

UW School of Energy Resources

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Presented to
Wyoming Legislature
*Joint Minerals, Business &
Economic Development Committee*
August 12, 2021



UNIVERSITY
OF WYOMING

School of
Energy Resources

THE WORLD NEEDS MORE COWBOYS.

Topics

- SER history, mission and pillars
- Overview of ongoing research
- Emerging area: Hydrogen
- Research topical deeper dive
 - Rare earth elements and critical minerals
 - Carbon engineering

SER's Mission:

Energy-driven
economic development
for Wyoming



*BUCKING
THE SYSTEM
SINCE 1886.*

SER History

Language extracted from SF-0037

- To provide nationally competitive undergraduate and graduate instruction in energy related disciplines, particularly those of importance to develop Wyoming's energy resources
- To advance the state-of-the-art in Wyoming energy related science, technology and economics research
- To support scientific and engineering outreach...
- Maintain flexibility in its focus and structure to be capable of responding to the changing needs of Wyoming's energy industries with regard to instruction, research and outreach

ORIGINAL SENATE
FILE NO. 0037

ENGROSSED

ENROLLED ACT NO. 65, SENATE

FIFTY-EIGHTH LEGISLATURE OF THE STATE OF WYOMING
2006 BUDGET SESSION

AN ACT relating to the University of Wyoming; creating the school of energy resources; providing for the University of Wyoming energy resources council; requiring reports; providing an appropriation; and providing for an effective date.

Be It Enacted by the Legislature of the State of Wyoming:

Section 1. W.S. 21-17-116 is created to read:

21-17-116. School of energy resources; creation authorized; University of Wyoming energy resources council established; reports.

(a) Subject to legislative appropriation, the University of Wyoming shall operate the school of energy resources.

(b) The school of energy resources shall have the following objectives:

(i) To provide nationally competitive undergraduate and graduate instruction in energy related disciplines, particularly those of importance to develop Wyoming's energy resources;

(ii) To advance the state-of-the-art in Wyoming energy related science, technology and economics research; and

(iii) To support scientific and engineering outreach through dissemination of information to Wyoming's energy industries, companies, community colleges and governmental agencies.

1

SER Governance: Energy Resources Council

- **Cindy Crane (Chair)** – *President and CEO of Rocky Mountain Power (Retired), CEO of Enchant Energy*
- **Senator James Anderson (Co-Chair)** – *Wyoming State Senator, Senate District 28*
- **Representative Mike Greear** – *State Representative & Chairman, House Minerals, Business and Economic Development Committee*
- **Carl Bauer** – *Director, National Energy Technology Laboratory, U.S. Department of Energy (Retired)*
- **Thomas Botts** – *Executive VP of Global Manufacturing, Shell Corporation (Retired)*
- **Mark Doelger** – *President, Barlow & Haun, Geologists*
- **David Emery** – *Chairman, President and CEO, Black Hills Corporation (Retired)*
- **Vello Kuuskraa** – *President and Chairman of the Board, Advanced Resources International*
- **Randall Luthi (ex-officio)** – *Chief Energy Advisor, Governor Gordon’s Administration*
- **Charlene Russell** – *Chief Commercial Officers, Carbon America*
- **Ed Seidel (ex-officio)** – *President, University of Wyoming*
- **Dave True (ex-officio)** – *University of Wyoming Board of Trustees*
- **John Koprowski (ex-officio)** – *University of Wyoming Dean of Haub School of Environment and Natural Resources*

***Established
in 2006 by
Wyoming
SF0037***



SER Pillars

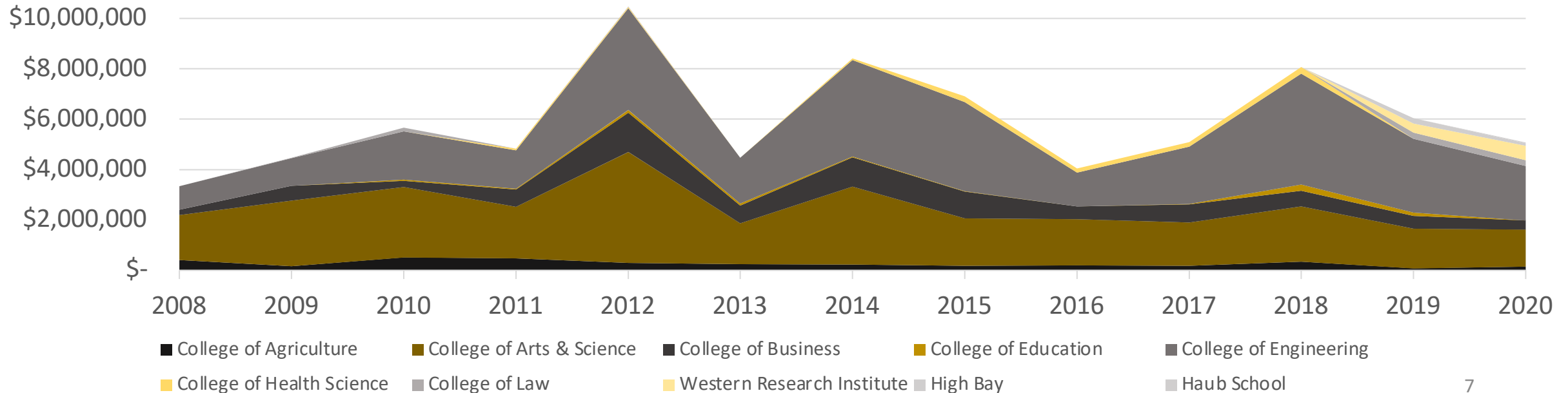
- **Academics**
 - Train students for careers in the Wyoming energy industries
- **Outreach**
 - Engage with stakeholders across state and beyond
 - Support elected and appointed officials
- **Research**
 - Conduct applied research focused on commercialization
 - Develop technologies to advantage utilization of Wyoming natural resources
 - Focus on economic development



SER Financial Outlays

- Historically, a significant portion of SER's budget is allocated to UW colleges
- From 2008, over \$76M of funds appropriated to SER have been spent by UW colleges for a wide variety of purposes, averaging approximately \$6 M/yr
- Commitments have included program support, GA's, start-up, salaries, matching funds, major equipment, and research funds

College Funding By Fiscal Year



Examples of SER Faculty Contributions

- SER Professor of Economics
- SER Academic Director
- Recent publication sponsored by the Wyoming Energy Authority: ***The Fiscal and Economic Impacts of Federal Onshore Oil and Gas Lease Moratorium and Drilling Ban Policies***



- SER Professor of Law
- Recognized legal scholar on issues such as oil and gas regulation, public land energy development, and pore space ownership and use
- Recent publication: ***The Carbon Storage Future of Public Lands***



Leading scholars focused on Wyoming issues and working with state officials and the federal delegation

SER Academics

*THE WORLD NEEDS MORE
OUTSIDE THINKERS*

Energy Resource Management and Development



- Bachelor of Science (120 credits)
 - Professional Land Management
 - Energy and Environmental Systems
- Energy Resource Management Minor (12 credits)
- Interdisciplinary focus
- 5th highest salary of degrees at UW
- 95% placement rate

SER Research Portfolio

*THE WORLD NEEDS MORE
ADVENTUROUS SPIRIT.*

SER Research Structure

Center of
Economic Geology
Research

Center of Carbon
Capture and
Conversion

Center for Energy
Regulation and
Policy Analysis

Faculty-led
Centers of Excellence

Center for Air Quality

Center for Produced
Water Management

Center for Biogenic
Natural Gas Research

Center for Wind Energy Research

Partner Organization

Enhanced Oil Recovery Institute

Staff-led Centers of Excellence



SER Research Portfolio

- Carbon capture, use and storage
- Unconventional oil and gas production
- Rare earth elements and critical minerals
- Carbon engineering
- Novel combustion approaches (e.g., FPO)
- Social license to operate in Wyoming
- Energy regulation and policy analysis
- Technology and knowledge transfer
- Air quality modeling and prediction
- Produced water treatment and reuse
- Machine learning/AI energy systems



SER CCUS Research

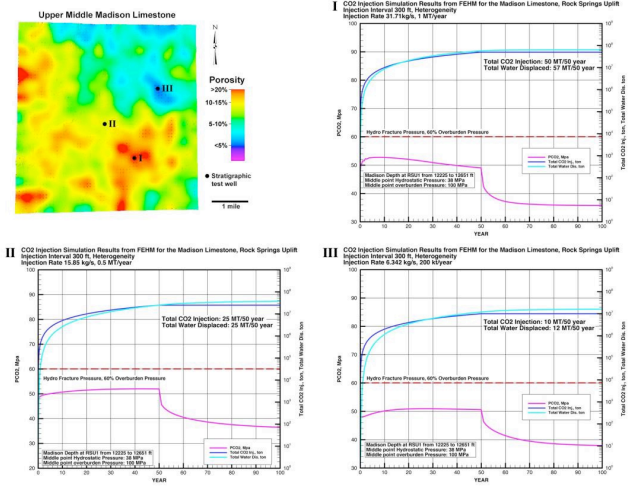
U.S./China Clean Energy Research Center for CCUS



Re-entry (WY-CUSP)



Pressure Management (BEST)



Drilled PRB #1 (Dry Fork Station)

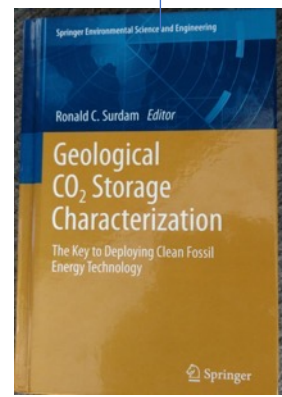


- Drill PRB #2 (Dry Fork Station)
- First Class Vi Permit underdevelopment
- Project Blue Bison, (Blue H2)

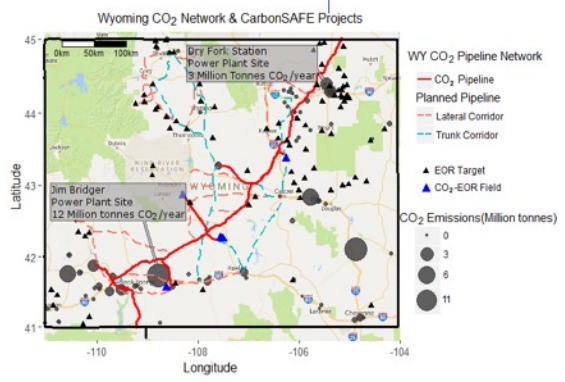
2006
SER-CMI founded



Drilled RSU #1 (WY-CUSP)



Best Practices



CarbonSAFE

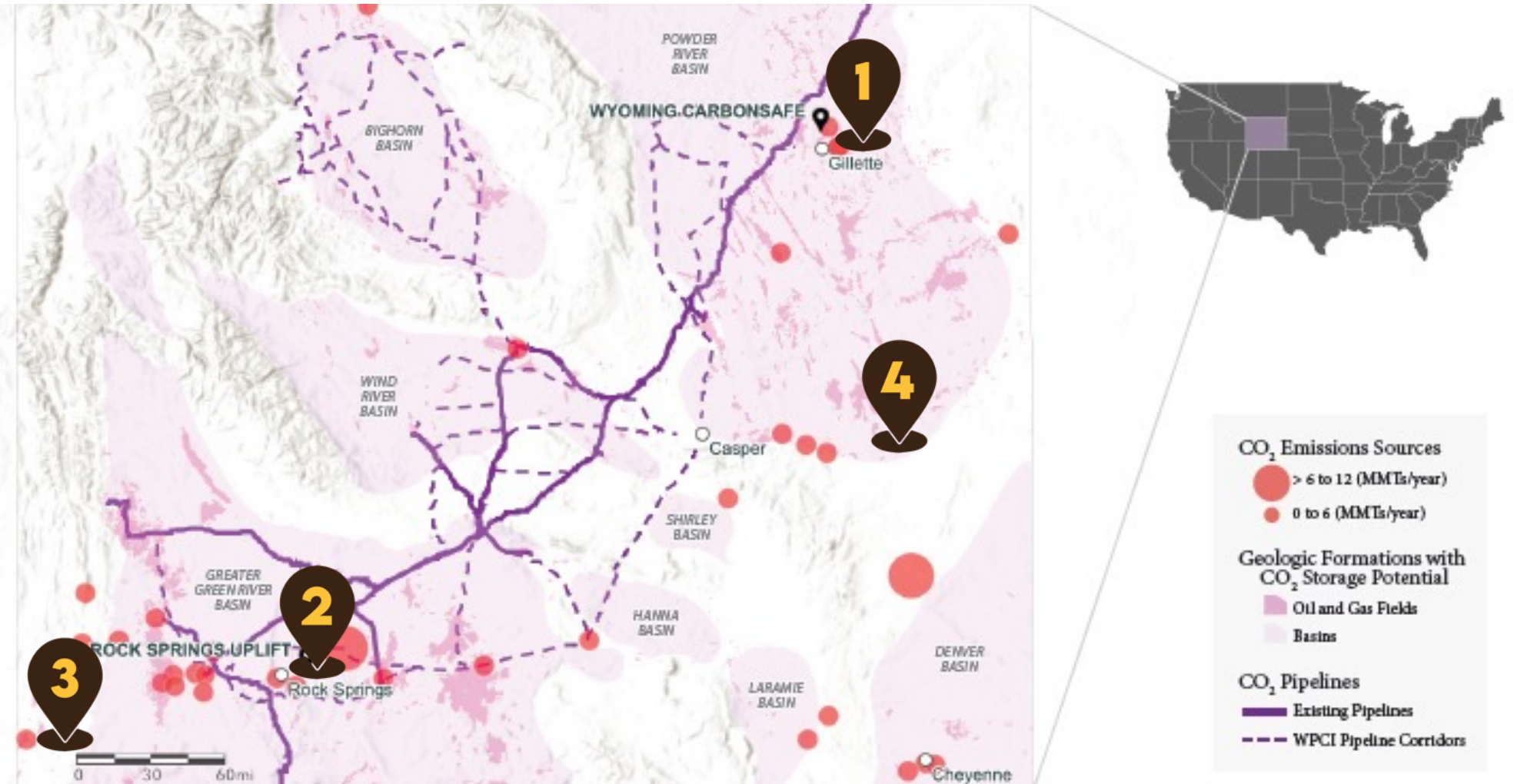


3D Seismic (Dry Fork Station)

Statewide Assessment

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)



WY's CCUS accomplishments

- Only State to have 2 fully characterized CO2 storage reservoirs
- Class VI Permits underdevelopment
- Each storage site lies on either end of CO2 pipeline
- Wyoming Pipeline corridor initiative (WCPI)
- CCUS friendly regulatory framework
- Primacy for CO2 injection
- Potential CO2 targets identified in every Wyoming geologic basin
- Storage capacity for over 26 billion tons of CO2 storage
- Wyoming Integrated Test Center
- National and international reputations in CCUS



Emerging Area: Hydrogen

*THE WORLD NEEDS MORE
UNSHAKEABLE DETERMINATION*




HYDROGEN ENERGY IN WYOMING

WHAT IS HYDROGEN?



The development of hydrogen would diversify Wyoming's energy economy.







-  **ELEMENT**
Hydrogen is the lightest and most abundant element in the universe.
-  **ENERGY CARRIER**
Because hydrogen does not exist freely in the quantity and concentration of other fuels and generally must be produced using other forms of energy, it is known as an energy carrier.
-  **FUEL**
Once produced, hydrogen can be burned with oxygen to create a zero carbon fuel. It can be used in fuel cells or internal combustion engines and produces clean power or heat at the point of use.

WHY USE HYDROGEN?



Early progression hydrogen would position Wyoming as a leader and first to market.



-  **INFINITE SOURCE**
Hydrogen can be produced from existing Wyoming sources of energy including coal, gas, wind, solar, and nuclear.
-  **MINIMAL CARBON FOOTPRINT**
Hydrogen extraction is possible from multiple Wyoming energy sources with a minimal carbon footprint and a by-product of only water vapor.
-  **TRANSPORTATION**
Hydrogen can be transported and exported in large volumes as hydrogen or ammonia through existing Wyoming rail and pipeline infrastructure.
-  **STORAGE**
Hydrogen can be stored in large quantities for long periods of time.

HOW DOES HYDROGEN WORK?

BLUE HYDROGEN



Produced from fuels such as coal, natural gas, or biomass using steam methane reforming or gasification with carbon capture & storage (CCS).

GREEN HYDROGEN



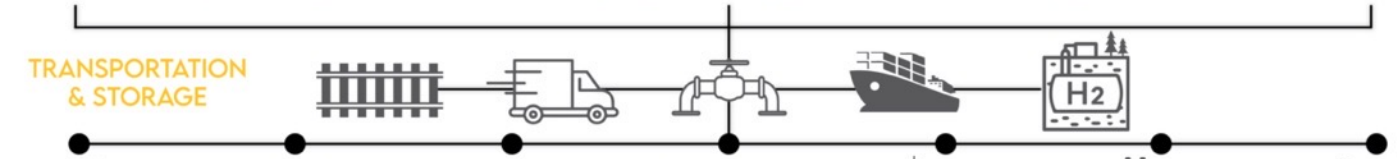
Produced from renewable energy sources such as wind or solar using electrolysis to separate water into hydrogen and oxygen.

PINK HYDROGEN



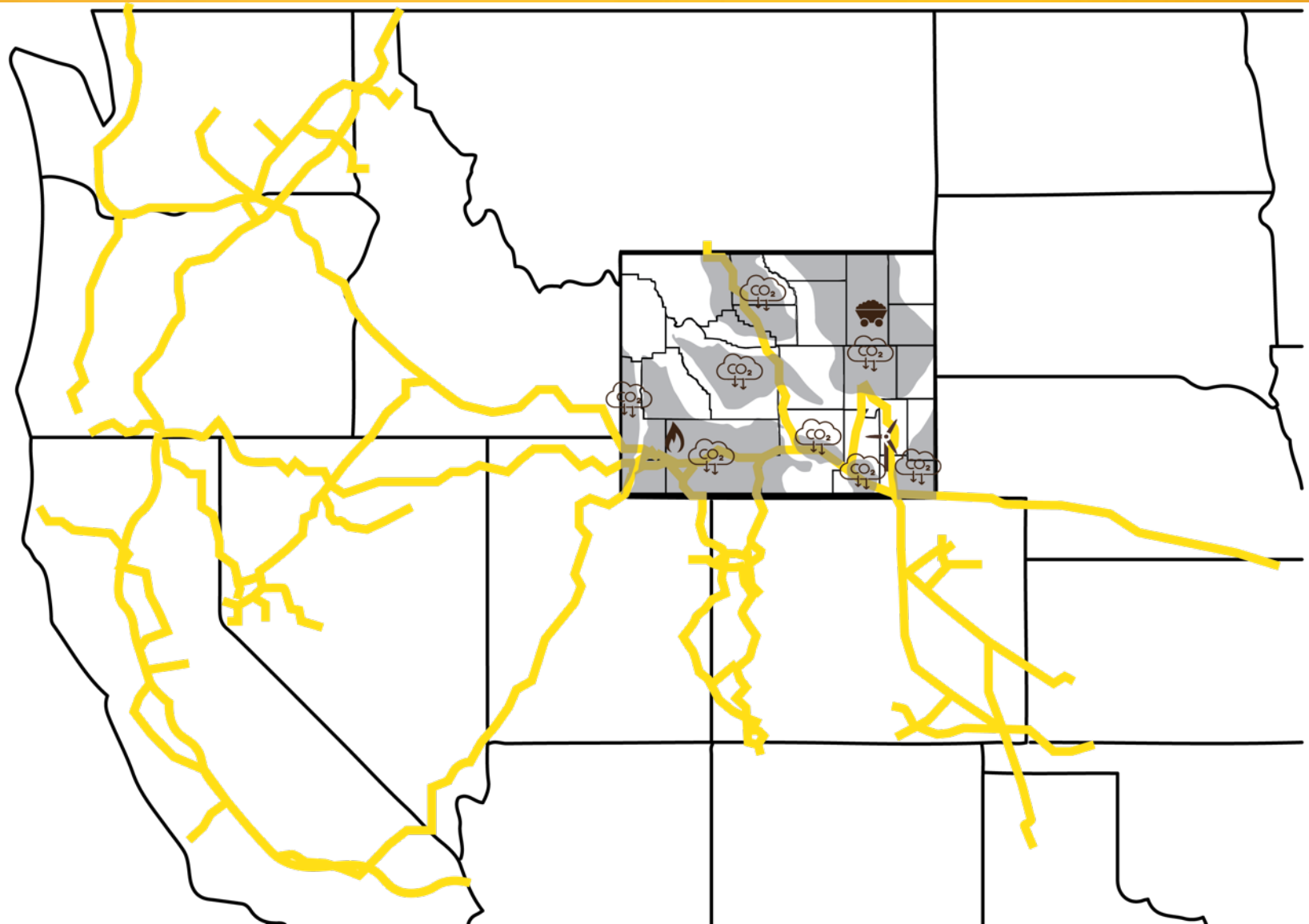
Produced from clean nuclear sources using electrolysis to separate water into hydrogen and oxygen.

TRANSPORTATION & STORAGE



APPLICATIONS & USES

Wyoming as a H₂ Headwaters State



H₂ Center of Excellence

Select areas of interest:

- Quantify costs of Wyoming-produced hydrogen
- Identify and map potential markets
- Identify sources of produced water
- Map CO₂ storage sites near potential hydrogen hubs
- H₂ storage opportunities and seed studies
- Pipeline blending and retrofitting studies



Carbon Engineering

*THE WORLD NEEDS MORE
UNBENDABLE OPTIMISM*

Carbon Engineering Initiative

Develop new environmentally friendly uses for Wyoming coal:

- Primary objective is to sell more coal to non-thermal markets.
- Make products that command price premiums over the btu value of Wyoming coal.
- Develop a diversified economy that takes advantage of Wyoming's vast mineral wealth.

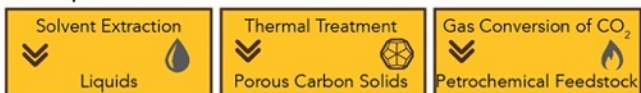


Thermo-chemical (Coal Refinery) Process Technology

The process consists of the deliberate decomposition of coal to make high-volume, environmental and health friendly, non-combustion products.



- Integrates 3 proven technology platforms to convert coal



- Products range from engineered commodities, high-value chemical compounds, and petrochemical feedstocks.
- Zero waste and low carbon footprint
- Commercial-scale conversion expected

Thermo-chemical Processing Solvent Treatment, Pyrolysis & Separation

Subject of Patent Application:
WO 2019/055529



Soil Fertility Products
Building Materials
Engineered Carbon & Char Products



Phenol, Creosote, Base Oils
Graphine Oxide
Paving and Roofing Products
Resins & Coatings
Carbon Fiber Mats



Petrochemical Feedstocks for use in other conversion processes

Carbon Engineering Projects

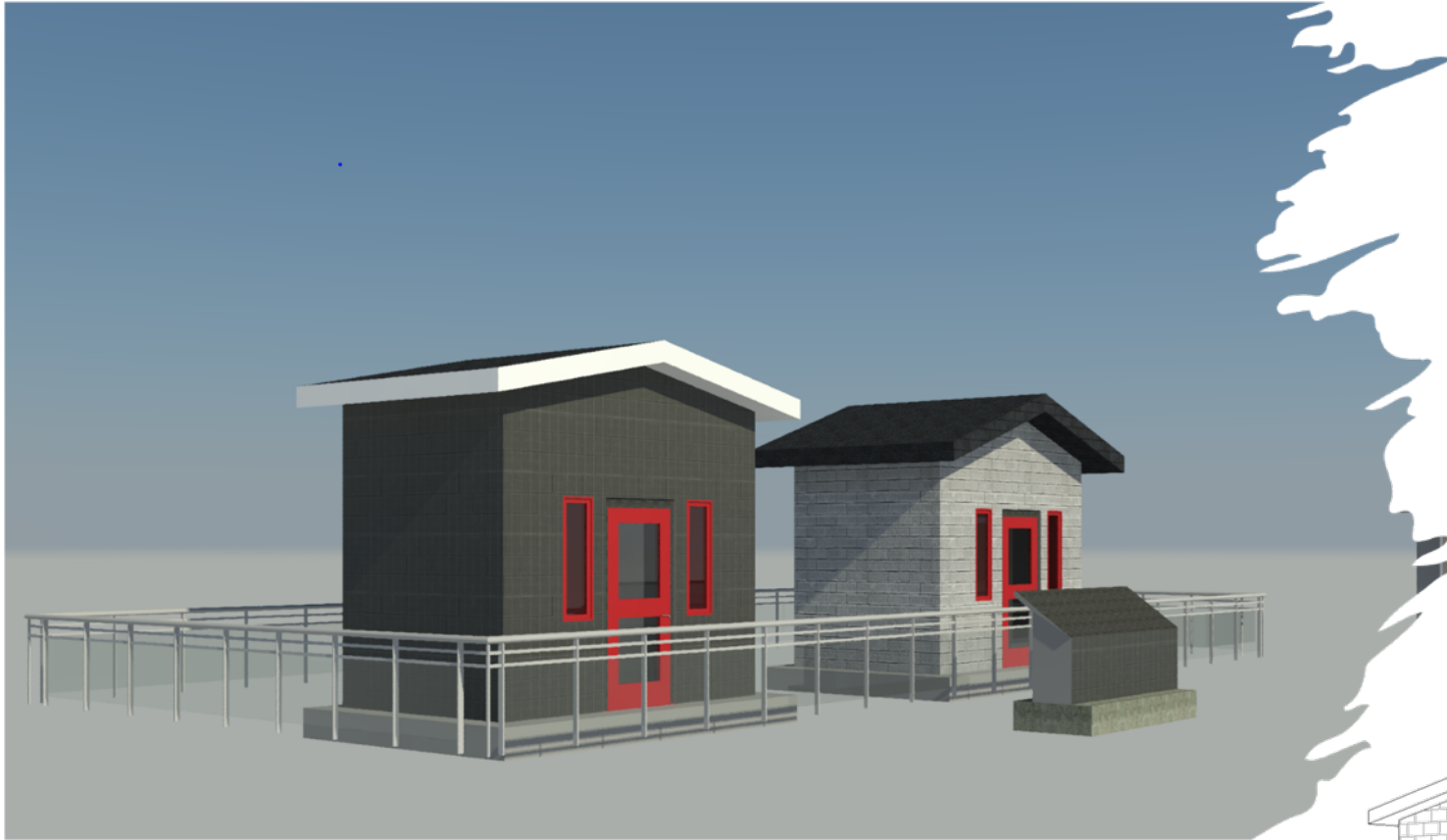
Coal-based:

- 1) **Soil amendments**-nitrogen enriched coal char. Currently being demonstrated at a sugar beat test site near Wheatland
- 2) **Asphalt and paving additives**-Proven in the laboratory and will be benched marked against oil-based materials this year
- 3) **High temperature composites**-High T resins that exhibit superior temperature resistance to oil-derived products on the market.
- 4) **Graphene**: Coal derived graphene oxides for resins and coatings
- 5) **Building products**: Coal based bricks with superior thermo-properties to conventional materials.
- 6) **Energy storage devices**: For use in electric utilities and energy storage
- 7) **Petrochemicals and Hydrogen**: Dry methane reforming with CO₂ produced from coal pyrolysis ($\text{CO}_2 + \text{CH}_4 = \text{CO} + \text{H}$)
- 8) **High-value chemicals**: Flash pyrolysis and solvent extraction to make intermediate products needed for the fibers, resin, polymers and asphalt materials



Coal derived 'Green' Building Products

For more information on CEI contact Richard Arthur Horner (rhorne@uwyo.edu)

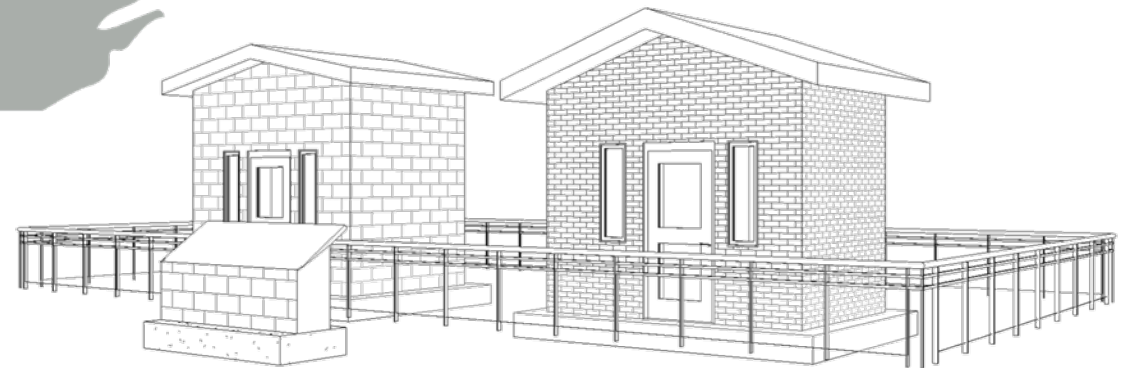


The Coal House:

- Constructed entirely of coal derived products
- Under site selection



Char Bricks derived from PRB coal



Rare Earth Elements and Critical Minerals

*THE WORLD NEEDS MORE
RELENTLESS CURIOSITY*

Primer on Rare Earth Elements (REEs)

Rare Earth Elements (REEs):

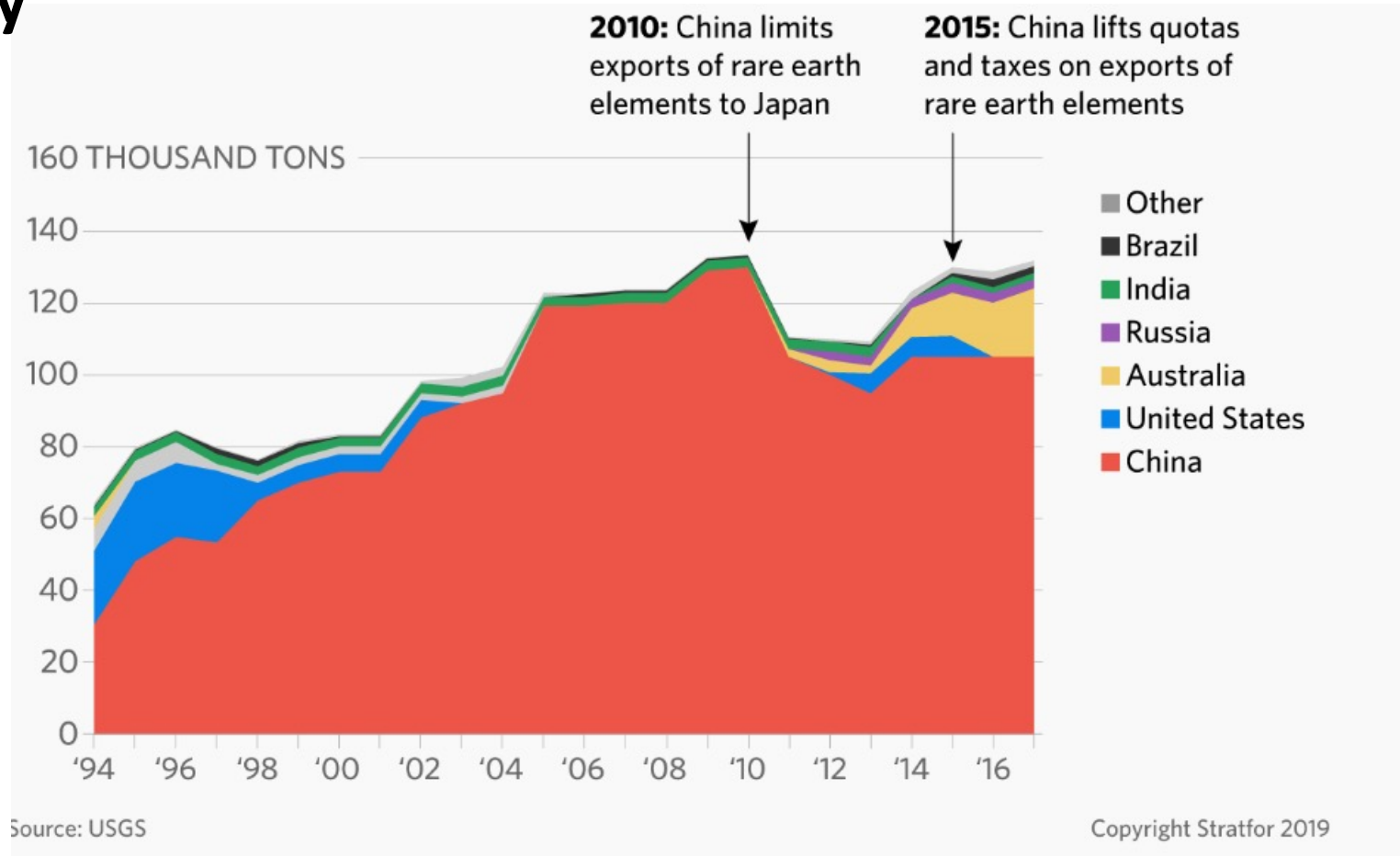
➤ Used in manufacture of:

- **Wind Turbines** (Pr, Nd, Dy)
- **Cordless Power Tools** (Pr, Nd, Tb, Dy)
- **Ear Phones** (Pr, Nd, Gd)
- **Energy Efficient Light Bulbs** (Y, Eu)
- **LCD and Plasma Screens** (Y, Ce, Eu, Tb)
- **Hybrid Vehicles** (Pr, Nd, Sm, Gd, Tb, Dy)
- **Rechargeable Batteries** (La, Ce)
- **Missile Guidance and defense** (Pr, Nd, Sm, Tb, Dy)
- **Smartphones** (La, Ce, Pr, Nd)

➤ Nearly 85% of REEs come from China

1																	2	
H																	He	
3	4											5	6	7	8	9	10	
Li	Be											B	C	N	O	F	Ne	
11	12	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
Na	Mg											Al	Si	P	S	Cl	Ar	
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr	
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe	
55	56	Ln	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	
Cs	Ba		Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn	
87	88	Ac																
Fr	Ra																	
		57	58	59	60	61	62	63	64	65	66	67	68	69	70	71		
		La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu		

REE Market Share by Country



<https://worldview.stratfor.com/article/geopolitics-rare-earth-elements>

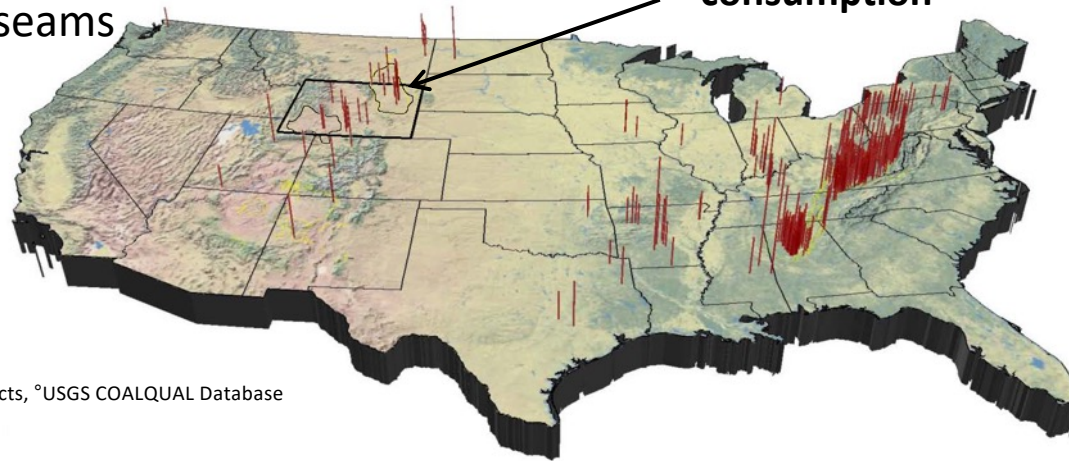
Rare Earth Elements in Coal

REEs in Coal:

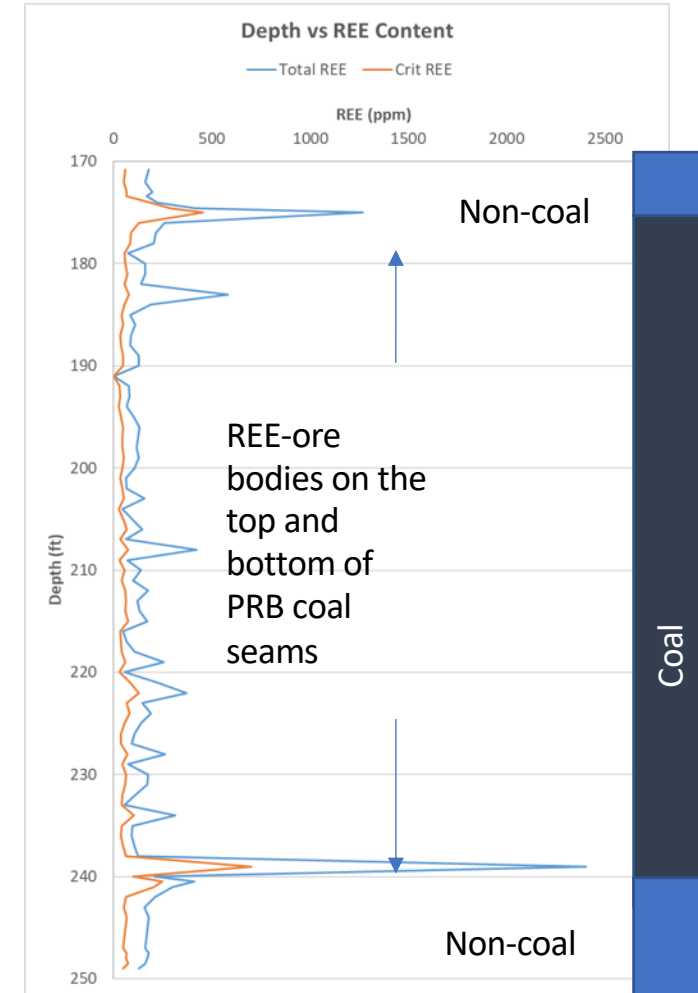
- Highest concentrations collect at the bottom and top of coal seams

*REEs in excess of 1000 ppm in some coal samples**

Wyoming Coal = 40% of U.S. thermal coal consumption



*Ekman 2012, Bagdonas et al. 2016, 2019 and current NETL projects, °USGS COALQUAL Database



Coal Ash REE Pilot & Coal REEs

Rare Earth Elements in Coal

- Coal Ash Pilot- 3 yr. \$1.6M project (NETL, Campbell County, and Gillette)
- Cooperative Agreement NETL- “Cores of Opportunity”
- Preliminary findings
 - Potentially favorable concentrations of Critical Elements. These include Ti, Mg, Sr, Ba, Fe, Al, and REEs.
 - High calcium in PRB coals makes it easier to concentrate REEs
- Up to 400 ppm REE in coal ash, up to 870 ppm (dry coal) 2,580 ppm (ash basis) in coal seams.

Industry Partners include Black Hills Energy, Basin Electric, Dry Fork Mine, Kemmerer Coal Mine, PacifiCorp, and Peabody

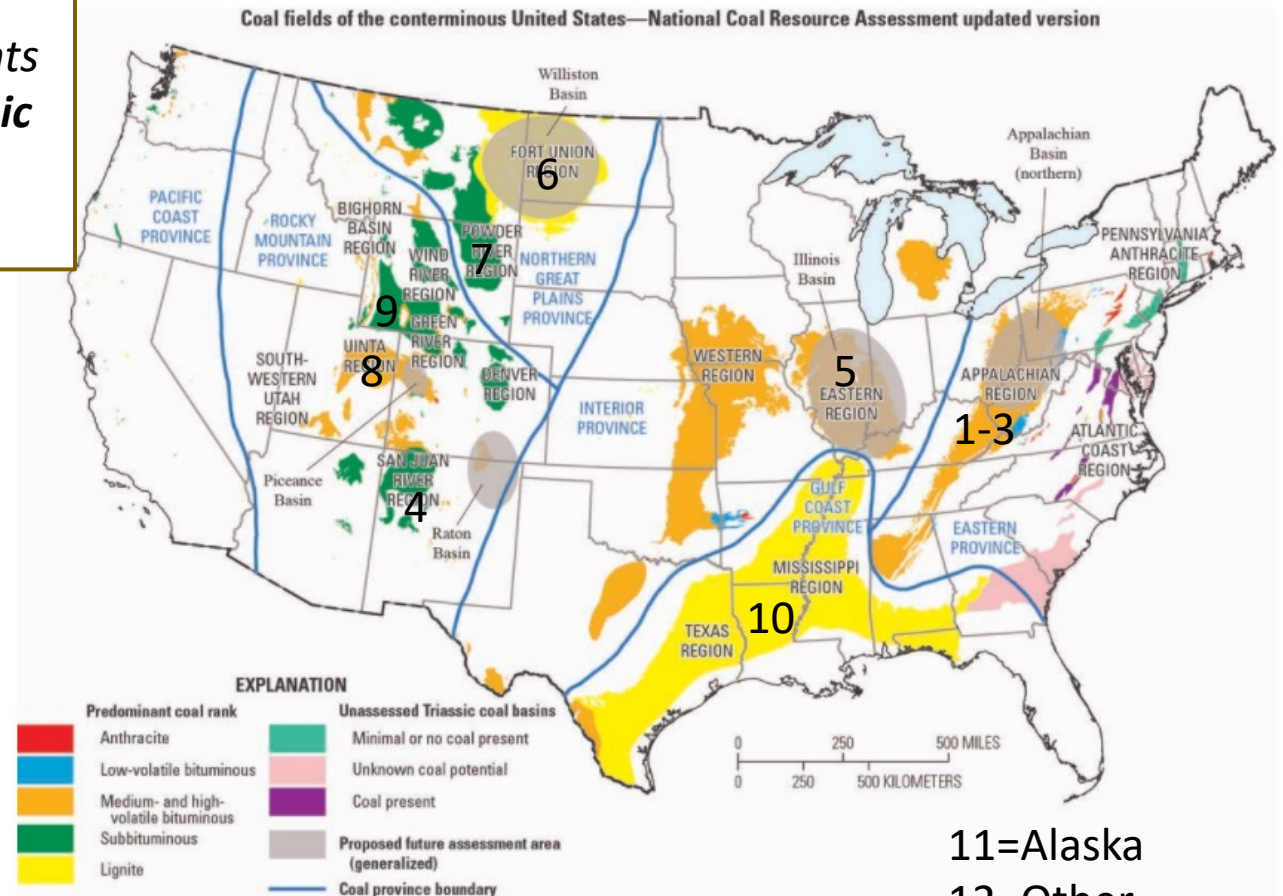


DOE Carbon Ore, Rare Earth and Critical Minerals Initiative for U.S. Basins

Overall Program Goal: To catalyze regional economic growth and job creation by realizing the full potential value of natural resourcescoals and associated by-products and waste streams for the production of rare earth elements and critical minerals to enhance our national and economic security. They can also be used as sources of carbon for production of high-value, nonfuel, carbon based products.

University of Wyoming has two projects

- \$1.9 million collaborative project in Powder River Basin
- \$1.9 million collaborative project in Green River/Wind River Basins



11=Alaska
12=Other

A map of the various coal fields of the conterminous United States.(Public domain.)

CORE-CM Outcomes

The Project will:

1. Bring together a diverse group of stakeholders across the mineral value chain (n=104 and growing)
2. Develop implementation strategies to kick start a new industry pertaining to coal to products, rare earth elements, and critical minerals
3. Develop workforce training programs and technology transfer forums at the community colleges
4. Develop regional Technology Innovation Centers

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