EERC | UND UNIVERSITY OF NORTH DAKOTA

Critical Challenges. Practical Solutions.

Energy & Environmental Research Center (EERC)

THE MARKET FOR HYDROGEN

June 7, 2024

Tyler Hamman
Assistant Vice President for Strategic Partnerships

OUR VISION

TO LEAD THE WORLD IN
DEVELOPING SOLUTIONS
TO ENERGY AND ENVIRONMENTAL CHALLENGES.



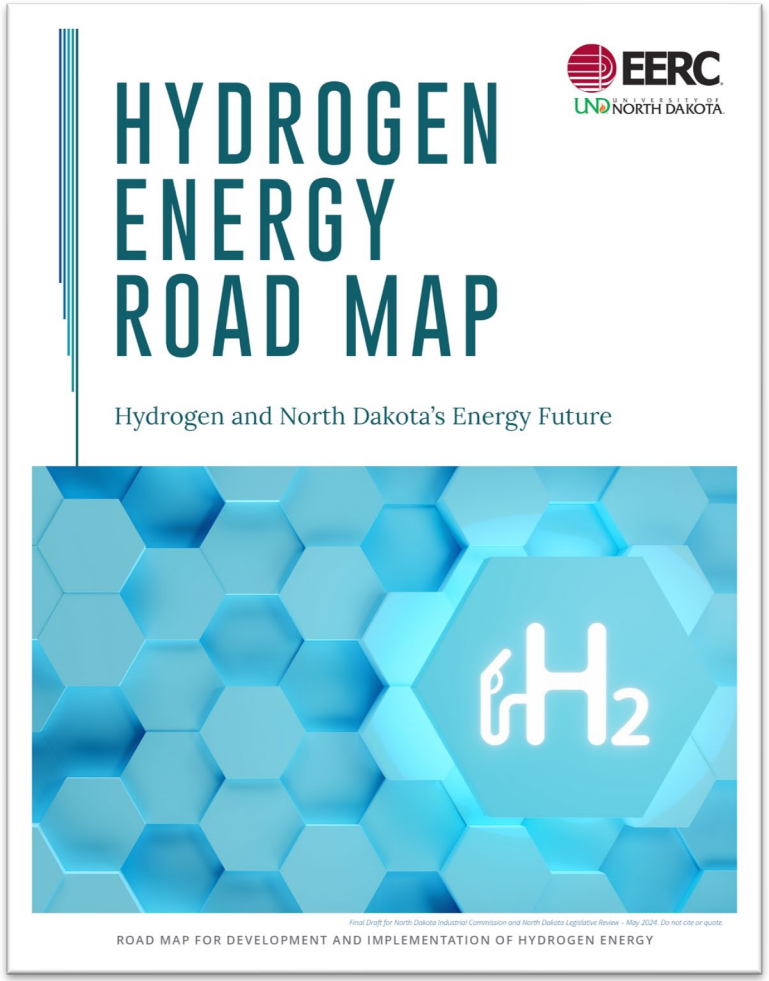

CORE RESEARCH PRIORITIES

- Carbon Management
- Oil & Gas
- Hydrogen
- Alternative Fuels & Renewable Energy
- Coal Utilization & Emissions
- Energy–Water
- Rare-Earth Elements and Critical Materials


OUR FACILITIES

254,000 FT^2 OF FACILITIES

HYDROGEN ENERGY ROAD MAP



- Directed by North Dakota Legislature in 2020 (SB 2014)
  - Major Topics:
    - ♦ Basis for Hydrogen
    - ♦ Producing Low-Carbon Hydrogen
    - ♦ Working with Hydrogen
    - ♦ Opportunities for North Dakota
    - ♦ Hydrogen Policy

WHAT IS HYDROGEN?

Hydrogen (H_2) is the simplest and most abundant element known. You might recognize it from the chemical formula for water – H_2O!

- Hydrogen can be made using a variety of domestic energy resources.
- Hydrogen can be produces through several processes, including:
  - Electrolysis; Direct Solar Water Splitting
  - Steam Methane Reforming
  - Biological (e.g., algae)
- Currently, the U.S. produces 10 million metric tons of hydrogen each year.

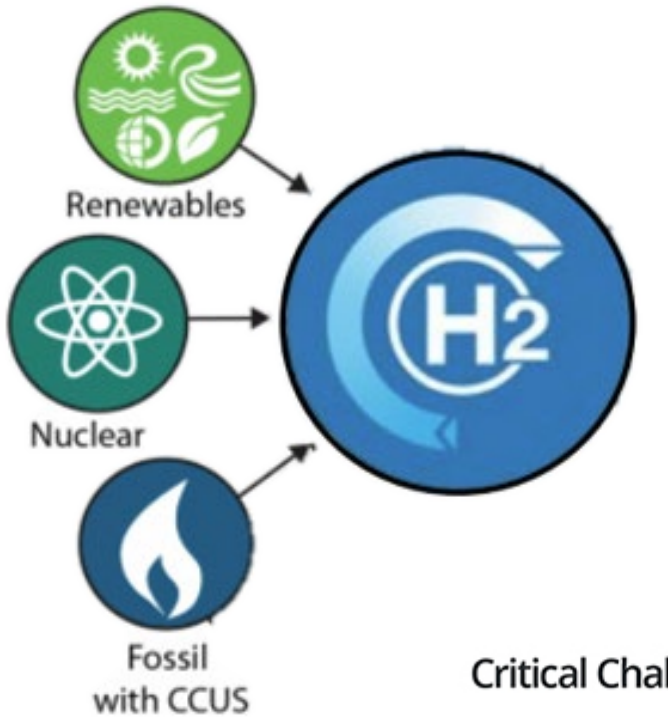
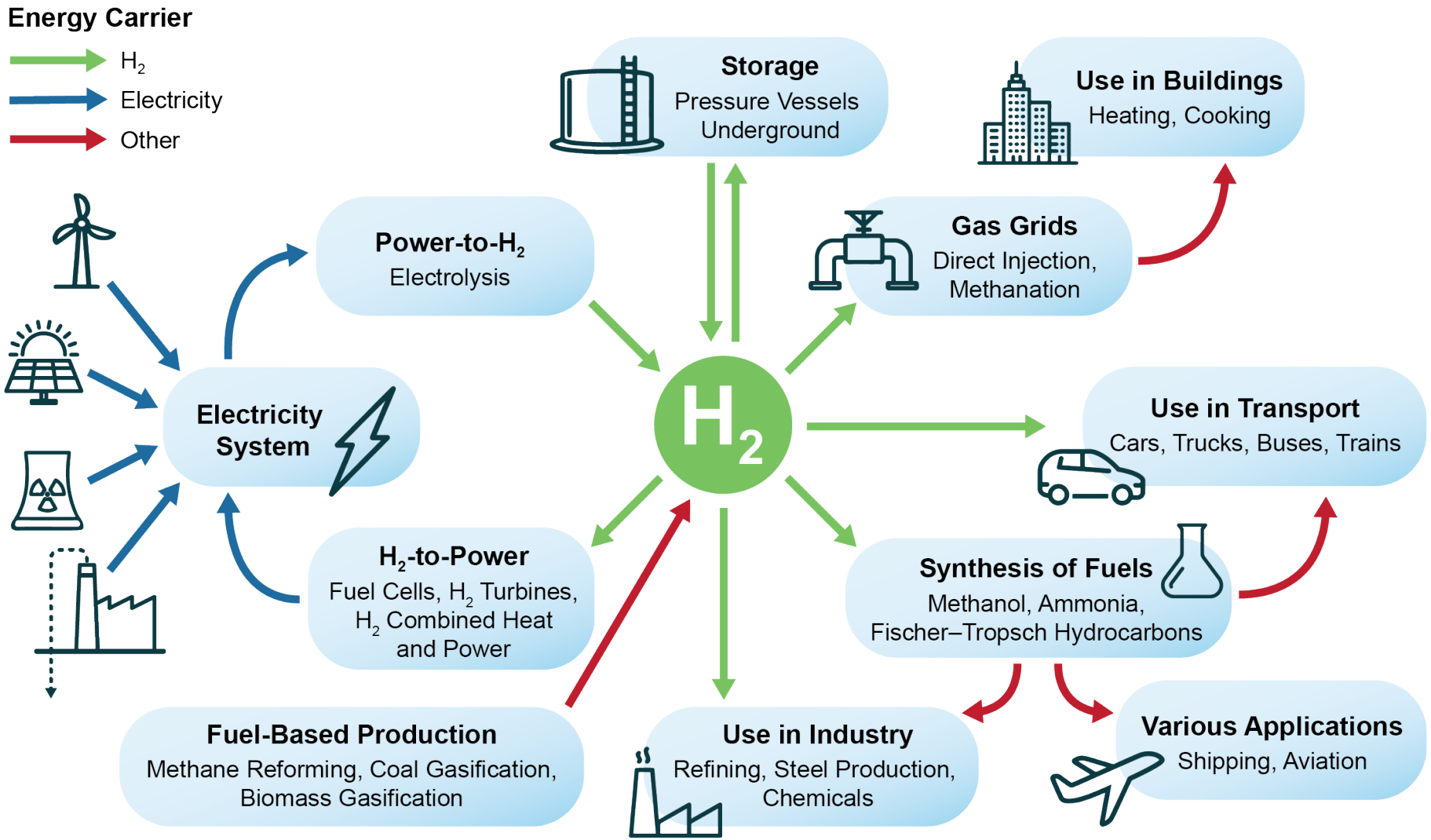


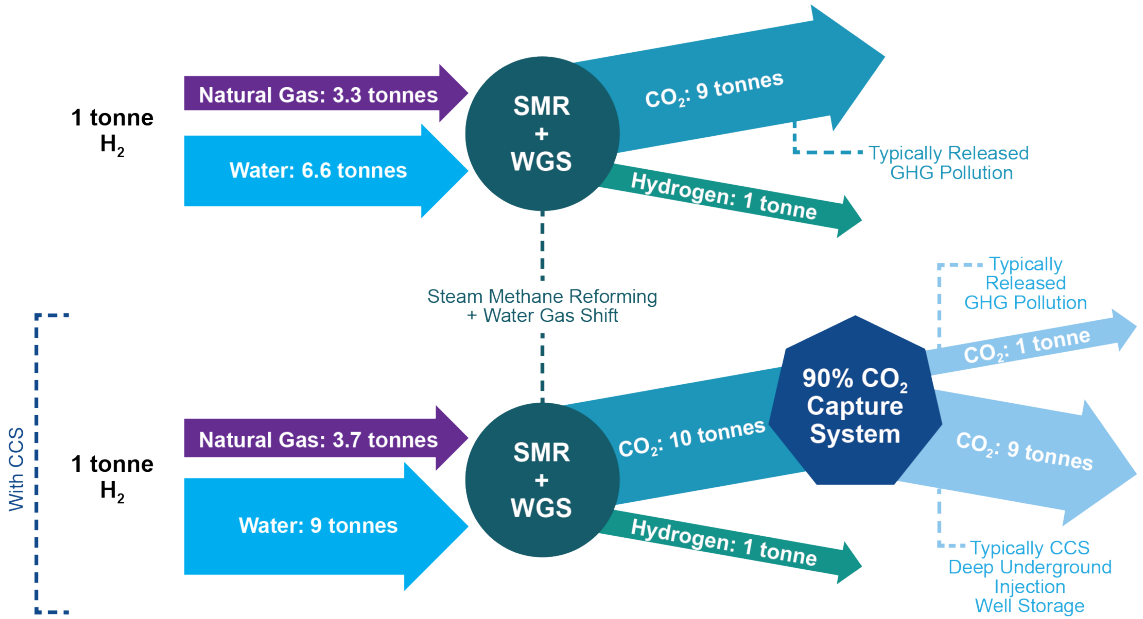
Image courtesy of OECD, 2023.

WHY HYDROGEN?

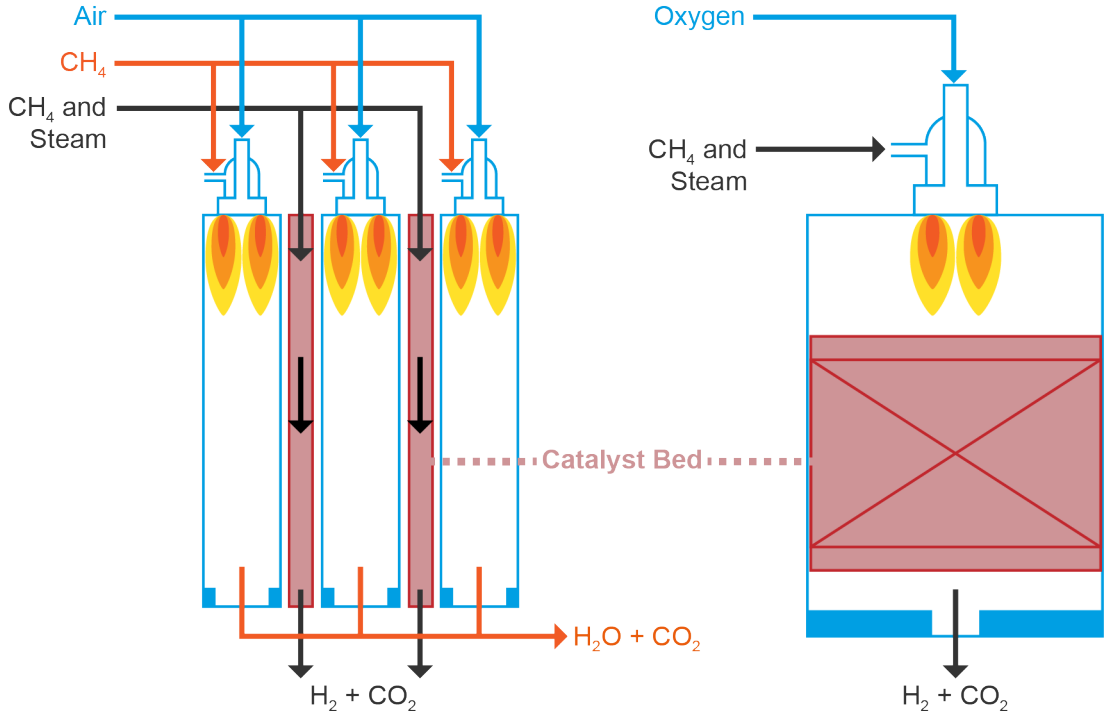


HYDROGEN PRODUCTION

CO_2 EMISSIONS FROM TODAY'S MOST COMMON HYDROGEN PRODUCTION METHOD

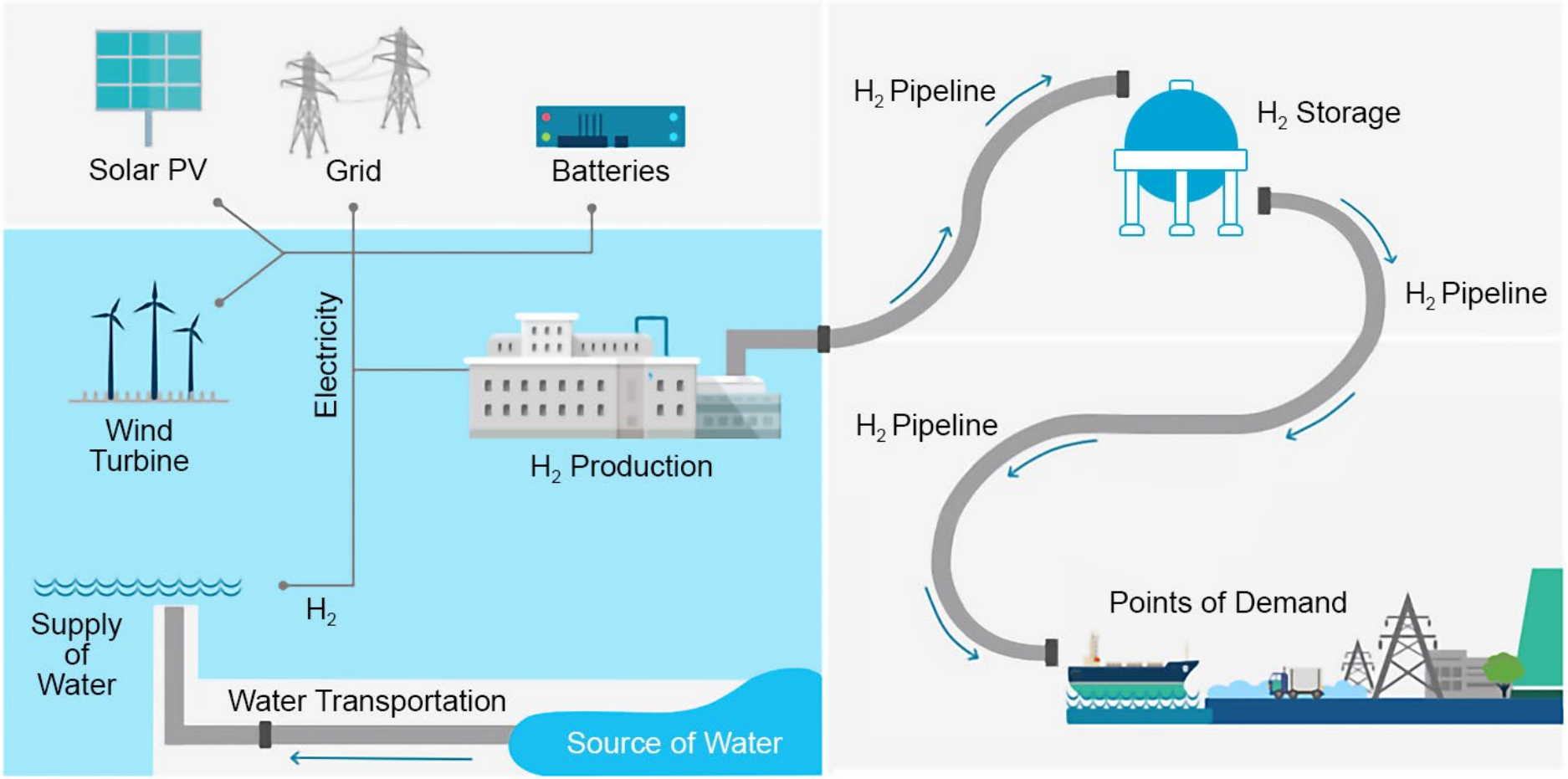


SMR (LEFT) VERSUS ATR (RIGHT) FOR HYDROGEN PRODUCTION



HYDROGEN PRODUCTION

NET-ZERO (GREEN) HYDROGEN FROM RENEWABLE ENERGY



PATH FORWARD

Lessons Learned

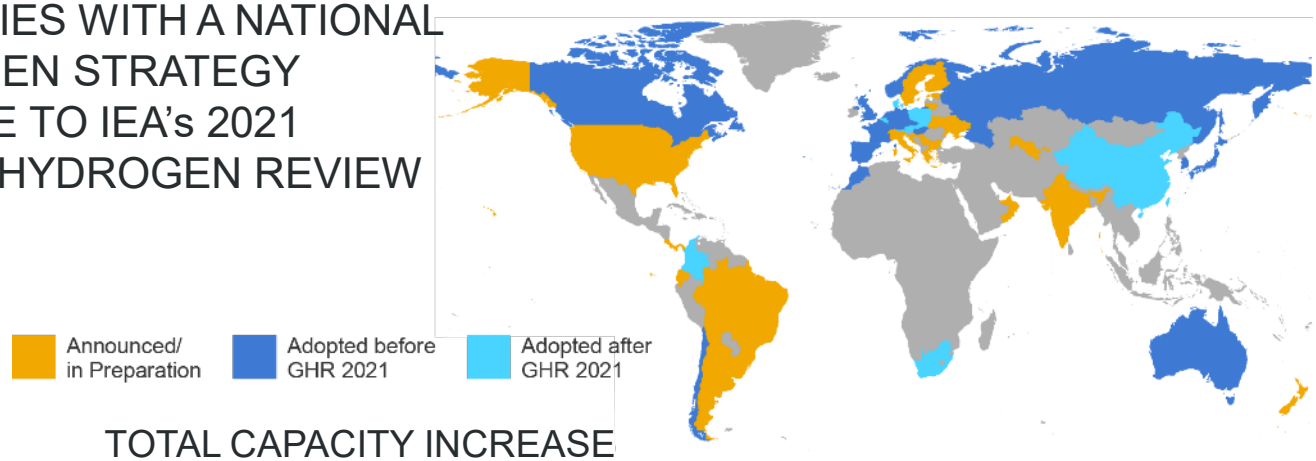
- 2003 State of the Union, President Bush directs $1.2 billion to develop H_2-powered automobiles

  "…so that the first car driven by a child born today could be powered by hydrogen, and pollution-free."

- Chicken and Egg Problem…
  - Market hesitant to commit to production without confidence in demand and vice versa

PATH FORWARD

COUNTRIES WITH A NATIONAL HYDROGEN STRATEGY RELATIVE TO IEA's 2021 GLOBAL HYDROGEN REVIEW

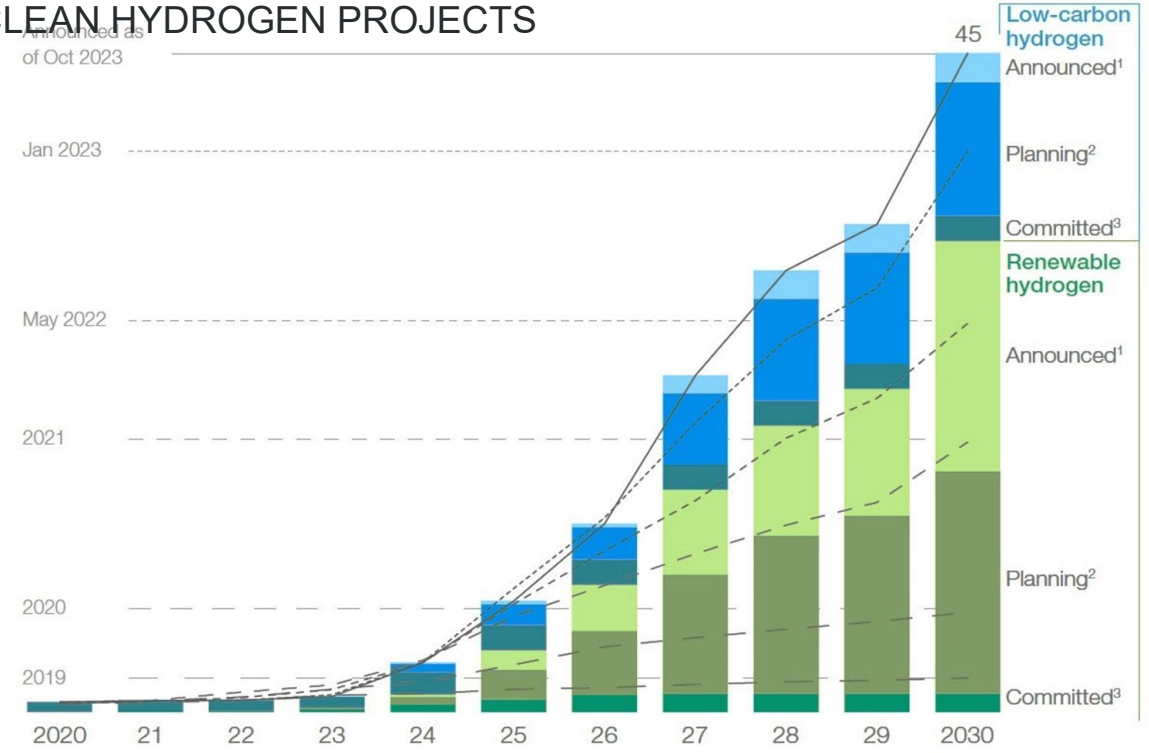


What has Changed

- Ever-increasing global focus on decarbonized fuels
- Maturing technology = decreasing cost
- Increased federal support
  - $8 billion clean H_2 program under IIJA
  - 45V Production tax credit for clean H_2
- Diversifying end-uses

IEA HYDROGEN POLICY CATEGORIES

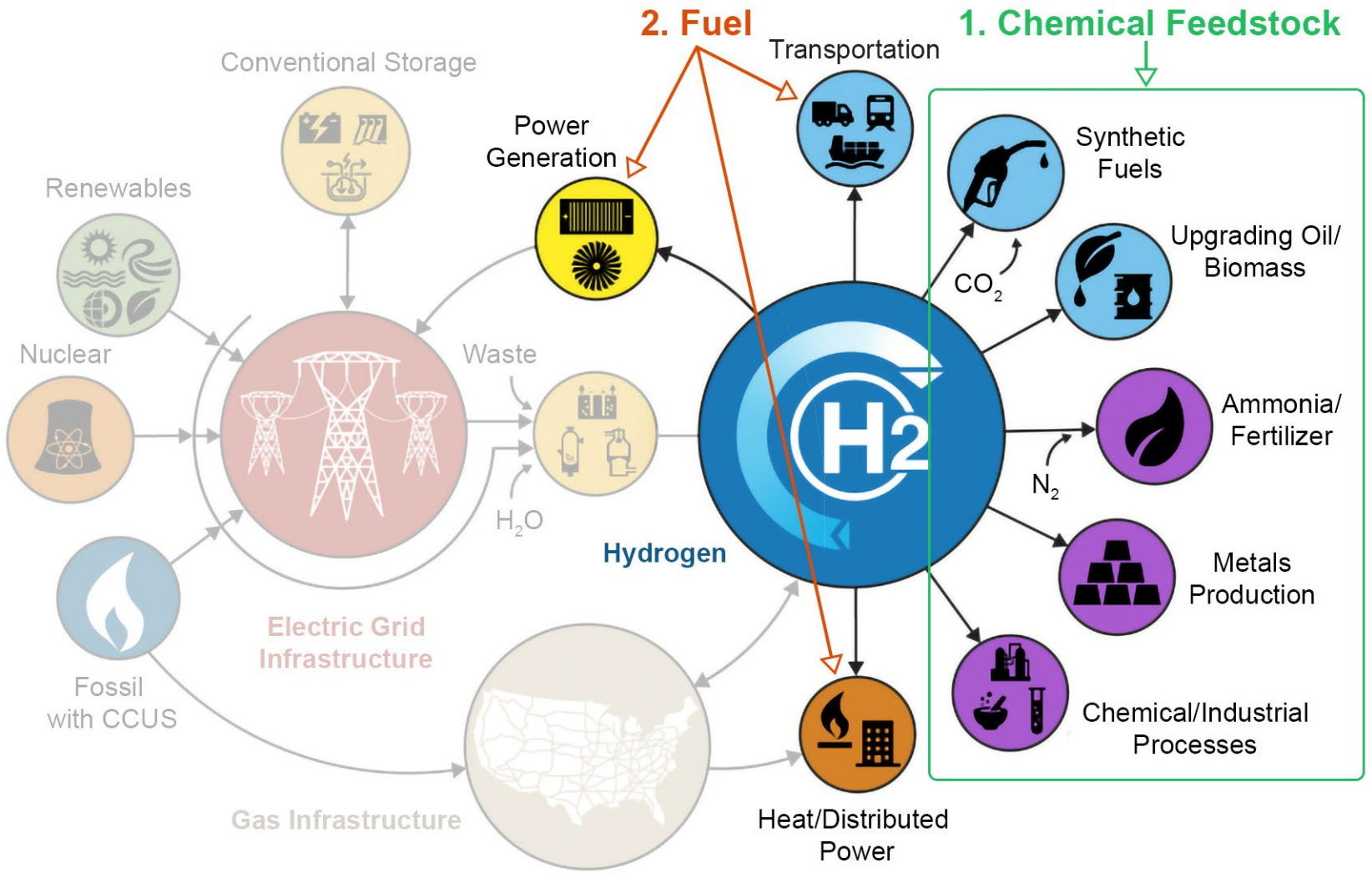
TOTAL CAPACITY INCREASE OF ANNOUNCED GLOBAL CLEAN HYDROGEN PROJECTS



HYDROGEN HAS MANY POTENTIAL USES – BUT TWO MAJOR GROUPS

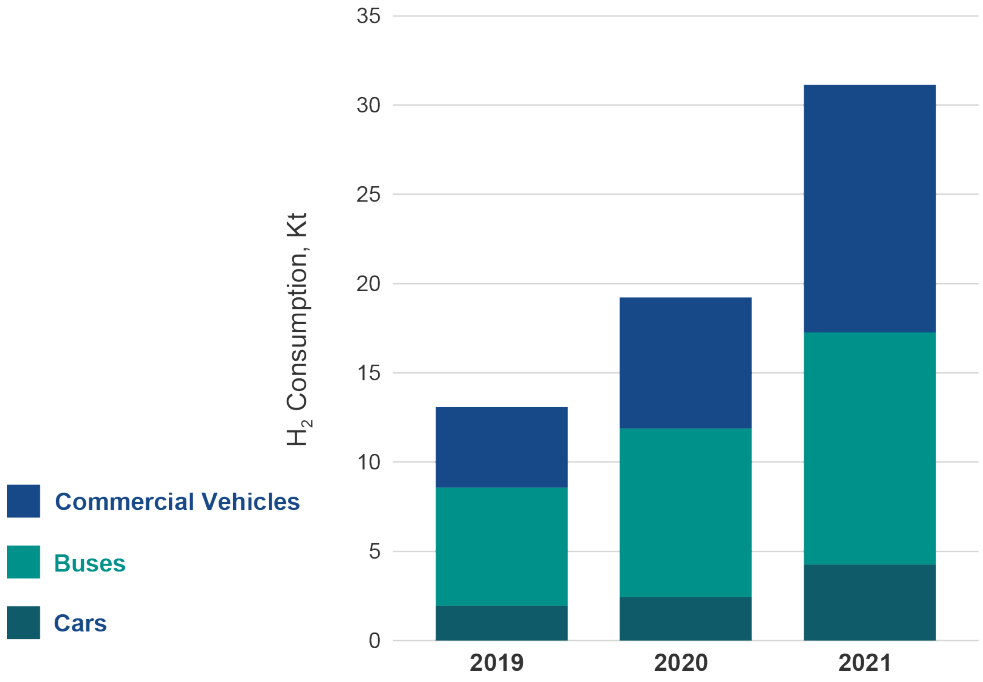
1. Today's major market is as a chemical feedstock.
2. To attain low-cost economy of scale, hydrogen likely will need to capture a portion of the fuel / energy carrier market.

The transportation market is roughly 66x the size of the ammonia market.

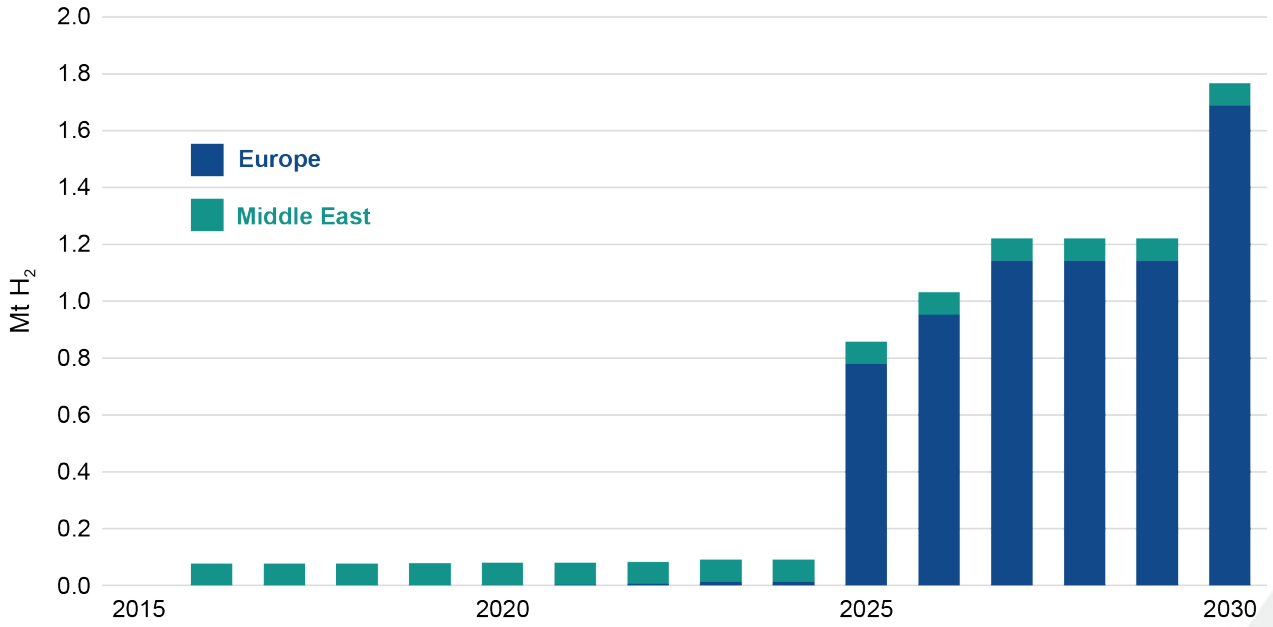


HYDROGEN USE EXPECTED TO GROW TENFOLD BY 2050

GLOBAL HYDROGEN CONSUMPTION IN ROAD TRANSPORT

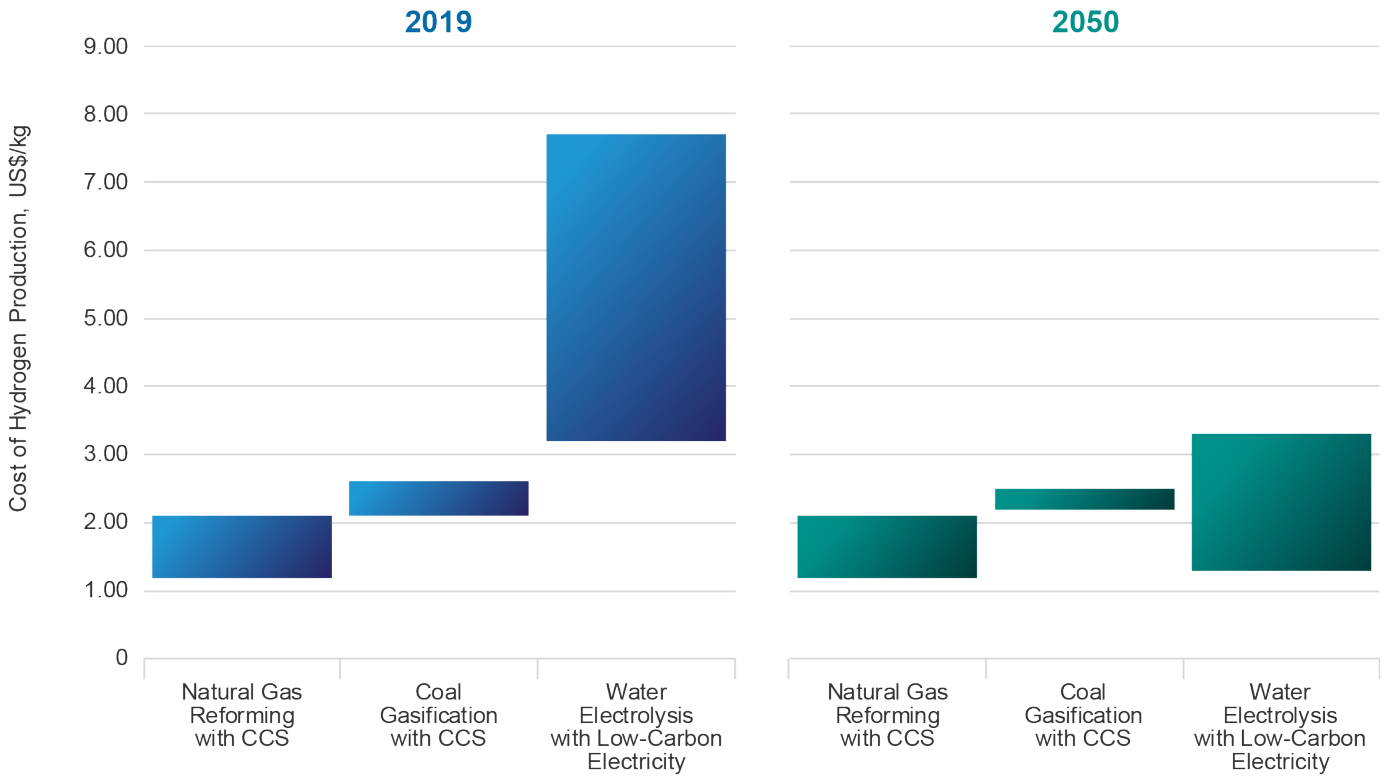


LOW-CARBON HYDROGEN PRODUCTION CAPACITY FOR STEELMAKING VIA DIRECT REDUCED IRON



DECLINING COSTS WILL DRIVE COMPETITION

COST PROJECTIONS FOR LOW-CARBON HYDROGEN



1 Dollar

1 Kilogram

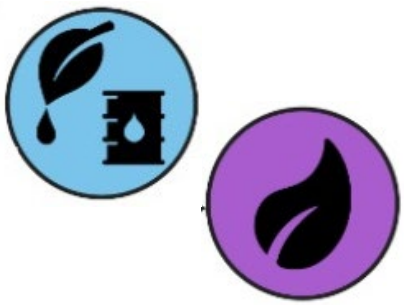
1 Decade

ENERGY earthshots U.S. DEPARTMENT OF ENERGY | Hydrogen

LOW-CARBON HYDROGEN END-USE MARKET EVOLUTION

Immediate market: minimal end-user adjustments

- Current hydrogen end-uses, especially internal uses
- Liquid-hydrocarbon fuel processing and ammonia production for fertilizers
- Roughly 10 million tonnes per year (tpa) in US



Near-term market: limited end-user adjustments

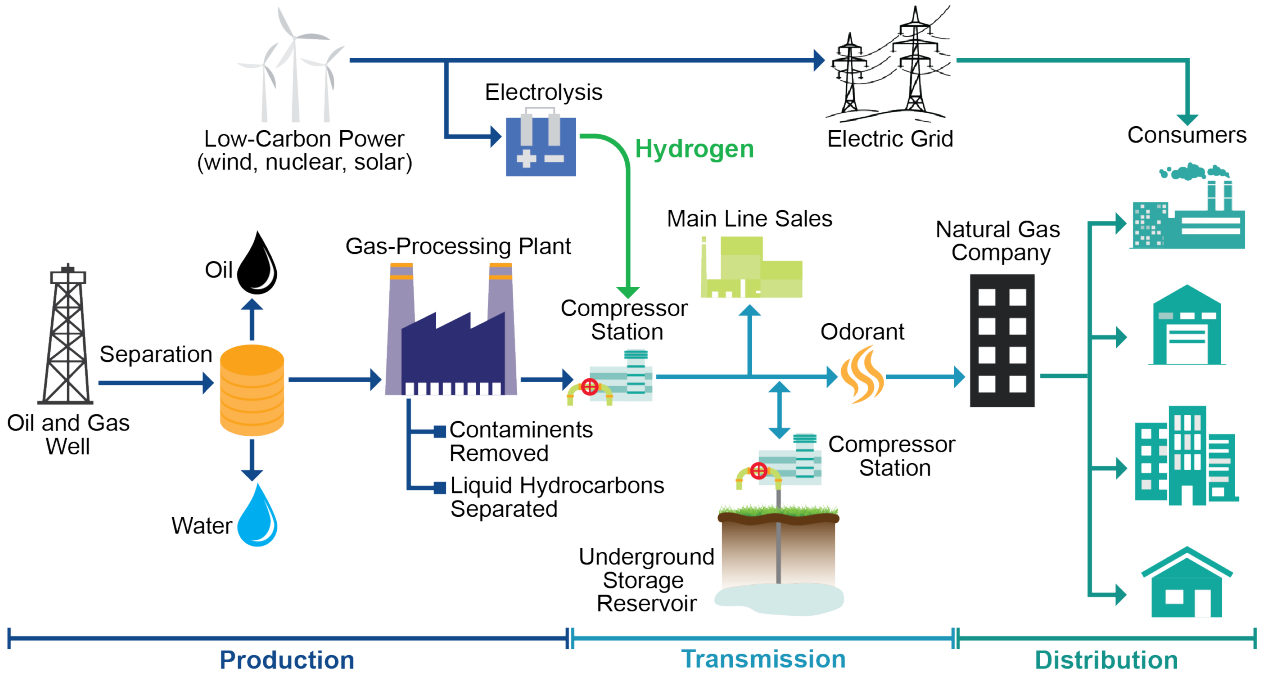
- Limited amounts (likely less than 20 vol%) of hydrogen blended into natural gas
- Fuel end-uses for distribution (heating) and electric power generation as well as non-traditional hydrogen chemical end-uses

Longer-term market: substantial end-user adjustments to equipment/ appliances, infrastructure, and workforce

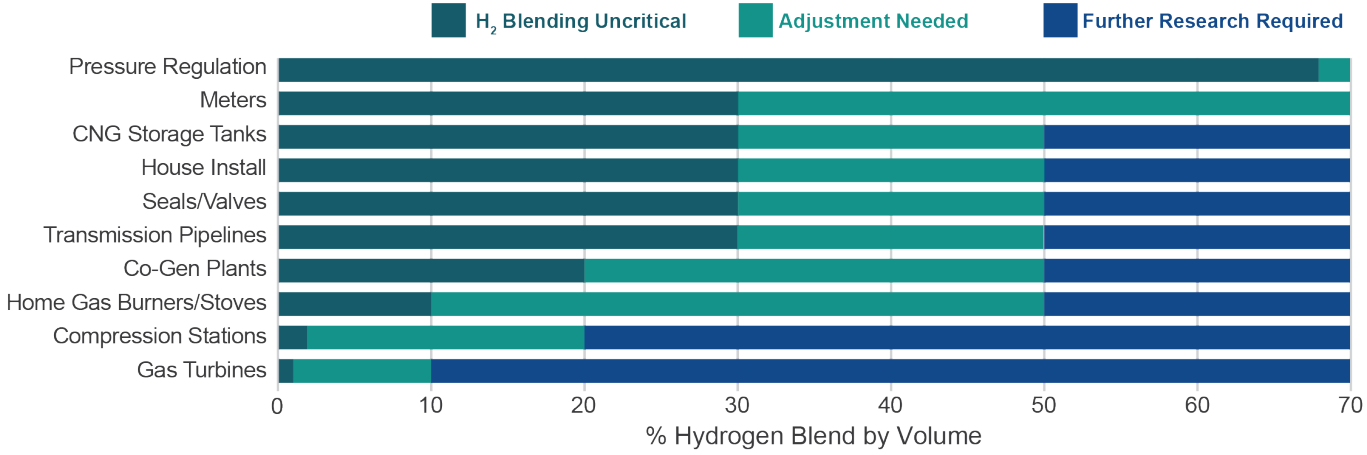
- Higher concentration blends and pure hydrogen: 50-70 million tpa by 2050 in US
- End-uses, many served by existing transmission pipelines:
  - Distribution (heating) and electric power generation
  - Long-term, large-volume and long-distance energy storage and transportation
  - Transportation-fuel end-uses: fuel cell heavy-duty trucks, marine, rail, and othe

NEAR-TERM MARKET DEVELOPMENT

- Hydrogen blending into existing natural gas pipelines
- Supplying green or blue hydrogen to existing demand at petroleum and renewable oil refineries
- Ammonia production



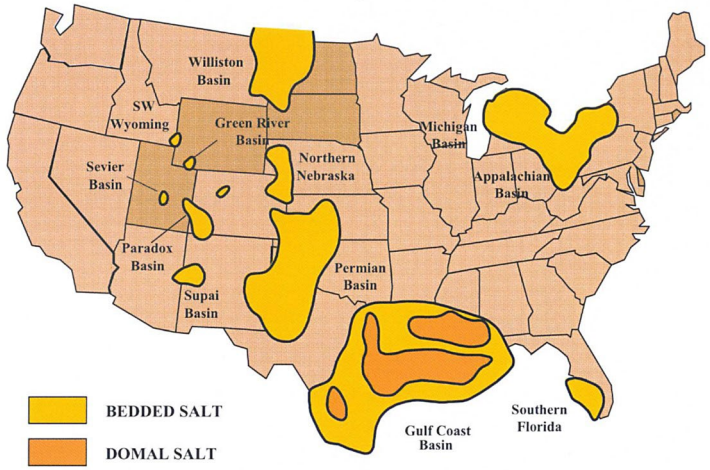
NOTIONAL LOW-CARBON HYDROGEN BLENDING UPSTREAM OF THE NATURAL GAS TRANSMISSION NETWORK



ESTIMATED HYDROGEN BLEND LIMITS FOR EXISTING INFRASTRUCTURE

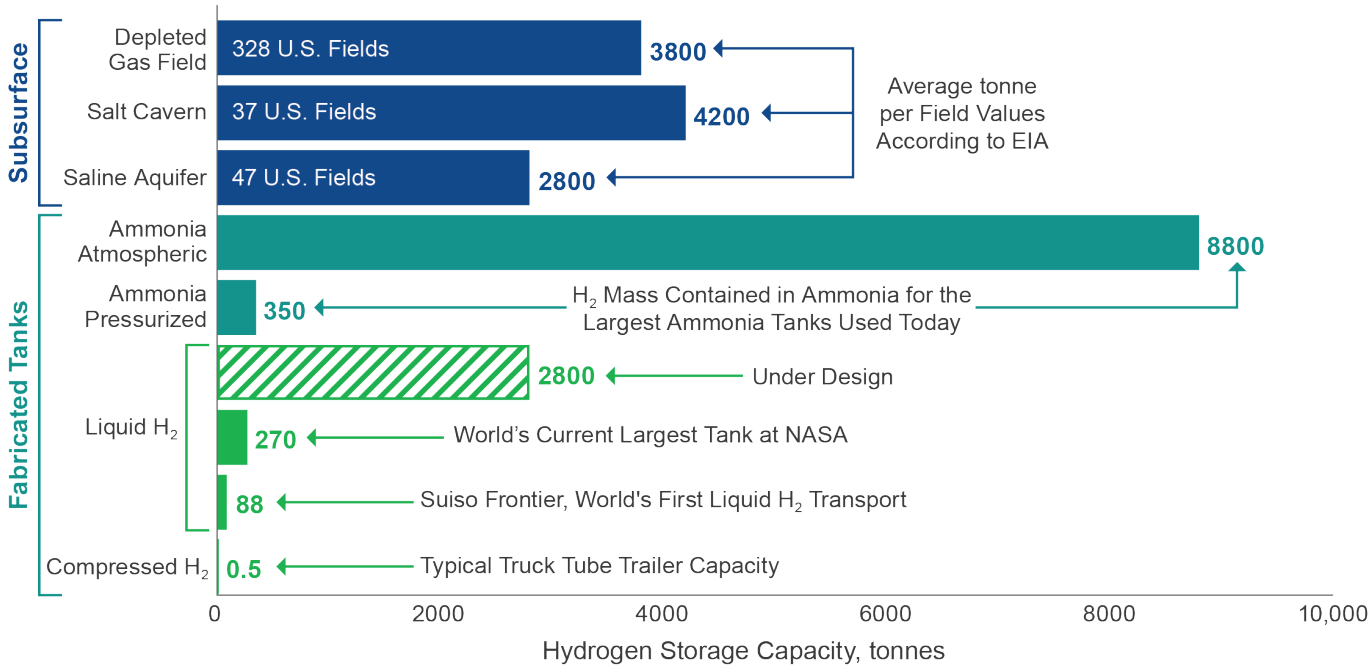
LONG-TERM MARKET DEVELOPMENT

- Infrastructure, infrastructure, infrastructure…
  - Hydrogen transport, bulk storage
- Continued deployment in the transportation sector



U.S. BEDDED AND DOMAL SALT FORMATIONS

HYDROGEN STORAGE CAPACITIES BY APPROACH

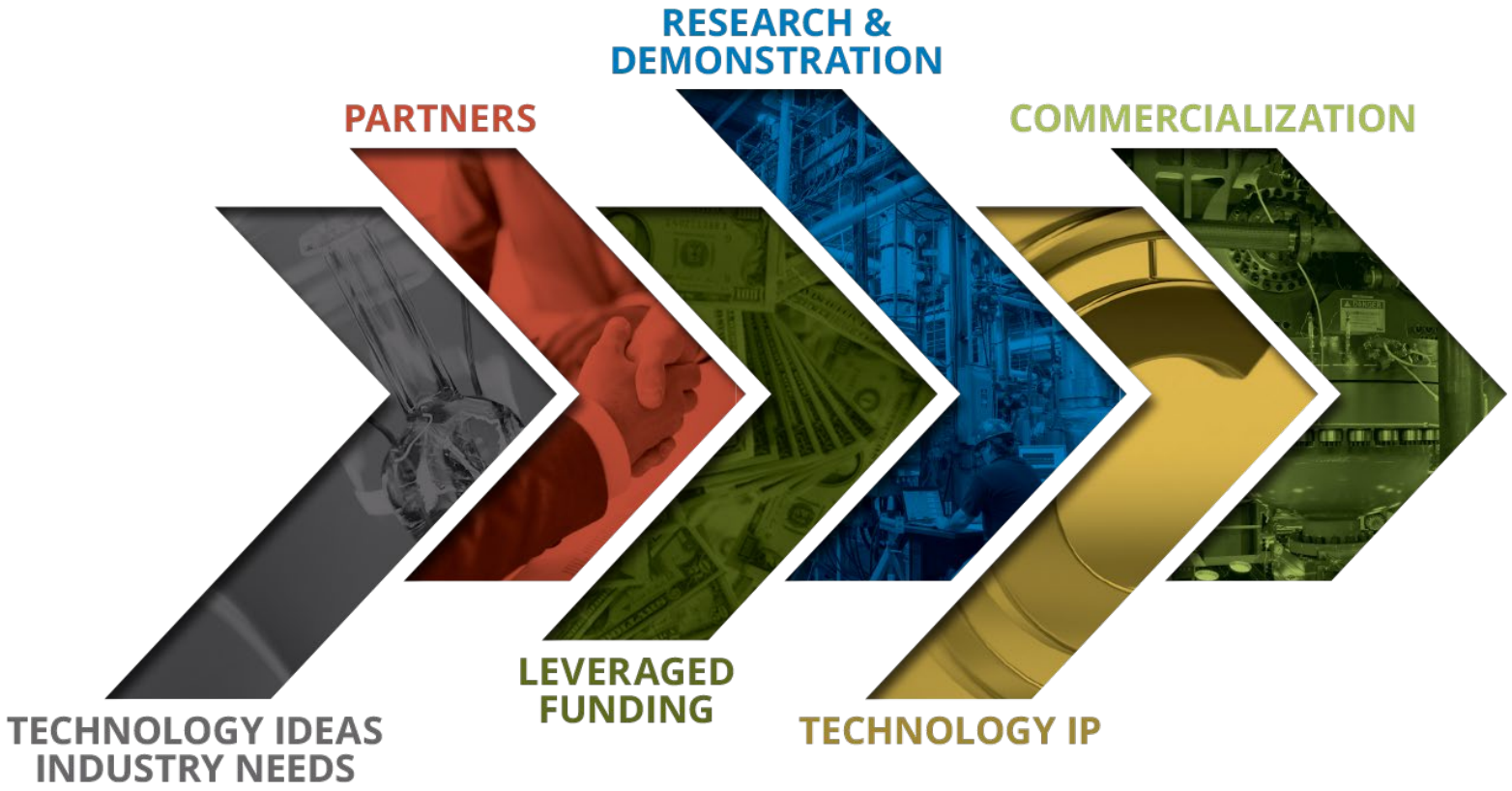


BIG OPPORTUNITIES, BIG CHALLENGES

Commercial Clean Hydrogen Deployment Essential to Achieving Decarbonization Goals	Challenges to Clean Hydrogen Deployment
Clean hydrogen accounts for 8% of US emissions reductions in a Net Zero by 2050 scenario*	Development of clean hydrogen production • Successful implementation of Regional Clean Hydrogen Hubs – Heartland Hydrogen Hub
Costs to achieve net zero increase by 0.5-1% GDP without clean hydrogen*	Tax Credit Uncertainty • Proposed section 45V tax credit guidance
Billions in private sector investment, value-added energy opportunities	Demand-side market development
Job creation	Continued support for transportation infrastructure network, CCS, permitting reform

*Source: “Harnessing Hydrogen: A Key Element of the U.S. Energy Future” National Petroleum Council, April 2024

TECHNOLOGY TO MARKET



Tyler Hamman
Assistant Vice President for Strategic Partnerships
thamman@undeerc.org
701.777.5074

Energy & Environmental Research Center
University of North Dakota
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018

www.undeerc.org
701.777.5000

THANK YOU

Critical Challenges. Practical Solutions.

EERC | UND UNIVERSITY OF NORTH DAKOTA

Critical Challenges. Practical Solutions.