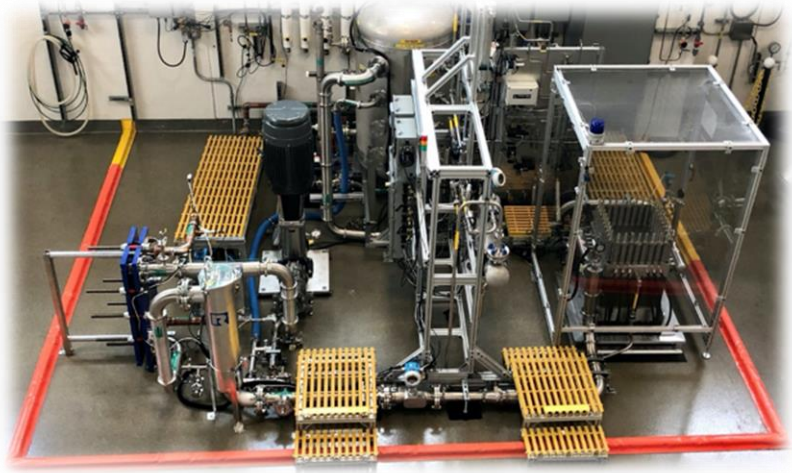
# U.S. Hydrogen Strategy and NREL Capabilities





Genevieve Saur - Genevieve.Saur@nrel.gov

Renewable Energy Hamburg: Forum Internationales "Facilitating Transatlantic Renewable Energy Cooperation U.S.-Hamburg"

October 10, 2023

# Recent Legislation Highlights

## Bipartisan Infrastructure Law

- **Includes $9.5B for clean hydrogen**:
  - $1B for electrolysis
  - $0.5B for manufacturing and recycling
  - $8B for at least four regional clean hydrogen hubs (Announcement soon)

## Inflation Reduction Act

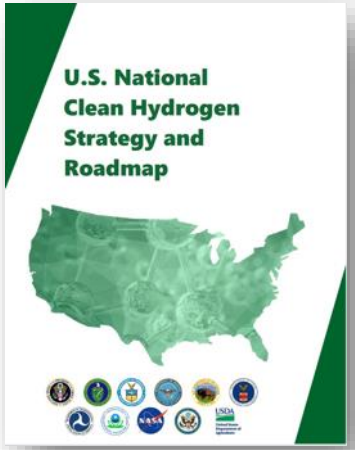
- **Includes significant tax credits** (e.g., up to $3/kg for production of clean hydrogen)

## Recently released US strategy documents

- US National Clean Hydrogen Strategy and Roadmap (Final)
- Pathways to Commercial Liftoff: Clean Hydrogen
- Clean Hydrogen Production Standard (CHPS)

## Administration Goals include:

- **Net-zero emissions economy by 2050 and 50–52% reduction by 2030**
- **100% carbon-pollution-free electric sector by 2035**




# Inflation Reduction Act (IRA) – Examples of $H_2$ and Fuel Cell Incentives

## Clean Hydrogen Production Tax Credit (45V) up to $3/kg

| Carbon Intensity (kg $CO_2$ per kg $H_2$) | Max Tax Credit ($/kg $H_2$)* |
|---|---|
| 4–2.5 | $0.60 |
| 2.5–1.5 | $0.75 |
| 1.5–0.45 | $1.00 |
| 0.45–0 | $3.00 |

**Clean Hydrogen Production Standard** (CHPS) Draft Released

## Qualified Commercial Clean Vehicles Credit (45W)

Creates a **new 30% credit** for commercial fuel cell electric vehicles through 2032, capped at **$40,000**:

- Class 1–3 vehicles: **$7,500 tax credit** for purchase of qualified clean vehicles
- Class 4 and above: **$40,000 tax credit**

## Alternative Fuel Refueling Property Credit (30C)

**Tax credit up to 30%** of the cost of alternative fuel refueling property up to **$100,000**

View more at: www.energy.gov/eere/fuelcells/financial-incentives-hydrogen-and-fuel-cell-projects
https://www.hydrogen.energy.gov/pdfs/clean-hydrogen-production-standard.pdf

* Well to gate, using GREET

# Drivers to Enable Clean Hydrogen at Scale and Cross-Agency roles, examples

| Supply | Midstream | End Use Demand |
|---|---|---|
| Production Tax Credit 45V, 45Q (Treasury) | Fueling Corridor Grants (DOT/JO) | Vehicle Tax Credits, Clean Fuels Credits, 48C (Treasury) |
| Electrolyzer RD&D BIL (DOE) | Bipartisan PIPES Act NPRM (DOT PHMSA) | State Policies (ZEV Mandates, H2 PTC)[1] |
| Manufacturing Tax Credit 48C (Treasury/DOE) | Manufacturing Tax Credit 48C (Treasury/DOE) | Clean Power Rule NPRM (EPA) |
| Regional Clean H2 Hubs BIL (DOE) | Regional Clean H2 Hubs BIL (DOE) | Buy Clean Standards (EOP) |
| | | Agency offtake (DOD, USPS, USDA, DOT, EPA, etc.) |
| | | Regional Clean H2 Hubs BIL (DOE) |

JO: Joint Office of Energy and Transportation; EOP: Executive Office of the President
NPRM: Notice of proposed rulemaking

1: ZEV Mandates see: https://www.c2es.org/document/us-state-clean-vehicle-policies-and-incentives/. Colorado's H2 PTC see: https://leg.colorado.gov/bills/hb23-1281.

https://www.energy.gov/sites/default/files/2023-06/h2amr-plenary-satyapal-2023_0.pdf

# Manufacturing of Hydrogen Production Equipment and Fuel Cells Eligible for $4 Billion in Tax Credits, among other technologies

## What is 48C?

- Competitively awarded Investment Tax Credit (ITC) established in 2009 with $2.3B
- Expanded by IRA with $10B available; guidance issued March 2023
- Projects receive up to 30% ITC
- Treasury, IRS, and DOE have opened applications for Round 1, which allocates up to $4B
- Approximately 40% of credits ($1.6B) will be allocated to projects in coal communities

- **Clean Energy Manufacturing and Recycling**
- **Critical Materials Processing, Refining, and Recycling**
- **Industrial GHG Emissions Reductions**

**Timeline & Review**

**Notice Released:** May 31

**Informational Webinar:** June 27

**Concept Papers Due:** July 31

**Full Applications Due:** July 2023

https://www.energy.gov/sites/default/files/2023-06/h2amr-plenary-satyapal-2023_0.pdf

# US Transportation Opportunities

## Funding Opportunities

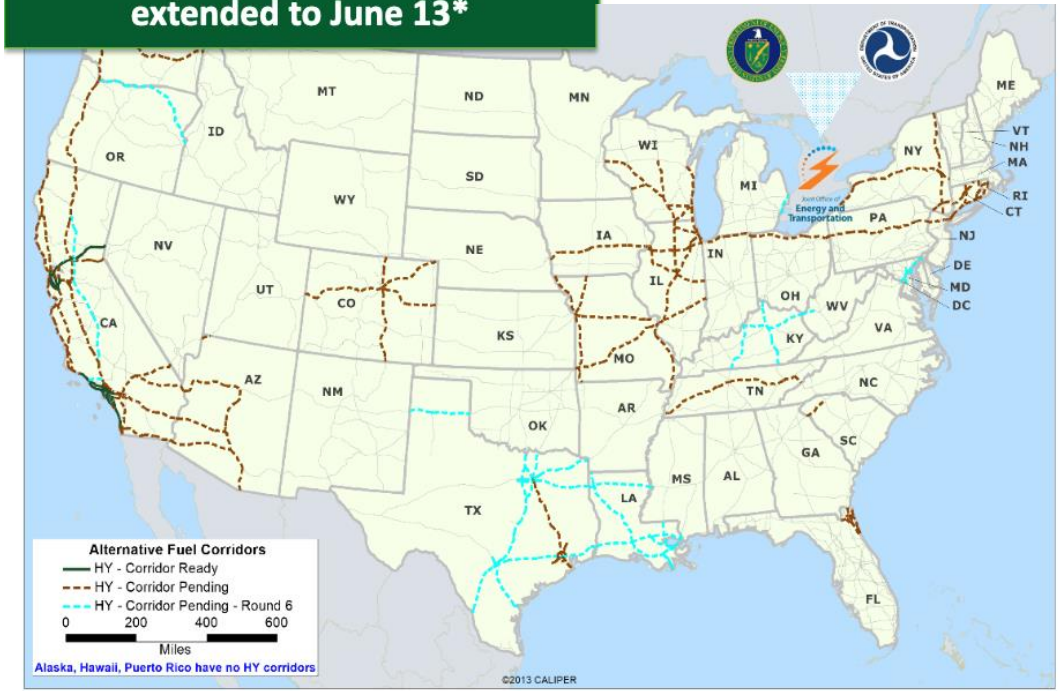
- **National Electric Vehicle Infrastructure (NEVI) Formula Program (DOT):** $5B for states to build a national EV charging network along corridors
- **Charging & Fueling Infrastructure (CFI) Discretionary Grant Program (DOT):** $2.5B in community and corridor grants for EV charging, as well as hydrogen, natural gas, and propane fueling infrastructure – applications now open!
- **Low- or No-Emission Vehicle Program (DOT):** $5.6B for low- and no-emission transit bus deployments – includes hydrogen

*www.driveelectric.gov/contact*

**Fueling corridors of interest for $H_2$**

**Deadline for the CFI program extended to June 13***

Joint Office of Energy and Transportation




*https://www.fhwa.dot.gov/environment/cfi/

# New EPA and DOT PHMSA Notice of Proposed Rules

## EPA issued proposed carbon emissions standards for fossil fuel-fired power plants

| New Turbines | Phase II (beginning 2032) | Phase III (beginning 2038) |
|---|---|---|
| Intermediate generators (20-50% capacity factor) | **Blending up to 30% low-GHG $H_2$** by volume can be used to meet the 1000-lb $CO_2$/MWh standard | |
| Base load generators (over ~50% capacity factor) | **Blending up to 30% low-GHG $H_2$** can be used to meet the 680-lb $CO_2$/MWh standard | **Blending up to 96% low-GHH $H_2$** can be used to meet the 90-lb $CO_2$/MWh standard |

For existing turbines >300 MW capacity, > 50% capacity factor: highly efficient generation coupled with 30% co-firing by volume low-GHG $H_2$, by 2038 co-firing with 96% low-GHG $H_2$

Clean Air Act Section 111 Regulation of Greenhouse Gas Emissions from Electric Generating Units (epa.gov)

## PHMSA issued proposed $H_2$ pipeline leak detection and repair as part of Leak Detection and Repair Rule

"Unless otherwise specified in the proposed amendments, the proposals in this NPRM apply the same requirements to hydrogen gas pipelines (and other gas pipelines) as to natural gas pipelines."

NPRM: Notice of Proposed Rulemaking

https://www.phmsa.dot.gov/news/usdot-announces-bipartisan-pipes-act-proposal-modernize-decades-old-pipeline-leak-detection

https://www.energy.gov/sites/default/files/2023-06/h2amr-plenary-satyapal-2023_0.pdf

# ~$8 Billion funding in 1 year 2022-2023!

**~$8Billion in Funding Announced in 2023!**

**June 2022**

- Clean $H_2$ Production, Storage, Transport, & Utilization

**Aug 2022**

- FOA for Clean $H_2$ Technologies & Decarbonize Grid
- IRA Passed

**Oct 2022**

- Draft National Clean $H_2$ Strategy & Roadmap Released
- H2Hubs FOA
- FOA for Nuclear-Coupled $H_2$ Production & Use
- Phase-One Winners of Incubator Prize
- $1.5M to Train the $H_2$ Workforce at MSIs

**Dec 2022**

- Lab Call for Technology Commercialization Fund
- H2TwinCities Winners Announced
- $47M for Affordable Clean $H_2$ Technologies

**Feb 2023**

- $7.4M for Zero-Emission M&HD Vehicles, Expansion of EV Charging in Underserved Communities


- Pathways to Commercial Liftoff: Clean $H_2$

**April 2023**

- $750M FOA Electrolysis, Manufacturing, & Recycling
- Nine Mile Point Begins $H_2$ Production
- President Biden Visits Cummins Power Generation Facility


- $4.5M for Turbine Efficiency Research

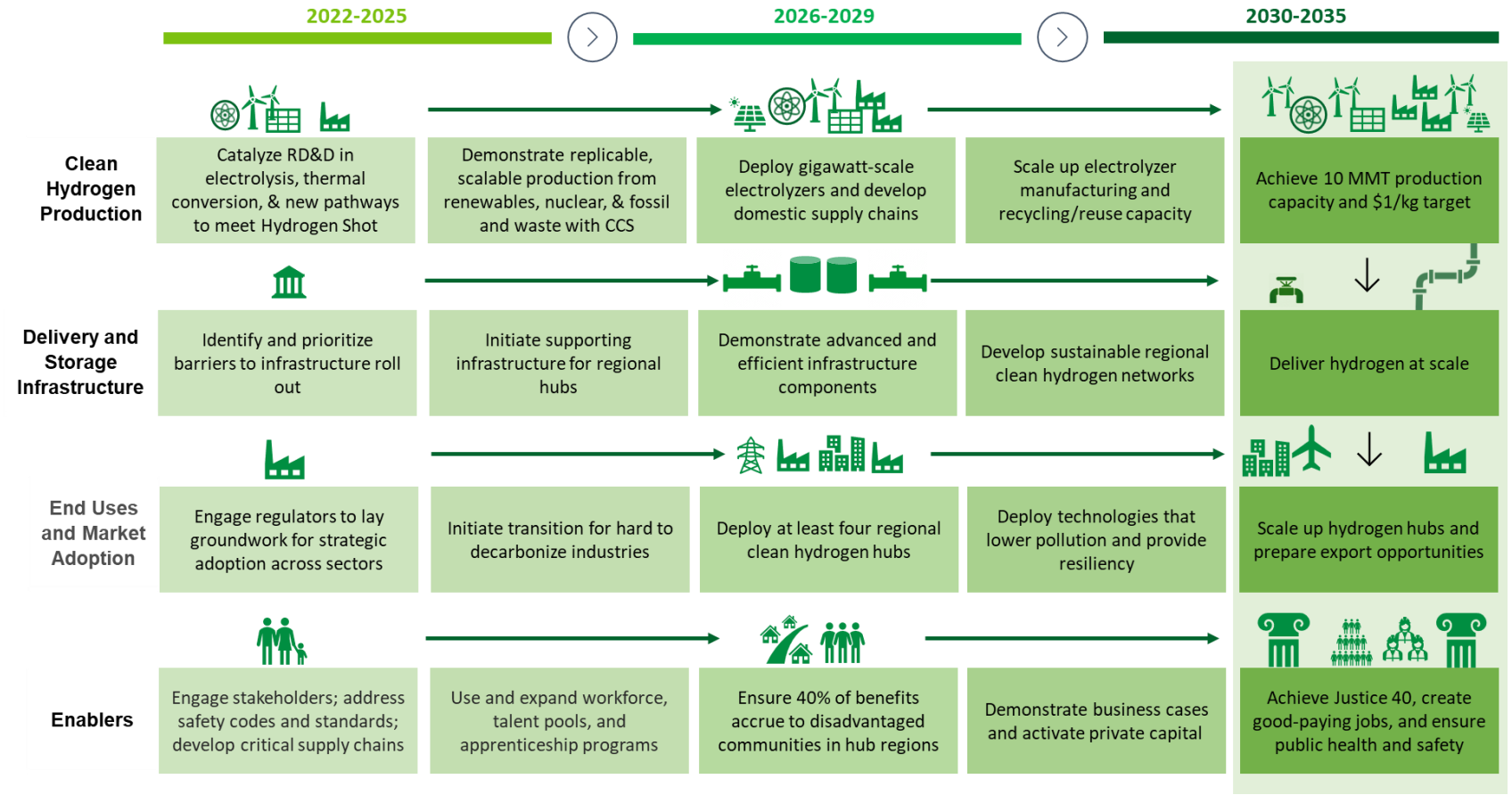
**June 2023**

- National Clean $H_2$ Strategy & Roadmap Released

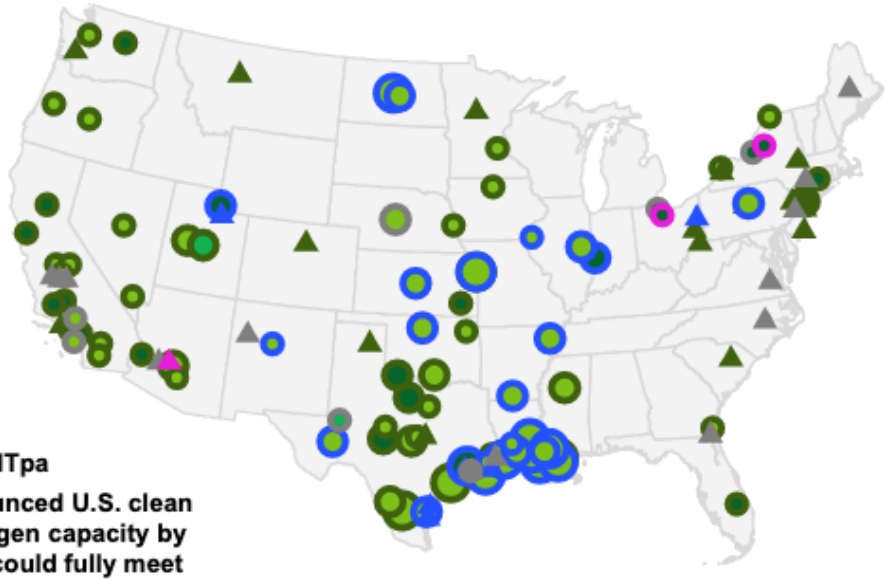

- $60M to Advance Clean $H_2$ Tech & Improve Power Grid

https://www.energy.gov/sites/default/files/2023-06/h2amr-plenary-satyapal-2023_0.pdf

# Actions from DOE Draft National Strategy and Roadmap



# Announced hydrogen projects across value chain, could fully meet 2030 target of 10 MMTpa demand



**12 MMTpa**

**Announced U.S. clean hydrogen capacity by 2030 could fully meet 10MMTpa expected demand**

Clean hydrogen production projects

**1.4 MMTpa**

**Clean hydrogen production projects**

Production projects which are being developed independently from midstream infrastructure and end uses

Integrated projects

**10.5 MMTpa (0.5 MMTpa operational)**

**Integrated projects**

Projects where production is co-developed with midstream infrastructure and / or specific end use(s)

Midstream and end use projects

**< 0.1 MMTpa**

**Midstream and end use projects**

Projects focused on midstream infrastructure and / or end uses without production co-development

**Announced H2 capacity**, ktpa

- >150
- 20 - 150
- 0 - 20
- N/A

**Hydrogen Pathway**

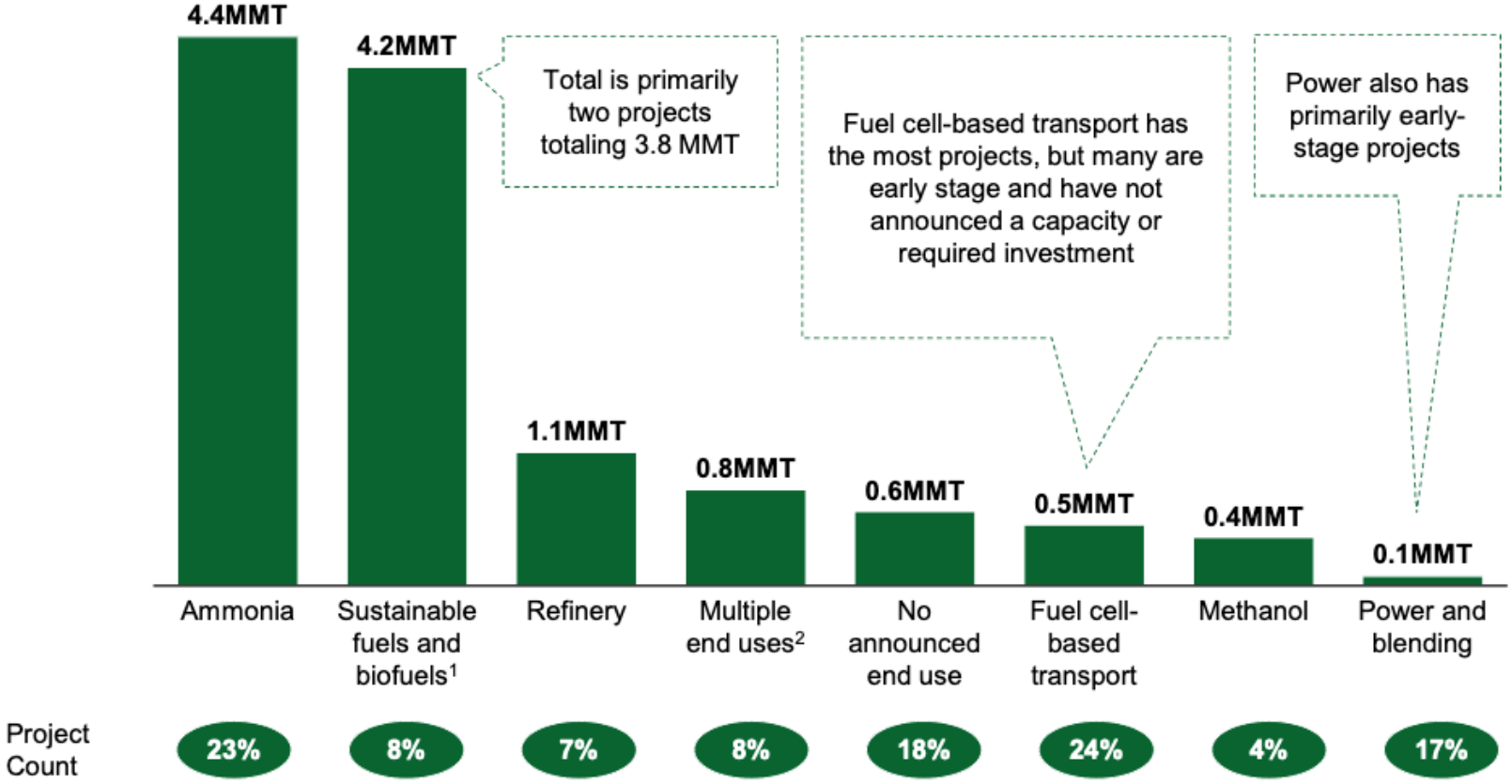
- Renewables w/ electrolysis
- Nuclear w/ electrolysis
- SMR/ATR + CCS
- Methane pyrolysis / N/A / Other

**Project type**

- Clean hydrogen production projects
- Midstream and end use projects
- Integrated projects

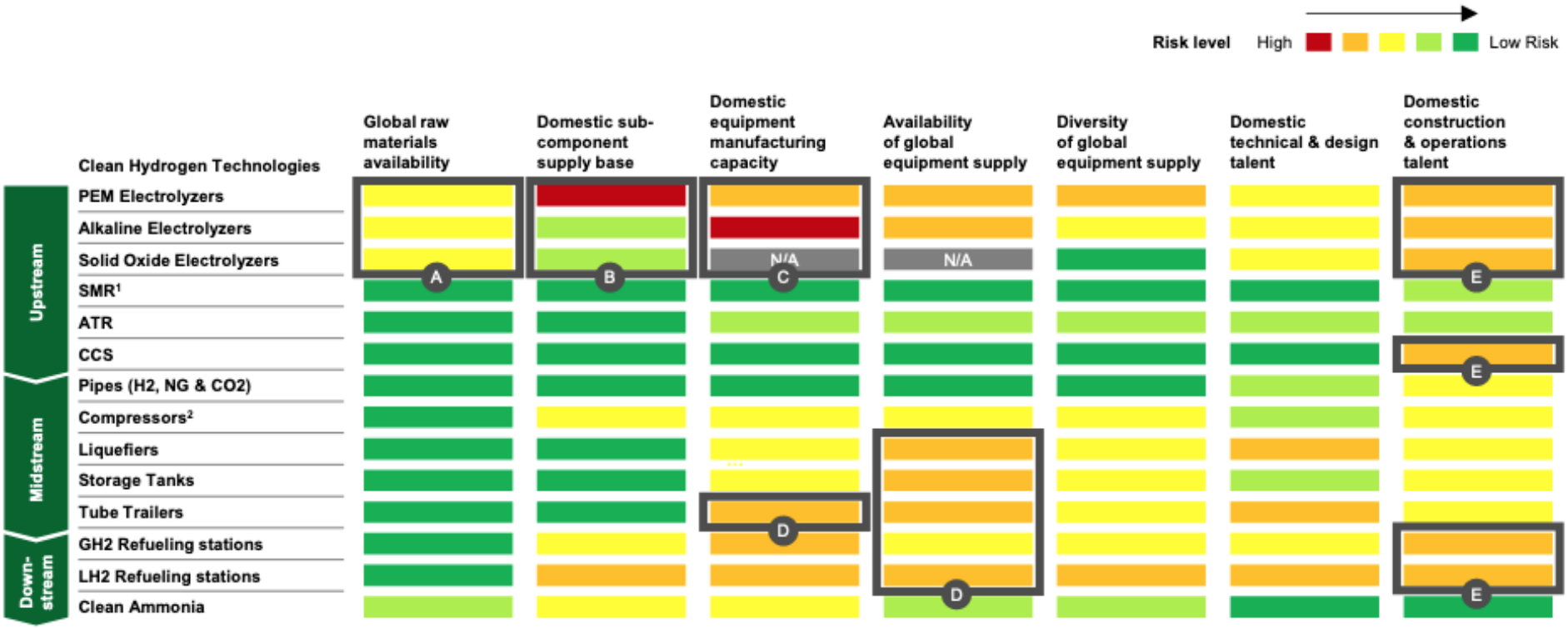
https://liftoff.energy.gov/wp-content/uploads/2023/05/20230523-Pathways-to-Commercial-Liftoff-Clean-Hydrogen.pdf

# Announced US clean hydrogen projects by target end-use sector, MMTpa




https://liftoff.energy.gov/wp-content/uploads/2023/05/20230523-Pathways-to-Commercial-Liftoff-Clean-Hydrogen.pdf

# Potential Supply Chain Vulnerabilities, 2025




https://liftoff.energy.gov/wp-content/uploads/2023/05/20230523-Pathways-to-Commercial-Liftoff-Clean-Hydrogen.pdf

# National Renewable Energy Laboratory

**Make**

**Move**


**Store**

**Use**

R&D on Advanced Production Technologies

Infrastructure Research & Large Scale Demonstration and Deployment

Hydrogen Storage Materials and Systems Research

Hydrogen Penetration into Heavy-Duty Transportation Sector

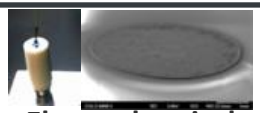
Expanding Green Hydrogen Into New End-Use Cases

**Underpinned by Safety Codes and Standards, Validation, and Analysis**

NREL Transforming ENERGY

## NREL's Hydrogen Program Strategy: Implementing DOE Vision, Accelerating Progress & Impact

# From Powders to Power—Fundamental Science to Large-Scale Validation



**Electrochemical Characterization:**
RDE & RRDE stations for Mass & Specific Activity, ECA, ORR; EQCMB, Seiras

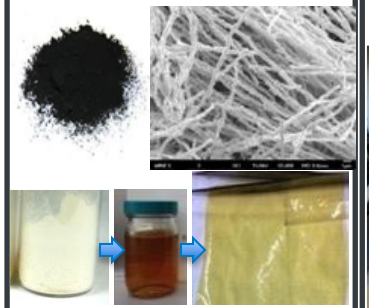
**Roll-to-roll manufacturing:**
Micro-gravure coating, Slot die coating

**Manufacturing Lab**
QC Diagnostic Development, Areal characterization, Roll-to-roll demonstration

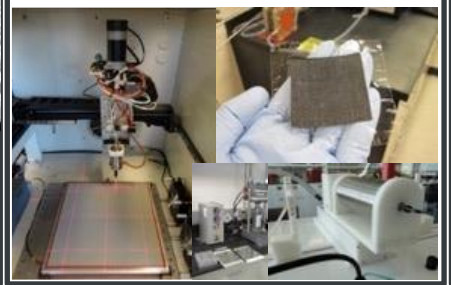
Powders → Power

**Systems Integration**

**Material Synthesis:**
Catalyst & Membrane Development



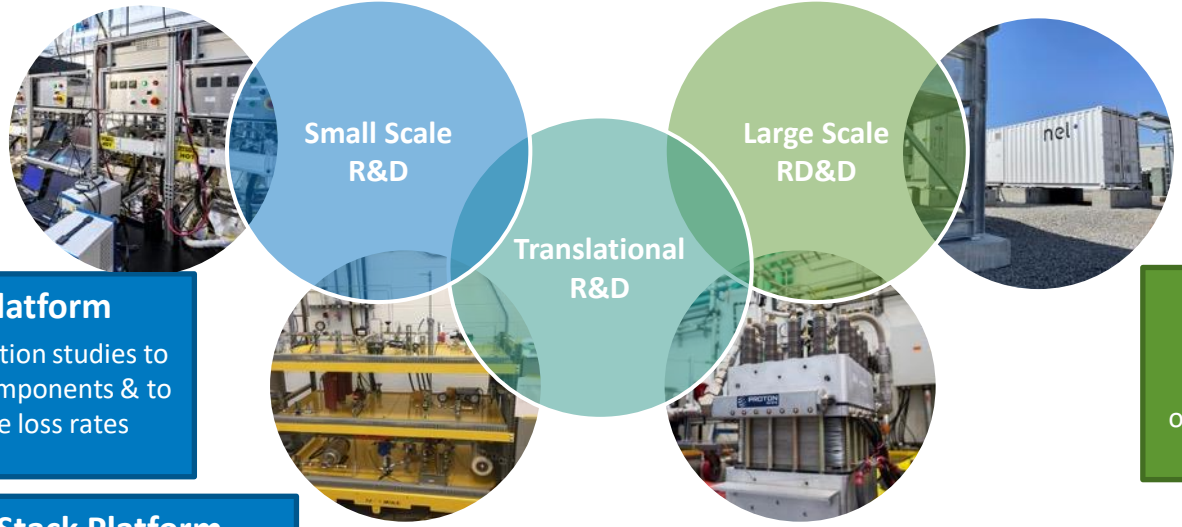
**MEA integration**
Coating, Spraying, Painting, Electrospinning, Lamination, Hot Press Transfer, Edge protection



**Performance and Durability Evaluation**
In-situ Diagnostics, PEMFC, AEMFC, Electrolyzer; Single Cell, Stacks, Spatial

**Systems-focus**
**ANALYSIS-driven**
**R&D**

# Growing Electrolyzer Capability at NREL
# From Watts to Multi-MegaWatts




**Single Cell Platform**

Accelerated degradation studies to optimize material components & to determine voltage loss rates

**Short Stack Platform**

In-situ high–speed cell voltage, stack, and balance of plant (BOP) performance monitoring for continual intermittent operation

**Full Stack Platform**

Scaling electrolysis to characterize durability, response, and controls of multiple stacks

**Full System Platform**

Energy systems integration, durability, control & optimization with electrolysis, storage, and end uses

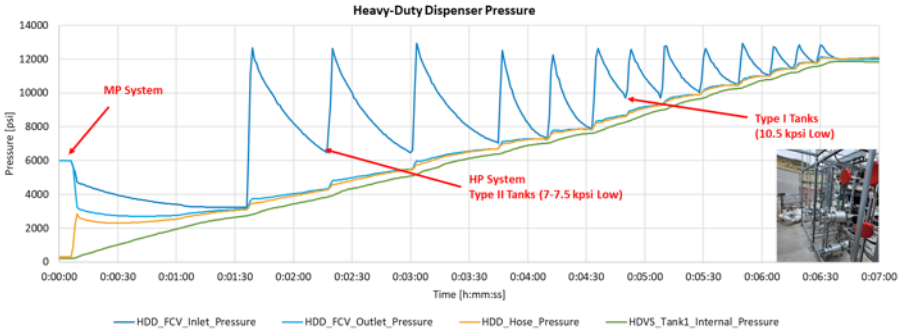
**Experimental capabilities to accelerate advances from fundamental, single cell research to integrated systems research; with industry relevant scale and operation conditions**

Images: NREL

# NREL Heavy-Duty Fast Flow R&D Achievements

- HD system comprised of:
  - **Heavy-Duty Dispenser** (HDD)
  - **Heavy-Duty Vehicle Simulator** (HDVS)
    - +80 kg fill mass (equivalent to a Class 8 truck)
    - Type IV and Type III tanks
    - Configurable volume & heavily instrumented
  - **Bulk gas storage** ~650 kg (Low, Med, High Pressure)
    - Limited back-to-back fueling capability
  - **Brine based precooling system & micro-channel heat exchanger.**
  - **HD gas management panel**
    - Configurable for cascade fueling approach
    - Gas recirculation to save on cost

**NREL's Heavy-Duty Hydrogen Fast-Flow Research Station**





# NREL's Offshore wind-hydrogen production research

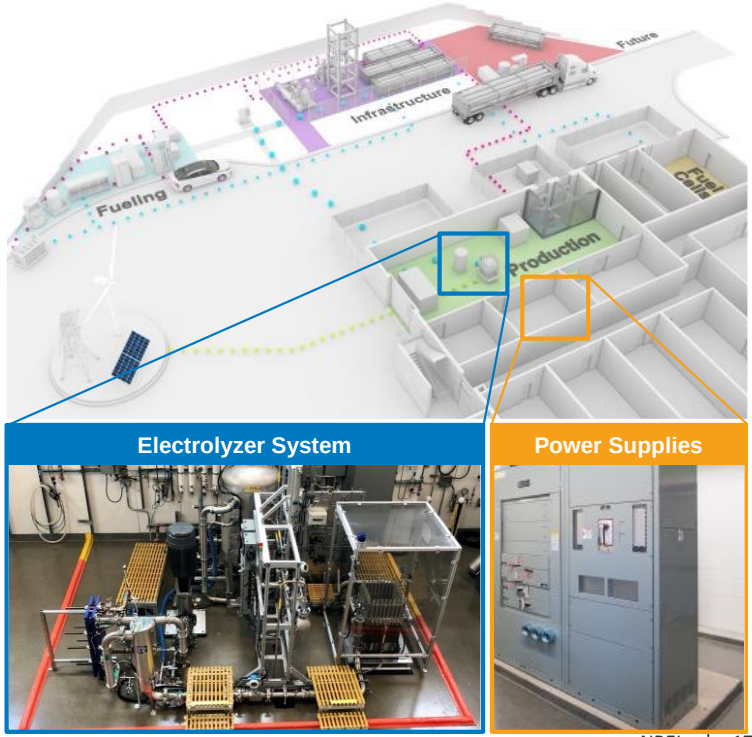
- **Industry project** to de-risk development with testing to understand fast-control effects that the PEM electrolyzer will have on wind turbine controls
- **Collaboration with TNO** in Netherlands to compare analyses for 1) state of industry and 2) identify key gaps and barriers

Image from Strom of Strohm, Siemens concept


Image from Recharge

Image from Howden of Holland Hydrogen 1

**NREL's Hydrogen Infrastructure Testing and Research Facility (HITRF)**



# Thank You

**www.nrel.gov**

This work was authored in part by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Hydrogen and Fuel Cell Technologies Office. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.