UW SCHOOL OF ENERGY RESOURCES

A Mid-Century Net-Zero Scenario for the State of Wyoming and its Economic Impacts (FE0032150)

2023 FECM/NETL SPRING R&D PROJECT REVIEW MEETING

Presented By:
Eugene Holubnyak

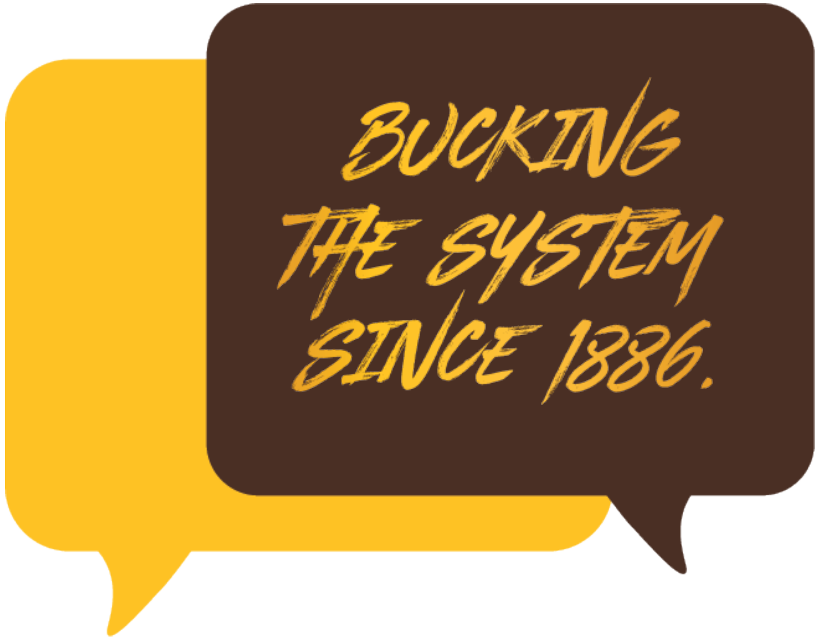
April 19, 2023

THE WORLD NEEDS MORE COWBOYS.

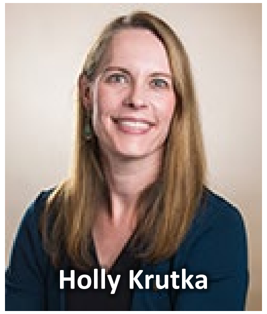
University of Wyoming | School of Energy Resources

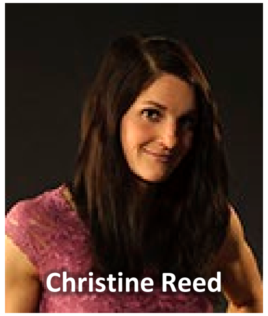
SER’s Mission:

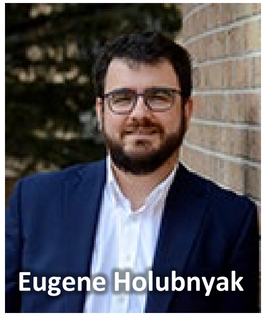
Energy-driven economic development for Wyoming

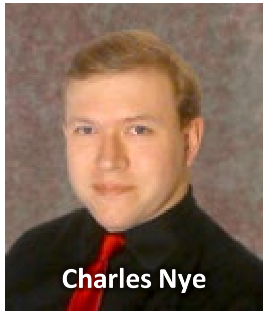


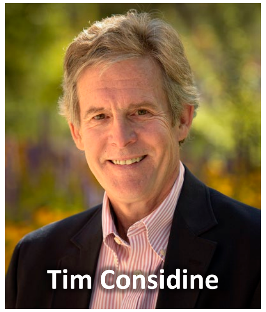
Team







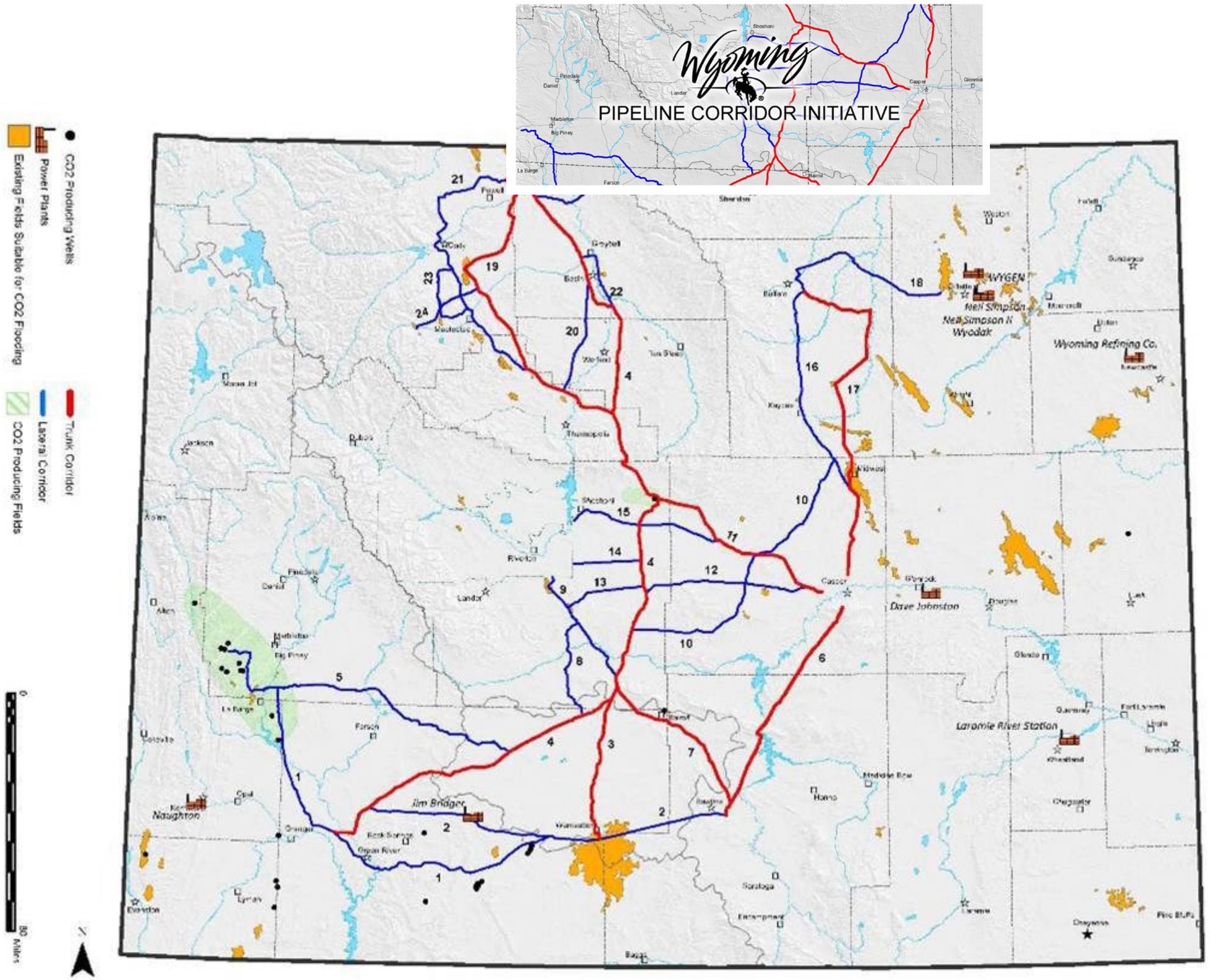




Project PI
Holubnyak
Executive Director
Krutka
Task 1 Project Management and Planning
Quillian
Task 2 Base Case: The Role of Fossil Energy in Wyoming's Economy
Considine
Task 3 Defining a Wyoming Hydrogen Economy
Holubnyak
Subtask 3.1 Markets & Partners
Coddington
Subtask 3.2 Feedstock & Energy Sources; Subtask 3.4 Transport Potential, Subtask 3.7 H2 Center of Excellence at SER
Holubnyak
Subtask 3.3 Storage Potential
McLaughlin
Subtask 3.5 Water Consumption & Resources
Nye
Subtask 3.6 Stakeholder Outreach & Educaiton
Reed

Outline

- Policy considerations
- Natural gas to Hydrogen
- Potential markets and economics
- Water
- Outreach



Wyoming’s Energy Portfolio and the Need for Diversification

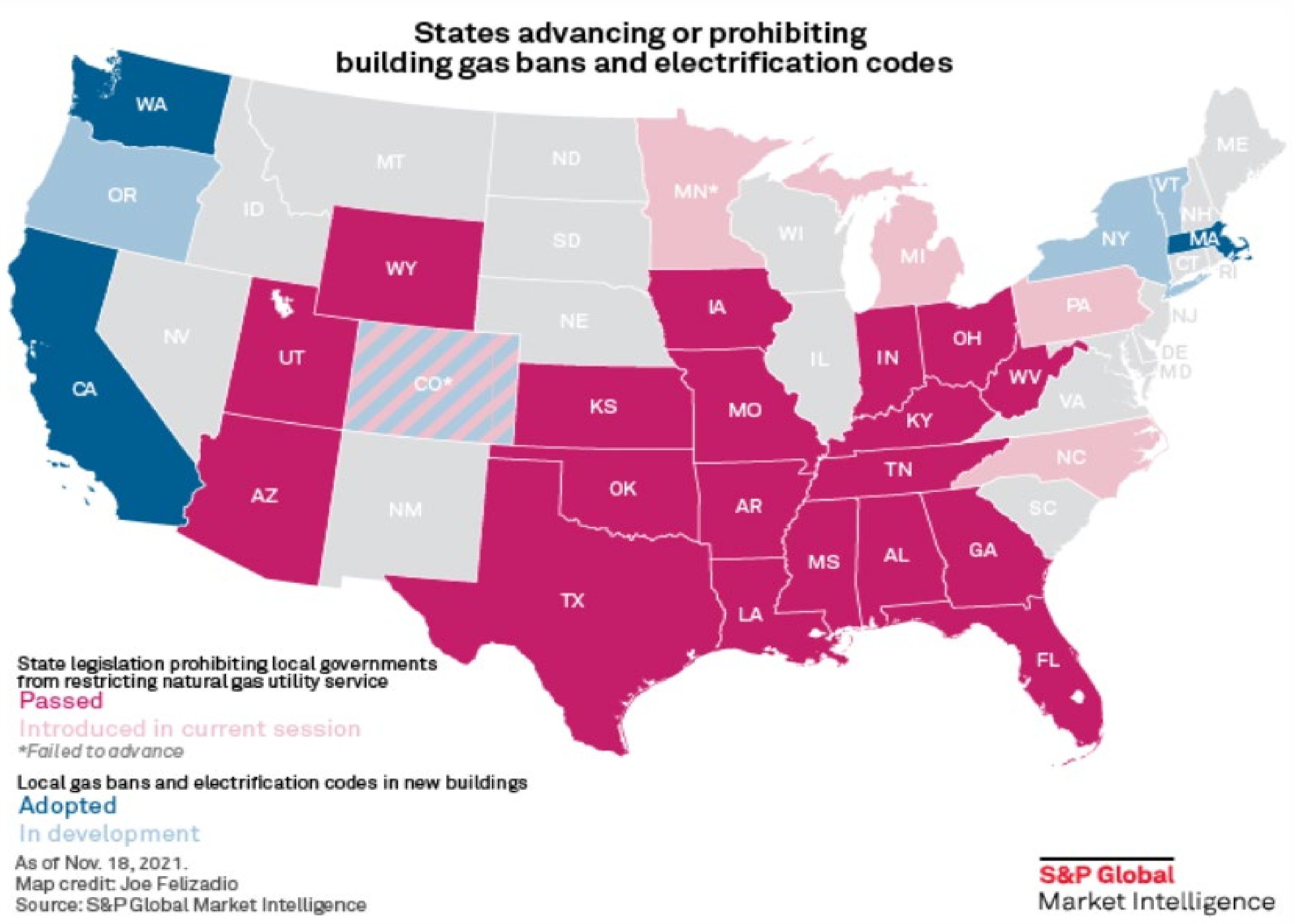
- Competitive Position of Wyoming Fossil Energy
  - Third largest energy producer in USA
  - Largest net energy exporter
  - #1 Coal Producer – 218 million tons
  - #8 Crude Oil producer – 232 thousand barrels per day
  - **#9 Natural Gas Producer – 1.3 trillion cubic feet**
    - **California, Nevada, Oregon, Washington**
- Economic Impacts of Fossil Energy in Wyoming
  - Direct: 16,265 full & part-time jobs, $7.9 billion in GDP
  - Total Impacts including direct, indirect (supply chain) & induced (household spending) roughly 32,000 jobs and $10 billion in GDP
- Property & Severance Tax Revenues – $1.7 billion
- Federal Royalties – $860 million (Wyoming receives about half)

Renewable Portfolio Standards, Clean Energy Standards Greenhouse Gas Reduction

State	Renewable Portfolio Standards/ Clean Energy Standards	Greenhouse Gas Reduction
California	RPS/CES: 50% by 2026 60% by 2030 100% by 2045 Blue H_2 acceptable "so far" CCUS methodology for the LCFS	Carbon neutrality by 2045 AB32 scoping plan revision general negative as to natural gas
Nevada	RPS: 50% by 2030 (with interim targets)	Zero or near-zero by 2050
Oregon	RPS: 50% by 2040 (with interim targets)	100% below baseline by 2040
Washington	RPS/CES: 100% by 2045 (with interim targets)	95% below baseline by 2050 Cap and invest program being implemented

Other Policy Considerations

- Natural gas bans
- ESG
- Carbon Markets
    - Regulated
    - Voluntary
        - American Carbon Registry
        - Verra (expected early 2023)



Estimated Production-Stage Methane Emissions For Natural Gas Consumed In Each State

- Emission intensity is source dependent
- Markets dictate change and producers comply with new demands

- Public-private collaboration success story
  - The School of Energy Resources' Center for Air Quality
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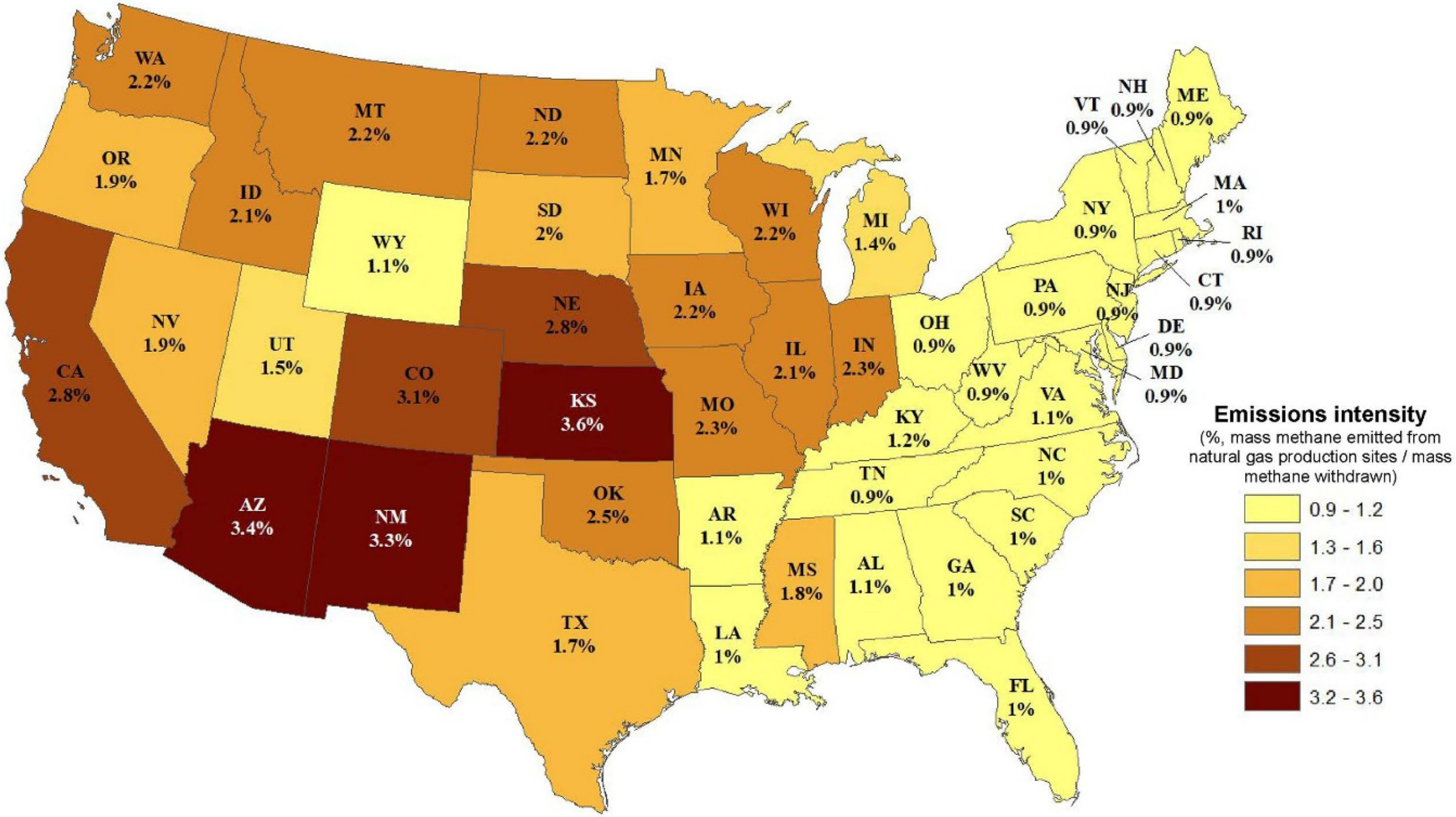


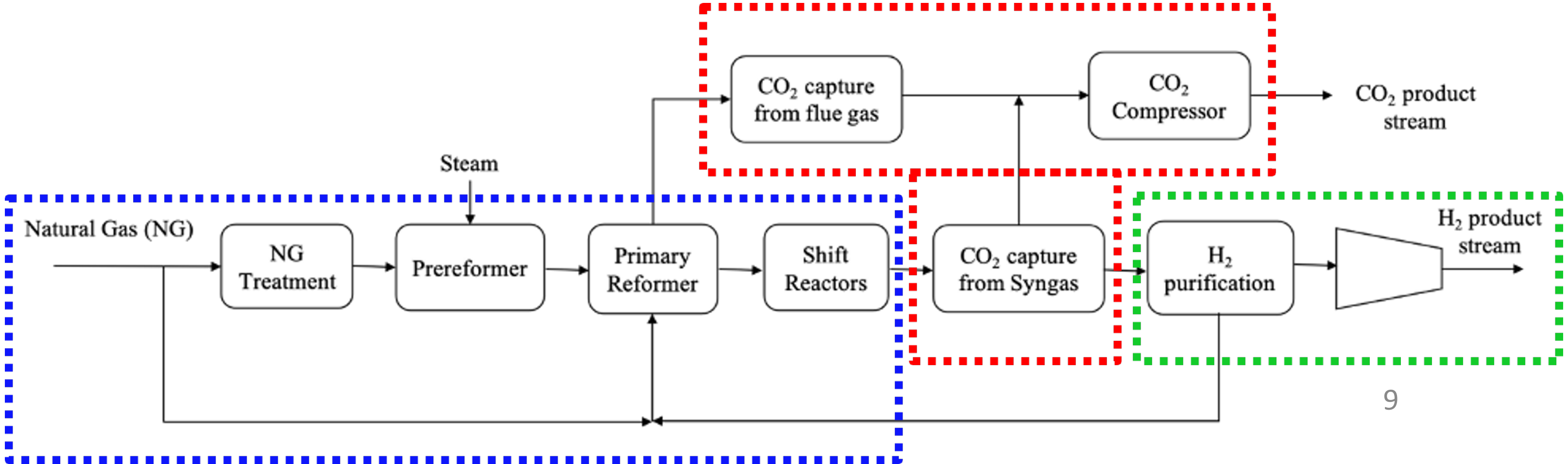
D Burns and E Grubert, Environ. Res. Lett. 16 (2021) 044059

Blue Hydrogen Model Progress Summary

- The team has developed a preliminary process model of blue hydrogen produced from natural gas.
- This process model provides a detailed mass, energy, and performance description of the entire hydrogen production plant, which will be used to evaluate process water use and economics, as well as life cycle greenhouse gas emissions.
- The process yield of blue hydrogen is 0.264 kg H_2/ kg of natural gas used, which highly matches with that reported by a recent NETL study (2022).
- An engineering-economic model will be developed in conjunction with the process model to estimate the cost of blue hydrogen produced from natural gas in Wyoming.

Production stream form SMR section

Components	Inlet Feed (mole fraction)		Product stream from SMR
	NG	Steam	Syngas (mole fraction)
CO_2	**0.01**	**0.0**	**0.153**
CH_4	0.931	0.0	0.042
CO	0.0	0.0	0.003
H_2O	**0.0**	**1.0**	**0.197**
H_2	**0.0**	**0.0**	**0.602**



Current Externally Funded Projects

- Initial engineering of the CO_2 capture unit of TEP Blue Bison ATR Plant
- Technical analysis for a power-to-gas project via biomethanation technology at Jonah Energy site located in Wyoming
- Feasibility Study of Green Hydrogen Generation and Transport in SW Wyoming
- Nuclear microreactors program

Idaho National Laboratory

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

WYOMING ENERGY AUTHORITY

TALLGRASS
Leading Energy Solutions

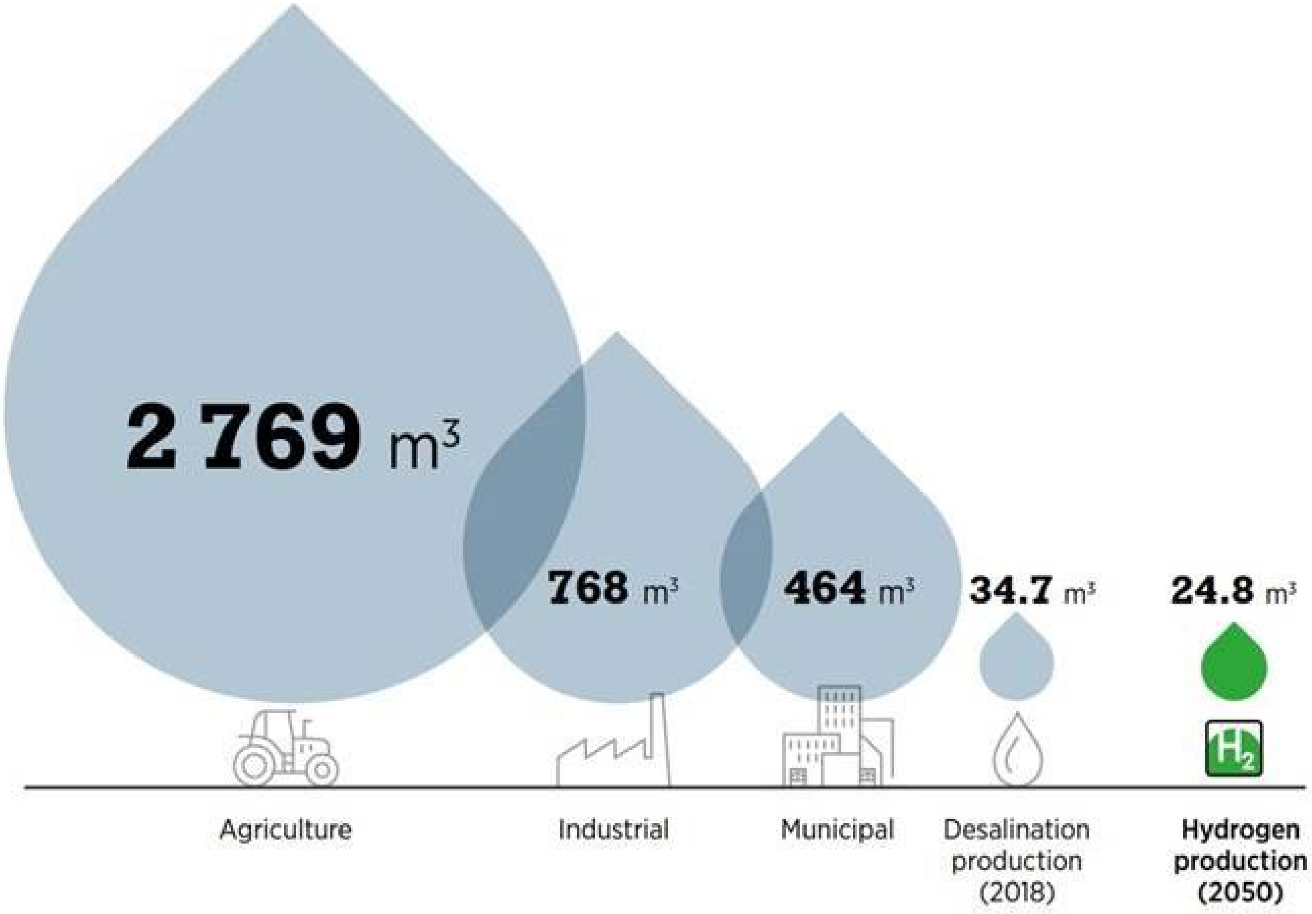
THE ANSCHUTZ CORPORATION

Williams

JONAH ENERGY LLC

Water Consumption by Hydrogen Production – World Outlook

- Hydrogen production is expected to scale 10x from current levels by 2050
- Hydrogen industry is forecasted to re-purpose water from existing industries:
    - Refineries and blue hydrogen
    - Natural gas
    - Coal and gasification
- Water use by Hydrogen production marginal compared to other industries, municipal, recreational, or agricultural activities



Water Consumption by Hydrogen Production – World Outlook

- Significant cooling load for electrolysers
  - 30 to 40 kg of water kgH_2o/kgH_2 for makeup in evaporative cooled systems.
  - The cooling demand for the electrolyser can typically increase by 40-70%
- Other cooling loads
  - The multi-stage compressors with intercooling to compress the produced hydrogen to a suitable pressure for storage or use
- Raw water feed for high purity electrolyser requirements
  - 20-40% of the water sent to waste
- Water disposal – due to the feedwater impurities
  - Waste treatment facility or onsite treatment or disposal
- Additional 60-95 kgh_2o/kgh_2 .
  - 60-70% for cooling water makeup

Hydrogen Production - Water Demand Accounting for Evaporative Cooling

H_2 production pathway	Stoichiometric demand (L/kg H_2)	Total demand (L/kg H_2), assuming good quality raw water import and evaporative cooling
Natural Gas reforming (grey H_2)	4.5	*15-40
Natural Gas reforming with carbon capture (blue H_2)	4.5	*18-44
Biogas reforming (can be classified as green H_2)	4.5	*20-45
Coal gasification (black H_2)	C:H ratio and coal moisture content	70
Biomass gasification (can be classified as green H_2)	C:H ratio and biomass moisture content	60
Water electrolysis (green H_2)	9	60-95

https://www.ghd.com/en/perspectives/water-for-hydrogen.aspx

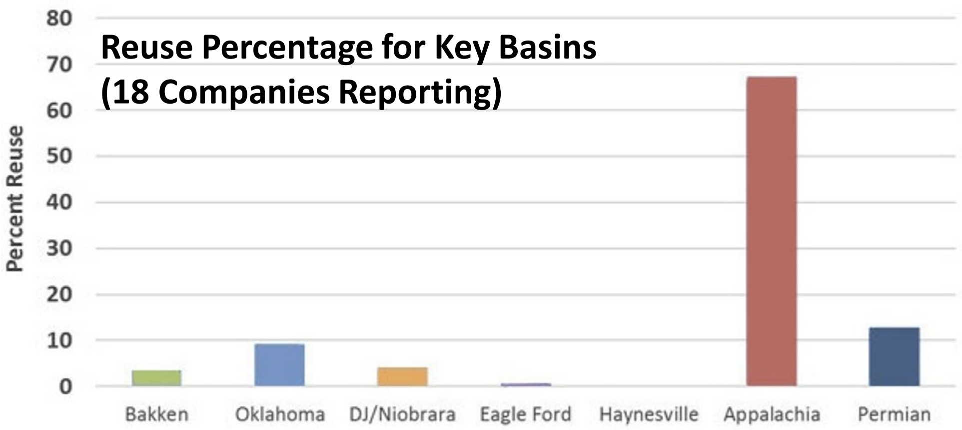
Permian Basin: Produced Water Reuse and Marketplace

- Challenge and opportunity
- Optimize hydrogen production methods with desalination/water treatment
- Water demand: 1.3B bbls/annum
- Produced water: 1.6B bbls/annum
- Asking prices $0.48-1.02/barrel

www.genesiswatertech.com

Water Acquisition Costs per Barrel for Seven Counties in the Permian Basin

State	Data Points	County	Price High	Price Low	Price Average	Price Median	Today's Volume Median
TX	36	Reeves	$2.00	$0.30	$0.58	$0.57	50,000
TX	33	Yoakum	$1.00	$0.45	$0.77	$1.00	20,572
TX	33	Martin	$1.40	$0.35	$1.06	$0.50	8,572
TX	31	Midland	$3.00	$0.10	$0.52	$0.50	6,857
TX	14	Howard	$0.65	$0.30	$0.48	$0.48	30,000
NM	60	Lea	$1.00	$0.50	$0.80	$1.00	17,142
NM	21	Eddy	$1.25	$1.00	$1.02	$1.00	27,428



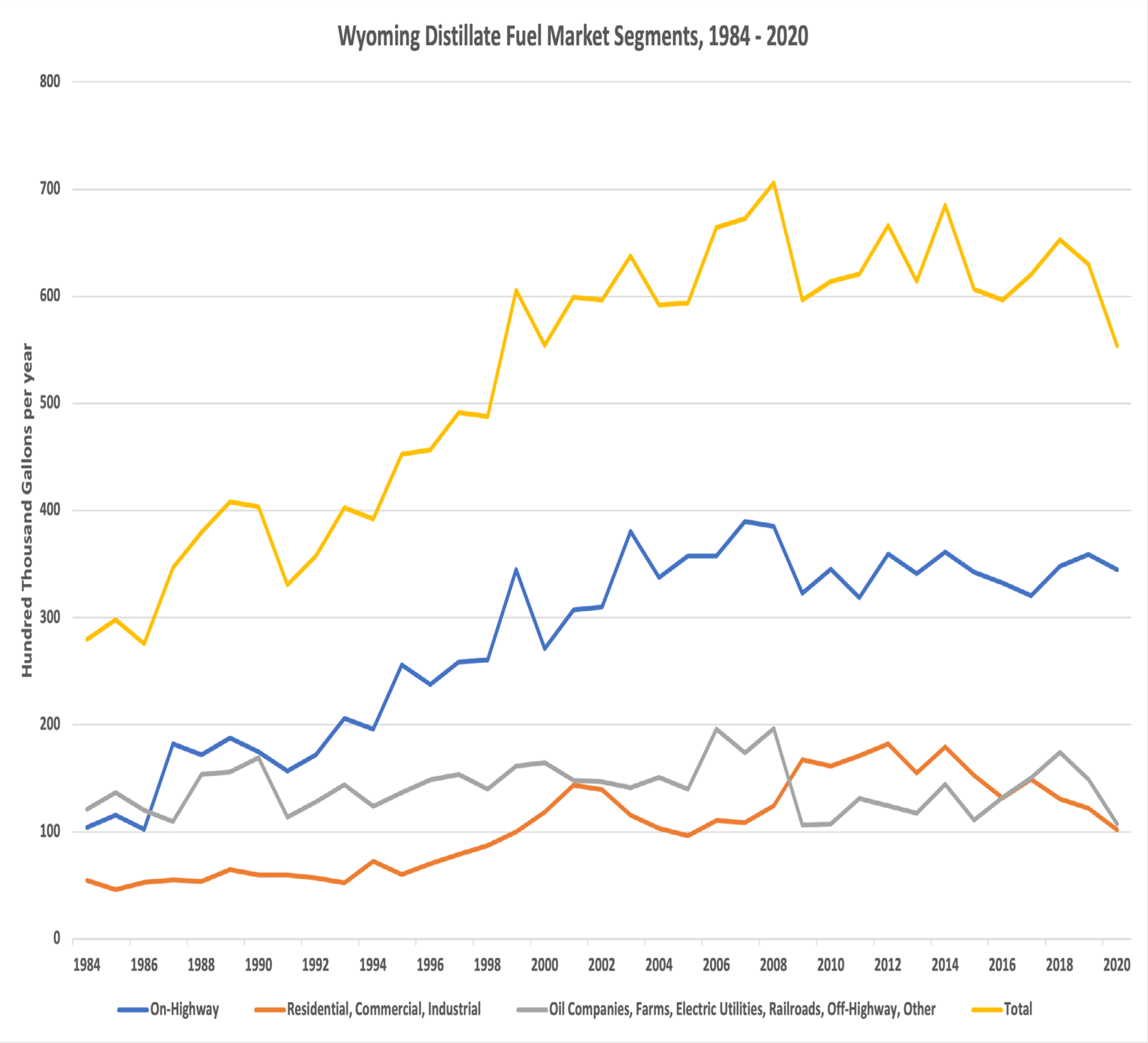
Sourcewater https://www.sourcewater.com/

GWPC: Produced Water Report: Regulations, Current Practices, and Research Needs, 2019

Source: Jacobs Engineering

Rocky Mountain Market for Hydrogen in Transport?

- If we produce H_2 who will buy it?
- What is the ***potential*** size of H_2 market?
- Consider Wyoming distillate use: 600k gallons / year
- Replacing Wyoming diesel use w/ H_2 would require
  - 3 coal to H_2 plants (660,000 Kg / day), or
  - 4 CH_4 to H_2 facilities (483,000 Kg / day)
- Replacing WY, CO, ID, MT, & UT distillate use:
  - 16 coal to H_2 plants using 29 MST of coal, or
  - 19 CH_4 to H_2 plants using 532 million Mcf of CH_4
- Will estimate impacts on jobs, economic output, and tax revenues for proposed and potential Wyoming projects



Rocky Mountain Market for Hydrogen in Power?

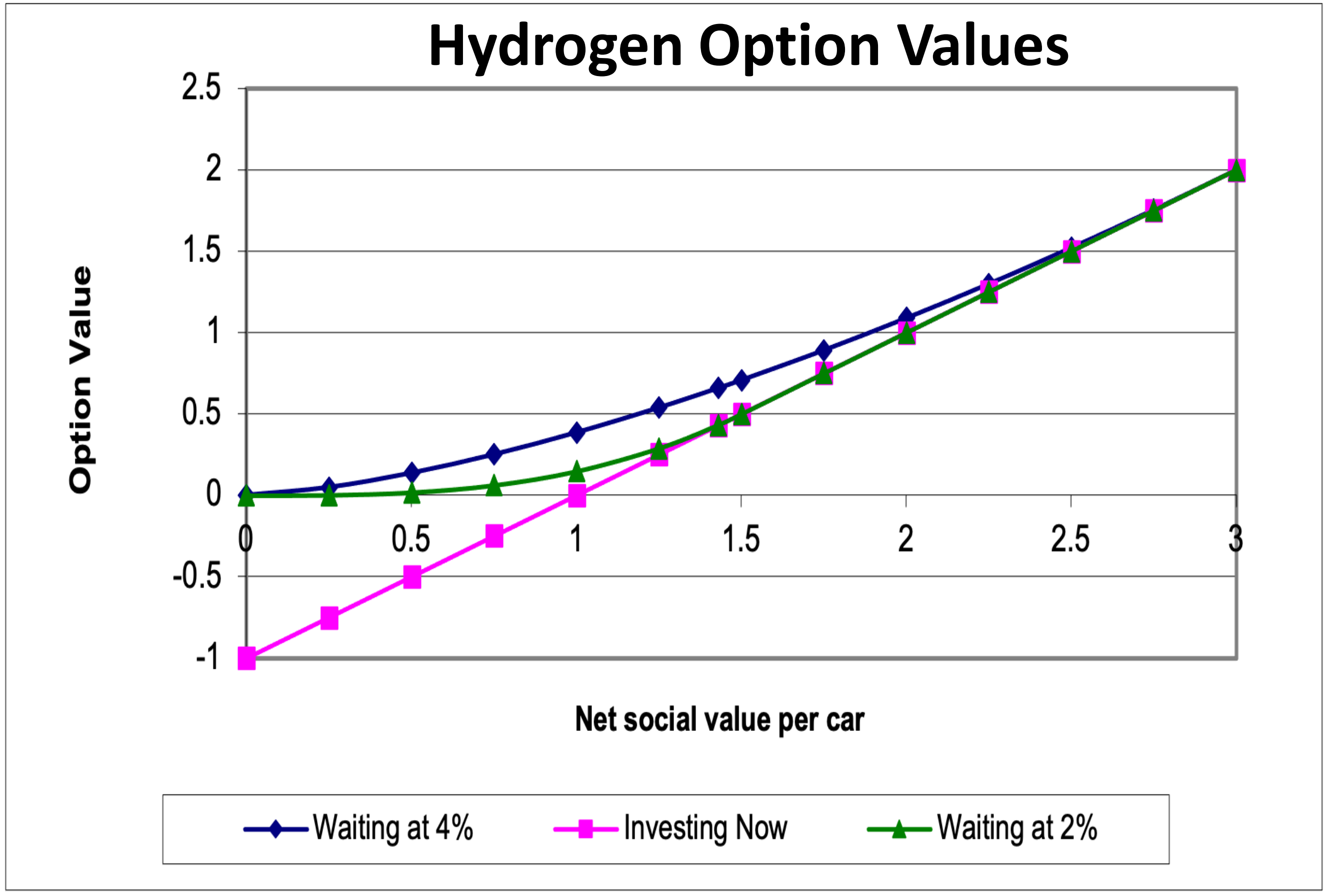
- 2.5 GW of Wyoming coal capacity closing by 2037
- Replacing this capacity with hydrogen would allow
  - 4 coal to H_2 plants, or
  - 5 CH_4 to H_2 facilities
- Replacing WY, CO, ID, MT, & UT coal use:
  - 8 coal to H_2 plants, or
  - 10 CH_4 to H_2 plants consuming 532 million Mcf
- Power storage is another market opportunity
- Analysis of ammonia market is next with
  - Estimation of world ammonia market model that
  - Could be a useful tool for determining how prices for NH_3 are affected by
    - New capacity (gray, blue, green) , and
    - More expensive natural gas

- **Planned Power Plant Closures in Wyoming**

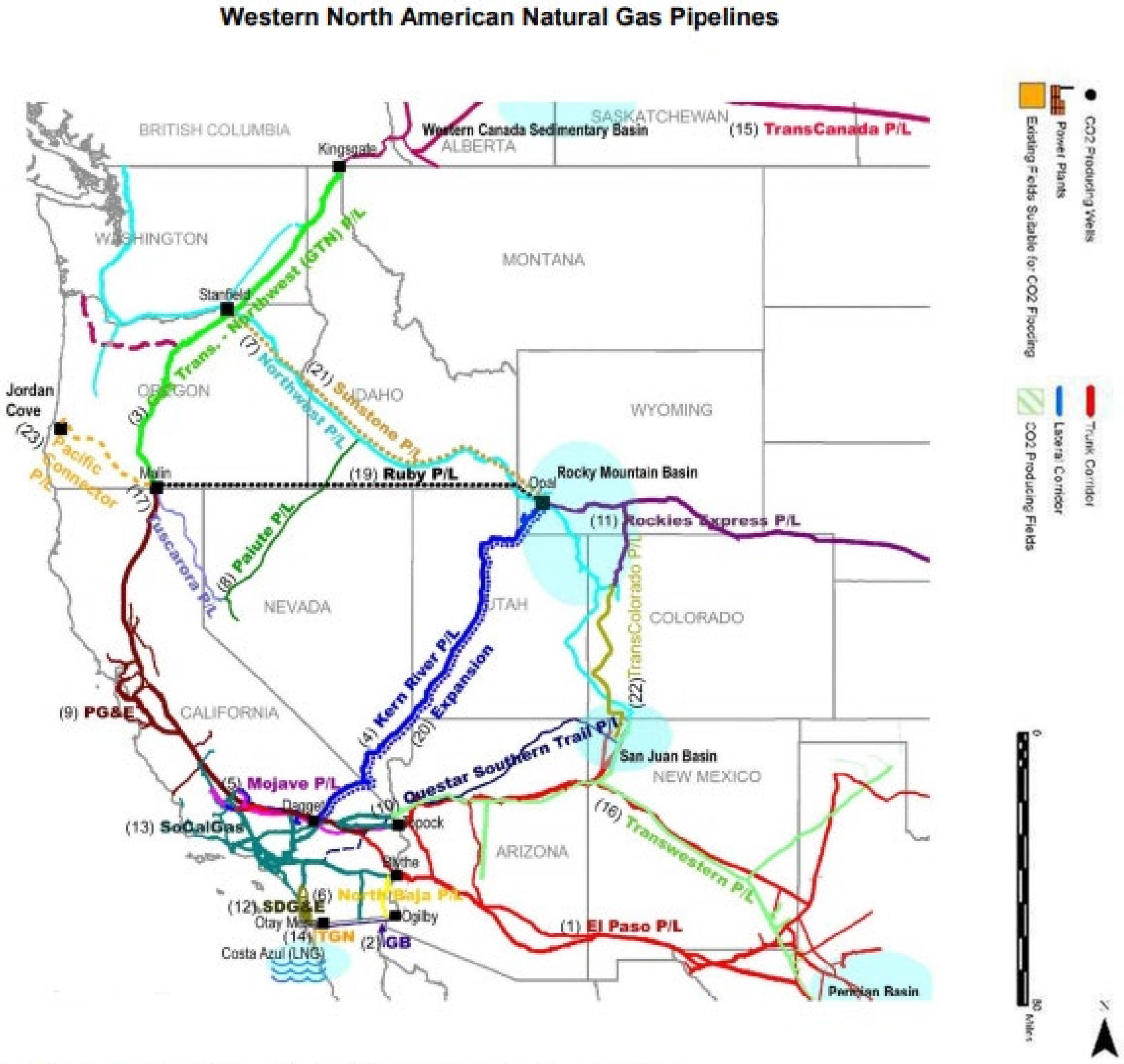
Plant Name	Capacity (MW)	Closure Date
Dave Johnston 1	99	2028
Dave Johnston 2	106	2028
Dave Johnston 3	220	2028
Dave Johnston 4	330	2028
Naughton 1	156	2025
Naughton 2	201	2025
Jim Bridger 1	351	2023
Jim Bridger 2	356	2028
Jim Bridger 3	349	2037
Jim Bridger 4	353	2037
Total	2,521	

Hydrogen Investment under Uncertainty

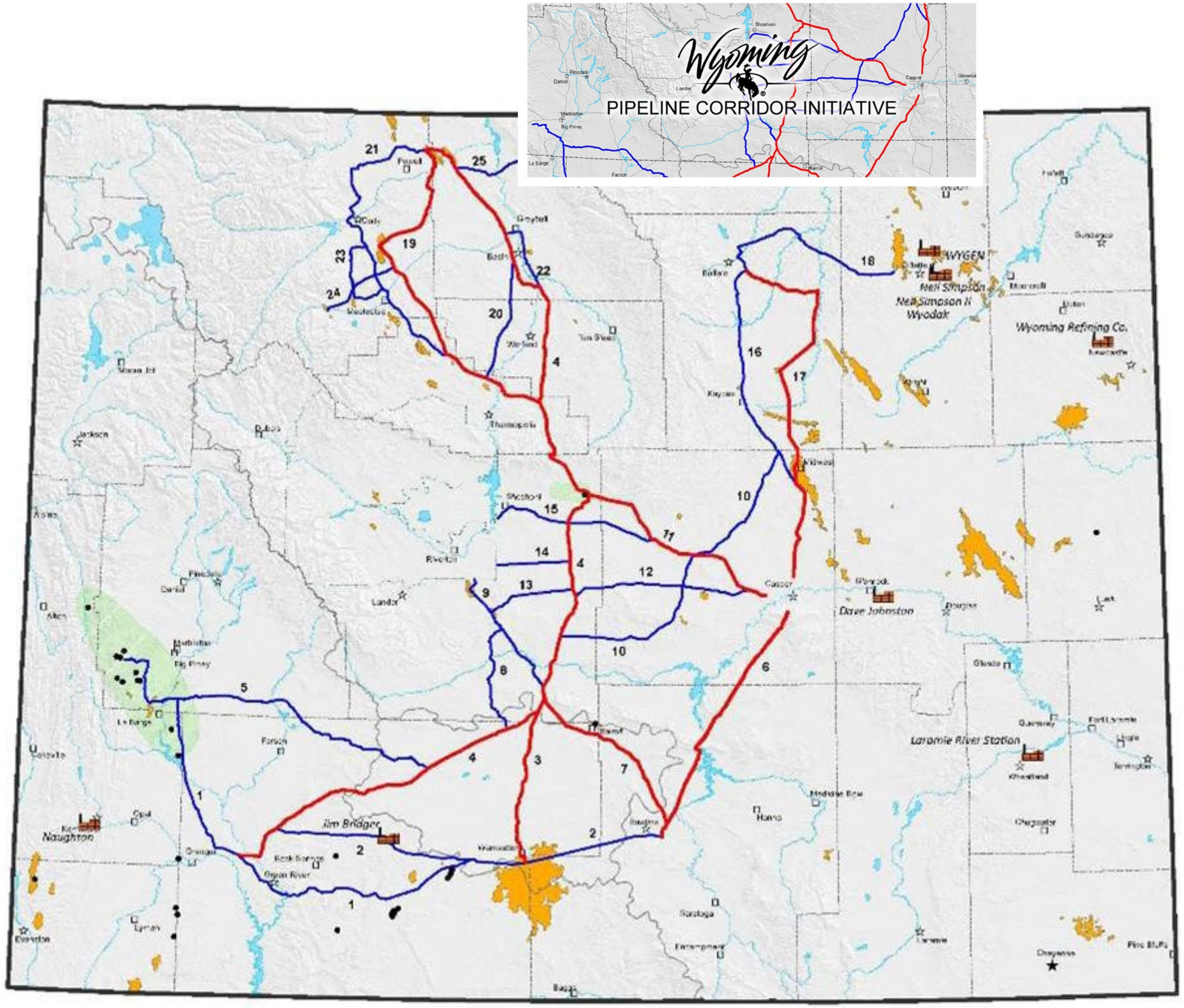
- Many uncertainties surround hydrogen investments
  - Costs, performance
  - Market access / demand
  - Tax policy
- Facing these uncertainties investors often wait for a much higher rate of return
- Option valuation can help identify the optimal time to wait
- Example: If a net social value of H_2 of 1.3 appreciates at 4%,
  - A $500 value from waiting &
  - Optimal time to invest is over 20 years
- At 2% appreciation (lower return from waiting)
  - A $290 value from waiting &
  - Optimal time to invest is 5 years



Regional CO_2 Pipelines

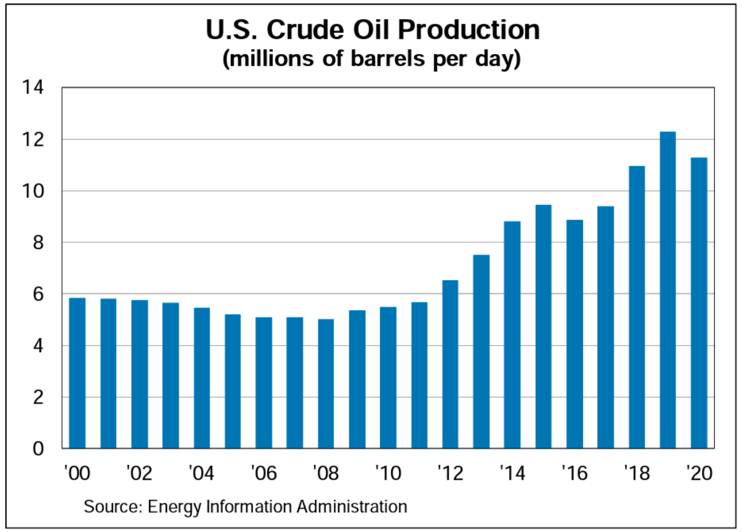


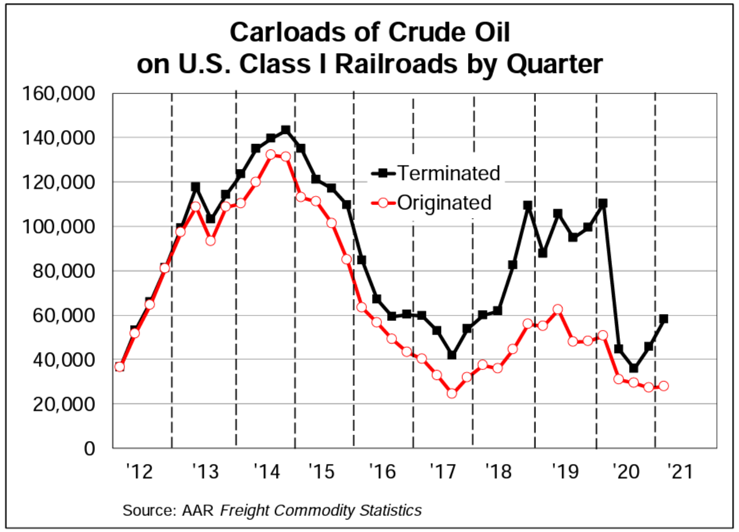
Source: 2016 California Gas Report, Prepared by the California Gas and Electric Utilities.



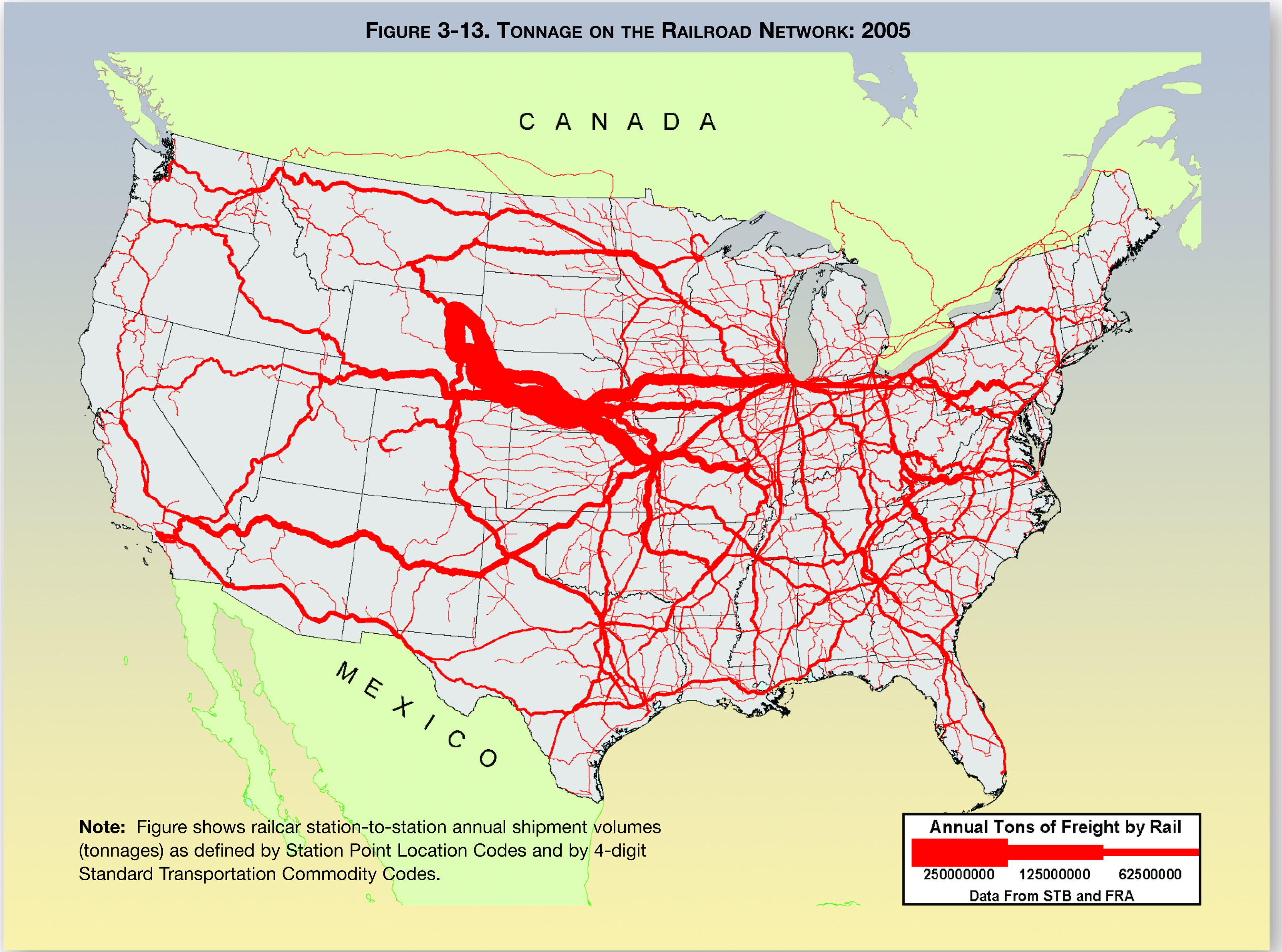
AAR-Crude-Oil-Fact-Sheet

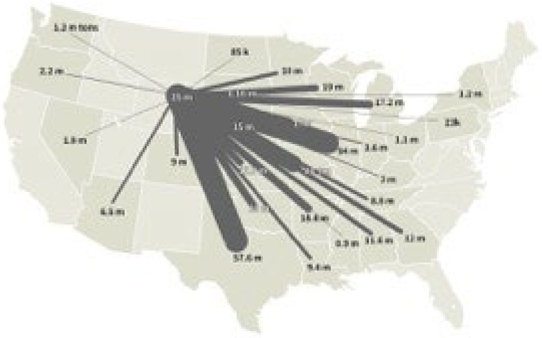
- 2008, railroads originated **9,500** carloads of crude oil
- 2014, shale revolution, peaked at **493,146** carloads, **52X**
- 2021, U.S. Class I railroads terminated **236,069** carloads of crude oil
    - A variety of factors affect rail crude oil volumes, including pipeline capacity and crude oil prices.
- More than 99.99% of all hazmat moved by rail reaches its destination without a release caused by a train accident.





Rail freight tonnage





https://ops.fhwa.dot.gov/freight/freight_analysis/nat_freight_stats/docs/07factsfigures/pdf/fig3_13.pdf

List of Stakeholders

- Wyoming Energy Authority
- Regulators
- Industry
- National Labs
- Academia
- Tribes

Tribal Outreach

- Tribal leadership from the Wind River Reservation October 12, 2022
- SER hosted a presentation to learn about Tribal Governance.
- Wahleah Johns, Director of the U.S. Department of Energy (DOE) Office of Indian Energy Policy and Programs, was invited to speak at SER's annual law and policy conference on October 14, 2022
- Discussion with the Greater Yellowstone Coalition, representatives from the local K-12 schools on the Wind River Reservation, SER and other research units at UW on December 14, 2022
- A meeting is scheduled for January 24 with Tribal leadership to discuss the implementation of a course on tribal governance and energy development.

Request for Proposals
Hydrogen: Make, Move, Use or Store

- Total budget $650,000 for 7 projects
- Seed money to develop sustainable program
- Progress on the research infrastructure
- Helps to facilitate proposals for external funding
- Projects update meeting with industry during National Labs Day on campus of UW
    - Hiring is complete
    - Laboratories are being equipped and experiments are in progress
    - Results are being analyzed
    - New areas of interest are being identified
- Round 2 is expected June 15, 2023

Research on Campus
Hydrogen: Make, Move, Use or Store

1. Soheil Saraji – **A Multiscale Study of Hydrogen Geochemical Reactivity and Transport for Geo-Storage in Deep Saline Aquifers** – Petroleum Engineering
2. Charlie Zhang, Selena Gerace, Muskan Kuinkel – **Economic analysis of building new pipelines vs converting existing natural gas pipelines in gaseous hydrogen transportation** – Civil and Architectural Engineering
3. Saman Aryana - **Phase Behavior of Hydrogen and Blended Gas** – Chemical Engineering
4. Kam Ng – **Experimental Investigation of the Effect of Underground Hydrogen Storage on the Hydraulic and Mechanical Properties of Rock Reservoirs** – Civil and Architectural Engineering
5. Sarah Buckhold, Michael Stoellinger, Jonathan Naughton – **Stranded Wind Energy for Hydrogen Production in the State of Wyoming** – Mechanical Engineering
6. Haibo Zhai – **Technological Learning and Resources Required for Large-Scale Blue Hydrogen Production toward Energy Earthshot Target** – Civil and Architectural Engineering
7. Minou Rabiei, Morteza Dejam, Vamegh Rasouli – **Feasibility Study of Developing Salt Caverns for Hydrogen Storage in Wyoming** – Petroleum Engineering

21	21	106
20	16	95
21	21	109
18	17	86
23	20	107
17	18	87
20	18	96
20	21	88
17	17	85
17	18	85
25	23	119
18	16	88
19	20	100
19	21	106
20	18	91
21	19	99
17	18	95
18	18	91
18	20	97
21	20	98
23	20	101

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HYDROGEN ENERGY RESEARCH CENTER

Presented By:
Eugene Holubnyak

eholubny@uwyo.edu

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