

# Hydrogen and Fuel Cell Perspectives

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Clean Energy Ministerial's (CEM) Nuclear Innovation: Clean Energy Future (NICE Future) Initiative, Hydrogen Initiative (H2I), International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE) Joint Webinar

March 18, 2020

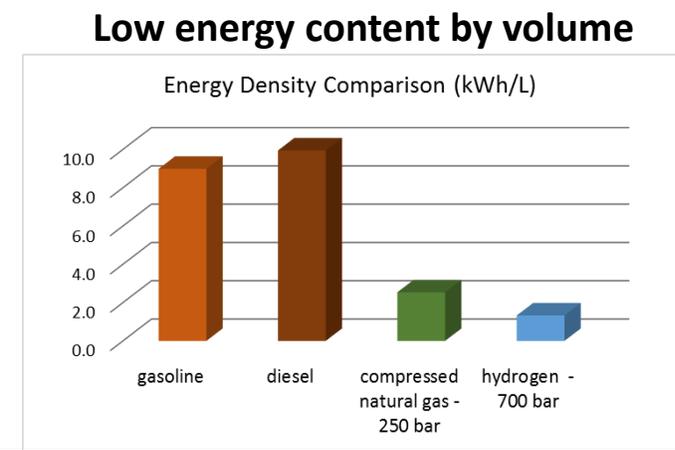
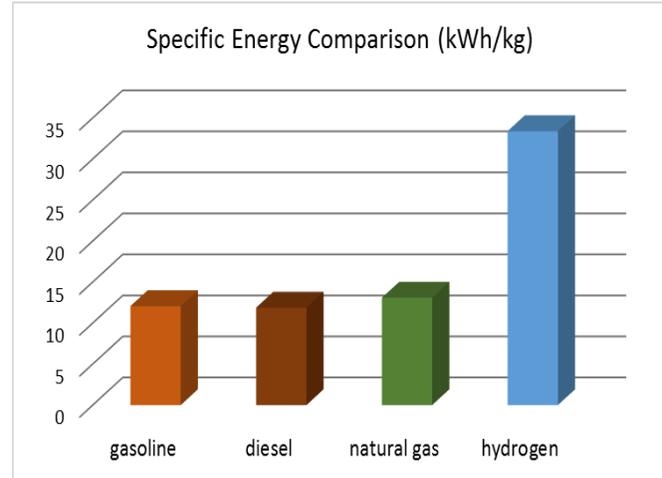
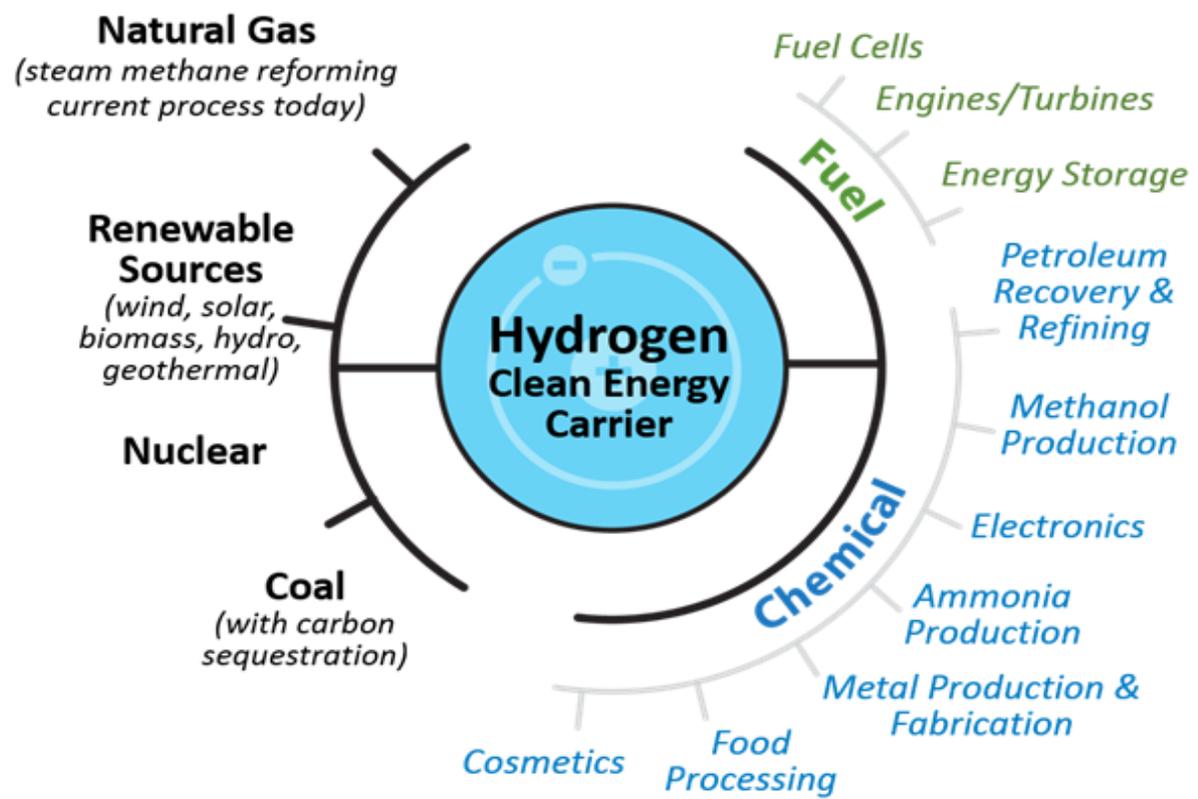


# Hydrogen – One Part of a Comprehensive Energy Strategy

H<sub>2</sub> can be produced from diverse domestic sources

Many applications rely on or could benefit from H<sub>2</sub>

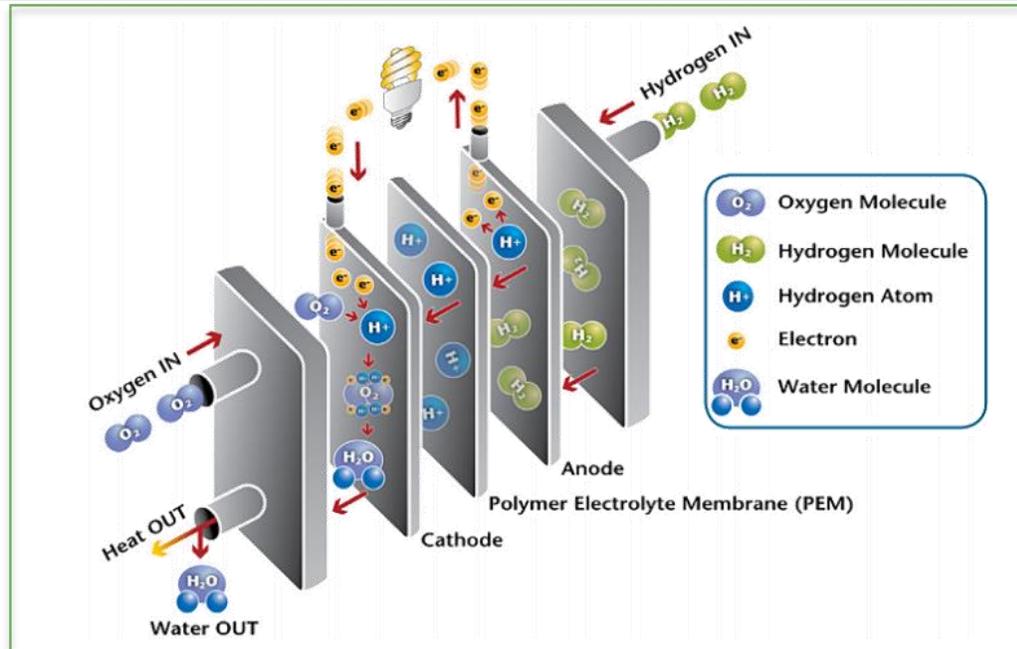
High energy content by mass  
Nearly 3x more than conventional fuels



Clean, sustainable, versatile, and efficient energy carrier

# Fuel Cell Basics

Fuel cells can operate on hydrogen or other fuels and do not involve combustion so have high electrical efficiencies



Convenient   
  Quiet   
  Clean



Refuels in minutes



No noise in operation



Zero tailpipe emissions

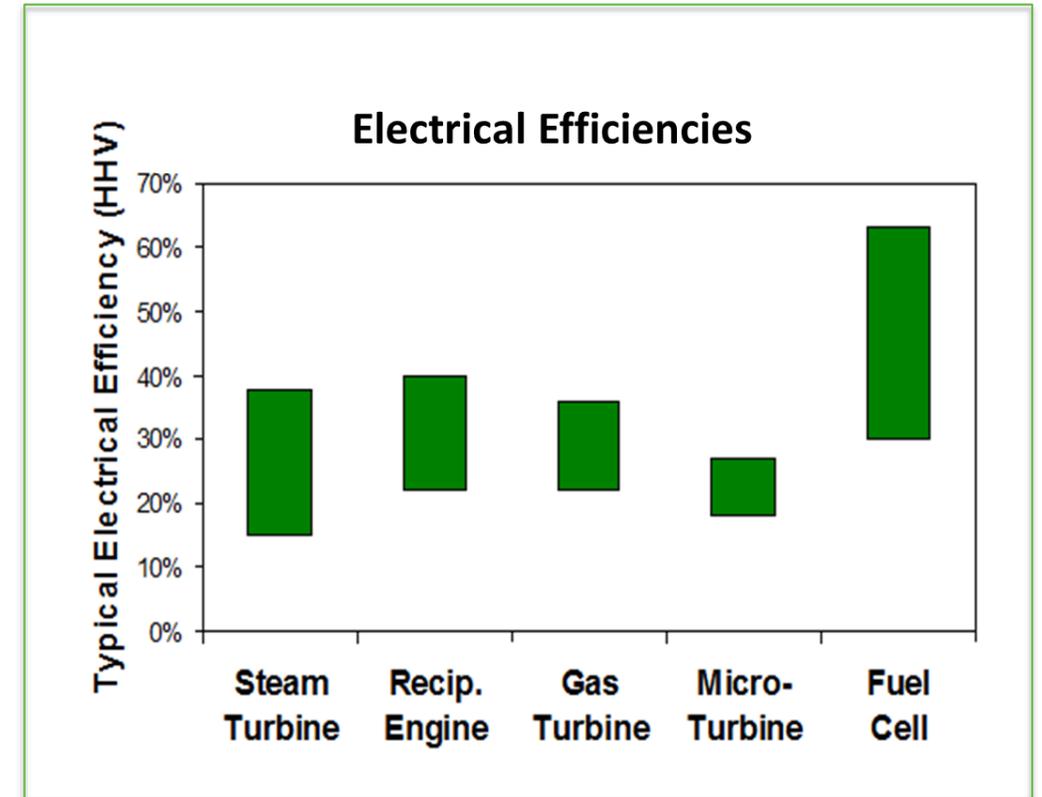
Versatile and easily scalable



Transportation

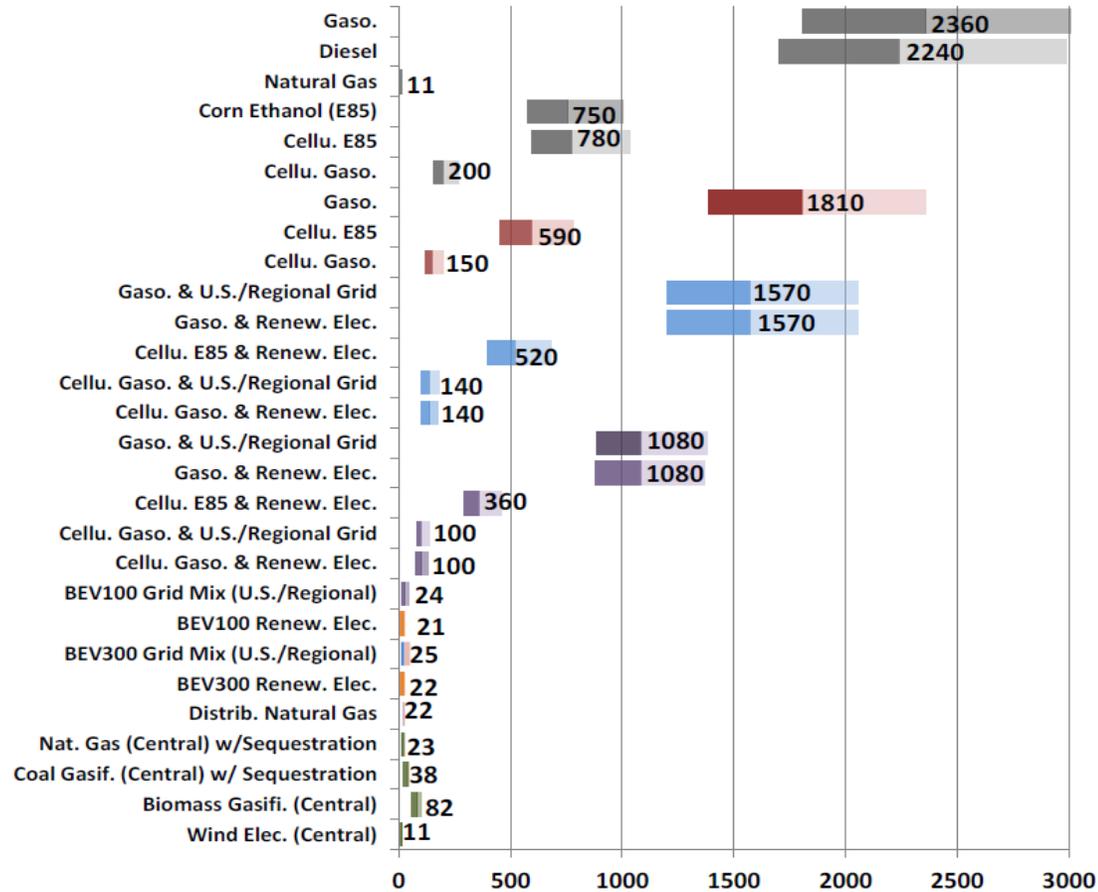


Stationary

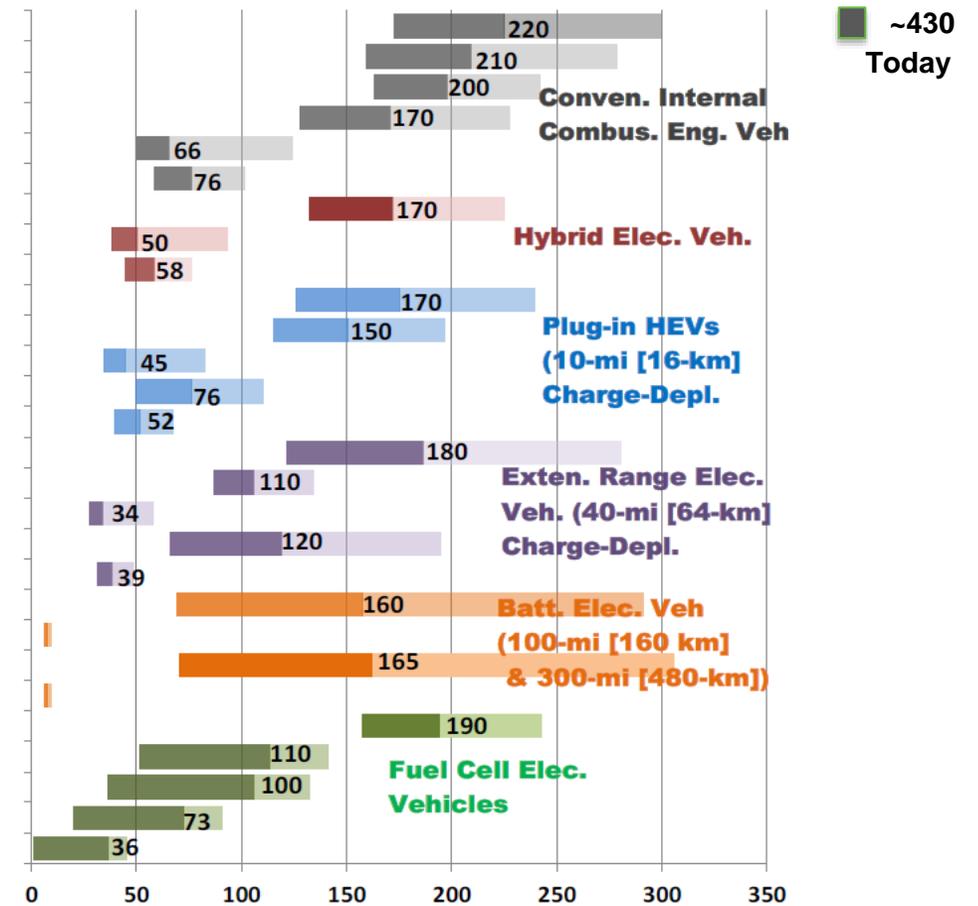


# Example of Well-to-Wheels Analysis: Petroleum Use and Emissions

## Petroleum Use, BTUs/Mile

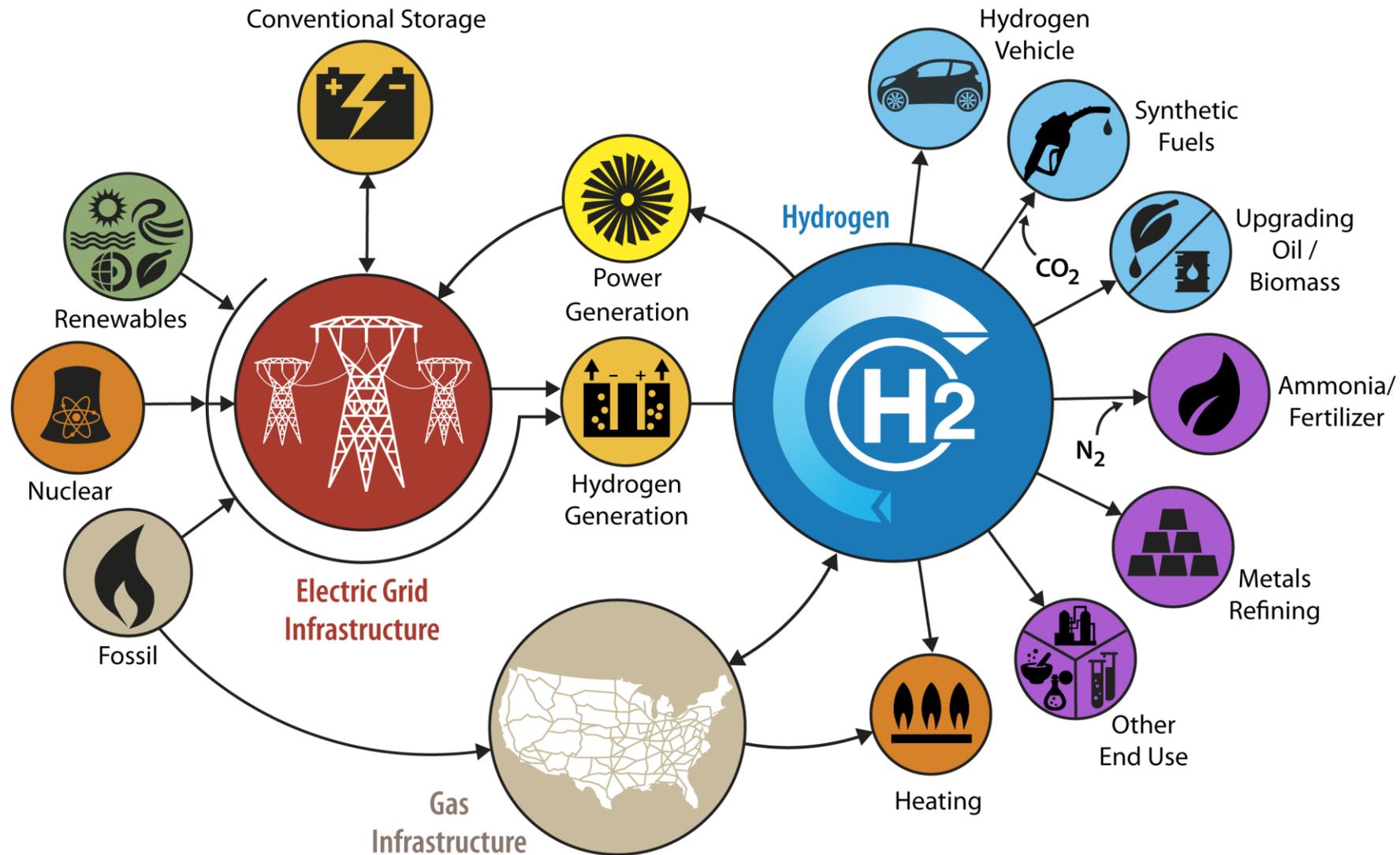


## GHG Emissions, gCO<sub>2</sub>/Mile



Program Record #13005: [http://www.hydrogen.energy.gov/pdfs/13005\\_well\\_to\\_wheels\\_ghg\\_oil\\_ldvs.pdf](http://www.hydrogen.energy.gov/pdfs/13005_well_to_wheels_ghg_oil_ldvs.pdf); shows future (2035) technology pathways; updates underway will include heavy duty vehicles- focus for H2

# H<sub>2</sub>@Scale: Enabling affordable, reliable, clean, and secure energy across sectors



# Guiding Legislation and Budget

## Energy Policy Act (2005) Title VIII on Hydrogen

- Authorizes U.S. DOE to lead a comprehensive program to enable commercialization of hydrogen and fuel cells with industry.
- Includes broad applications: Transportation, utility, industrial, portable, stationary, etc.

### Program To Date

- **\$100M to \$250M per year**
- **100 to 200+ projects per year**
- **>100 organizations & extensive collaborations**
- **Includes H2, fuel cells and cross cutting RD&D:**
  - H2 production, delivery, storage, utilization (including fuel cells)
  - Analysis, systems development/integration, safety, codes and standards, education & outreach
- **Reduced fuel cell cost 60%, quadrupled durability, reduced electrolyzer cost 80% and other advances**

Funding in \$K	FY 2018	FY 2019	FY 2020
<b>Fuel Cell R&amp;D</b>	32,000	30,000	26,000
<b>Hydrogen Fuel R&amp;D</b>	54,000	39,000	45,000
Hydrogen Infrastructure R&D	-	21,000	25,000
<b>Technology Acceleration</b>	19,000	21,000	41,000
Safety, Codes, and Standards	7,000	7,000	10,000
<b>Systems Analysis</b>	3,000	2,000	3,000
<b>Total</b>	<b>\$115,000</b>	<b>\$120,000</b>	<b>\$150,000</b>

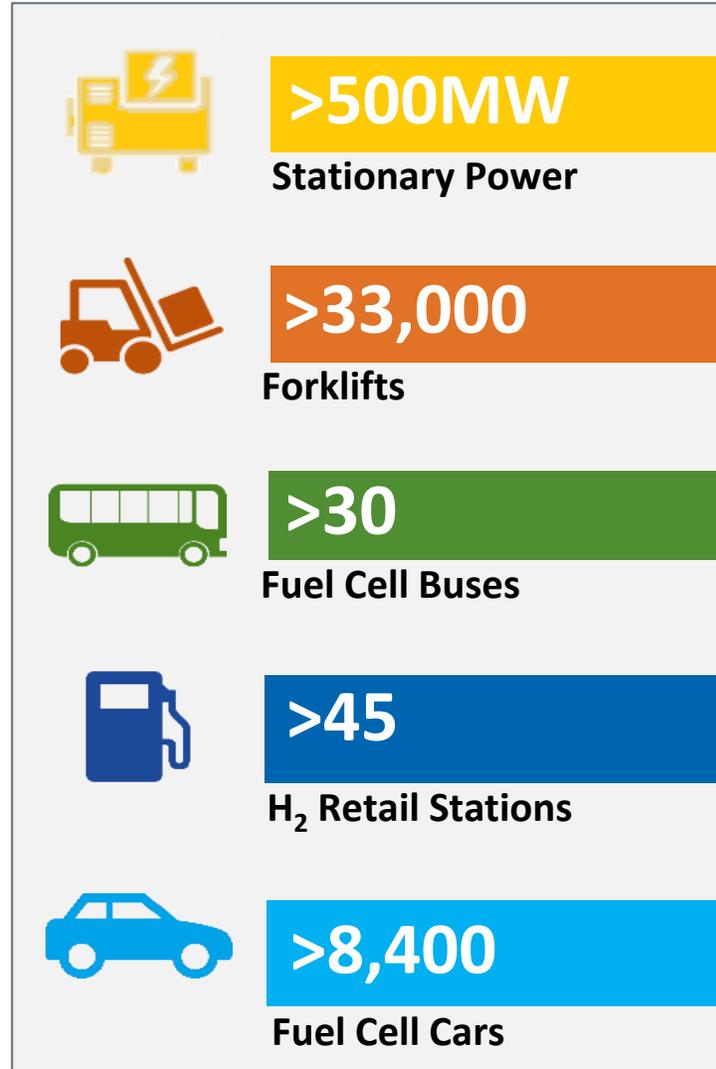
DOE Office	Funding (in \$K)
EERE (FCTO) - Lead	\$150,000
Fossil Energy (SOFC)	\$30,000
Nuclear Energy	\$11,000*

• EERE: Energy Efficiency and Renewable Energy Office  
 • FCTO: Fuel Cell Technologies Office  
 • SOFC: Solid Oxide Fuel Cell Office

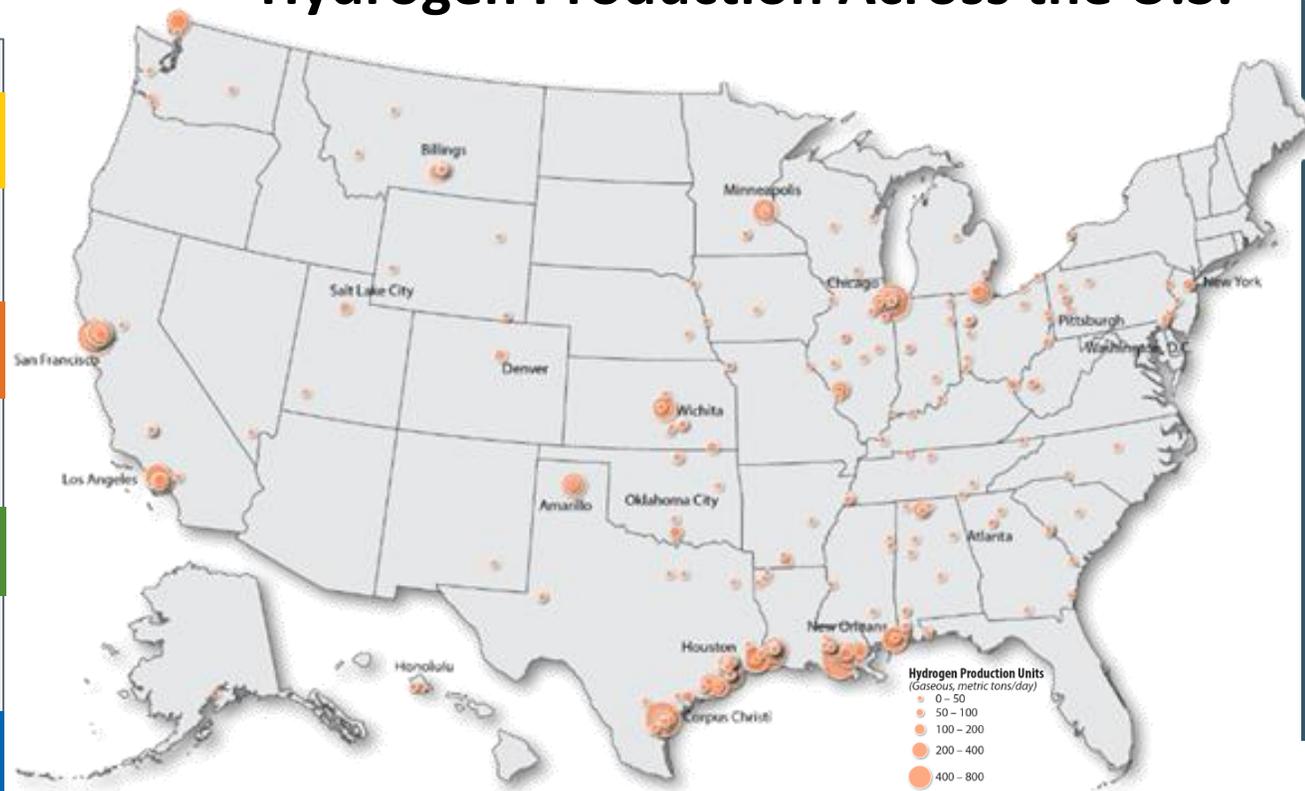
\* FY20 Appropriations for nuclear to H2 demonstration project with FCTO (\$10M)

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

## Examples of Applications



## Hydrogen Production Across the U.S.



- 10 million metric tons produced annually
- More than 1,600 miles of H<sub>2</sub> pipeline
- World's largest H<sub>2</sub> storage cavern

## Hydrogen Stations: Examples of Plans Across States

### California

200 stations planned - CAFCP goal

### Northeast

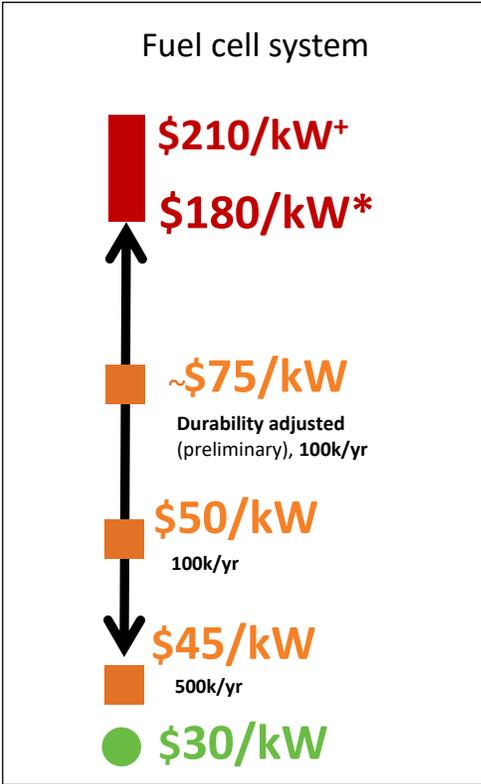
12 – 20 stations planned

HI, OH, SC, NY, CT, MA, CO, UT, TX, MI, and others

# R&D focus is on Affordability and Performance: DOE Targets Guide R&D

Key Goals: Reduce the cost of fuel cells and hydrogen production, delivery, storage, and meet performance and durability requirements – guided by applications specific targets

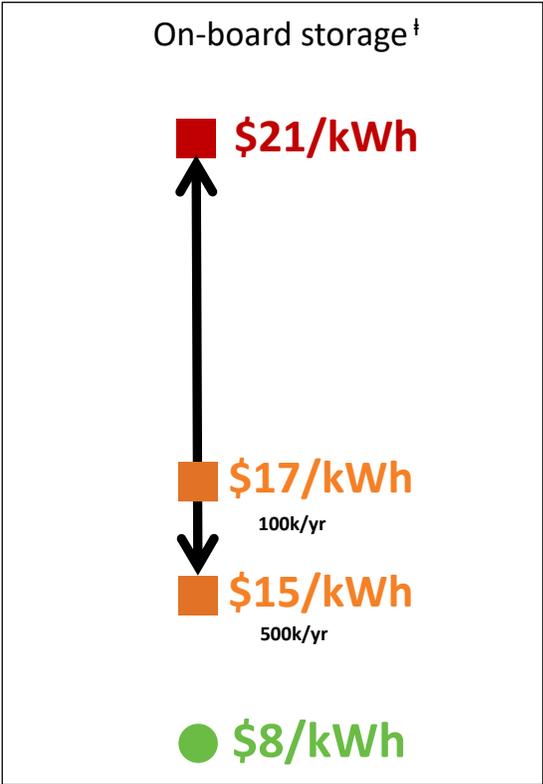
## Fuel Cell R&D



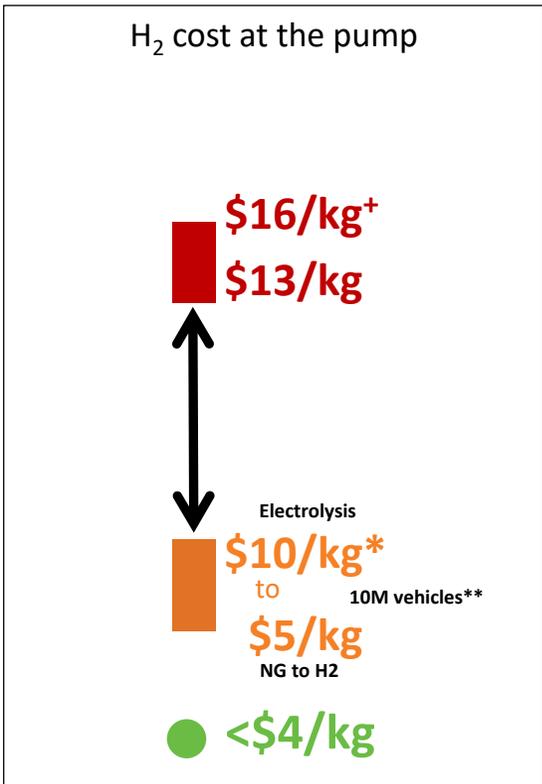
<sup>+</sup>Based on commercially available FCEVs

\*Based on state of the art technology

## Hydrogen R&D



<sup>†</sup>Storage costs based on preliminary 2019 storage cost record

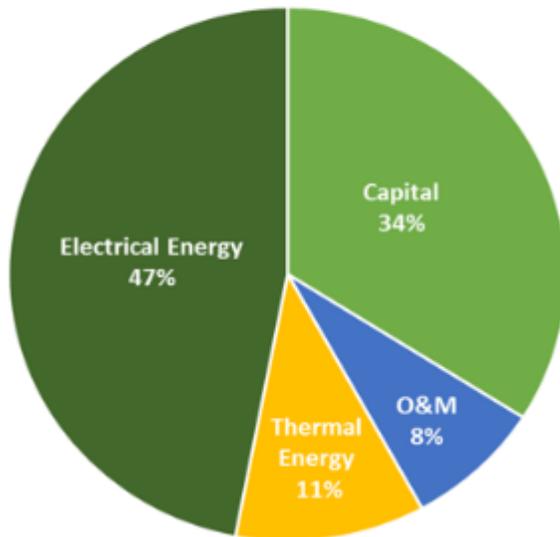


<sup>+</sup>For range: H<sub>2</sub> production from natural gas (NG), delivered dispensed at today's (2018) stations (~180kg/d)  
<sup>\*</sup>For range: Assumes high volume manufacturing in 1) H<sub>2</sub> production costs ranging from \$2/kg (NG) to \$5/kg (electrolysis manufactured at 700 MW/year), and 2) Delivery and dispensing costs ranging from \$3/kg (advanced tube trailers) to \$5/kg (liquid tanker or advanced pipeline technologies).  
<sup>\*\*</sup> Range assumes >10,000 stations at 1,000 kg/day capacity, to serve 10 million vehicles



# Hydrogen R&D Areas – Examples

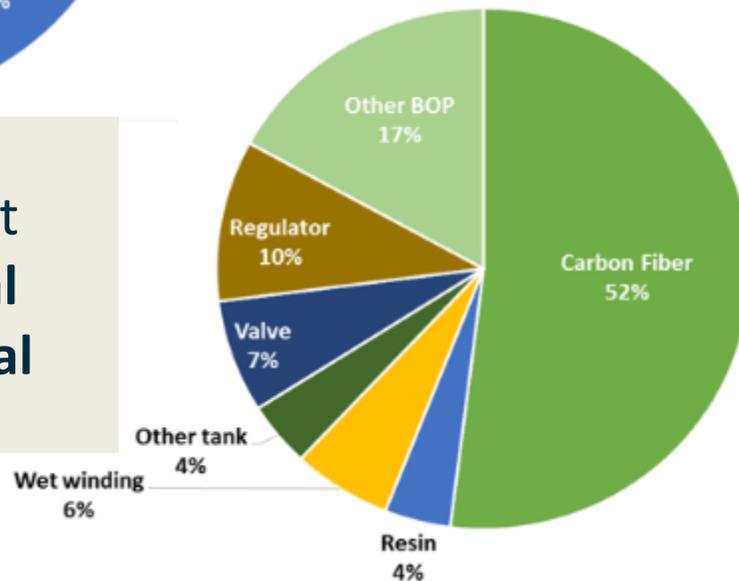
**Hydrogen Production Cost**  
(High Temperature Electrolysis)



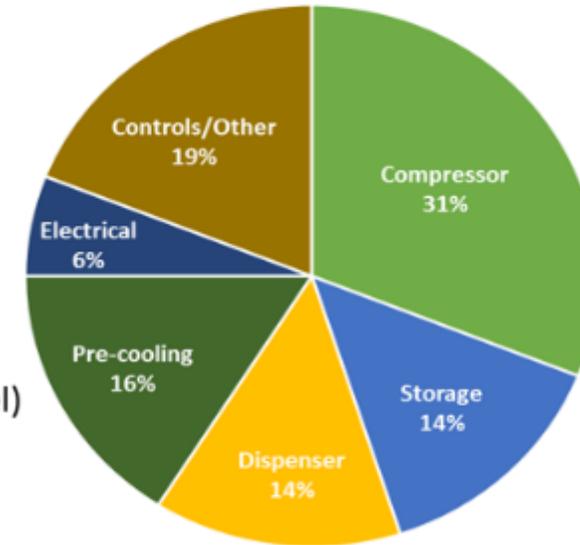
H<sub>2</sub> Production (Electrolysis) Cost Drivers: **Electrical energy and capital costs**

H<sub>2</sub> Onboard Storage Cost Drivers: **Carbon Fiber Precursors and Processing**

**Hydrogen Storage Cost**  
(Onboard 700 Bar Hydrogen Storage Vessel)



**Hydrogen Infrastructure Cost**  
(700 Bar Hydrogen Station)

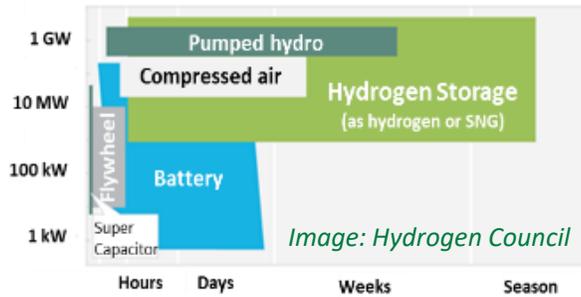


H<sub>2</sub> Infrastructure Cost Drivers: **Compressors and Storage**

Note: Updates to be published May, 2020

# Increased Activities on Hydrogen, Energy Storage, Hybrid Systems

Overview of Energy Storage Technologies in Power and Time



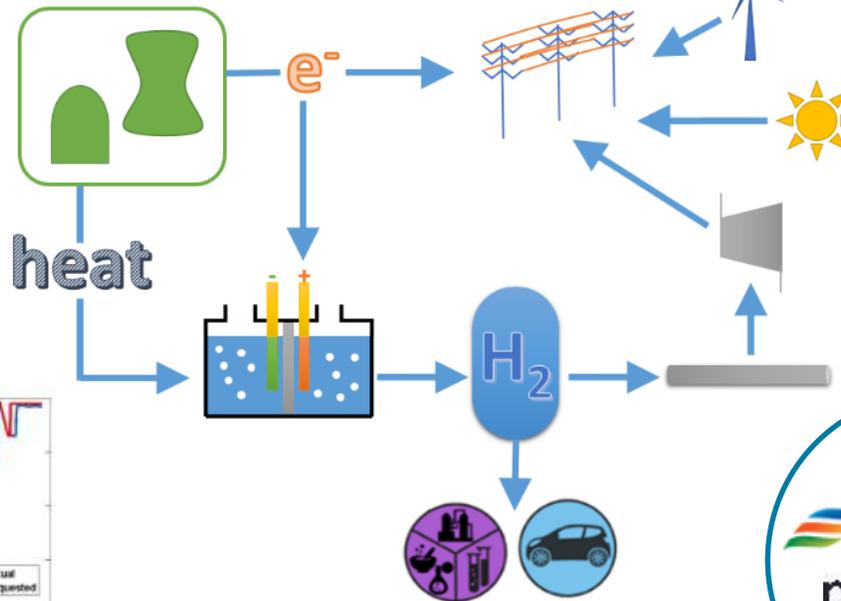
H<sub>2</sub> energy storage

Increased opportunities for nuclear and hydrogen

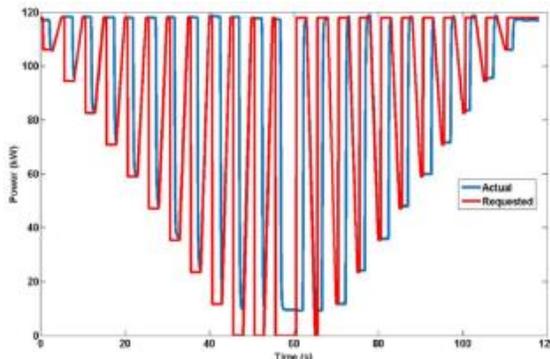


25 kW high-temperature electrolysis @ INL Energy Systems Laboratory

Thermal Integration



Dynamic response



Dynamic electrolyzer response – INL & NREL

DOE Industry demos



Recently announced demonstrations

Multiple end use applications

# New Project: Electrolyzer Operation at Nuclear Plant and In-House Hydrogen Supply

Clean H<sub>2</sub> production enabling dispatchable, carbon-free power

## Objectives

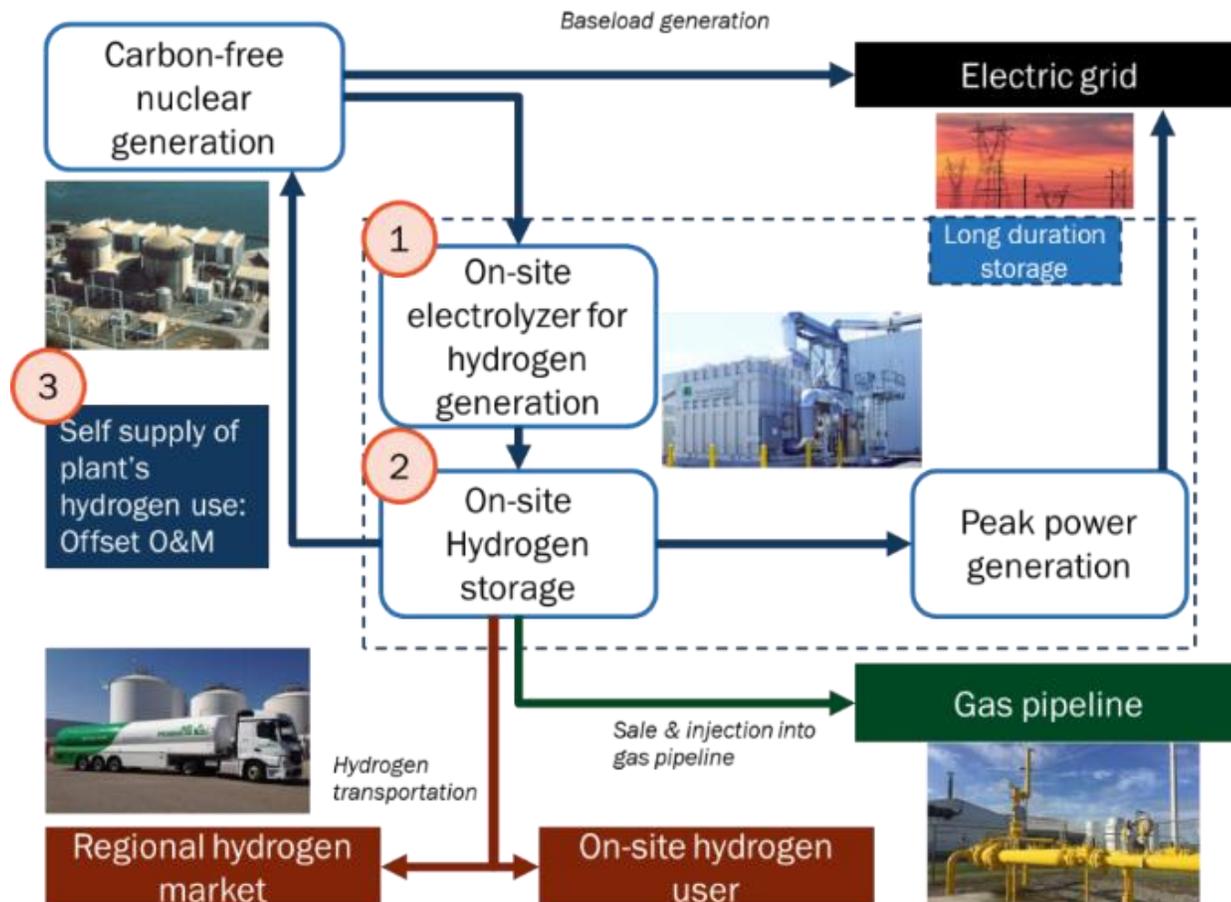
- Develop an integrated hydrogen production, storage, and utilization facility at a nuclear plant site, based on a PEM electrolyzer
- Demonstration of economic supply of carbon-free hydrogen for internal nuclear site use.
- Dynamic control of the electrolyzer

## Expected Outcomes

- Scaled-up hydrogen production in the U.S. power sector through a dynamically operable hydrogen production facility at a nuclear plant enabling nuclear units to be dispatchable.
- Demonstrated mechanism for hydrogen-based energy storage systems to improve nuclear plant participation in organized power markets.

## Program Summary

Partners: Exelon & Nel Hydrogen, INL, NREL, ANL  
Period: 36 months  
Total budget: \$7.2 million



Based on original proposal submission; final project under negotiation

A top-down view of several hands of different skin tones clasped together in a circle, resting on a green grassy surface. The hands are arranged in a supportive grip, with some fingers overlapping. Two gold rings are visible on the hands. The overall image conveys a sense of unity and teamwork.

# Collaboration & Resources

# Global Government Partnerships to Accelerate Progress on Hydrogen and Fuel Cells



Elected Chair and Vice-Chair, 2018

Mission Innovation Hydrogen Challenge Launched 2017

Hydrogen Energy Ministerial (HEM) Launched 2018

Clean Energy Ministerial Hydrogen Initiative Launched 2019

## The International Partnership for Hydrogen and Fuel Cells in the Economy

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

Activities: Working Groups on Regulations, Codes, Standards & Safety; Education & Outreach

Develops country updates on policies, status, shares best practices

Task force on developing H<sub>2</sub> production analysis methodology to facilitate international trade

Coordinates activities among global and regional partnerships



Find IPHE on Facebook, Twitter and LinkedIn  
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[www.iphe.net](http://www.iphe.net)



Formed 2003

19 Countries and EC

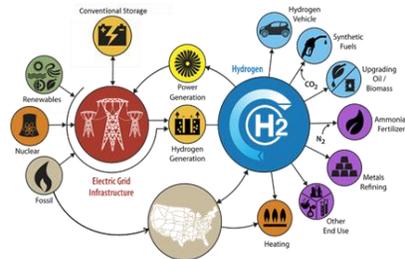
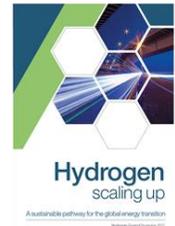
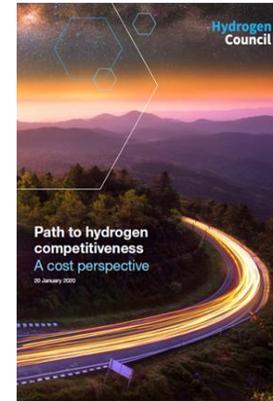
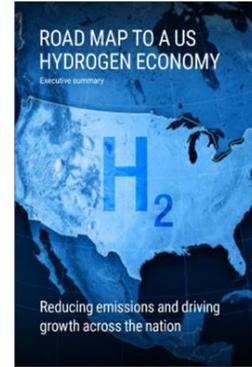
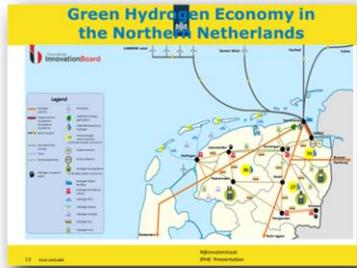
International Energy Agency (IEA)



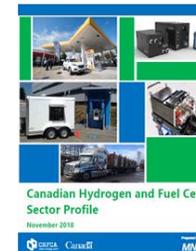
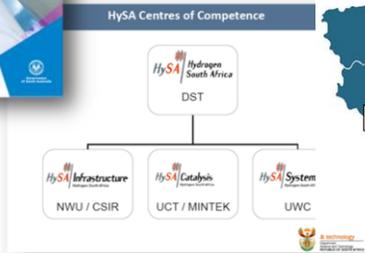
# Roadmaps and Plans Developing in Multiple Regions



Drivers include: Energy security, energy efficiency & resiliency, economic growth, innovation & technology leadership, environmental benefits



**Global Action Agenda released at Hydrogen Energy Ministerial, Tokyo (9/25/2019)**  
**Aspirational Targets:**  
 "10, 10, 10"  
 10M systems,  
 10K stations, 10 years



High priority areas include: Global harmonization of codes and standards and addressing gaps, safety



# Global Snapshot of Status and Goals



More than 1/3 million stationary fuel cells, 15,000 fuel cell electric vehicles, 400 stations  
 Over 1 GW of fuel cells shipped in 2019  
 Plans developing for applications across sectors

 IPHE Member Countries

 2030 Vehicles & Stations Goal<sup>1</sup>

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

Based on IPHE Country Updates  
 US: CA Fuel Cell Partnership goal



# Example of Collaboration: Global Center for H<sub>2</sub> Safety (CHS)

IPHE Steering Committee action: Increase awareness of safety partnership.  
Promotes safe operation, handling and use of hydrogen across all applications.



**CENTER FOR 水素安全センター**  
**Hydrogen SAFETY**  
Connecting a Global Community

水素は、石油、風力、太陽光、その他のエネルギー資源から作られている。水素はエネルギーキャリアーとして注目されている。

年間7千方トン

化学工業 石油精製 電子工業 医薬品業界

世界中では毎年7,000万トンの水素が産業用途として生産されている。

## 輸送分野の水素利用:

汚染物質、炭素排出量、騒音の削減手段として、トラックや船舶にゼロエミッションの燃料電池活用への関心が急速に高まっている。

60 輛 燃料電池電車

[www.aiche.org/CHS](http://www.aiche.org/CHS)

## Information to be available in multiple languages

**CENTER FOR 水素安全センター**  
**Hydrogen SAFETY**  
Connecting a Global Community

1 <b>H</b> 水素 1.008	4 <b>Be</b> ベリリウム 9.0121831
3 <b>Li</b> リチウム 6.94	12 <b>Mg</b> マグネシウム 24.305

水素自動車とその水素ステーションは安全に使用できる:  
水素は目新しいものではなく、50年以上にわたって産業界で広く使用されており、安全に使用できるように基準、標準、設計手法などが整備されてきた。

あらゆる燃料はエネルギーを持っており、どれも不適切に取り扱うと危険である。他の燃料と同様、水素もその特性に基づいて設計されたシステムで慎重に使用する必要がある。水素ステーションと燃料電池車(FCEV)は、安全確保のために確立された安全基準に基づいて設計されている。

燃料電池車は、従来の内燃式エンジンよりもクリーンで効率的である。タンクから供給された水素と空気中の酸素から電気を発生させ、排出されるのは水蒸気だけである。

## 輸送分野の水素利用:

水素は、石油、風力、太陽光、その他のエネルギー資源から作られている。水素はエネルギーキャリアーとして注目されている。

年間7千方トン

化学工業 石油精製 電子工業 医薬品業界

世界中では毎年7,000万トンの水素が産業用途として生産されている。

1,991億米ドル  
2023年見込みの売上規模

58万台  
2023年見込み台数

汚染物質、炭素排出量、騒音の削減手段として、トラックや船舶にゼロエミッションの燃料電池活用への関心が急速に高まっている。

60 輛 燃料電池電車

11,000 台  
公道上の水素自動車台数  
2018年実績

20,000 台  
水素燃料のフォークリフト  
2018年実績

# Resources and Announcements

## Save the Date

May 19 – 21, 2020 Annual Merit Review and Peer Evaluation Meeting for the Hydrogen and Fuel Cells Program in Washington D.C.



## Oct 8 - Hydrogen and Fuel Cells Day

(Held on its very own atomic-weight-day)



## Resources



Visit [H2tools.org](https://h2tools.org/) for hydrogen safety and lessons learned

<https://h2tools.org/>

INCREASE YOUR  
**H<sub>2</sub>IQ**

Download the H2IQ resource for free:

[energy.gov/eere/fuelcells/downloads/increase-your-h2iq-training-resource](https://energy.gov/eere/fuelcells/downloads/increase-your-h2iq-training-resource)

Join monthly H2IQ hours to learn more about hydrogen and fuel cell topics

[.energy.gov/eere/fuelcells/fuel-cell-technologies-office-webinars](https://energy.gov/eere/fuelcells/fuel-cell-technologies-office-webinars)



Learn more:

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

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

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