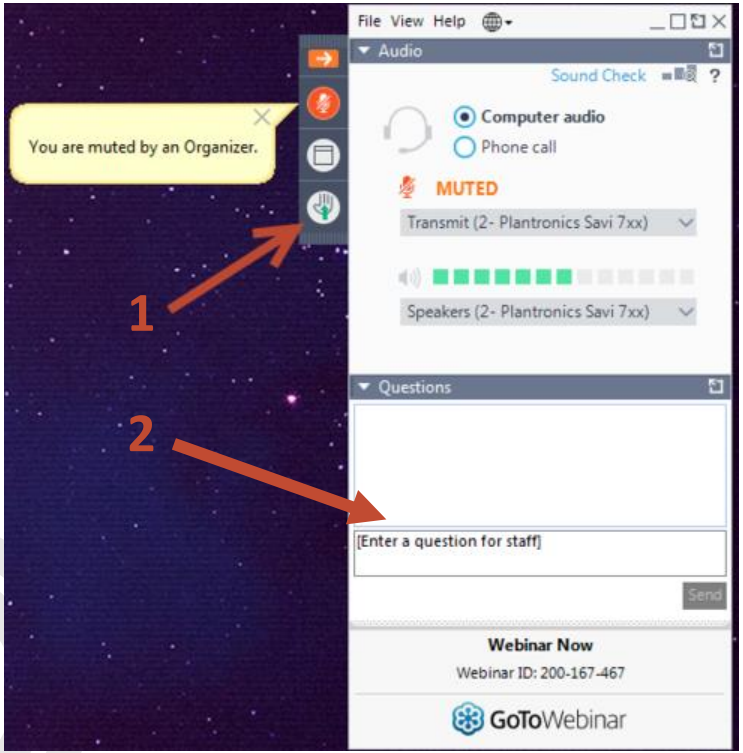
Carbon Capture, Utilization & Storage Workshop

QUESTIONS

Submit questions two ways:

1. Raise your hand and the moderator will call on you to unmute your line

2. Type a question into the question box



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NARUC-WIEB CCUS WORKSHOP SCHEDULE

1. Sept. 11: The Case for Carbon Capture, Utilization, and Storage
2. **Sept. 18: Breaking It Down: CCUS Technologies**
3. Sept. 25: Financial Incentives and Investment Efforts
4. Oct. 2: Project Update Part I: Domestic CCUS Development Efforts
5. Oct. 9: Project Update Part II: International CCUS Development Efforts
6. Oct. 16: Regulatory Considerations and Policy Recommendations

Full Agenda | Registration

All webinars are held from 1:00 – 2:00 pm ET

Western Interstate Energy Board

UPCOMING NARUC EVENTS

Innovation Webinars

- Oct 22, 3-4PM (ET): Emerging Possibilities for Bulk Energy Storage
- Nov 19, 3-4PM (ET): Where the Wind Blows: Offshore Wind Outlook for State Regulators

NARUC Annual Meeting – Nov 9-11

- Registration open
- https://www.naruc.org/meetings-and-events/naruc-annual-meetings/2020-annual-meeting/

UPCOMING WIEB EVENTS

Save-the-Dates

Fall 2020 JOINT CREPC-WIRAB MEETING Webinar Series

Fridays: October 23, October 30, November 6, and November 13, 2020

11:00 – 12:30 PM (MT) / 10:00 – 11:30 AM (PT)

You are invited to join us on Fridays this October and November for the Fall 2020 Joint CREPC-WIRAB Meeting Webinar Series, where western electric utility policymakers and regulators, industry experts, consumer advocates, and other stakeholders will explore and discuss current and emerging electricity trends, challenges, and opportunities for the Western Interconnection.

https://westernenergyboard.org/

Joint CREPC-WIRAB Meetings are conducted by the Committee on Regional Electric Power Cooperation (CREPC)—a joint committee of the Western Interstate Energy Board and the Western Conference of Public Service Commissioners—and the Western Interconnection Regional Advisory Body (WIRAB).

Western Interstate Energy Board

THANK YOU

Join us for the next webinar in the NARUC-WIEB CCUS Workshop

Friday, Sept. 25 | 1:00 – 2:00 pm ET

Financial Incentives and Investment Efforts

- Michael Nasi, Partner, Jackson Walker LLP
- Shannon Angielski, Executive Director, Carbon Utilization Research Council

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