NASEO
National Association of State Energy Officials

NASEO Webinar: Clean Hydrogen 101

September 28, 2022

Welcome and Zoom 101

Kirsten Verclas, Managing Director, National Association of State Energy Officials

Speakers

- Connor Dolan, Vice President of External Affairs, Fuel Cell & Hydrogen Energy Association
- Dr. Chris San Marchi, Technical Staff, Sandia National Laboratories
- Rachel Fakhry, Senior Advocate, Climate and Clean Energy Program, Natural Resources Defense Council

US Hydrogen Trends & Policy Developments

Connor Dolan
Vice President of External Affairs
Fuel Cell and Hydrogen Energy Association

September 28, 2022

Benefits of Hydrogen

Economic growth and employment

Resiliency and reliability

Reduction in local air pollutants

Reduction in greenhouse gases

FCHEA
Fuel Cell & Hydrogen Energy Association

Uses of Hydrogen

Power generation and grid balancing

Centralized power (including storage) and distributed power (off-grid, backup power)

Hydrogen as an energy carrier and storage medium

Transportation fuel (including material handlings, light- and heavy- duty vehicles, captive fleets, rail)

Feedstock for industrial applications (ammonia, methanol, refineries, steel) and long-distance transport (aviation, marine)

Heating fuel for **residential and commercial buildings** (including blending hydrogen into the gas grid)

FCHEA
Fuel Cell & Hydrogen Energy Association

Clean hydrogen

H_2

Hydrogen generated with low- and zero- carbon produced

Clean Hydrogen Production Pathways

- Water electrolysis using low- and zero-carbon electricity (e.g., nuclear, solar, wind)
- Reformer-based hydrogen with carbon capture and storage (CCS) and/or renewable natural gas (RNG) feedstock
- Methane pyrolysis with carbon black byproduct
- By-product hydrogen recovered from other industrial processes

FCHEA supports a **pathway agnostic** approach to advancing clean hydrogen production

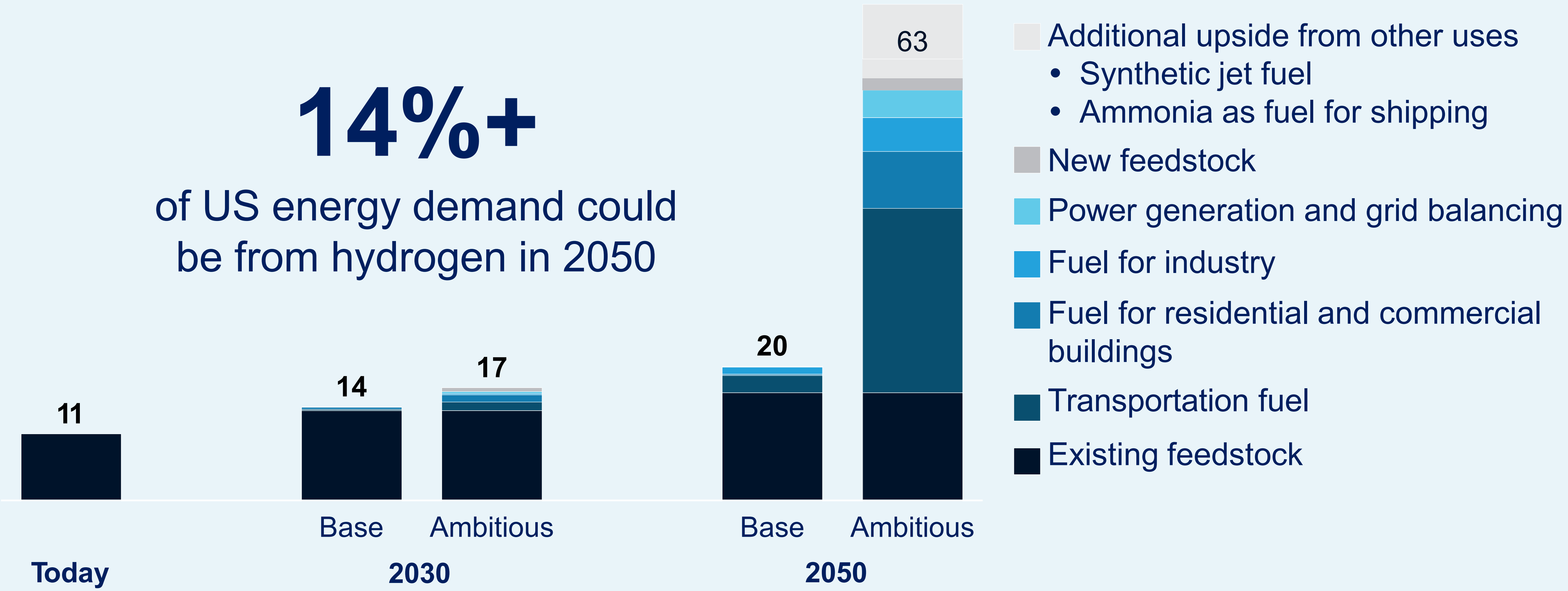
FCHEA Fuel Cell & Hydrogen Energy Association

High-growth pathway for hydrogen

Million metric tons per year

14%+

of US energy demand could be from hydrogen in 2050



1. Demand excluding feedstock, based on IEA final energy demand for the US
2. Assuming that 20% of jet fuel demand would be met from synthetic fuel and 20% of marine bunker fuel from ammonia

Note: Some numbers may not add up due to rounding

FCHEA Fuel Cell & Hydrogen Energy Association

Scaling up Economic Opportunities: Investments and Jobs

Annual investment

$1bn	$2bn	$8bn
2022	**2025**	**2030**
Early scale-up	Diversification	Broad rollout

New jobs[1]

+50,000	+100,000	+500,000
2022	**2025**	**2030**
Early scale-up	Diversification	Broad rollout

1. Includes direct, indirect, and resulting jobs

FCHEA Fuel Cell & Hydrogen Energy Association

The US economy would benefit through emissions reduction, growth, jobs, & use of domestic energy resources

Hydrogen in the US could …

In 2050

... Strengthen the US economy

~$750 bn

in revenue

3.4m

jobs

... Create a highly competitive source of domestically produced low-emission energy

~100%

domestically produced

... Provide significant environmental benefits and improve air quality

-16%

CO_2

-36%

NOx

Note: Final energy demand excluding feedstock; share of abated CO^2 emissions relative to US emissions in 2050 as forecasted in the IEA Reference Technology Scenario; for NOx, for tailpipe emissions only, based on EPA current NOx emissions

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Bipartisan Infrastructure Law Clean Hydrogen Programs

Regional Clean Hydrogen Hubs – provides $8 billion to develop at least four large-scale hydrogen production and utilization projects across the country.

- FOA released last week. Concept papers are due November 7, 2022. Full applications due April 7, 2023.
- $7 billion released with plans to fund 6 - 10 hubs
- DOE has defined a four-phase structure across 8-12 years for planning, development, construction, and operation of the hubs
- Hubs must have diversity of geographic location, production feedstock, and end-use applications

Clean Hydrogen Strategy and Roadmap – directs the development of the first U.S. national strategy to facilitate a clean hydrogen economy.

- Draft Strategy and Roadmap released last week for comment. Final document to be released end of year.

Clean Hydrogen Production Qualifications – directs the development of a clean hydrogen production carbon intensity standard.

- Draft standard released last week for comment by 10/20. Set at 4 kg Co2 to 1 kg H2.

Clean Hydrogen Electrolysis Program – provides $1 billion for demonstration, commercialization, and deployment of electrolyzer systems.

Clean Hydrogen Manufacturing and Recycling – provides $500,000,000 to support a clean hydrogen domestic supply chain.

Bipartisan Infrastructure Law Energy Policiy

Grants for Charging & Fueling Infrastructure – Provides $2.5 billion to support development of alternative fueled infrastructure, including hydrogen fueling stations, along designated corridors.

Low or No Emission Bus Grants – Provides $5.6 billion for the purchase or lease of zero emission and low-emission transit buses and to purchase, construct, or lease bus related facilities, including fuel cell electric buses.

Congestion Mitigation and Air Quality Improvement Program – Provides $13.2 billion for CMAQ programs and added eligibility for the purchase of medium- and heavy-duty zero-emission vehicles and related charging/fueling equipment.

Energy Efficiency and Conservation Block Grant Program – Provides $550 million to the program and amended to allow for financing of energy efficiency, zero-emission transportation, and associated infrastructure.

Carbon Reduction Program – Provides $6.4 billion for projects that support the development of alternative fuel vehicles, including hydrogen fueling and zero-emission vehicles.

Electric or Low-Emitting Ferry Program – Provides $250 million for the purchase of hydrogen, electric, or low-emission ferries.

Port Infrastructure Development Program Grants – Provides $2.25 billion for port electrification, microgrids, and hydrogen refueling infrastructure for medium or heavy-duty trucks that service the port.

Inflation Reduction Act of 2022 Financial Incentives

Clean Hydrogen Production Credit – Creates a new ten-year incentive for clean hydrogen with up to $3.00 / kilogram production tax credit (PTC) or 30% investment tax credit (ITC). The level of the credit provided is based on carbon intensity of the hydrogen production pathway.

Kg of CO2 per kg of H2	Credit Value ($)
4 - 2.5 kg CO2	$0.60 / kg of H2
2.5 - 1.5 kg CO2	$0.75 / kg of H2
1.5 - 0.45 kg CO2	$1.00 / kg of H2
0.45 - 0 kg CO2	$3.00 / kg of H2

Energy Credit – Extends the 30% fuel cell ITC through 2024 before a transition to the technology-neutral Clean Energy Investment Credit. Also adds a new provision to the energy ITC for energy storage, including hydrogen storage.

Carbon Oxide Sequestration Credit – Extends the credit through 2032 and provides an enhanced rate for carbon captured for storage and utilization.

Clean Vehicle Credit – Creates a new clean vehicle credit that provides up to $7,500 through 2032 for the purchase of fuel cell electric vehicles.

Qualified Commercial Clean Vehicles Credit – Creates a new 30% credit for commercial fuel cell electric vehicles through 2032 which is capped at $40,000.

Alternative Fuel Refueling Property Credit – Extends the credit through 2032 and increases the current 30% credit cap from $30,000 to $100,000 for hydrogen fueling stations.

Advanced Energy Project Credit - Revives the credit and provides $10 billion to fund manufacturing projects producing fuel cell electric vehicles, hydrogen infrastructure, electrolyzers, fuel cells, and a range of other products.

Inflation Reduction Act of 2022 Energy Policy

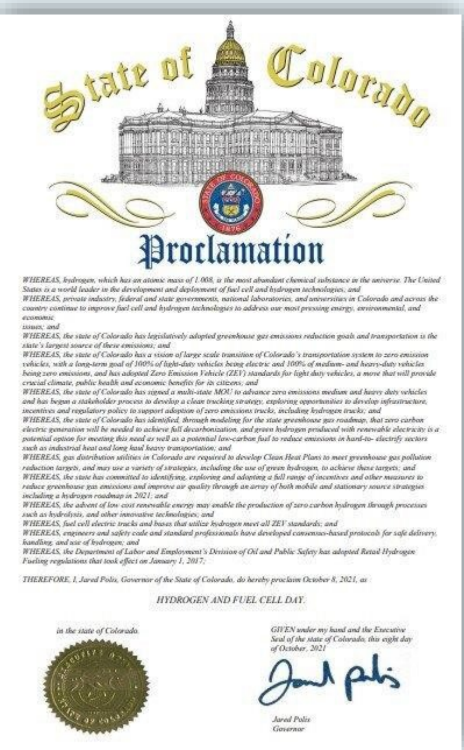
Clean Heavy-Duty Vehicles – $1 billion. $600 million in funds are provided to cover the costs of purchasing, installing, operating, and maintaining zero-emission vehicles and infrastructure to support those vehicles.

Grants to Reduce Air Pollution at Ports – $2.25 billion. Grants are directed to purchase and install zero- emission equipment and technology at ports, as well as the development of climate action plans at ports. $750M to be directed at ports in nonattainment areas.

Greenhouse Gas Reduction Fund – $18.9 Billion. $7 billion in funds is available for grants deployment of zero-emission technologies. $11.9 billion in funds is available for grants for financial assistance and technical assistance through, with $8 billion of these funds available specifically for low-income and disadvantaged communities.

Alternative Fuel and Low-Emission Aviation Technology Program – $ 96.9 million. $244.5 million is dedicated for projects relating production, transportation, blending, storage of sustainable aviation fuel. $46.5 million is directed to projects relating to low-emission technologies.

National Hydrogen & Fuel Cell Day | 10·08



State of Colorado

Proclamation

WHEREAS, hydrogen, which has an atomic mass of 1.008, is the most abundant chemical substance in the universe. The United States is a world leader in the development and deployment of fuel cell and hydrogen technologies; and
WHEREAS, private industry, federal and state governments, national laboratories, and universities in Colorado and across the country continue to improve fuel cell and hydrogen technologies to address our most pressing energy, environmental, and economic
issues; and
WHEREAS, the state of Colorado has legislatively adopted greenhouse gas emissions reduction goals and transportation is the state's largest source of these emissions; and
WHEREAS, the state of Colorado has a vision of large scale transition of Colorado's transportation system to zero emission vehicles, with a long-term goal of 100% of light-duty vehicles being electric and 100% of medium- and heavy-duty vehicles being zero emissions, and has adopted Zero Emission Vehicle (ZEV) standards for light duty vehicles, a move that will provide crucial climate, public health and economic benefits for its citizens; and
WHEREAS, the state of Colorado has signed a multi-state MOU to advance zero emissions medium and heavy duty vehicles and has begun a stakeholder process to develop a clean trucking strategy, exploring opportunities to develop infrastructure, incentives and regulatory policy to support adoption of zero emissions trucks, including hydrogen trucks; and
WHEREAS, the state of Colorado has identified, through modeling for the state greenhouse gas roadmap, that zero carbon electric generation will be needed to achieve full decarbonization, and green hydrogen produced with renewable electricity is a potential option for meeting this need as well as a potential low-carbon fuel to reduce emissions in hard-to- electrify sectors such as industrial heat and long haul heavy transportation; and
WHEREAS, gas distribution utilities in Colorado are required to develop Clean Heat Plans to meet greenhouse gas pollution reduction targets, and may use a variety of strategies, including the use of green hydrogen, to achieve these targets; and
WHEREAS, the state has committed to identifying, exploring and adopting a full range of incentives and other measures to reduce greenhouse gas emissions and improve air quality through an array of both mobile and stationary source strategies including a hydrogen roadmap in 2021; and
WHEREAS, the advent of low cost renewable energy may enable the production of zero carbon hydrogen through processes such as hydrolysis, and other innovative technologies; and
WHEREAS, fuel cell electric trucks and buses that utilize hydrogen meet all ZEV standards; and
WHEREAS, engineers and safety code and standard professionals have developed consensus-based protocols for safe delivery, handling, and use of hydrogen; and
WHEREAS, the Department of Labor and Employment's Division of Oil and Public Safety has adopted Retail Hydrogen Fueling regulations that took effect on January 1, 2017;

THEREFORE, I, Jared Polis, Governor of the State of Colorado, do hereby proclaim October 8, 2021, as

HYDROGEN AND FUEL CELL DAY

in the state of Colorado.

GIVEN under my hand and the Executive Seal of the state of Colorado, this eight day of October, 2021

Jared Polis
Governor

GOVERNOR DOUGLAS A. DUCEY

STATE OF ARIZONA

PROCLAMATION

WHEREAS, by 2050, hydrogen could create up to 3.4 million jobs and generate $750 billion in annual revenue nationally; and

WHEREAS, hydrogen energy offers an opportunity to advance America's energy independence; and

WHEREAS, hydrogen will advance United States transportation, power, and manufacturing opportunities; and

WHEREAS, fuel cells utilizing hydrogen or hydrogen-rich fuels are clean, efficient, and resilient technologies that can be used as a primary or backup power source; in zero-emission light-duty motor vehicles, buses, and trucks; in heavy-duty vehicles used in the logistics industry; and for portable power; and

WHEREAS, the State of Arizona is a leader in manufacturing and emerging transportation and clean energy technologies; and

WHEREAS, Arizona's emerging hydrogen vehicle manufacturing ecosystem will lead to high-paying jobs that attract top tech talent, stimulate local economic growth, better position Arizona as a national leader in energy innovation, and ensure a healthier and more prosperous future for our great state.

NOW, THEREFORE, I, Douglas A. Ducey, Governor of the State of Arizona, do hereby proclaim October 8, 2021 as

HYDROGEN & FUEL CELL DAY

IN WITNESS WHEREOF, I have hereunto set my hand and caused to be affixed the Great Seal of the State of Arizona.

GOVERNOR

DONE at the Capitol in Phoenix on this Thirtieth day of September in the year Two Thousand and Twenty-One, and of the Independence of the United States of America the Two Hundred and Forty-Sixth.

ATTEST:

SECRETARY OF STATE

A Resolution

BY

SENATOR ANTANI

Honoring 2021 National Hydrogen and Fuel Cell Day.

WHEREAS, The members of the Senate of the 134th General Assembly of Ohio are pleased to recognize October 8, 2021, as National Hydrogen and Fuel Cell Day; and

WHEREAS, Hydrogen, the most abundant substance in the universe, and the fuel cells that can be created from it represent an exciting and cutting-edge vision of the future, one that stands to address the pressing energy, environmental, and economic issues facing our state and country. Private and public institutions have dedicated themselves to continuing to improve these technologies, and National Hydrogen and Fuel Cell Day represents an excellent time to celebrate their efforts; and

WHEREAS, Through the work of impactful organizations, partnerships, universities, and laboratories, Ohio has proven itself to be a leader in scientific industries and fields, and our state is poised to continue to do so regarding the advancement of hydrogen fuel cells. It is in the best interest of Ohio and the well-being of its people to invest, encourage, and promote these technologies; and

WHEREAS, Our history as a country has always been marked by innovation and by breaking barriers that create a new dawn out of what previously seemed impossible. Hydrogen fuel cells have already helped take us to the moon, and we are certain that they will help us push even further into what our future holds; therefore be it

RESOLVED, That we, the members of the Senate of the 134th General Assembly of Ohio, in adopting this Resolution, recognize October 8, 2021, as National Hydrogen and Fuel Cell Day; and be it further

RESOLVED, That the Clerk of the Senate transmit a duly authenticated copy of this Resolution to the news media of Ohio.

I, Vincent L. Keeran, hereby certify that the above is a true and correct copy of Senate Resolution Number 190, adopted by the Ohio Senate, October 05, 2021.

Vincent L. Keeran
Clerk of the Senate

Senator Matt Huffman
President of the Senate

Senator Niraj Antani
Senatorial District No. 6

Governor Michelle Lujan Grisham
@GovMLG

.@SecGranholm is right: clean hydrogen is the future, and New Mexico is getting in on the ground floor.

Investing in the development of clean hydrogen will reduce greenhouse gas emissions, create jobs and diversify New Mexico's economy: it's a win-win-win. #NationalHydrogenDay

U.S. Department of Energy @ENERGY · Oct 8, 2021
Behold, the power of hydrogen! Catch this explainer from @SecGranholm on how clean hydrogen made from multiple energy resources can take on the climate crisis 💪 #NationalHydrogenDay #HydrogenNow

2:10 PM · Oct 8, 2021 · Twitter Web App

FCHEA

Fuel Cell and Hydrogen Energy Association
1211 Connecticut Avenue, Suite 650
Washington, DC 20036
202-261-1331 | www.fchea.org

Thank You

Energy & Homeland Security

Hydrogen Safety, Codes & Standards

Chris San Marchi, Sandia National Laboratories (CA)

NASEO Briefing, September 28, 2022

SAND2022-13211 PE

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia LLC, a wholly owned subsidiary of Honeywell International Inc. for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

WHAT DOES HYDROGEN TECHNOLOGY LOOK LIKE?

...a lot like every day

gas

liquid

HYDROGEN PROPERTIES: *GAS*

	Hydrogen gas	Natural Gas	Gasoline
Color	No	No	Yes
Toxicity	None	Mild	High
Odor	Odorless	Mercapton	Volatiles
Buoyancy Relative to air	14X Lighter	2X Lighter	3.75X Heavier (vapor)
Autoignition temperature (˚C)	585	539	232
Minimum ignition energy (mJ)	0.017	0.288	0.25-0.30
Energy by weight	2.8X > Gasoline	~1.2X > Gasoline	43 MJ/kg
Energy By volume	4X < Gasoline	1.5X < Gasoline	120 MJ/Gallon

Shamelessly borrowed from the Center for Hydrogen Safety

HYDROGEN PROPERTIES: *CRYOGENIC*

	Liquid Hydrogen	Liquid Natural Gas
Temperature (K) Boiling Point	20 (-423˚F)	112 (-258˚F)
Condenses air	Yes	No
Liquid density (kg/m³)	~70	423
Vapor density (kg/m³) at Boiling Point	1.2	1.81
Vapor density (kg/m³) at room temperature (293K)	0.08	0.67
Temperature at Buoyancy (K)	22 (-420˚F)	170 (-153˚F)
Flammability range (mole %) by weight	4 to 75	5 to 15

HYDROGEN IS MANAGED LIKE OTHER FUEL GASES

Gaseous

- Train
- Ship
- Truck

- Pipelines

- Pressure Vessels
- Subsurface

Delivery ***Storage***

Liquid

- Train
- Ship
- Truck

- Cryogenic Vessels

Carriers

SOLID
LIQUID
GAS

WHAT IS THE BEST METHOD TO TRANSPORT AND STORE H_2?

- **"It depends…"**
  - **The standard engineering answer to a poorly posed question**
- **Gaseous**
  - **Typically high-pressure to achieve volumetric density**
  - **Current state-of-the-art for vehicle fuel, very large (geologic) storage, and long distance, high volume transport (e.g., pipelines)**
- **Liquid**
  - **Very low temperature (~20K; in comparison LN2 ~ 77K)**
  - **Current state-of-the-art for some transport and storage applications**
- **Carriers**
  - **Not economical at present**
  - **Often toxic**

WHAT ARE THE HYDROGEN CHALLENGES?

- **Hydrogen technologies are not new**
  - Cornerstone of astronautics
  - “Chemical” hydrogen is used extensively in industry (10B kg/yr in US)
  - Hydrogen pipelines exist to serve industry (>2,500 km in US)
- **Commercial uses are growing**
  - Fuel cell cars, buses, trains, boats, back-up power, etc.
  - H_2-powered materials handling equipment (e.g., forklifts)

economics

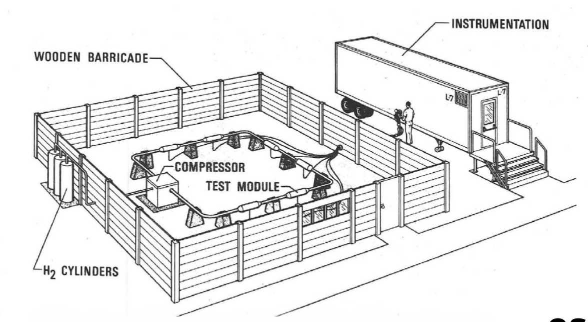
- **Green hydrogen is too expensive**
  - Supply chain for non-industrial use is nascent
  - Infrastructure at scale cannot be replaced/developed overnight
    - Gas network is estimated to be valued at >$1,000B
    - Over 150,000 gasoline stations in US (value ~$100B)

safety

- **Hydrogen is managed as chemical, not as energy/fuel**
  - We need “*non-hardhat*” relationship with hydrogen

U.S. DOE HAS RICH HISTORY OF FUNDING HYDROGEN SAFETY R&D

The national laboratories maintain unique infrastructure for study of hydrogen safety

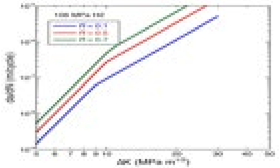


Experimental Hydrogen Pipeline Facility

HEML established

Critical assessment of fracture testing (SAND2010-4633)

Full-scale PV testing for Lift Trucks



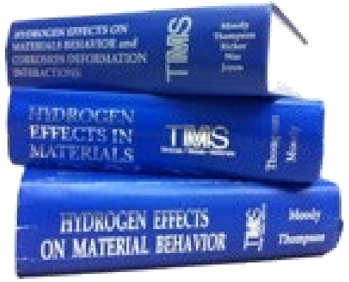
MOU on high-hardenability steels for PVs

ASME CC 2938: Fatigue design curves for PVs

H-Mat Hydrogen Materials Compatibility Consortium

1970 1990 2000 2010 2012 2014 2016 2018 2020 2022

Organization of International Hydrogen Conferences ('88, '94, '02, '08, '12, '16)



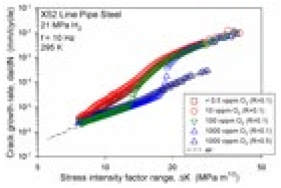
Hydrogen-Materials Workshop 2003

Technical Reference v.1

Hydrogen-Materials Workshop 2010

Technical Reference v.2

Demonstration and model of impurity effects on fatigue

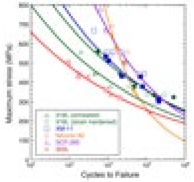


Trends established for pipeline materials

Assessment of pipeline welds

Development of performance-based method in SAE J2579

Evaluation of low-cost alternatives to 316L



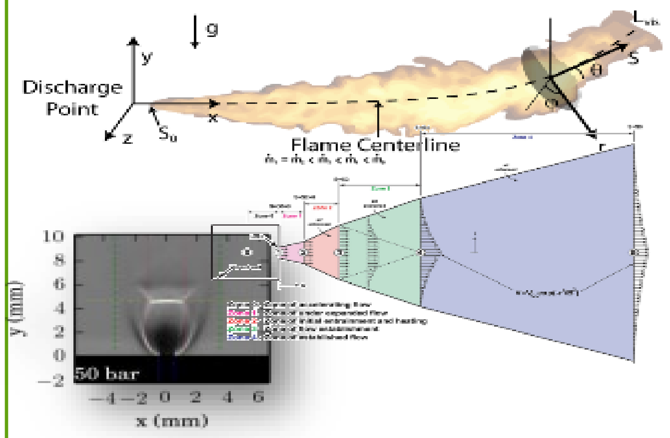
HyBlend U.S. DEPARTMENT OF ENERGY

Re-assessment of life predictions for ASME Div 3 PVs

CONSISTENT, ACCEPTED, AND RIGOROUS SAFETY ANALYSIS

HyRAM+
Hydrogen Plus Other Alternative Fuels Risk Assessment Models

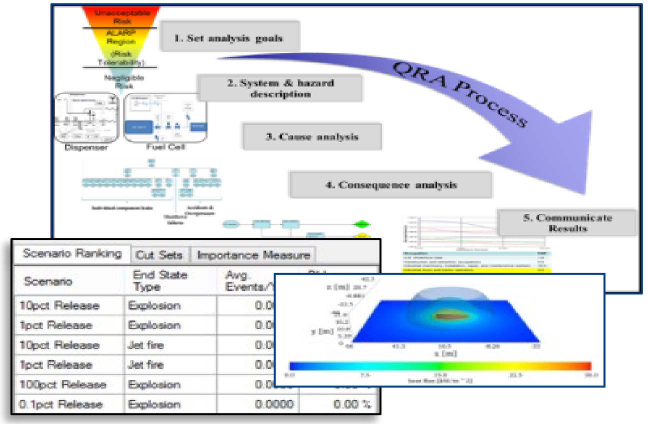
Behavior R&D



Develop and validate scientific models

to accurately predict hazards and harm from liquid releases, flames, etc.

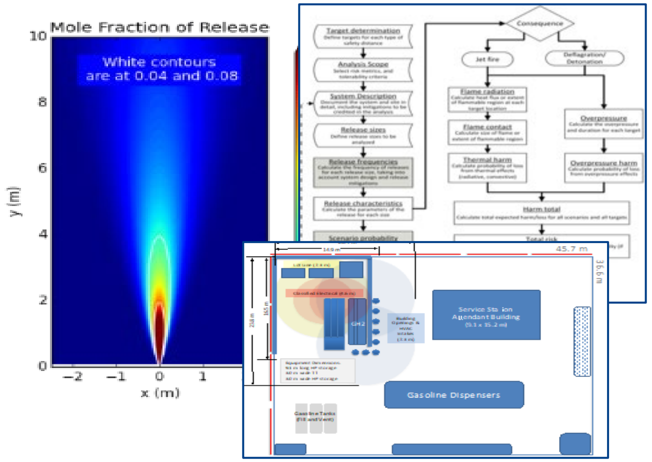
Risk R&D



Develop integrated methods and algorithms

for enabling consistent, traceable and rigorous quantitative risk assessment (QRA)

Application in Safety, Codes, and Standards



Apply QRA & behavior models to real problems

in hydrogen infrastructure and emerging technology

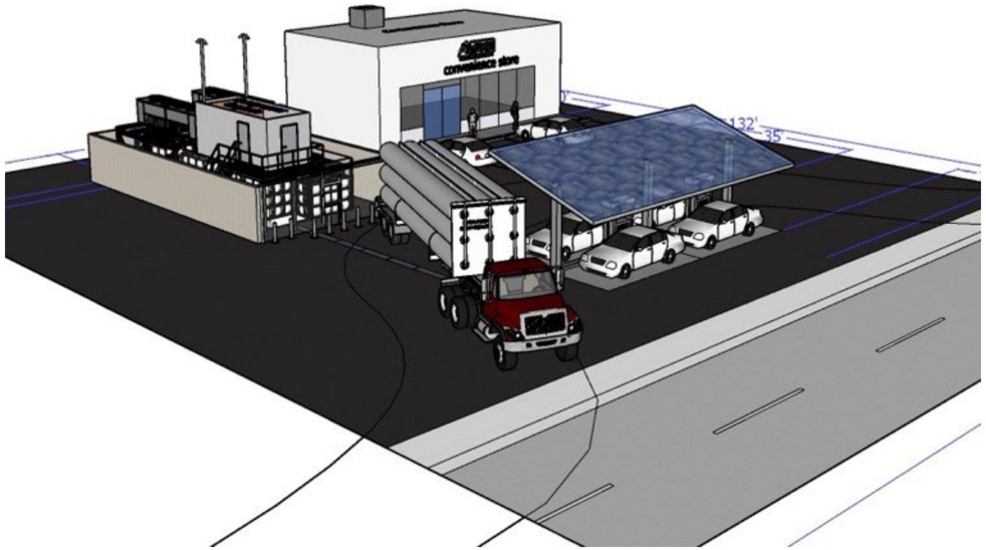
Developing methods, data, tools for H_2 safety, codes and standards

Tool available online: [HyRAM]

Traditional safety distances for hydrogen systems were based on consensus without a documented scientific analysis

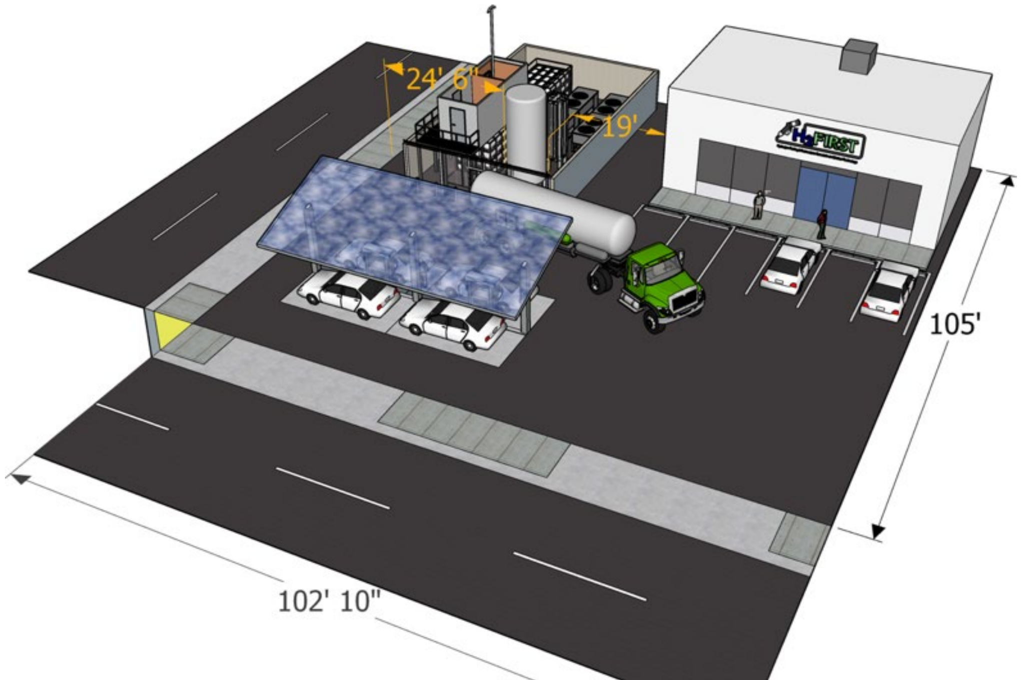
Compressed H_2 storage (GH2)

Previous DOE-funded research led to science-based safety distances for GH2



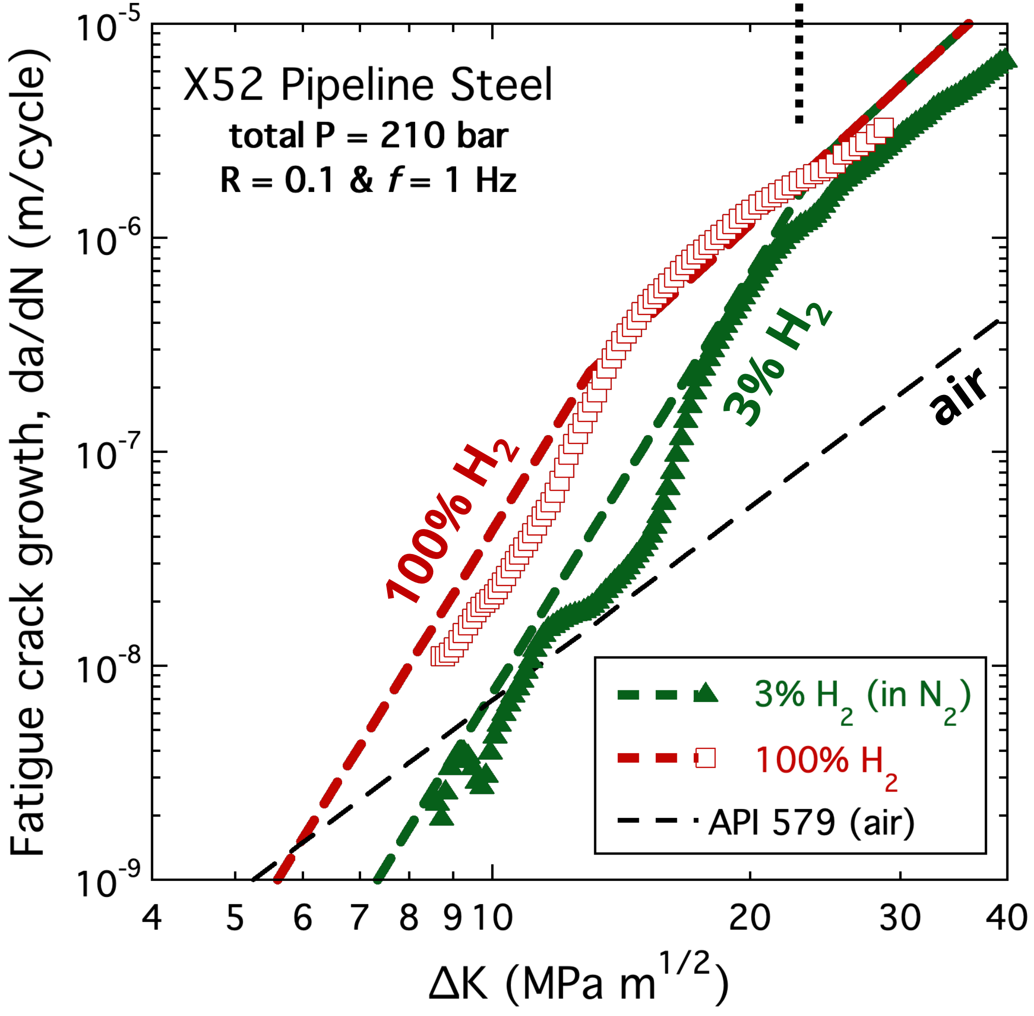
Liquid H_2 storage (LH2)

Science-based risk assessments recently led to substantially reduced safety distances for LH2 (NFPA 2, 2023 edition)



HYDROGEN EFFECTS ON MATERIALS ARE OFTEN MISUNDERSTOOD

Intermediate stress (ΔK) | **Large stress (ΔK)**



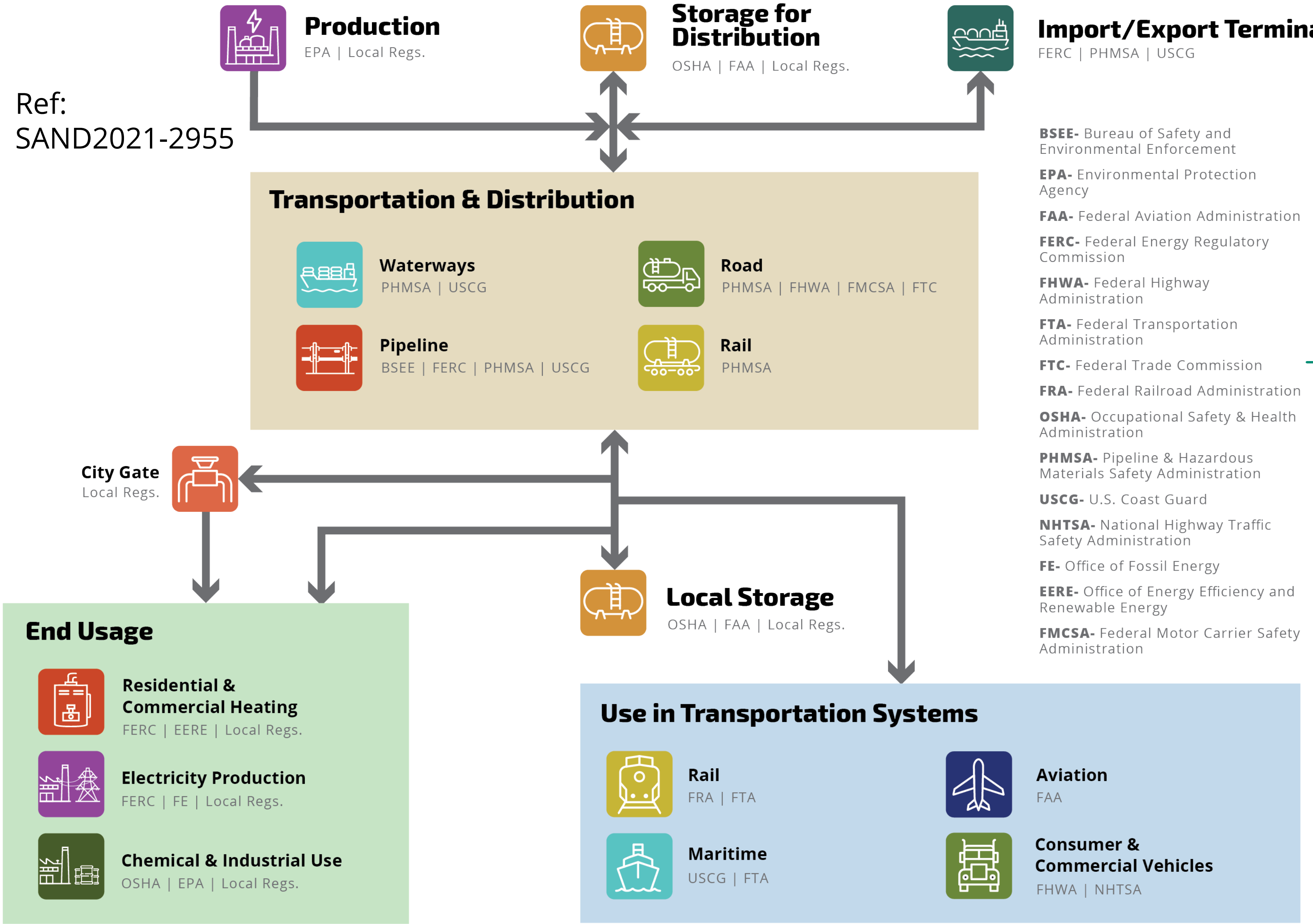
- **Low hydrogen partial pressure has a large effect on fatigue and fracture properties of *structural metals***
  - **Material response in hydrogen environments is nuanced and depends sensitively on *materials*, *environmental* and *mechanics* (stress) variables**
- **Hydrogen effects in *structures* are managed (knowingly or unknowingly)**
  - **Materials strength and applied stresses are the principle means of managing hydrogen effects**
  - **At low stress, hydrogen effects can be minimal**

Structural integrity for hydrogen service can be managed, but the operating conditions and state of the asset must be known

Ref.: San Marchi et al, PVP2021-62045

REGULATORY MAP – COLLABORATION IS NECESSARY

Ref: SAND2021-2955



BSEE – Bureau of Safety and Environmental Enforcement
EPA – Environmental Protection Agency
FAA – Federal Aviation Administration
FERC – Federal Emergency Regulatory Commission
FHWA – Federal Highway Administration
FTA – Federal Transportation Administration
FTC – Federal Trade Commission
FRA – Federal Railroad Administration
OSHA – Occupational Safety & Health Association
PHMSA – Pipeline & Hazardous Materials Safety Administration
USCG – U.S. Coast Guard
NNTSA – National Highway Traffic Safety Administration
FE – Office of Fossil Energy & Carbon Management
EERE – Office Energy Efficiency and Renewable Energy
FMCSA – Federal Motor Carrier

THANK YOU

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HyBlend U.S. DEPARTMENT OF ENERGY

H-Mat Hydrogen Materials Compatibility Consortium

HyRAM+ Hydrogen Plus Other Alternative Fuels Risk Assessment Models

***Additional Resources*:**

- https://h2tools.org/
- https://hyram.sandia.gov/
- https://h-mat.org/
- https://www.sandia.gov/matlsTechRef/

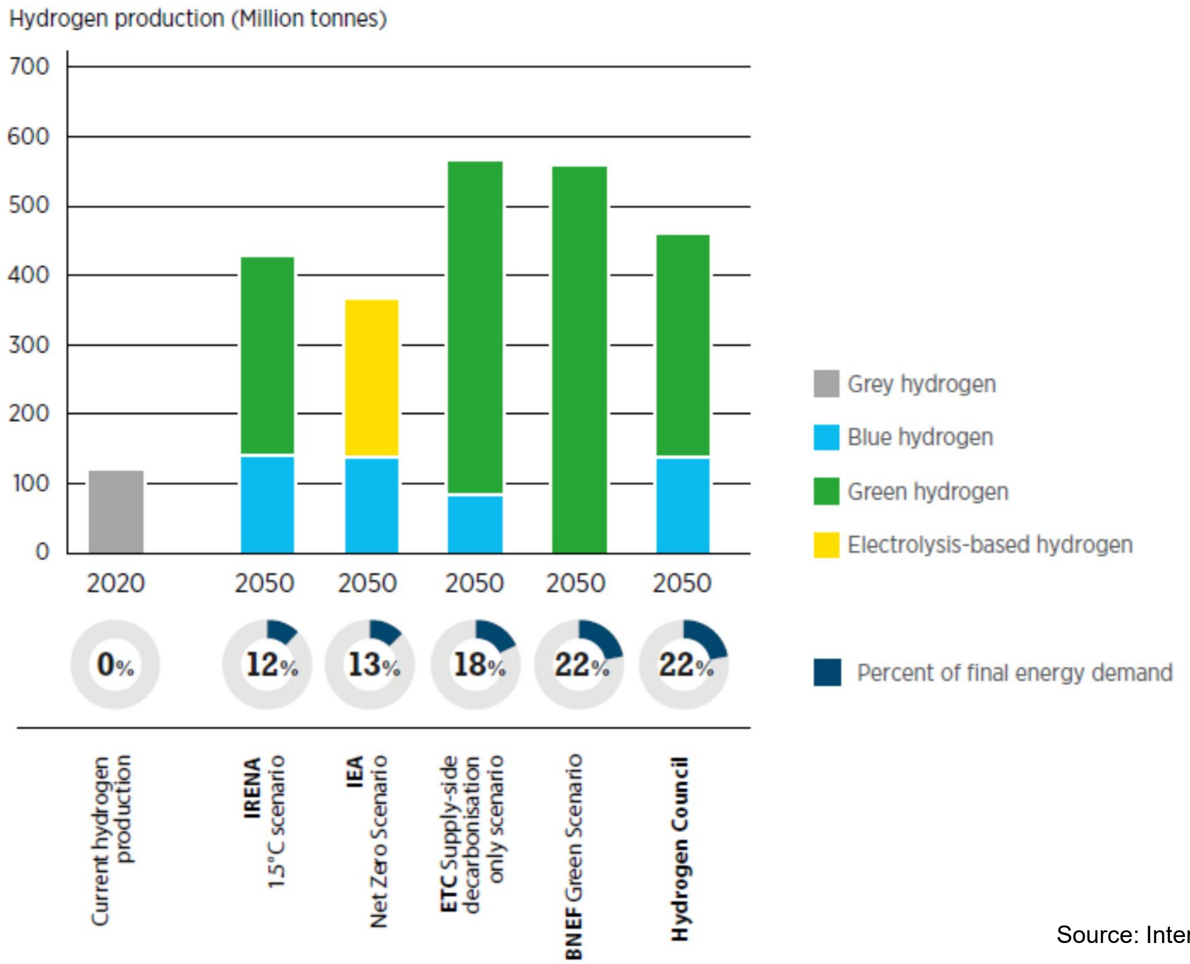
NRDC

Hydrogen Briefing

September 2022

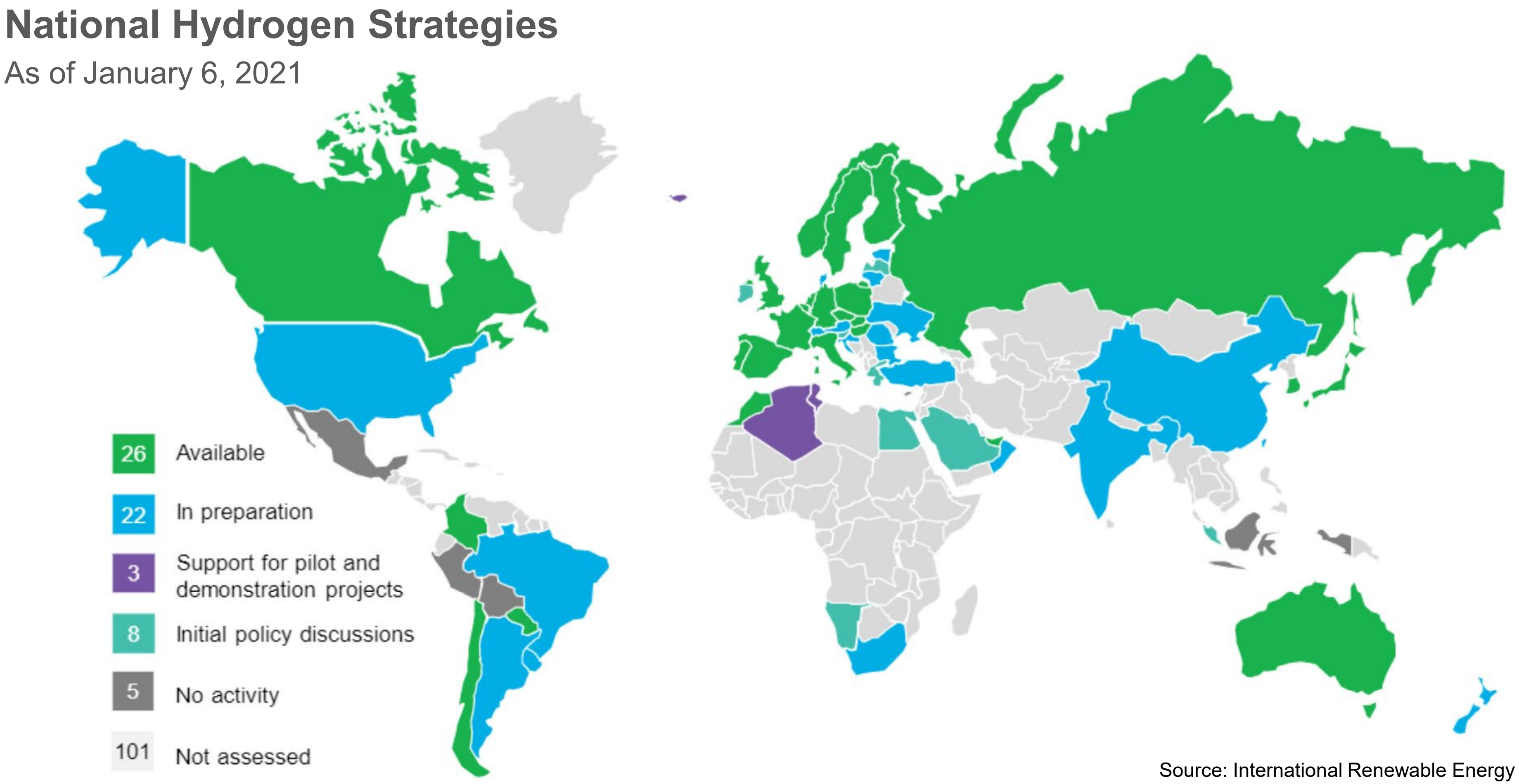
Clean hydrogen is poised to play a key role in meeting global climate goals.

Estimates for Global Hydrogen Demand in 2050



Source: International Renewable Energy Agency

By 2025, national hydrogen strategies could cover countries representing more than 80% of global GDP.



Source: International Renewable Energy Agency, BloombergNEF

The United States now offers the largest clean hydrogen subsidies in the world.

United States: Hydrogen technology receives substantial support and funding under the Infrastructure Investment and Jobs Act

ENERGY

US climate bill includes massive, game-changing green hydrogen incentives

By Loz Blain
August 10, 2022

Four Western states joining forces to create hydrogen hubs

By Alejandra O'Connell-Domenech | Feb 25, 2022

Four Northeast states form consortium to develop regional clean hydrogen hub

New York, Connecticut, Massachusetts, and New Jersey to join dozens of corporations and universities in demonstrating shared vision for clean energy.

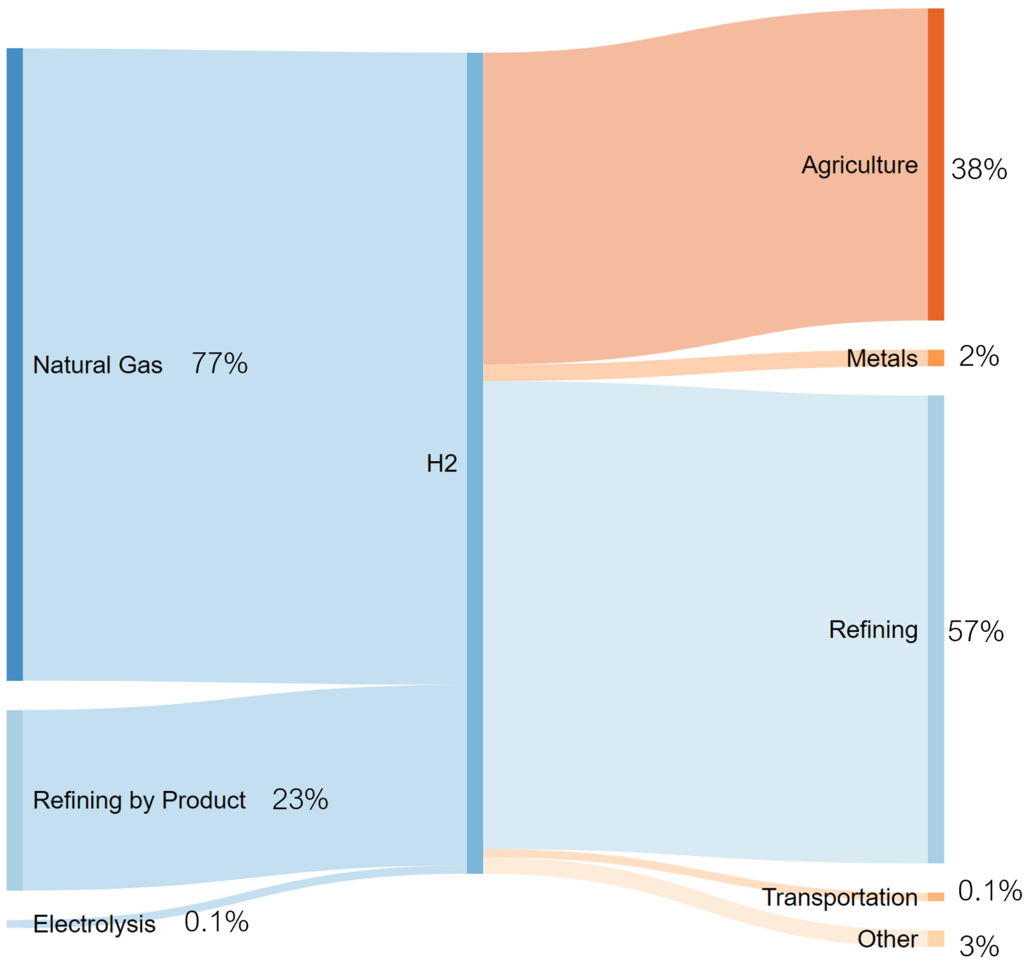
MARCH 25, 2022 ANNE FISCHER

Louisiana, Arkansas, Oklahoma join hydrogen hub chase

March 10, 2022

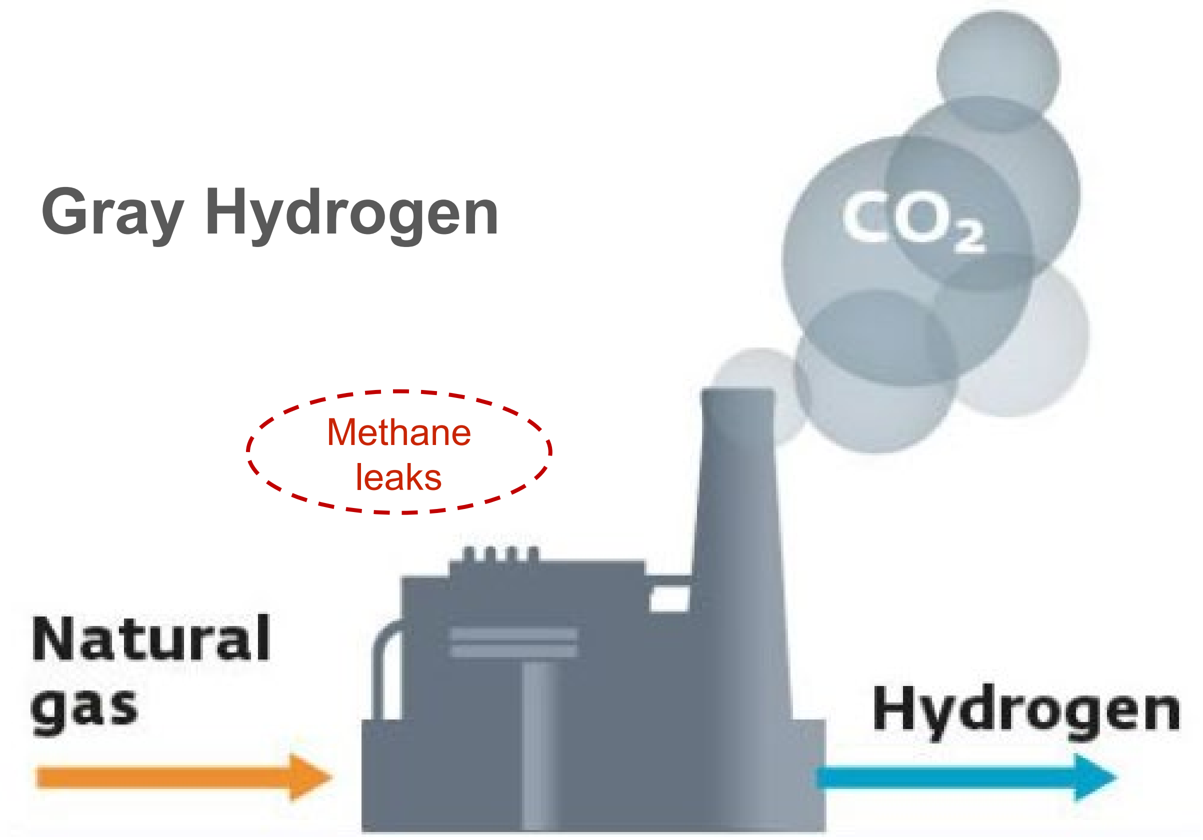
Background

Today, hydrogen is mainly used in refining and chemical production.



95% of today's hydrogen is produced from natural gas.

Gray Hydrogen

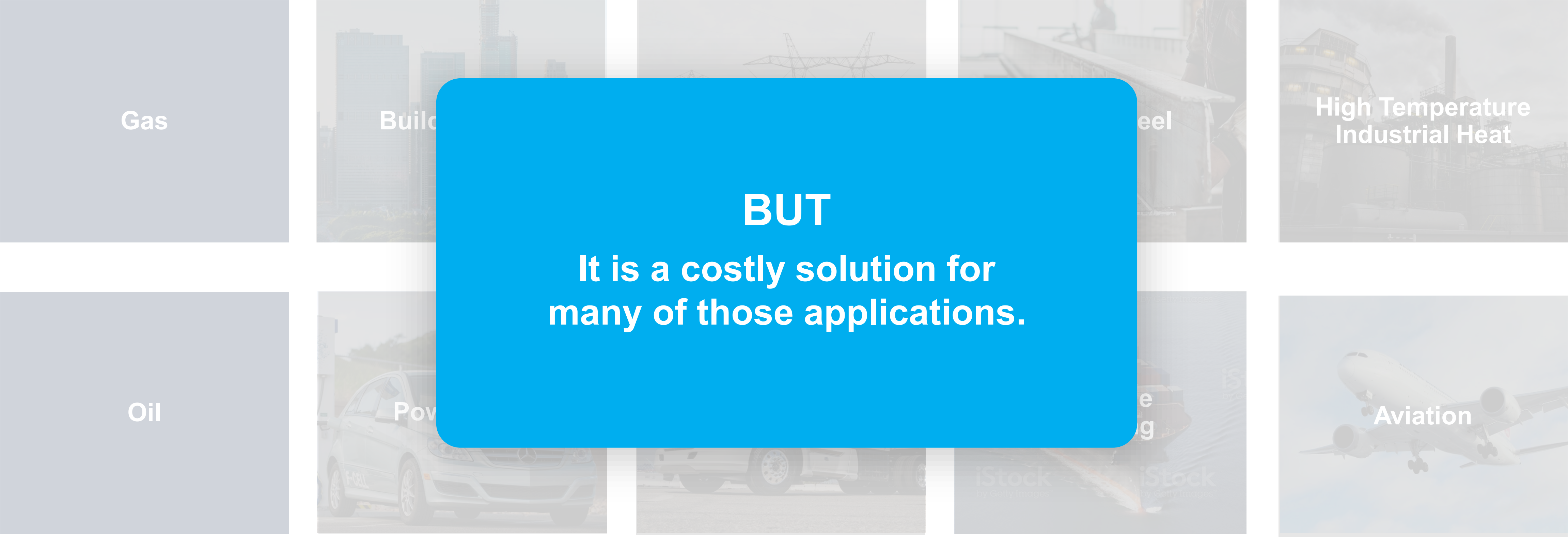


~2%

of U.S. CO_2 emissions

Hydrogen for Decarbonization

Hydrogen can fuel nearly everything fossil fuels can

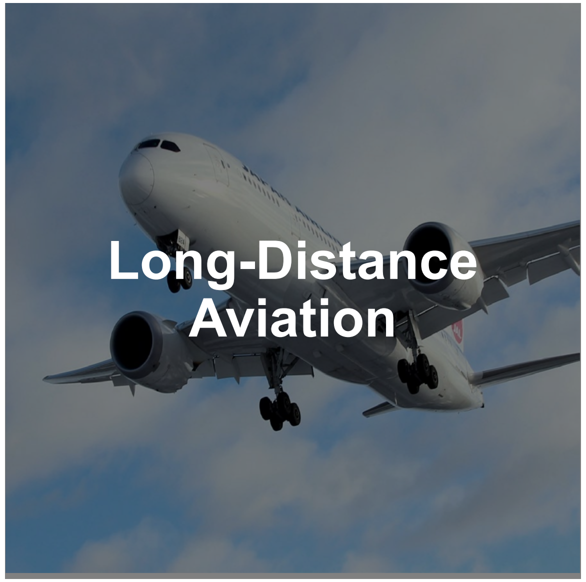


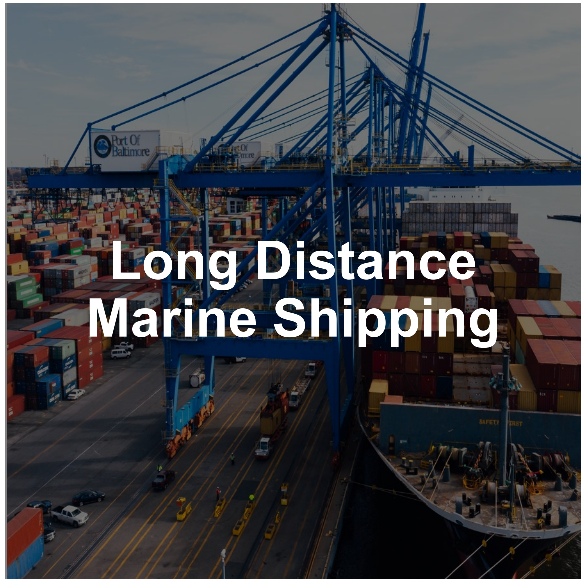
BUT

It is a costly solution for many of those applications.

Hydrogen Benefits

Hydrogen is a potential solution for challenging sectors with no better alternatives.





Hydrogen Challenges

When feasible, direct electrification should be prioritized.

Direct Electrification

Heat Pump: Efficiency 100-400%

Hydrogen

Hydrogen Boiler: Efficiency Max ~95%

Extra Step: Hydrogen Production. ~20-25% losses

Hydrogen may stall climate progress and increase costs for Americans if it's not strategically deployed.

Green hydrogen takes over five times more energy to produce heat compared to electrification

Number of wind turbines needed to cover heating demand in the UK where one symbol = 1,500 turbines

Source: Energy Monitor analysis of Committee on Climate Change and Renewable UK figures. This is illustrative for the UK assuming all gas used for heating is substituted with green hydrogen or using heat pumps. In reality not only wind power would be used to provide the electricity.

NRDC

OUR WORK OUR EXPERTS OUR STORIES GET INVOLVED ABOUT US

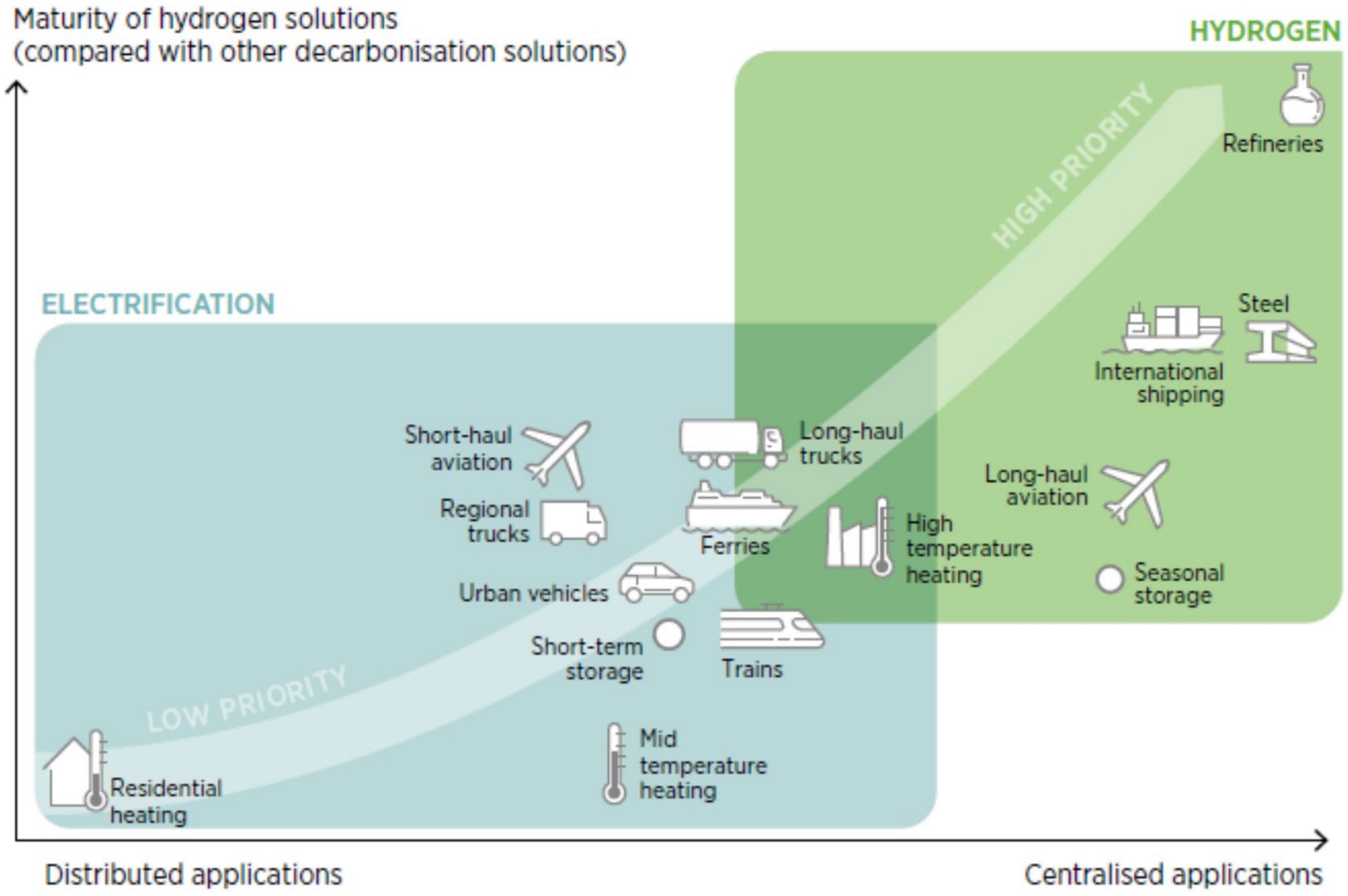
EXPERT BLOG › JACQUELINE ENNIS

The Hidden Costs of Untargeted Hydrogen Deployment

September 22, 2022 | Jacqueline Ennis

There's strong consensus around "good" and "bad" hydrogen uses.

Clean Hydrogen Policy Priorities



Source: International Renewable Energy Agency

DOE and the global community agree: Hydrogen should be reserved to the hardest-to-electrify applications

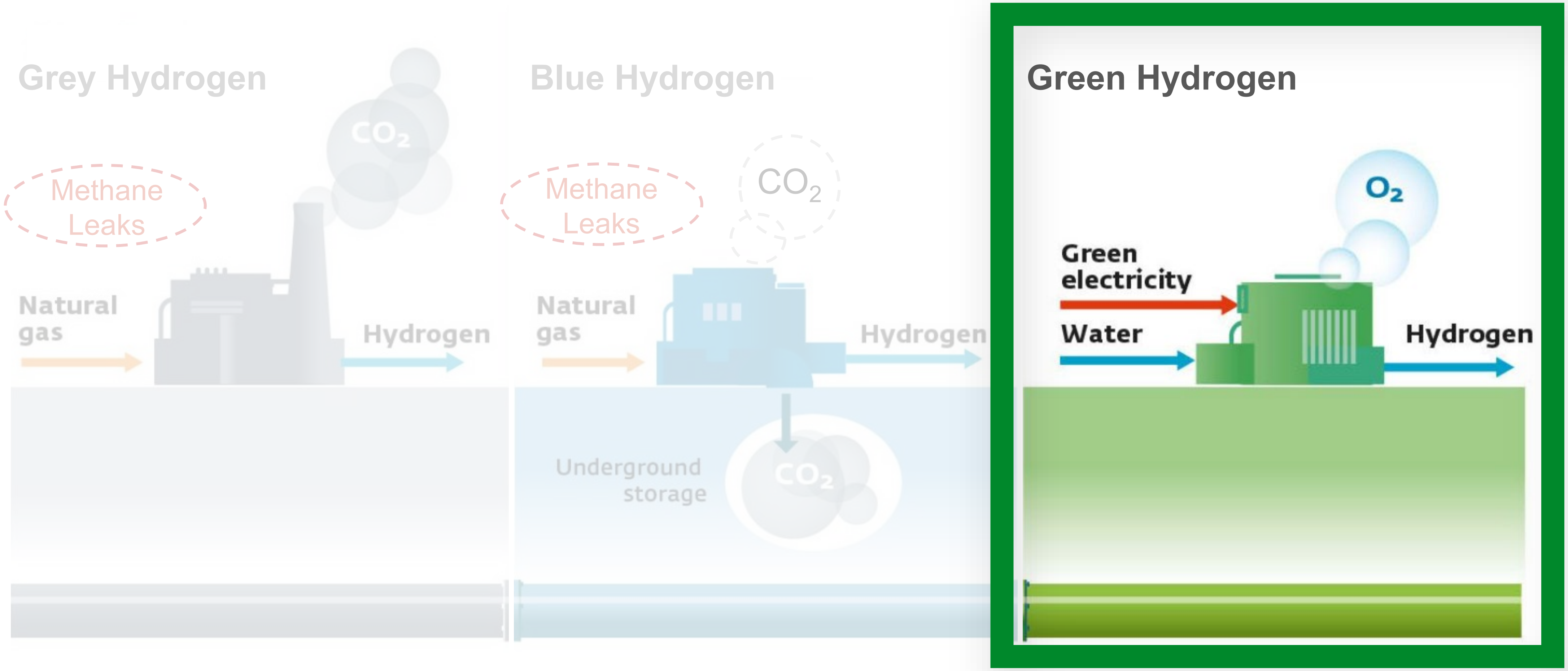
"The foundation of this draft roadmap is based on **prioritizing three key strategies** to ensure that clean hydrogen is developed and adopted as an effective decarbonization tool and for **maximum benefits** for the United States.
DOE will:
(1) Target strategic, high-impact uses for clean hydrogen. This will ensure that clean hydrogen will be utilized in the highest value applications, where limited deep decarbonization alternatives exist. Specific markets include the industrial sector, heavy-duty transportation, and long-duration energy storage to enable a clean grid."

- DOE, Draft National Hydrogen Roadmap and Strategy

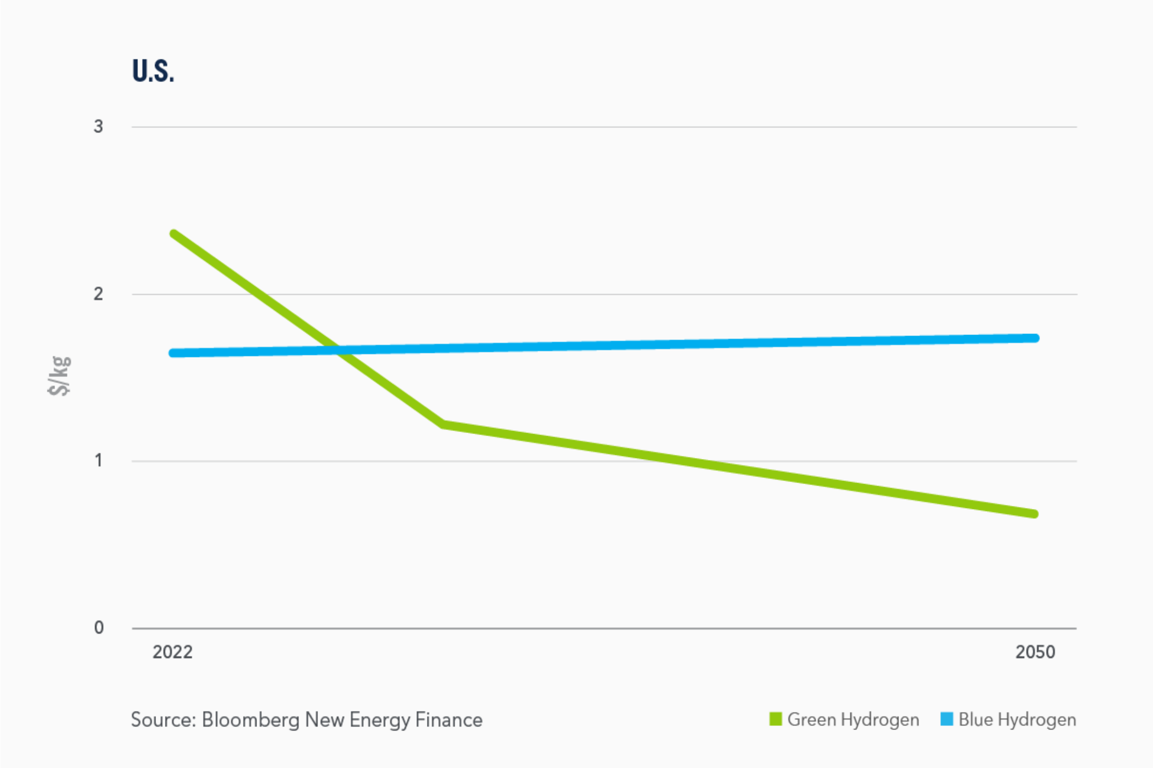
"Hydrogen production, transport and use incur high energy losses, such that its widespread use across sectors that can be more efficiently decarbonised with alternative clean energy solutions may increase the costs of transitioning to a clean economy."

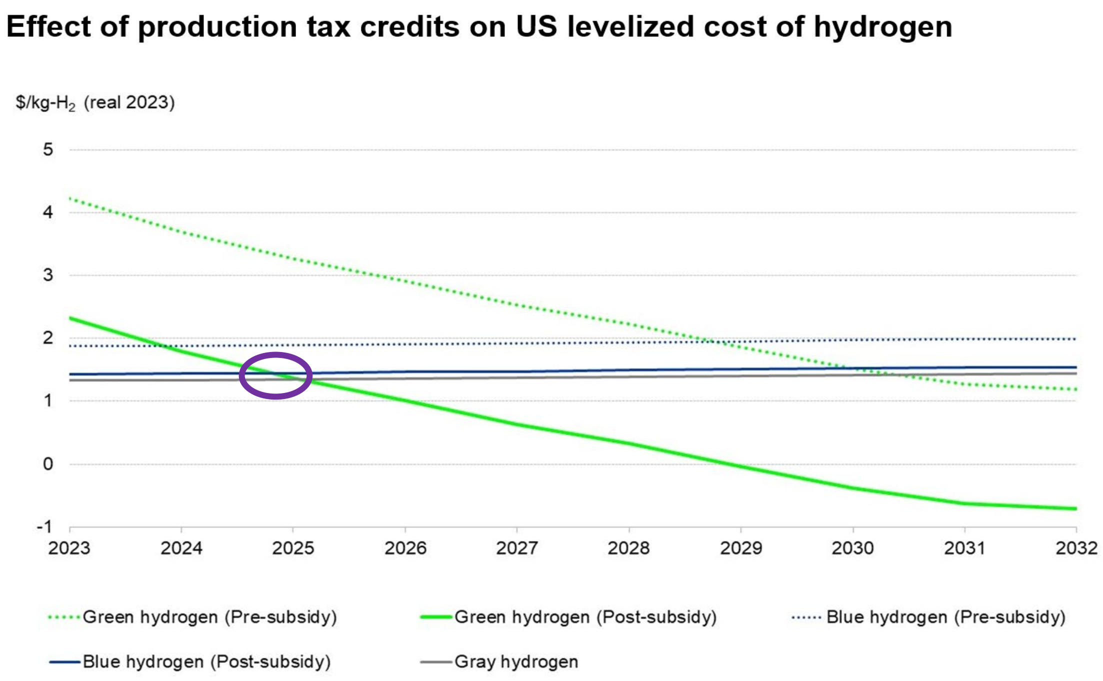
- IEA, IRENA, UN High Level Champions, "The Breakthrough Agenda Report 2022"

Hydrogen production must be cleaned up.



Green hydrogen is set to outcompete blue hydrogen in many places in the United States by 2030. IRA set to accelerate that.





Source: Source: BloombergNEF

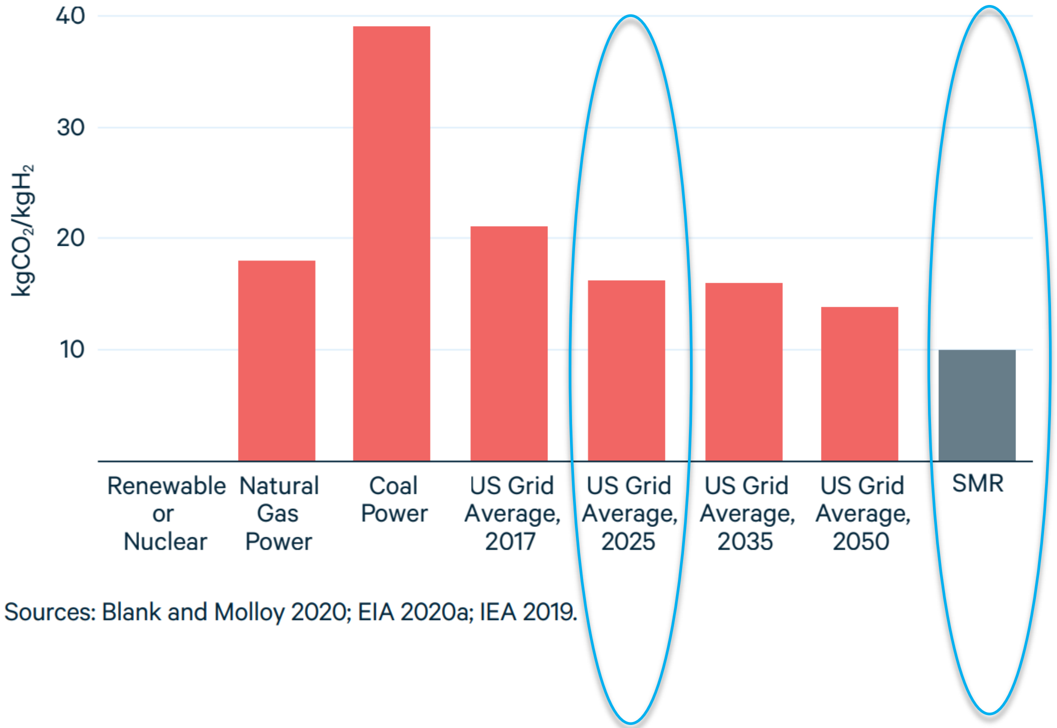
Ditching colors and moving to a carbon intensity construct: Rigorous standards and verification will be vital.

kgCO2e/kgH2

'Blue' hydrogen may be worse than gas and coal, say researchers

April 28, 2022

Figure 3. CO_2 Emissions from Electrolysis, by Power Source



Sources: Blank and Molloy 2020; EIA 2020a; IEA 2019.

Hydrogen Leakage Can Lead to Climate Warming. Caution is Imperative.

Environmental Defense Fund

STUDY: Emissions of Hydrogen Could Undermine Its Climate Benefits; Warming Effects Are Two to Six Times Higher Than Previously Thought

Scientists say leakage risk has been overlooked and understated; warn careful measures are needed to achieve promised advantage

UK government warns of global warming risks related to hydrogen leaks

The UK Department for Business, Energy and Industrial Strategy has published new research showing that hydrogen leaks could have an indirect climate-warming impact, partly offsetting efforts to reduce carbon dioxide emissions.

APRIL 12, 2022 EMILIANO BELLINI

EDF: @ 10% leakage rate, blue hydrogen could ***increase*** near-term warming impact by 25%.

Policy Landscape

Generous federal incentives and support mechanisms: IIJA

- **DOE Clean hydrogen production standard**
  - Draft standard out, 4 kgCO2e/kgH2

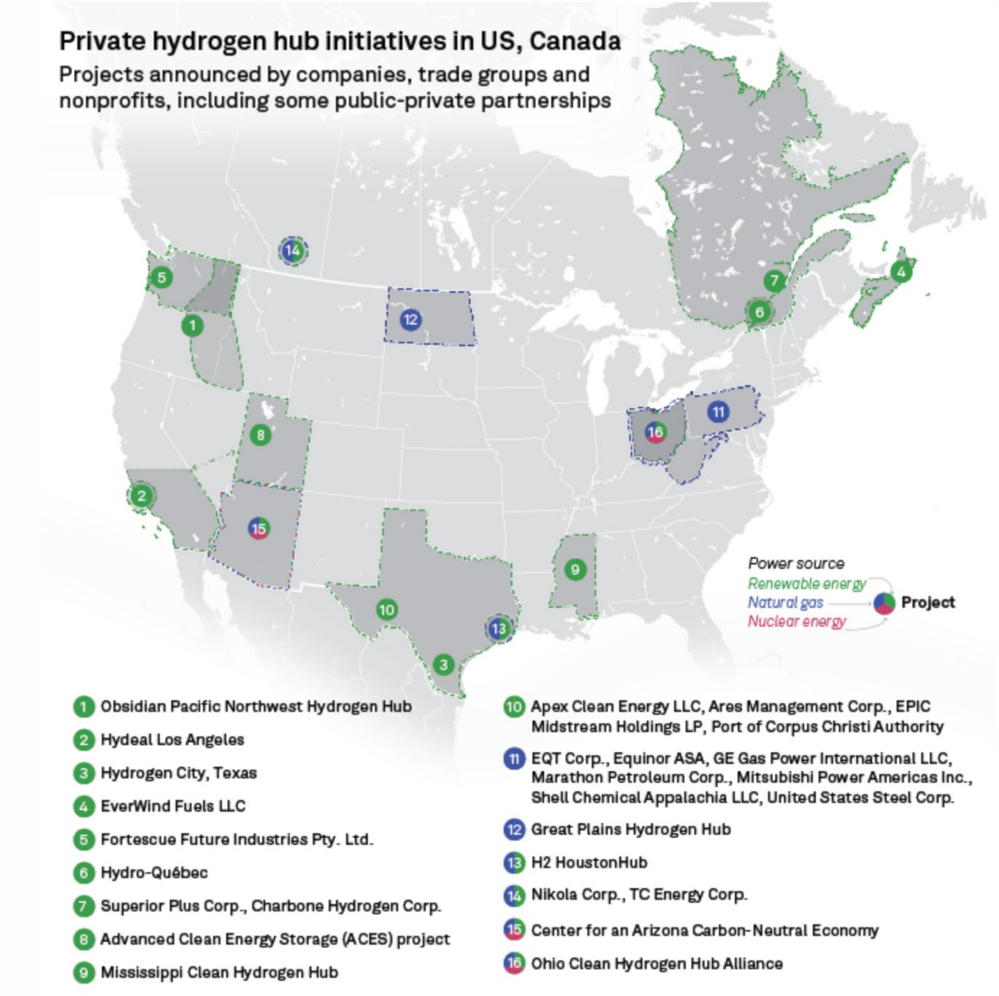
- **DOE National Hydrogen Roadmap**
  - Draft out

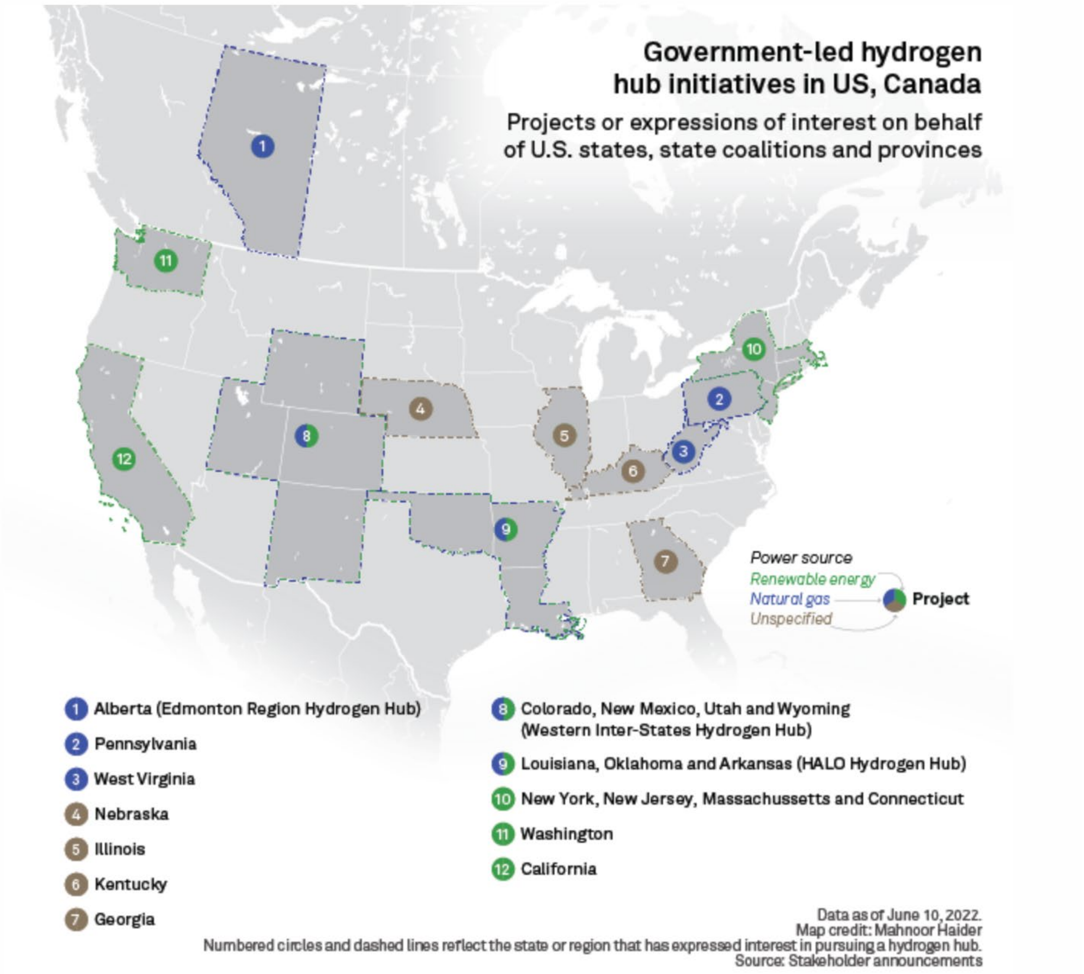
- **DOE Hydrogen Hubs**
  - $8 billion authorized over 2022-2026 to create at least 4 hydrogen hubs (expect closer to 6-10)

  - Requirements to consider:
    - Feedstock diversity:
      - Gas
      - Nuclear
      - Renewables
    - Geographic diversity (at a minimum two hubs in gas-producing regions);
    - Emphasis on a vision for a national hydrogen network.

  - Anticipated timeline:
    - Funding Opportunity Announcement out
    - Concept papers due by November 7; Applications due by April 7 2023

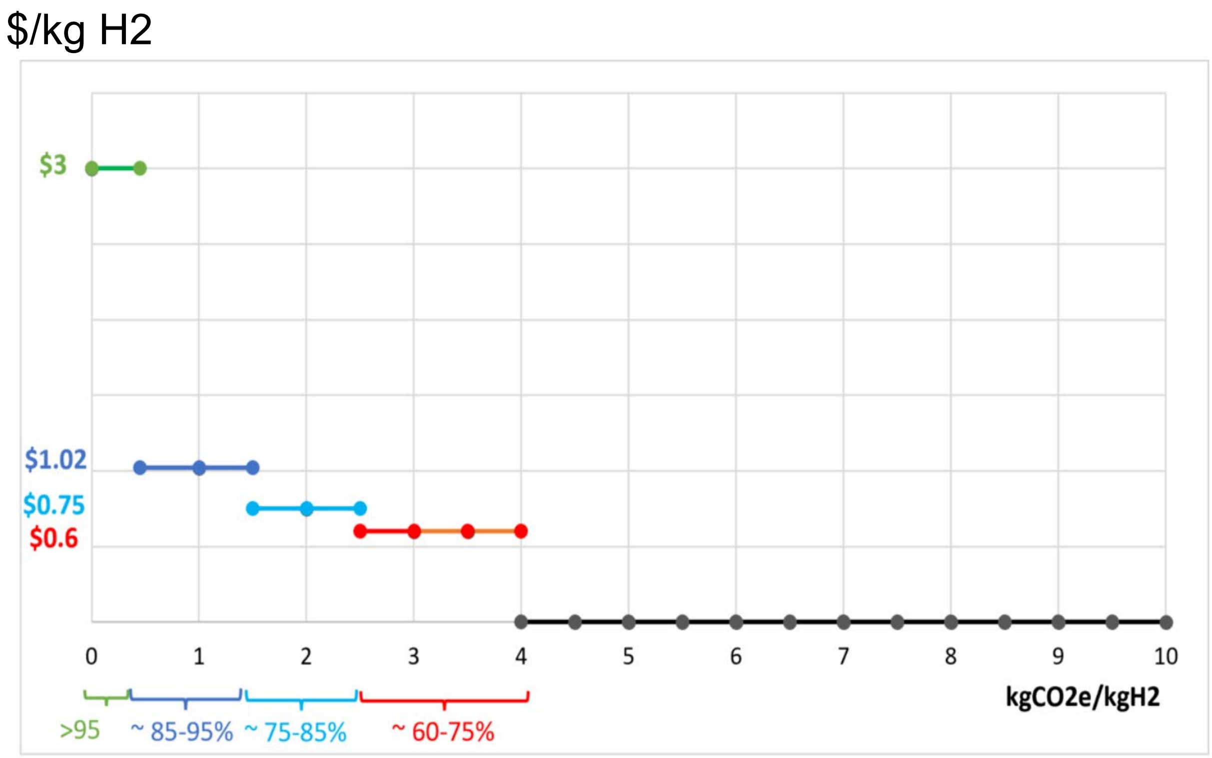
State hub activity is proliferating.





Generous federal incentives and support mechanisms: IRA

- 10-yr Production Tax Credits (PTC) for "clean" hydrogen
- Biggest hydrogen subsidies in the world; long-lived (all facilities that commence construction by 2032)
- Technology-neutral; "clean" hydrogen defined as achieving at a minimum ~60% GHG reductions relative to "grey" hydrogen
- Huge implications:
  - Green hydrogen can start competing with grey hydrogen in some places in the U.S. today, and in most places by 2030; this is more than 10 years ahead of schedule
  - Green hydrogen can start competing with fossil fuels in some difficult applications – steel, fertilizer, trucks



NRDC Blog: IRA Hydrogen Incentives: Climate Hit or Miss? TBD.

Recommendations

General principle: Hydrogen in service of affordable decarbonization.

[Hydrogen deployment] must be done in a strategic and holistic way, taking into consideration the potential role of hydrogen within a portfolio of solutions to tackle the climate crisis.

- *DOE, Draft National Hydrogen Strategy and Roadmap*

Hydrogen deployment should support the most affordable, efficient and beneficial transition to a clean economy.

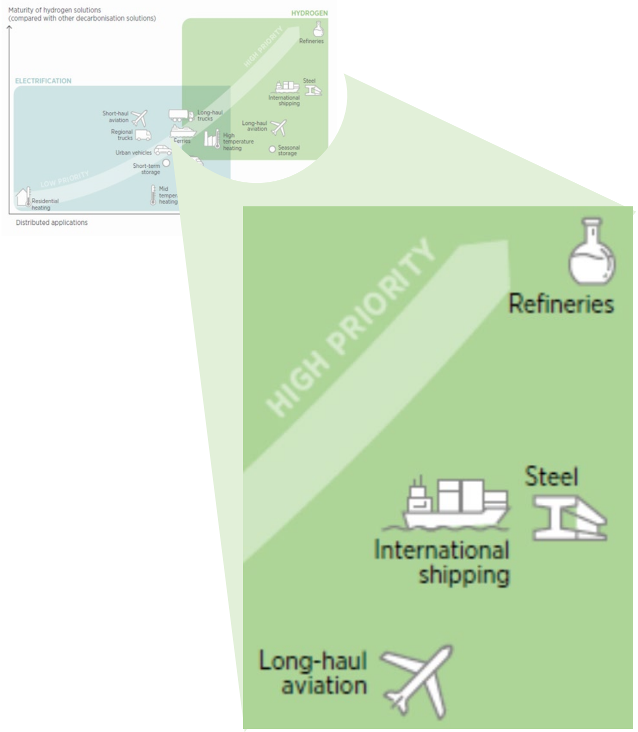
Production: Rigorous standards and prioritize green hydrogen. Big opportunity for state leadership and race to the top.

- Framework should include lifecycle emissions, “well-to-gate”;
- Low and climate-aligned carbon intensity limit on lifecycle emissions – no more than 2-2.5 kgCO2e/kgH2;
- Prioritize green hydrogen:
  - Best technoeconomics
  - Most promising long-term viability and export potential
  - Lowest air pollution risks

	Lifecycle Emissions of “ Clean Hydrogen” kgCO2/kgH2
DOE draft CHPS	4
IRA, maximum allowable emissions	4
European Commission (DELIVERED, i.e. includes delivery emissions, not just production)	3.4
Several groups proposal to DOE in their responses to the Hydrogen Hubs RFI	2 - 2.5
New Mexico House Bill 4 - Hydrogen Hub Development Act (not passed)	2

BUT: will look for hubs that maximize emissions reductions

End-Uses: Strongly focus on "grey to green" shift and hard-to-electrify applications.



(1) Target strategic, high-impact uses for clean hydrogen. This will ensure that clean hydrogen will be utilized in the highest value applications, where limited deep decarbonization alternatives exist.

-- DOE Draft National Hydrogen Roadmap and Strategy

Pipelines: Too soon. Prioritize co-location.

- Lock-in and stranded asset risks due to uncertainties
  - European “No-regret hydrogen” proposal
  - National Academies of Science: hydrogen deployment will unlikely be localized; networks will likely be more regional

- Leakage risks

- Prioritize co-location of hydrogen production and use until market matures

Ensure Benefits for Labor Groups and Local Communities

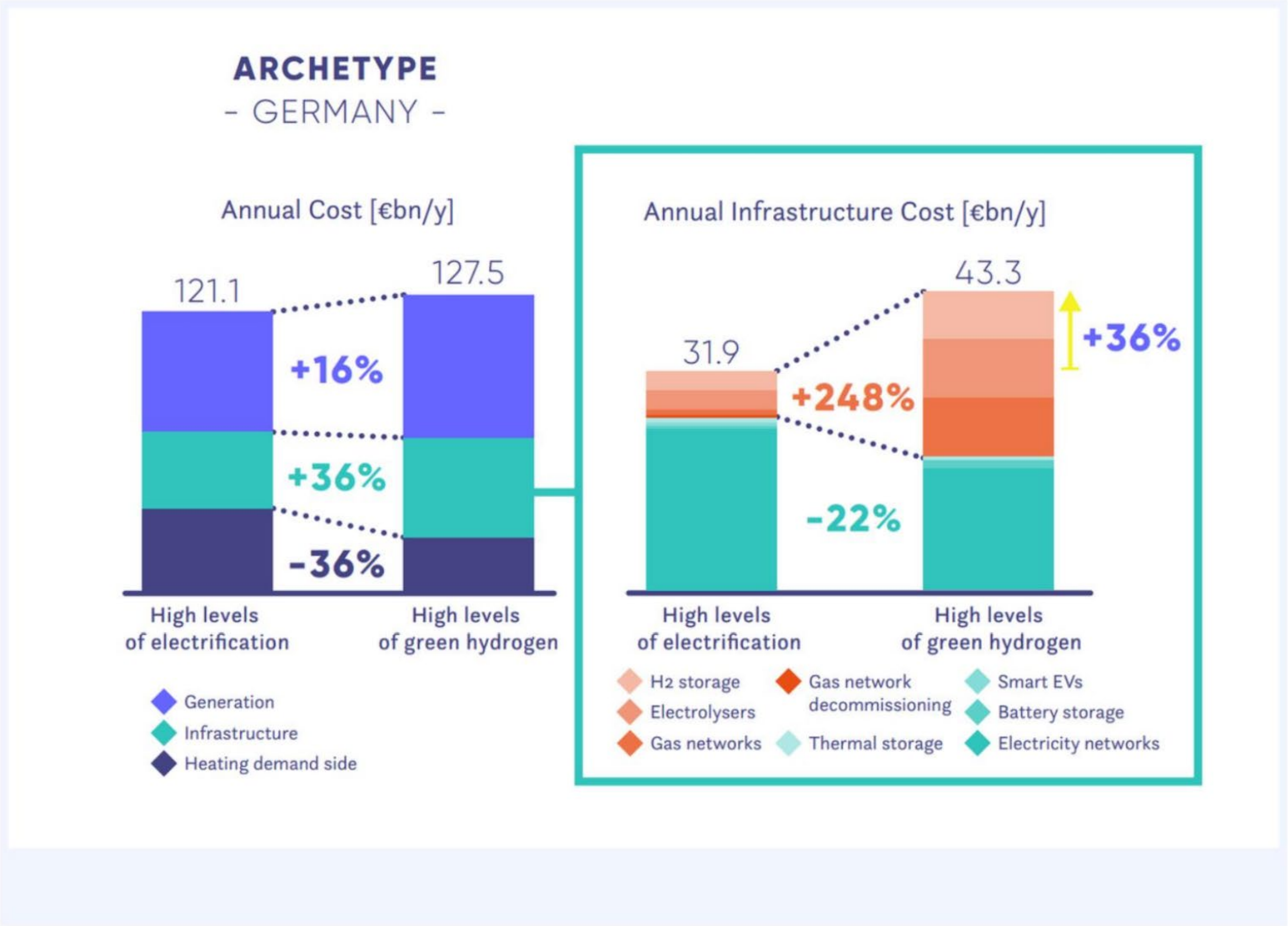
- Engage early! And meaningfully. We need to bring our societies with us.
- Community Benefits Agreement required in hubs process.

Questions?

rfakhry@nrdc.org

APPENDIX

European Climate Foundation: System "Supersizing"



Thank you for attending!

Clean Hydrogen State Working Group Members: Please join the 4:00 pm ET link on your calendars for a states only kick-off of the Working Group!