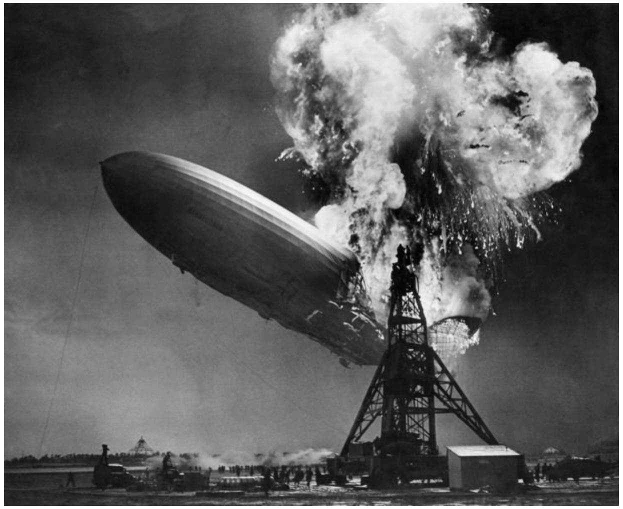
Fossil Blue Hydrogen

“Just use clean electricity”



1937: Hindenburg hydrogen airship explodes in New Jersey

Tom Solomon, 350NM
June 26, 2024

For the To Nizhoni Ani June 26, 2024 Hydrogen Information Summit

Agenda

- Basics of hydrogen, what, how, why
- Blue hydrogen: science and global warming
- Water use to make hydrogen
- Pipeline risks: hydrogen, ammonia
- Summary position on hydrogen

Blue Hydrogen Key Messages

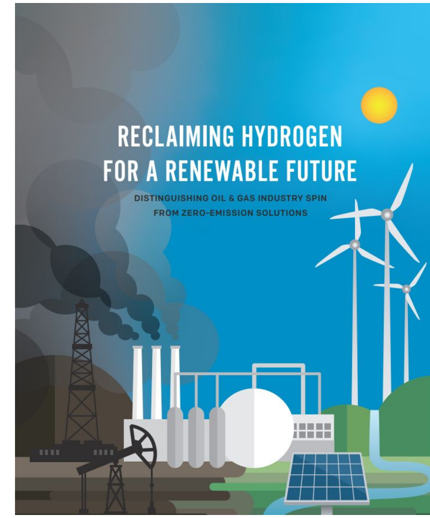
- Blue hydrogen from methane is a fossil fuel program.
- The carbon footprint of blue hydrogen is >20% worse than burning fossil natural gas directly, per scientific studies.
- Hydrogen is a wasteful energy carrier, 2.3x worse vs electricity.
- The NM WISHH hydrogen hub proposal failed in 2023, as did four 2022 hydrogen hub bills, due to determined opposition. They would have increased CO2 emissions.
- Hydrogen is a solution in search of a problem, to help sell more natural gas. Using electricity is nearly always better.

Recommended: Hydrogen Fact Sheet

*Jan 15, 2023 story: New Mexico Lawmakers aim to attract hydrogen investments

Why the Hydrogen Hype?

- Hydrogen is being pushed by industry, <u>not</u> by the environmental community.
  - This Earth Justice report warns of the hype:
    - https://earthjustice.org/features/green-hydrogen-renewable-zero-emission

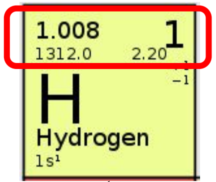


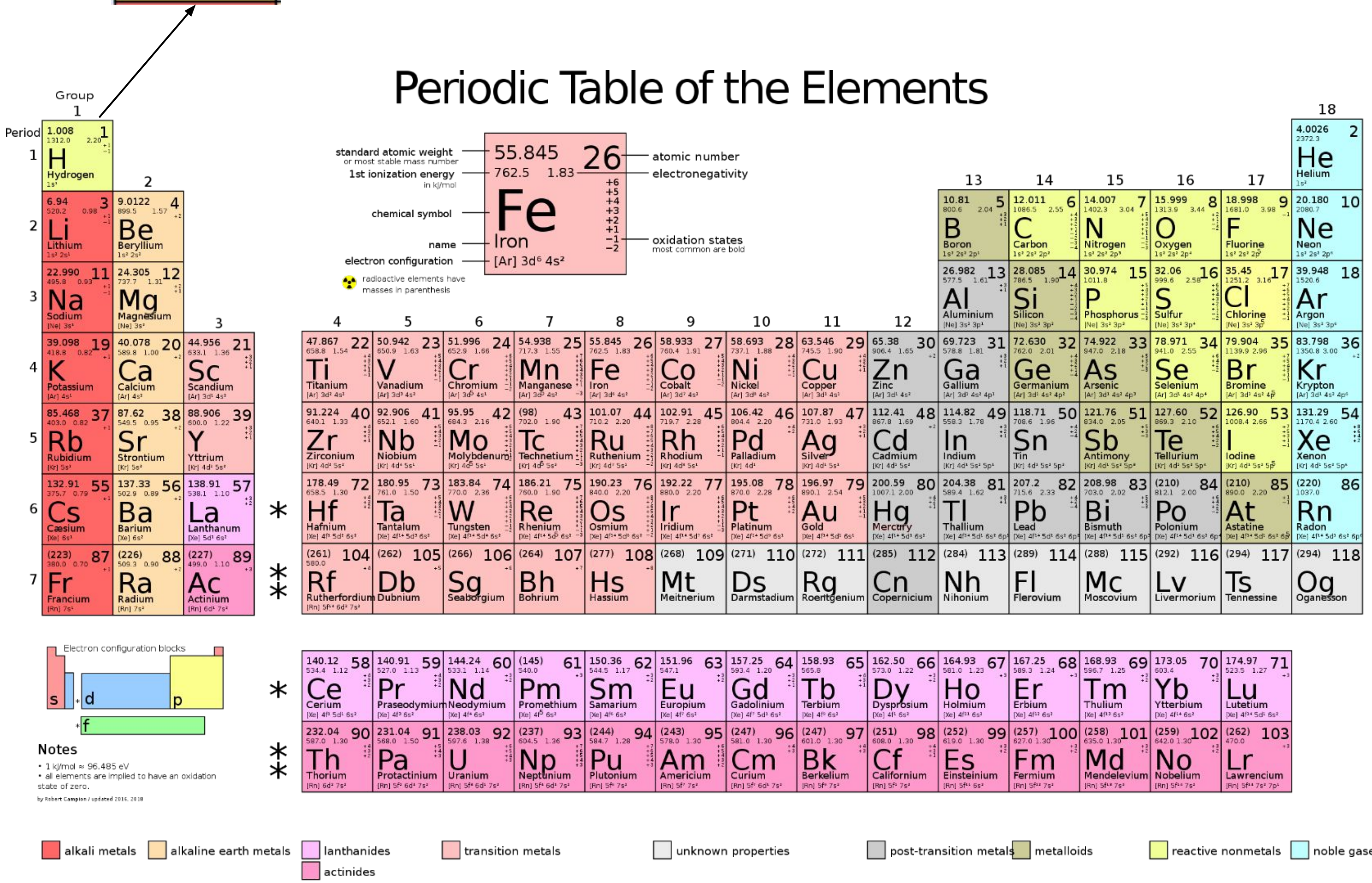
- The hydrogen hype is led by **oil, gas & pipeline companies**.
  - <u>EU Hydrogen Council</u>: Red=oil/gas, Blue = auto
  - Hydrogen provides a path to **sell more gas** & delay the clean energy transition
  - Behind it: FTI Consulting, oil & gas industry PR firm

Oil companies include BP, Shell, Chevron, Saudi Aramco, Sinopec, Adnoc, Kogas, Baker Hughes, Petronas, SoCalGas

Making H2 Takes Lots of Energy

Hydrogen is the smallest atom in the universe. Pure hydrogen (**H2),** is **highly reactive**. In nature it usually found combined with **oxygen** in **water**, (H_2O) or with **carbon** in **methane**, (CH_4).
It takes lots of energy to pull pure hydrogen* from these substances.





* It takes ~50 kWh and ~25 liters of water to create 1 kg of <u>green</u> hydrogen

https://www.spglobal.com/platts/en/market-insights/latest-news/electric-power/031920-cost-logistics-offer-blue-hydrogen-market-advantages-over-green-alternative

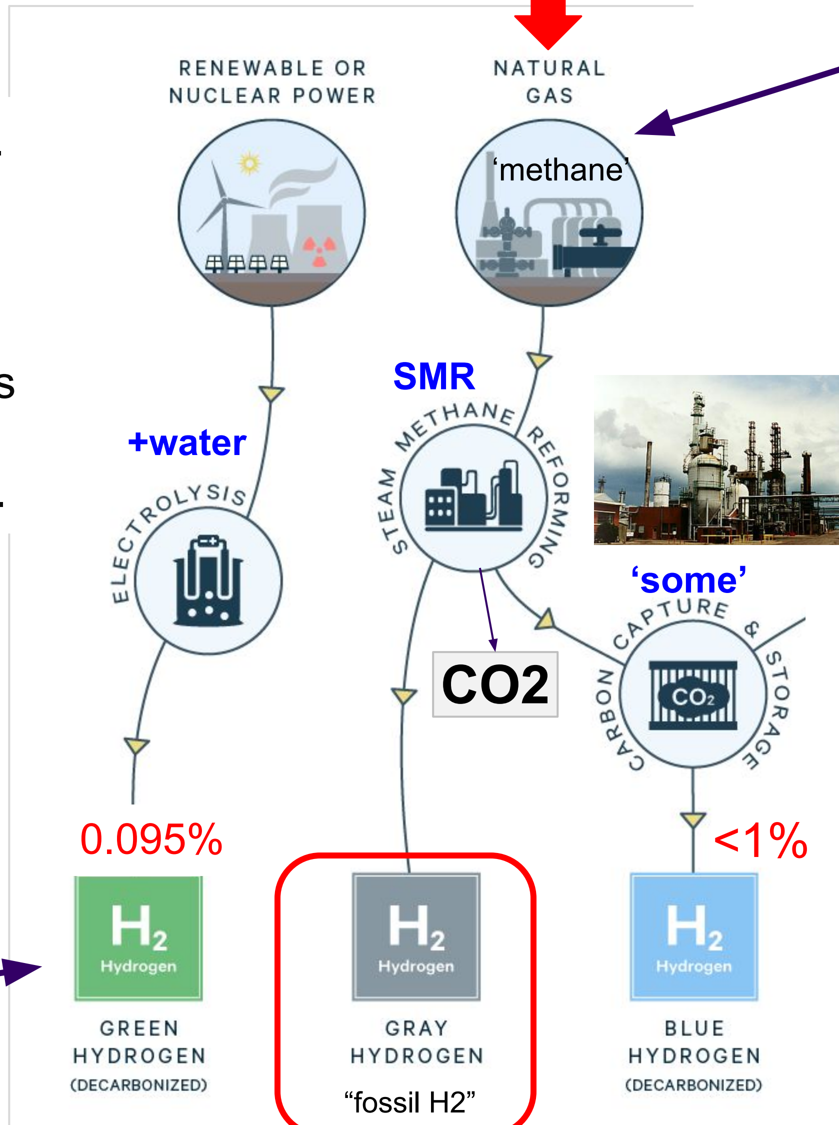
99.9% of Hydrogen is from Fossil Fuels

In 2022 **<u>99.9% of global demand</u>** for hydrogen (**95M** metric tons) was made from **fossil fuels**.

Only **0.095M** metric tons of **green H2** was produced, ie **<u>0.1%</u>** (IEA).

2.3% of global CO2 emissions come from producing **hydrogen.**

Types or '**colors**' of hydrogen, by source



"**Gray hydrogen**" is made by mixing fossil methane (natural gas) with high temperature steam. That SMR process produces one part hydrogen with **twelve parts carbon dioxide (CO2)**, a GHG.

For "**Blue hydrogen**" some*, not all, of the CO2 is then captured and stored in an underground site. In 2022 under 1% was **blue** hydrogen.

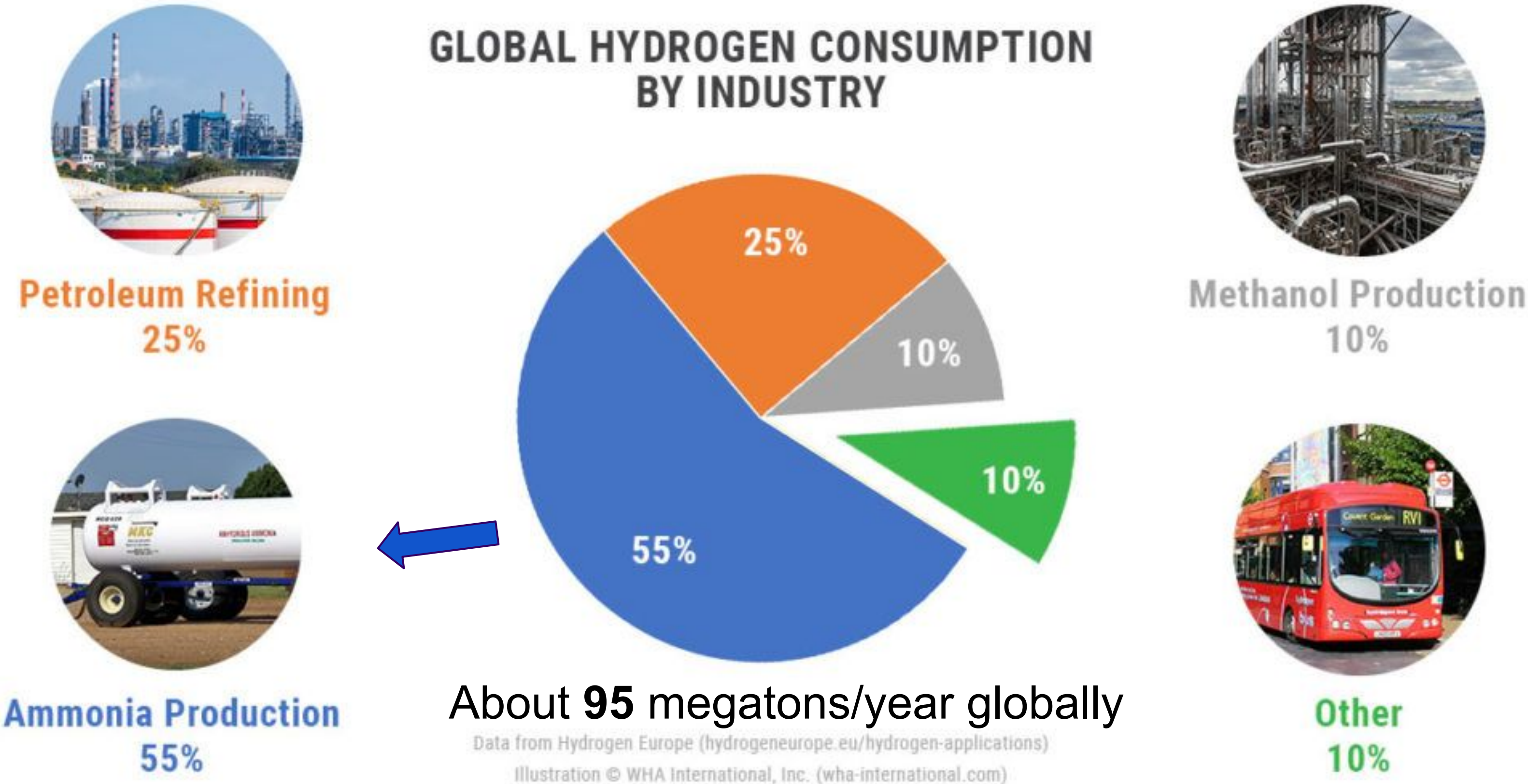
https://iea.blob.core.windows.net/assets/c5bc75b1-9e4d-460d-9056-6e8e626a11c4/GlobalHydrogenReview2022.pdf

Updated: June 2024

* per IEEFA 2022, actual CCS projects **average 45% capture**, far below the claimed 90+%

Where is Hydrogen Used Today?

This chart shows global use. In the United States, the 10Mt/year demand for hydrogen is mostly for **ammonia fertilizer** and **petroleum** refining (DOE). Making hydrogen today produces 2.3% of global CO2 emissions.



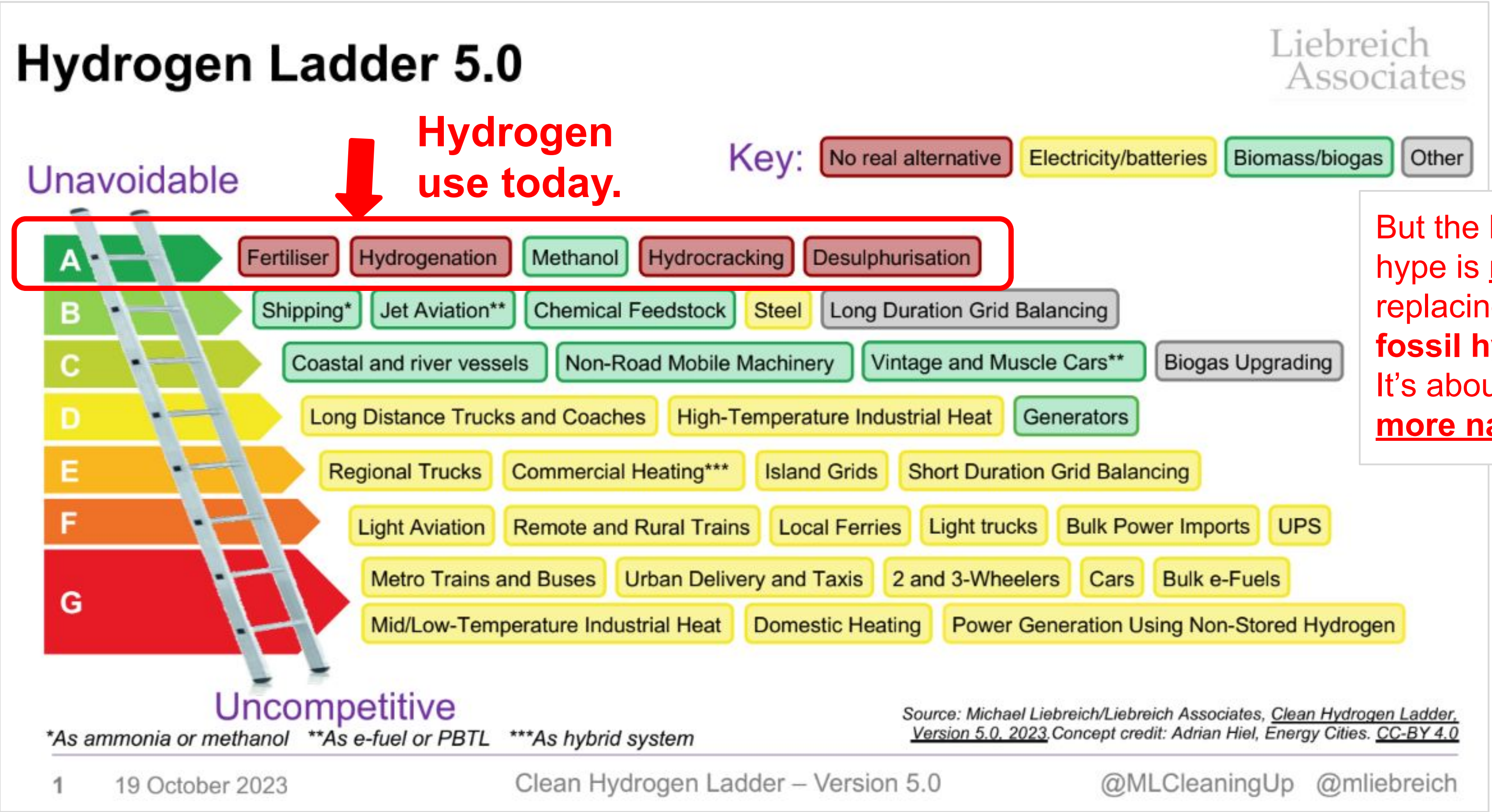
About **95** megatons/year globally

NH3 mostly for fertilizer

https://www.eia.gov/energyexplained/hydrogen/use-of-hydrogen.php
https://wha-international.com/hydrogen-in-industry/

Hydrogen Use-Case Ladder

The top of the ladder, level A, are the current uses of grey hydrogen in the economy. Those uses, **principally for fertiliser, oil refining and petrochemicals production** - currently account for around 2% of global CO2 emissions. Clean hydrogen has to win here, as there is no alternative.



But the hydrogen hype is not about replacing grey **fossil hydrogen**. It's about selling **more natural gas**.

https://www.linkedin.com/pulse/hydrogen-ladder-version-50-michael-liebreich

M. Barnard H2 Analysis

NM Hydrogen Ecosystem - Redfern

Like It Or Not, a Hydrogen Ecosystem Is Coming to New Mexico

Production, distribution, power generation, carbon capture all in the works: Questions, concerns, confusion abound.

Published on May 21, 2024
By **Jerry Redfern**

May 21, 2024

The Tallgrass ecosystem includes a [carbon capture and sequestration project] **with New Mexico Tech**. The university has been studying the geology of the **San Juan Basin** since 2020 with the goal of getting three **sequestration wells*** operational in a few years. The project is in the middle of its federal permitting process and could be approved sometime next year.

It also includes the Escalante **coal-fired power plant retrofitted to burn hydrogen**, along I-40 between Albuquerque and Gallup and the **hydrogen pipeline linking Farmington to central Arizona and crossing the Navajo Nation**, a controversial project still in the planning stages.

It's expected to include a **hydrogen production facility or two in or near Farmington,** with exact locations to be determined.

Tallgrass has to **build another pipeline, this one for carbon dioxide**, running from the Escalante power plant to the future carbon sequestration wells, roughly 100 miles to the north and crossing the eastern reaches of the Navajo Nation.

* San Juan Basin CCS Carbonsafe

Escalante Coal-to-H2 project

Former 253MW Escalante Coal Power Plant, **Prewitt, NM**, Closed in 2020.

The eH2 plan: spend $600M on conversion, to produce hydrogen from natural gas & hydrogen-electricity **by 2025**. Create **60 jobs**

eh2power.com

Must build new:

- Air Separation Unit
- Steam Methane Reformer
- Carbon capture unit
- CO2 sequestration unit

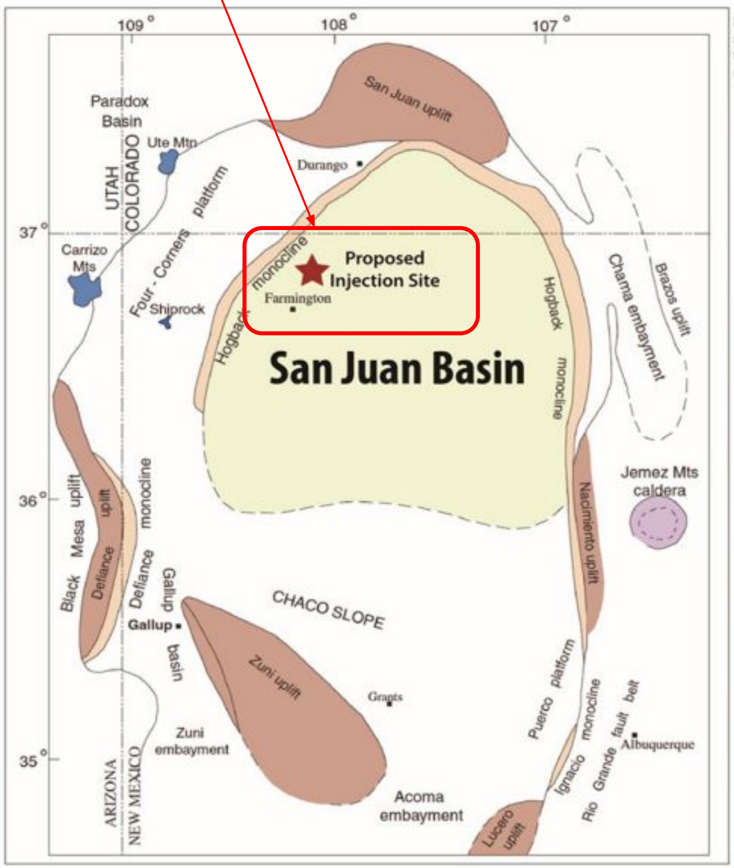
Cuts electricity output from **253MW** to **~164MW**, thus unprofitable per eH2 CEO.

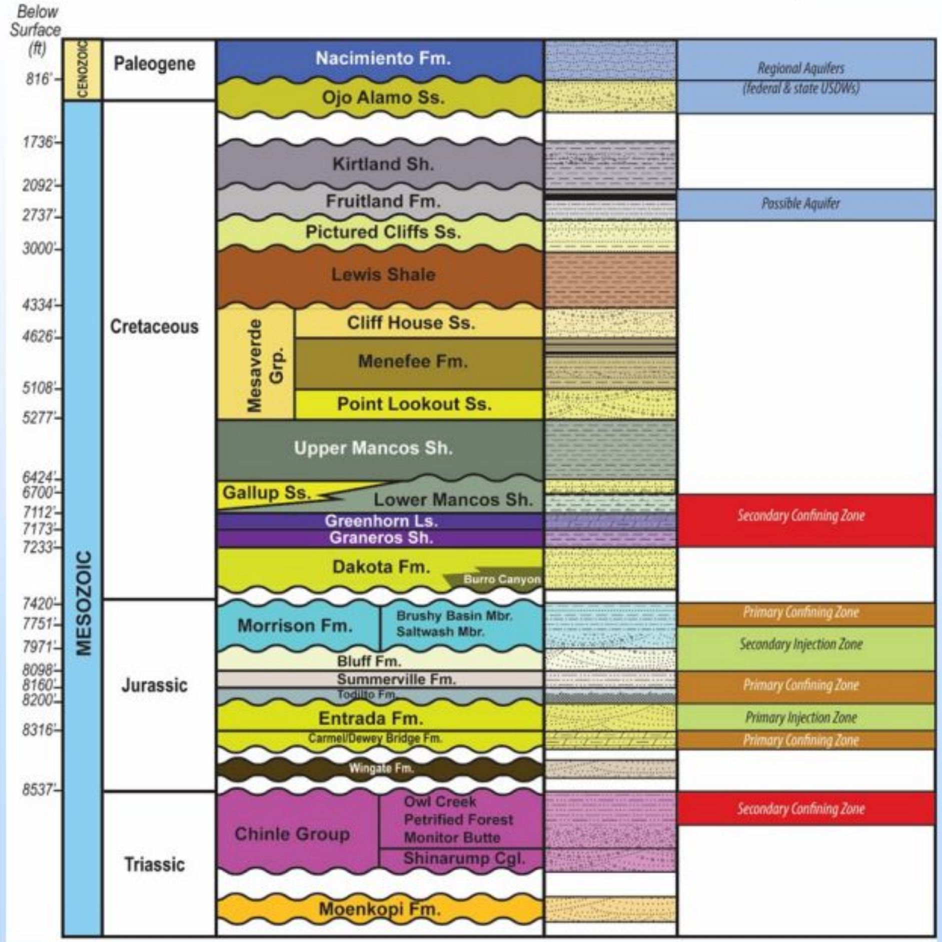
Plans to sell the hydrogen:
- inject 5% into gas pipeline
- make ‘green’ cement (?)

San Juan Basin (SJB) CarbonSAFE Site

- **CCS carbon storage & sequestration** site 10 miles NE of Farmington

Storage Complex @ San Juan Basin





https://netl.doe.gov/sites/default/files/netl-file/22CM_CTS15_Ampomah.pdf
https://www.netl.doe.gov/project-information?p=FE0032064

Let’s Look at the Science of Blue Hydrogen

Paper: How Green Is Blue Hydrogen?

https://onlinelibrary.wiley.com/doi/full/10.1002/ese3.956

Energy Science & Engineering
Open Access

MODELLING AND ANALYSIS | Open Access

How green is blue hydrogen?

Robert W. Howarth, Mark Z. Jacobson,

First published: 12 August 2021 | https://doi.org/10.1002/ese3.956 |

"**To call it a zero-emissions fuel is totally wrong**," said Robert W. Howarth, a biogeochemist and ecosystem scientist at Cornell and the study's lead author. "What we found is that **it's not even a low-emissions fuel, either**." They found that **the greenhouse gas footprint of blue hydrogen was more than 20 percent greater than burning natural gas** or coal for heat.

Very generous assumptions:

Baseline assumptions for blue hydrogen:

- **3.5% upstream methane emissions** (% of consumption), modeled down to 1.45%.
- **85% carbon capture** during SMR
- 65% **capture of flue gases** from combustion for heat & pressure (which no-one does)

Abstract

Hydrogen is often viewed as an important energy carrier in a future decarbonized world. Currently, most hydrogen is produced by steam reforming of methane in natural gas ("gray hydrogen"), with high carbon dioxide emissions. Increasingly, many propose using carbon capture and storage to reduce these emissions, producing so-called "blue hydrogen," frequently promoted as low emissions. We undertake the first effort in a peer-reviewed paper to examine the lifecycle greenhouse gas emissions of blue hydrogen accounting for emissions of both carbon dioxide and unburned fugitive methane. Far from being low carbon, greenhouse gas emissions from the production of blue hydrogen are quite high, particularly due to the release of fugitive methane. For our default assumptions (3.5% emission rate of methane from natural gas and a 20-year global warming potential), total carbon dioxide equivalent emissions for blue hydrogen are only 9%-12% less than for gray hydrogen. While carbon dioxide emissions are lower, fugitive methane emissions for blue hydrogen are higher than for gray hydrogen because of an increased use of natural gas to power the carbon capture. Perhaps surprisingly, the greenhouse gas footprint of blue hydrogen is more than 20% greater than burning natural gas or coal for heat and some 60% greater than burning diesel oil for heat, again with our default assumptions. In a sensitivity analysis in which the methane emission rate from natural gas is reduced to a low value of 1.54%, greenhouse gas emissions from blue hydrogen are still greater than from simply burning natural gas, and are only 18%-25% less than for gray hydrogen. Our analysis assumes that captured carbon dioxide can be stored indefinitely, an optimistic and unproven assumption. Even if true though, the use of blue hydrogen appears difficult to justify on climate grounds.

How Green is Blue Hydrogen, https://onlinelibrary.wiley.com/doi/full/10.1002/ese3.956
H&J rebuttal to the the Romano rebuttal https://onlinelibrary.wiley.com/doi/10.1002/ese3.1154

Blue H2: 20% Worse Than Burning Methane

The New York Times

For Many, Hydrogen Is the Fuel of the Future. New Research Raises Doubts.

Industry has been promoting hydrogen as a reliable, next-generation fuel to power cars, heat homes and generate electricity. It may, in fact, be worse for the climate than previously thought.

Aug 12, 2021
"the **greenhouse gas footprint of blue hydrogen was more than 20% greater** than burning natural gas or coal for heat."

- But a new peer-reviewed study on the climate effects of hydrogen … casts doubt on its role in tackling the greenhouse gas emissions that are the driver of catastrophic global warming.
- Most hydrogen used today is extracted from natural gas in a process that requires a lot of energy and emits vast amounts of CO2. Producing natural gas also releases methane, a particularly potent GHG.
- "**To call it a zero-emissions fuel is totally wrong**," said Robert W. Howarth, a biogeochemist and ecosystem scientist at Cornell and the study's lead author. "What we found is that **it's not even a low-emissions fuel, either**." In all, they found that **the greenhouse gas footprint of blue hydrogen was more than 20 percent greater than burning natural gas** or coal for heat.
- To arrive at their conclusion, Dr. Howarth and Mark Z. Jacobson, a professor of civil and environmental engineering at Stanford and director of its Atmosphere/Energy program, **examined the life cycle greenhouse gas emissions of blue hydrogen. They accounted for both carbon dioxide emissions and the methane that leaks from wells and other equipment during natural gas production**.
- The researchers assumed that **3.5 percent of the gas drilled from the ground leaks** into the atmosphere, an assumption that draws on mounting research that has found that **drilling for natural gas emits far more methane than previously known.**
- ***They modeled 1.4% leakage and even then, blue H2 is worse for the climate than burning methane***

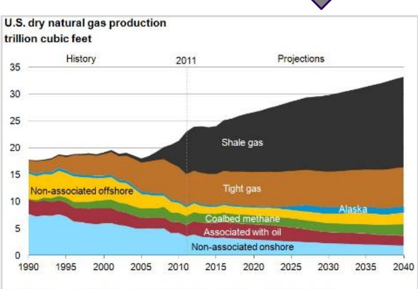
Link https://www.nytimes.com/2021/08/12/climate/hydrogen-fuel-natural-gas-pollution.html
How Green is Blue Hydrogen? https://onlinelibrary.wiley.com/doi/full/10.1002/ese3.956

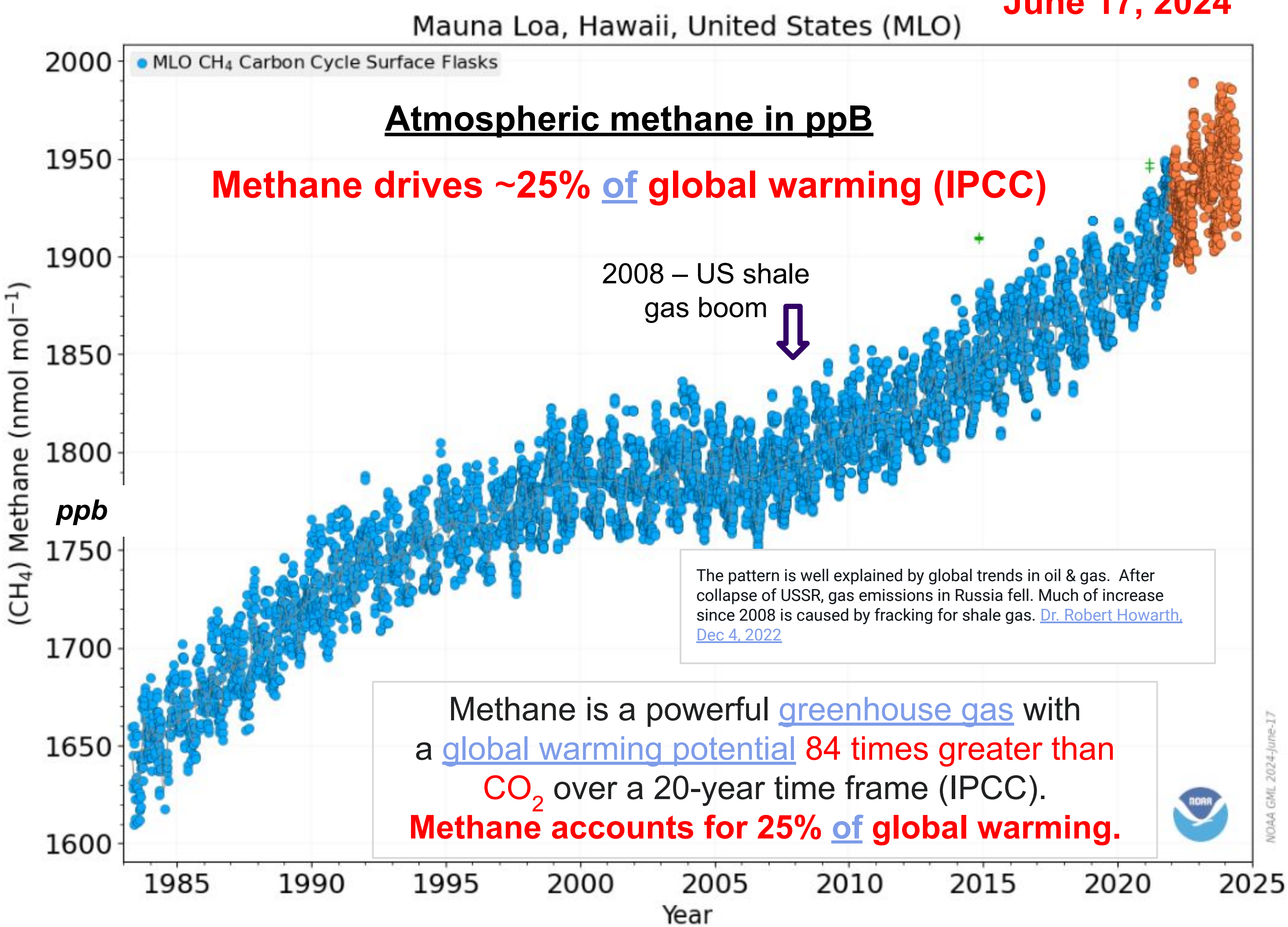
Methane Levels Rising Sharply

June 17, 2024

~90% of ‘[natural gas](#)’ is **methane**

The US shale gas boom started ~ 2008





Atmospheric methane in ppB

Methane drives ~25% of global warming (IPCC)

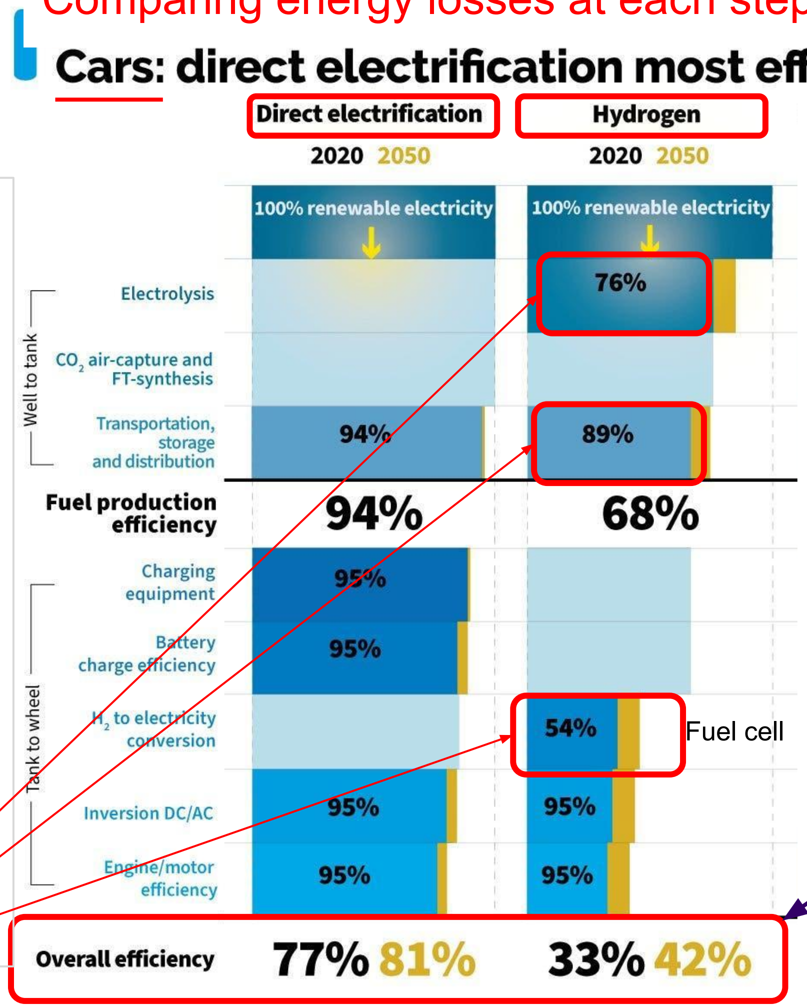
The pattern is well explained by global trends in oil & gas. After collapse of USSR, gas emissions in Russia fell. Much of increase since 2008 is caused by fracking for shale gas. Dr. Robert Howarth, Dec 4, 2022

Methane is a powerful greenhouse gas with a global warming potential 84 times greater than CO_2 over a 20-year time frame (IPCC).
Methane accounts for 25% of global warming.

https://gml.noaa.gov/dv/iadv/graph.php?code=MLO&program=ccgg&type=ts Howarth 2019 study https://bg.copernicus.org/articles/16/3033/2019/
https://en.wikipedia.org/wiki/Atmospheric_methane https://www.ipcc.ch/report/ar5/wg1/
https://www.nationalgeographic.com/environment/article/fracking-boom-tied-to-methane-spike-in-earths-atmosphere?loggedin=true

Hydrogen Wastes Energy

Comparing energy losses at each step in **transportation**



Hydrogen is not a natural fuel; it is an energy carrier like electricity.

As an energy carrier it is wasteful, **less than half as efficient as electricity**, suffering large **energy losses** during multiple conversions.

The three worst steps are:
1) during electrolysis
2) in transport & storage
3) in the fuel cell

Hydrogen is wasteful. Electricity is 2.3x better.

power to wheels

Notes: To be understood as a... fferent production methods. Hydrogen includes onboard fuel compression. Excluding mechanical losses.

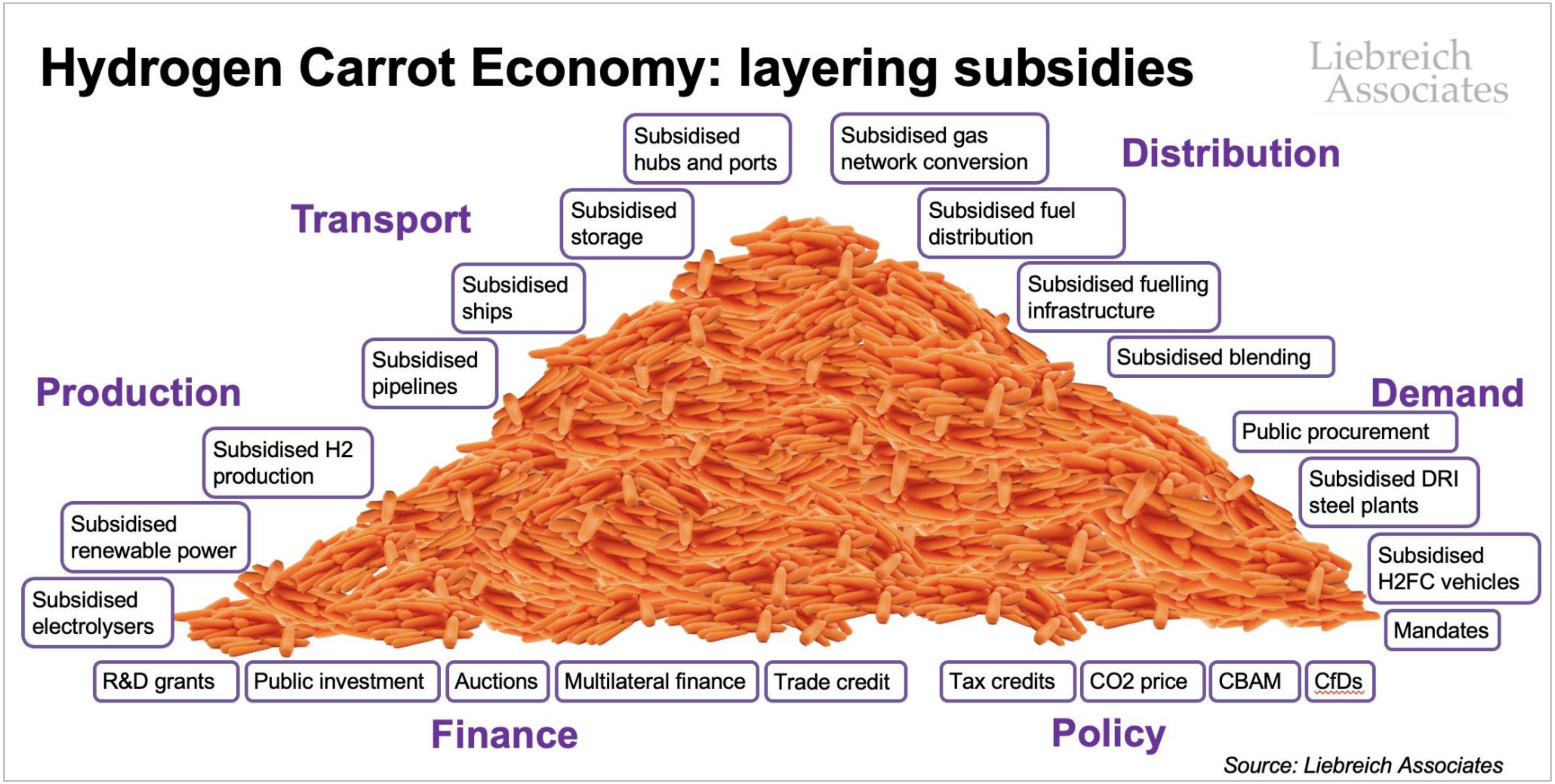
TRANSPORT & ENVIRONMENT transportenvironment.org

...orldbank (2014), Apostolaki-Iosifidou et al. (2017), Peters et al. (2017), Larmanie et al. (2012), Umweltbundesamt (2019), National Research Council (2013), Ricardo Energy & Environment (2020), DOE (no date), ACEA (2016).

https://www.transportenvironment.org/sites/te/files/publications/2020_12_Briefing_feasibility_study_renewables_decarbonisation.pdf

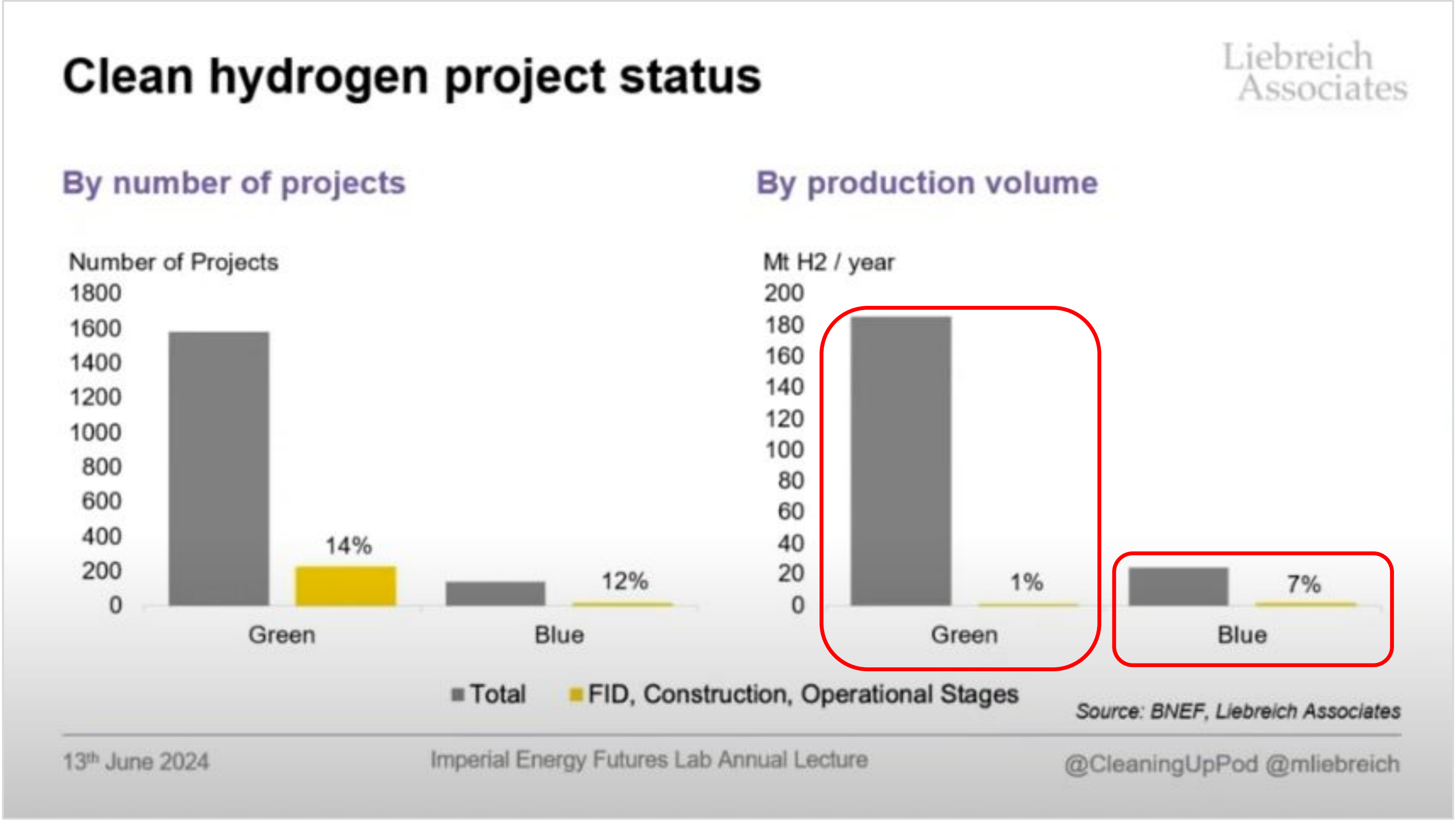
Many Hydrogen Subsidies

Many, many hydrogen subsidies* are available: for **production, transportation, distribution and use**. Unlike other renewable energy subsidies, these can be **layered** on top of each other.



*45V tax credits https://www.energy.gov/eere/fuelcells/financial-incentives-hydrogen-and-fuel-cell-projects

Clean Hydrogen: Big Plans, Few Takers



- Despite plans to produce 180 Mt of green hydrogen per year, **only 1% of those projects are funded**.
- **Only 7% for blue hydrogen** (fossil H2 with capture)

Water Used to Make Hydrogen

20-30 liters of water is used to make 1kg of hydrogen, gray/blue or green (**about 3 gallons per pound**).

- Water to make **hydrogen from natural gas** is **~22 kg H20 per kg H2**.
- From energypost.eu/hydrogen-production-in-2050-how-much-water-will-74ej-need/
  - **Water consumption comes from two steps: hydrogen production and the production of the upstream energy carrier**. The **minimum <u>water electrolysis</u> requires is about <u>9 kg</u> of water per kg of hydrogen**. However, taking into account the process of water **demineralisation**, **the ratio can range between 18 kg and 24 kg** of water per kg of hydrogen or even **up to 25.7-30.2**.
  - **For steam reforming of <u>methane</u>, the minimum water consumption is 4.5 kg H2O/kg H2** (needed for the reaction), which **increases to <u>6.4-32.2</u> kgH2O/kgH2 when considering the water for the process and cooling**.

- To make **green hydrogen from electrolysis** takes about **27kg of water for 1kg of hydrogen**.
  - This accounts for lifecycle water used in de-mineralization, electrolysis, and to produce the electricity, including water used to manufacture PV panels & wind turbines.

https://energypost.eu/hydrogen-production-in-2050-how-much-water-will-74ej-need/

NM.gov Clean Hydrogen Fact Sheet Jan 2023

NEW MEXICO
CLEAN HYDROGEN
FACT SHEET

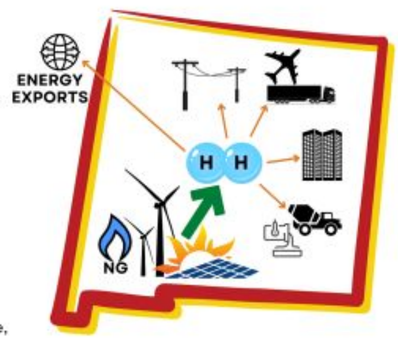
As a national leader in clean energy, New Mexico is looking to diversify its energy exports and include clean hydrogen as a key sector of the economy. We plan to make, move, store, and use clean hydrogen here in New Mexico as well as export and sell to neighboring states.

MAKE

Clean hydrogen is primarily produced in one of two ways:

Electrolysis uses electricity to split water molecules. Hydrogen is captured with oxygen as the byproduct.

Steam methane reformation with carbon capture uses natural gas to produce hydrogen while capturing the carbon byproduct.



MOVE

Clean hydrogen can be moved as a gas or in other forms, such as ammonia, from production to market in New Mexico and across the nation by using existing and new pipeline infrastructure, on-road transportation, and rail.

STORE

Clean hydrogen can be stored in underground salt caverns and geologic structures, in storage tanks, or indefinitely in above-ground cryogenic tanks.

USE

Clean hydrogen can be used in several applications, most notably:

Generating electricity in power plants

Powering long-haul semi-trucks, other commercial vehicles, and aircraft

Capturing and storing excess electricity produced from wind and solar during periods of high generation but low demand

Providing a fuel to use across other hard-to-decarbonize sectors like cement processing, and steel and chemical manufacturing

WHY CLEAN HYDROGEN?

Converting hydrogen to energy does not produce greenhouse gases or harmful air pollutants.

New Mexico already has the skilled labor force needed to support this industry.

WATER

Water use for the clean hydrogen economy must be considered carefully. The use of alternative sources, like produced and brackish water, is a priority. The four projects planned in New Mexico as part of the Western Interstate Hydrogen Hub would produce about 850 metric tons of clean hydrogen daily while consuming between 3 and 9 acre-feet of water depending on the method of production. This level of water use is a small fraction of the water that will be freed up by retiring fossil fuel electricity generation.

325,851 gal per acre-ft

NEW MEXICO
CLEAN HYDROGEN
FACT SHEET

ESTABLISHING THE CLEAN HYDROGEN ECONOMY IN NEW MEXICO

Governor Michelle Lujan Grisham set New Mexico on the path to more jobs and better public health with her *Executive Order 2022-013 Establishing the Clean Hydrogen Development Initiative and Implementing Various Measures to Foster a Hydrogen Economy for the Benefit of all New Mexicans.*

The Western Interstate Hydrogen Hub (WISHH) coalition, an unprecedented partnership between New Mexico, Colorado, Wyoming and Utah, submitted a concept paper to the U.S. Department of Energy (DOE) for hydrogen hub funding under the federal Bipartisan Infrastructure Law. Our concept paper was one of 33 that DOE encouraged to move forward out of the 79 submitted.

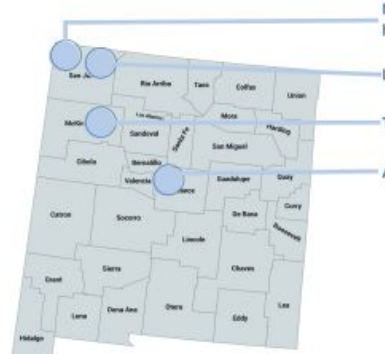
WISHH is requesting the maximum award of $1.25 billion from DOE. If awarded, this would bring an estimated $710 million in federal funds and private investments into our state while accelerating job growth and economic diversification and furthering our ambitious climate change goals.

RESOURCE NEEDS

To maintain our position as a national clean energy leader and build a sustainable hydrogen economy worthy of DOE investment of $1.25 billion, the state agencies will require $24.2 million over the next four to six years, including $3.0 million in recurring funding. This includes:

- $310 thousand in FY23 for the partnering agencies to support development of the full WISHH proposal to DOE
- $8.3 million for the Energy, Minerals and Natural Resources Department to establish a New Mexico-based carbon capture, use, and storage program
- $9.4 million for the Environment Department to advance a clean hydrogen program
- $6.2 million for the Economic Development Department to support innovative hydrogen-related business initiatives

NEW MEXICO HYDROGEN HUB PROJECTS



WHAT IS A CLEAN HYDROGEN HUB?
A clean hydrogen hub is a network of clean hydrogen producers, consumers, and connective infrastructure. It contains all facets of a hydrogen ecosystem: production, delivery, storage, and end uses. A clean hydrogen hub must be self-sustaining after DOE's initial investment.

1-3 M gal/day of water to make 850 metric tons of hydrogen

Hydrogen Pipelines: Safety Issues with Blending

Jan 2023 Pipeline Safety Report from Pipeline Safety Trust Jan '23

Pipeline Safety TRUST

New gas transmission pipelines* designed for exclusive hydrogen service

New smaller diameter gas transmission pipelines may be suitable for hydrogen service if knowledge gaps can be resolved, pipeline integrity can be demonstrated, and pipelines can be sited to ensure that failures will not result in deaths or injuries.

Hydrogen blending into *gas distribution systems:*

Should not be permitted at any level because of hydrogen's ability to explode, especially in buildings. Downstream gas pipeline systems within buildings are not designed for hydrogen.

Hydrogen blending into *gas transmission systems* supplying gas distribution systems:

As most gas transmission pipelines feed into distribution systems—where blending is inappropriate— **hydrogen blending should not be allowed** in such existing gas transmission pipelines.

Hydrogen blending into limited gas transmission pipelines, not supplying gas distribution systems:

May be suitable for hydrogen blends that only service major industrial gas users, if knowledge gaps can be resolved and pipeline integrity can be demonstrated for hydrogen service.

*1,600 miles of hydrogen pipelines in the US- DOE

https://pstrust.org/wp-content/uploads/2023/01/PST-Hydrogen-Summary-for-Policymakers-1.pdf . 1,600mi of H2 pipeline in the US

Ammonia Pipeline Risks

U.Penn-2023: The U.S. has about 3,100 miles of ammonia pipelines.

Ammonia pipelines typically operate at 250 psi. At this pressure, ammonia is a relatively heavy liquid.

Ammonia is toxic and a high health hazard.

US Ammonia pipeline network

https://www.energy.gov/sites/default/files/2021-05/052721-h2iqhour_0.pdf

OSHA: Ammonia is considered a high health hazard because it is corrosive to the skin, eyes, and lungs. Exposure to 300 parts per million (ppm) is immediately dangerous to life and health. Ammonia is also flammable at concentrations of 15% to 28% by volume in air.

Safety- per the US DOT PHMSA - from 2002-2010, there were 53 incidents of ammonia pipeline leaks, 15% from vandalism. A Nov 2007 incident occurred in Florida in which “three teenagers drilled a hole into the pipe, immediately releasing product and a vapor cloud into the surrounding area, causing serious injuries to one of the teens and requiring the hospitalization of several fire fighters... 300 people were evacuated from their homes as a safety precaution.”

https://kleinmanenergy.upenn.edu/research/publications/ammonias-role-in-a-net-zero-hydrogen-economy/

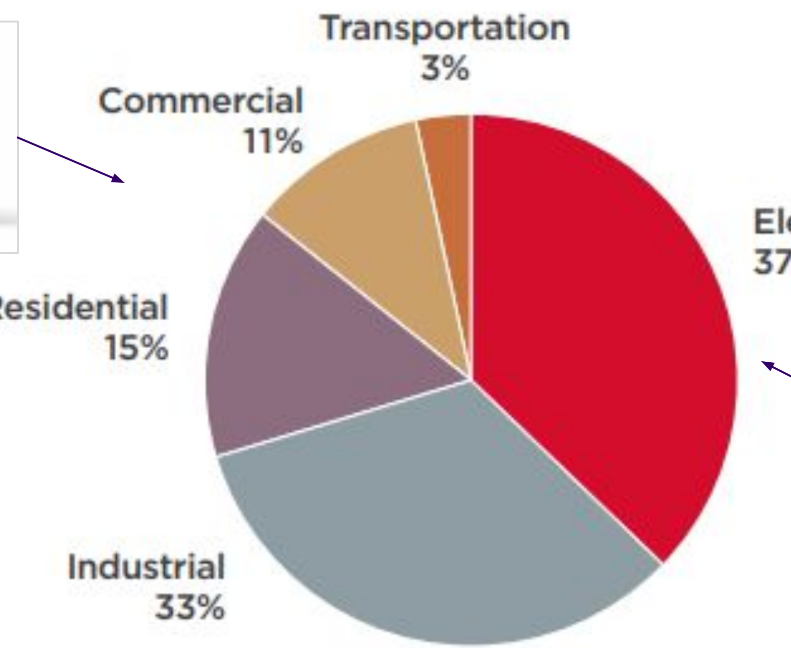
US Natural Gas Use to Decline

Gas is due to be replaced by solar, wind, batteries and heat pumps.

Thus the push for hydrogen.

In 2021, the United States used about 30.28 trillion cubic feet (Tcf) of natural gas, about 31.35 quadrillion British thermal units (BTU).

U.S. Natural Gas Consumption by sector, 2021



Total = 30.28 trillion cubic feet

Data source: U.S. Energy Information Administration, Monthly Energy Review, Table 4.3, April 2022, preliminary data. Note: Transportation includes pipeline and distribution use and vehicle fuel.

Natural gas is 90% methane

https://www.mdd.com/forensic-accounting-articles/introduction-to-natural-gas/

https://www.eia.gov/totalenergy/data/monthly/pdf/mer.pdf Heat pumps outsell gas furnaces in 2023 82% of new electricity is renewables

350NM Position on Hydrogen

“Use electricity instead”

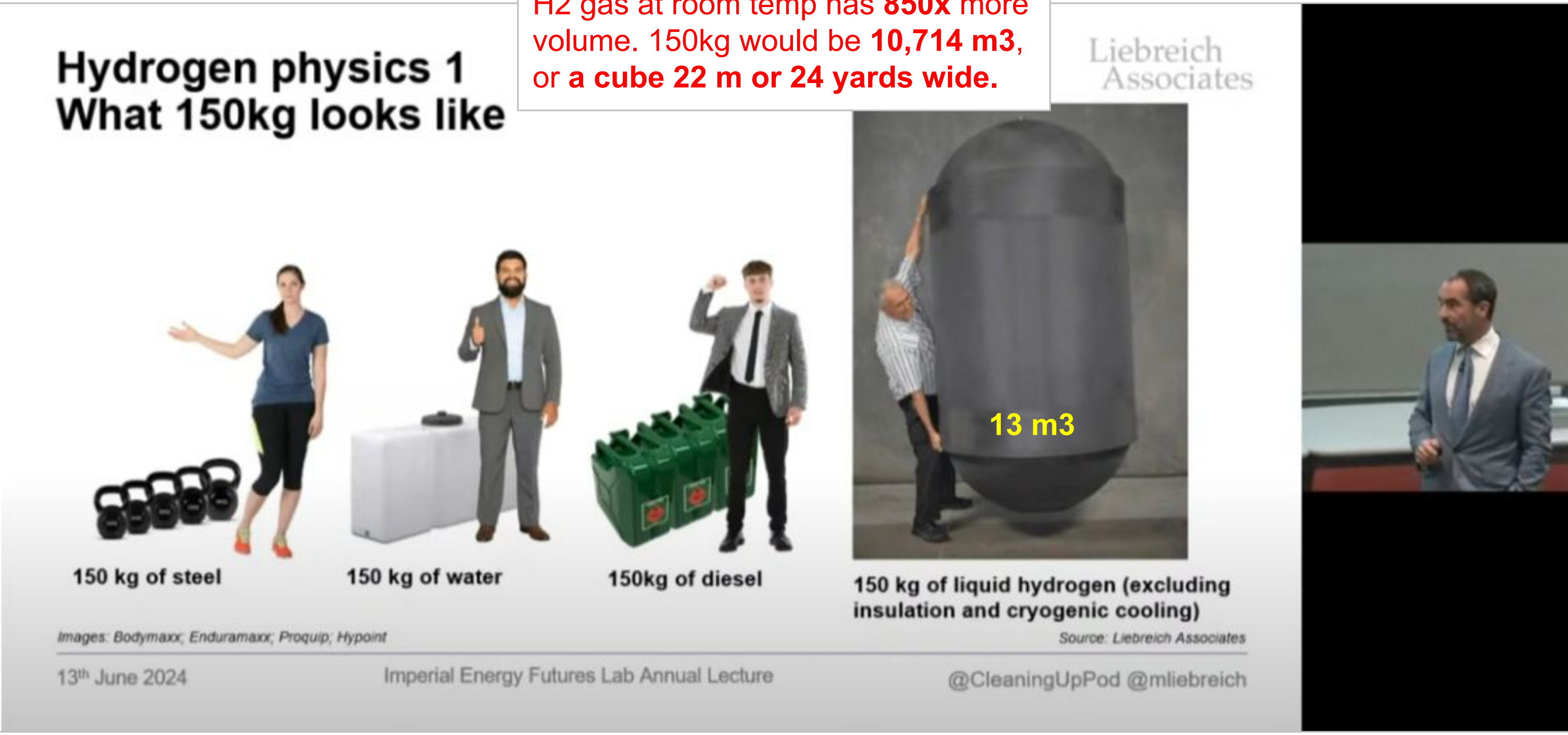
- The US currently produces 10 Mt /year of hydrogen, mostly to make ammonia and refine oil.
- 99.9% of that is unabated ‘gray’ hydrogen made from fossil fuels (mostly methane). Its CO2 climate pollution is vented directly into the air with no capture. That is a significant, though not a top tier, climate problem, comprising 2.3% of global greenhouse gas emissions. Burning coal, methane (aka natural gas), gasoline and diesel are much bigger climate problems.
- Producing so-called ‘blue hydrogen’ (gray hydrogen w/CCS) from methane is not a climate solution. Scientific studies show that making blue hydrogen emits 20% more climate pollution than burning methane directly. Direct methane emissions also cause 25% of global warming.
- **Today’s unavoidable uses of hydrogen (such as making ammonia for crop fertilizer) should eventually be converted to green hydrogen from water. But renewable energy should be prioritized first to replace the burning of coal, methane, gasoline and diesel.**
- **All other proposed new uses of hydrogen should be resisted until every other option is explored, because there are better, cleaner, cheaper and less wasteful solutions available, such as direct electrification and batteries.**
- Industry is pushing to find new uses for hydrogen in order to sell more ‘natural gas’, period.
- **There is every reason to believe most of those hydrogen projects will fail.**

Backup

Michael Liebreich debunks Hydrogen

Cold liquid H2 is at -423F or -253C.

H2 gas at room temp has **850x** more volume. 150kg would be **10,714 m3**, or **a cube 22 m or 24 yards wide.**



H2 Blending for Power is Dumb

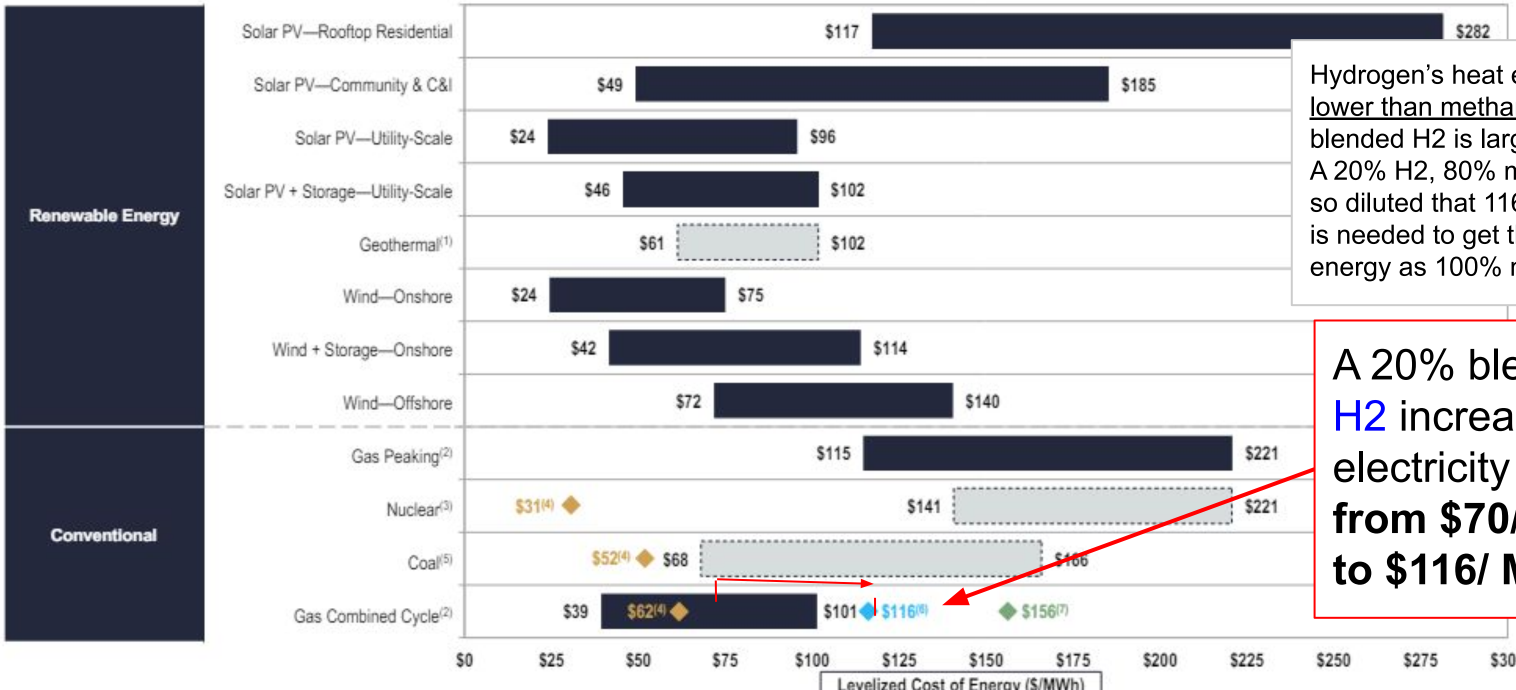
Here is why blending clean #hydrogen into gas grids is such a colossally wasteful thing to do. “Basically you go to all the cost, effort, leakage risk, etc of making clean hydrogen, and then do a bunch of low-value things with it. https://twitter.com/MLiebreich/status/1638461123014868992 “ - M Liebreich

Hydrogen Blending Costs 66% more

LCOE | LAZARD'S LEVELIZED COST OF ENERGY ANALYSIS—VERSION 16.0

Levelized Cost of Energy Comparison—Unsubsidized Analysis

Selected renewable energy generation technologies are cost-competitive with conventional generation technologies under certain circumstances



Hydrogen's heat energy is 68% lower than methane by volume, so blended H2 is largely a diluent. A 20% H2, 80% methane blend is so diluted that 116% of the blend is needed to get the same heat energy as 100% natural gas.

A 20% blend of blue H2 increases cost of electricity by 66%, **from \$70/ MWh avg to \$116/ MWh.**

Source: *Lazard and Roland Berger estimates and publicly available information.*

Note: Here and throughout this presentation, unless otherwise indicated, the analysis assumes 60% debt at an 8% interest rate and 40% equity at a 12% cost. See page titled "Levelized Cost of Energy Comparison—Sensitivity to Cost of Capital" for cost of capital sensitivities.

(1) Given the limited data set available for new-build geothermal projects, the LCOE presented herein represents Lazard's LCOE v15.0 results adjusted for inflation.

(2) The fuel cost assumption for Lazard's unsubsidized analysis for gas-fired generation resources is \$3.45/MMBTU for year-over-year comparison purposes. See page titled "Levelized Cost of Energy Comparison—Sensitivity to Fuel Prices" for fuel price sensitivities.

(3) Given the limited public and/or observable data set available for new-build nuclear projects and the emerging range of new nuclear generation strategies, the LCOE presented herein represents Lazard's LCOE v15.0 results adjusted for inflation (results are based on then-estimated costs of the Vogtle Plant and are U.S.-focused).

(4) Represents the midpoint of the unsubsidized marginal cost of operating fully depreciated gas combined cycle, coal and nuclear facilities, inclusive of decommissioning costs for nuclear facilities. Analysis assumes that the salvage value for a decommissioned gas combined cycle or coal asset is equivalent to its decommissioning and site restoration costs. Inputs are derived from a benchmark of operating gas combined cycle, coal and nuclear assets across the U.S. Capacity factors, fuel, variable and fixed operating expenses are based on upper- and lower-quartile estimates derived from Lazard's research. See page titled "Levelized Cost of Energy Comparison—Renewable Energy versus Marginal Cost of Selected Existing Conventional Generation Technologies" for additional details.

(5) Given the limited public and/or observable data set available for new-build coal projects, the LCOE presented herein represents Lazard's LCOE v15.0 results adjusted for inflation. High end incorporates 90% carbon capture and storage ("CCS"). Does not include cost of transportation and storage.

(6) Represents the LCOE of the observed high case gas combined cycle inputs using a 20% blend of "Blue" hydrogen, (i.e., hydrogen produced from a steam-methane reformer, using natural gas as a feedstock, and sequestering the resulting CO_2 in a nearby saline aquifer). No plant modifications are assumed beyond a 2% adjustment to the plant's heat rate. The corresponding fuel cost is \$5.20/MMBTU, assuming ~\$1.40/kg for Blue hydrogen.

Blue H2

(7) Represents the LCOE of the observed high case gas combined cycle inputs using a 20% blend of "Green" hydrogen, (i.e., hydrogen produced from an electrolyzer powered by a mix of wind and solar generation and stored in a nearby salt cavern). No plant modifications are assumed beyond a 2% adjustment to the plant's heat rate. The corresponding fuel cost is \$10.05/MMBTU, assuming ~\$4.15/kg for Green hydrogen.

LAZARD

https://www.lazard.com/research-insights/2023-levelized-cost-of-energyplus/

80% Wasted in Power-to-H2-to-power

The problem with making green hydrogen to fuel power plants

Some utilities are using plans for combusting hydrogen as a rationale to continue investing in new fossil-gas power plants, even though it will be costly to switch that infrastructure from burning fossil gas to burning hydrogen.

The fundamental problem lies in the laws of physics. **Between 50 and 80 percent of the energy value of clean electricity is lost** in the process of making hydrogen and then burning it to generate electricity.

https://www.canarymedia.com/articles/hydrogen/the-problem-with-making-green-hydrogen-to-fuel-power-plants

100% Hydrogen Power Plants Don't Exist

Pure 100% hydrogen-burning power plants **don't exist**.

GE, Siemens and Mitsubishi are designing turbines that can combust a **mix of methane and hydrogen**. For example 30% H2 in this one:

Entergy Texas is building the OCAPS **Orange County Advanced Power Station**, a 1,215-megawatt facility in Orange, Texas, due to operate in 2026.

Mitsubishi Power is making the two turbines for Entergy's Orange County project, part of a model the company is selling that can burn **30 percent hydrogen along with gas.** "The turbine equipment can support conversion into 100% hydrogen-powered operations in the future."

Orange County Advanced Power Station, a 1,215 megawatt facility in Orange, Texas. Construction started in early 2023, and the project is expected to be completed by 2026.

* https://www.entergy.com/entergypowerstexas/project/
https://www.washingtonpost.com/climate-environment/2023/05/01/power-plants-hydrogen-climate-change/
https://www.power-technology.com/projects/orange-county-advanced-power-station-texas-usa/?cf-view

Ammonia & Methanol are bad fuels

	Diesel	Methanol	Ammonia
Tons CO2e per Ton Fuel	3.1	4.0	7.3
Adjusted for Energy density	3.1	8.9	17.4
Ratio	1	2.9	5.6

Table of CO2e emissions for diesel, methanol and ammonia as a maritime fuel

June 6, 2023 - Michael Barnard, Clean Technica

When I was in Glasgow at Stena Sphere's technical summit recently, methanol as a shipping fuel was central to the discussions of maritime decarbonization. Ammonia was smelling up the wings but not present, as an ammonia organization had declined to send a representative. Stena has not ruled out ammonia, but does have a joint venture with Proman for methanol, which means that stakeholders in the group are already somewhat committed to the pathway. That's going to be challenge for them, but Maersk is much more committed.

Let's start with the basics.

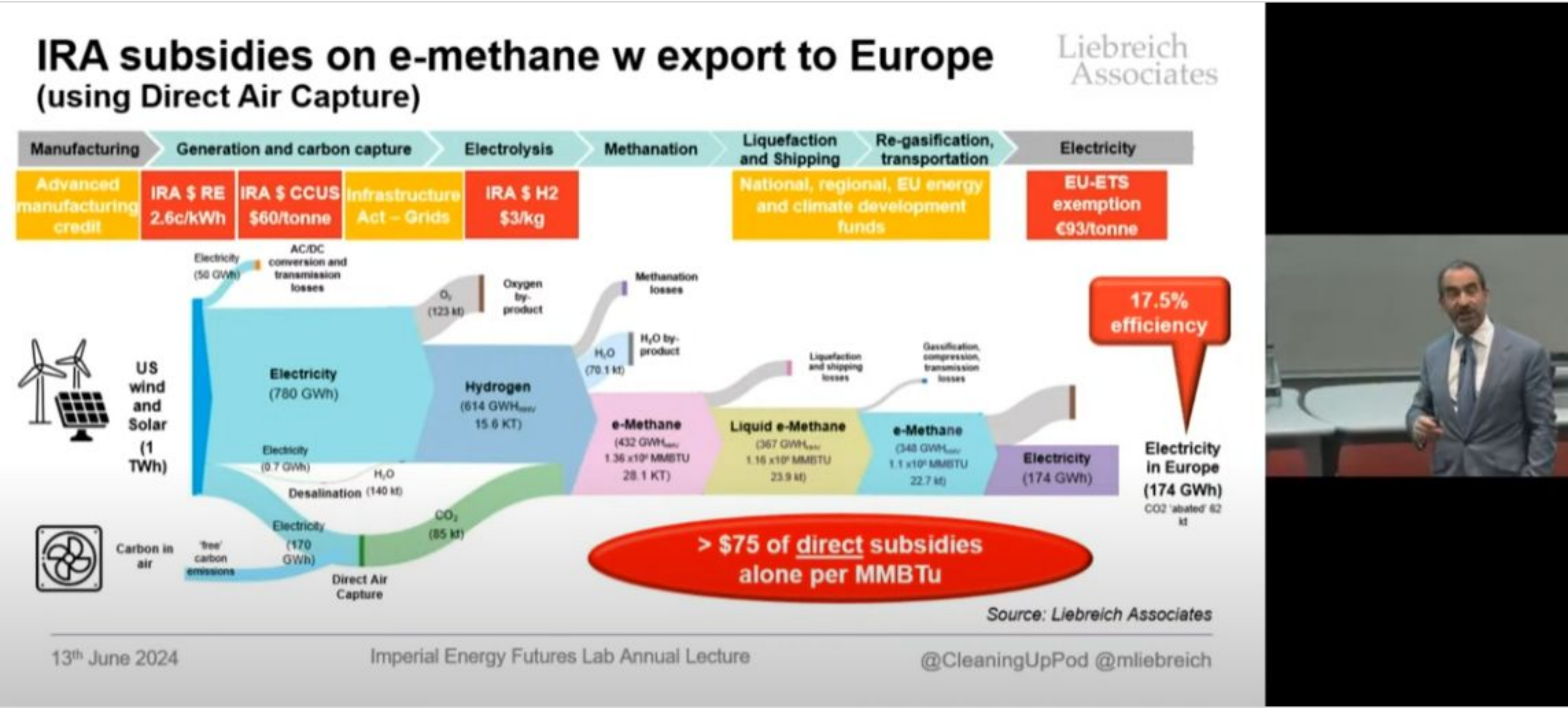
Ammonia isn't an alcohol. It's a nitrogen atom and three hydrogen atoms. We manufacture about 150 million tons of it as well, almost entirely for fertilizer, and also manufacture it mostly from natural gas. It's not as good at burning as methanol, it has the advantage that it doesn't have carbon, so no CO2, and the disadvantage that it has lots of nitrogen and so is more likely to **create N2O with its global warming potential of 265 times that of CO2**. Oh, and when it interacts with water it turns from a liquid whose fumes will screw a sailor up for life to a corrosive gas that will just kill them before turning into a third chemical that goes back to being really bad for human health.

As both ammonia and methanol are made from fossil fuels, they are both climate change problems.

Ammonia represents demand for about 30 million tons of hydrogen a year, and each ton of hydrogen drags 8-10 tons of CO2e behind it between upstream emissions and CO2 from steam reformation with natural gas. **That's about 7 tons of CO2e per ton of ammonia.** it has a lower energy density than methanol, about 42% that of resid or diesel. That means that while it doesn't produce CO2 when burned (no carbon in the NH3 molecule), **ammonia's actual carbon footprint per nautical mile is nearly six times that of resid or diesel today**.

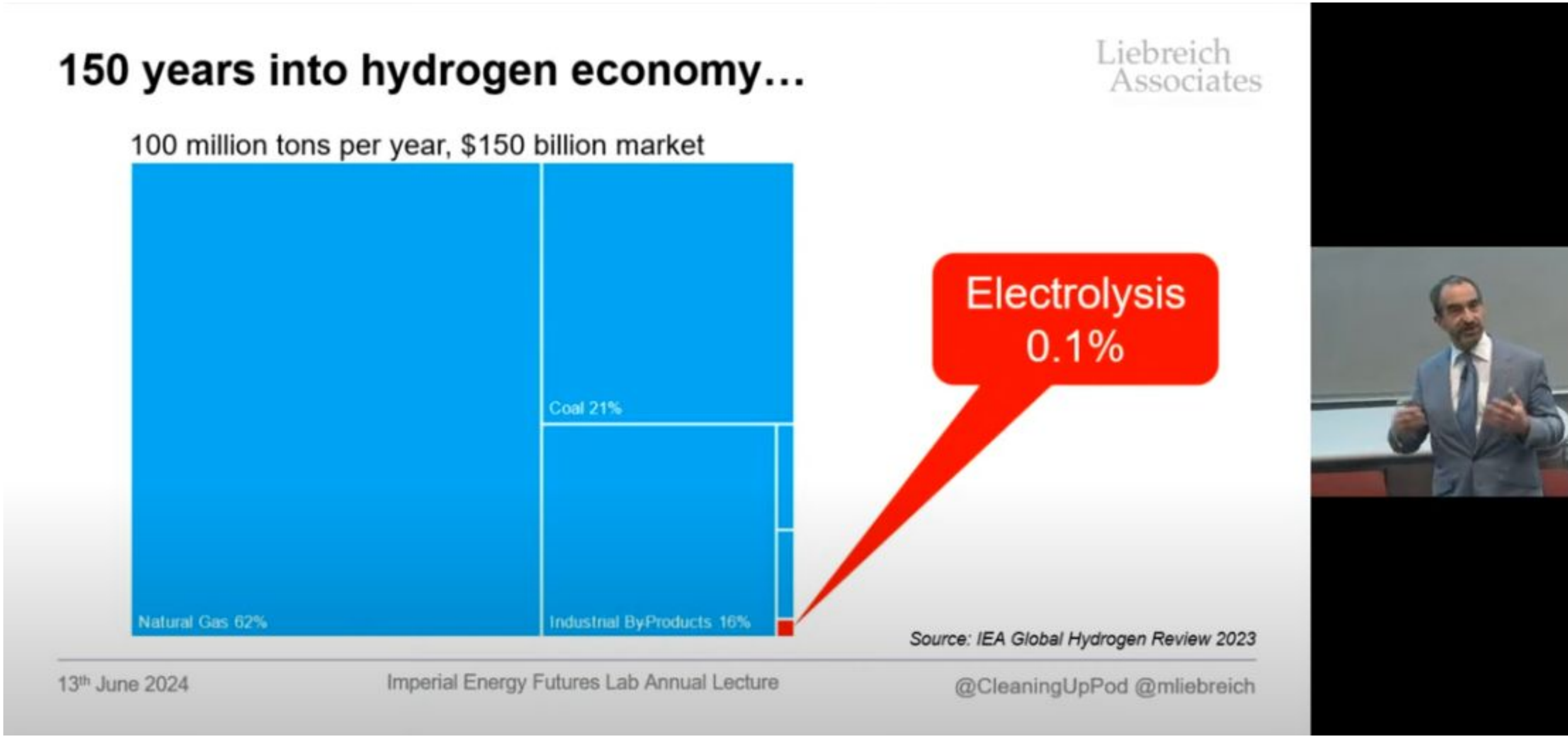
https://cleantechnica.com/2023/06/12/methanol-ammonia-tell-a-good-shipping-fuel-story-but-stop-before-the-tragic-finale/

Michael Liebreich debunks Hydrogen



Hydrogen Comes from Fossil Fuels

IEA global hydrogen review 2023 link p64



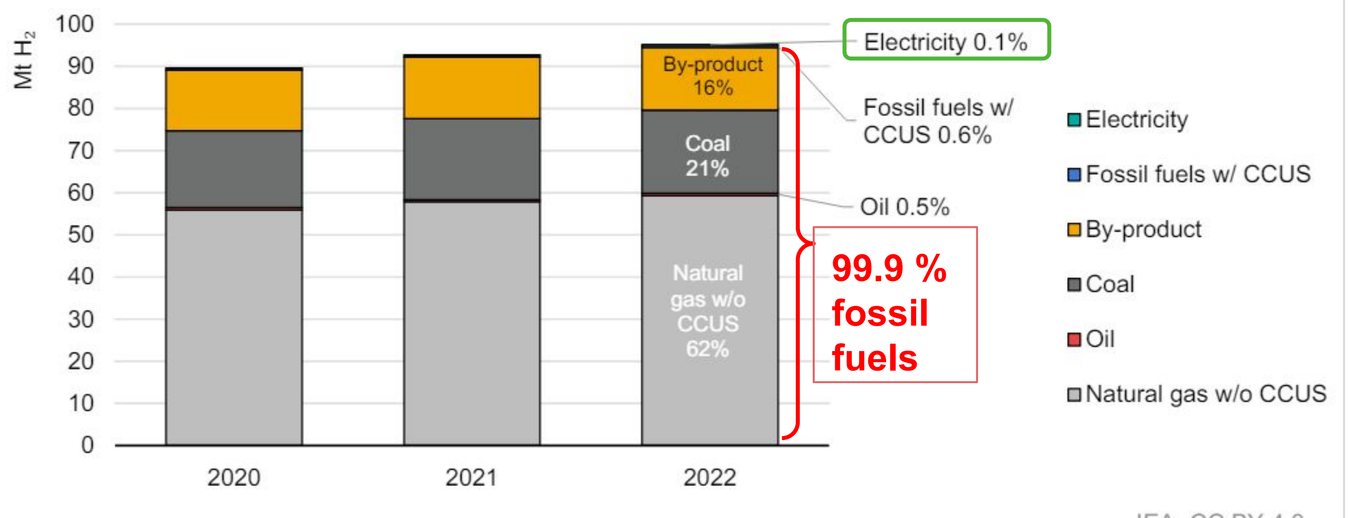
99.9% of Hydrogen from Fossil Fuels

0.1% of hydrogen comes from electricity

IEA: 95 Mt of hydrogen was produced in 2022. **99.9%** was from fossil fuels.

Only **0.1% (0.095 Mt) was produced from water & electricity** (electrolysis)

Figure 3.1 Hydrogen production by technology, 2020-2022



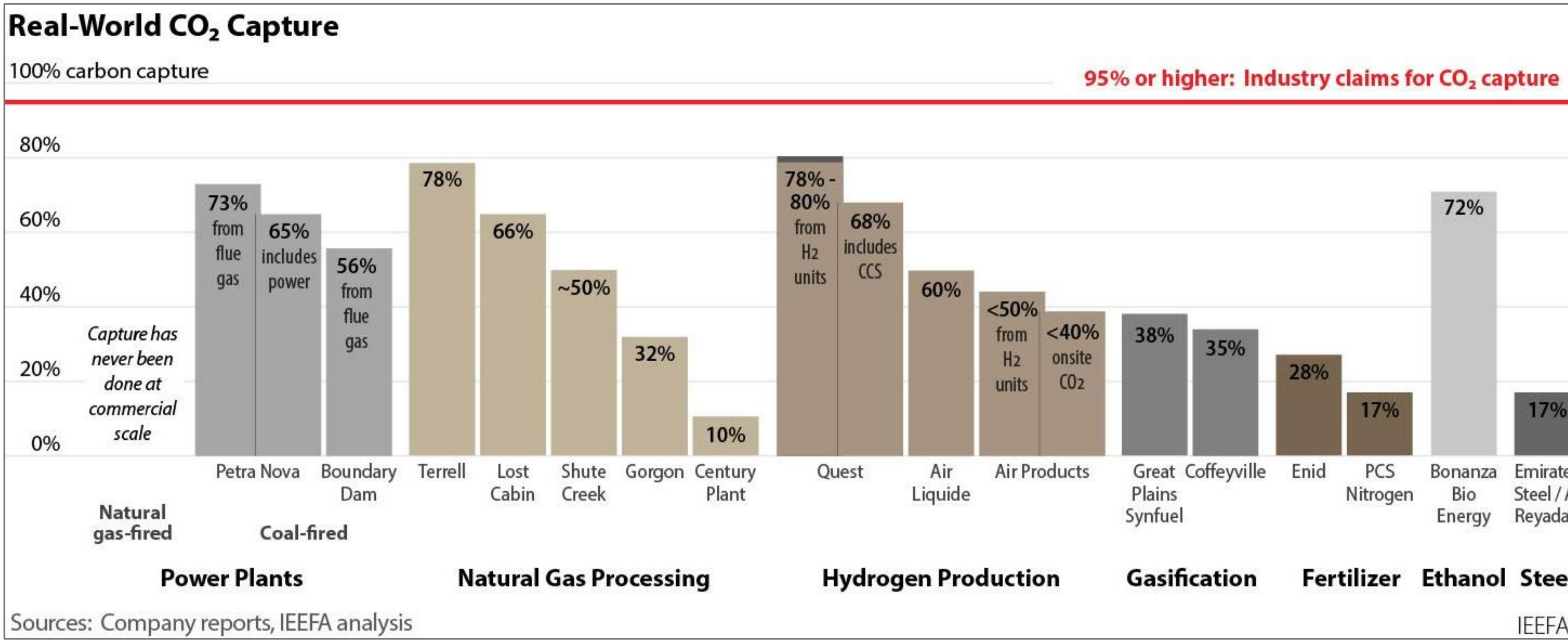
Note: CCUS= carbon capture, utilisation and storage.

IEA global hydrogen review 2023: p.64

"Global hydrogen production reached almost 95 Mt in 2022, an increase of 3% compared to 2021 (Figure 3.1). As in 2021, production was dominated by the unabated use of fossil fuels. **Natural gas** without carbon capture, utilisation and storage (CCUS) accounted for **62%** of global production, while **unabated coal**, mainly located in China, was responsible for **21%** of global production. **By-product hydrogen**, which is produced at refineries and in the petrochemical industry during naphtha reforming, and often used for other refinery and conversion processes (e.g. hydrocracking, desulphurisation), accounted for **16%** of global production."

CCS Carbon Capture Real World Failure

Claims of 95% capture are not supported
Real world results show 45% capture

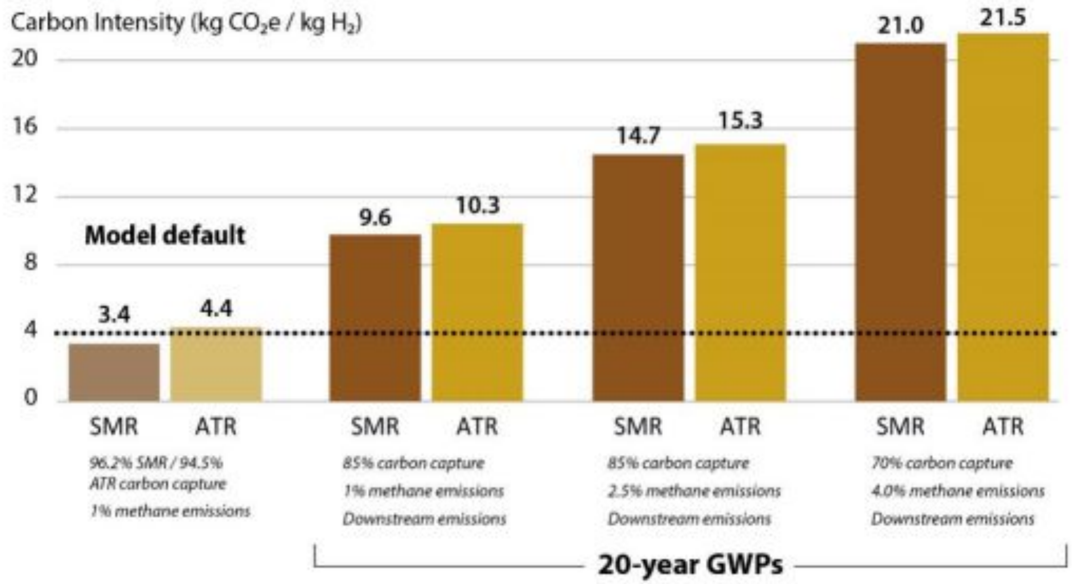


IEEFA Blue Hydrogen Report

Only with best-best-best case assumptions can Blue hydrogen meet the 4:1 clean hydrogen standard for tax credits.

And 4:1 CO_2e to H_2 is NOT clean.

Figure 7: Range of Carbon Intensities Reflecting 20-year GWPs and More Realistic Real-world Assumptions About Methane Emissions, CO_2 Capture Rates and Downstream Hydrogen Emissions



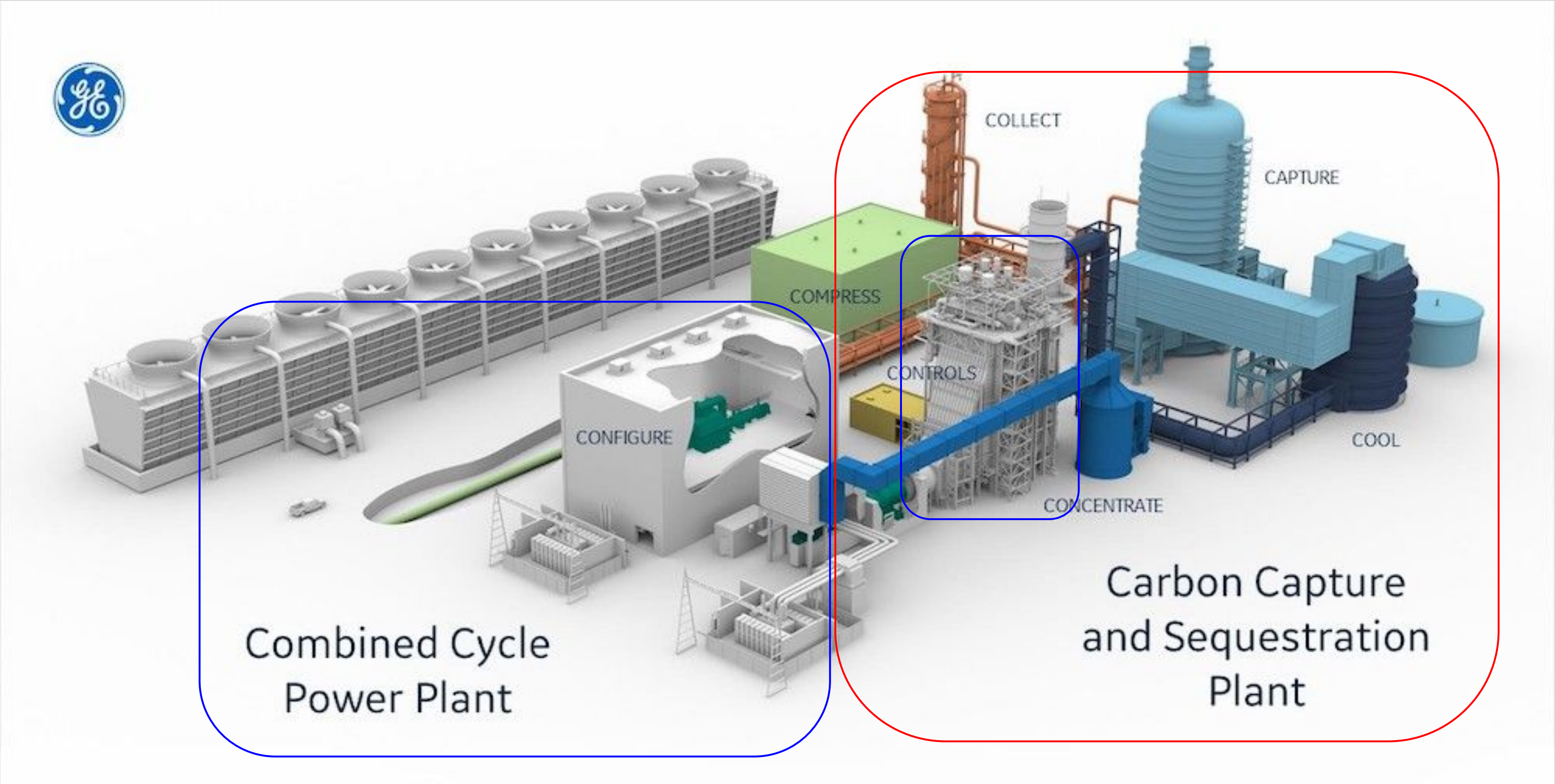
Source: IEEFA runs with DOE's GREET model.

As can be seen, using 20-year GWPs with a more realistic 85% carbon capture rate and a 2.5% upstream methane emission rate produces carbon intensities for blue hydrogen between three and four times more than DOE's clean hydrogen standard.

Even with 100-year GWPs, blue hydrogen's carbon intensity would be between two and three times more than the DOE standard, as shown in Figure 8.

https://ieefa.org/resources/blue-hydrogen-not-clean-not-low-carbon-not-solution

GE Carbon Capture & Seq Design 2022



"But large-scale adoption of CCUS has been elusive, mainly because many projects struggle to be economically viable. Most of the carbon capture facilities around the world today are associated with industrial facilities. There are a few carbon capture demonstration projects with coal-fired power plants, but none are connected to operating gas-fired plants. A full-scale carbon capture facility would essentially require a new round of construction and maybe **double the footprint of any power plant** to which it's attached. Adding a carbon capture system into a combined-cycle power plant requires integrating heat and steam." - General Electric

https://www.ge.com/news/reports/capturing-carbon-ge-has-been-working-on-ccus-solutions-in-the-us-and-europe-next-stop-asia

Bayotech: Gray Hydrogen

No provision for carbon capture

Input	Value
Water	16.3 L
Electricity (imported)	0.490 MJ
Natural gas	3.04 kg
Output	
Hydrogen	1 kg
CO_2 (fossil)	9.21 kg
CH_4 (fugitive loss)	0.0560 kg

Steam methane reforming: inputs and outputs to produce 1 kg hydrogen [41].

- Bayotech produces **gray** hydrogen from natural gas (methane) with a 'more efficient', **modular** version of SMR steam methane reforming. They call them hydrogen hubs. **They emit CO2.**
- Bayotech's website showed their process emits **9,090 kg of CO2** for every **1,000 kg of hydrogen**, ie a **9:1 ratio of CO2 to H2**.
  - Natural gas is consumed at about 3:1, so ~3,040 kg NG needed per 1,000 kg H2
- They propose hydrogen as a **road transportation fuel**, but the US hydrogen pipeline network totals to a **tiny 1600 miles** and would have to be expanded 100x, 1000x to be effective, at great expense. Electric power lines to supply EV charging are everywhere.

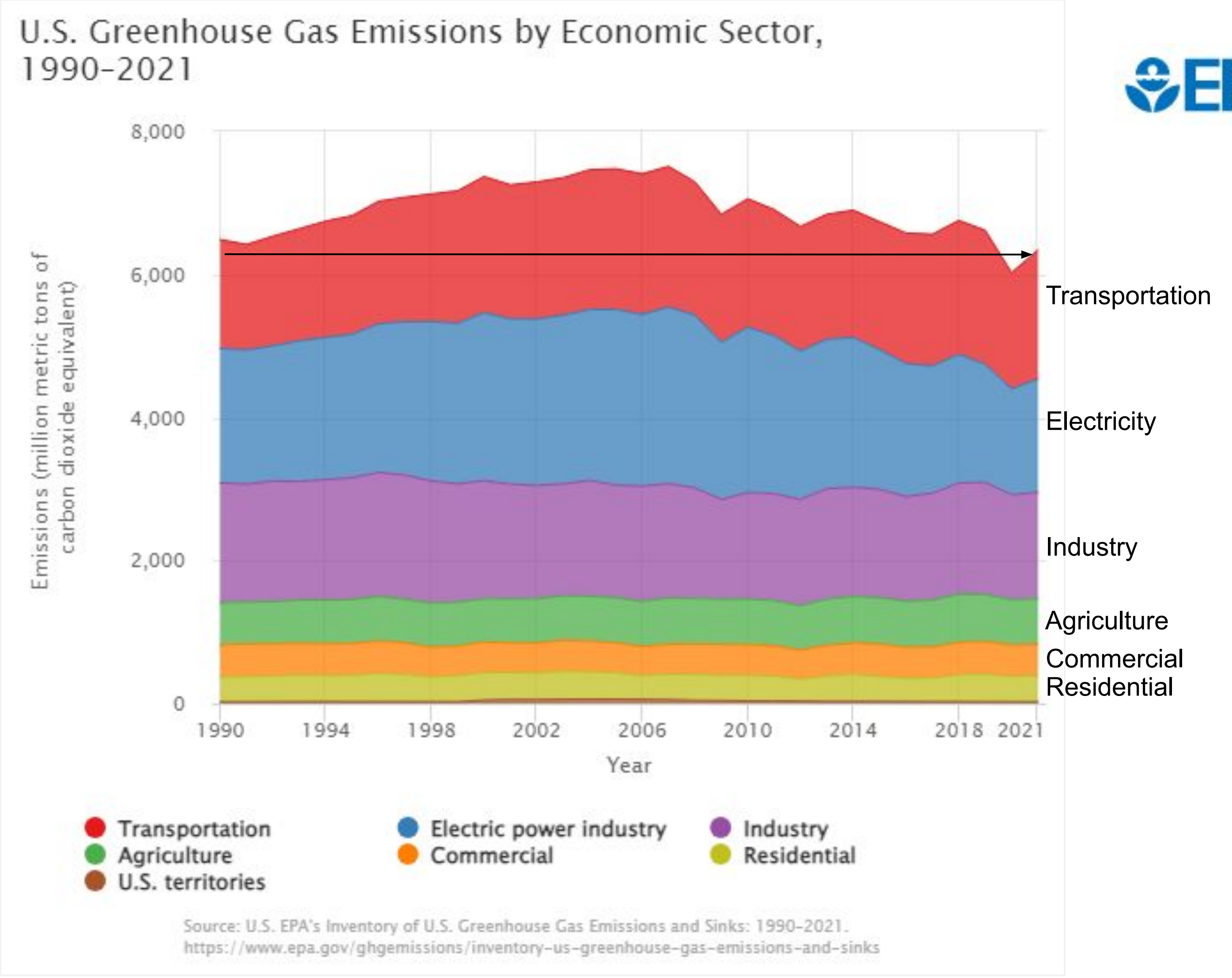
H2-1000 Hydrogen Generation System

Hydrogen	
Flow	1,000 kg/day
Composition	SAE J2719 (Fuel Cell Grade)
Emissions	
Process Water	1,000 – 2,880 gal/day
CO2	9,090 kg/day
SOx	Negligible
NOx	53 ppmw
CO	>89 ppmw
Noise	>ANSI/CSA FC-5, 76dB(A) at 23 feet

https://bayotech.us/hydrogen-production/
https://www.energy.gov/eere/fuelcells/hydrogen-pipelines

US GHG Emissions ~6.3 GT / year

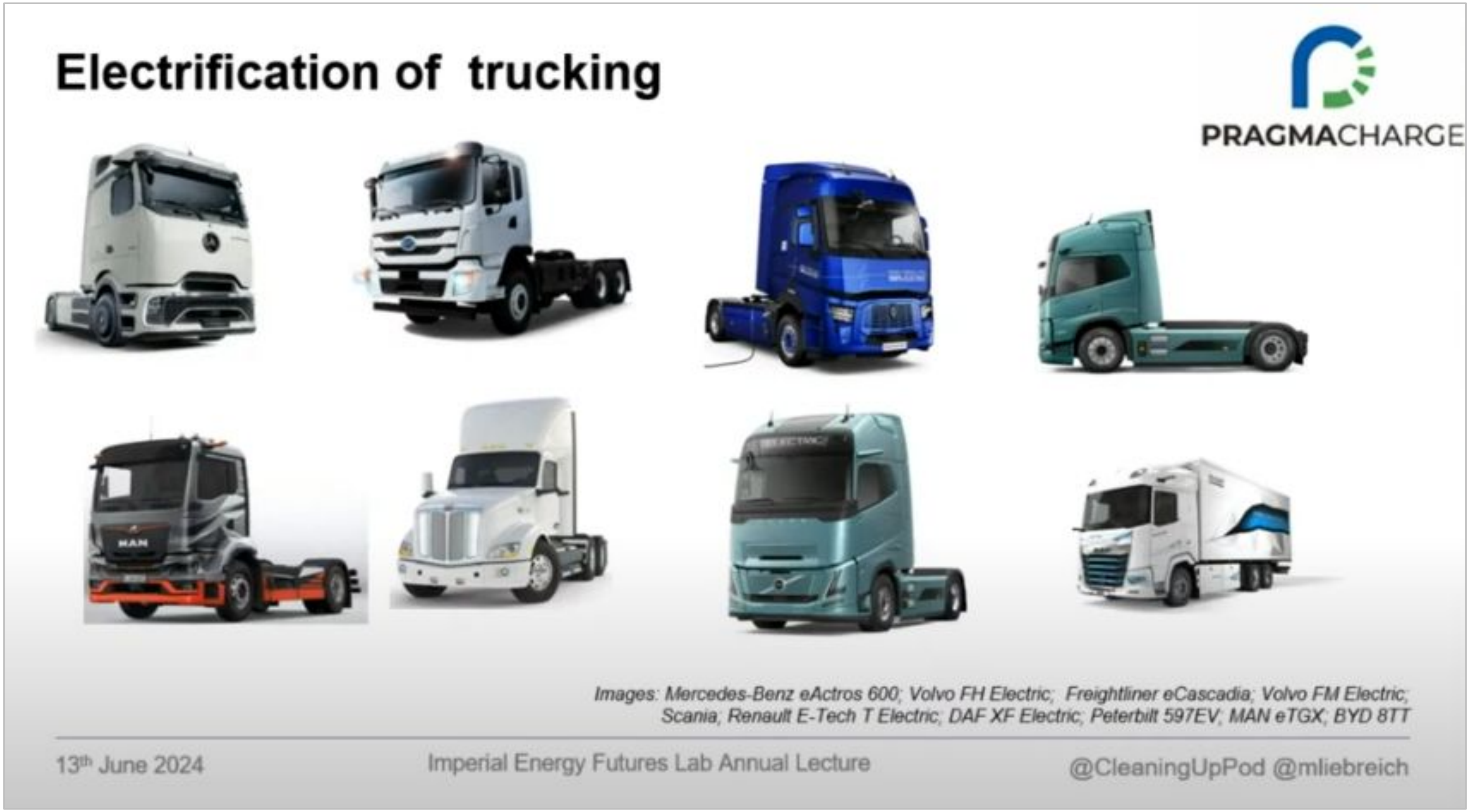
This is our 15% of global GHG emissions



Note: https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks

Every Major Truck Maker Has an Electric Semi Truck

Freightliner, Volvo, Peterbilt, MAN, Mercedes-Benz, etc.



Hydrogen Science Coalition 3 principles

https://h2sciencecoalition.com/

Three evidenced-based recommendations for Hydrogen's role in the energy transition to 2050

1. **The only near zero-emission hydrogen is renewable hydrogen**
    - The proposed Clean Hydrogen Definition meets the same GHG emissions intensity levels as the Green Hydrogen Standard, but <u>accounts for all GHG emissions</u> in the hydrogen supply chain. This amounts to 1 kg of CO2e emitted per kg of hydrogen produced.

1. **Renewable hydrogen should be prioritised to decarbonise <u>existing</u> fossil-based hydrogen**

2. **Hydrogen shouldn't delay accelerating the deployment of existing electrification and energy efficiency solutions**

https://www.oecd-forum.org/posts/hydrogen-s-role-in-the-energy-transition-to-2050-three-evidenced-based-recommendations

TNA Hydrogen Summit Agenda

HYDROGEN INFORMATION SUMMIT

Wednesday, June 26, 2024

8:00 AM – 12:00 PM MDT

Shiprock Chapter House, Shiprock, NM

AGENDA

Facebook Live Event: Click Here to Join Event

#	Topic	Speaker	Time
1	Continental Breakfast		8:00-8:30 am
2	Welcome Introductions Housekeeping	Eleanor Smith, Tó Nizhóní Ání (TNA) Community Organizer Jessica Keetso, Tó Nizhóní Ání (TNA) Community Organizer Nicole Horseherder, Tó Nizhóní Ání (TNA) Director & Diné Language Translator	8:30-8:45 am
3	What is being proposed on Navajo with Hydrogen?	Eleanor Smith, TNA Jessica Keetso, TNA Nicole Horseherder, TNA	8:45-9:15 am
4	Question/Answer		9:15-9:30 am
5	Climate Change and Blue Hydrogen	Tom Solomon, 350NewMexico	9:30-10:00 am
6	Question/Answer		10:00-10:15 am
7	Diné Language Translation by Nicole Horseherder, TNA		10:15-10:45 am
8	BREAK (Time TBD)		
9	Environmental Justice, Community Engagement & Consent	Dr. Ruhan Nagra, University of Utah School of Law, Environmental Justice Clinic	10:45-11:15 am
10	Question/Answer		11:15-11:30 am
11	Hydrogen on Navajo Recent Updates	Jessica Keetso, TNA Eleanor Smith, TNA Nicole Horseherder, Diné Language Translator	11:30-11:45 am
12	Next Steps, Recommendations & Wrap-up	Jessica Keetso, TNA Eleanor Smith, TNA Nicole Horseherder, Diné Language Translator	11:45 am – 12:00 pm

link

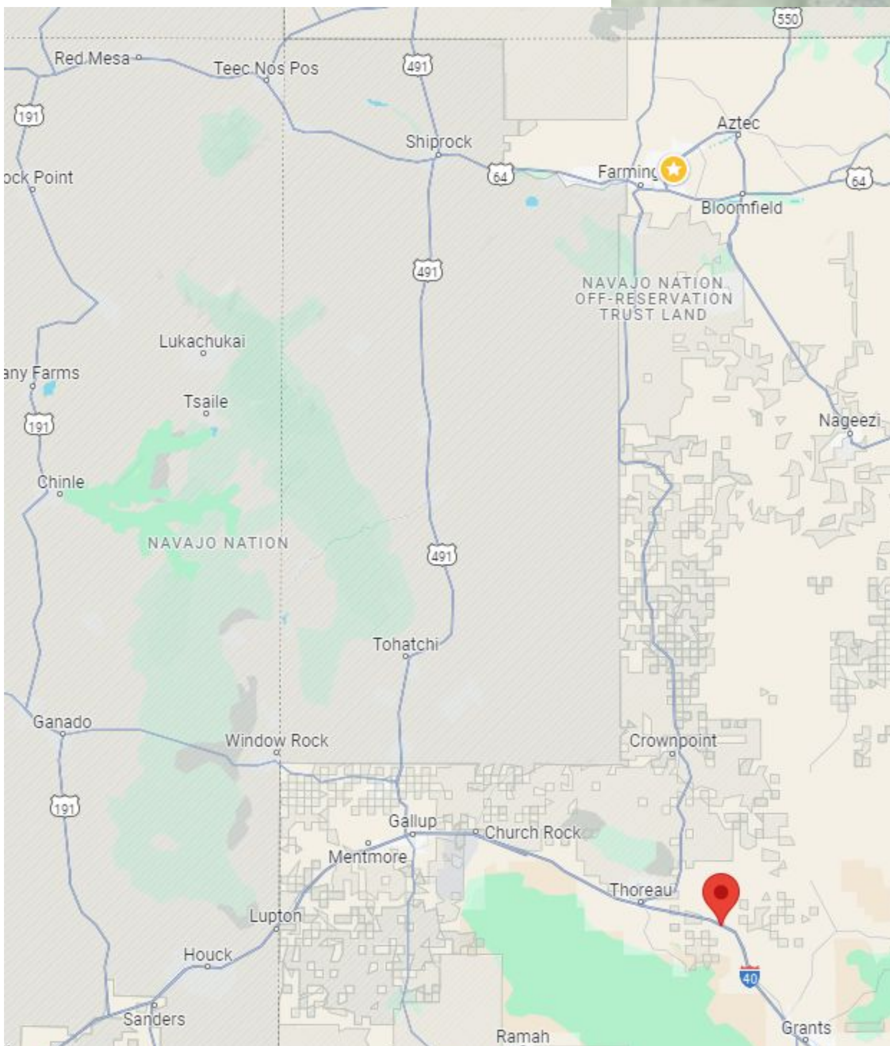
TNA Hydrogen Info Summit

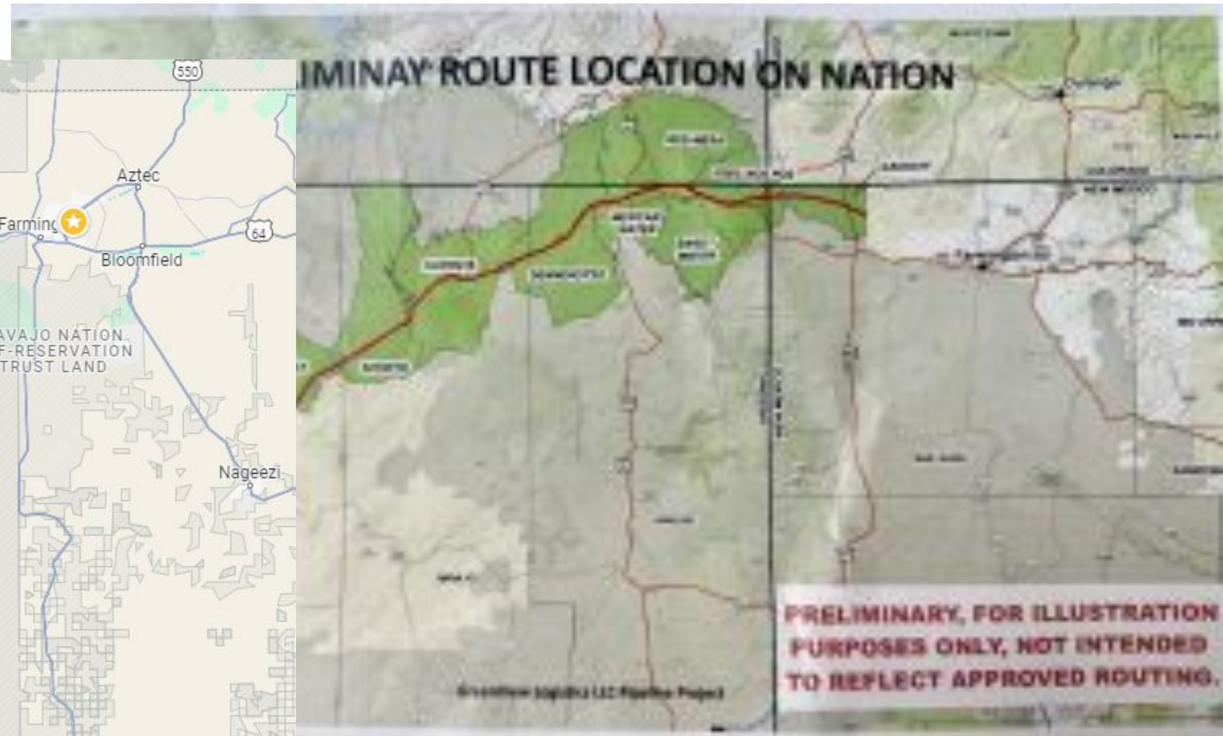
TNA, ToNizhoniAni, is hosting a Hydrogen Information Summit on Wed, June 26, 2024, from 8:30am-12:00pm, at the Shiprock Chapter house.

We are respectfully requesting your presence, either in-person or via Zoom, to conduct a **presentation on the scientific facts of blue hydrogen production and the potential impacts of creating a 200+ mile long pipeline to carry blue hydrogen and ammonia,** as the developers have stated is their plan. Our Navajo community members have been requesting more education in terms of potential impacts and scientific facts and we feel you both are best scientific experts on hydrogen.

A link to our FB event announcement in Shiprock- https://www.facebook.com/events/873051071486445/?ref=newsfeed

Navajo Nation Discord Over Proposed Pipeline on NM Tribal Land





July 14, 2023

https://www.sfreporter.com/news/2024/05/29/like-it-or-not-a-hydrogen-ecosystem-is-coming-to-new-mexico/

https://www.okenergytoday.com/2023/07/navajo-nation-discord-over-proposed-pipeline-on-nm-tribal-land/

Escalante 200 MW Solar Project

IRA has a $10BN USDA program to shut down old rural co-op coal plants & replace them with clean energy

This coal-heavy rural co-op utility is buying its first solar plants

Colorado-based Tri-State will soon serve half its customers' electricity needs with renewable energy, thanks to new Inflation Reduction Act policies.

June 13, 2024

- Tri-State reported that electricity was flowing from the largest third-party solar project it has contracted for thus far, a 200-megawatt site developed by Origis Solar at the former Escalante Station coal-fired power plant in New Mexico.

- It will pay $7.1M in taxes to the county over its lifetime.

200-MW New Mexico solar project replaces retired coal plant

The project will pay approximately $7,100,000 in taxes to the county and $2,400,000 in taxes to the school district over its lifetime.

Gridworks, headquartered in Albuquerque provided construction services for the project, employing an estimated 400 people during that time. Origis Energy Services will provide long-term operations and maintenance services for the project, employing approximately four to six on-site jobs. Approximately 500,000 Boviet solar panels were used in the project. Array Technologies

https://www.canarymedia.com/articles/utilities/this-coal-heavy-rural-co-op-
https://www.solarpowerworldonline.com/2024/06/new-mexico-solar-project-replaces-retired-coal-plant/

Escalante Coal-to-H2 project

"Tri-State Generation and Transmission Association **closed** its **253-megawatt coal-fired generating station** at Prewitt near Grants at the end of 2020. ~100m West of Abq.

The **closure eliminated 107 jobs** at the plant, and potentially scores more at a nearby coal mine that supplies fuel for the generating station."

Former 253MW Escalante Coal Power Plant in Prewitt, NM, **closed in 2020**.

https://www.abqjournal.com/1408313/latest-business-news-107.html

Escalante Coal-to-H2 project

Former 253MW Escalante Coal Power Plant, Prewitt, NM, Closed in 2020.

The eH2 plan: spend ~~$425M~~ $600M on conversion, to produce hydrogen from natural gas & hydrogen-electricity **by 2025**. Create ~~110~~ **60 jobs**

eh2power.com

Must build new:

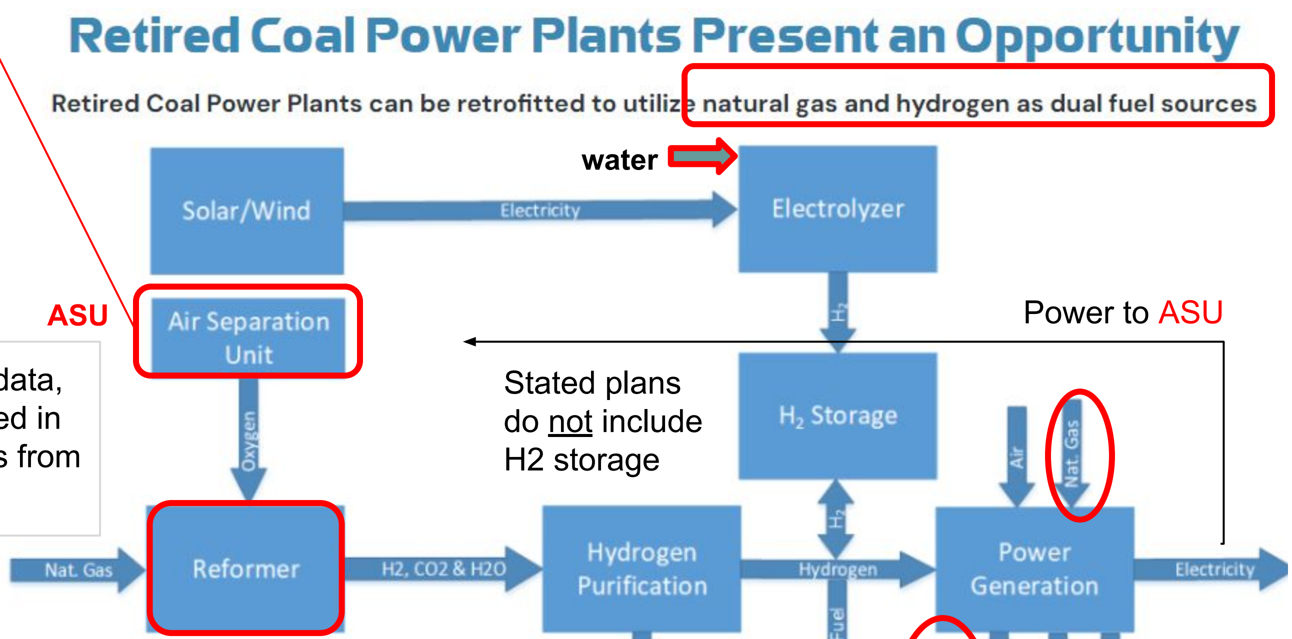
- Air Separation Unit
- Steam Methane Reformer
- Carbon capture unit
- CO2 sequestration unit

Cuts electricity output from **253MW** to **~164MW**, thus unprofitable per eH2 CEO.

Plans to sell the hydrogen:
- inject 5% into gas pipeline
- make ‘green’ cement (?)

eH2 Escalante Coal-to-H2 project

2024 diagram



Stated plans do not include H2 storage

net 151 to 176 MW

Based on the Linde facility data, we infer that water consumed in hydrogen production ranges from **5.85-13.2 L H20 / kg H2.**

Steam methane reformer plant with carbon capture at the Valero Refinery in Port Arthur, TX

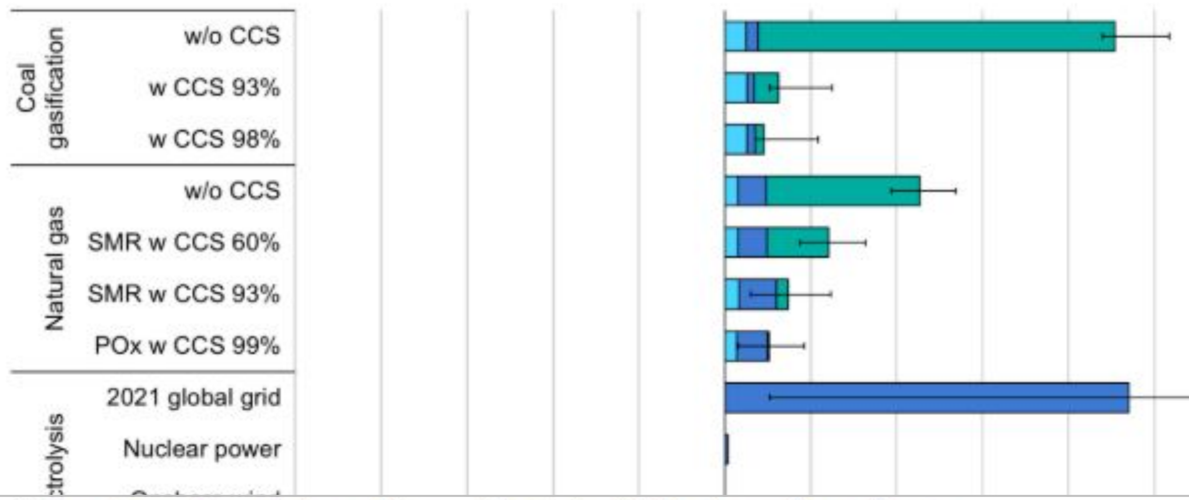
Real-world capture rates run ~45%, accounting for emissions to power CCS - IEEFA.

https://www.eh2power.com/
https://watersmartsolutions.ca/wp-content/uploads/2020/12/Water-for-the-Hydrogen-Economy_WaterSMART-Whitepaper_November-2020.pdf
http://ieefa.org/wp-content/uploads/2022/02/Reality-Check-on-CO2-Emissions-Capture-at-Hydrogen-From-Gas-Plants_February-2022.pdf

Emissions & Energy Use in Hydrogen

Figure 3.15 Comparison of the emissions intensity of different hydrogen production routes, 2021

IEA 2023 global hydrogen review: Emissions from natural gas SMR w/o CCS = 12 kg CO2e / kg H2, from grid powered electrolysis = 24 kg CO2e / kg H2.



30 35 40
kg CO_2-eq/kg H_2

Direct emissions

IEA. CC BY 4.0.

Notes: CCS = carbon capture and storage; POx = partial oxidation; SMR = steam methane reforming.

Upstream and midstream emissions include CO_2 and methane emissions occurring during the extraction, processing, and supply of fuels (coal, natural gas) or production, processing, and transport of biomass. Error bars for natural gas and coal represent the impact of the observed range of upstream and midstream emissions today on emissions intensities. For natural gas, the lower bound corresponds to best available technology today (4.5 kg CO_2-eq/GJ), and the upper bound to the 95% percentile of the world range (28 kg CO_2-eq/GJ). For coal, the lower bound corresponds to the 5% percentile (6 kg CO_2-eq/GJ) and the upper bound to the 95% percentile (23 kg CO_2-eq/GJ) of global upstream and midstream emissions of coal supply. The 2021 world grid average is based on a generation-weighted global average of the grid electricity intensity, with the error bars representing the 10% percentile (50 g CO_2-eq/kWh) and 90% percentile (700 g CO_2-eq/kWh) across countries. The grid electricity intensities include direct CO_2, methane (CH_4) and nitrous oxide (N_2O) emissions at the power plants, but not upstream and midstream emissions for the fuels used in the power plants.

Electrolysis refers to low-temperature water electrolysis with an assumed overall electricity demand of 50 kWh/kg H_2, including compression to 30 bar.

Hydrogen production from natural gas via SMR is based on 44.5 kWh/kg H_2 for natural gas in the case of no CO_2 capture, on 45.0 kWh/kg H_2 for natural gas in the case of 60% capture rate, and on 49 kWh/kg H_2 for natural gas and 0.8 kWh/kg H_2 for electricity in the case of a 93% capture rate. Hydrogen production from natural gas via POx is based on demands of 41 kWh/kg H_2 for natural gas and 0.6 kWh/kg H_2 for electricity in the case of a 99% capture rate.

Hydrogen production from coal is based on gasification, with demands for coal of 57 kWh/kg H_2 and for electricity of 0.7 kWh/kg H_2 in the case of no CO_2 capture, demands for coal of 59 kWh/kg H_2 for a CO_2 capture rate of 93% and demands for coal of 60 kWh/kg H_2 for a CO_2 capture rate of 98%.

https://iea.blob.core.windows.net/assets/ecdfc3bb-d212-4a4c-9ff7-6ce5b1e19cef/GlobalHydrogenReview2023.pdf

eH2: Funded by Tallgrass Energy

"We own and operate more than **8,300 miles of natural gas pipeline**, more than 850 miles of crude pipeline" – tallgrassenergy.com/About

Tallgrass Energy Acquires 75 Percent Membership Interest in Escalante H2 Power

Mon, August 9, 2021, 4:33 PM · 3 m

$600M project puts NM town at center of hydrogen debate

BY KEVIN ROBINSON-AVILA / JOURNAL STAFF WRITER

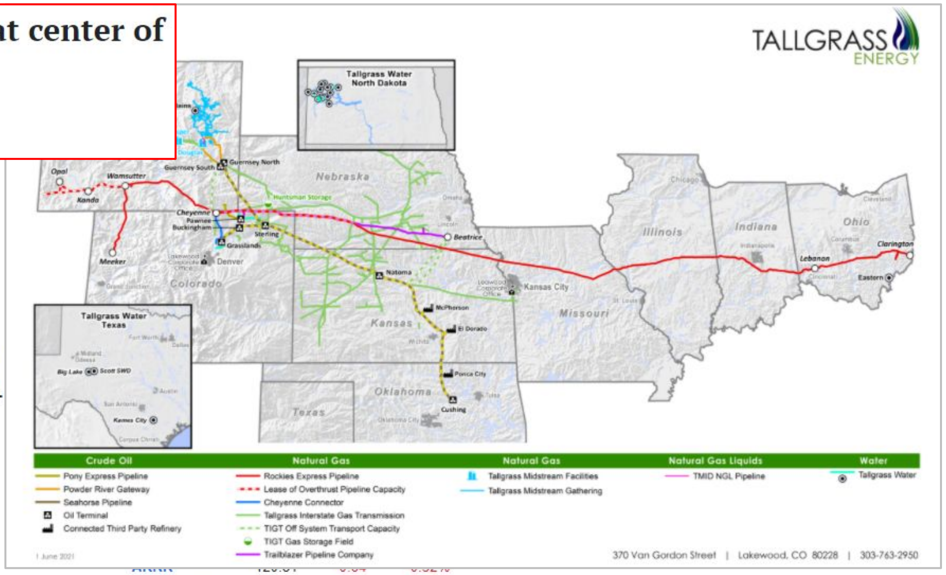
PUBLISHED: SUNDAY, JANUARY 16TH, 2022 AT 8:02PM

TALLGRASS ENERGY

Escalante Power Project to Convert Coal-fired Power Plant to Clean Hydrogen

LEAWOOD, Kan., August 09, 2021--(BUSINESS WIRE)--Tallgrass Energy, LP announced today that it has closed on the purchase of a 75 percent membership interest in Escalante H_2 Power (EH2 Power). EH2 Power is developing a first-of-its-kind hydrogen-to-power project at Tri-State Generation and Transmission Association, Inc.'s Escalante Generating Station near Prewitt, New Mexico, by converting the retired coal-fired power plant into a clean hydrogen-fired power generating facility.

"Our acquisition of a 75 percent membership interest in EH2 Power further advances our overall hydrogen development and clean energy infrastructure strategy," said Tallgrass CEO William R. Moler. "We believe the Escalante Station is



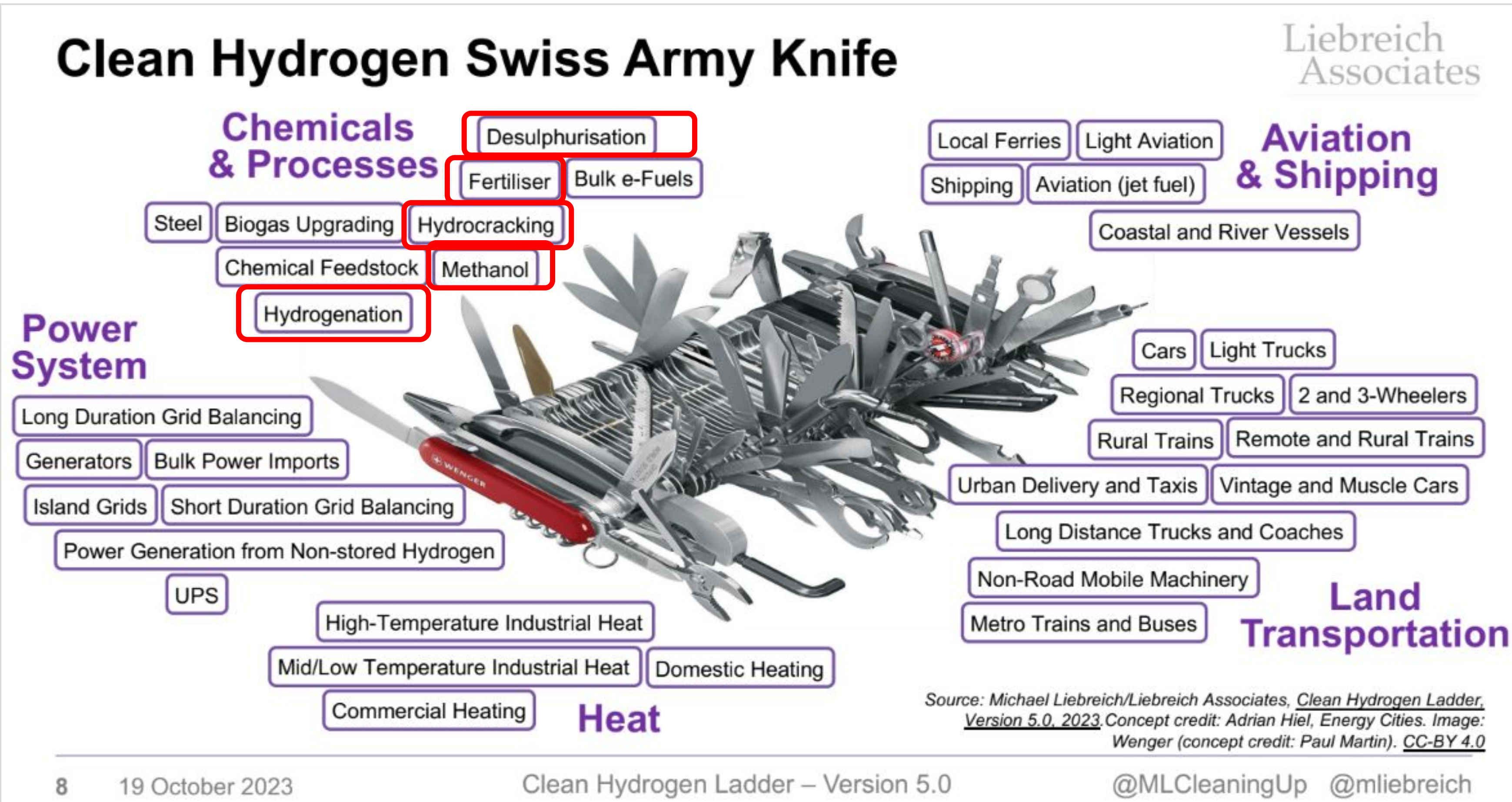
Tallgrass shareholders approve Blackstone-led buyout of pipeline operator Apr 16,2020

- eH2 Power will likely use the $85/ton **45Q tax credits** for carbon sequestration
  https://www.iea.org/policies/4986-section-45q-credit-for-carbon-oxide-sequestration

https://www.tallgrassenergy.com/ In April 2020 Blackstone bought Tallgrass

The Hydrogen Swiss Army Knife

Industry proposes to use hydrogen for **nearly everything**.
But you wouldn't build a house with a Swiss knife.



https://www.linkedin.com/pulse/hydrogen-ladder-version-50-michael-liebreich

Hydrogen must solve its climate problem

Hydrogen must solve its climate problem

Tom Solomon Op Ed published in the Abq Journal **Aug 3, 2023** (responding to this Van Romero op ed on hydrogen)

Ever wonder why hydrogen is pushed as a climate solution and is it really?
The 'why' starts with the 2017 creation of the Hydrogen Council, a consortium of oil, gas and other industrial companies, formed to market hydrogen as a solution to the forecasted revenue declines from the clean energy transition. Their website includes such members as Exxon-Mobil, Shell, BP, Chevron, Saudi-Aramco and others. Second, per the International Energy Agency (IEA), 99% of global hydrogen is produced from fossil fuels, mostly from methane (ie natural gas). Yes, 'green' hydrogen is also produced from the electrolysis of water, but at less than 0.1%. Third, production of hydrogen is a serious climate problem, per the IEA, contributing over 2% of all global greenhouse gases. This is because 12 tons of CO2 are emitted per ton of hydrogen produced (IEA). So before hydrogen can be proposed as a climate solution, it must first solve its own carbon emissions problem.
Is there a proposed solution? Yes, it is to apply carbon capture and sequestration (CCS). There are at least two serious climate problems with that, besides the added cost:
1) CCS does not address the problem of upstream methane emissions from natural gas extraction, which have never been solved. According to the IPCC, methane emissions cause 25% of all global warming.
2) CCS, despite rosy claims of 90% + capture, has an actual history of failing to meet operational or economic goals over the dozen or so projects built, from Boundary Dam in Canada, to the now shuttered Texas Petra Nova project. See the 2022 IEEFA report, "Reality Check on CO2 Emissions Capture at Hydrogen-From-Gas Plants".
As it stands today, producing more fossil hydrogen will make the climate crisis worse. All the marketing in the world won't change that.

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Sources:
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(2)https://www.iea.org/reports/global-hydrogen-review-2022/executive-summary
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(4)IEA https://www.iea.org/reports/global-hydrogen-review-2022/executive-summary
(5)IPCC AR6 https://www.ipcc.ch/report/ar6/wg3/figures/summary-for-policymakers/figure-spm-1/

The Hydrogen Economy Would Increase Electricity Demand over 50%

The Proposed Hydrogen Economy Increases Electricity Demand over 50% Tom Solomon Feb 2024

The so-called hydrogen economy is a solution proposed by the gas industry, not to climate change, but to the 'problem' of declining natural gas sales as the clean energy transition cuts the use of gas in water and space heating and in power plants. Industry plans for hydrogen will boost demand for natural gas in two ways. First is as a hydrogen feedstock, and second and more deceptively, by increasing total electricity demand by 62% just to make green hydrogen, providing them a reason to keep gas-fired electric plants operating when they would otherwise close. This white paper details how that will work.

First, let's be clear on why we must care about natural gas, aka methane, or CH4.
According to NASA, methane pollution causes 20-30% of all global warming, because this heat-trapping gas is 85 times more powerful than CO2 and because methane is emitted into the air from gas and oil wells, pipelines and compressor stations all along the production and distribution chain. And it is building up in the atmosphere, increasing from 1800ppB in 2010 to over 1950 ppB per NOAA by 2023. We need to rapidly replace methane with clean energy, not find new ways to use it. The second reason to question hydrogen is that in many, many proposed applications there are solutions that are simply better, cheaper and faster to implement, mostly involving direct electrification. Spending today to push hydrogen into areas where it won't compete risks wasting money on stranded assets.

The gas industry benefits from pushing hydrogen in two ways.
First, since 95% of all hydrogen today is made by steam reforming of methane (CH4), new markets for hydrogen mean new markets for methane, aka natural gas.
Second, the proposed 'better' way of producing hydrogen is to run clean electricity through water (H2O) in an electrolyser. That product is labeled as 'green' hydrogen. Ironically this will also benefit the gas industry by delaying the closure of existing gas-fired electric plants because of the very wasteful nature of using manufactured hydrogen as a fuel and the increase in electricity to make it. For example only 33% of the clean energy used to make green hydrogen is left to power the wheels of a fuel cell car after all the heat losses from electrolysis, transport and in the fuel cell. Compare that to an electric vehicle which preserves 77% of that clean energy because batteries and electric motors are 95% efficient.

The inefficiency of the hydrogen economy drives some huge numbers for clean energy.
-According to the "DOE Hydrogen Shot challenge" we'd need to produce 50 M Tonne per year of green hydrogen in 2050 and 10 MT by 2030. The green energy required to make 50MT of hydrogen is staggering, estimated at 2500 TWh (teraWatt hours). To put that in perspective, the electricity consumed in 2022 in the whole US was 4050 TWh. So just to make the green hydrogen for this proposed 'hydrogen economy', we'd need to build 62.5% more solar, wind and geothermal generators than we already must build to replace today's dirty coal and gas power plants which are the #2 source of climate pollution.
-Will the electricity utilities and the gas industry use this 2500 TWh of extra demand to argue that 'they can't afford to close down their operating coal and gas plants' because there's too much demand for electricity? Of course they will. It's already happening in Arizona.
-In addition, the economics of gray vs green hydrogen will likely boost the use of fossil gray hydrogen in the short term, despite promises and good intentions. Gray hydrogen today costs about $1.50 per kg ($0.98-2.93) per Bloomberg 2023 vs. green hydrogen which is about 5x more expensive at $4-12 per kg. Yes, predicted cost reductions for green hydrogen show it becoming cheaper than gray in the 2030's if economies of scale kick in. Will that happen by then? Maybe. In the meantime expect the push to use fossil gray or blue hydrogen instead, with all the harmful climate impacts that implies.
There is one good reason to produce green hydrogen, which is to replace the US's current 10MT per year production of methane-based gray hydrogen. (It is used in oil refining, to make ammonia fertilizer and various chemicals). That would require only one fifth of the DOE's 50MT hydrogen shot.
Let's prioritize cutting the main sources of climate pollution and help EJ communities and the climate crisis by closing coal and gas power plants.
That's the better path forward.

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