Why Hydrogen?
How it fits into a future energy economy and why Wyoming must act now

WEBINAR
Thursday, July 29, 2021
1:00 – 2:00 PM

University of Wyoming | School of Energy Resources

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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.

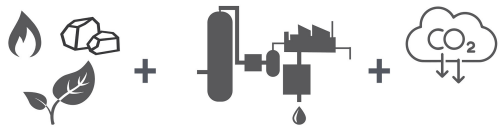
MINIMAL CARBON FOOTPRINT
Hydrogen extraction is possible from multiple Wyoming energy sources with a minimal carbon footprint and a by-product of only water vapor.

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

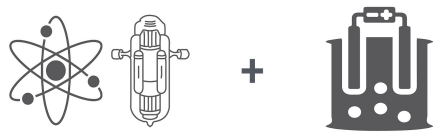


Produced from fuels such as coal, natural gas, or biomass using steam methane reforming or gasification with carbon, capture & storage (CCS).

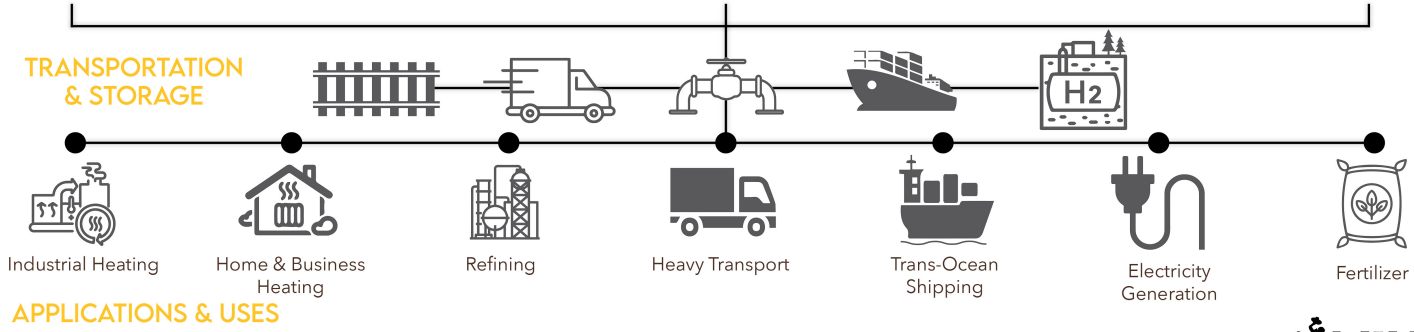
GREEN HYDROGEN

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.



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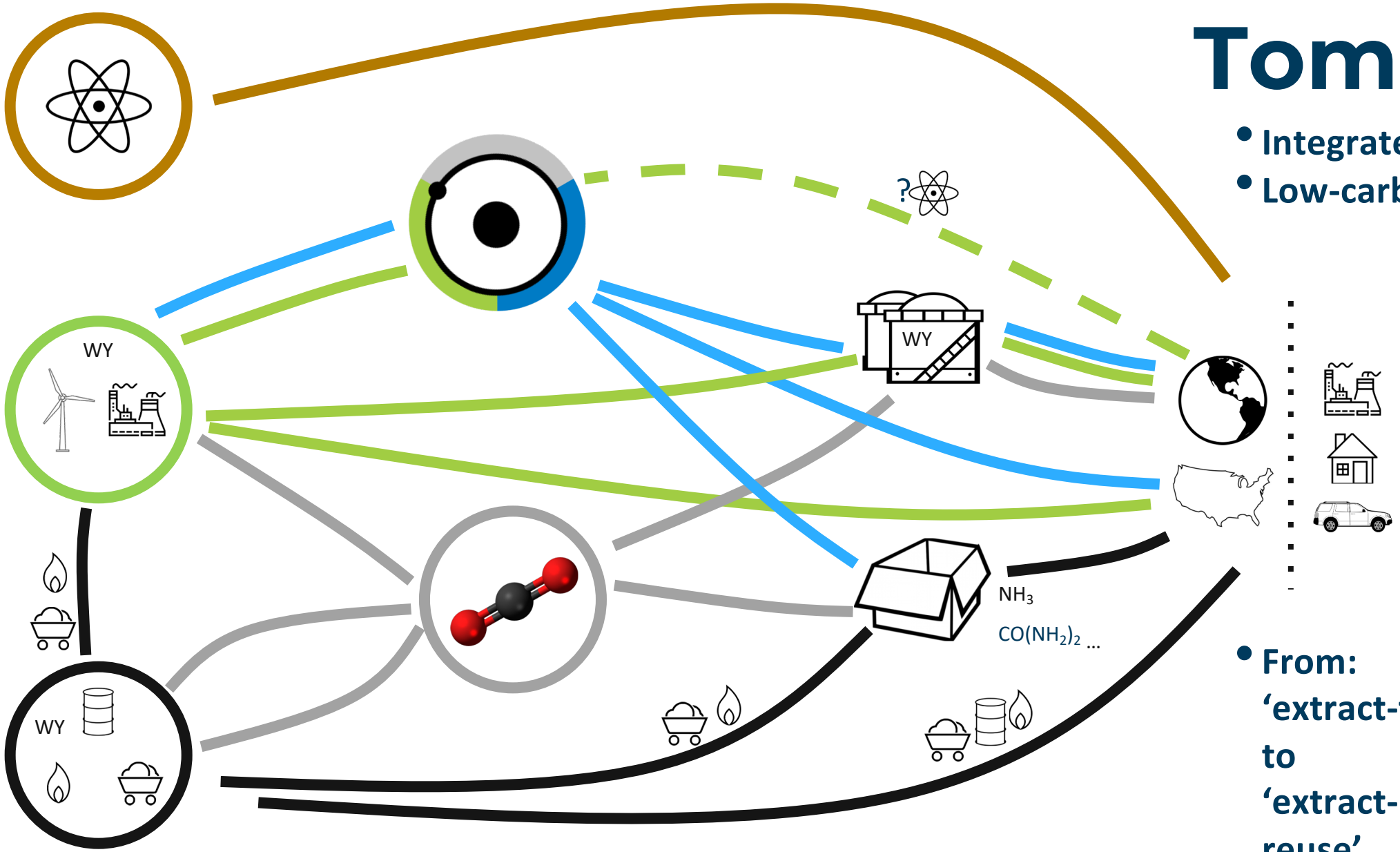
Hydrogen: Why Wyoming?

Dr. Glen Murrell

Tomorrow?



- Integrated energy economy
- Low-carbon intensity

- From: ‘extract-transport-consume’, to ‘extract-upgrade-store-reuse’

WYOMING ENERGY AUTHORITY

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 **CO_2 management infrastructure** already*
- *It has an existing **Hydrogen manufacturing** industry.*
- *It has a head start on many **policy** reqs.*
- *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 Pilot RFP

Black Hills Energy / Black & Veatch / GE / Tallgrass Energy
"Wyoming Hydrogen Demonstration Pilot Project"

- *feasibility study for a natural gas-fed blue hydrogen gas generator with carbon capture; a green hydrogen gas generator fed with renewable energy and water; and a conceptual engineering assessment of equipment modifications of GE LM6000 combustion turbines to accommodate blended fuel mix of hydrogen and methane.*

Williams Companies / UWSER
"Williams Southwest Wyoming Hydrogen Hub"

- *evaluate water access and compatibility as well as asset integrity in support of green hydrogen production and transport in the vicinity of Wamsutter and Opal, Wyoming.*

Jonah Energy / NREL
"Green Hydrogen through Power to Gas Study"

- *to create "green" hydrogen and renewable natural gas through biomethanation.*

Stay Connected

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Why Hydrogen?

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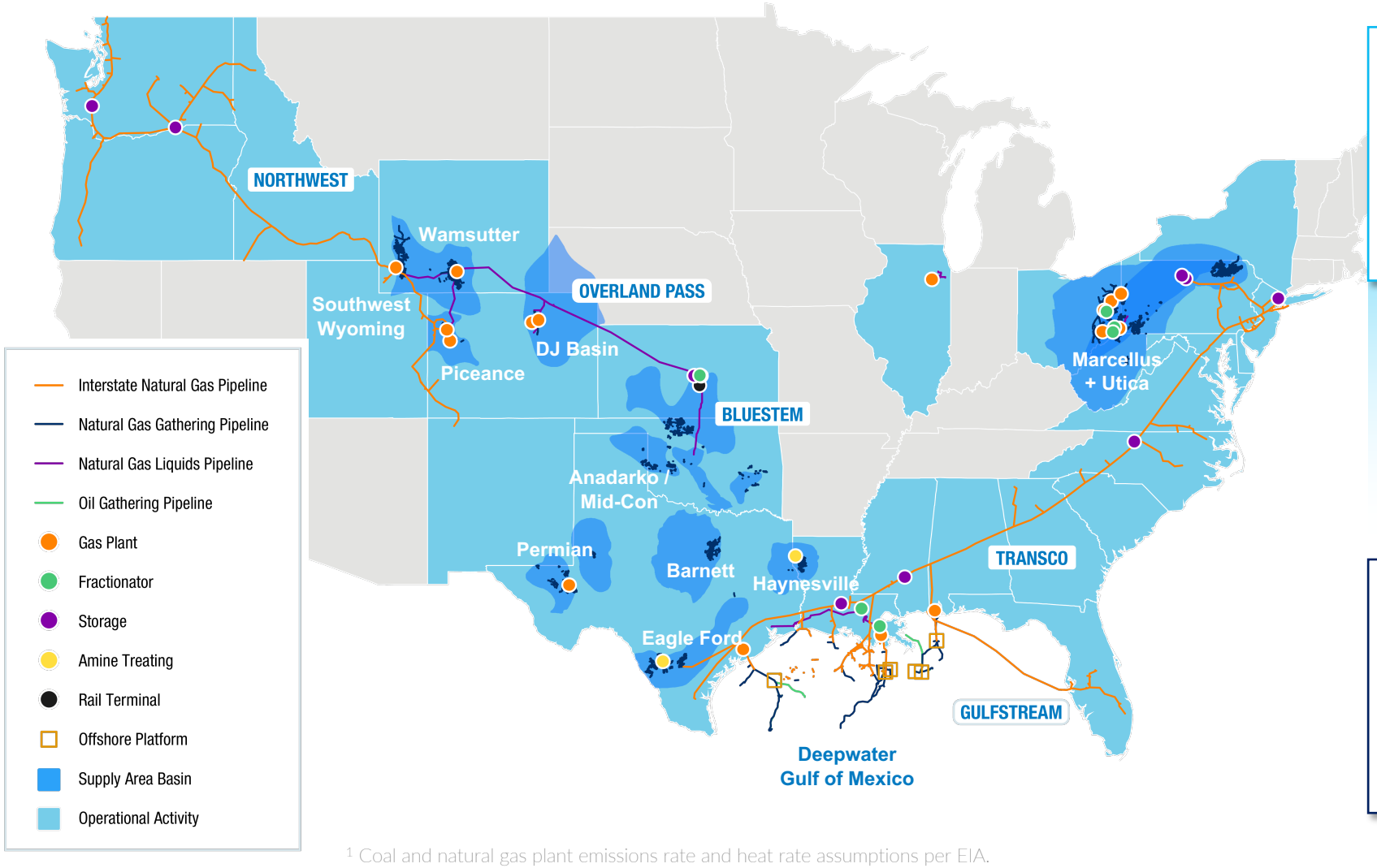
Brian Hlavinka

Director, Emerging Opportunities

July 29, 2021

Williams® WE MAKE CLEAN ENERGY HAPPEN®

Large-scale, irreplaceable natural gas infrastructure



Handling

30%

nation's natural gas

1.26 million MT CO_2 avoided each day by combusting 29.8 MMDth of gas v. coal [1]

Directly Serving

600

customers

Indirectly serving over **35 million** energy consumers [2]

Transco

Nation's largest and fastest growing major pipeline

Serving

15

key supply areas

[1] Coal and natural gas plant emissions rate and heat rate assumptions per EIA.

[2] Based on customer count statements of major gas and electric utilities served by Transco, Northwest Pipeline, and Gulfstream.

Committed to a clean energy future

Williams recognizes the risks of climate change and our strategy provides a practical and immediate path to reduce industry emissions and grow a clean energy economy

Right Here, Right Now Opportunities

Goal: 56% absolute reduction in company-wide greenhouse gas emissions by 2030

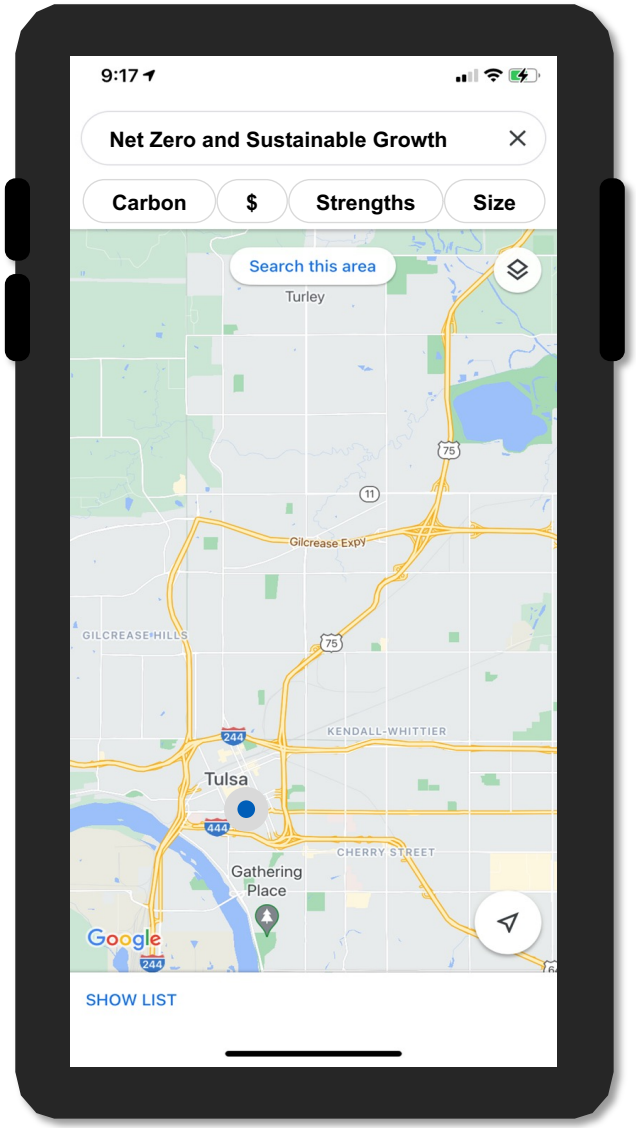
Leverage our natural gas-focused strategy and technology that is available today to focus on immediate opportunities to reduce emissions, scale renewables and build a clean energy economy.

Future Innovation and Technologies

Our path to net zero by 2050 involves a combination of immediate and long-term solutions, including investments in renewables, technology and the best and brightest talent who are committed to doing what is right.

Note: 56% absolute reduction measured against 2005 emissions

Our Direction will be Guided by these Principles



Achieve **carbon reductions** for ourselves, our customers, and partners in the energy transition

Create value with actionable investment opportunities rooted in environmental and economic returns

Target opportunities where have **strategic advantage** from our midstream competencies and infrastructure.

Provide **scalable** options for the future

Growing a Sustainable Business

Strategic Programs to Reduce Emissions and Deliver Returns

Focusing on what we can do today and creating options for the future.

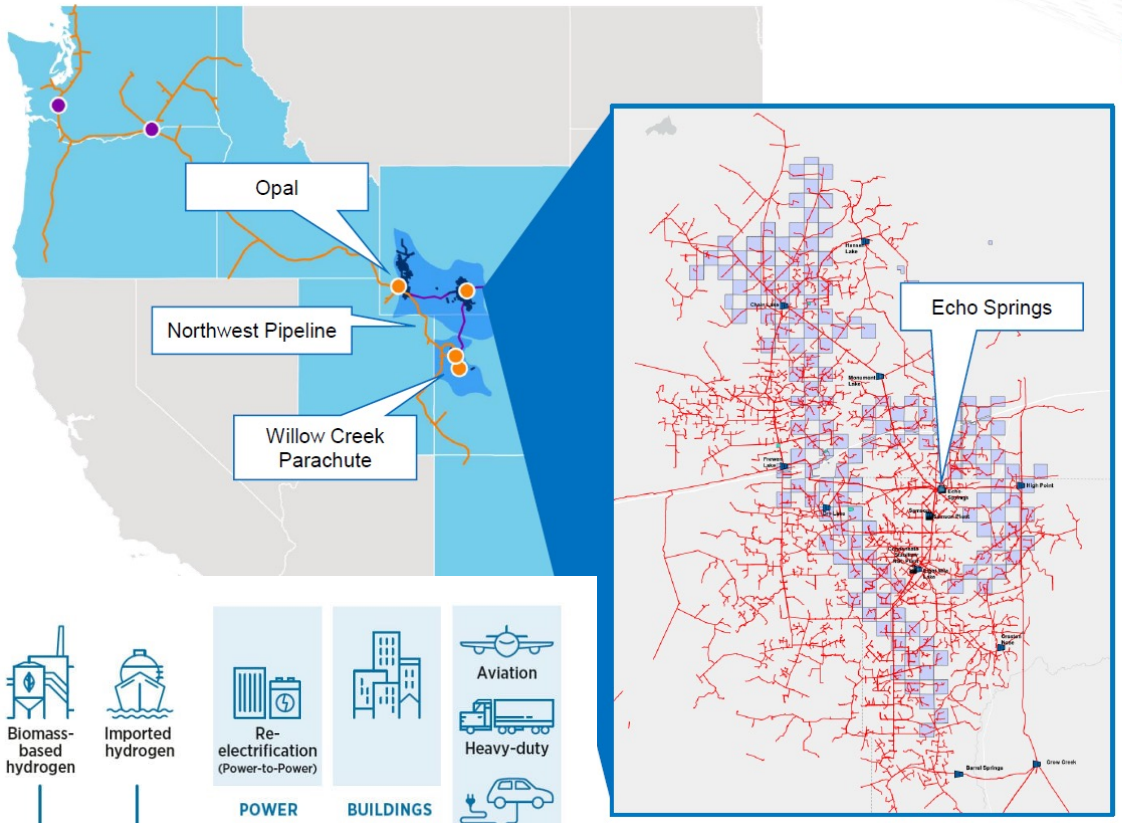
Creating Value with a Net Zero Approach

Williams®

WE MAKE CLEAN ENERGY HAPPEN™

- **Solar Program** – Developing 16 solar projects generating clean energy to reduce utility demand at current and future facilities
- **Renewable Natural Gas Initiative** – Constructing new interconnects and investing in projects to expand RNG production
- **Low Carbon Gas Product Offering** – Working with customers and partners to offer products like responsibly sourced gas (RSG) and carbon offset natural gas
- **Hydrogen Development Program** – Leading efforts to develop H_2 infrastructure, production, and opportunity to blend into natural gas pipelines
- **Carbon Capture Utilization and Storage (CCUS) Development Program** – Creating opportunity for fossil-based fuels to play a larger role in a clean energy future
- **Renewable Power Generation and Transmission** – Partnering with renewable energy developers by bringing Williams' infrastructure-focused expertise to support projects
- **Clean Energy Hub Partnerships** – Integrating renewable and other low carbon technologies into existing infrastructure to drive production and delivery of clean molecules at scale
- **Corporate Venture Program** – Exploring investments in innovation to enable a low carbon future
- **Carbon Markets Program** – Optimizing carbon attributes to achieve emissions goals and create additional revenue opportunities

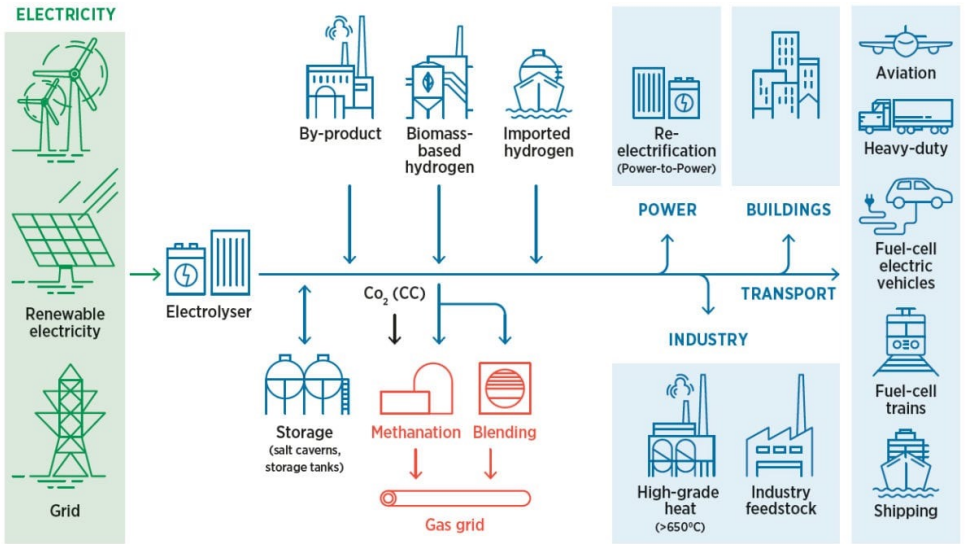
Hydrogen – The Next Generation of Clean Energy?



Wyoming Wind

Williams is gaining acreage in southwest Wyoming. Our Wamsutter gathering business is situated within the footprint, with other pipelines and facilities less than 125 miles away.

= 85,130 acres



Goal: produce $2-3/kg green H_2
produce $25-35/MMBTU RNG

Destinations are not limited to our pipelines

- Connecting low-cost supply to high-demand markets

Why Hydrogen?

University of Wyoming
School of Energy Resources

JULY 29, 2021

C H2 FC Clean Hydrogen Future Coalition

CHFC Members

174 Power Global

American Gas Association

American Public Gas Association

Bayotech

bp

California Fuel Cell Partnership

Chevron

ClearPath Action

Duke Energy

EN Engineering

Energy Infrastructure Council

Engie

Gas Technology Institute

GE Gas Power

Int'l Brotherhood of Boilermakers

Int'l Brotherhood of Electrical Workers

INGAA

LanzaTech

Linde

Nikola

North America's Building Trades Union

North Slope Borough

Nuclear Energy Institute

ONE Gas

Sempra Energy

Siemens Energy

Tennessee Valley Authority

U. of Wyoming School of Energy Resources

UND Energy & Environmental Research Center

Voice of the Arctic Inupiat

Wabash Valley Resources

Williams Companies

CHFC Foundational Principles

(1) Clean hydrogen is a critical pathway to achieve U.S. decarbonization objectives.

(2) Investments in the full value chain of clean hydrogen production, transport and delivery, storage and use, as well as the infrastructure across multiple sectors, will be necessary to scale clean hydrogen in the U.S.

(3) Policies designed to stimulate clean hydrogen production and use throughout the U.S. economy should be fuel agnostic and technology neutral, with a focus on achieving near-net zero CO_2 hydrogen production.

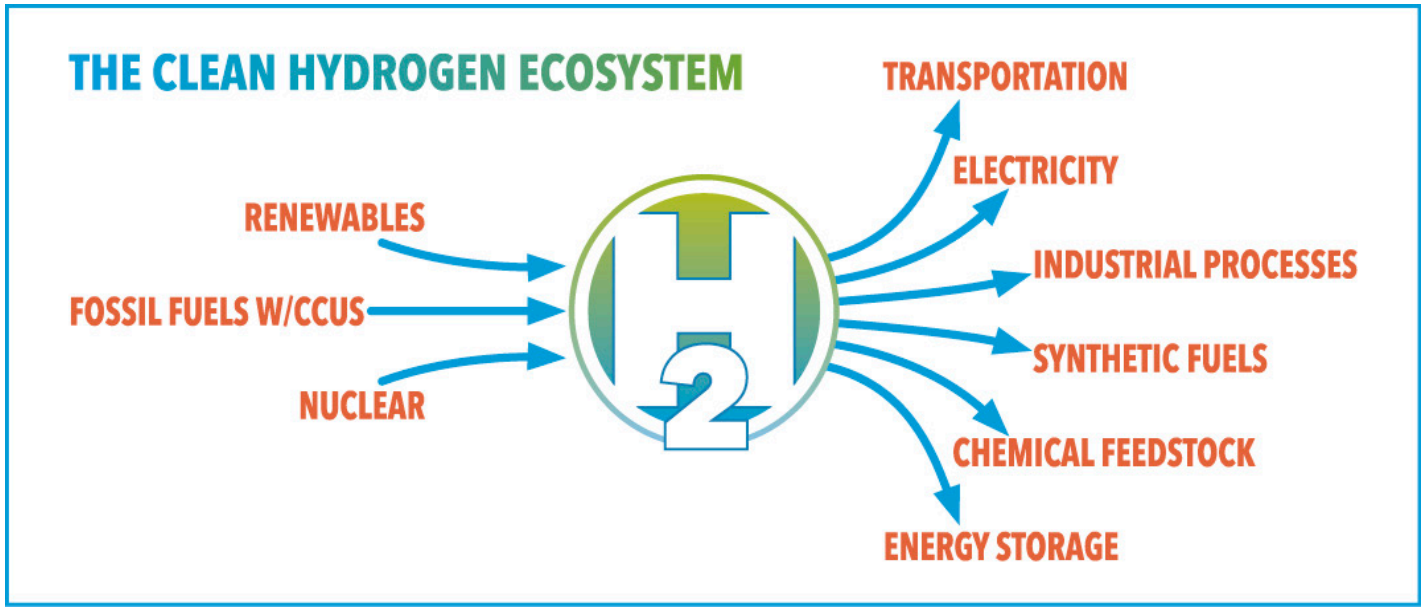
(4) Skilled labor and the use of existing infrastructure are essential to the deployment of clean hydrogen throughout our economy.

Coalition Efforts to Support Mission

- Develop and communicate a clear message on the role of clean hydrogen in the transition to a zero CO_2 economy.
- Educate policymakers about the need for and benefits of clean hydrogen.
- Identify and prioritize policy designs to support clean hydrogen production, transport, delivery, storage, and end-use markets.
- Collaborate with other groups, stakeholders and environmental NGOs in the development of policies to support hydrogen.
- Advocate and lobby for federal legislative, regulatory and other policies that support the coalition mission.

Coalition Messaging

Clean Hydrogen.
What the planet has been waiting for.



- Over 95% of domestic hydrogen production is from fossil fuels and emits CO_2. However, there are numerous options for producing near zero CO_2 – or "clean" – hydrogen
- Clean hydrogen offers a pathway to decarbonize a range of sectors, including transportation, electric power, chemical production, and heavy industry
- Clean hydrogen can be produced from a variety of methods and resources, and can be transported, stored and utilized in numerous applications

Administration Support - DOE

EarthShot

- DOE's Hydrogen Program is hosting its first virtual Hydrogen Shot Summit on August 31 and September 1, 2021
- Two-day summit will bring together stakeholders from industry, research, academia, and government to identify pathways to meet DOE's Hydrogen Shot ($1 per 1 kilogram in 1 decade)
- The summit will also feature breakout sessions covering multiple hydrogen production pathways and other topics, including:
  - Electrolysis
  - Thermal conversion with carbon capture and storage
  - Advanced pathways
  - Deployment and financing
- Agenda will be announced shortly and the topics will align with the subjects that were included in the Hydrogen Shot RFI responses

Administration Support - Budget

Treasury Support in FY 2022 Budget Request

- Defines "low-carbon" hydrogen as *hydrogen produced using zero-carbon emissions electricity and water as a feedstock, or hydrogen produced using natural gas as a feedstock and with all carbon emitted in the production process captured and sequestered.* This definition appears to exclude biomass or gasification production methods.
- 10 year PTC per kg of hydrogen produced for us in energy, industrial and transportation sectors.
- Allows for direct pay option

DOE FY 2022 Budget Request

Office of Fossil Energy and Carbon Management: $890 million ($140 million above FY 2021 enacted)

- CCUS and Power Systems: $531.5 million ($84.7 million above FY 2021 enacted)
- Natural Gas Technologies: $130 million ($73 million above FY 2021 enacted)

Office of Energy Efficiency and Renewable Energy (EERE): $4.73 billion ($1.87 billion above FY 2021 enacted)

- Hydrogen and Fuel Cell Technologies: $197.5 million ($47.5 million above FY 2021 enacted)

Congressional Support: House FY 2022 Energy-Water Appropriations Bill

Energy Efficiency and Renewable Energy

- Vehicle Technologies: $530 million
  - Supertruck III: $30 million
- Hydrogen and Fuel Cell Technologies: $195 million
  - H2@Scale: $100 million
  - Heavy-Duty Transportation and Industrial Applications of H2: $114 million
  - Sustainable Aviation Applications of H2: $70 million
  - Fuel Cell Technologies: $30 million
  - Modeling and Characterization of Perovskites as Catalysts for Hydrogen Extraction: $2.5 million
  - Office of Nuclear Energy Demonstration Project (cost-share with EERE): $15 million
  - Electrolyzer Development: $14 million
  - Solar Fuels R&D for H2 Production: $10 million
  - System Development and Integration $60 million

Fossil Energy and Carbon Management

- Advanced Energy and Hydrogen Systems (CCUS and Power Systems): $92 million
- Natural Gas Hydrogen Research (Natural Gas Technologies): $20 million

Crosscutting Initiatives

Energy Storage – includes low-carbon hydrogen storage

Industrial Decarbonization

Hydrogen Energy and Fuel Cell Coordination

- Report directs DOE to coordinate efforts across EERE, FECM, NE, OE, and Science

Hydrogen Tax Legislation

Clean Hydrogen Production Incentives Act (S. 1017) – Sen. Martin Heinrich (D-NM)

- Establishes PTC for hydrogen produced from renewable energy and nuclear resources (fossil with CCUS not eligible).

Hydrogen Utilization and Sustainability Act (S. 1266) – Sen. Young (R-IN) and Whitehouse (D-RI)

- Adds qualified hydrogen as a qualifying resource in Section 45 to qualify for the existing clean electricity production tax credit

Clean Hydrogen Production Act (S. 1807) – Sen. Tom Carper (D-DE)

- Creates tiered hydrogen PTC that is valued based on lifecycle GHG emissions reduction relative to conventional SMR carbon intensity
- Included in Clean Energy for America Act (S. 1298) following Committee markup

Energy Sector Innovation Credit Act (*discussion draft*) – Sens. Mike Crapo (R-ID) and Sheldon Whitehouse (D-RI)

- Creates a clean hydrogen PTC based on average wholesale price of a kilogram of hydrogen in the prior calendar year multiplied by the amount of clean hydrogen produced and sold to an unrelated person
- Credit phases down and eventually phases out based on market penetration of technology

Hydrogen Legislation

Clean Hydrogen Deployment Act (*Energy and Commerce Committee discussion draft*)

- Establishes a DOE pilot program for which DOE would be required to select at least five projects to use low-emissions hydrogen and to provide annual payments to those projects based on the cost difference between the eligible clean hydrogen used and conventional hydrogen or other non-hydrogen fuel or feedstock.

Clean Energy Hydrogen Innovation Act (H.R. 1788) – Rep. Greg Pence (R-IN)

- Amends eligibility for loan guarantees to include projects relating to hydrogen production, delivery, infrastructure, storage, fuel cells, and end uses.

Advancing the Clean Hydrogen Future Act (S. 2200) – Sen. Martin Heinrich (D-NM)

- Establishes electrolysis RD&D program with goal of reducing cost of hydrogen produced via electrolysis to less than $2/kg by 2026 – included in Senate Bipartisan infrastructure package

Bipartisan Energy Infrastructure Package - Hydrogen Provisions

Closely tracks Senator Manchin's draft clean hydrogen RD&D bill

- Includes an R&D program, $8B for clean hydrogen hubs, national roadmap requirement, funding for a clean hydrogen manufacturing and recycling program, and Senator Heinrich's electrolysis bill
- Establishes clean hydrogen definition:
  - **Carbon intensity equal to or less than 2 kg of CO_2-equivalent *at the site of production* per kg of H_2 produced**
- Establishes Office of Clean Energy Demonstrations to oversee demo projects authorized under the bill or the Energy Act of 2020

Likely to include surface transportation infrastructure legislation from Senate Environment and Public Works Committee, including:

- Grant program for Alternative Fuel Corridors designed to strategically deploy alternative fueled vehicles, includes hydrogen refueling infrastructure

New ESIC H_2 Production Tax Credit Bill Draft

Senators Whitehouse (D-RI), Crapo (R-ID), Bennet (D-CO), Barrasso (R-WY), Hickenlooper (D-CO) and Risch (R-ID) – Seeking CHFC Support

Bill provides a PTC valued at **250% of wholesale price/kg H_2**

- **Tier determinations are locked in based on the wholesale market price reported by the Secretary two years prior to commence construction date. Treasury and Energy will review definition of "clean" H2 in 5 years.**
- Zero and net-negative get double the value of H_2 with a CI of less than 2 kg CO_2e/kg H_2
- CO_2 intensity is based on process-only emissions

The value of the PTC remains based on market penetration of clean H_2 - **market H_2 penetrations have increased by 0.25% for each tier**:

Credit values determined by tiers of market penetration:

- Tier 1: 0–0.75% receives 60% of basis price;
- Tier 2: 0.75–1.5% receives 45%;
- Tier 3: 1.5–2.25% receives 30%;
- Tier 4: 2.25–3% receives 15%
- Above 3% the PTC is eliminated

market penetration	$/kg H_2 at CI < 2.5kg CO_2/kg H_2	$/kg H_2 at CI ≤ 0 kg CO_2/kg H_2
Tier 1	$1.50	$3.00
Tier 2	$1.125	$2.25
Tier 3	$0.75	$1.50
Tier 4	$0.375	$0.75

Each market tier (0.75%) equivalent to ~ 930,000 metric tons (based on electric sector)

- Tier size likely to grow with increased electrification

Sen. Carper Hydrogen Production Tax Credit Bill

Lifecycle GHG Emission	PTC $Value per kg (% of credit)	ITC % Value (% of credit)
95 - 100%	$3.00 (100%)	30% (100%)
85 – 95%	$1.02 (34%)	10.2% (34%)
75 – 85 %	$0.75 (25%)	7.5% (25%)
50 - 75%	$0.60 (20%)	6% (20%)

- Creates an ITC and PTC for hydrogen production – cannot claim both
- Credit value based on % reduction from conventional steam methane reforming carbon intensity
- Credit is per kg clean H_2 for 10 years from placed in service date, but is not guaranteed
  - There is a phaseout that begins when CO_2 emissions from transportation fuels are less than or equal to 25% of the CO_2 emissions from transportation fuels in 2021
  - This applies to all facilities, no matter where they are in the 10-year credit claiming period
- DOE and EPA to publish guidance on methods to determine LCA which includes upstream and downstream emissions
- Includes ability to generate hydrogen from grid electricity – by using RECS
- Includes prevailing wage and apprenticeship requirements
- If taking any other tax credit, including sections 45, 48 and 45Q, a project cannot qualify for the PTC.

QUESTIONS

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Wyoming H_2 Research Opportunities

Holly Krutka, PhD
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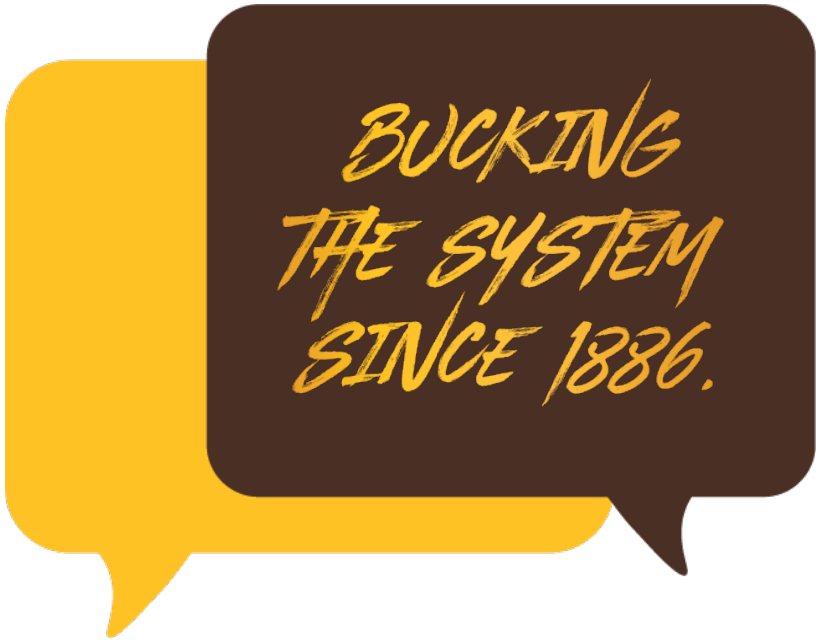
THE WORLD NEEDS MORE COWBOYS.

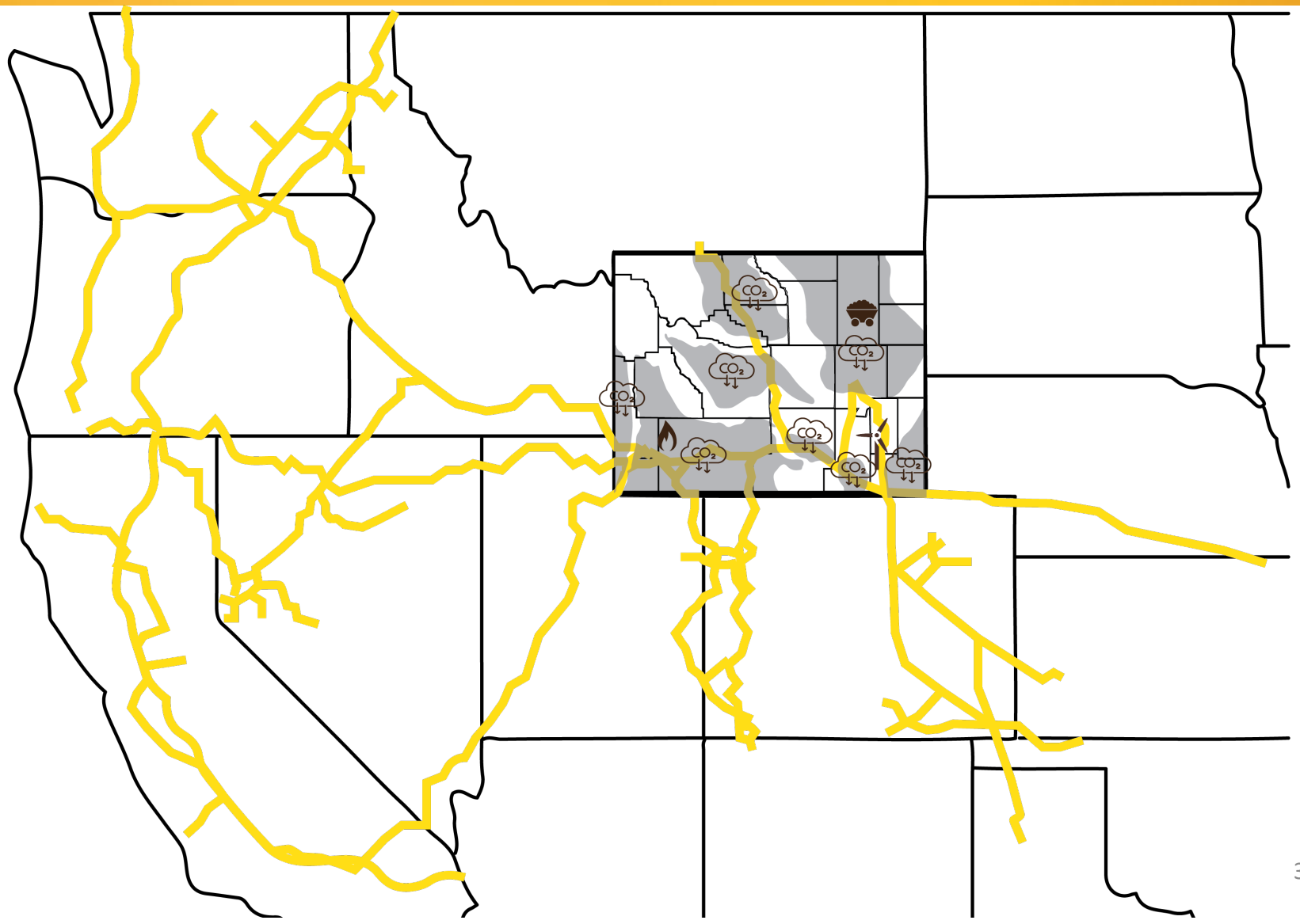
UNIVERSITY OF WYOMING | School of Energy Resources

SER's Mission:

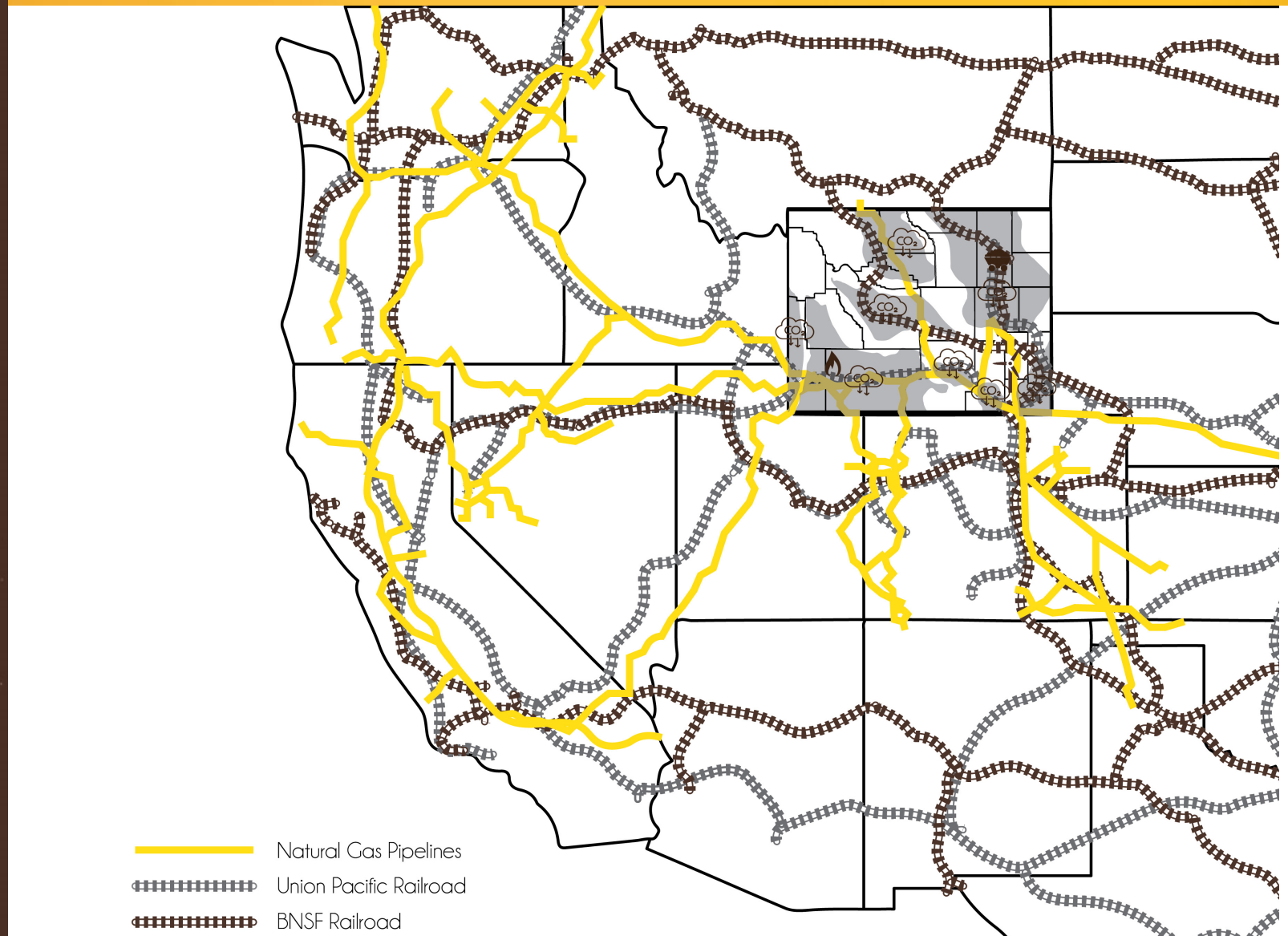
Energy-driven economic development for Wyoming



Wyoming as a H_2 Headwaters State



Wyoming as a H_2 Headwaters State



H_2 Center of Excellence

Select areas of interest:

- Quantify costs of Wyoming-produced hydrogen
- Identify and map potential markets
- Identify sources of produced water
- Map CO_2 storage sites near potential hydrogen hubs
- H_2 storage opportunities and seed studies
- Pipeline blending and retrofitting studies

Talk to me about opportunities to support this center of excellence!

Wyoming H_2 Research Opportunities

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