UW SCHOOL OF ENERGY RESOURCES

Regulatory and Policy Challenges for Hydrogen Ecosystem Growth

Presented By:
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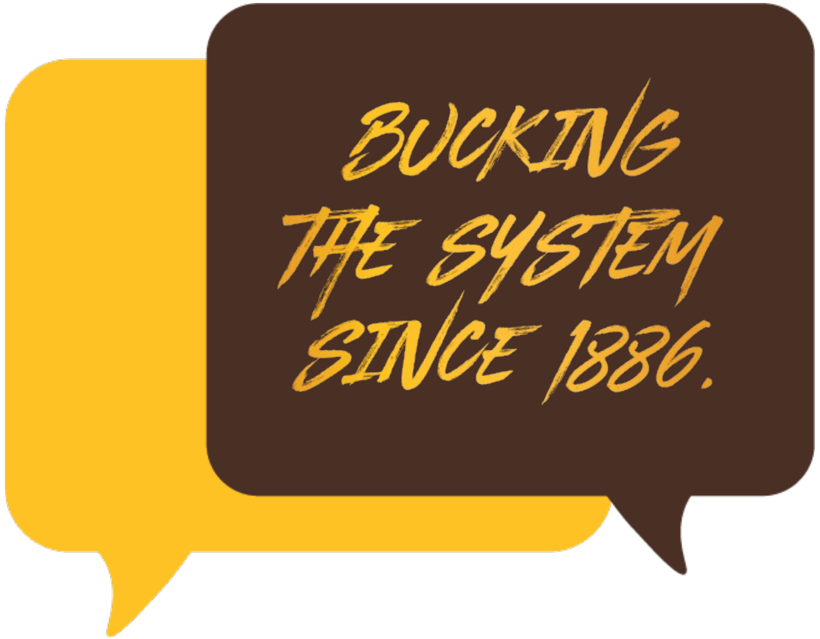
THE WORLD NEEDS MORE COWBOYS.

University of Wyoming | School of Energy Resources

SER's Mission:

Energy-driven economic development for Wyoming



About the School of Energy Resources

The School of Energy Resources (SER) at the University of Wyoming collaborates with state, national, and international stakeholders to advance energy technologies and policies to grow and support Wyoming's robust energy sector. **SER's mission is to promote energy-driven economic development for the state of Wyoming**. It leads the University of Wyoming's talent and resources for interdisciplinary research and outreach, fulfilling Wyoming's promise to be a global leader in a thriving and sustainable energy future.

SER Research Structure

Center of Economic Geology Research

Center of Carbon Capture and Conversion

Center for Energy Regulation and Policy Analysis

3D Visualization Center

Hydrogen Energy Research Center

Staff-led Centers of Excellence

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

Nuclear Energy Research Center

Partner Organization

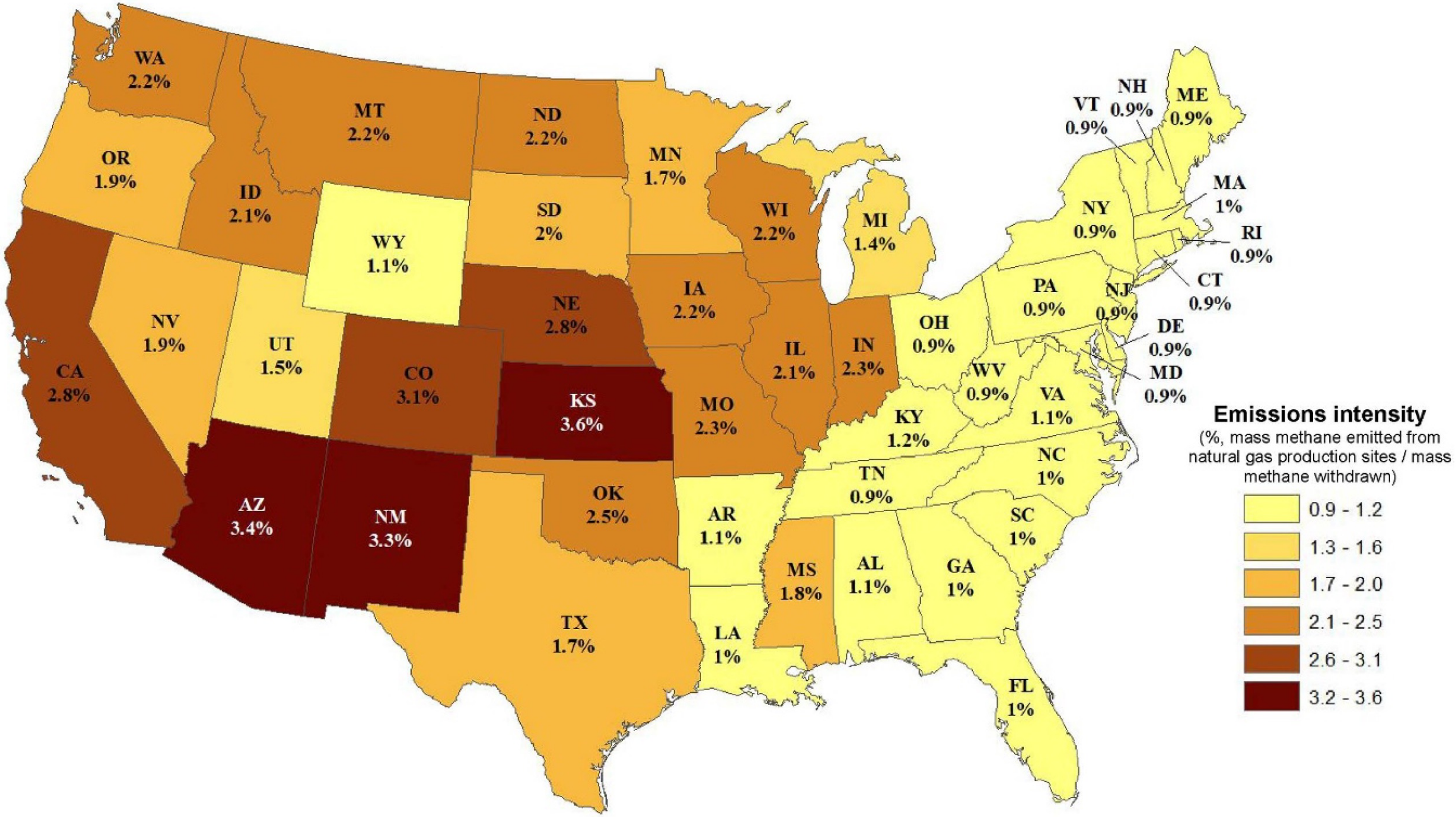
Enhanced Oil Recovery Institute

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)

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

- 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
-



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

Production Tax Credit for Clean Hydrogen

Base credit is \$0.60 / kg, but multiplied by 5X if projects pay at or above the prevailing wage; additional enhancement for facilities in coal-affected communities.

Additional enhancement if located in coal-affected regions (10%, but confirm it applies)

The Investment Tax Credit can be applied for hydrogen uses (i.e. fuel cells)

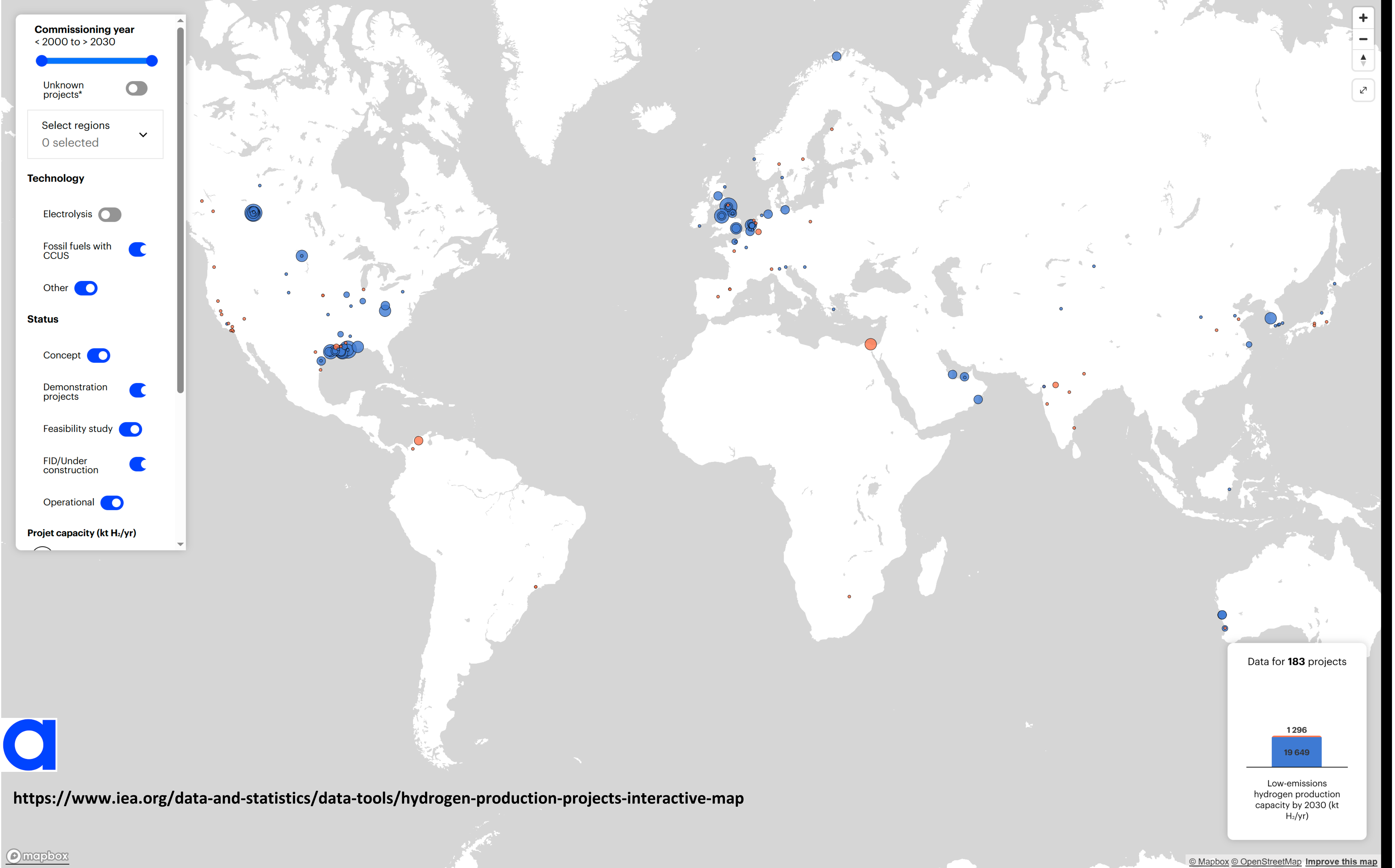
Lifecycle GHG Intensity	PTC \$Value per kg (% of max credit)	ITC % Value (% of max credit)
< 0.45 kg	\$3.00 (100%)	30% (100%)
< 1.5 and ≥ 0.45 kg	\$1.00 (33.4%)	10.2% (34%)
< 2.5 and ≥ 1.5 kg	\$0.75 (25%)	7.5% (25%)
≤4 and ≥ 2.5 kg	\$0.60 (20%)	6% (20%)

45V Final Treasury Rule

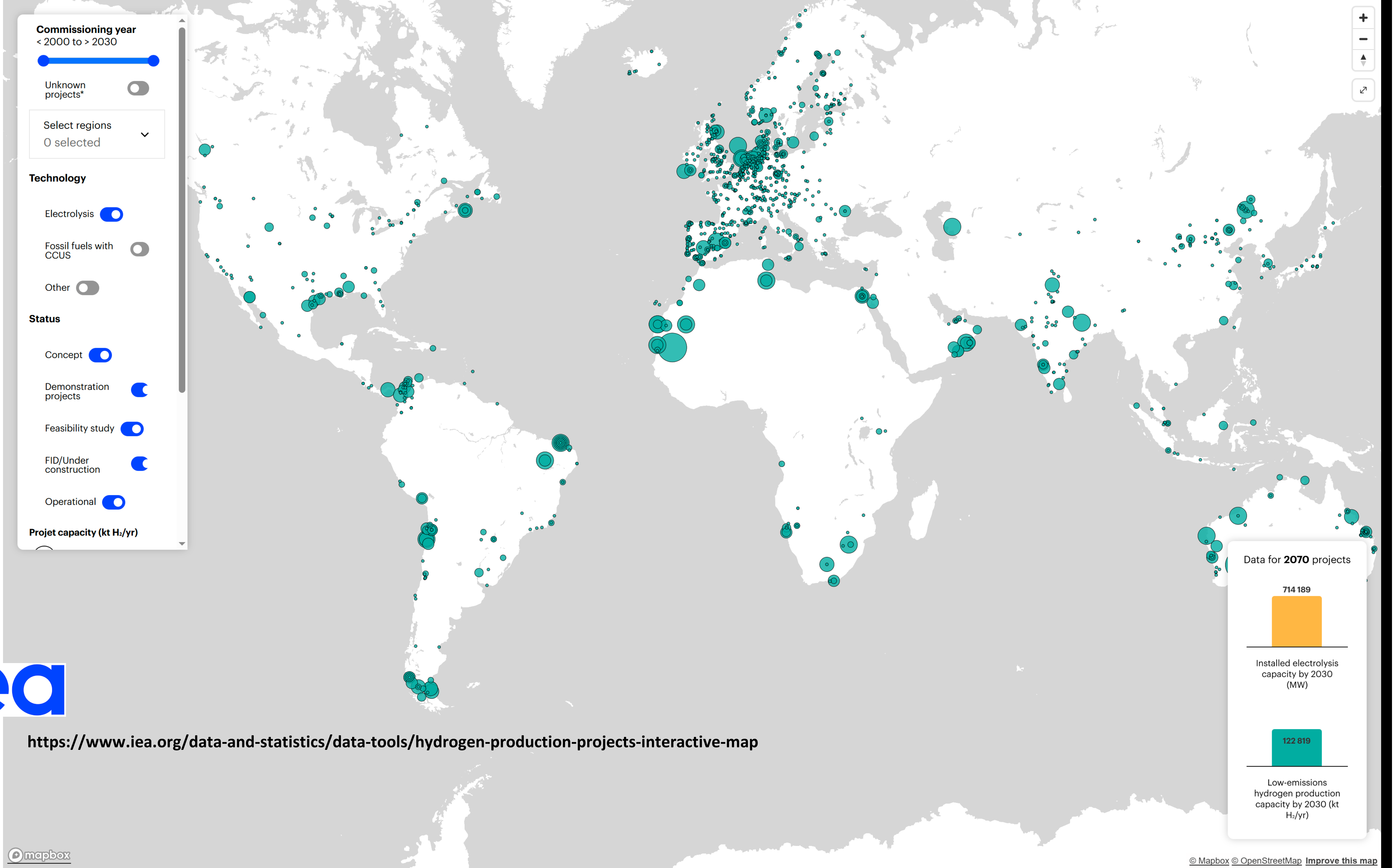
- 45VGREET model
  - Use 45VGREET in place at the beginning of construction OR version at begin operations date
- Time-matching (hourly matching required 1/1/28 for all H_2 production)
  - Annual time-matching until 1/1/30
  - All production facilities to use hourly matching 1/1/2030
- Incrementality - clean electricity sources operational no more than 3 years before H2 production
- Clean electricity sources must be operational no longer than 3 years before H_2 production
  - State Policy Pathway: Existing clean electricity sources can qualify if the state has a cap-and-trade policy that includes electricity imports; if C&T is economy-wide, the state must also have an RPS/CES; and H_2 production must also be in a qualifying state.
  - Existing Nuclear Units: up to 200 MW per reactor can qualify if the unit meets all 3 tests for risk of retirement
- Deliverability - clean electricity sources must be located within the same region
  - Energy Attribute Certificates for an electricity source can meet the deliverability requirement if the generation's cross-region delivery can be tracked and verified (this includes transmission rights and electricity delivery to H2 production regions tracked hour-to-hour).

45V Final Treasury Rule (cont.)

- Exclude certain H_2 produced - lifecycle analysis applies to all H_2 produced at facility
  - Facility must have an annual average of < 4 kgCO_2e/kg H_2 (clean H_2 definition) and can then select hours of production that meet a credit tier
- Differentiated natural gas - no recognition of natural gas supplies with lower upstream leakage rates
  - Required use of differentiated upstream methane emission rates after 45VGREET (~2026) is updated to reflect data from revised Subpart W, P, and C reporting. Super Emitter Program must be maintained.
- Renewable natural gas (RNG) - requirements similar to the 3-pillars were expected
  - Recognizes 3 sources of RNG: landfill, wastewater, and manure management
  - No averaging of methane sources for CO_2 intensity at a facility; use methane source-specific accounting
- Book-and-claim accounting
  - Early projects Attribute Certificate (EAC), a tradeable contractual instrument issued through a qualified gas EAC registry or accounting system.
- Provisional Emission Rate
  - A petition for a PER can be filed only for H_2 produced through a process that is not included in 45VGREET
  - Class 3 FEED study is required to complete an Emissions Value Request application for DOE.



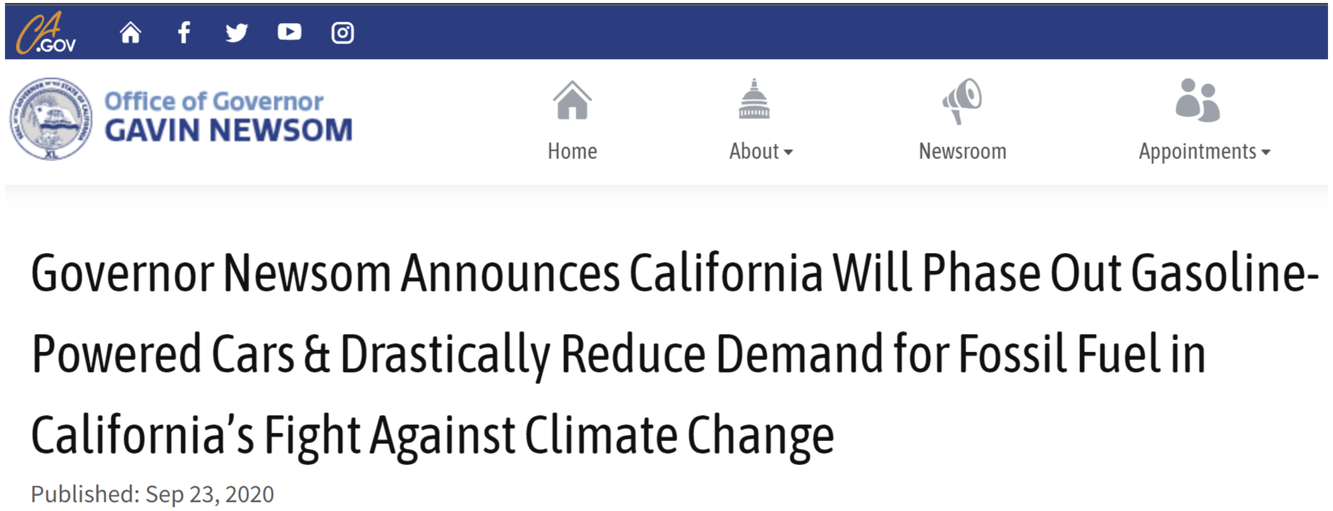
https://www.iea.org/data-and-statistics/data-tools/hydrogen-production-projects-interactive-map



https://www.iea.org/data-and-statistics/data-tools/hydrogen-production-projects-interactive-map

Zero-Emission Vehicle Mandates

- Norway 2025
- Denmark 2030
- Netherlands 2030
- Sweden 2030
- India 2030
- France 2040
- United Kingdom 2040
- Sri Lanka 2040
- Canada - British Columbia (2040)
- China (no date set)

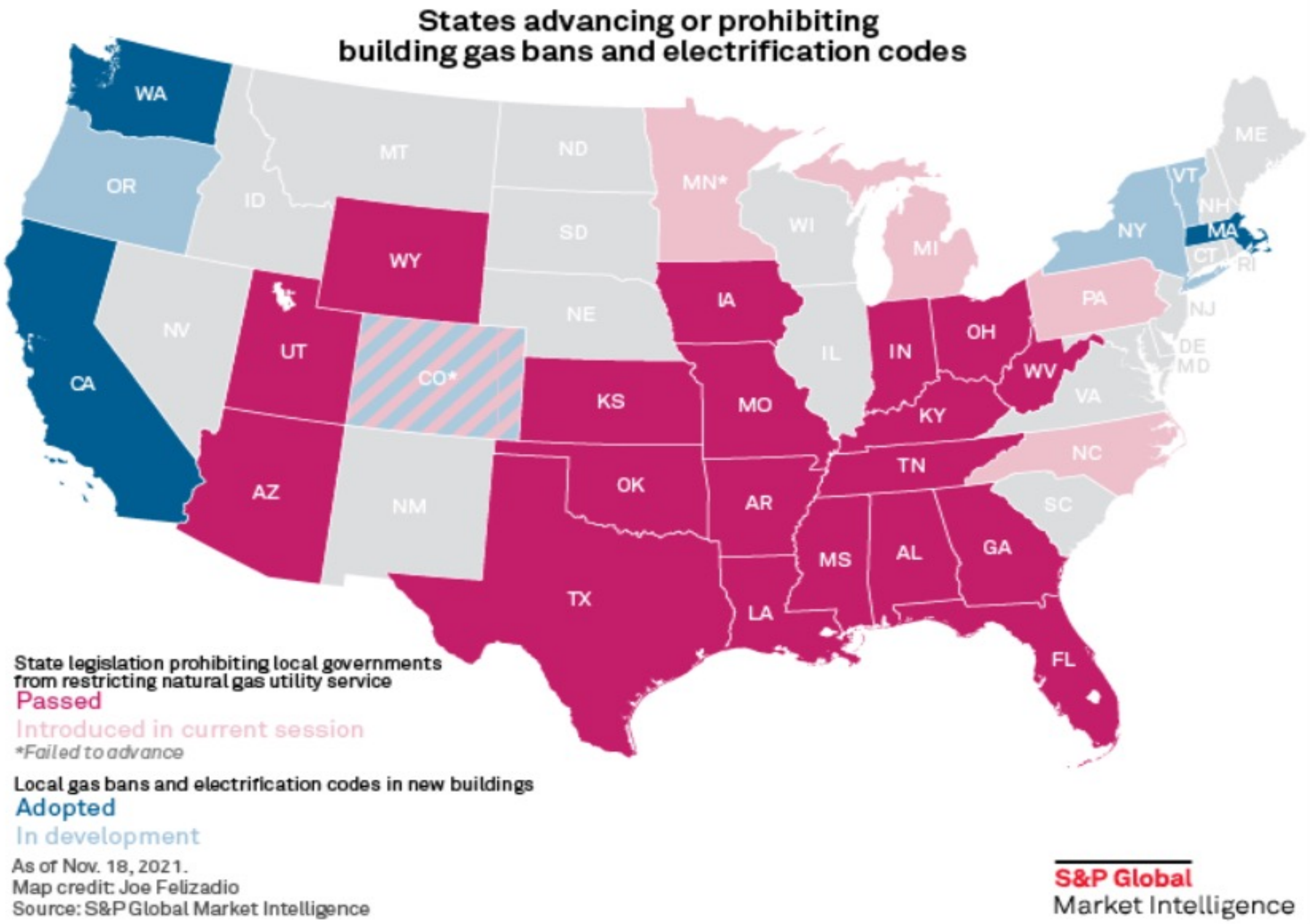


Renewable Portfolio Standards, Clean Energy Standards
Greenhouse Gas Reduction

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

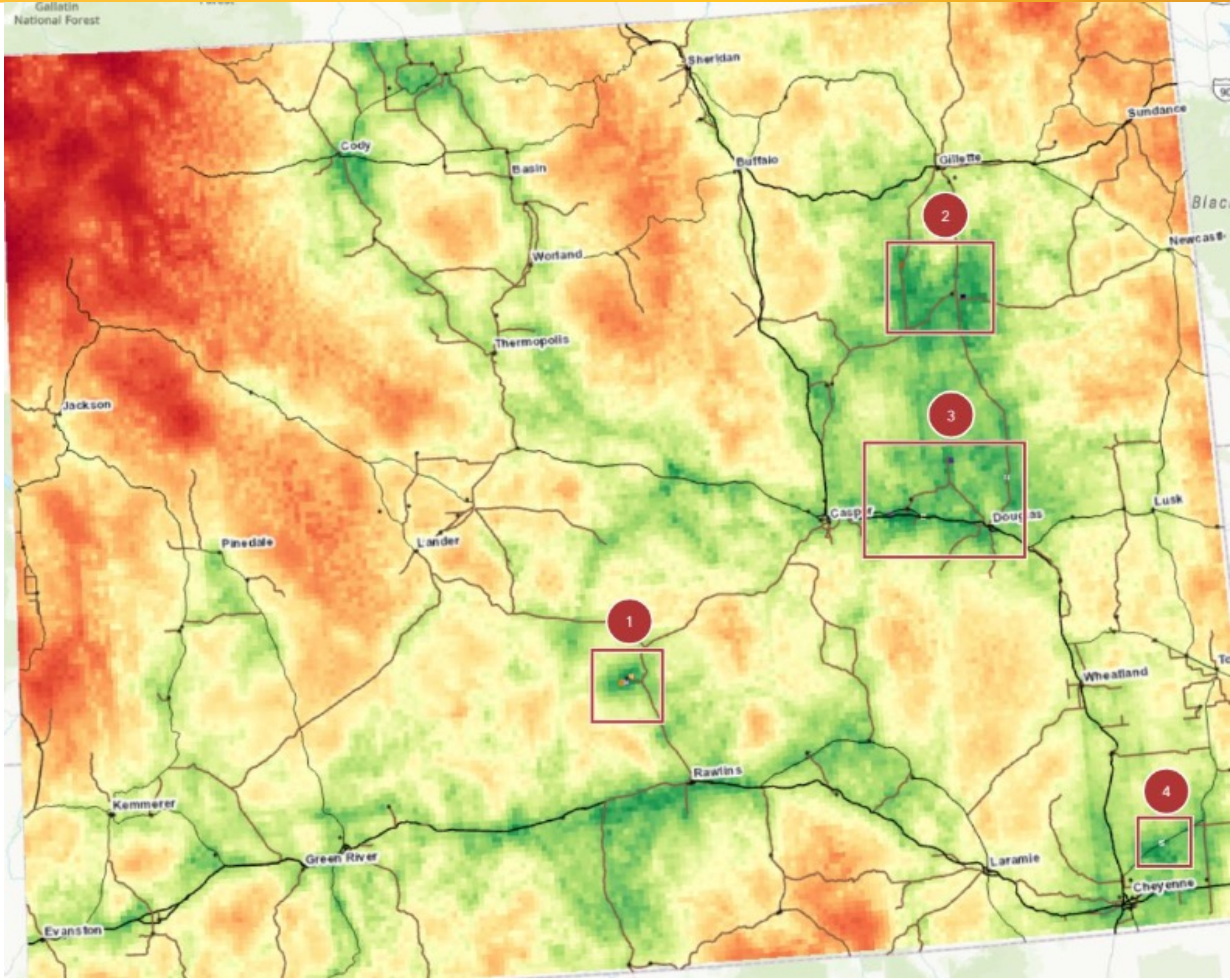
Other Policy Considerations

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



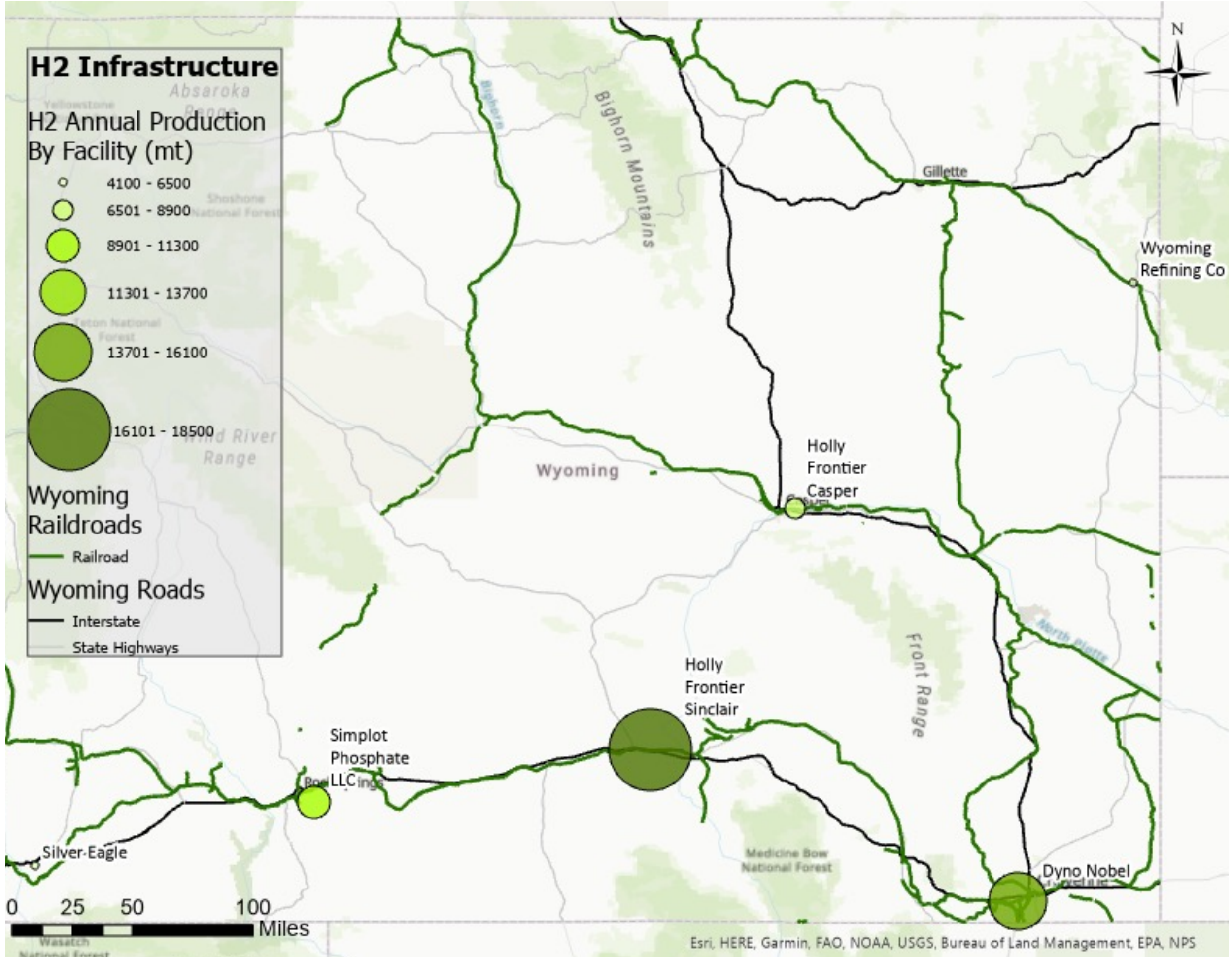
Wyoming Hydrogen from Natural Gas

- Suitability Model considering no company-specific infrastructure.
- This model indicates the best areas for hydrogen to be produced in WY
  - The Powder River Basin
  - The Bairoil area Greater Green River Basin
  - The Denver-Julesburg Basin



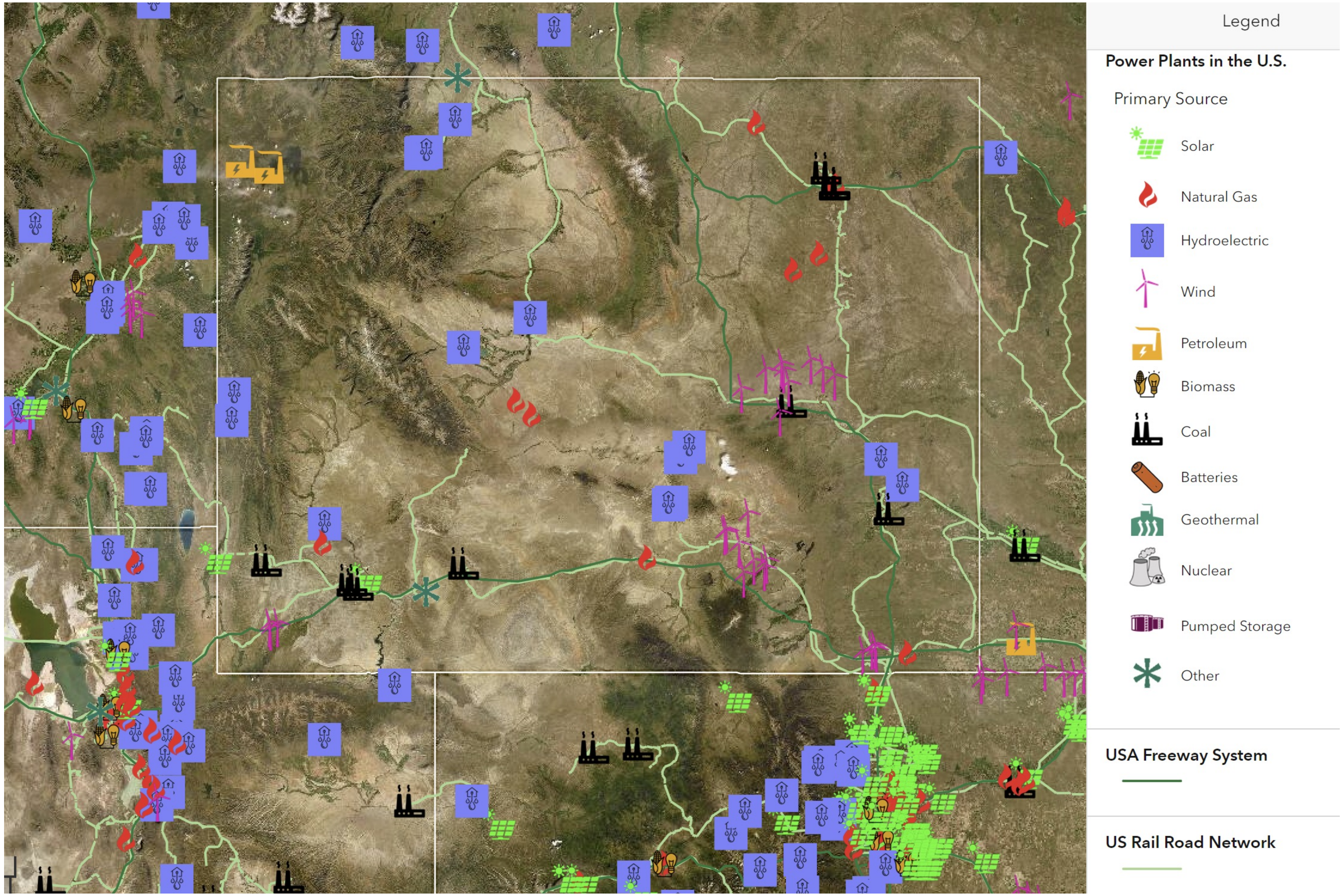
Hydrogen Production Facilities, Roads, and Railways

- Wyoming has limited demand for hydrogen, and that hydrogen is mainly made by the industry that uses it
- Hydrogen is currently transported on interstates and major highways by truck
- A minor option for transportation is railways
- There are currently six locations that are generating hydrogen on site:
  - The Holly Frontier Sinclair (HFS) refinery in Sinclair
  - The Dyno Nobel ammonium nitrate plant in Cheyenne
  - The Simplot phosphate plant in Rock Springs
  - The HFS refinery in Casper
  - The Wyoming Refinery Company refinery
  - New Castle refinery, and
  - The Silver Eagle refinery in Evanston



Mapping Resources

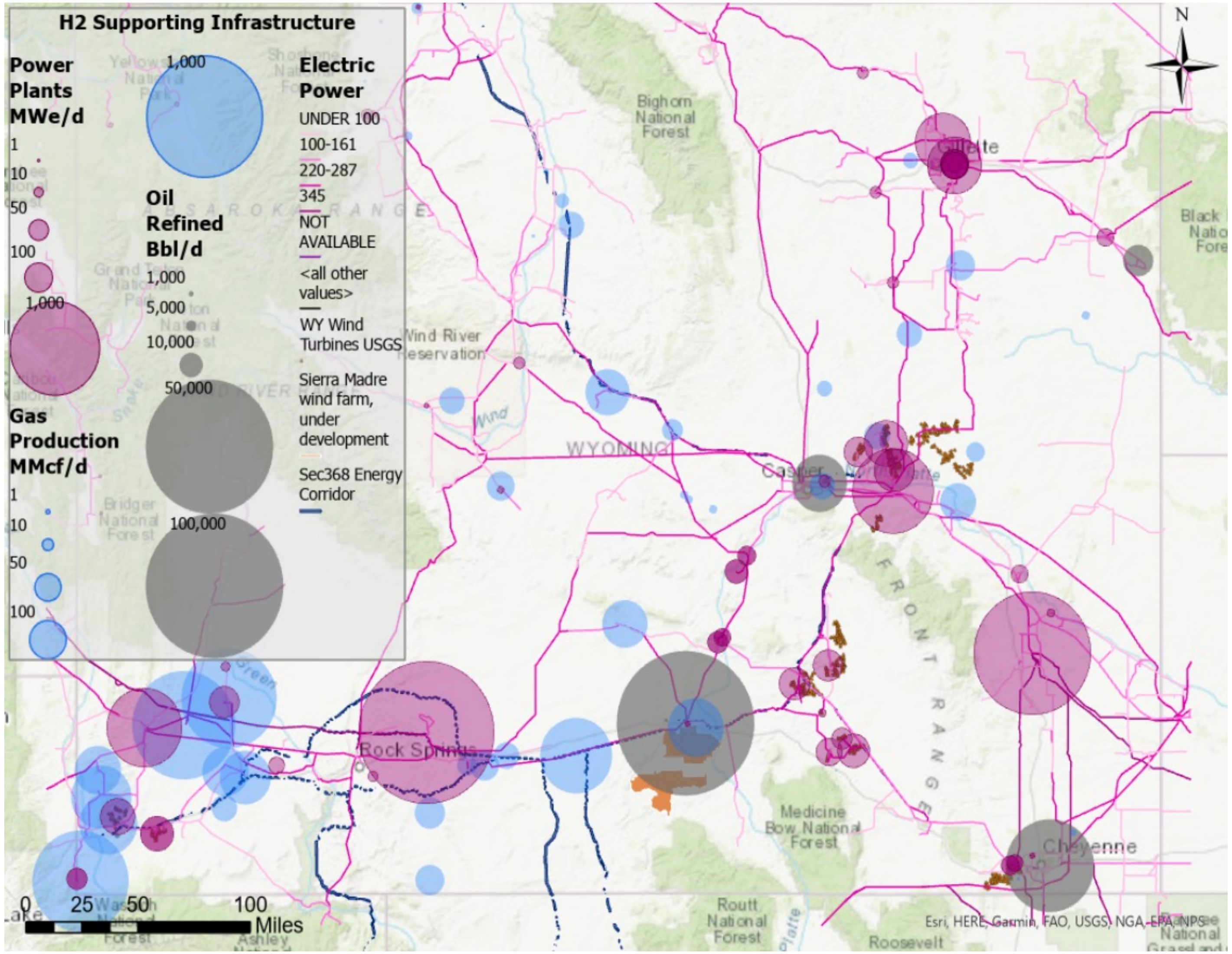
- ArcGIS Map layer example: powerplants, USA freeway and railway in Wyoming and neighboring states



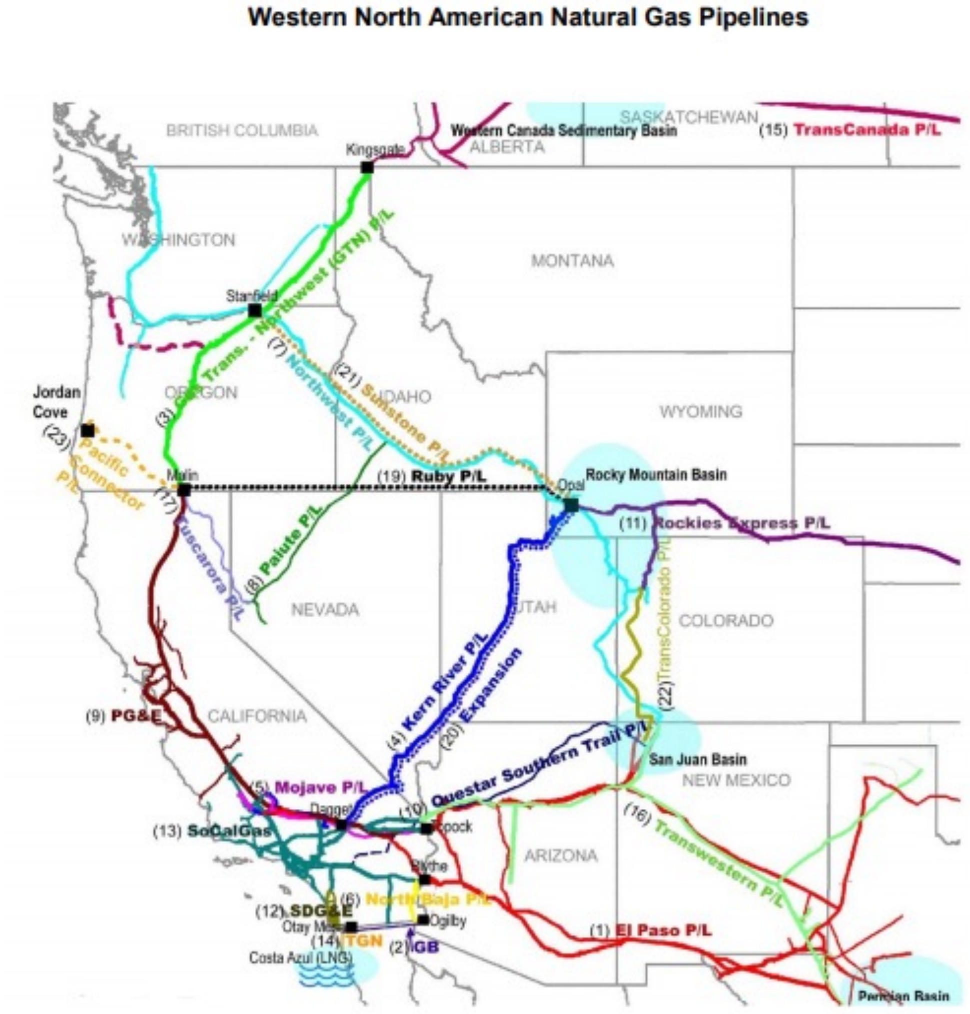
Infrastructure Which does not Support Hydrogen but has the Potential

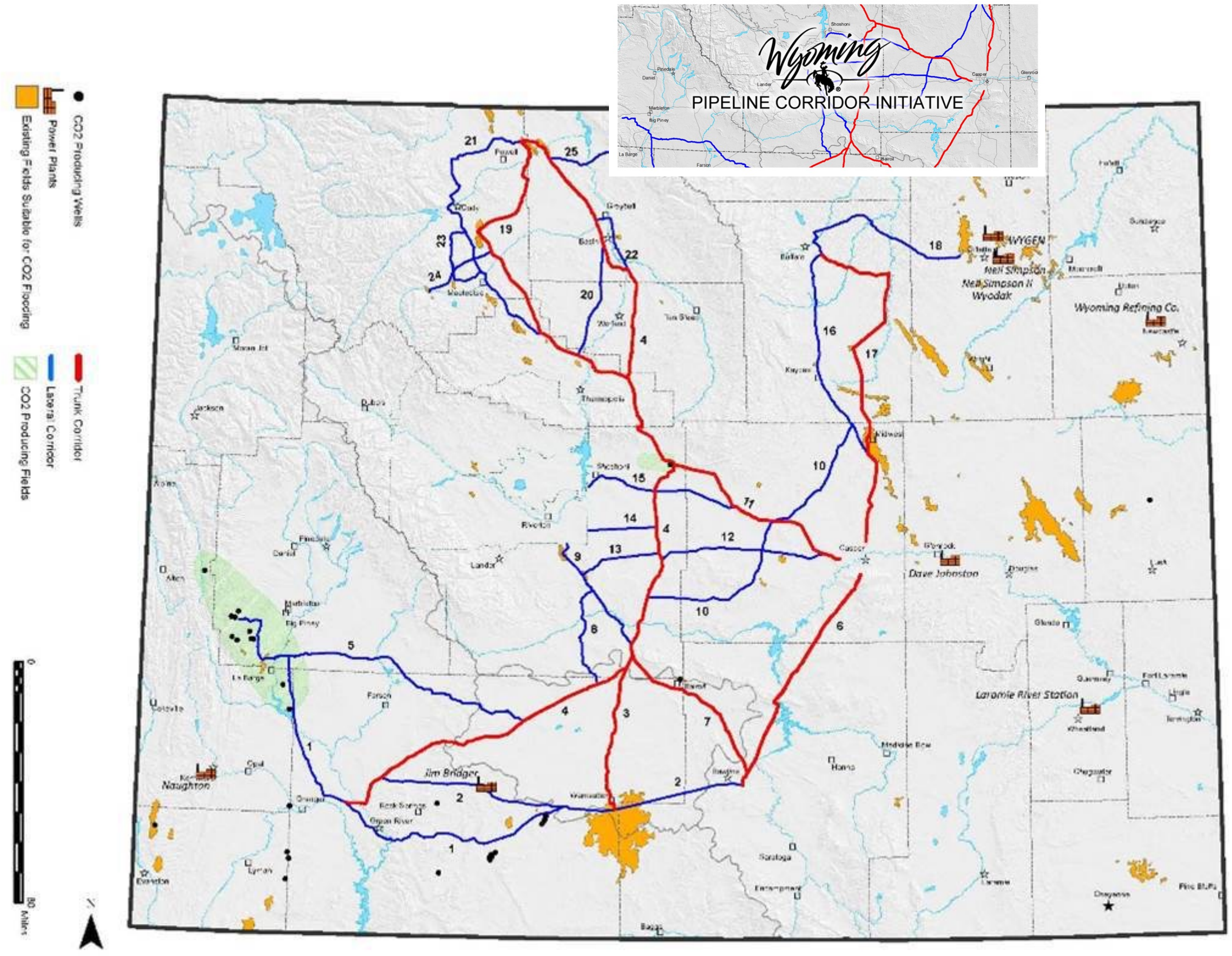
- Gas processing plants, oil refineries, and power generation
- The network of electric transmission lines and energy corridors connecting these facilities

- This Map excludes storage for hydrogen or CO2. Wyoming has options for geologic storage of gas in every basin. Some of these options are proven for CO_2 storage but need further work before they are proven to store hydrogen. All geologic storage would need further infrastructure development before it could be used.



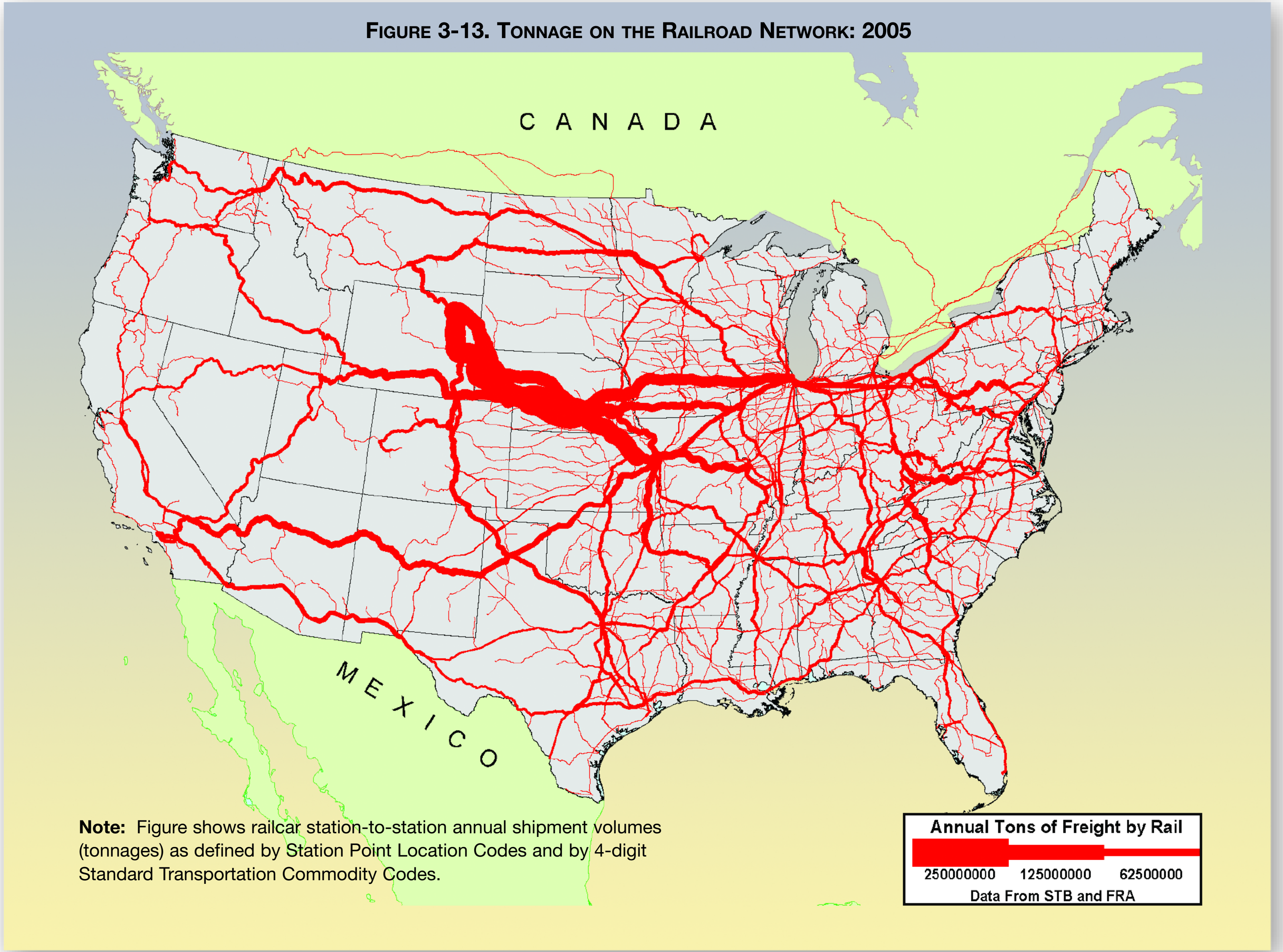
Regional CO_2 Pipelines





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

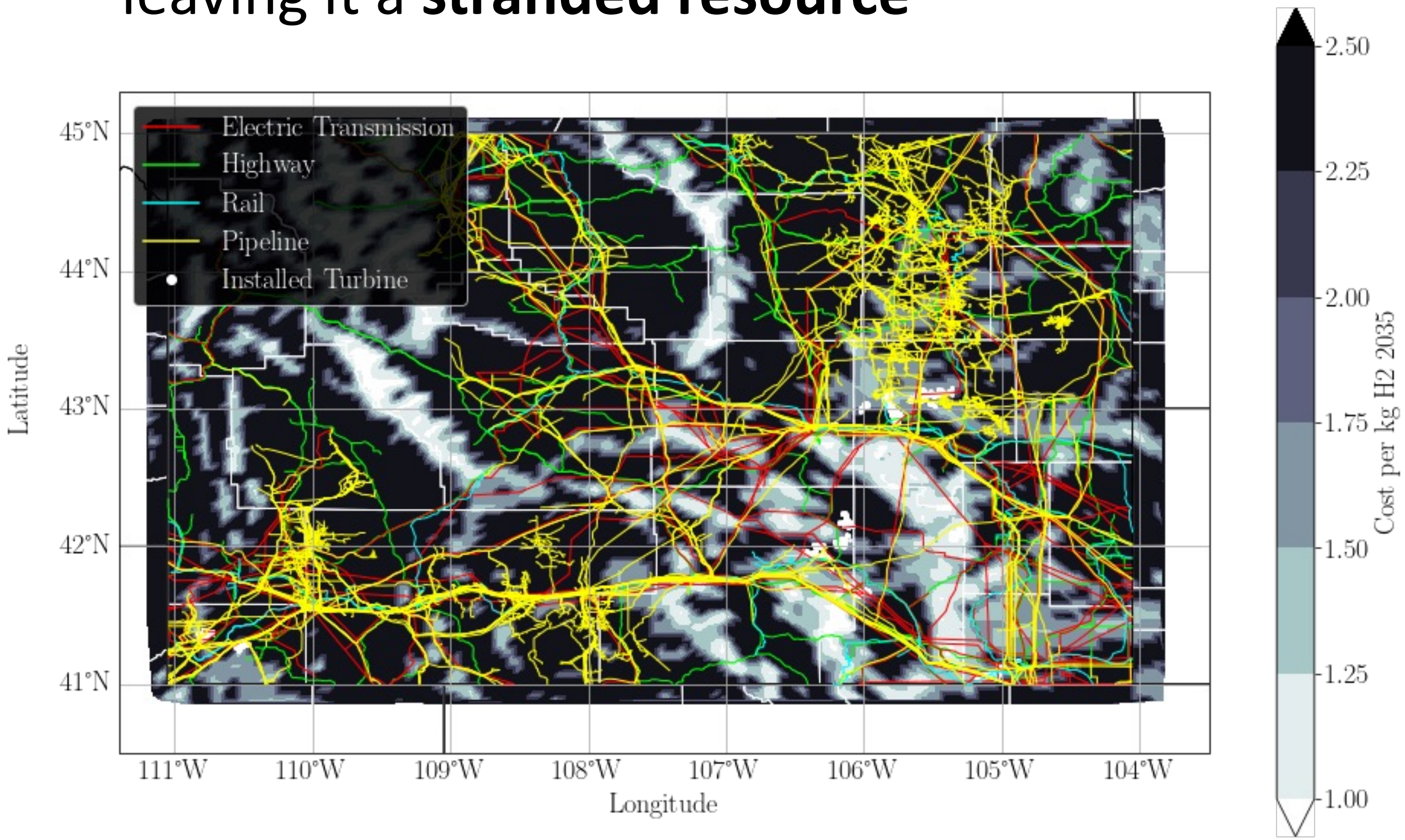
Rail freight tonnage

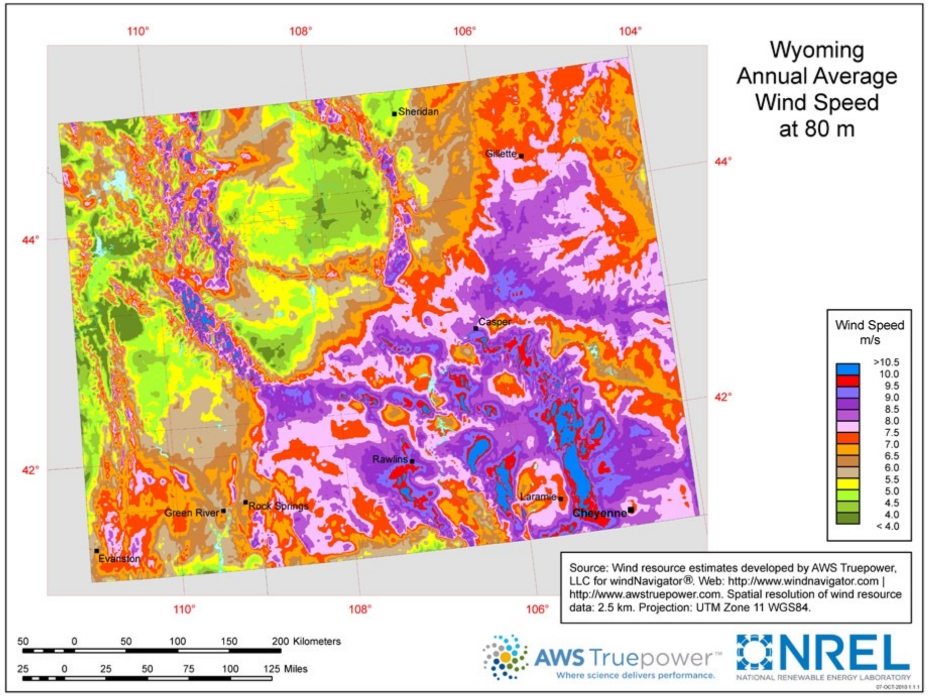


https://ops.fhwa.dot.gov/freight/freight_analysis/nat_freight_stats/docs/07factsfigures/pdf/fig3_13.pdf

Wyoming’s Stranded Renewable Energy

- Wyoming has some of the best wind resources in the country
- Much of it remains **inaccessible** due to its distance from existing electrical infrastructure, leaving it a **stranded resource**

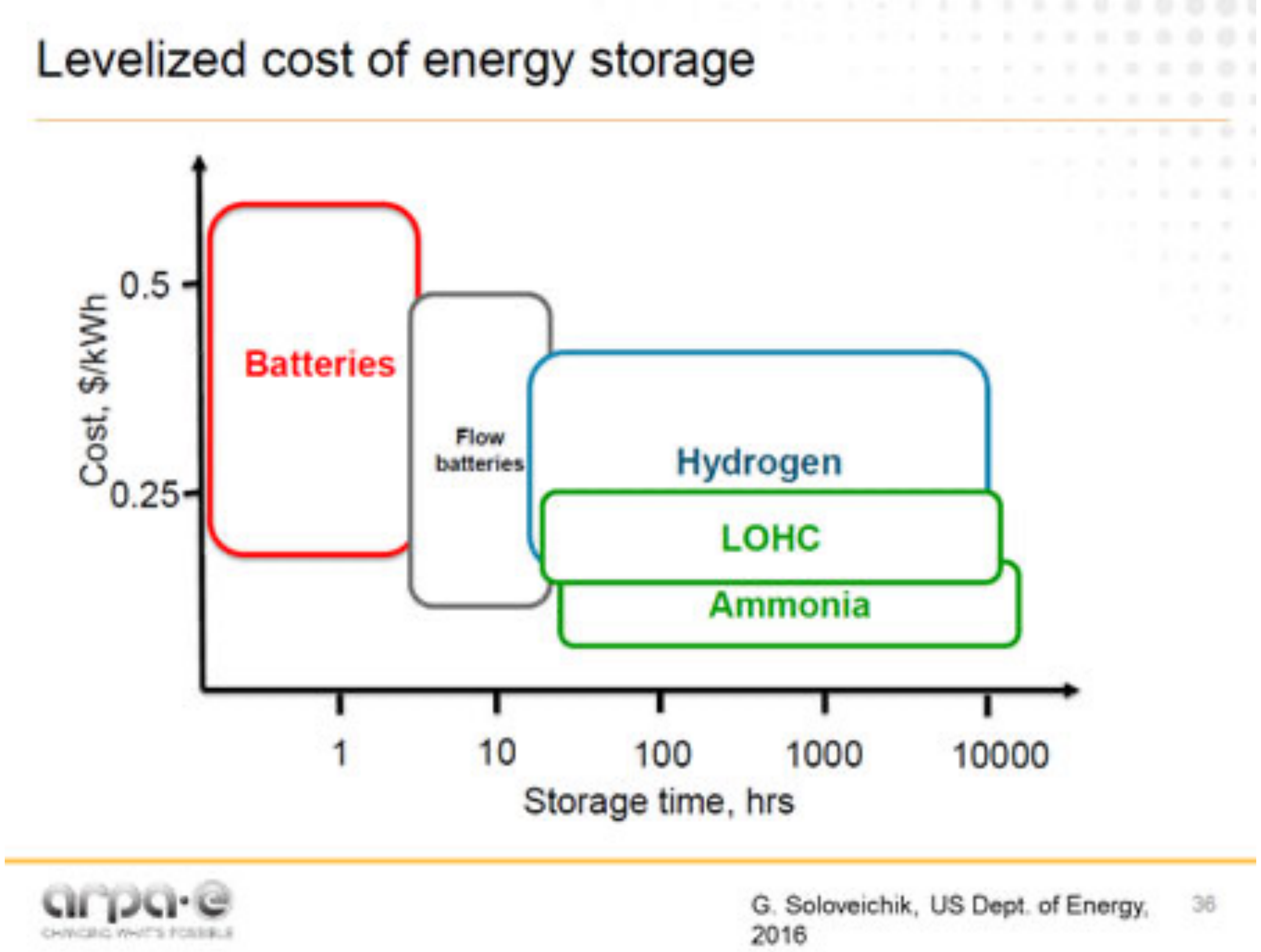




- Could Wyoming’s stranded renewable energy resource be harvested as Hydrogen or derivative:
  - SAF
  - Methanol
  - Ammonia

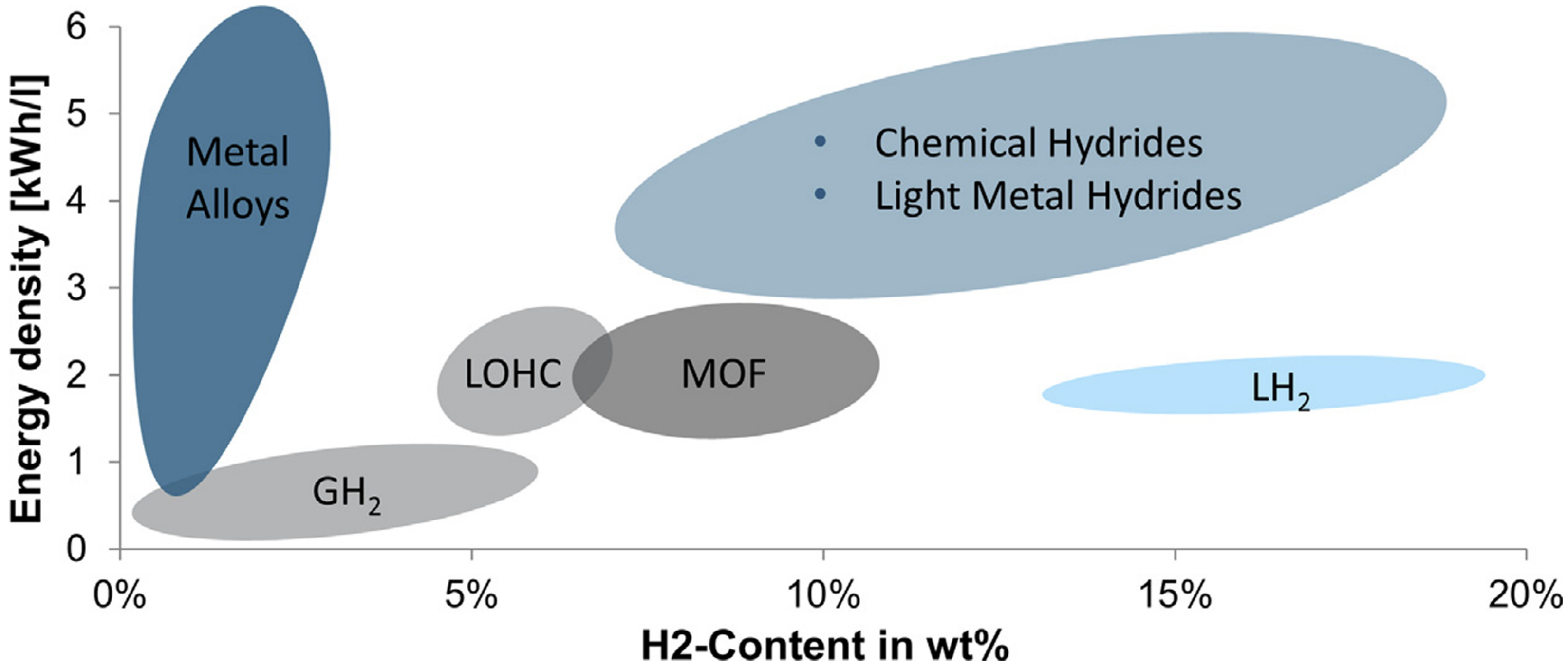
Hydrogen as Energy Storage Vehicle

- Energy storage is important
  - To prolong life of fossil fuel energy generators →CO_2 storage will manage emissions
  - To help with manage variable power from wind/solar
- Underground hydrogen is the largest "battery" we can build
- Hydrogen storage also works on longer times scales (seasonal)



Comparison of Different Hydrogen Storage Technologies

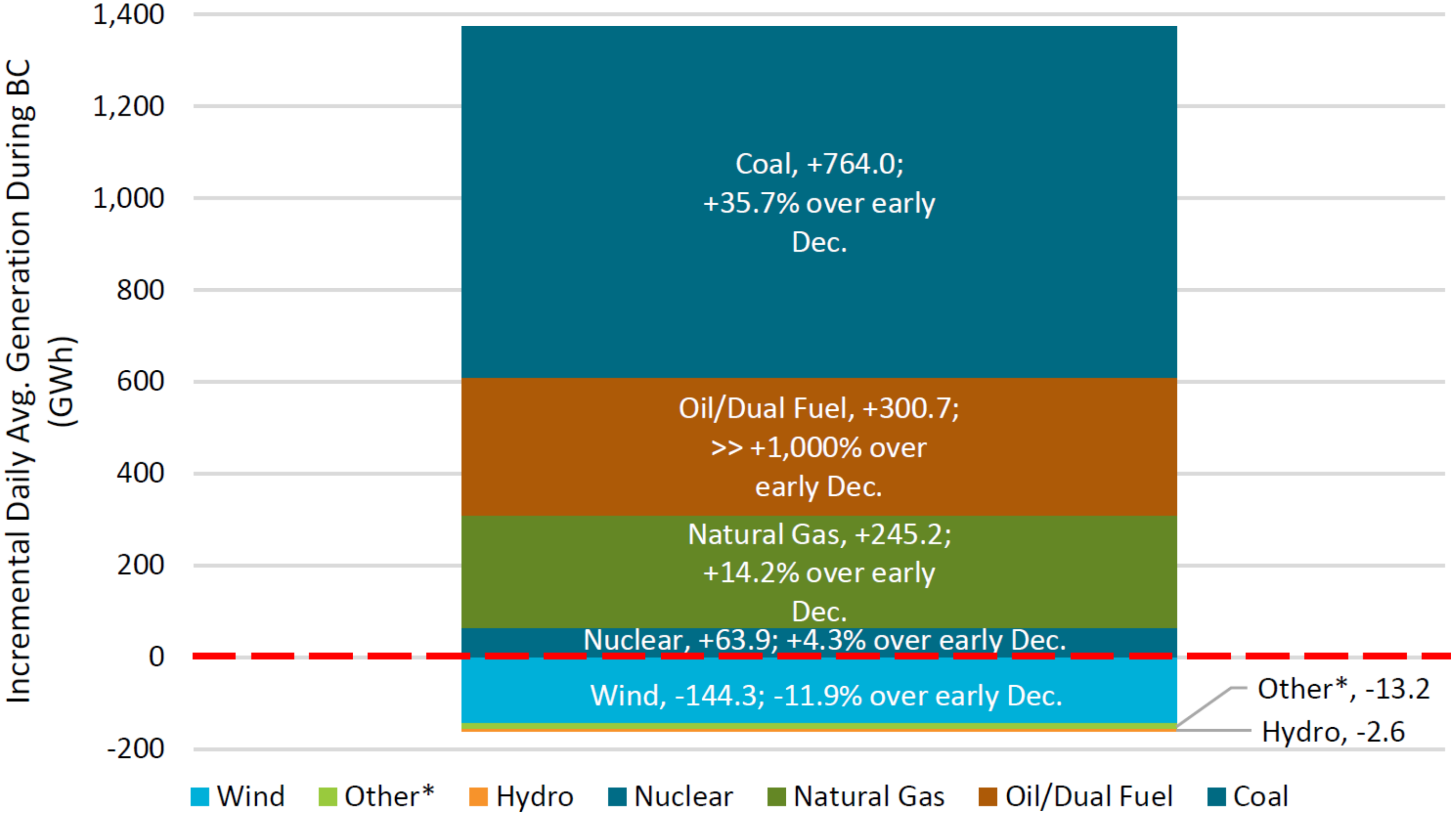
- LOHC– Liquid Organic Hydrogen Carriers
- MOF– Metal Organic Frameworks
- GH_2– Gaseous Hydrogen
- LH_2– Liquid Hydrogen



M. Reuß et al./Applied Energy 200 (2017) 290–302
Edwards R et al. Well-to-Tank Report Version 4.a. In: Godwin S et al., editors. JEC Well-to-Wheels Analysis. Joint Research Centre; 2014. p. 148.

Power Plant Performance at Elevated Demand Requirements During the *Explosive Cyclogenesis* Cold Weather Event, Now Known as the "Bomb Cyclone (BC)

Exhibit ES-1. Fuel based generation resilience during the Bomb Cyclone, six ISOs



* 'Other' includes misc. categories, including other, refuse, solar, diesel, and multiple fuels

The winter storm that highlighted a period of deep freeze blanketing much of the eastern half of the United States **from December 27, 2017, through January 8, 2018**. Fossil fuels, particularly coal, responded to the system's needs during this event.

During the worst of the storm from January 5-6, 2018, actual U.S. electricity market experience demonstrated that **without the resilience of <u>coal- and fuel oil/dual-firing plants</u>—its ability to add 24-hour baseload capacity—the eastern United States would have suffered severe electricity shortages, likely leading to widespread blackouts.** Experience with such blackouts indicates the potentially enormous toll in both economic losses and human suffering associated with widespread lack of electricity, utilized as the primary home heating source for nearly 40 percent of U.S. households, and necessary for running the electric fans of natural gas furnaces, for extended periods.

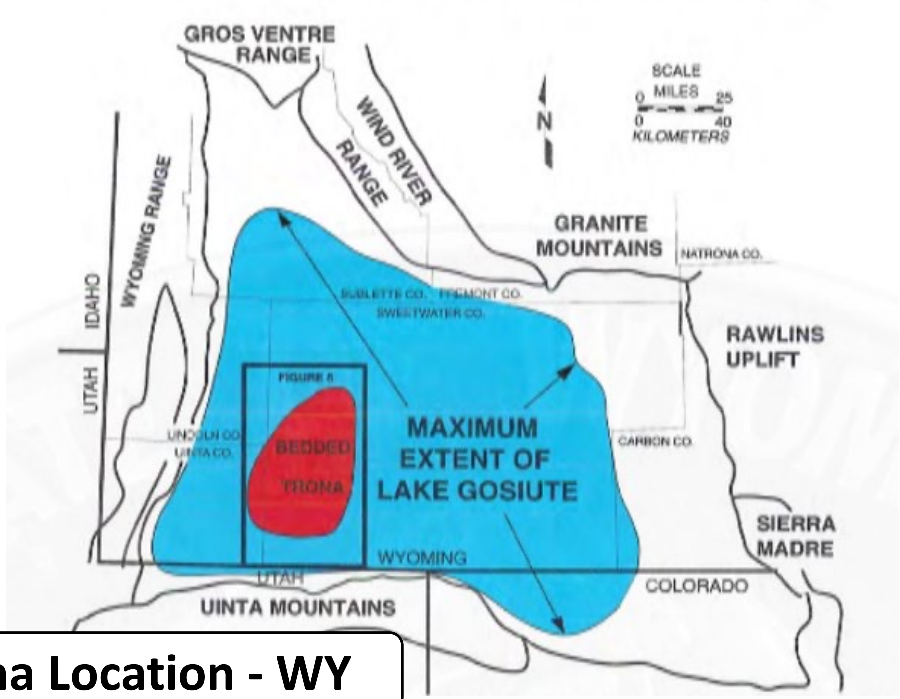
National Energy Technology Laboratory (NETL)

Peter Balash, Ken Kern, John Brewer, Justin Adder, Christopher Nichols, Gavin Pickenpaugh, and Erik Shuster

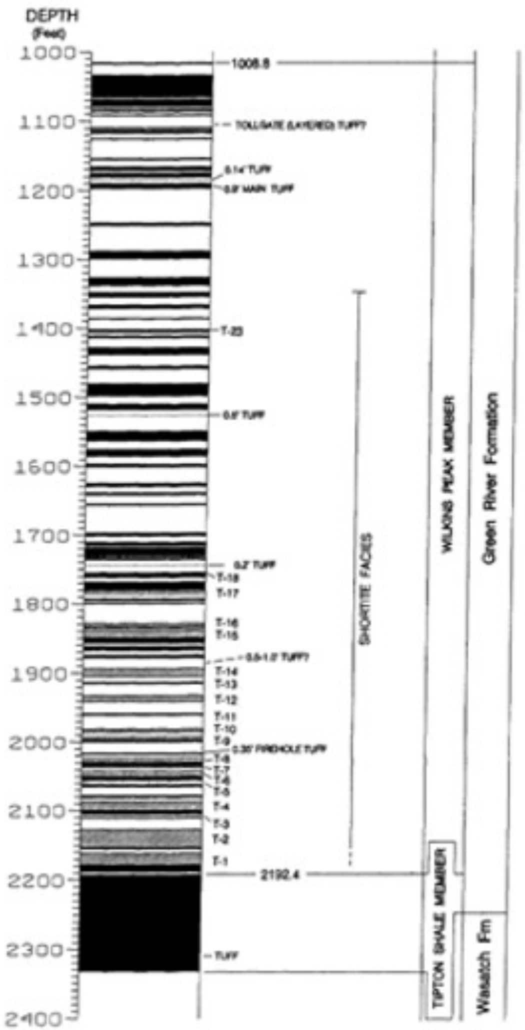
https://www.netl.doe.gov/projects/files/ReliabilityandtheOncomingWaveofRetiringBaseloadUnitsVolumeITheCriticalRoleofThermalUnits_031318.pdf

Comparison of Salt and Trona for Hydrogen Storage

- Salt Caverns are suitable for storage since:
  - Highly impermeable
  - Low cushion gas
  - High deliverability



Trona Location - WY



Aspect	Trona
Depth	viable
Thickness	Challenging
Solubility	Different from halite
Creep Behavior	Different from halite

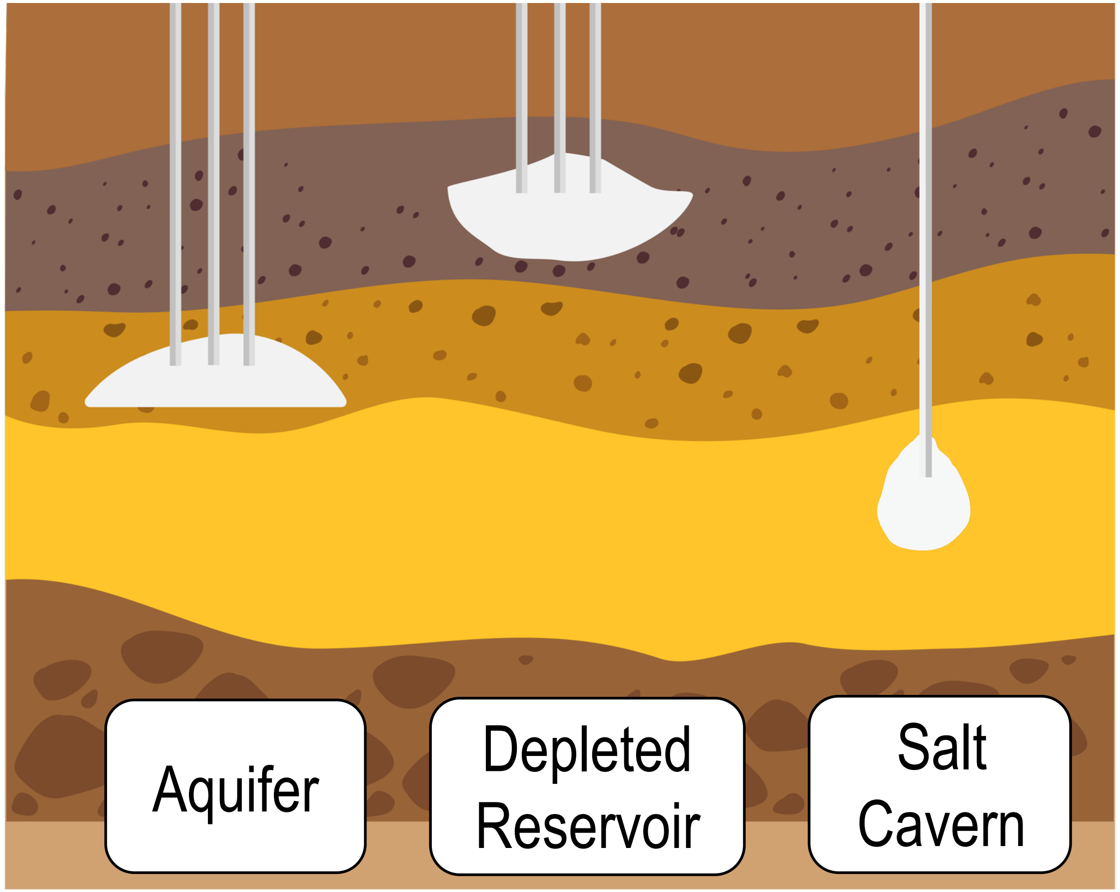
Underground Hydrogen Storage - WY

Subsurface hydrogen storage is used as a:

- long-term storage
- Larger capacity
- Lower risk media

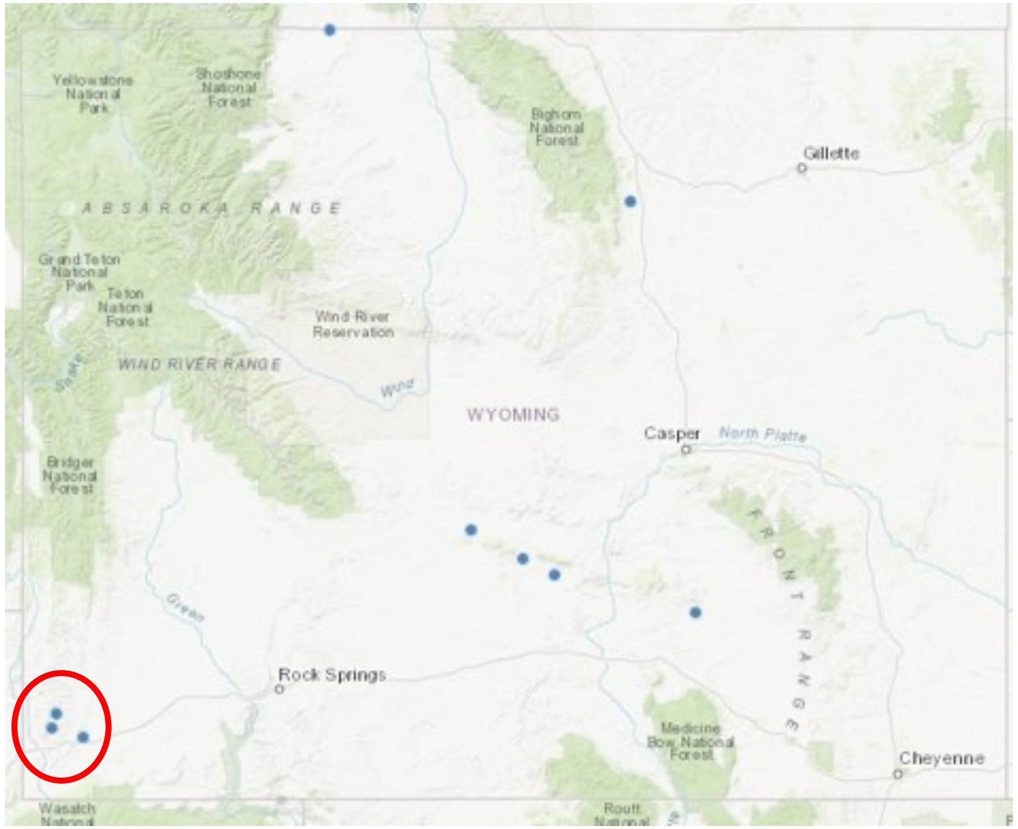
UHS Potential - WY

- Depleted hydrocarbon reservoirs
- Saline Aquifers
- Salt Caverns



Underground Hydrogen Storage - WY

Natural Gas Storage - WY



Why NG Storage Sites?

- Availability of the infrastructure
- Reducing the risk of pure hydrogen storage
- Natural gas acts as cushion gas
- Reduction of CO_2 emissions

Screening Criteria

Technical

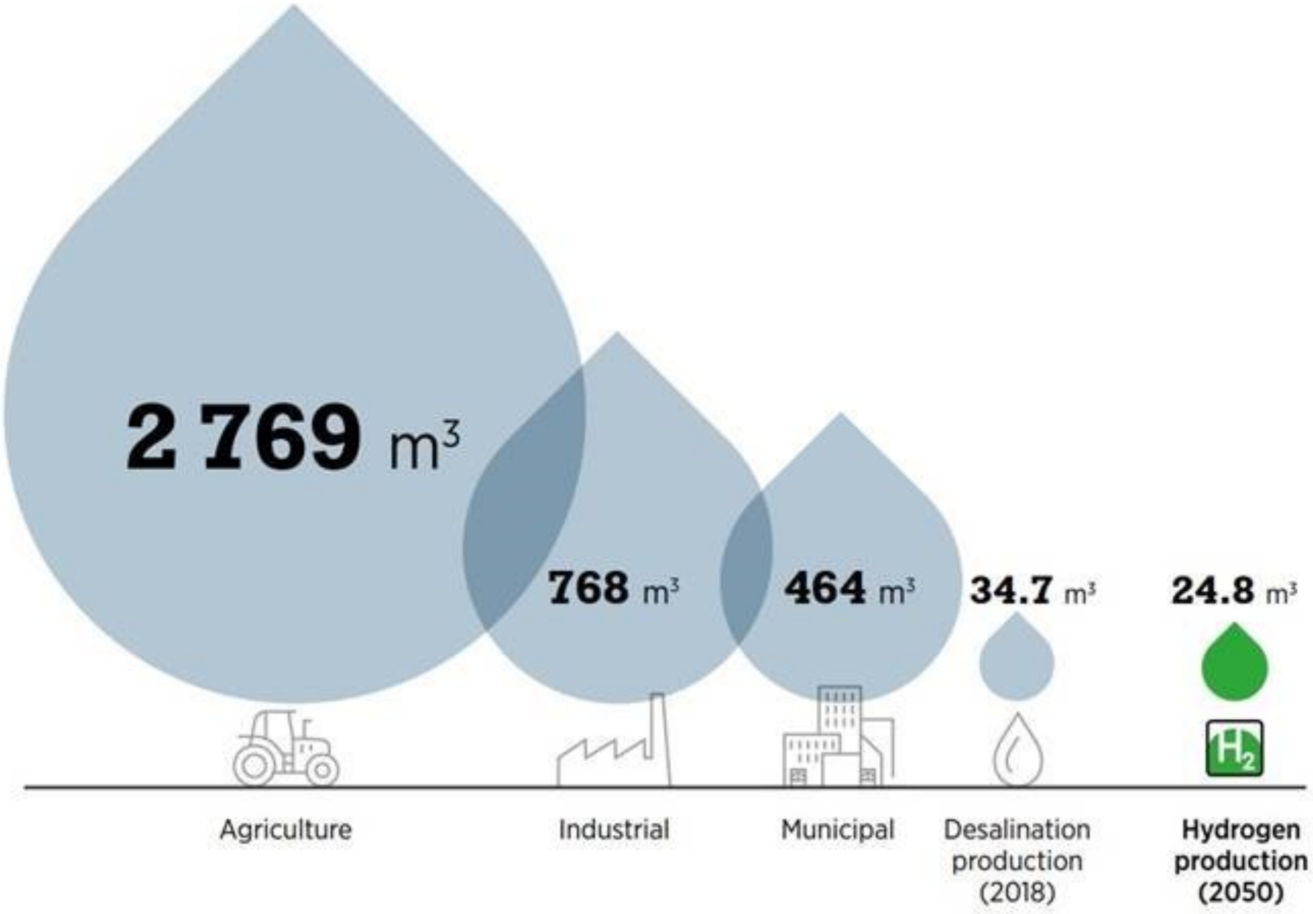
Economics

HSE

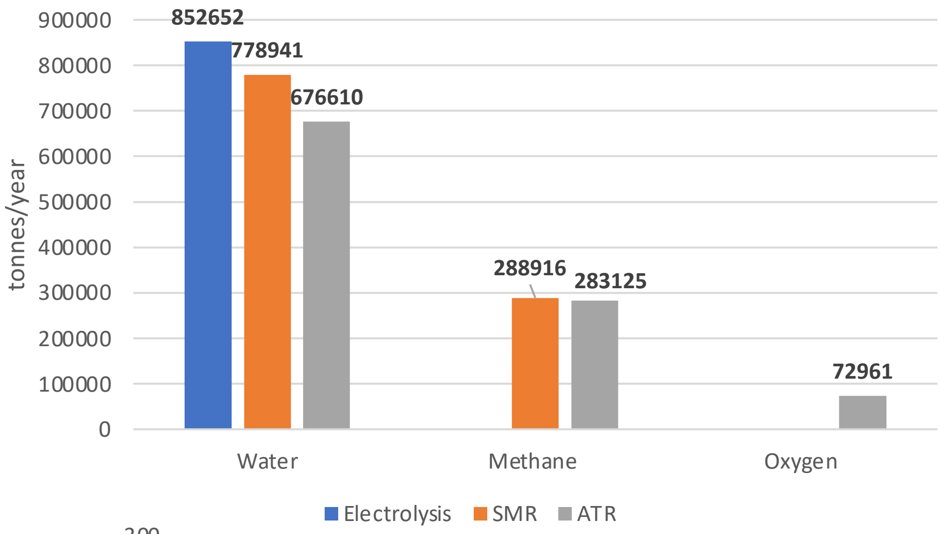
Social

Water Consumption by Hydrogen Production – World Outlook

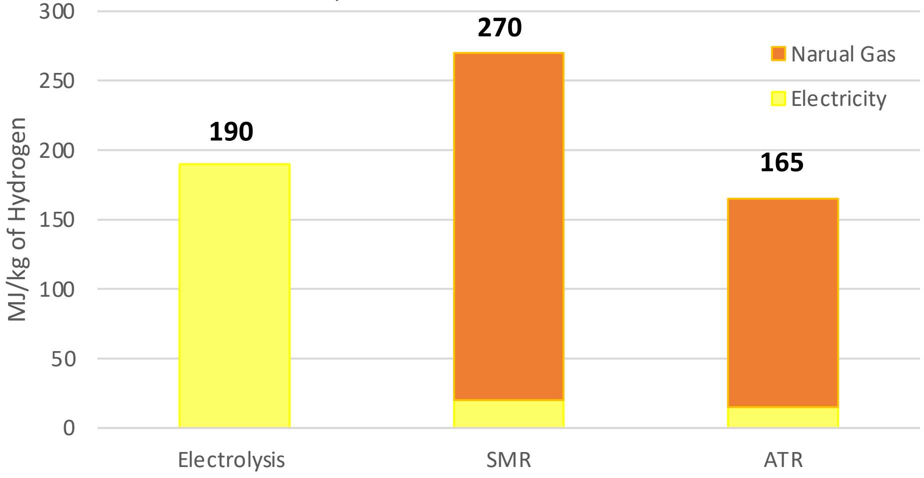
- Hydrogen production is expected to scale 10x from current levels by 2050
- Hydrogen industry is forecasted to re-purpose water from existing industries:
  - Refineries and blue hydrogen
  - Natural gas
  - Coal and gasification
- Water use by Hydrogen production marginal compared to other industries,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

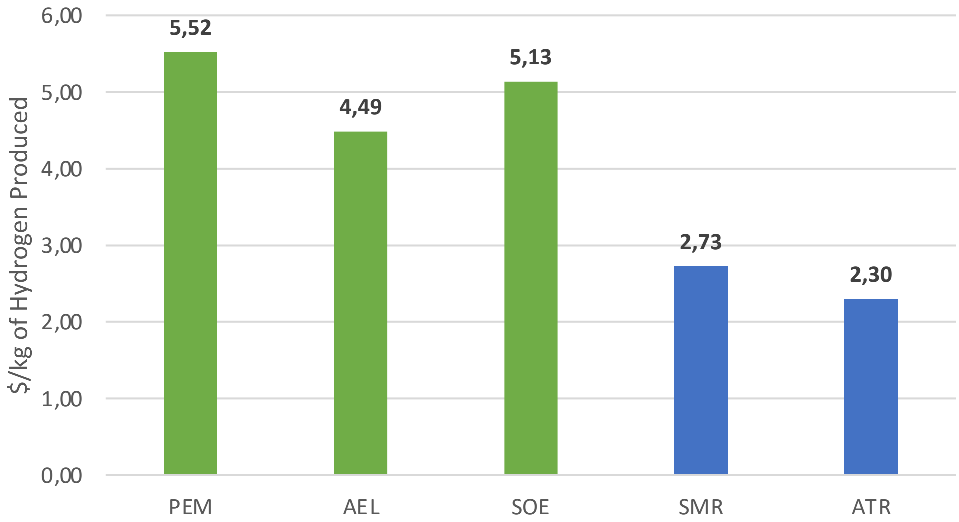


Electrolysis, ATR and SMR Briefly



Hydrogen Generation Method	Water Consumed per kg of H_2 Produced	Total Water Used per kg of H_2 Produced
Electrolysis	8.9	11.9
Steam Methane Reformation (SMR)	4.5	11.0
Autothermal Reformation (ATR)	3.8	9.8





How much PW is generated

- Nationally, the production of crude oil, natural gas, and produced water all increased between 2017 and 2021
- Between 2017 and 2021:
  - Crude oil – net increase of 20.18%
  - Natural gas – net increase of 17.21%
  - Produced water – net increase of 6.02%

Table 5-61: Oil and Gas Production for Wyoming by Development Method - 2021

Type of Hydrocarbon	Number of Wells Producing	Total Volume of Produced Water Brought to Surface (bbl/year)	Volume of Hydrocarbon Produced
Conventional Formations			
Crude oil	7,057	1,159,342,111	23,827,883 bbl
Natural gas	17,582	228,909,681	1,077,926 Mmcf
Other (Condensate, etc.)	0	0	6,389,501 bbl
Unconventional Formations			
Crude oil	2,350	128,348,565	55,072,749 bbl
Natural gas	182	43,281,587	3,467 Mmcf
Other (Condensate, etc.)	0	0	0
Total	27,171	1,559,881,944	85,290,133 bbl 1,081,393 Mmcf

https://www.gwpc.org/

Produced Water Treatment is Costly for Operators

Treatment of Produced Water

- General treatment: removal oil and grease, suspended solids, bacteria and iron
- Advanced treatment: safe surface discharge; extends to the removal of salt, ammonia, and dissolved organics

Cost Breakdown	Cost Range, $/bbl
Sourcing from ground or surface water	$0.15-0.60/bbl avg
Storage/transportation	$0.50-1.50/bbl avg $4.00-5.00/bbl long-haul
Disposal	$0.40-1.00/bbl avg
Treatment – Recycling	$0.20-0.85/bbl avg >$0.85/bbl for high chemical demand
Treatment - Advanced	$0.90-3.00/bbl membrane $2.50-9.00/bbl thermal

Source: https://www.gwpc.org/

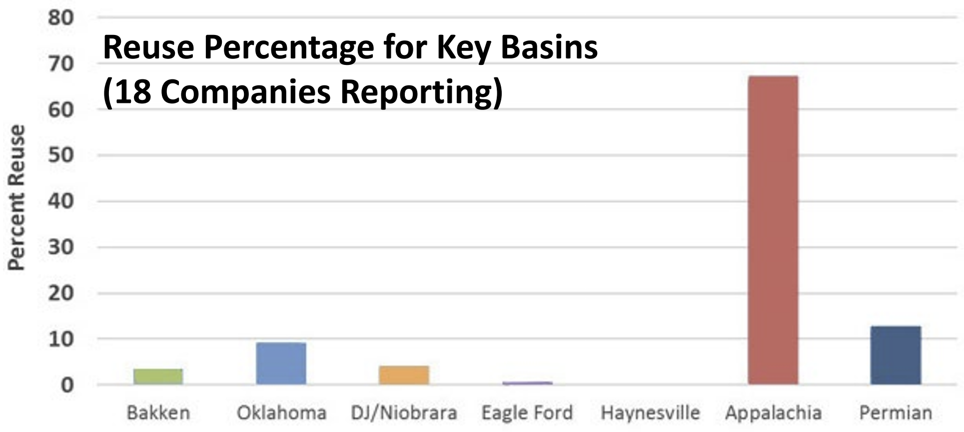
Permian Basin:
Produced Water Reuse and Marketplace

- 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



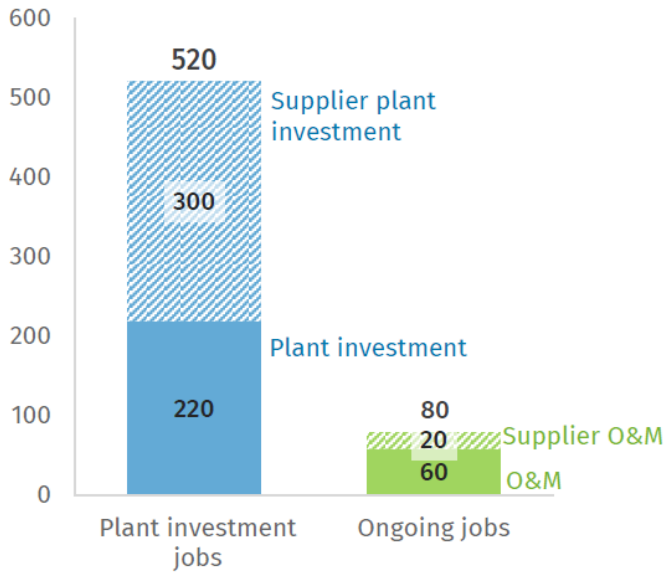
Sourcewater https://www.sourcewater.com/ *GWPC: Produced Water Report: Regulations, Current Practices, and Research Needs, 2019* *Source: Jacobs Engineering*

Workforce Research

- 2008 DOE study estimated H_2 transformation of the U.S. economy by 2050
  - H2 training was needed for new skills
  - Significant job growth potential – 250K+ jobs by 2050
- DOE developed models for estimating jobs
  - JOBS FC and JOBS H_2
- Hydrogen and Fuel Cells Career Map
  - https://www.energy.gov/eere/fuelcells/hydrogen-and-fuel-cells-career-map
- Rhodium Group: Clean Hydrogen Workforce Development: Opportunities by Occupation
  - https://rhg.com/research/clean-hydrogen-workforce-development/

Average annual jobs associated with a conventional hydrogen carbon capture retrofit with 500kt of annual CO_2 capture capacity

Plant investment jobs (left); ongoing operations & maintenance (O&M) jobs (right)



Source: Rhodium Group. Note: These employment estimates only include the jobs associated with adding carbon capture technology to a hydrogen facility. They do not include jobs maintained by continuing to operate a hydrogen production facility. We assume a 99% capture rate from the flue gas of the reformer. We do not assume capture on the combustion emissions. The lifetimes of hydrogen facilities retrofit with carbon capture will vary on a case-by-case basis.

Rhodium Group https://rhg.com/research/clean-hydrogen-workforce-development/

Occupational Types, Salaries, and Educational Requirements in the Hydrogen Industry

- The H_2 sector of the US economy will lead to vast new employment opportunities as businesses expand to serve growing markets and to meet new clean and sustainable energy requirements and mandates
- Many high-tech industries almost exclusively require highly educated workers with advanced degrees
- Many occupations in the H_2 sector include jobs that require associate's degrees, long-term on-the-job training, or trade certifications, including scientists, engineers, chemists, managers, and technicians, all of which pay higher than the US average wages.

Occupational Title	Average Annual Salary (2016$)	Minimum Educational Requirements
Hydrogen R&D director	129,000	Doctoral
Hydrogen energy development business director	138,000	Bachelor's
Hydrogen plant operations manager	95,200	Bachelor's
Hydrogen energy systems operations engineer	68,100	HSD/GED
Hydrogen energy systems designer	47,900	Apprenticeship/TS
Hydrogen systems program manager	73,220	Bachelor's
Hydrogen system technician	39,500	HSD/GED/OJT/TS/ Apprenticeship
Hydrogen energy junior technician	23,400	HSD/GED/OJT/TS/ Apprenticeship
Hydrogen energy engineer	72,300	Bachelor's
Hydrogen fueling station manager	58,300	Bachelor's
Hydrogen fueling station designer and project engineer	74,200	Bachelor's
Hydrogen fueling station operator	29,700	OJT
Emissions accounting and reporting consultant	64,200	Bachelor's
Emission reduction project manager	78,600	Bachelor's
Emission reduction project developer	63,450	Bachelor's
Emission reduction credit portfolio manager	47,400	Bachelor's
Hydrogen lab technician	40,600	Associate's
Hydrogen fuel truck transporter	36,950	OJT
Hydrogen pipeline construction worker	46,300	HSD/GED/OJT/TS/ Apprenticeship

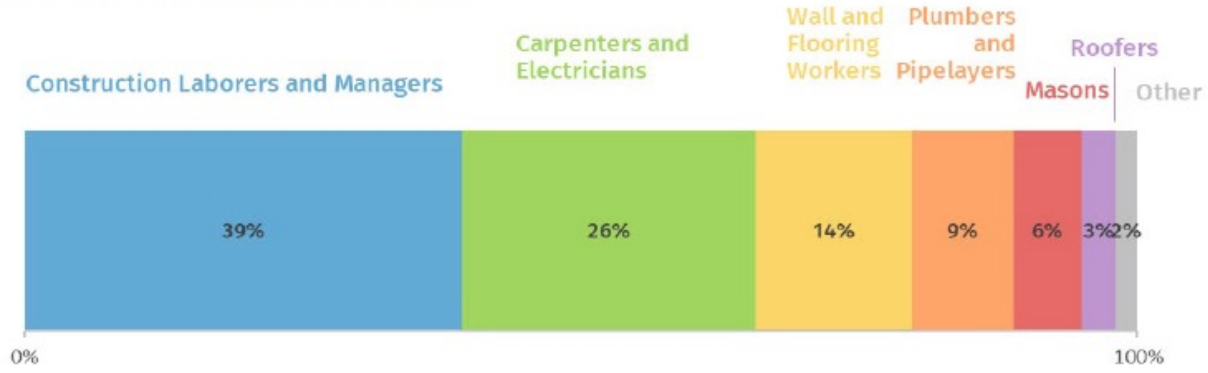
Bezdek, RH (2020). The hydrogen economy and jobs of the future. ECS Transactions, 96(1), 107.

Workforce Lessons Learned from CCS

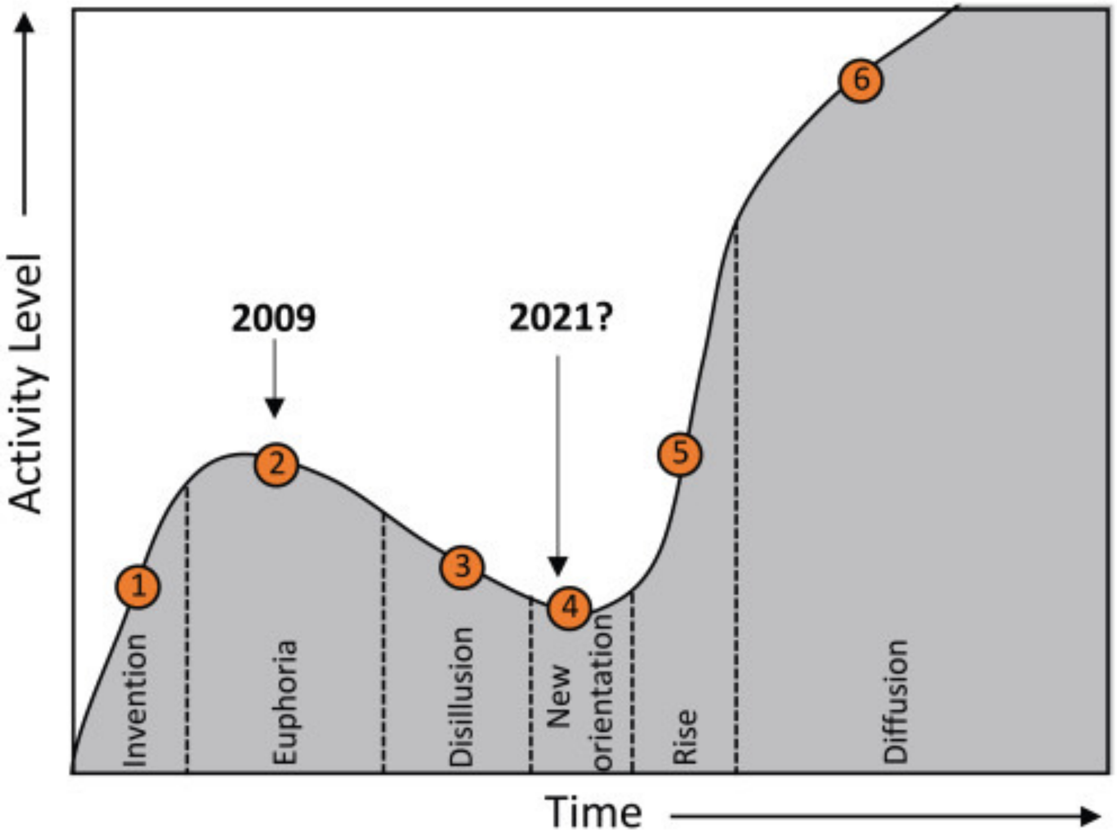
- Transferability of skills
  - What industries can transfer the workforce?
  - What is the potential for transfer vs. new training?
- Do we have a correct occupational breakdown?
  - BS vs PhD vs Trades
- How will we survive the next downturn?
  - Workforce sustainability

Occupational breakdown of construction trades associated with a conventional hydrogen carbon capture retrofit with 500kt of annual CO_2 capture capacity

% share of construction trades employment



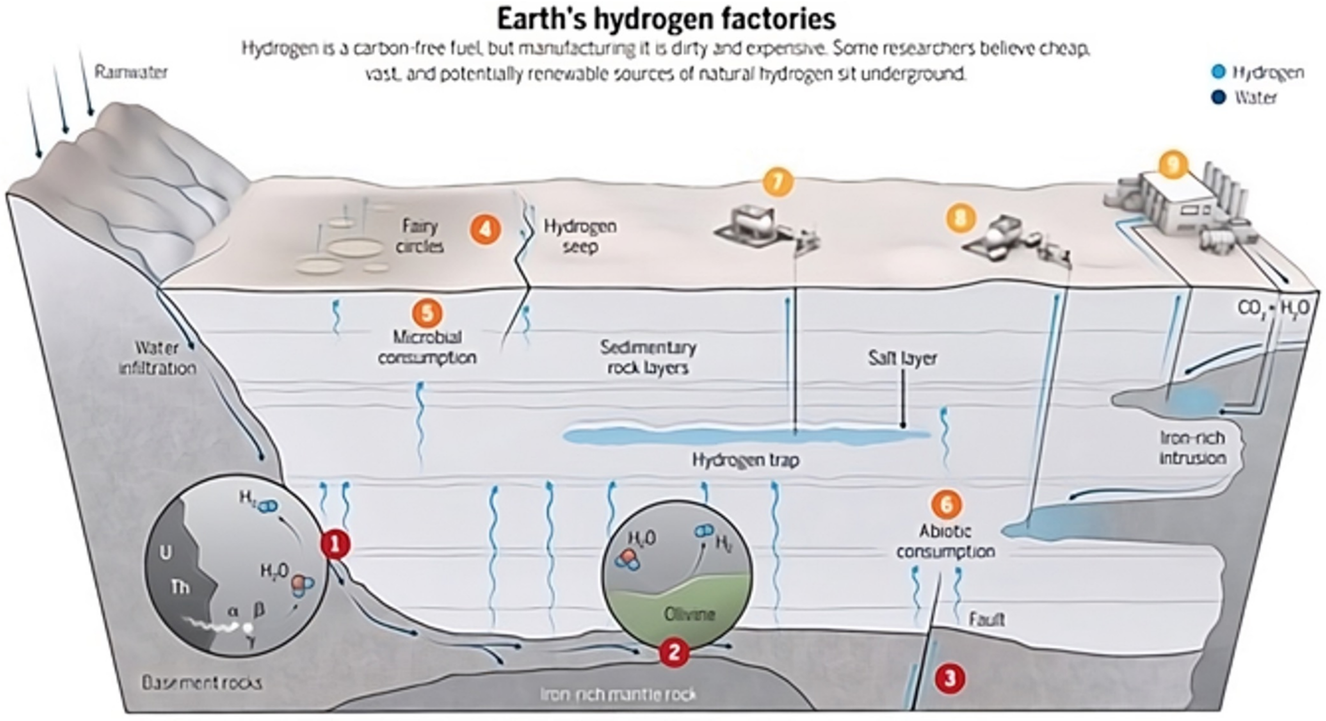
Source: Rhodium Group.



Emma Martin-Roberts et al., https://doi.org/10.1016/j.oneear.2021.10.002

Geologic H_2 Sourcing and Accumulation

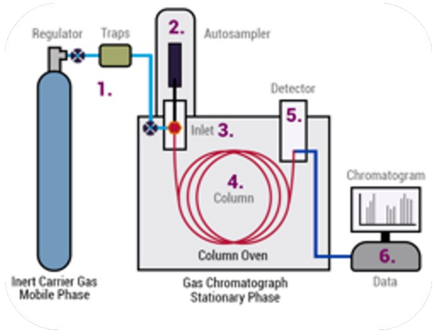
- **Process 1**
  - Hot water is split by iron-rich ultramafic rock, producing hydrogen gas
- **Process 2**
  - Off-gassing from the Earth's core/mantle percolates out over millions of years
- **Process 3**
  - Biogenic/microbial metabolism



Source: US Geological Survey

Geologic H_2 Prospecting: Challenge

H_2 is sneaky and invisible to most remote sensing. It has no normal spectroscopic signal.



Gold standard technique for gas analyses would not detect H_2 without special equipment.

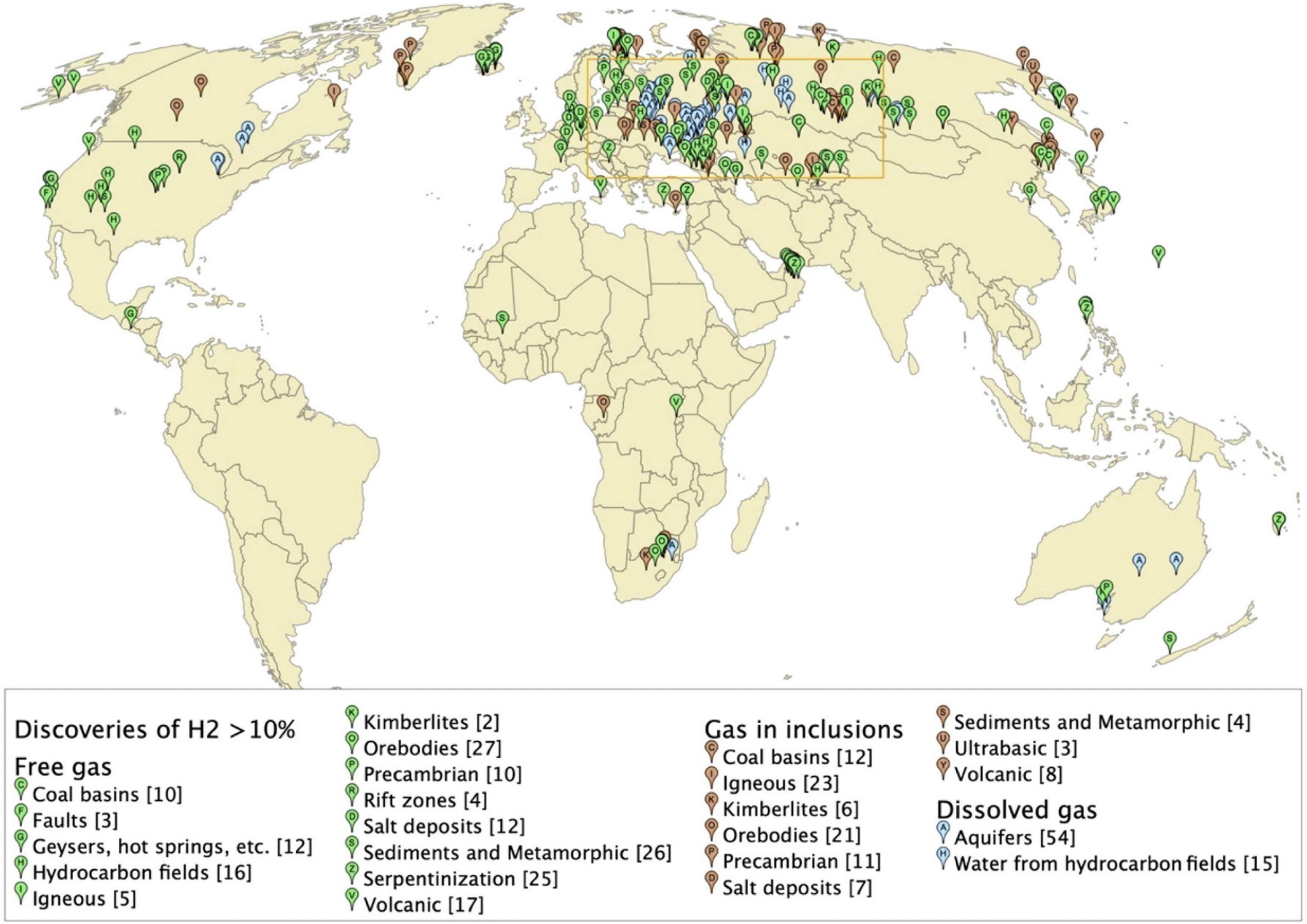
Everyone only drills in areas with oil and gas. Most H_2 reservoirs probably aren't in the same places.

Exploration only occurs with a reason to make the effort. H_2 only recently gained value.

You *have to* look for H_2 to find it.

Where do See H_2

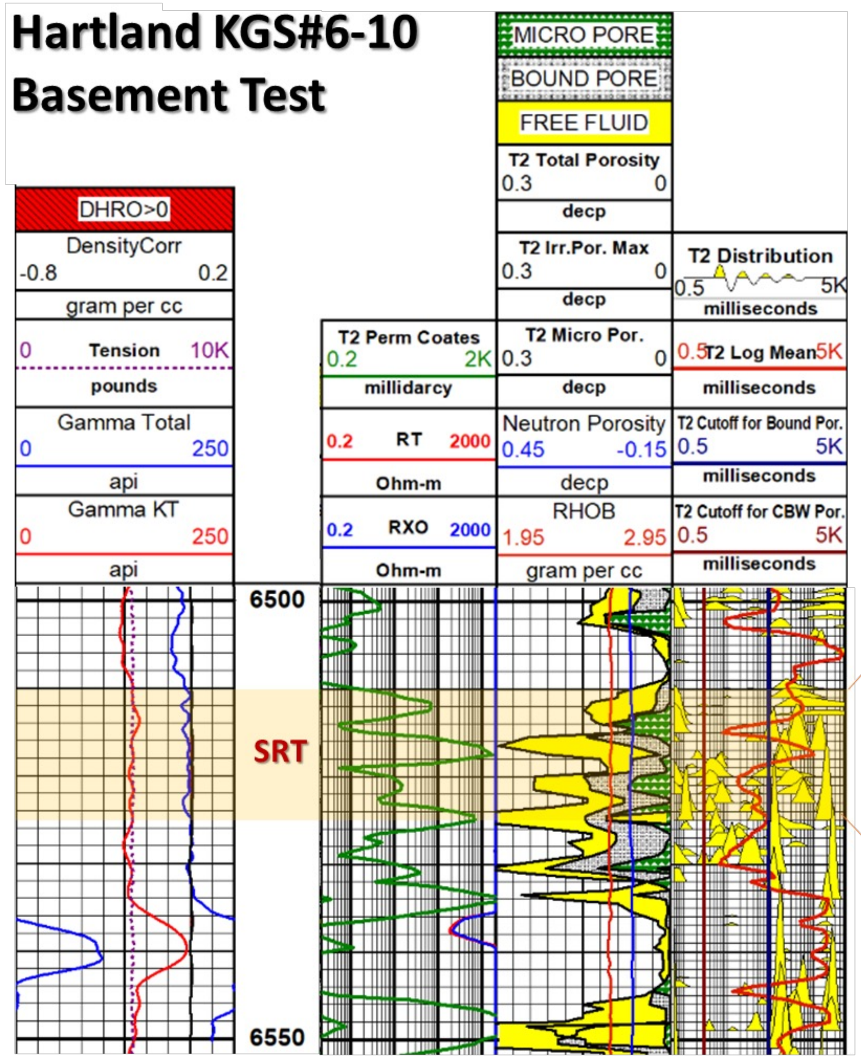
- Hydrogen is often not measured and has been neglected
- 5 out of 14,242 samples of natural gas from wells across the USA reported hydrogen at concentrations greater than 10%
    - Inadequate analytical equipment
- Being the lightest of all the gases, it diffuses rapidly in air and different materials. Therefore, it quickly leaves the place of its generation and can not be retained in geologic traps for long periods
    - Biogenic process?

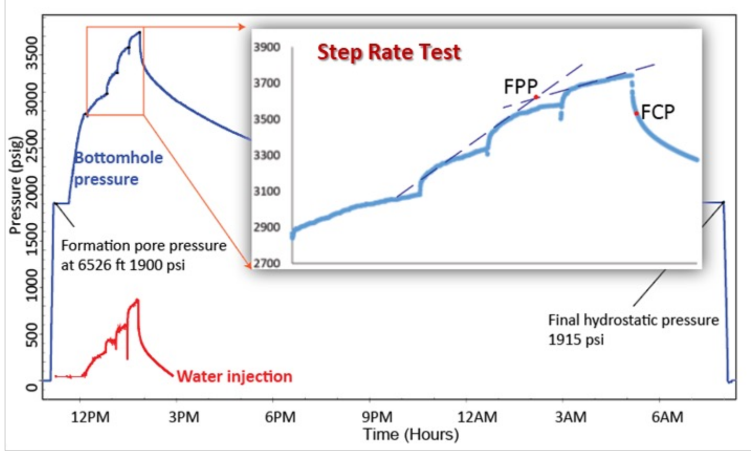


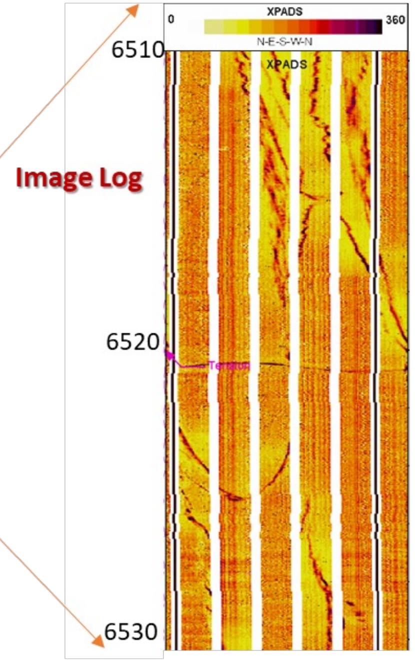
Zgonnik, Earth-Science Reviews 203, 2020

Kansas CarbonSAFE: Well Testing: SRT, Falloff, Interference

- Two wells drilled ~500 ft to the granite basement
- “Methane kick” was noted on the mud log that turned out to be a “mystery” gas
- Even for the “science well,” the level of readiness to detect Helium and Hydrogen was inadequate







Is There a Proof of Concept?

France
Est. 45-250 million tons
(possibly ~$1 trillion)

Australia
Est. 200 thousand tons - 8.8 million tons

Albania
Est. 5-50 thousand tons

USA
Multiple sites, ? tons

Discoveries made just in the last ~16 months

From just **1** French reservoir

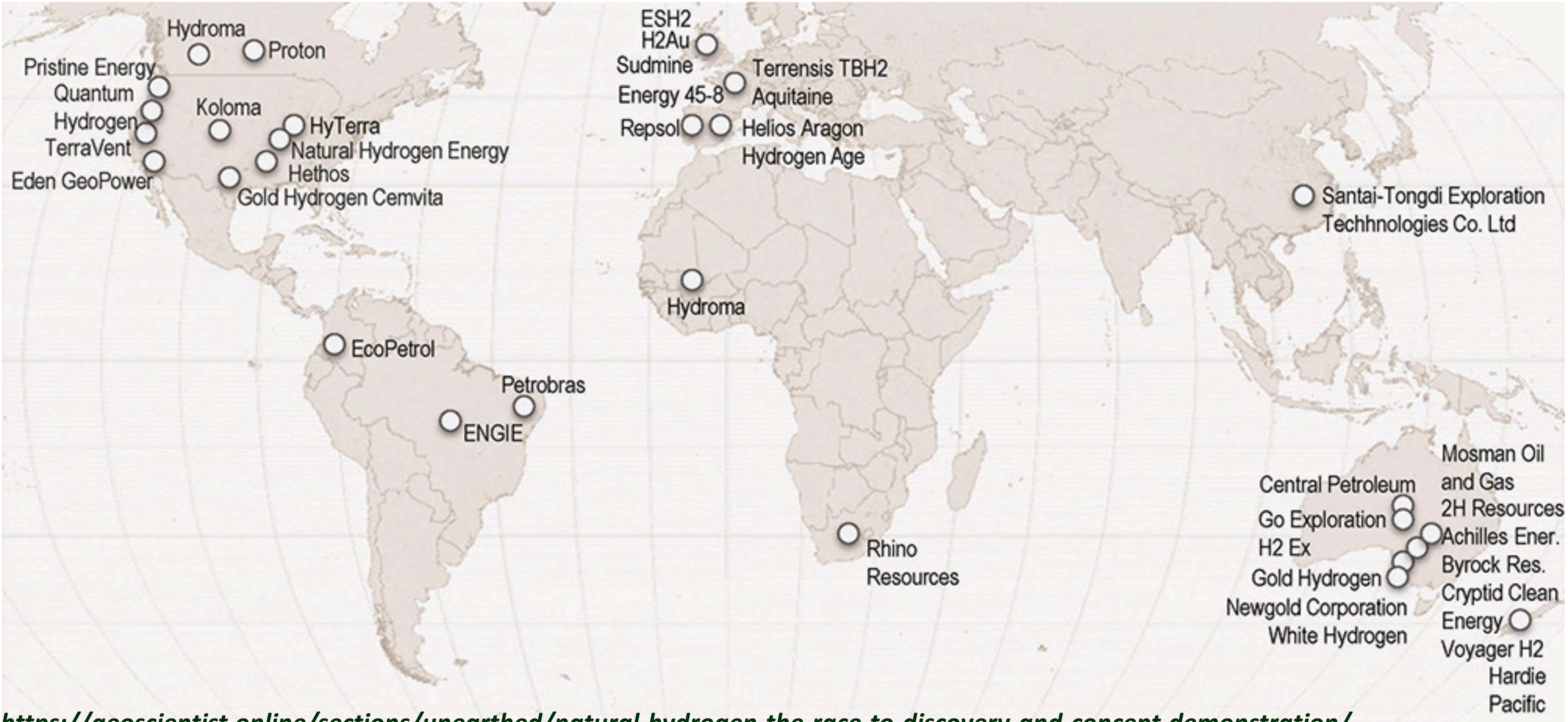
Lower range: **45M tons H_2** – *enough to power Google for 46 years*

Upper range: **250M tons H_2** – *equal to USA's entire gasoline usage for a year*

Production Cost: $0.50 – $1/kg

***10x–25x** cheaper than green H_2 today*

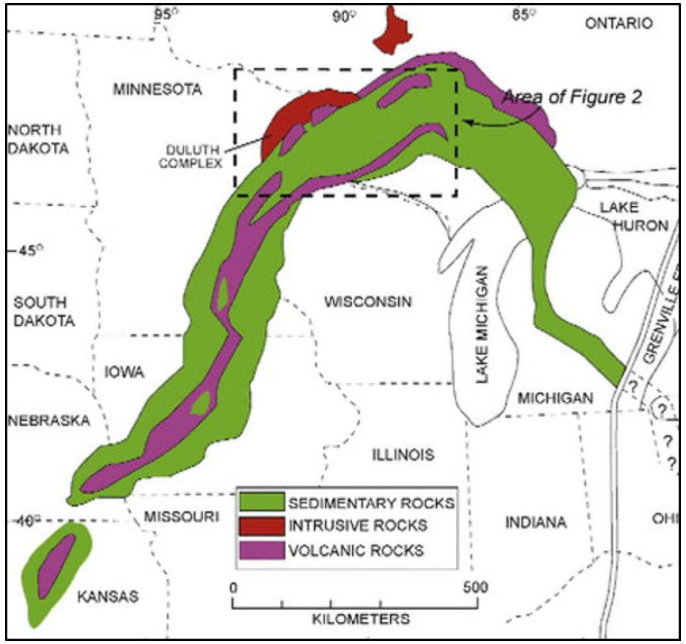
Countries With Natural Hydrogen Exploration Companies Established



https://geoscientist.online/sections/unearthed/natural-hydrogen-the-race-to-discovery-and-concept-demonstration/

Mid-Continent Rift is Becoming a Hydrogen play

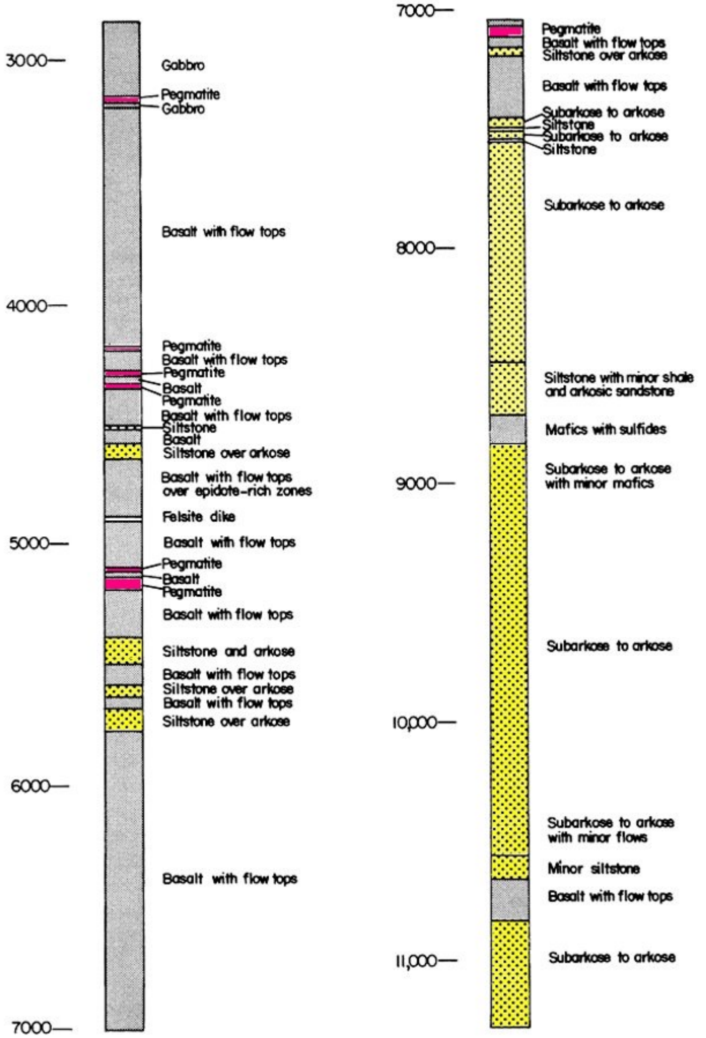
- Breakthrough Ventures, Khosla, and Climate Pledge Fund have already bet on Koloma, raising $341M in 8 months. They are dedicating focus and capital to drilling $8-10M appraisal wells in the Midwest USA.
- Other small geologic H_2 start-ups follow Koloma and focus on developing existing sites, not exploring them.
- The incumbent O&G is plagued by bureaucracy and will move slowly into H_2, just like they did for unconventionals/geothermal.
- Summary article on H_2 origins:
  - Guélard, J., V. Beaumont, V. Rouchon, F. Guyot, D. Pillot, D. Jézéquel, M. Ader, K. D. Newell, and E. Deville (2017), Natural H_2 in Kansas: Deep or shallow origin?, Geochem. Geophys. Geosyst., 18, 1841–1865, doi:10.1002/2016GC006544.
  - Deep crustal H_2 with radiogenic gases (4He and 40Ar) and metamorphic N_2 (δ15N averaging +2.5‰);
  - Surficial H_2 with methane produced in the sedimentary aquifer and the tubing by methanogenic organisms.



Midcontinent Rift's southernmost expression is in Kansas

One type well (Poersch #1) shows ~4000 ft of plus interbedded feldspar-rich sand/siltstones

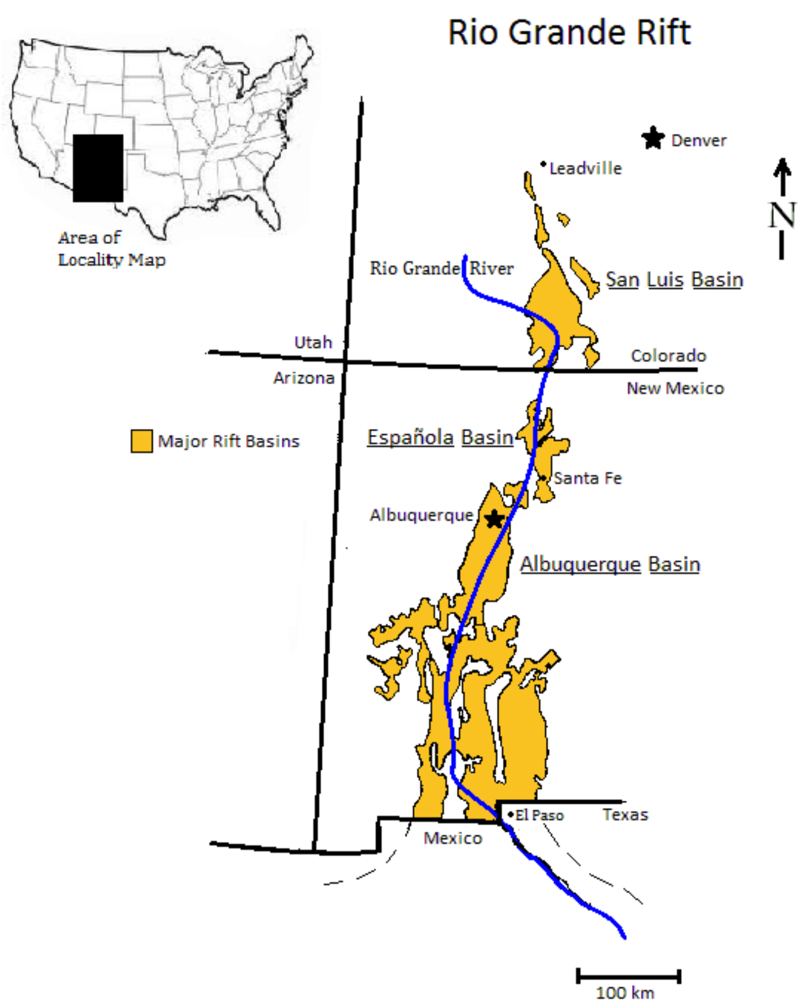
Depth is over 3000 ft

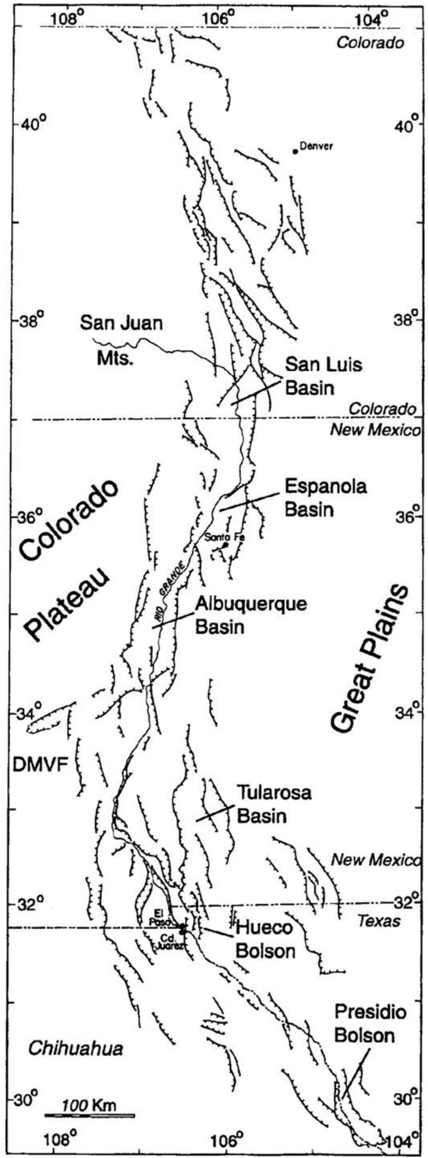


Texaco Poersch #1

Rio Grande Rift

- The US seems to have deposits of natural hydrogen along Rift systems. The most famous of these is the Mid-Continent Rift; however, it is not the only one
- Rio Grande Rift:
  - Near-total agreement that it reaches Leadville
  - A Minority opinion that it can be plotted up to just over the Wyoming boarder
  - Some very bold claims that it can be plotted into central Wyoming

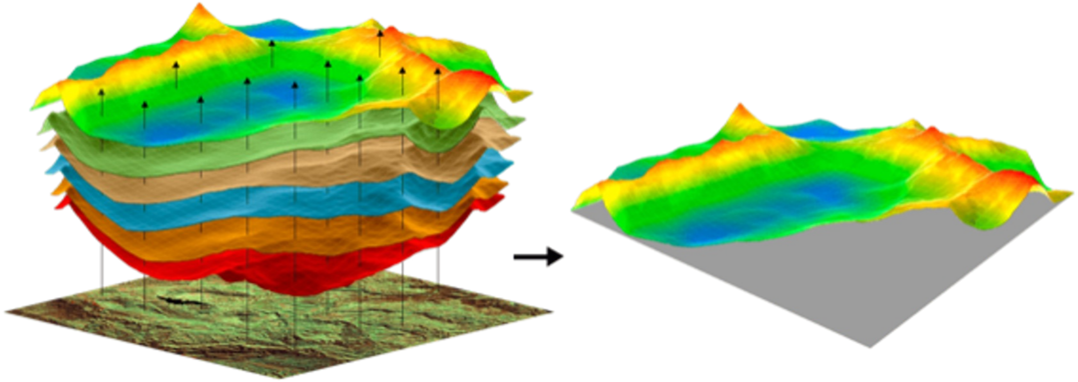




A map of the Rio Grande Rift's well-established position south of Leadville, CO (left) and a map of major Late Cenozoic normal faults, shown as dark lines (right). The Rio Grande Rift's northern tip is probably north of the CO-WY border shown here. https://doi.org/10.2113/34.1.121

Major Challenges

- Understanding geologic sourcing and migration pathways
- Sensors and other methods of detection that work at pressures and temperatures and are sufficiently compact
- Basin and reservoir modeling and simulation tools
- AI tools to expedite information processing and discovery
- Methods for containing Hydrogen
- Stimulation methods
- Drilling program?



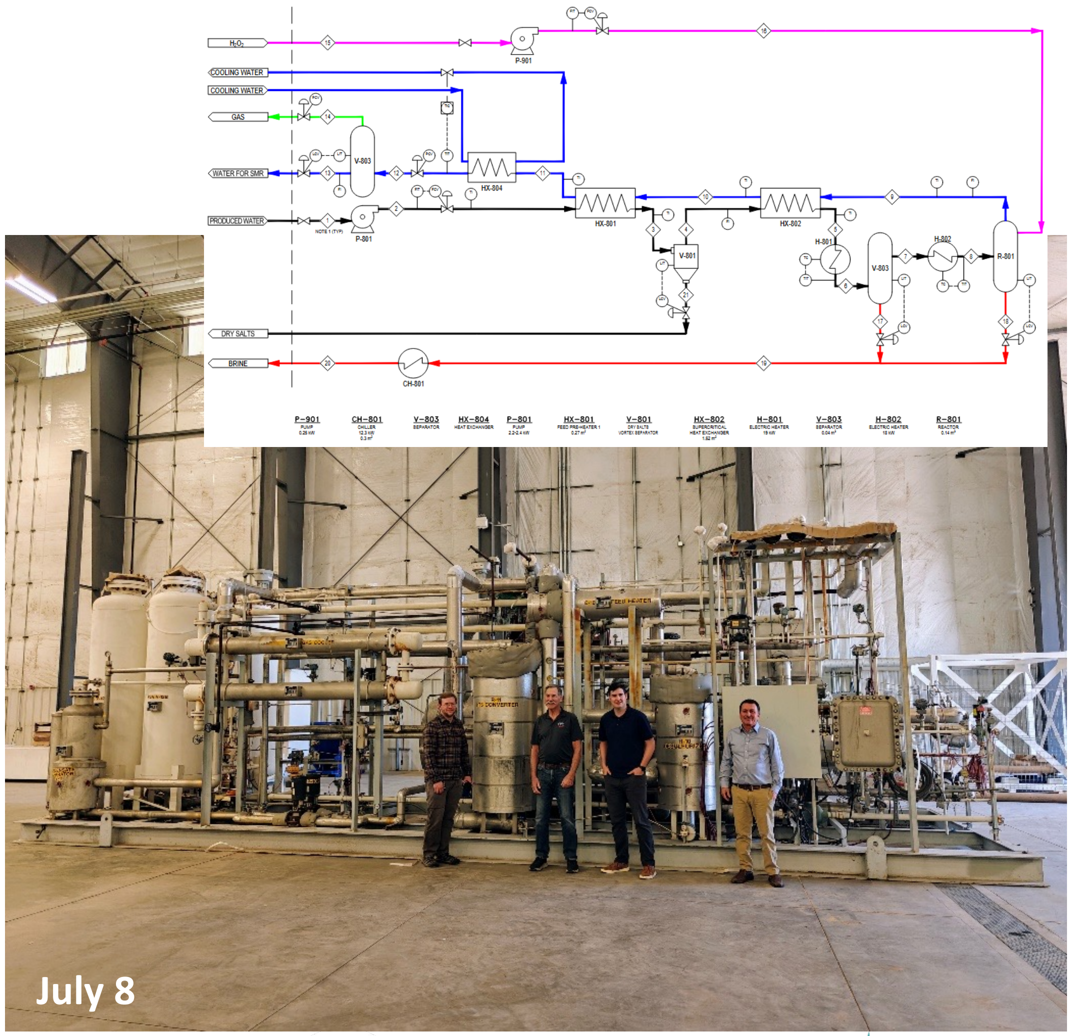
Current Externally Funded Projects

- Desalination and Steam Methane Reforming **(SCWDO-SMR)** with Williams, Los Alamos National Lab, and Engineering Procurement & Construction, LLC
  - **$10M**, 50% cost-share, DOE NETL funded
  - **$2.75M** WY Energy Matching Fund
  - Charles Nye - PI
- Geologic Hydrogen Production, Bureau of Economic Geology - lead
  - **$1.7M, ARPA-E,** 10% cost-share
  - Charles Nye, Co-PI
- Advancing Blue Hydrogen Production and Transport Infrastructure In Wyoming – Phase III **(New)**
  - $555k, WY Innovation Partnership
  - Dr. Haibo Zhai - PI
- H_2Net-Zero Scenario for Wyoming – **DOE NETL ($650k) – final technical report submitted**

Produced Water and Natural Gas to Hydrogen

The objective of this project is to conduct a pilot-scale field demonstration of 1 ton/day hydrogen production using O&G-produced water at a cost ~15% below existing methods of $1.30 – $2.10/kg of H_2

- We have a fully functioning OEM-recertified Steam Methane Reformer (SMR) for Hydrogen production (saved >$500k)
- We have designed most of an SCWDO system which can be built by a successful bidder under standard procurement.
  - This would be attached to the SMR to provide hot water reclaimed from produced water waste
  - Design work was led by LANL and collaboration with CCCC and EP&C.
- We do not currently have the ability to communicate with DOE. This prevents us from receiving a "No-Cost Time Extension". This is a standard document needed to regain time which was spent on pre-award negotiations.

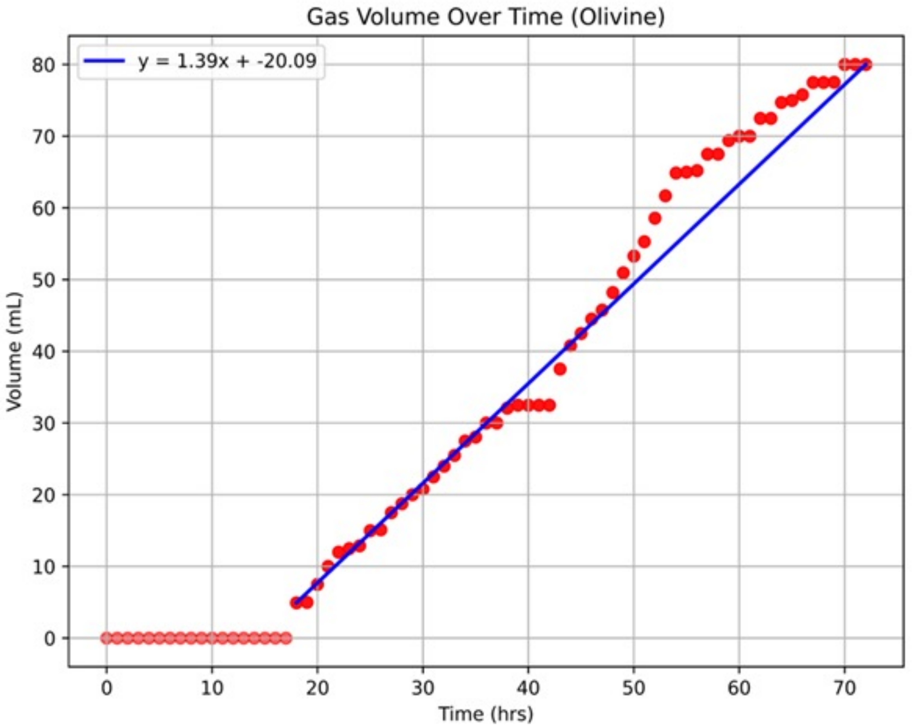


Total Project: $10M; Federal: $5M; State: $2.75M(WEA) + $550k(UW)
Private: $750k(EPC) + $950k(Williams)

UW School of Energy Resources | EPC Engineering, Procurement & Construction | Los Alamos National Laboratory | Williams | Wyoming Energy Authority

ARPA-E: Hydrogen from Rust (Fe_2O_3)

- Producing hydrogen from iron-bearing rocks under a subaward from UT-Austin.
- The team has collected rocks from the Iron Mines near South Pass City, WY.
  - Plans to collect a variety of reduced-iron rocks from around the state in May 2025.
- These rocks were exposed to water at high temperatures for 72hours. During this multi-day experiment Hydrogen was produced.
- This work has shown that even without a catalyst a Wyoming rock can produces hydrogen through a rusting-like reaction. This means our success criteria is already met!
- If this process can be scaled and accelerated the energy in un-minable Iron can be turned into hydrogen.



UW subaward is \$650k; UWyo input: \$0; Federal input: \$1.7M

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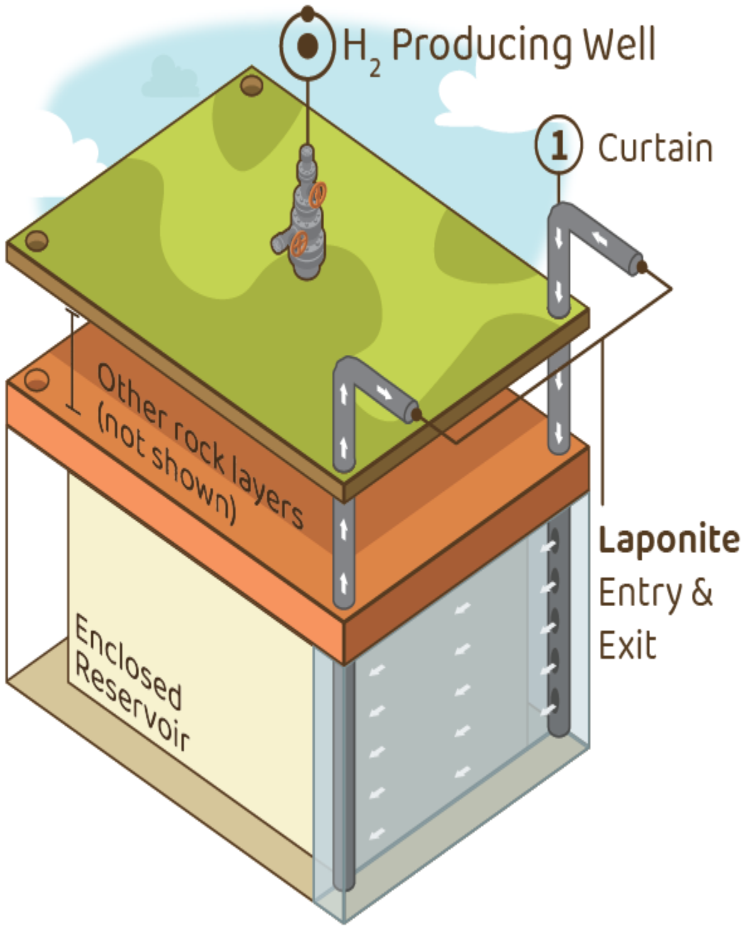
UW School of Energy Resources

Containment and Control of Geologic Hydrogen with Synthetic Clay Suspensions

- ARPA-E VISION Open: Containment and Control of Geologic Hydrogen with Synthetic Clay Suspensions
  - **Saman Aryana – PI;** Fed - $2.1M Cost-Share: $114k; 2 years
  - Partners: The National Energy Technology Laboratory
  - The primary objective of this project is to develop an economical and environmentally friendly H_2 subsurface containment strategy using synthetic smectite clay (Laponite®) suspensions. This strategy aims to create engineered subsurface flow barriers when natural ones are insufficient or reinforce natural subsurface seals to control and contain H_2 fluxes. These barriers will be deployed at or near geologic H_2 generation sites to prevent leakage and ensure safe and cost-effective H_2 storage





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THE WORLD NEEDS MORE COWBOYS.

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