



U.S. DEPARTMENT OF
ENERGY

Hydrogen and Fuel Cell Technologies: A MHDV Perspective

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U.S. Department of Energy

Smoky Mountains Mobility Conference, Chattanooga, TN

October 30, 2024



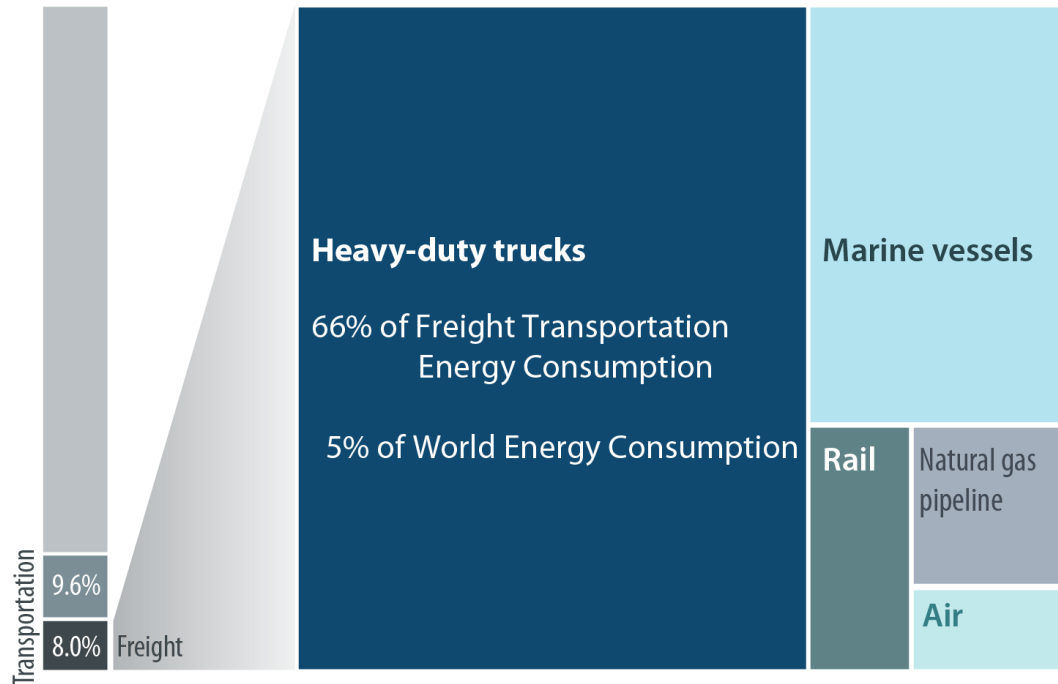
Heavy-Duty Trucks: Energy Consumption and Emissions

Heavy-duty trucks: 5% world's energy consumption

Transportation is largest source of greenhouse gas emissions in the U.S. – Trucks contribute to 7% total GHG

World Energy Consumption: Share of Freight Transportation

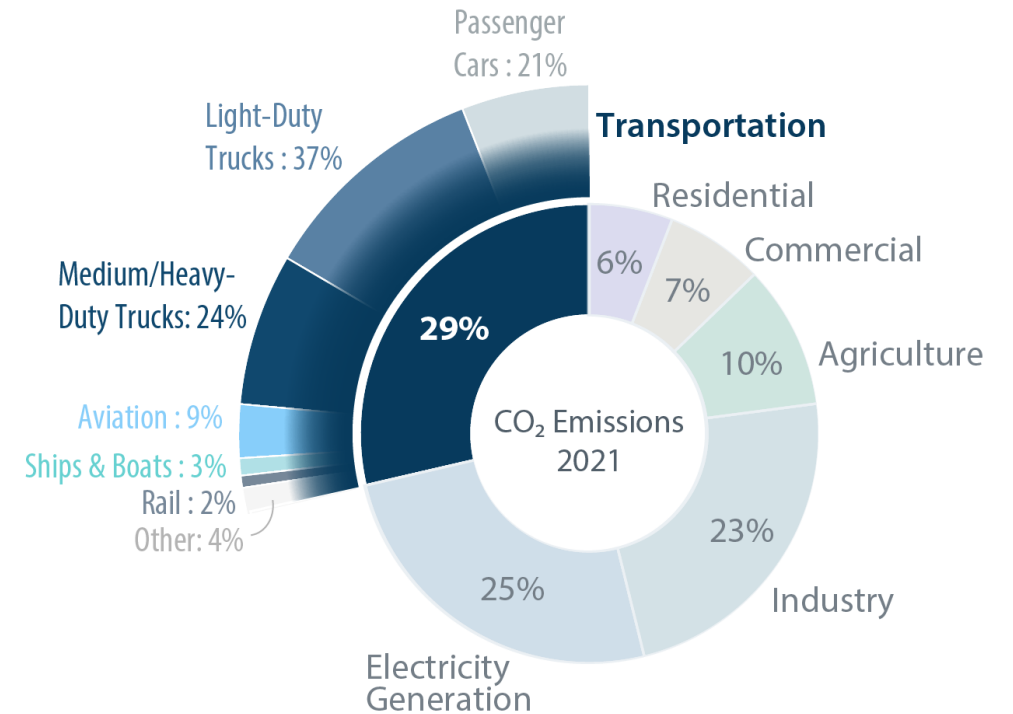
Total Energy Consumption
in 2020: 595 quad BTU



Source: EIA, International Energy Outlook (2023)
By A. Kusoglu



U.S. Greenhouse Gas Emissions by Sector



Source: US EPA
By A. Kusoglu



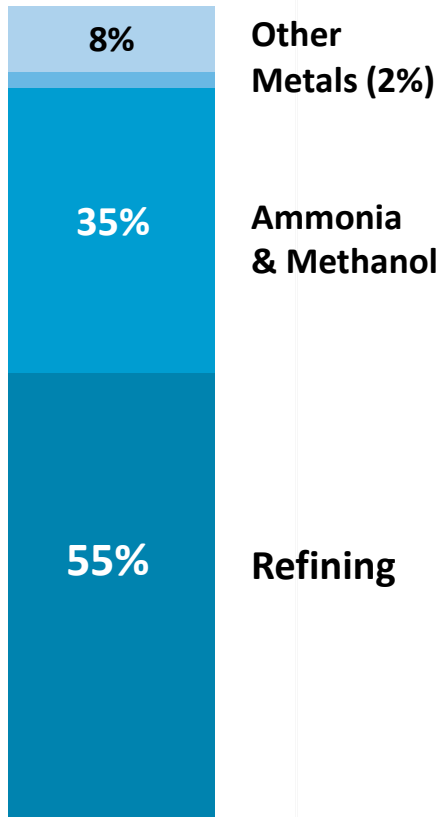
Snapshot of Hydrogen and Fuel Cells in the U.S.

10 million metric tons H₂ produced annually

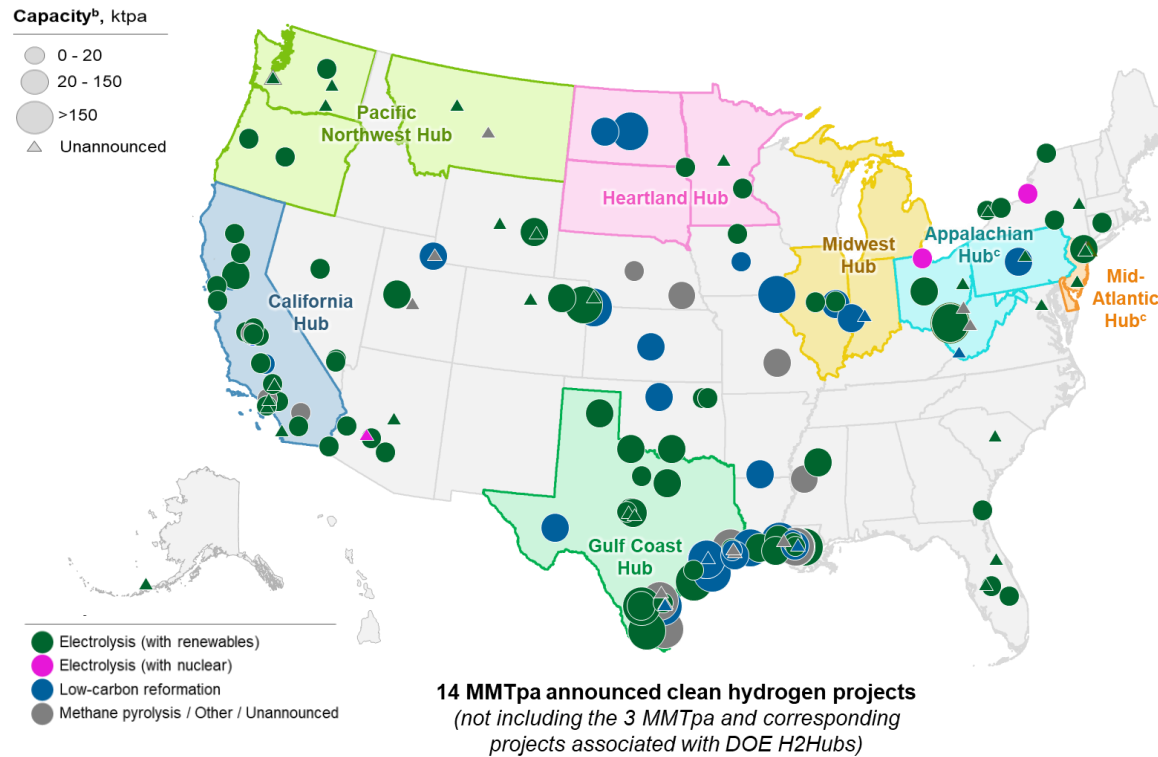
More than 1,600 miles of H₂ pipeline

World's largest H₂ storage cavern

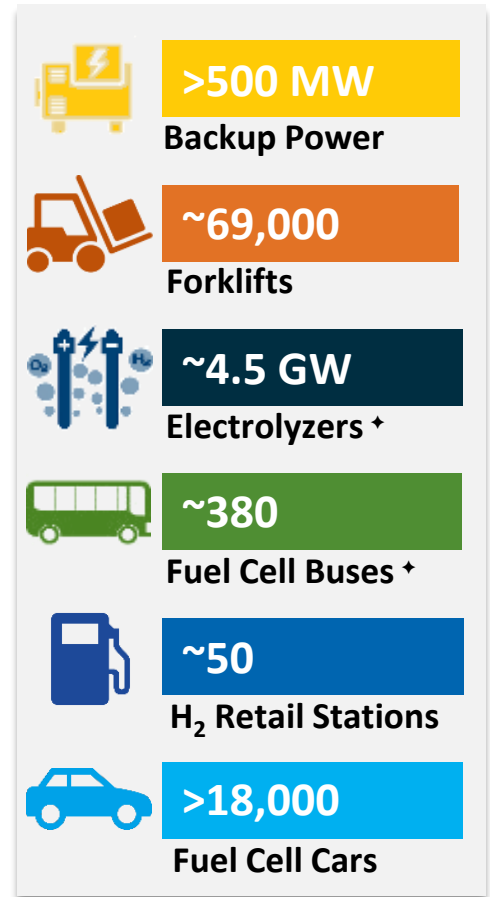
Use of Hydrogen in the U.S. Today



Clean hydrogen production projects announced as of Jan. 2024*



Examples of Deployments



*DOE Commercial Liftoff Report Updates available soon.

[†]Buses and electrolyzers include planned / under construction / deployed



Hydrogen

Hydrogen Energy Earthshot

“Hydrogen Shot”

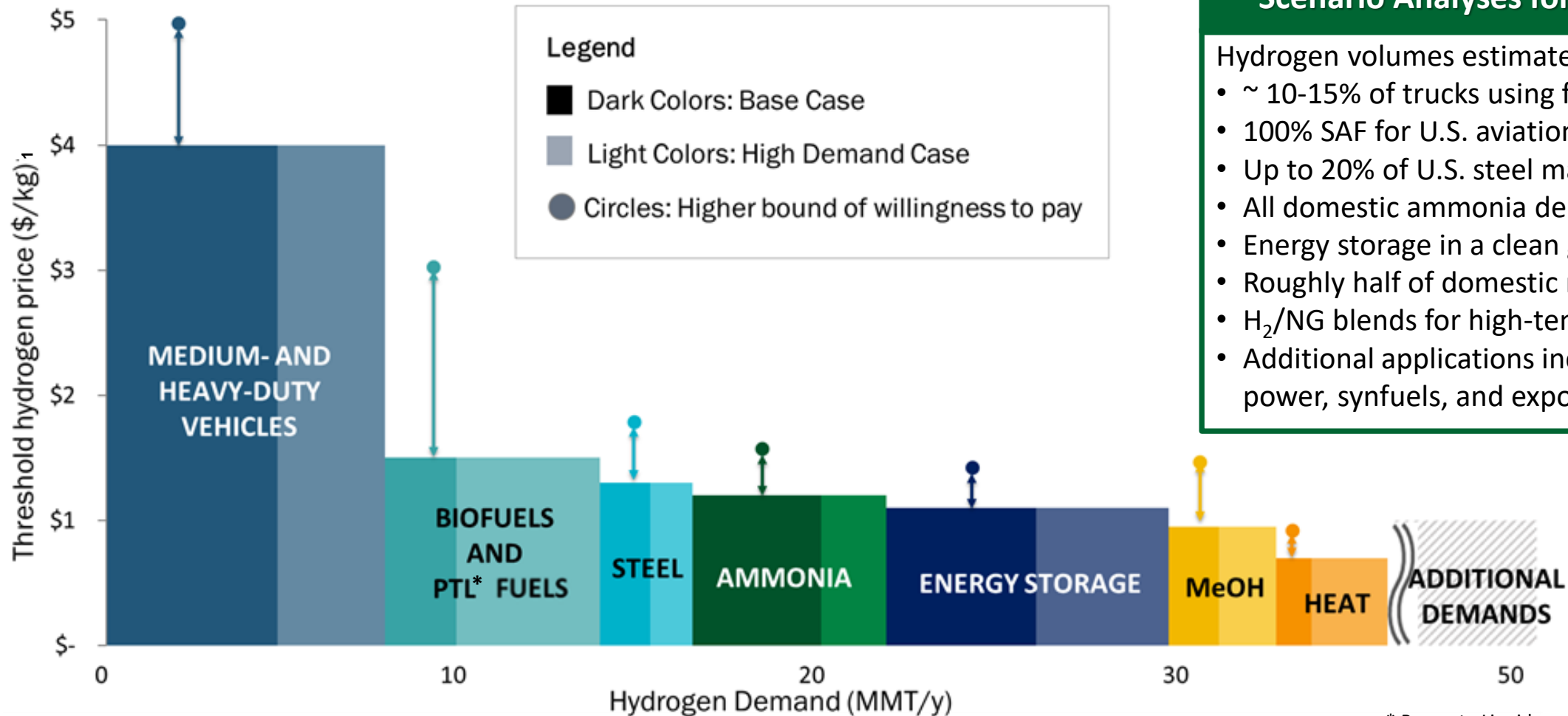
“1 1 1”

\$1 for 1 kg clean hydrogen in 1 decade

Strategy also includes delivery and storage infrastructure cost reduction

High-Impact Uses of Hydrogen

Clean Hydrogen Demand and Costs for Market Penetration



Scenario Analyses for H₂ Demand**

- Hydrogen volumes estimated for:
- ~ 10-15% of trucks using fuel cells
 - 100% SAF for U.S. aviation (35B gal) in 2050
 - Up to 20% of U.S. steel making
 - All domestic ammonia demand
 - Energy storage in a clean grid
 - Roughly half of domestic methanol
 - H₂/NG blends for high-temp heat in industry
 - Additional applications include stationary power, synfuels, and export potential

¹Costs include production, delivery, dispensing to the point of use (e.g., high-pressure fueling for vehicle applications)

* Power to Liquid

** Volumes dependent on multiple variables

President Biden Signs Key Bills into Law – Examples of Policies and Activities

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
- Requires developing a **National Clean Hydrogen Strategy and Roadmap**

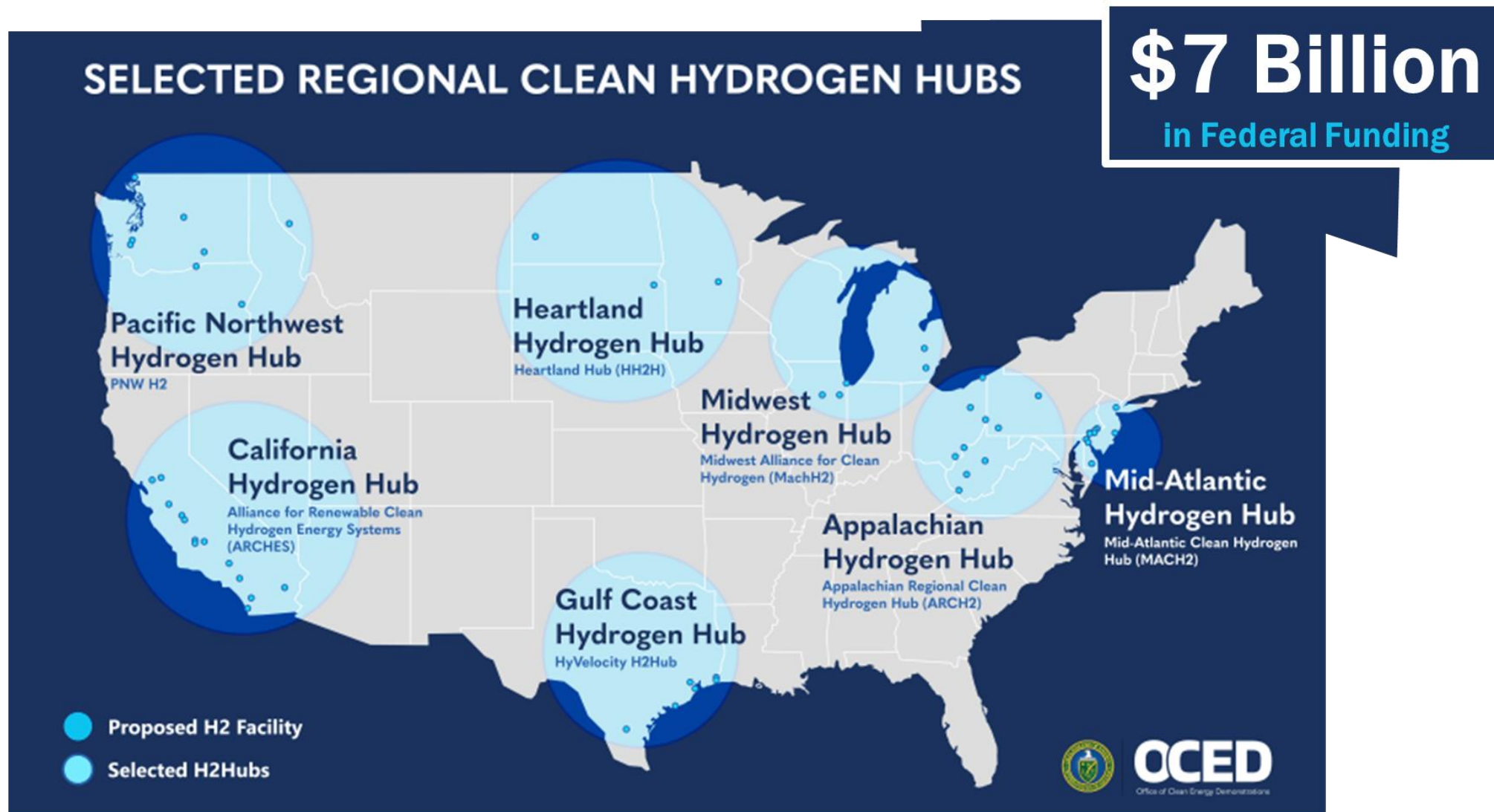


President Biden Signs the Bipartisan Infrastructure Bill into law on November 15, 2021. Photo Credit: Kenny Holston/Getty Images

Inflation Reduction Act

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

Focus on Regional Networks and Ramp-up Scale



+ **Tens of Billions of Dollars in Non-Federal Investment** to Achieve Market Lift-Off

~ 2 Million

Metric ton CO2 reduction annually [1]

\$1.2 Billion

Maximum Federal Cost Share [1]

Phase 1 (Planning and Development)

Federal

\$30 Million

Total

\$186 Million [1]

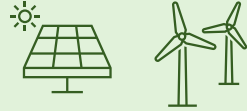
California



>10
Production Sites

>200,000
New Jobs [1]

Renewable Energy



Biomass



Electrolysis

Biogenic H2 with
Carbon Storage

H₂

Hundreds of MTPD

metric tons of clean
hydrogen produced daily [1]

~ 165 Miles



Open-Access Pipelines

60+



Heavy-duty
Fueling Stations



Liquefaction

Production Infrastructure [1]

Awarded

July 2024

End-Uses



Power Generation
Turbines and
Stationary Fuel Cells

200+



**Cargo-Handling
Equipment**

3



Ports

1



Marine Vessel

5,000+



Fuel Cell Trucks

1,000+



Fuel Cell Buses [1]

Community Benefits

Community Benefits
Working Group

Local Community
Engagement & Liaisons

Community Benefits
Auditing Team

Project Labor
Agreements

Justice 40
Commitment

Public Data
Platform [1,3]

~ **1.7 Million**

Metric ton CO2 reduction annually

[1]

\$1 Billion

Maximum Federal Cost Share

[1]

Phase 1 (Planning and Development)

Federal

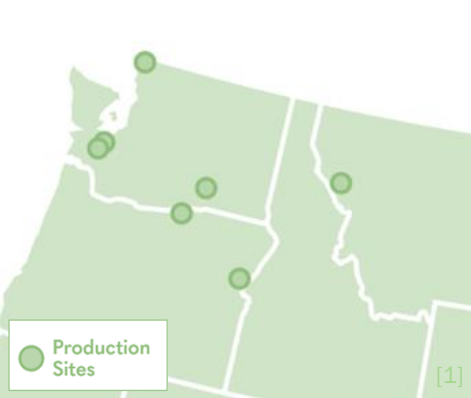
\$27.5 Million

Total

\$125 Million

[1]

Washington, Oregon,
and Montana



Production Sites

[1]

8

Nodes

i.e. groups of projects

>10,000

New Jobs

[1]

Renewable Energy



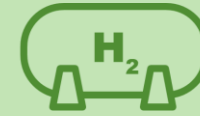
Electrolysis

H₂

335+ MTPD

metric tons of clean hydrogen produced daily

[1]



Storage

10+



Heavy-duty Fueling Stations

Along the I-5, I-90, & I-84 Corridors

[1]



Pipelines



Liquefaction

Production Infrastructure

Awarded

July 2024

End-Uses



Power Generation

Generators and Data Centers



Ports

Drayage, Cargo Handling



Industry



Fertilizer



Fuel Cell Trucks



Fuel Cell Buses

[1,2]

Community Benefits

Community Benefits Committee

Node-Level Local, Tribal, & Labor Advisory Boards

Redevelopment of Contaminated Brownfields

Project Labor Agreements

Justice 40 Commitment

Public Data Platform

[1,3]

~ **9 Million**

Metric ton CO2 reduction annually [1]

\$925 Million

Maximum Federal Cost Share [1]

Phase 1 (Planning and Development)

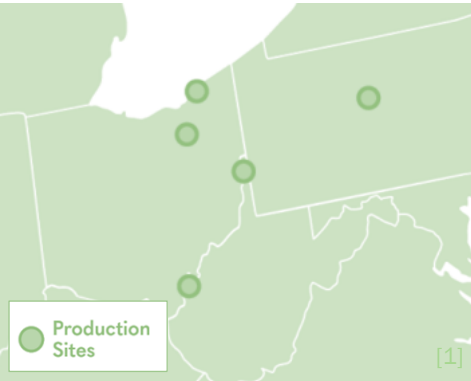
Federal

\$30 Million

Total

\$96 Million [1]

West Virginia, Ohio,
Pennsylvania



Low-Cost Natural Gas



Thermal Reforming
with Carbon Capture

Renewable Energy



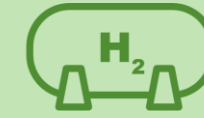
Electrolysis

H₂

1,500 MTPD

metric tons of clean
hydrogen produced daily

Production Infrastructure



Storage

Up to 18,000 Gallons LH₂



Heavy-duty
Fueling Stations



Pipelines



Liquefaction

Awarded

July 2024

End-Uses



Power Generation



Material-Handling
Equipment



Industry



Residential
Heat & Power

w/ Stationary Fuel Cells



Fuel Cell Trucks



Fuel Cell Buses

11

Project Sites

>21,000

New Jobs [1,3]

Community Benefits

Community Benefits
Steering Committee

Labor & Disadvantaged
Community Advisory Bodies

Labor & Trade
Negotiations

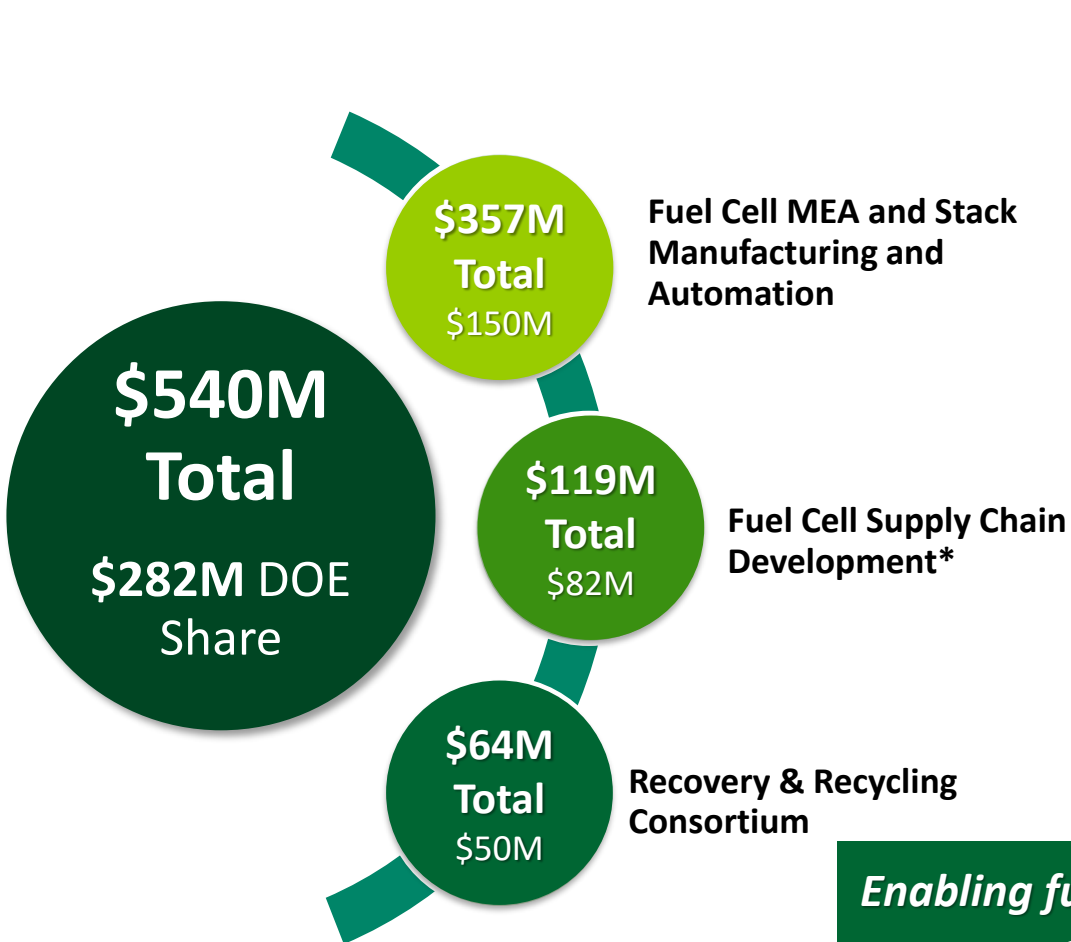
Air Quality
Monitoring

Justice 40
Commitment

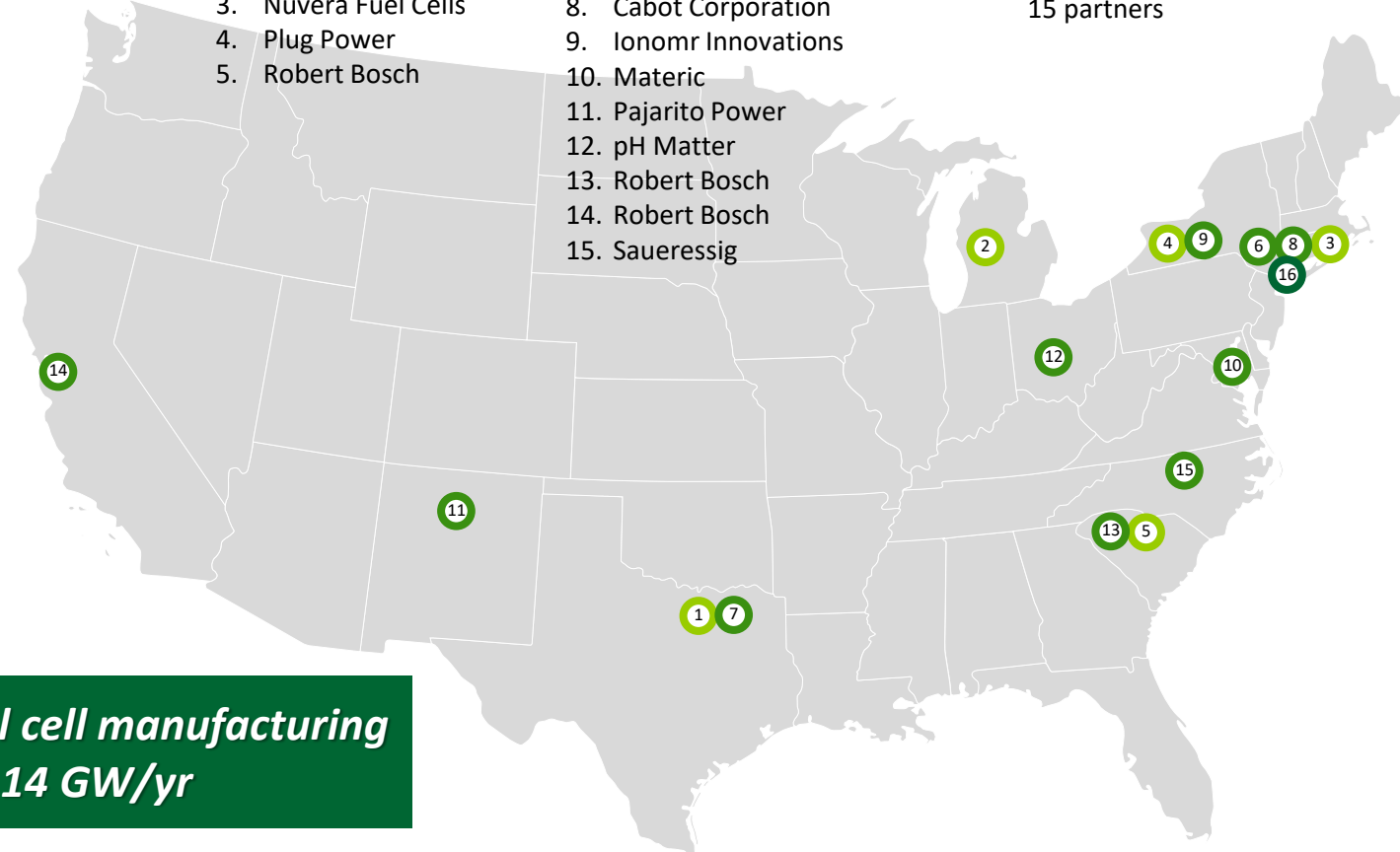
Public Data
Platform [1,4]

HFTO BIL FOA Selections

Clean Hydrogen Manufacturing and Recycling



- Fuel Cell Manufacturing**
 - Ballard Power Systems
 - General Motors
 - Nuvera Fuel Cells
 - Plug Power
 - Robert Bosch
- Fuel Cell Supply Chain**
 - AvCarb Material Solutions
 - Ballard Power Systems
 - Cabot Corporation
 - Ionomr Innovations
 - Materic
 - Pajarito Power
 - pH Matter
 - Robert Bosch
 - Robert Bosch
 - Saueressig
- Recycling Consortium**
 - American Institute of Chemical Engineers and 15 partners



Enabling fuel cell manufacturing of 14 GW/yr

*GDLs, Catalysts, Bipolar Plates, Non-PFSA Membranes

Source: HFTO; <https://www.energy.gov/articles/biden-harris-administration-announces-750-million-accelerate-clean-hydrogen-technologies->; <https://www.energy.gov/eere/fuelcells/bipartisan-infrastructure-law-clean-hydrogen-electrolysis-manufacturing-and-0>

BIL 816 FOA Funding Impacts

36 Projects

RD&D and manufacturing for domestic supply chain

Enables \$2/kg H₂ by 2026

RD&D for domestic manufacturing and support for H₂ Hubs

Electrolysis **10 GW/yr**

Supports production of 1.3M metric tons of H₂/year

\$1.1B

Total Project Costs

Including ~\$470M in federal cost share and ~\$590M in cost share

900+

Direct jobs created

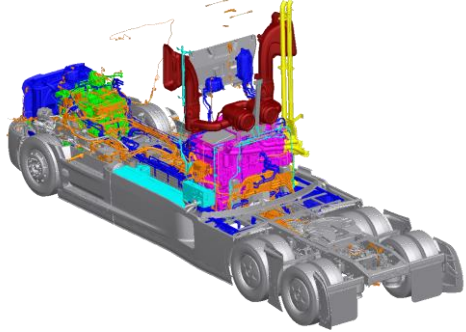
Plus, thousands of indirect jobs across the U.S.

23 States

Benefiting 24 disadvantaged communities across the U.S. with initiatives in workforce development, energy equity, and DEIA

Real-World Truck Demo Projects – SuperTruck 3

DAIMLER

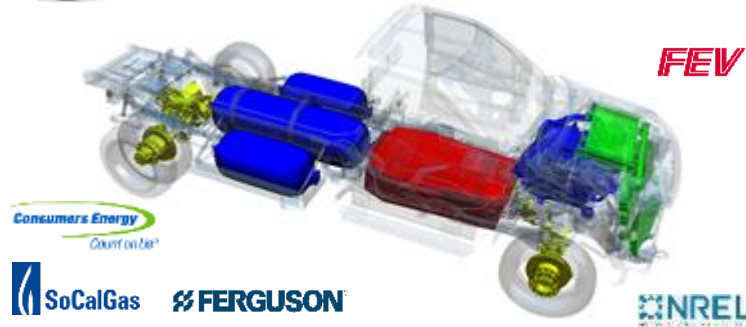


Goals:

- Demonstrate 2 total (Class 8) HD long-haul fuel cell electric trucks (B-sample & final truck demo)
- 6.0 mi/kg H₂ fuel economy
- 600-mile range (onboard LH₂ storage)
- 65,000 pounds GVW
- 25k hour lifetime

Images above are not final product and are subject to change

Ford Motor Company



Goals:

- Demonstrate 5 total (Class 4-6) MD vocational trucks
- 300+kW_{net} vehicle power, H₂ PEMFC + Li-Ion battery
- 300-mile range (700 bar H₂ storage)
- 10K/20K pounds payload/tow capacity
- Meet or exceed 7.3L gas performance

gm general motors



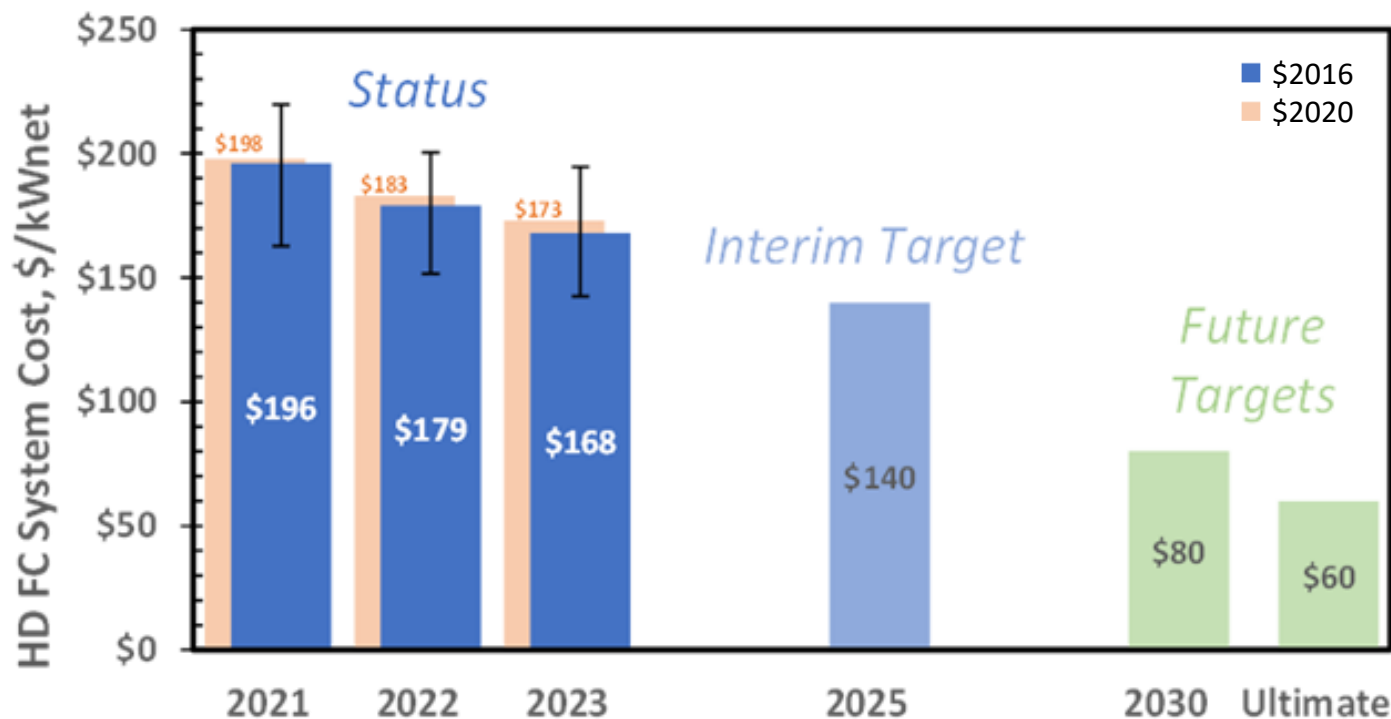
Goals:

- Demonstrate 8 total (Class 4-6) MD trucks- 4 fuel cell & 4 battery
- Fuel Cell System: 65% peak efficiency, <\$80/kW system cost (100K units/yr), 20K-30K hour life
- Demonstrate microgrid with electrolyzer & fuel cell (H₂ fueling & fast charging)

Analysis: Heavy-Duty Truck Fuel Cell Durability-Adjusted Costs (for 25,000-hour lifetimes)

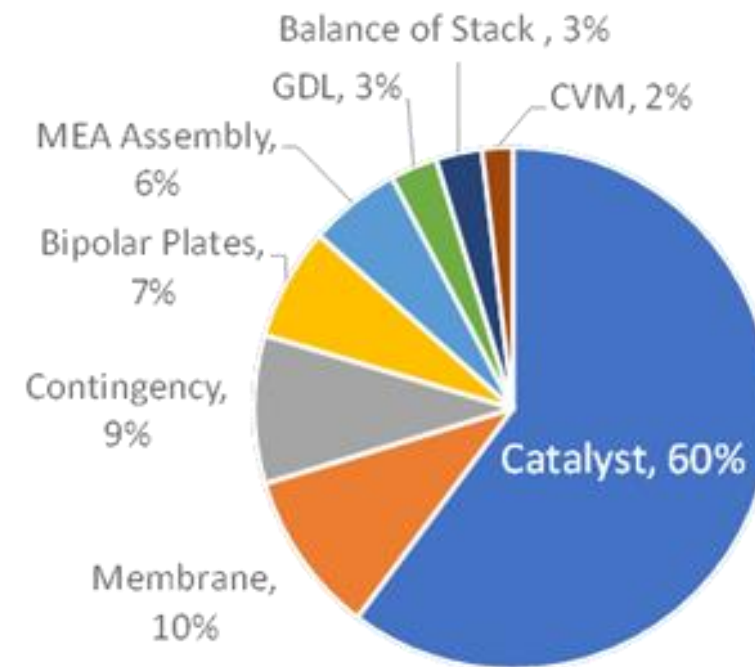
Modeled cost of a 275-kW_{net} PEMFC system

- ~\$170/kW_{net} at 50,000 systems/yr
- ~\$160/kW_{net} at 100,000 systems/yr



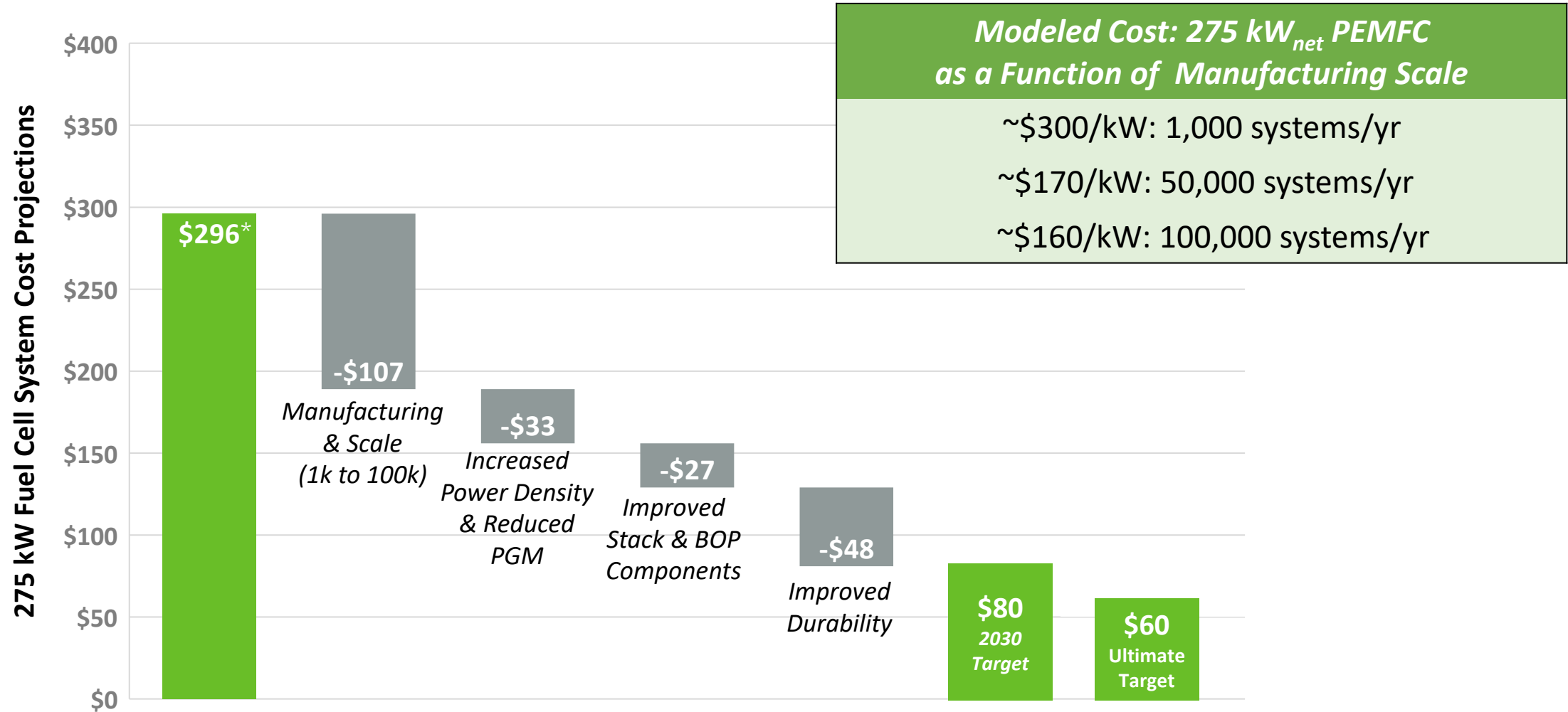
Cost status (2021, 2022, 2023) in 2016\$ (blue bars) and 2020\$ (orange bars) compared to the interim target (2025) for a manufacturing volume of 50,000 systems/yr. 2030 and ultimate targets are at 100,000 systems/yr.

Stack cost breakdown (\$105/kW_{net} at 50,000 systems/yr)



Catalyst cost projected to be largest single component of stack cost to meet durability requirements

Emphasis on Key Areas Drives Cost Reduction

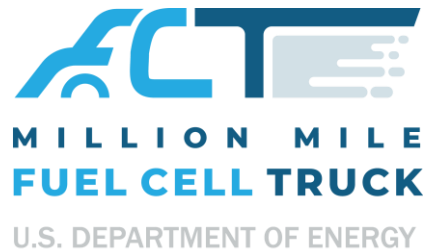


* For 1,000 systems/yr in 2020\$

Pathway towards cost target requires both technology improvements and manufacturing innovations

RD&D Consortia Approach to Accelerate Progress

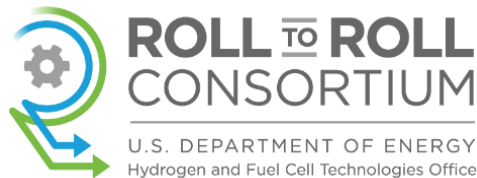
Consortia leverage the world-class capabilities, expertise, and research activities of core national labs, and foster collaborations among the labs, industry and universities



RD&D to improve fuel cell durability, performance and cost to better position fuel cells as a viable option for heavy-duty applications (*Core Labs: LANL, LBNL, ANL, NREL & ORNL*)

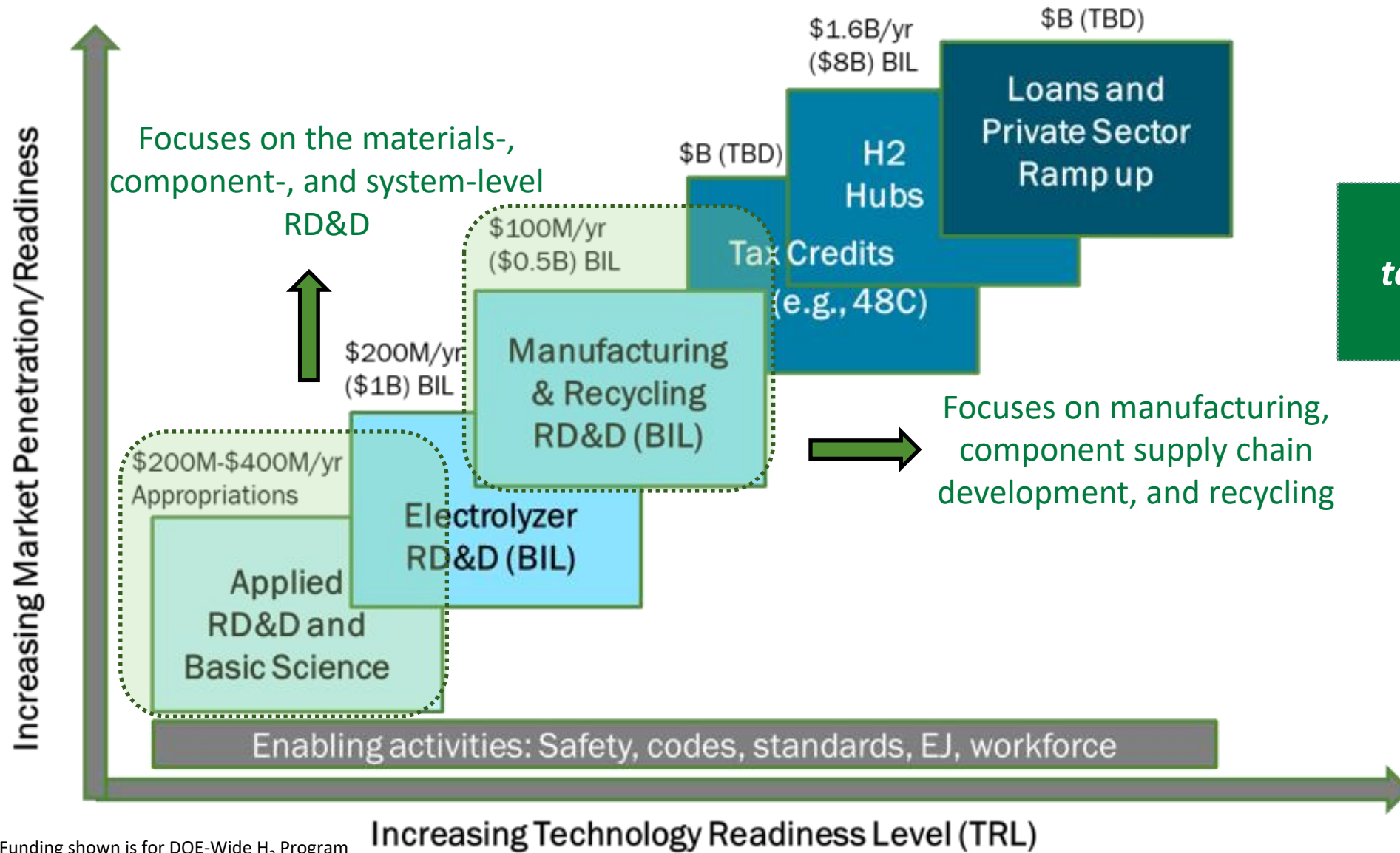


R&D of PGM-free catalysts/electrodes for use in fuel cells and electrolyzers (*Core Labs: ANL, LANL, NREL & ORNL*)



MEA manufacturing technology advancements to reduce costs for fuel cells and electrolyzers (*Core Labs: NREL, ANL, ORNL, LBNL & SNL*)

Hydrogen Program RDD&D Portfolio across TRLs



Advancing fuel cell technologies across the value chain

Resources and Opportunities for Engagement

Key Publications



www.hydrogen.energy.gov

Save the date!

HYDROGEN & FUEL CELL SEMINAR

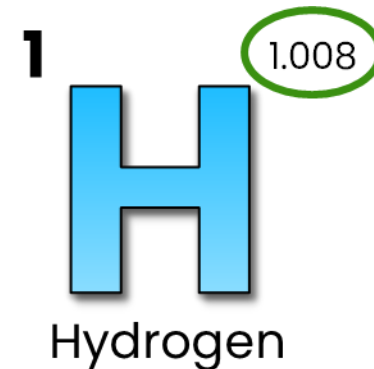
Organized by FCEA

Jan 14 – 16, 2025

Long Beach, California

Hydrogen & Fuel Cells Day October 8

- Held on hydrogen's very own atomic weight-day



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