U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Hydrogen and Fuel Cell Perspectives

Dr. Sunita Satyapal, Director, U.S. Dept. of Energy Hydrogen and Fuel Cells Program

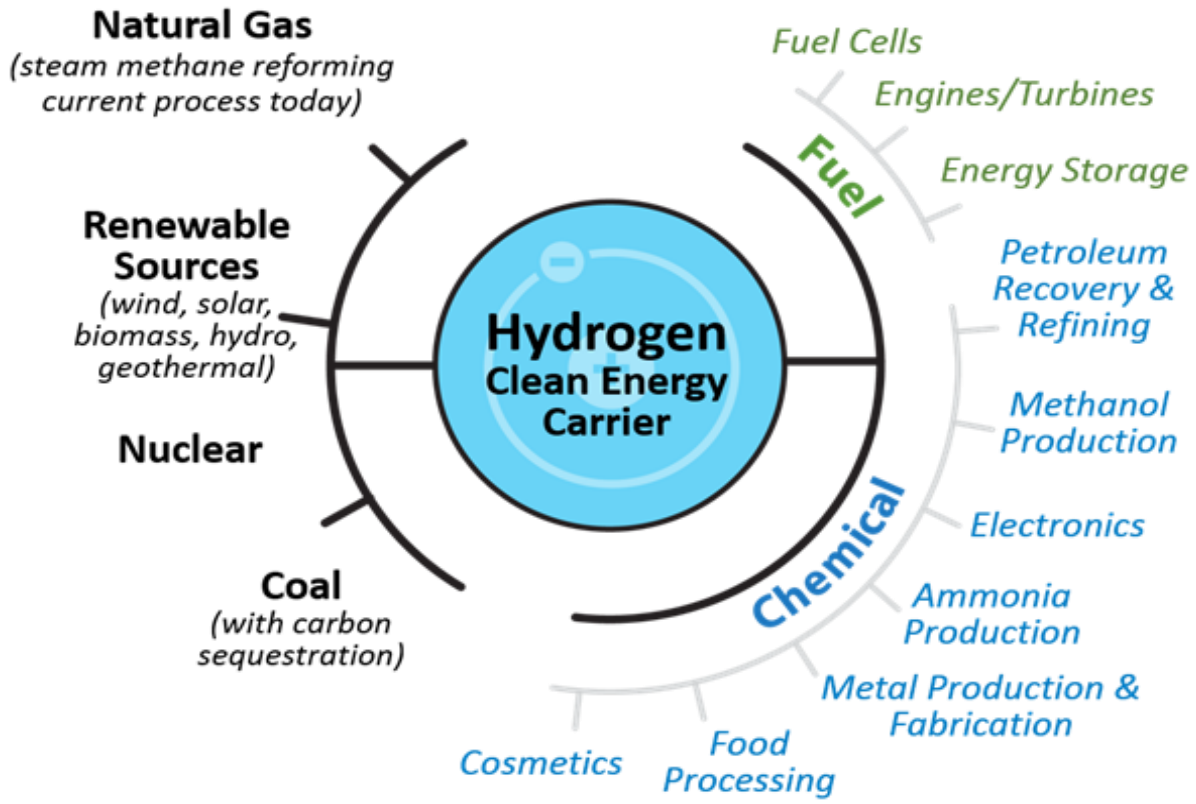
Clean Energy Ministerial's (CEM) Nuclear Innovation: Clean Energy Future (NICE Future) Initiative, Hydrogen Initiative (H2I), International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE) Joint Webinar

March 18, 2020

Hydrogen – One Part of a Comprehensive Energy Strategy

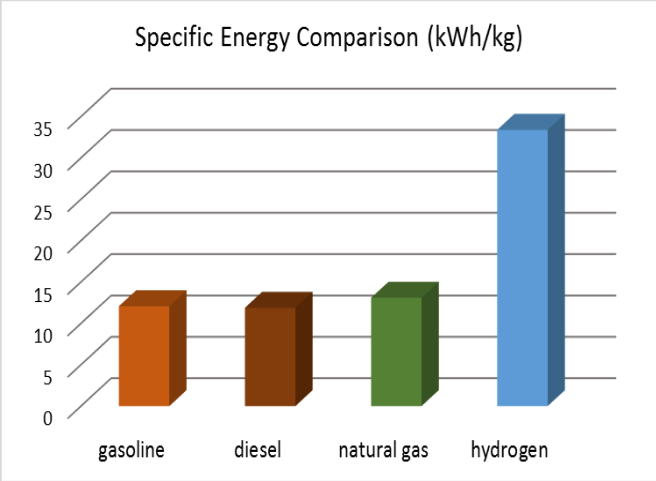
H_2 can be produced from diverse domestic sources

Many applications rely on or could benefit from H_2

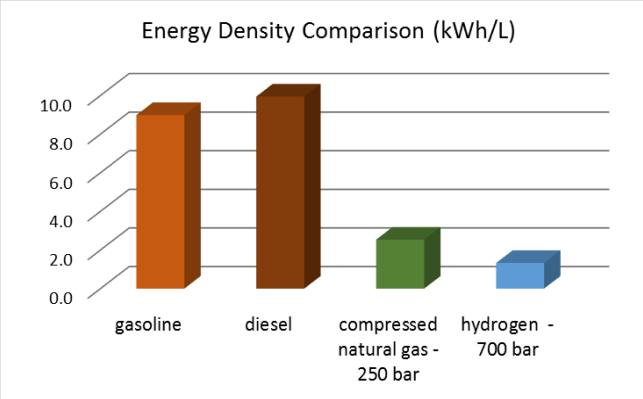


High energy content by mass

Nearly 3x more than conventional fuels



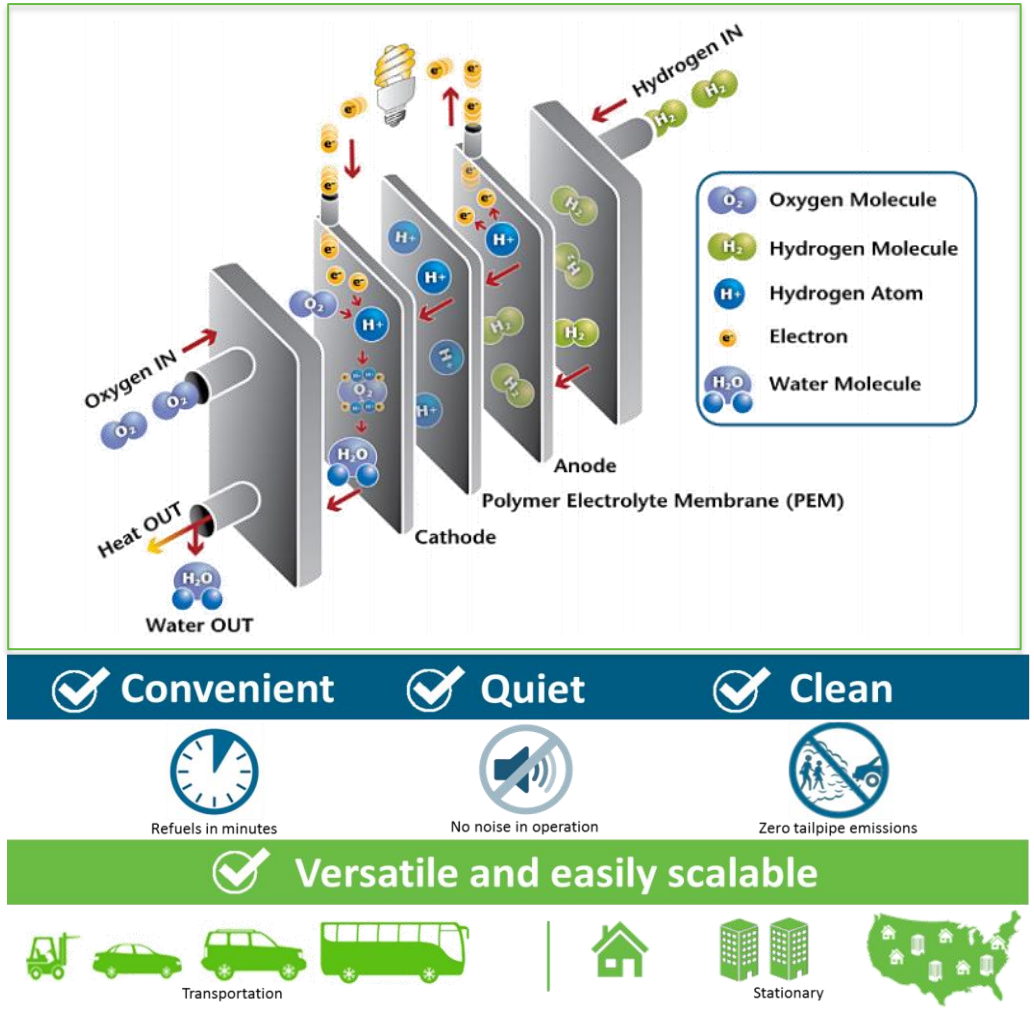
Low energy content by volume

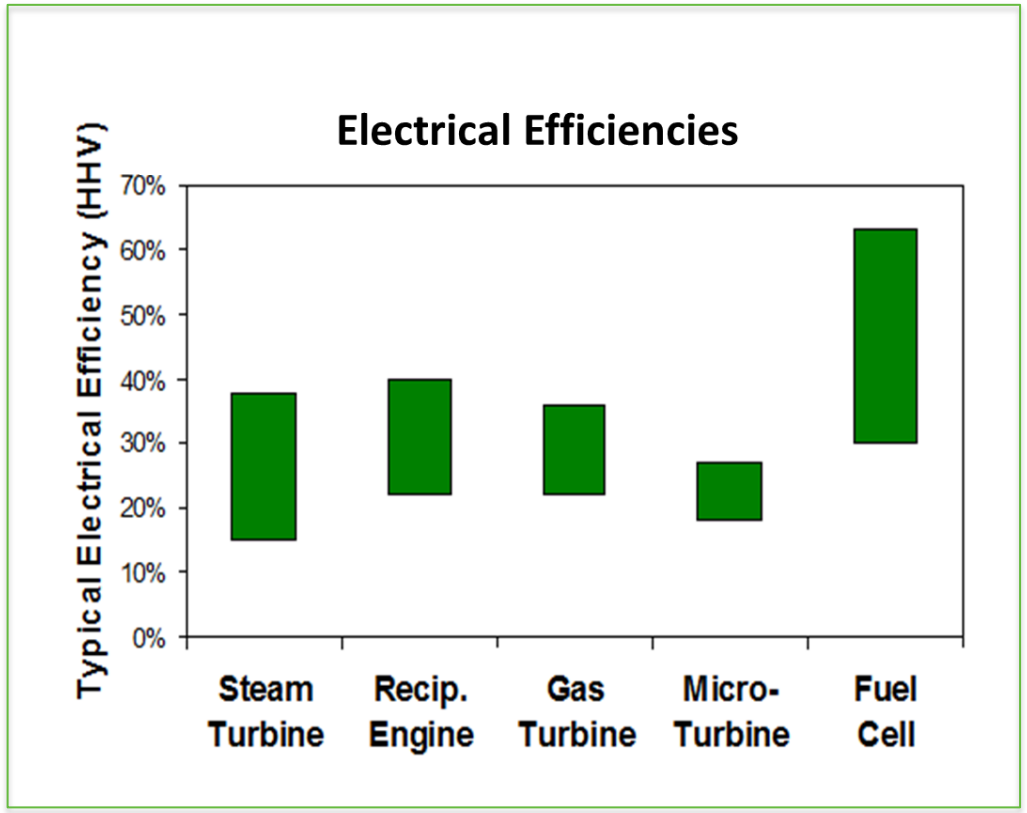


Clean , sustainable, versatile, and efficient energy carrier

Fuel Cell Basics

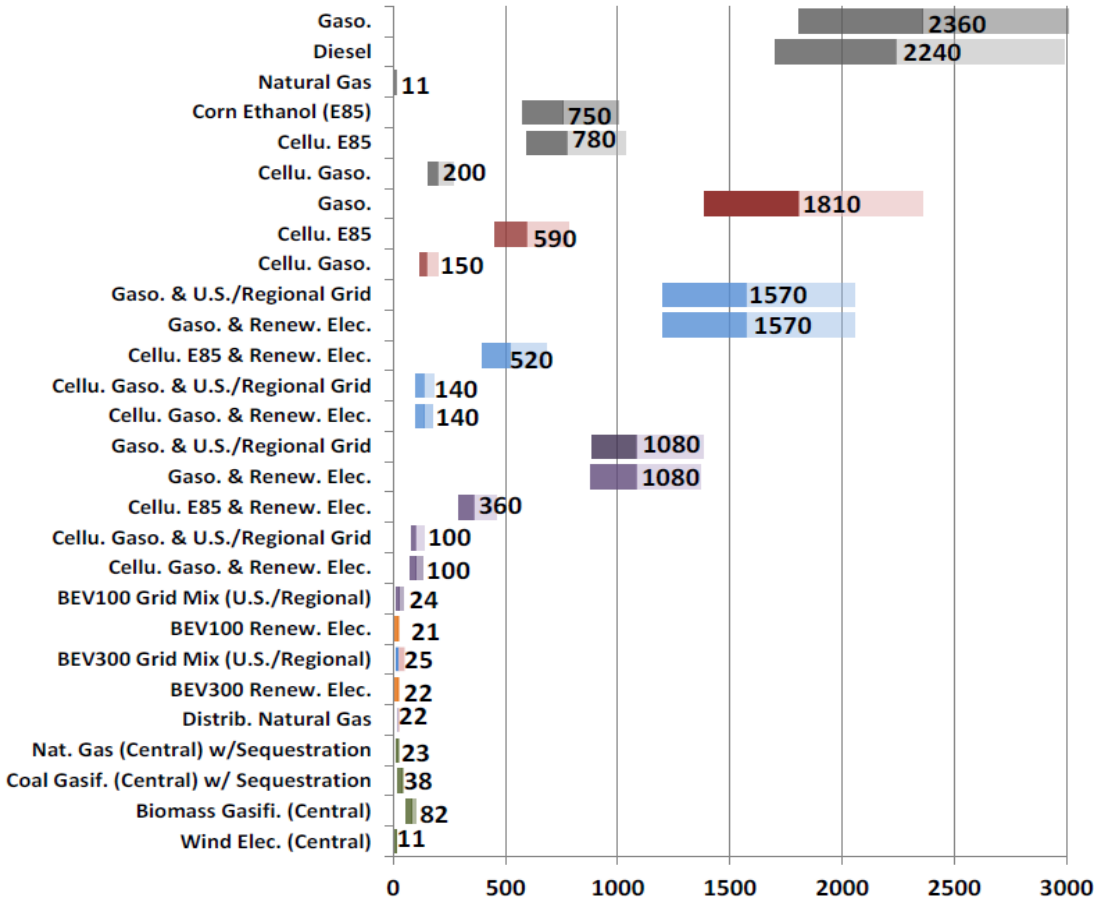
Fuel cells can operate on hydrogen or other fuels and do not involve combustion so have high electrical efficiencies



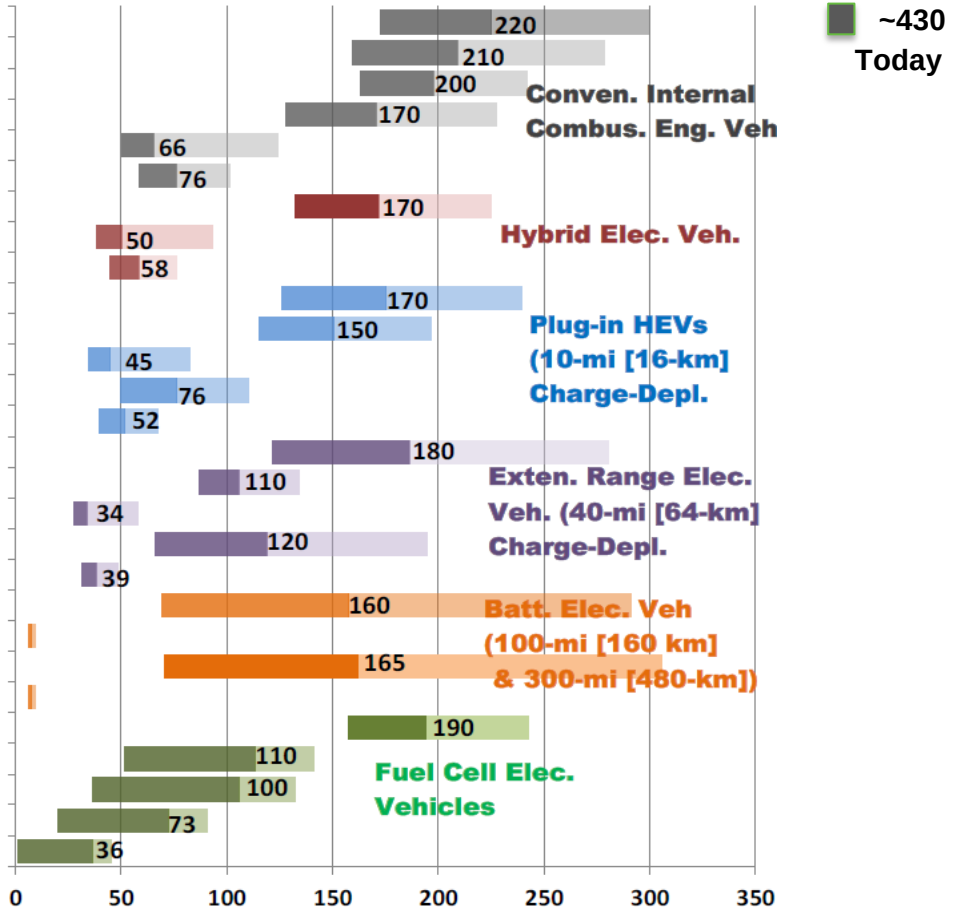


Example of Well-to-Wheels Analysis: Petroleum Use and Emissions

Petroleum Use, BTUs/Mile

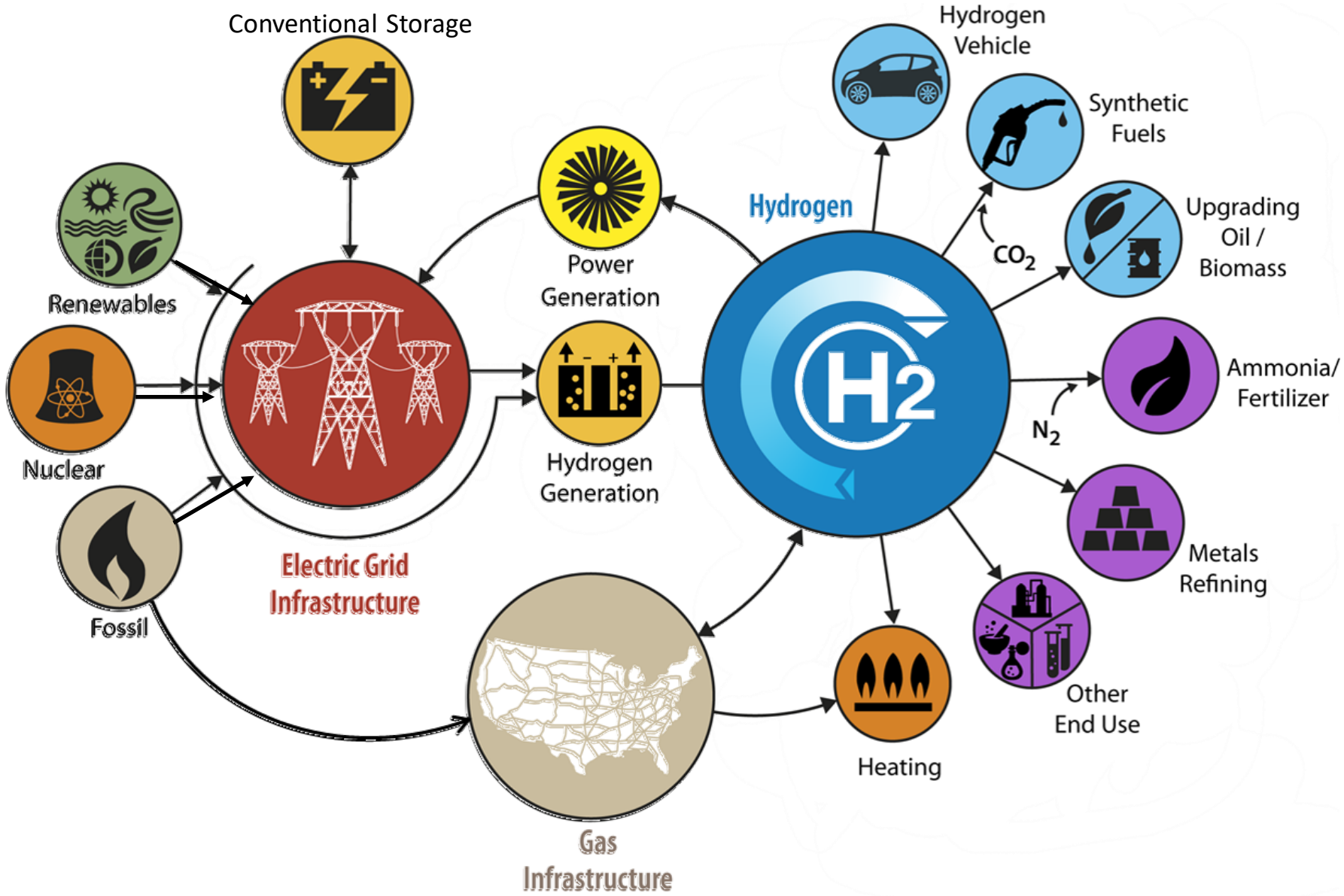


GHG Emissions, gCO_2/Mile

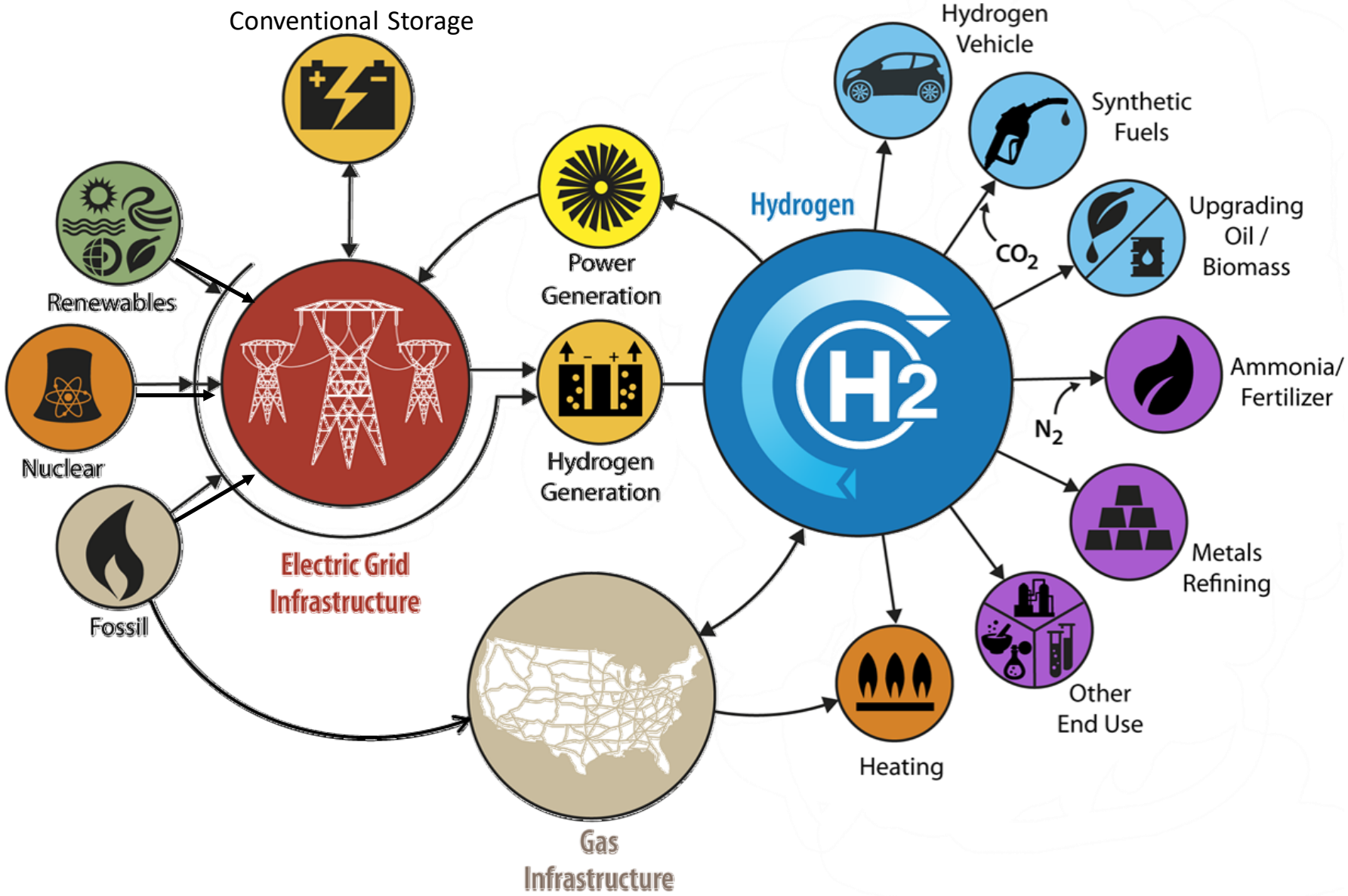


Program Record #13005: http://www.hydrogen.energy.gov/pdfs/13005_well_to_wheels_ghg_oil_ldvs.pdf; shows future (2035) technology pathways; updates underway will include heavy duty vehicles- focus for H2

H_2@Scale: Enabling affordable, reliable, clean, and secure energy across sectors



H_2@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
Fuel Cell R&D	32,000	30,000	26,000
Hydrogen Fuel R&D	54,000	39,000	45,000
Hydrogen Infrastructure R&D	-	21,000	25,000
Technology Acceleration	19,000	21,000	41,000
Safety, Codes, and Standards	7,000	7,000	10,000
Systems Analysis	3,000	2,000	3,000
Total	**$115,000**	**$120,000**	**$150,000**

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

>500MW
Stationary Power

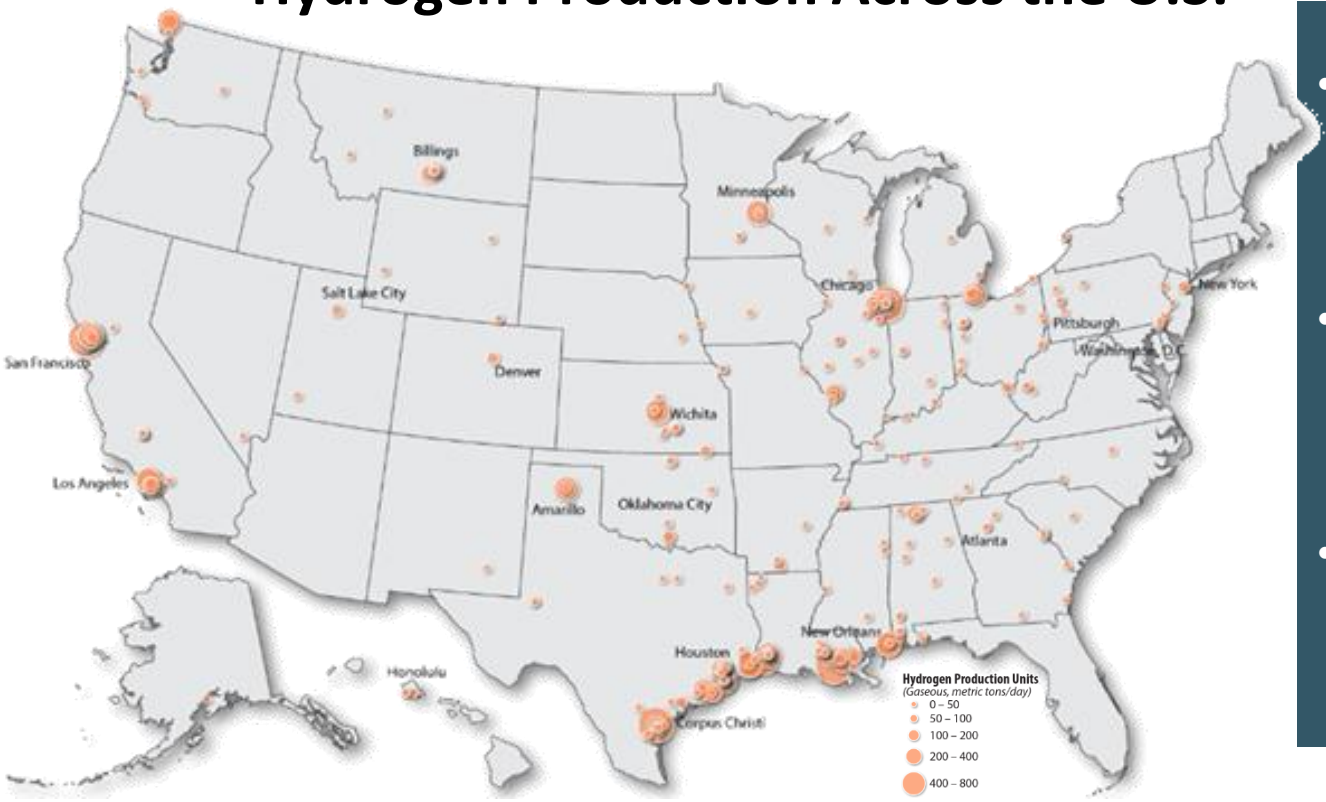
>33,000
Forklifts

>30
Fuel Cell Buses

>45
H_2 Retail Stations

>8,400
Fuel Cell Cars

Hydrogen Production Across the U.S.



- 10 million metric tons produced annually
- More than 1,600 miles of H_2 pipeline
- World's largest H_2 storage cavern

Hydrogen Stations: Examples of Plans Across States

California
200 stations planned - CAFCP goal

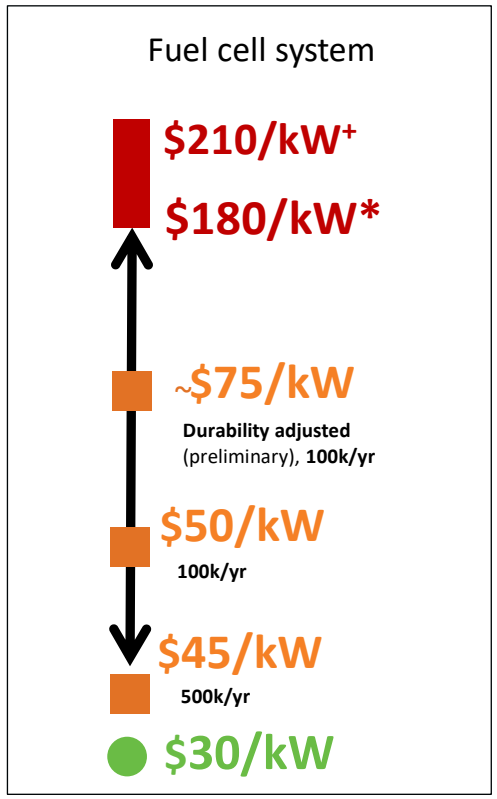
Northeast
12 – 20 stations planned

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

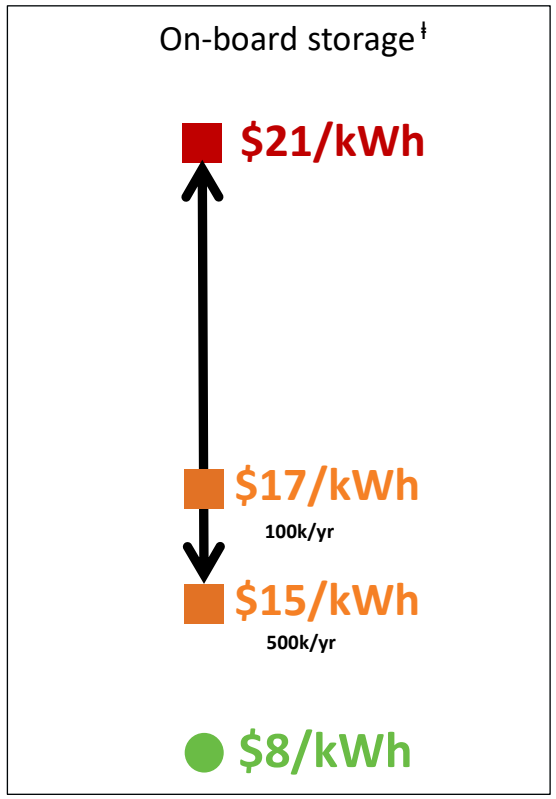
Fuel Cell R&D



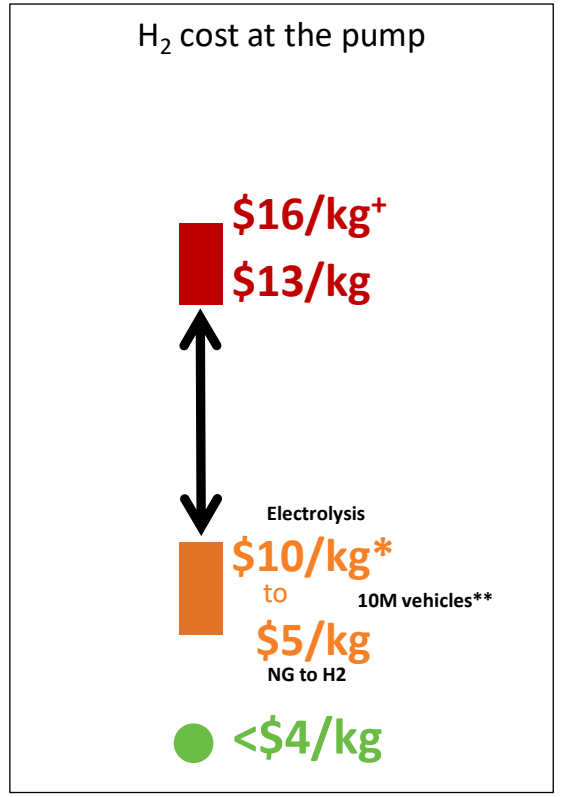
†Based on commercially available FCEVs

*Based on state of the art technology

Hydrogen R&D



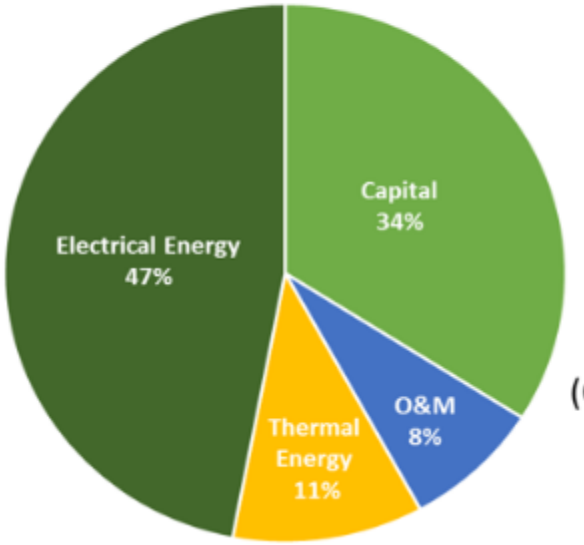
ǂ Storage costs based on preliminary 2019 storage cost record



†For range: H2 production from natural gas (NG), delivered dispensed at today's (2018) stations (~180kg/d)
*For range: Assumes high volume manufacturing in 1) H2 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).
** Range assumes >10,000 stations at 1,000 kg/day capacity, to serve 10 million vehicles

Hydrogen R&D Areas – Examples

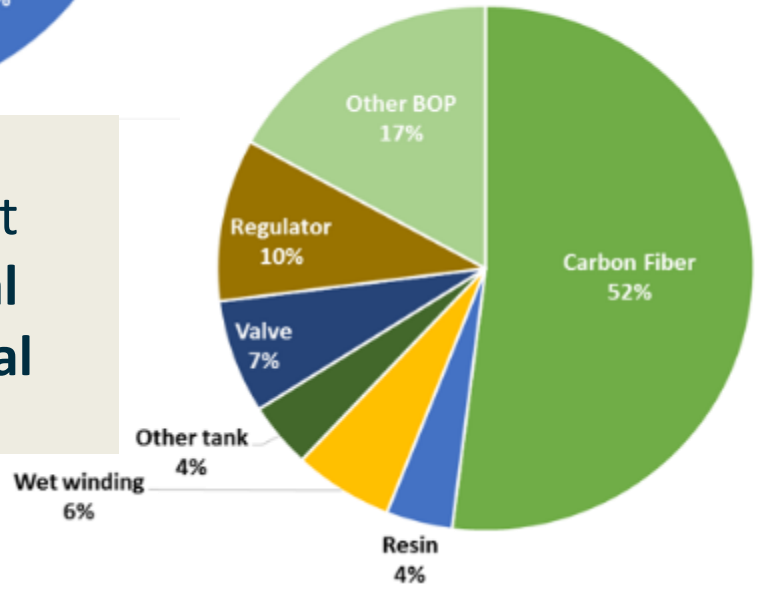
Hydrogen Production Cost
(High Temperature Electrolysis)



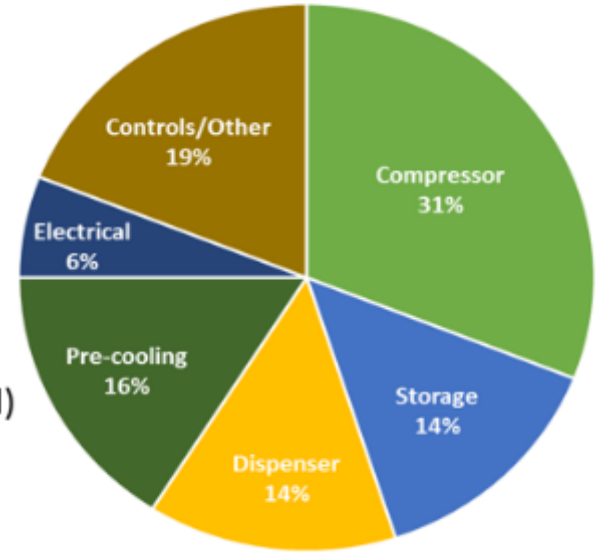
H_2 Production (Electrolysis) Cost Drivers: **Electrical energy and capital costs**

H_2 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_2 Infrastructure Cost Drivers: **Compressors and Storage**

Note: Updates to be published May, 2020

Increased Activities on Hydrogen, Energy Storage, Hybrid Systems

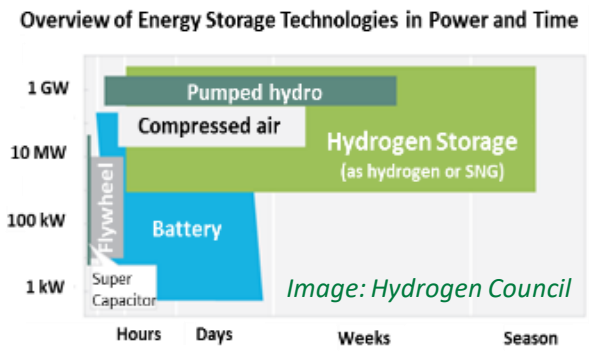


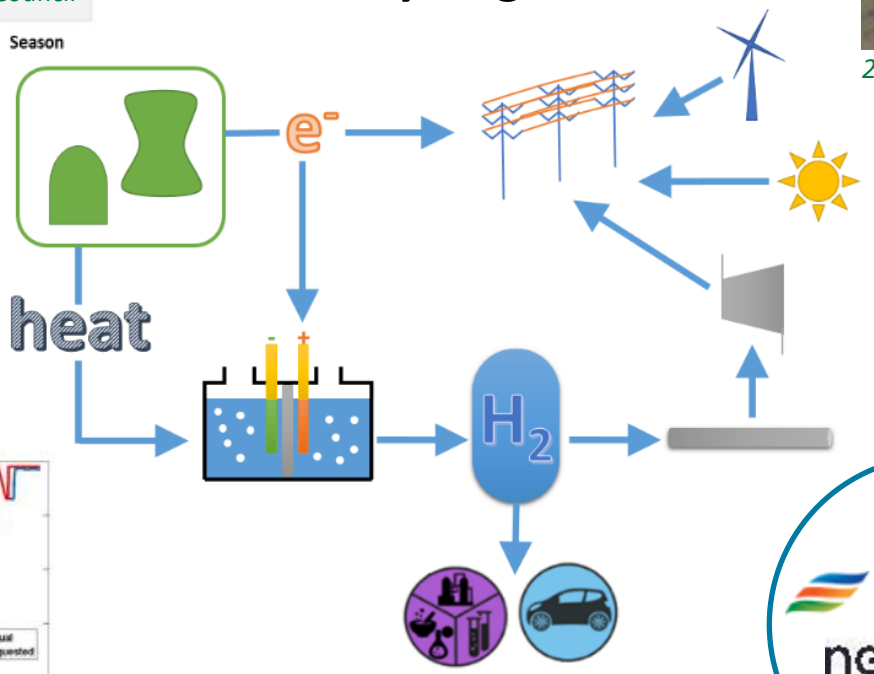
Image: Hydrogen Council

Increased opportunities for nuclear and hydrogen

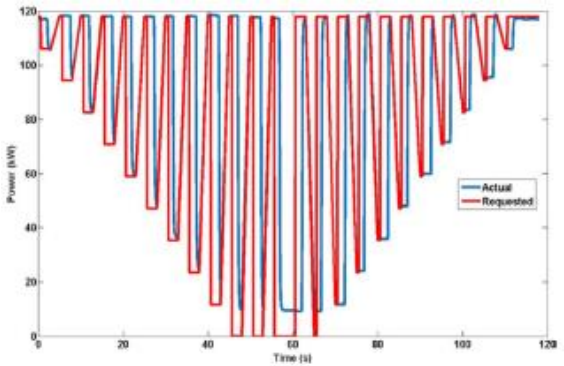
25 kW high-temperature electrolysis @ INL Energy Systems Laboratory

H_2 energy storage

Thermal Integration



Dynamic response



Dynamic electrolyzer response – INL & NREL

Multiple end use applications

DOE Industry demos

Exelon
nel
FirstEnergy Solutions
Xcel Energy
aps

Recently announced demonstrations

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

Clean H_2 production enabling dispatchable, carbon-free power

Objectives

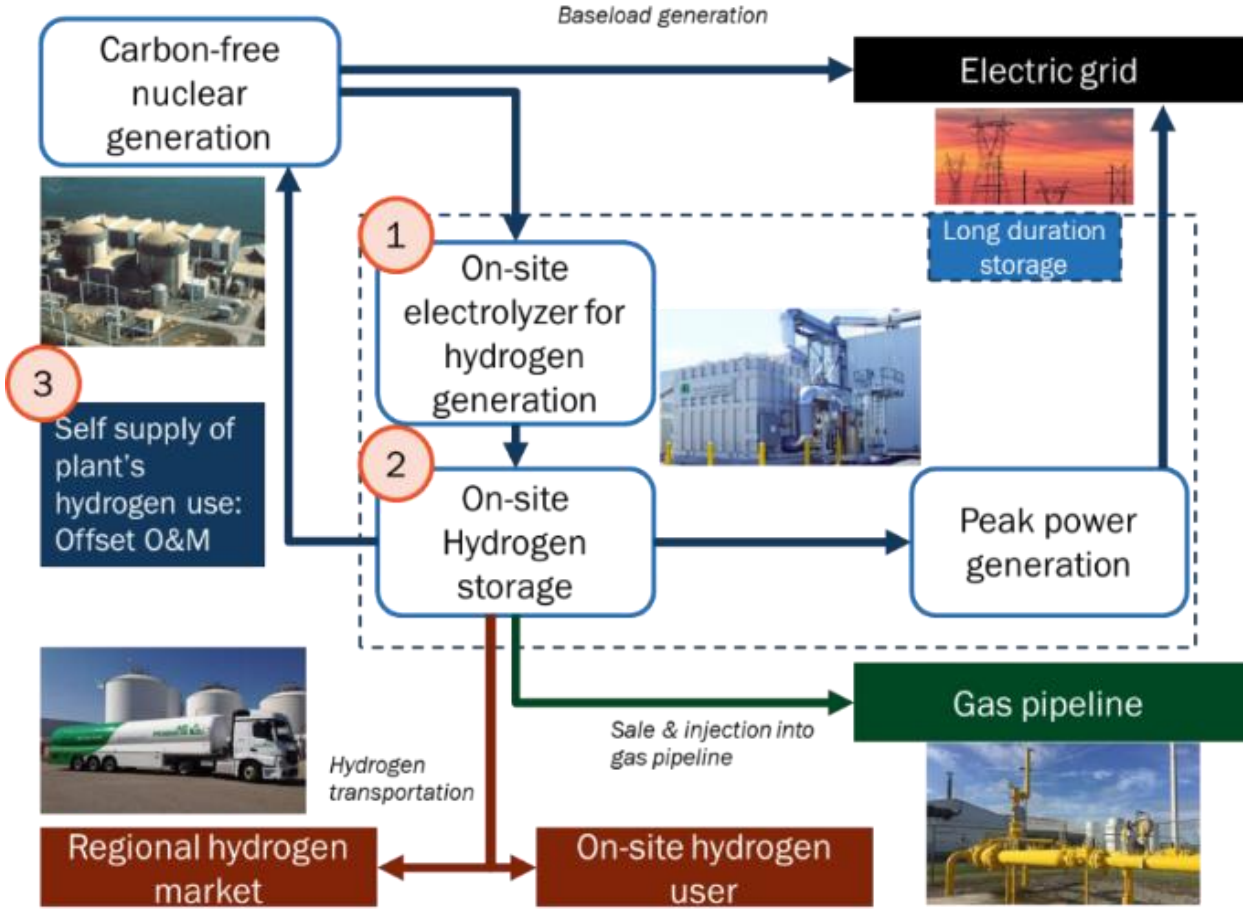
- Develop an integrated hydrogen production, storage, and utilization facility at a nuclear plant site, based on a PEM electrolyzer
- Demonstration of economic supply of carbon-free hydrogen for internal nuclear site use.
- Dynamic control of the electrolyzer

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


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_2 production analysis methodology to facilitate international trade

Coordinates activities among global and regional partnerships

Top Priorities

- SHARE INFORMATION
- INFORM FUTURE GOVERNMENT RD&D
- FOSTER COLLABORATION

Find IPHE on Facebook, Twitter and LinkedIn
Follow IPHE @The_IPHE

www.iphe.net

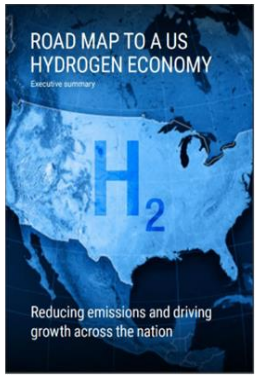
Formed 2003

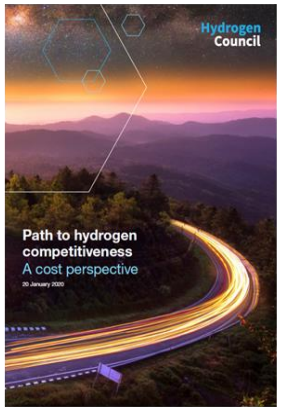
19 Countries and EC

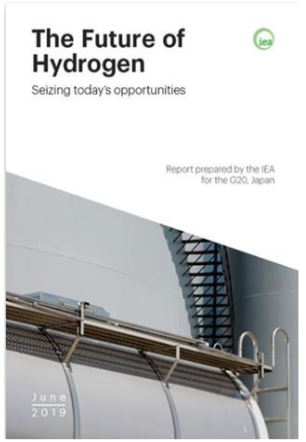
International Energy Agency (IEA)

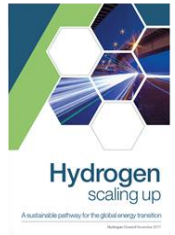
Roadmaps and Plans Developing in Multiple Regions

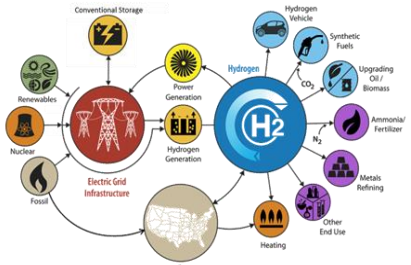
Drivers include: Energy security, energy efficiency & resiliency, economic growth, innovation & technology leadership, environmental benefits

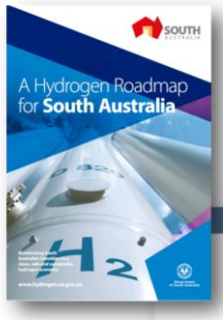


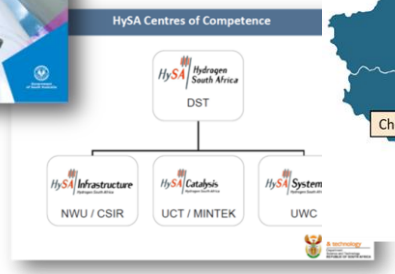




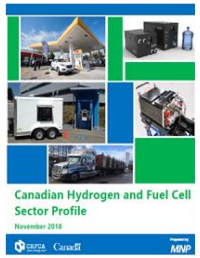






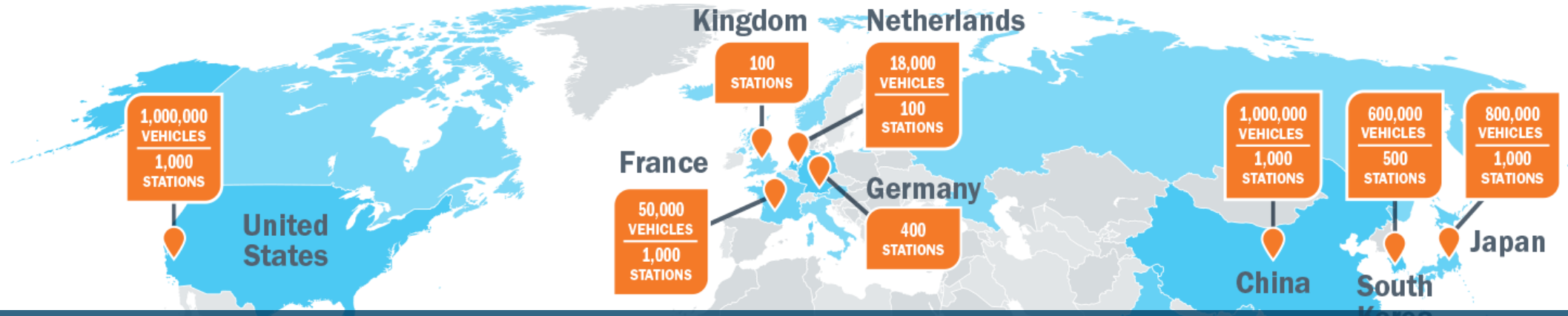


Global Action Agenda released at Hydrogen Energy Ministerial, Tokyo (9/25/2019) Aspirational Targets: "10, 10, 10" 10M systems, 10K stations, 10 years



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[1]

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

Example of Collaboration: Global Center for H_2 Safety (CHS)

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

IPHE

Hydrogen Council

hySafe

AIChE

Pacific Northwest NATIONAL LABORATORY

Includes over 40 partners from industry, government and academia

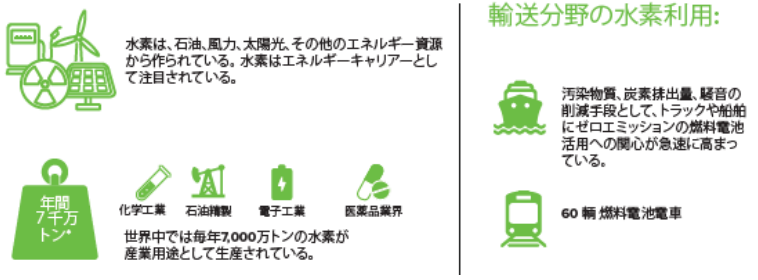
CENTER FOR Hydrogen SAFETY
Connecting a Global Community

HYDROGEN Safety Panel

HYDROGEN Emergency Response Training Resources

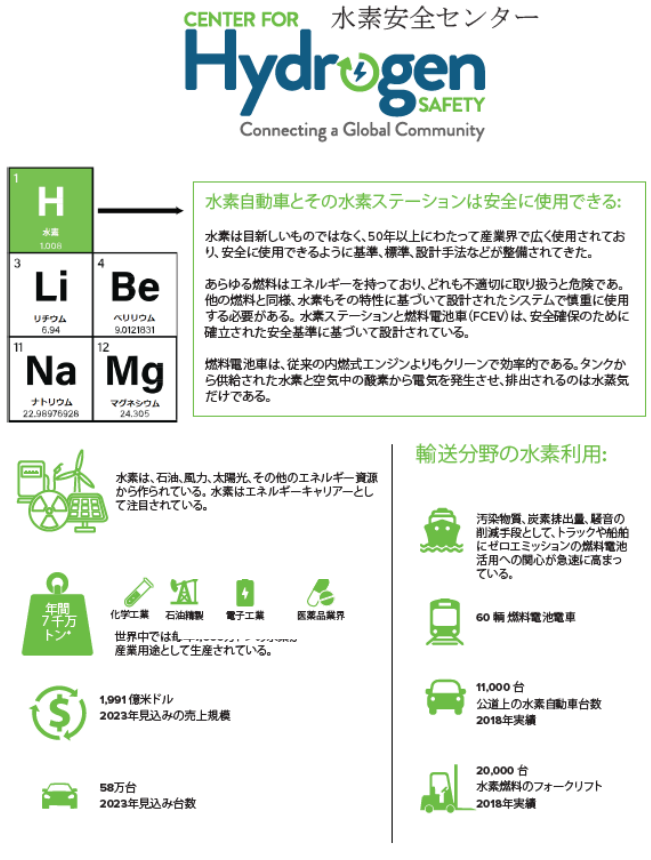
Access to >110 countries, 60,000 members

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



www.aiche.org/CHS

Information to be available in multiple languages



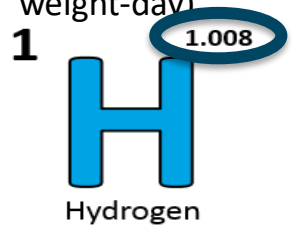
Resources and Announcements

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 for hydrogen safety and lessons learned

https://h2tools.org/

INCREASE YOUR H2IQ

Download the H2IQ resource for free:
energy.gov/eere/fuelcells/downloads/increase-your-h2iq-training-resource

Join monthly H2IQ hours to learn more about hydrogen and fuel cell topics
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Learn more at: energy.gov/eere/fuelcells AND www.hydrogen.energy.gov