

# CLEAN HYDROGEN MISSION

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MISSION

## Hydrogen Fuel Cell Off-Road Equipment and Vehicles Virtual Workshop

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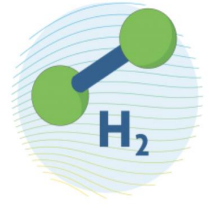
U.S. Department of Energy

September 22<sup>nd</sup>, 2021

# Welcome and Background



## Clean Hydrogen Mission Launched June 2021



CLEAN HYDROGEN MISSION

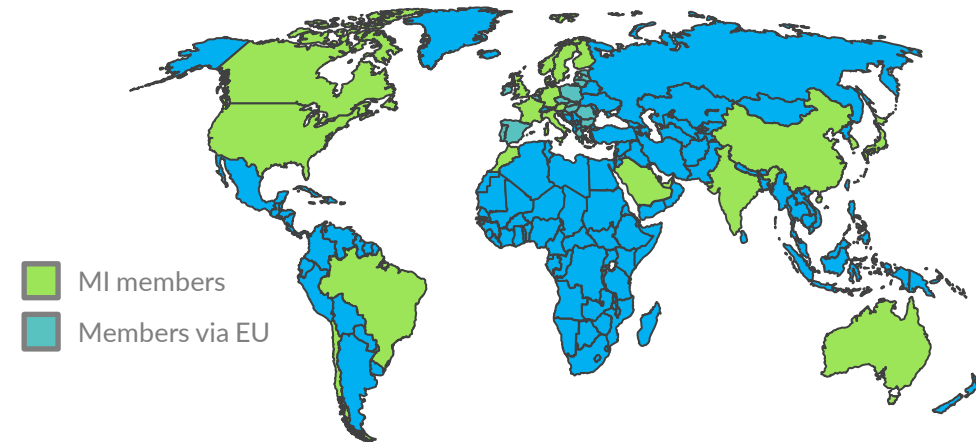


### The Mission:

Develop a global clean hydrogen economy by reducing *end-to-end* costs to **\$2 USD per kg by 2030**.

MI members commit to research, development, demonstration, and innovation and to **building over 100 large-scale Clean Hydrogen Valleys** to reduce costs and scale clean hydrogen technology.

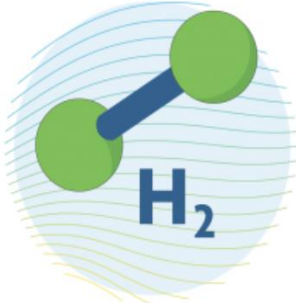
Clean Hydrogen Mission co-leads: Australia, Chile, European Commission, United Kingdom, United States



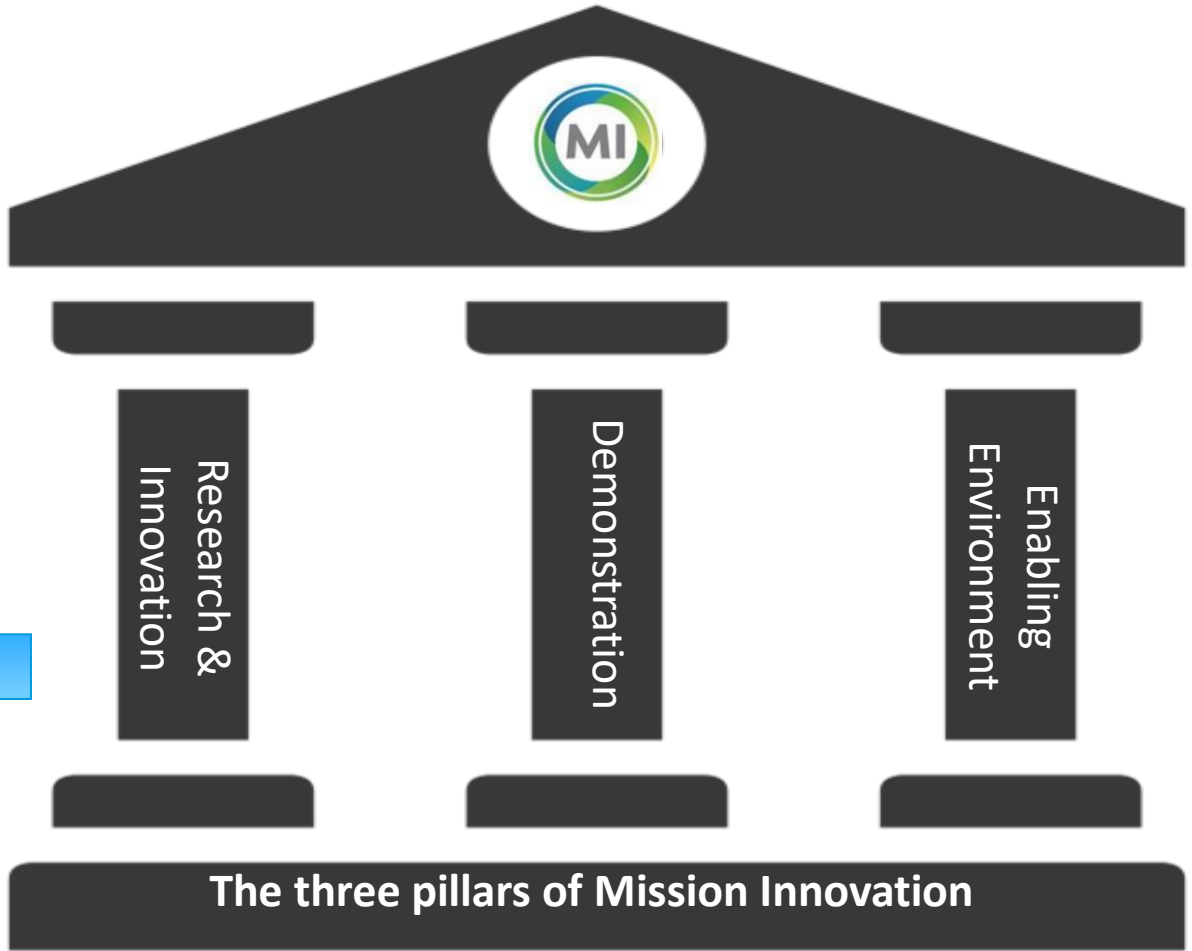
Over 17 Member Countries



# MI Workshop Background



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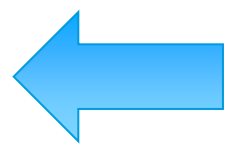


3 Working Groups:

Production

Distribution & Storage

End Use



This workshop is under the End Use WG

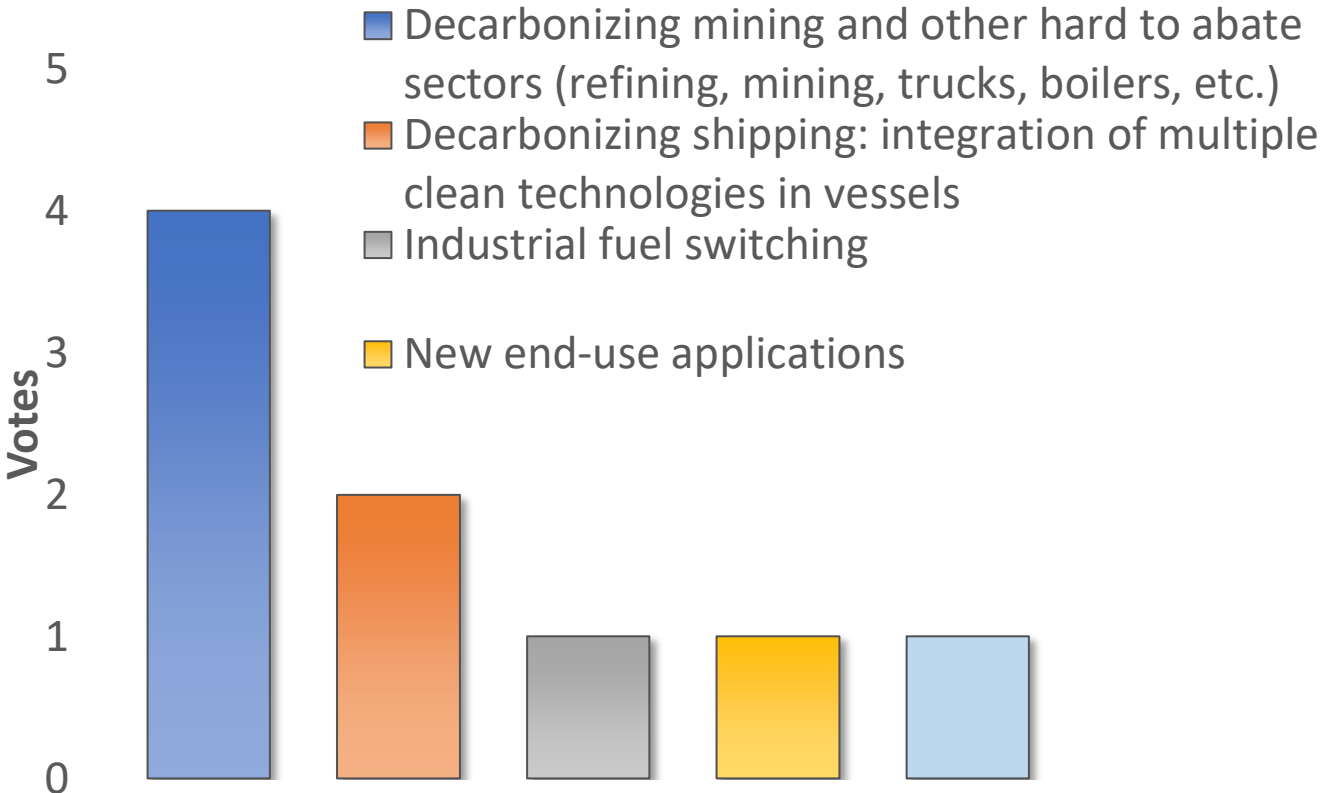
Co-hosted by: Australia, Chile, EC, US



# Basis for Workshop

17 Member Countries provided feedback on high priority areas of RD&D

Topic Votes – End Use



**First MI End Use WG Workshop focused on topic voted highest priority**

**Overarching goal Enable \$2/kg clean H2 from production to end use. Includes scaling up.**

# Workshop Objectives and Expected Outcomes

## Objectives:

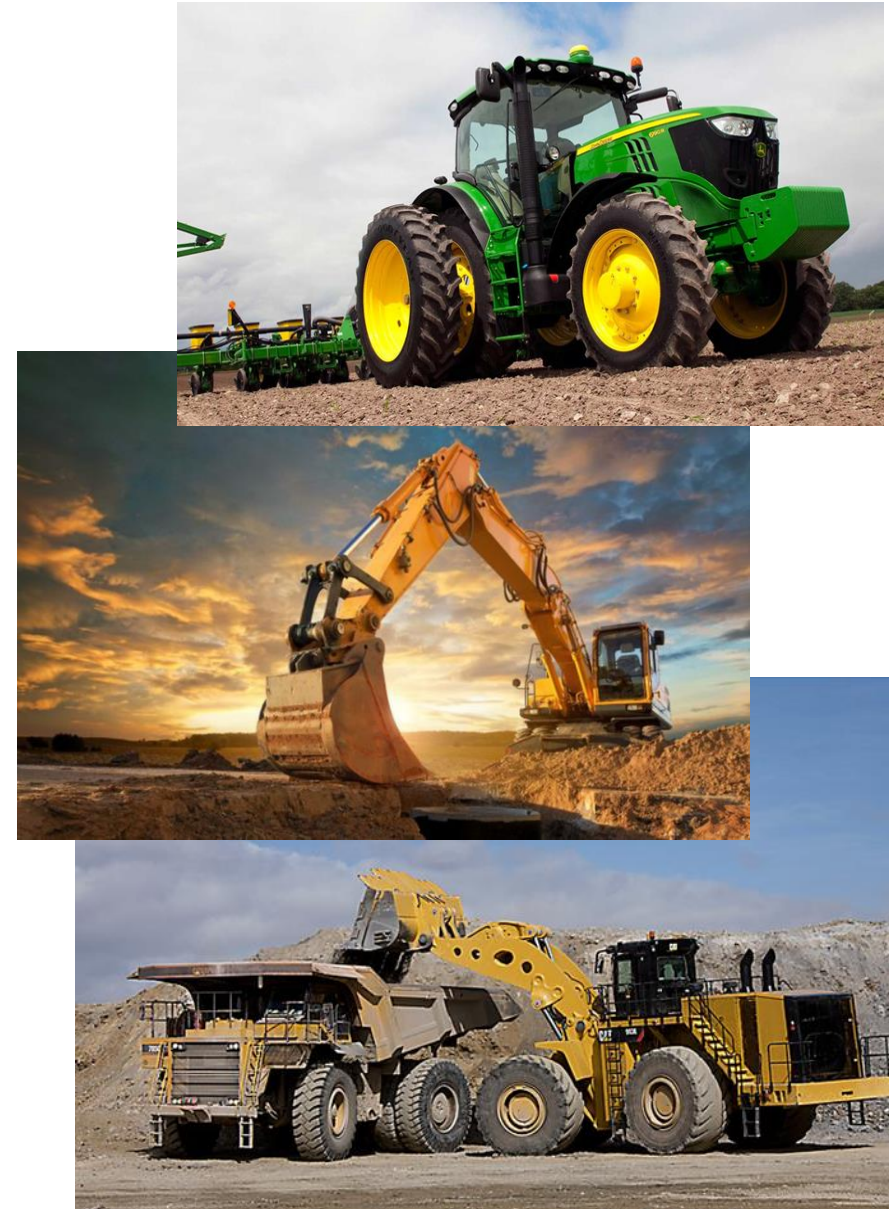
- Assess the application of hydrogen and fuel cell technologies for equipment applications in the heavy-duty (HD) off-road markets, initially focusing on the agriculture, construction, and mining market sectors
- Identify the current status/state-of-the-art for hydrogen fuel cell technologies
- Discuss operational requirements and lessons learned on early equipment demonstration projects
- Understand current technology gaps
- Discuss potential hydrogen refueling infrastructure pathways and challenges
- Assess current and future potential Total Cost of Ownership (TCO) analysis scenarios for selected equipment applications

## Expected Outcomes:

- Identify opportunities and challenges for commercialization
- Identify R&D activities to help accelerate commercialization

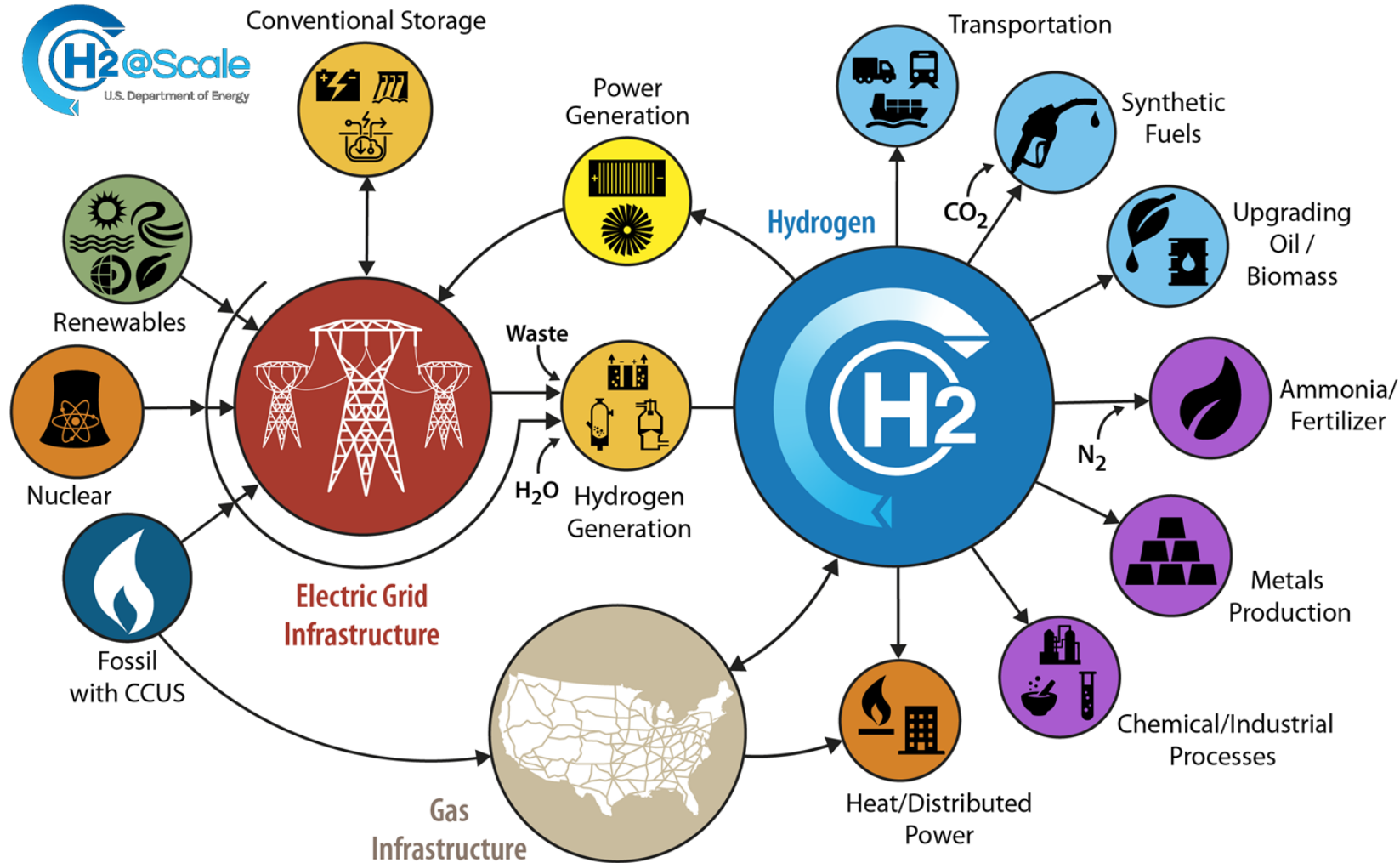


Discuss potential WG members





# Example: H2@Scale: Deep Decarbonization, Economic Growth, Jobs



- >70 MMT of H<sub>2</sub>/yr produced today globally with scenarios ~ 10X growth.
- End use applications at scale can drive demand and growth
- Global industry studies shows potential for \$2.5trillion, 30 million jobs, ~20% GHG reduction potential

# Example: Mining Trucks Worldwide

## Number of Mining Trucks:

~ 28,000 global fleet

## Annual Diesel Usage:

~ 90,000 liters/truck

~ 2.5 Billion liters

## Annual CO2 Emissions:

~ 68 Mt/year

## Share of Mine Energy Use:

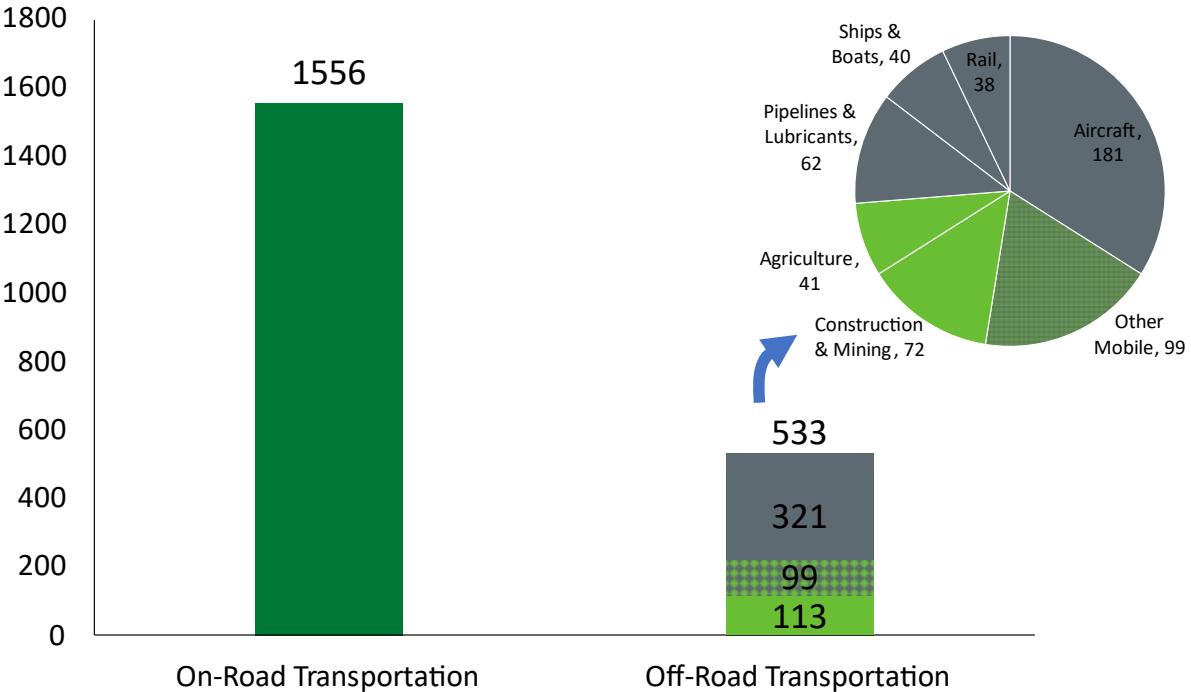
~30% to 50%



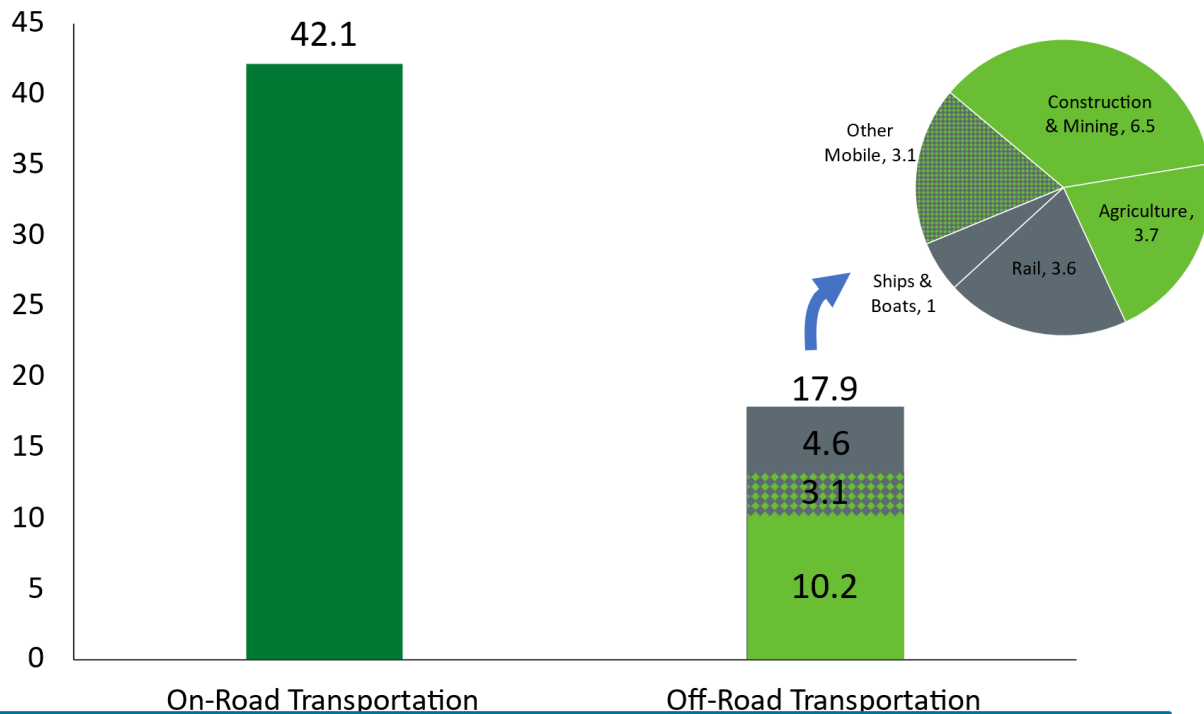
Mining trucks emit 68 million tons of CO2 (MtCO2) per year, equivalent to the total greenhouse gas footprint of Finland or New Zealand

# Off-Road Transportation Share of U.S. GHG Emissions and Diesel Fuel

2019 U.S. Mobile Source GHG Emissions [Mt of CO<sub>2</sub>e]



2019 U.S. Diesel Mobile Fuel Usage [Billions of Gallons]



Agriculture, Construction, and Mining vehicles and equipment can significantly reduce diesel consumption and related GHG emissions.

Source: U.S. EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks* report: Fast Facts: <https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P10127TU.pdf>; Full Report: <https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2019>; Annex 3: <https://www.epa.gov/sites/default/files/2021-04/documents/us-ghg-inventory-2021-annex-3-additional-source-or-sink-categories-part-a.pdf>



Notes: **On-Road Transportation** includes: Light-Duty Cars and Trucks, Medium-Duty and Heavy-Duty Trucks and Buses; **Off-Road Transportation Other Mobile** includes: snowmobiles, recreational equipment, logging equipment, lawn & garden equipment, railroad equipment, airport equipment, commercial equipment, industrial equipment, and trucks used off-road for commercial and industrial purposes.



# President Biden and Energy Secretary Granholm at Climate Summit



“...I’ve asked the Secretary of Energy to speed the development of critical technologies to tackle the climate crisis. No single technology is the answer on its own because every sector requires innovation to meet this moment.”

*President Joseph R. Biden  
April 23, 2021*



Launch of Hydrogen Energy Earthshot  
First of the Energy Earthshots  
June 7, 2021  
at DOE Hydrogen Program Annual Merit Review

*Secretary Jennifer Granholm  
June 7, 2021*



ENERGY  
**earthshots**  
U.S. DEPARTMENT OF ENERGY

Hydrogen

# Hydrogen Energy Earthshot

“Hydrogen Shot”

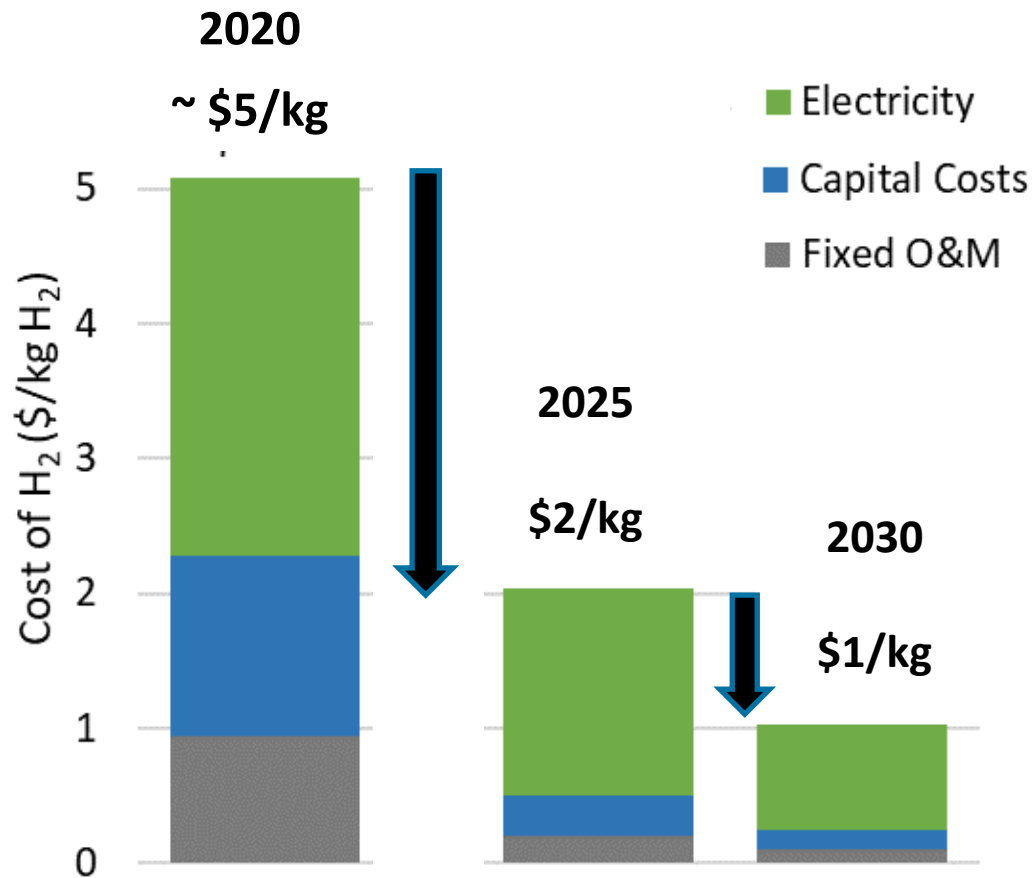
“1 1 1”

\$1 for 1 kg clean hydrogen  
in 1 decade

Launched June 7, 2021



## Example: Cost of Clean H<sub>2</sub> from Electrolysis



## One of several pathways

- Reduce electricity cost from >\$50/MWh to
  - \$30/MWh (2025), \$20/MWh (2030)
- Reduce capital cost >80%
- Reduce operating & maintenance cost >90%

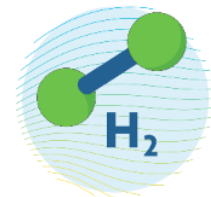
All pathways for clean hydrogen included: Thermal conversion with CCS, advanced water splitting, biological approaches, etc.

Delivery, storage, infrastructure, end use all required

2020 Baseline: PEM low volume capital cost ~\$1,500/kW, electricity at \$50/MWh. Need less than \$300/kW by 2025, less than \$150/kW by 2030 (at scale)



# Examples of International Collaborations



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The International Partnership for Hydrogen and Fuel Cells in the Economy

Enabling the global adoption of hydrogen and fuel cells in the economy

[www.iphe.net](http://www.iphe.net)

## Regulations, Codes, Standards, Safety and Education & Outreach Working Groups

## Task Force to facilitate international trade of H<sub>2</sub>

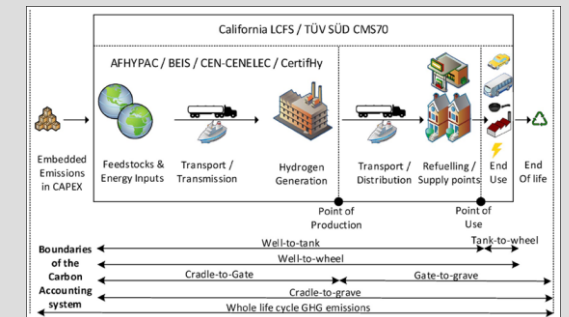
## H<sub>2</sub> Production Analysis (H2PA)

### RCS&S Compendium

Hydrogen Infrastructure				Hydrogen for Mobility/Traffic			
Hydrogen injection at transmission level	Hydrogen injection at distribution level	Methanation and injection of Methane (SNG) via methanation from hydrogen at transmission / distribution level	H <sub>2</sub> refilling station (HRS)	Maritime Infra	Mobility infra (tunnel, bridge, underground parking...)	Heavy Duty vehicles	H <sub>2</sub> production
Legal framework, permissions and restrictions and Ownership constraints (unbundling)	Legal framework, permissions and restrictions and Ownership constraints (unbundling)	Legal framework, permissions and restrictions and Ownership constraints (unbundling)	Land use plan (zone prohibition)	Off-shore refueling	Restrictions & Incentives	Type approval & individual vehicle registration - Process	Legal requirements (unbundling)
Permission to connect/inject	Permission to connect/inject	Permission to connect/inject	(LH <sub>2</sub> ) permitting requirements/ process (GH <sub>2</sub> ) Safety	On-shore refueling	Restrictions & Incentives	Restrictions & Incentives	Legal requirements (unbundling)

- Reports, workshops, safety sharing
- Assessing gaps
- Education, student engagement, compiling country info

- Developing a common analytical framework to determine emissions footprint for H<sub>2</sub>
- Harmonizing approach across countries and pathways



(Source: Abad et al., Energy policy 138 (2020) 111300)



# Upcoming Opportunities for Engagement

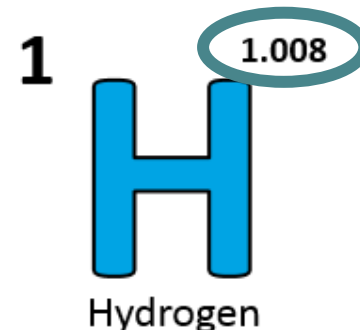


## Hydrogen

### DOE Annual Merit Review and Peer Evaluation Meeting June 6 -9, 2022

### Hydrogen and Fuel Cells Day October 8

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



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### Sign up to receive hydrogen and fuel cell updates

[www.energy.gov/eere/fuelcells/fuel-cell-technologies-office-newsletter](http://www.energy.gov/eere/fuelcells/fuel-cell-technologies-office-newsletter)

Learn more at: [energy.gov/eere/fuelcells](http://energy.gov/eere/fuelcells) AND [www.hydrogen.energy.gov](http://www.hydrogen.energy.gov)

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# Thank you

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[www.energy.gov/fuelcells](http://www.energy.gov/fuelcells)

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