Fuel Cell Technologies Office Update

Dr. Sunita Satyapal, Director, Fuel Cell Technologies Office

Hydrogen and Fuel Cell Technical Advisory Committee (HTAC) Meeting

November 04, 2019 – Washington DC

Agenda

- HTAC Scope
  - Membership
  - Energy Policy Act (EPACT) 2005 Title VIII
- Program Updates
  - FOA awards
  - Highlights (since last meeting)
  - Activities addressing HTAC recommendations
- Next Steps
  - Plans and strategies
  - Input areas

2019 HTAC Membership

HTAC Member and Affiliation	Expertise
Aszklar, Henry Independent Energy Consultant	**Energy Project Development & Financing**
Azevedo, Inês Carnegie Mellon University	**Behavioral/ Decision-Making Science**
Ffolkes, Marie Air Products and Chemicals, Inc.	**Hydrogen Production and Delivery**
Freese, Charles F. (Chair) General Motors Company	**Automotive Companies**
Hebner, Robert U. Of Texas at Austin	**Advanced power and energy technology R&D**
Irvin, Nick Southern Company	**Utilities/Advanced Energy Systems R&D**
Koyama, Harol H2 PowerTech	**Stationary Power and Markets**
Leggett, Paul Mithril Capital Management, LLC	**Venture Capital / Investment**
Leo, Anthony FuelCell Energy	**Stationary Fuel Cell and Hydrogen Production Technology Manufacturing**
Markowitz, Morry Fuel Cell and Hydrogen Energy Association (FCHEA)	**Hydrogen and Fuel Cells Industry Association**

HTAC Member and Affiliation	Expertise
Marsh, Andrew Plug Power	**Stationary and Transportation Fuel Cell Technology Manufacturing**
Mount, Robert Power Innovations	**Power management technology and integration**
Nocera, Daniel Harvard University	**Hydrogen Production R&D**
Novachek, Frank Xcel Energy	**Utilities (Electricity and Natural Gas)**
Powell, Joseph (Vice Chair) Shell Global Solutions	**Fuels Production and R&D**
Rogers, Paul The Adjutant General of the Michigan National Guard and Director of Military and Veterans Affairs	**Military Hydrogen and Fuel Cell Applications / R&D**
Rumsey, Jennifer Cummins Inc.	**Medium- and heavy-duty engine design and manufacturing**
Scott, Janea California Energy Commission	**State Energy Policies and Regulations**
Thompson, Levi University of Delaware	**Catalytic and Absorbent Materials R&D**

Hydrogen and Fuel Cell Technical Advisory Committee (HTAC) Scope

To advise the Secretary of Energy on:

1. **The implementation of programs and activities under Title VIII of EPACT**
2. **The safety, economical, and environmental consequences of technologies to produce, distribute, deliver, store or use hydrogen energy and fuel cells**
3. **The DOE Hydrogen & Fuel Cells Program Plan**

Title VIII Sec. 802- Purposes

1. Enable and promote comprehensive **development**, **demonstration**, and **commercialization** of H_2 and fuel cells with industry

2. Make **critical public investments** in building strong links to private industry, universities and National Labs to expand innovation and industrial growth

3. Build a mature H_2 economy for **fuel diversity** in the U.S.

4. Decrease the **dependency on foreign oil & emissions** and enhance energy security

5. Create, strengthen, and protect a **sustainable national energy economy**

Program Funding and Examples of Impact

Examples of Accomplishments

Innovation

Approx. **960** H_2 and fuel cell **patents**

enabled by FCTO funds

Approx. **37%** of H_2 and fuel cell patents

come from National Labs

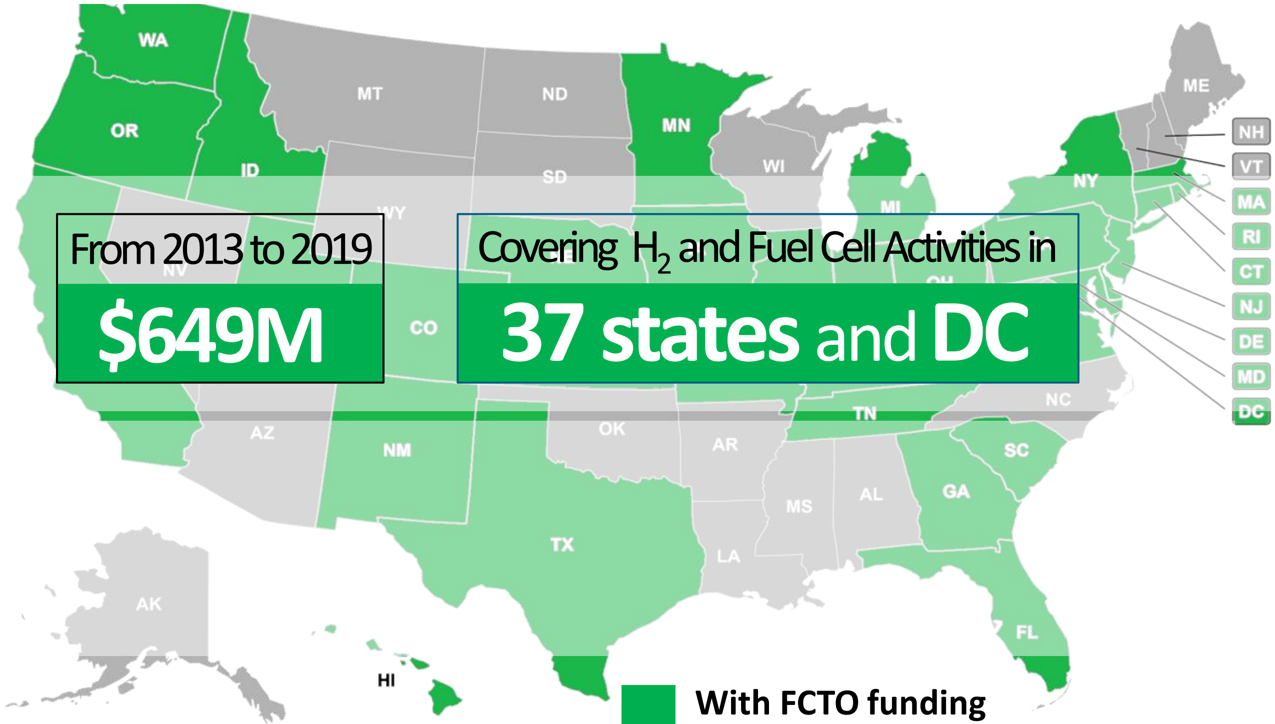
Market Impact

More than **30** **Technologies** commercialized by private industry

and over **65** **with potential** to be commercial in the next 3-5 years

can be traced back to FCTO R&D

EERE Fuel Cell Technologies Office Funding[1] FY 2013 – FY 2019



From 2013 to 2019

$649M

Covering H_2 and Fuel Cell Activities in

37 states and DC

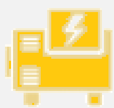
With FCTO funding

[1]Prime recipients only

DOE funded over 100 companies, 100 universities/nonprofits and 13 National Laboratories in the last decade

U.S. Snapshot of Hydrogen and Fuel Cells Applications

Examples of Applications in the United States



>500MW
Stationary Power

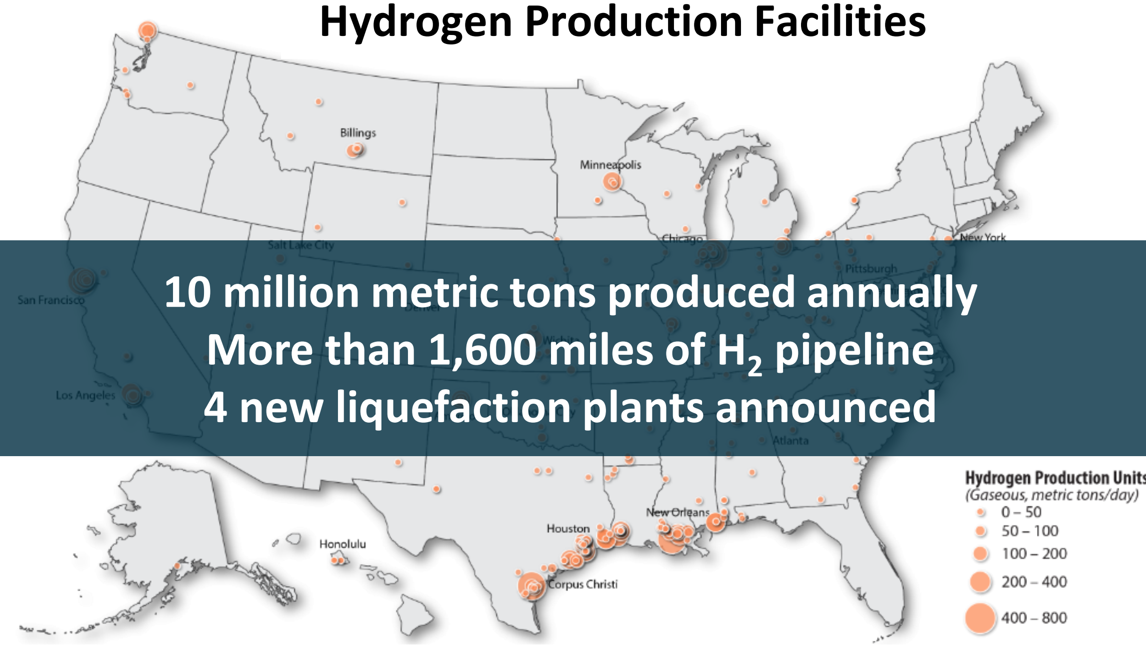
>28,000
Forklifts

>30
Fuel Cell Buses

>40
H_2 Retail Stations

>7,800
Fuel Cell Cars

Hydrogen Production Facilities



10 million metric tons produced annually
More than 1,600 miles of H_2 pipeline
4 new liquefaction plants announced

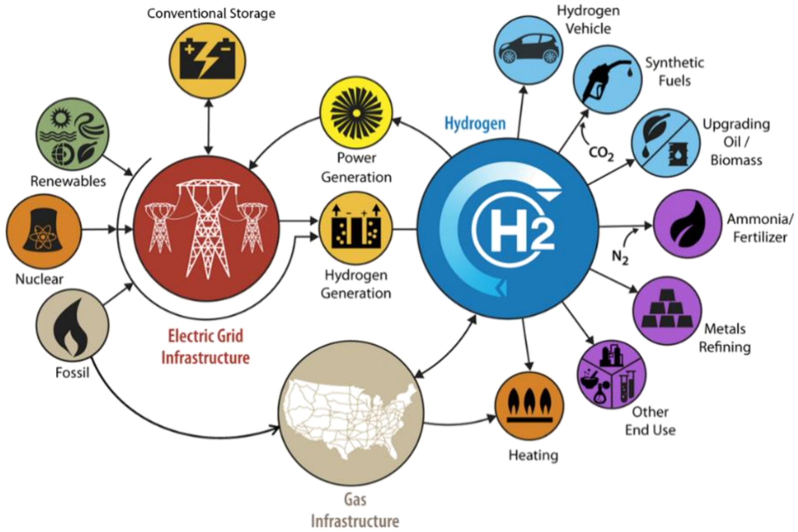
Hydrogen Stations: Examples of Plans Across States

California
CaFCP roadmap: 1,000 stations by 2030

Northeast
12 – 20 stations planned

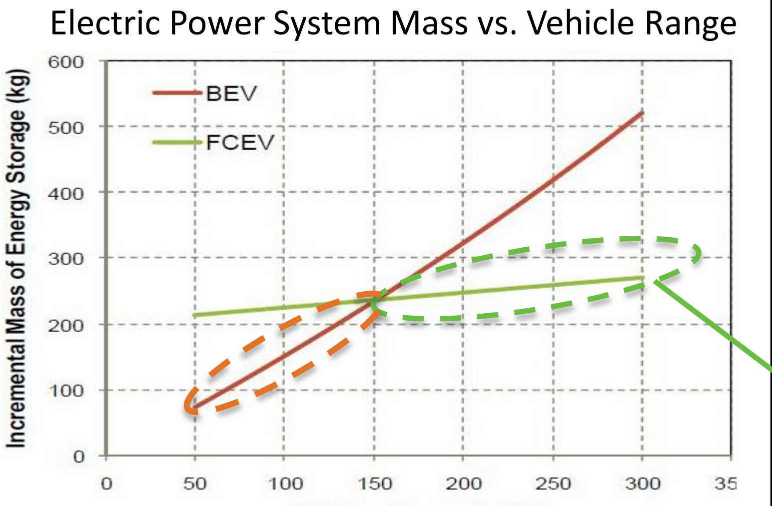
HI, OH, SC, NY, CT, MA, CO, UT, TX, MI, and others
with interest

Update since last HTAC: FOAs Announced Mar '19 H_2@Scale and Joint Truck FOA



H2@Scale

- Early Stage H2@Scale-Enabling R&D
  - Advanced H_2 storage & infrastructure R&D
  - Innovative concepts for hydrogen production & utilization
- H2@Scale Pilot Demo - Integrated Systems R&D



SOURCE: General Motors, Inc.

Joint Office Truck FOA

Three H_2 and Fuel Cells Topics included:

- Advanced storage for gaseous fuels
- High throughput hydrogen fueling
- Durable fuel cells with low PGM

Fuel cells can offer an advantage for longer driving range with less weight penalty

FY19 FCTO FOA Selections: 29 Projects $40M DOE Funding

(Note: Original selections below; award negotiations underway)

Topic Area	Awardee	DOE Share
Topic 1A: Novel Hydrogen Carrier Development	Colorado School of Mines	$0.4M
	University of Hawaii	$0.9M
	University of Southern California	$1M
	Washington State University	$1M
Topic 1B: H-Mat Materials Compatibility Consortium R&D: Hydrogen Effects in Materials for Fueling Infrastructure	Clemson University	$1M
	Colorado School of Mines	$1.4M
	Hy-Performance Materials Testing, LLC	$0.6M
	Massachusetts Institute of Technology	$1M
	The University of Alabama	$1M
	University of Illinois at Urbana-Champaign	$2M
Topic 2A: Advanced Water Splitting Materials Research (integrated with HydroGEN Consortium)	Georgia Institute of Technology	$1M
	Nexceris, LLC	$1M
	Redox Power Systems, LLC	$1M
	The Chemours Company FC, LLC	$1M
	The University of Toledo	$0.7M
	University of California: Irvine	$1M
	University of California: San Diego	$1M
	University of Florida	$1M
	University of Oregon	$0.5M
	University of South Carolina	$1M
	William Marsh Rice University	$0.8M
Topic 2B: Affordable Biological Hydrogen Production from Biomass Resources	Oregon State University	$1M
Topic 2C: Co-production of H2 and Value-add Byproducts	C-Zero, LLC	$1M
	University of Colorado, Boulder	$1M

FY19 FCTO FOA Selections: 29 Projects $40M DOE Funding

(Note: Original selections below; award negotiations underway)

Topic Area	Awardee	DOE Share
Topic 2D: Reversible Fuel Cell Development and Validation	FuelCell Energy, Inc	$2M
	Proton Energy Systems, Inc	$2M
Topic 3: H2@Scale Pilot - Integrated Production, Storage, and Fueling System	Exelon Corporation	$3.6M
	Frontier Energy, Inc.	$5.4M
	Giner ELX, Inc.	$4M

FY19 Commercial Trucks and Off-road Applications FOA Selections: 8 Hydrogen-based Projects ~$15M DOE Funding

(Note: Original selections below; award negotiations underway)

Topic Area	Awardee	DOE Share
1a – Advanced Storage for Gaseous Fuels	Northwestern University	$1M
	University of South Florida	$0.8M
3 - High Throughput Hydrogen Fueling Technologies for Medium- and Heavy-duty Transportation	Air Products and Chemicals, Inc.	$1.7M
	NEL Hydrogen Inc.	$2M
	Electricore, Inc.	$3M
4 – High-durability, Low Platinum Group Metal Membrane Electrode Assemblies (Meas) For Medium- And Heavy-duty Truck Applications	General Motors LLC	$2M
	Nikola Motor Company	$1.7M
	Carnegie Mellon University	$2M

Increased Efforts Planned on Hydrogen + Nuclear: A Growing Interest

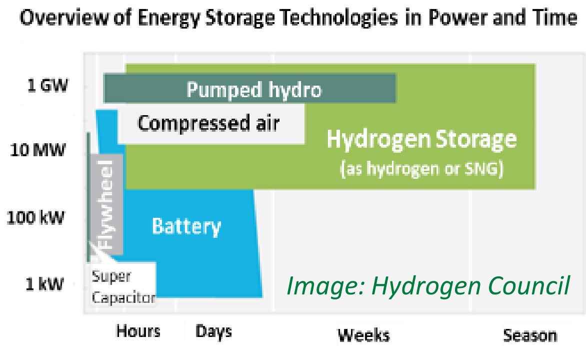


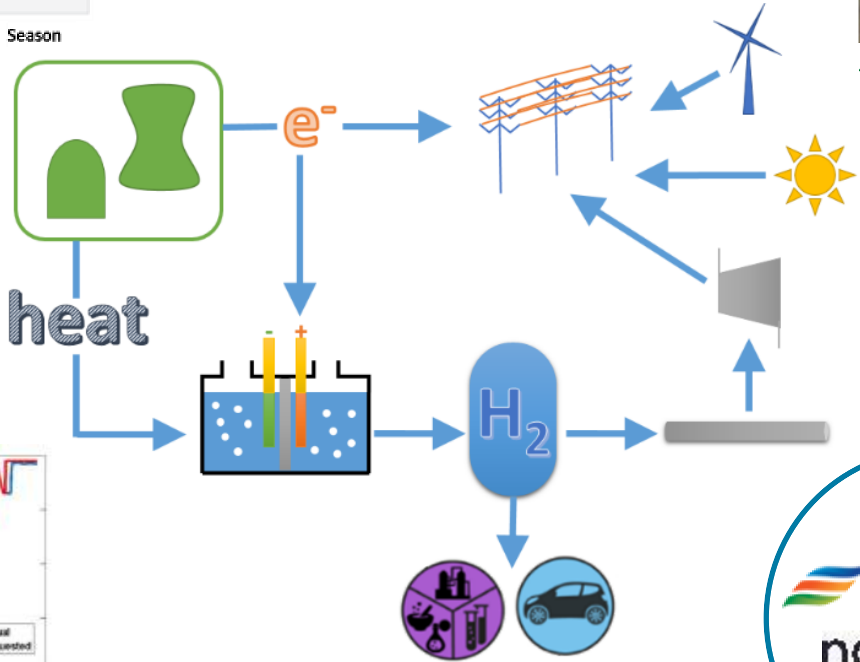
Image: Hydrogen Council

H_2 energy storage

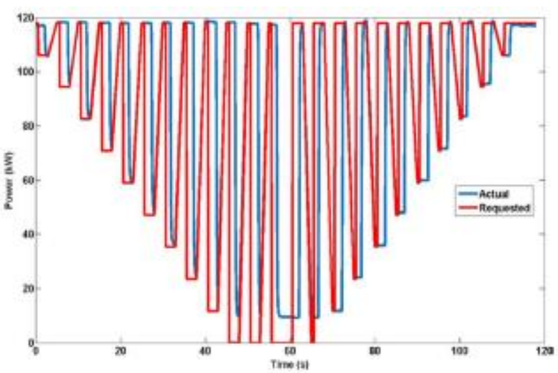
Increased joint efforts between EERE and NE

25 kW high-temperature electrolysis @ INL Energy Systems Laboratory

Thermal Integration



Dynamic response



Dynamic electrolyzer response – INL & NREL

Multiple end use applications

NE-EE Industry demos

Exelon
nel
FirstEnergy Solutions
Xcel Energy
aps

Recently announced demonstrations

H2@Rail, H2@Ports & H2@Datacenter Workshops

Main Challenges for Adoption

- Cost of hydrogen and investment required
- Hydrogen supply and storage is major impediment
- R&D and demos needed to gain knowledge and encourage industry adoption
- Harmonization of codes and standards for hydrogen
- Sharing best practices and information on safety, siting, etc.
- Public education and outreach

H2@Rail

- Fuel among freight rail's top three operating expenses.
- On-board storage technologies (i.e. LH2 tender car)
- Freight locomotives for long distance hauling is the most technically challenging

H2@Ports

- Hydrogen carriers, e.g. ammonia, for hydrogen storage challenges
- Demos at ports could accelerate hydrogen market development
- Maritime vessel design is a tailored process – hard to standardize

H2@Datacenter

- Unified standards for power requirements
- Low-end modular size requires ~30 tonne/day of hydrogen for a 20 MW data center
- Near term backup power offer solutions to promote adoption

Establishing Long Haul Truck Targets for Hydrogen Fuel Cell Trucks – final Peer Review underway

Technical targets for Class 8 long haul tractor trailer trucks powered by hydrogen and fuel cells.

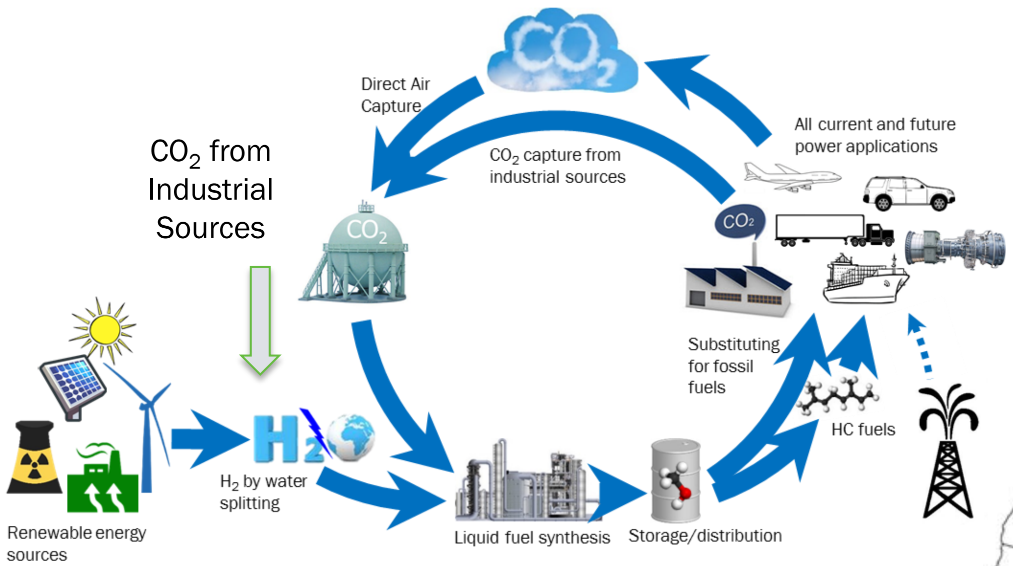
Characteristic	Units	Targets for Class 8 Tractors-Trailers	
		Interim (2030)	Ultimate[4]
Fuel Cell System Lifetime[1]	[hours]	25,000	30,000
Fuel Cell System Cost[2,3]	[$/kW]	80	60
Fuel Cell Efficiency (peak)	[%]	68	72
Hydrogen Fill Rate	[kg H_2/min]	8	10
Storage System Cycle Life	[cycles]	5,000	5,000
Pressurized Storage System Cycle Life	[cycles]	11,000	11,000
Hydrogen Storage System Cost[3]	[$/kWh] ($/kg H_2 stored)	9 (300)	8 (266)

1. Corresponding vehicle lifetime range is 1M miles (Interim) and 1.2M miles (Ultimate) based on average speed of 40 mph.
2. Interim and ultimate cost targets assume 100,000 units per year production volumes
3. Costs are in 2016 dollars
4. Analysis based on 2050 simple cost of ownership assumptions and reflects anticipated timeframe for market penetration.

Assuming trucks can be driven the maximum daily range (750 miles) between refueling

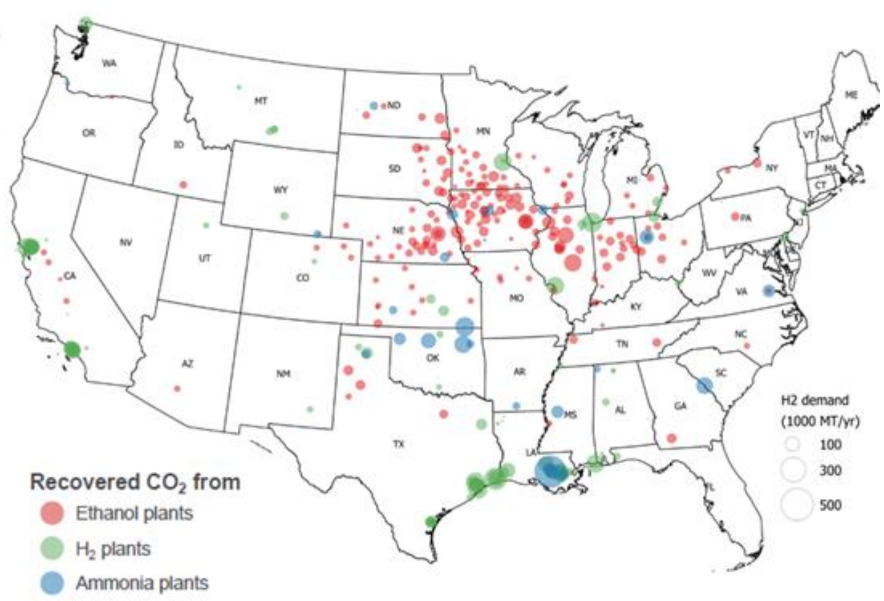
- Developed with input from the 21st Century Truck Partnership (21CTP), heavy duty workshop, cross-office (FCTO, VTO), Tech Teams
- Targets will be included in new Electrified Powertrain Roadmaps and will guide R&D

New area of interest: Liquid fuels from CO_2 and H_2



Coordination between FCTO and Bioenergy Technologies Office

New Tech Team being formed under US DRIVE



Source: A. Elgowainey, ANL

U.S. DRIVE

Definition:

- Is a voluntary government-industry partnership focused on advanced automotive and related energy infrastructure technology R&D
- Engages senior leaders in strategic discussion of research needs and priorities
- Enables frequent and regular interaction among leading technical experts in industry and government (including national laboratories)
  - Deep discussion of R&D challenges
  - Joint technical targets and roadmaps
  - R&D progress evaluation

Scope

- **Pre-competitive R&D**
- **Light-duty vehicles and related energy infrastructure**
- **Broad technology portfolio covers:**
  - Advanced combustion engines and low-carbon, high-efficiency fuels
  - Electric-drive technologies: advanced batteries, electric drive systems, vehicle-grid interaction, and fuel cells
  - Lightweight materials
  - Hydrogen technologies: production, delivery, on-board storage, codes and standards
  - Energy efficient mobility systems

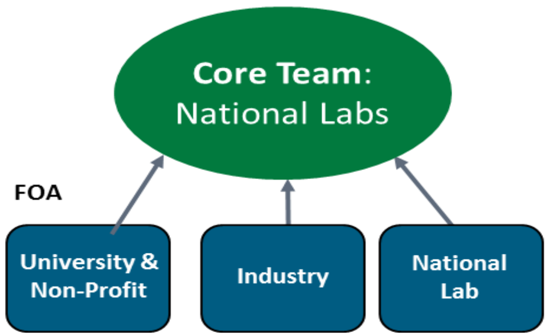
New Tech Team

- In FY20, U.S. DRIVE will add a new fuels tech team
- Focus:
  - low carbon/net zero carbon drop-in liquid fuels
  - Integrated analysis including techno-economic analysis and beyond
- Hydrogen will be an integral component in the development of the new fuels
  - FCTO will be a member of the tech team

Consortia Approach Complements FOA Projects

Early stage R&D:

National labs accelerate innovation and bring in new industry, university partners

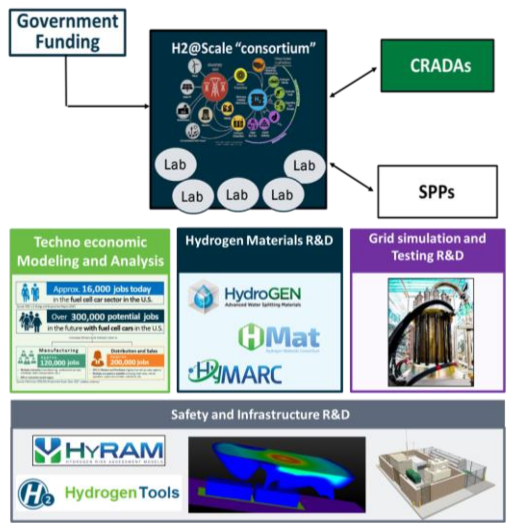


Launched and addressing R&D needs:

ElectroCat Electrocatalysis Consortium · H2MARC · HydroGEN Advanced Water Splitting Materials

Part of:

Energy Materials Network (EMN)
U.S. Department of Energy



Later stages:

Leverage private sector for large-scale demos

~25 Cooperative Research and Development Agreements between industry and national labs

Key Activity	FY 2018	FY 2019
	($ in thousands)	
Fuel Cell R&D	32,000	30,000
Hydrogen Fuel R&D	54,000	39,000
Hydrogen Infrastructure R&D	-	21,000
Systems Analysis	3,000	2,000
Safety, Codes and Standards	7,000	7,000
Technology Acceleration	19,000	21,000
Total	**115,000**	**120,000**

House Mark: $144M
Senate Mark: $160M

Office	FY 2018 ($ in thousands)
EERE (FCTO)	**115,000**
Science (Basic/xcut)	**19,000**
Fossil Energy (SOFC)	**30,000**
Total	**~164,000**

HTAC Recommendations Being Addressed (examples)

DOE Responses to 2017 HTAC Annual Report (Nov 2018)

Recommendations	Examples Since Last HTAC Meeting
it is critical that DOE remain actively engaged in developing broader goals for safety, codes, and standards	• Working with DOT and regional authorities to address restrictions on the use of FCEVs in tunnels in certain U.S. regions • R&D to enable reduced liquid hydrogen station footprint • Active participant in GTR Phase II Working Group • Co-chair of IPHE RCSS Working group and pursuing opportunities for collaboration on C&S, especially for heavy duty vehicles and fueling
Focus on initiatives and research that support the transition between early subsidized deployments and ultimate commercial H2@Scale concept for a mature ecosystem	• 2019 H2@Scale FOA awarded $13 million for **three H2@Scale Pilot projects** (with ~$15 million in industry cost share) • In addition, DOE Office of Nuclear Energy funded approximately $9 million in FY 2019 (with over $2 million in industry cost share) to demonstrate an electrolyzer producing hydrogen at the Davis-Besse nuclear power station in Ohio • In total, DOE 2018 and 2019 FOAs provided almost $90 million in funding for H2@Scale enabling R&D, including $18 million for heavy duty fuel cell truck applications (includes $3M from VTO)
Cost/availability of hydrogen fuel, hydrogen fuel infrastructure and difficulties with station siting/permitting and reliability continue to be a challenge	2019 H2@Scale FOA announced selections for (1) **Advanced hydrogen storage and infrastructure R&D** (over $10M for 10 projects) including novel materials/H_2 carriers and materials for H_2 infrastructure components and (2) **Innovative concepts for H_2 production and utilization** ($17M for 16 projects) including affordable domestic H_2 production technologies, co-production of H_2 for additional sources of revenue, and reversible fuel cell technologies

HTAC Recommendations Being Addressed (examples)

DOE Responses to HTAC Subcommittee Report on Competitiveness (Mar 2019)

Recommendations	Examples Since Last Meeting
FCTO should restore the Fuel Cell Technologies Market Report, an annual status report that provides a comprehensive snapshot of [industry] activity	• FCTO plans to re-initiate production of this report in FY 2020
Conduct competitiveness review and assessment and studies of demonstration and deployment initiatives/incentive programs to stimulate large-scale investments in domestic large-scale manufacturing of fuel cell and hydrogen technologies and US job creation	• FCTO will work with partners and stakeholder to determine the best approaches for implementing future competitiveness studies and analysis to guide activities. • FY 2018 FOA awarded $7.5 million for four new projects to enable cost-competitive manufacturing of megawatt-scale electrolyzers for applications such as the provision of grid services or hydrogen production at fueling stations • FY2019 FOA included funding for three pilot projects and electrolyzer manufacturing R&D

HTAC Impact – Examples

- **HTAC Annual Reports and Letters to DOE Secretary**
  - 2007 to Current
- **Subcommittee Outputs**
  - Competitiveness (2019)
  - Communication & Outreach (2018) – material online
  - Hydrogen Safety & Event Response (2017)
  - Manufacturing (2014)
- **Other Examples**
  - Affiliation with AIChE to form the Center for Hydrogen Safety in partnership with Pacific Northwest National Laboratory
  - Input on H-Prize – ***1st commercial system exported to Japan, manufactured in the US***

Potential Areas of Input by HTAC

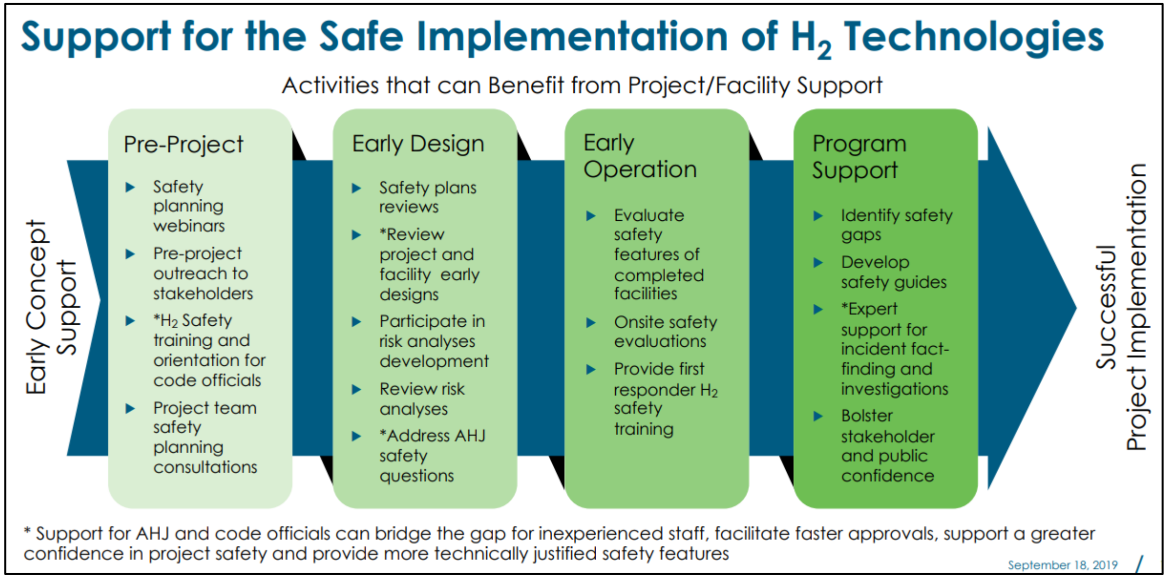
1) Plans and Roadmaps

- Program Plan (to be provided to HTAC for review in early 2020)
- "Dashboard" on metrics, status vs EPACT

2) Collaboration & Leveraging Examples

- Opportunities for collaboration on H2@Scale, especially for new applications (e.g., HDV, marine, rail, aviation, data centers, etc.)
- Global Action Agenda/Tokyo Statement and IPHE (see binder tab)
- MOUs and concrete collaboration opportunities (e.g. TARDEC-FCTO MOU, MEDC- DOE MOU)
- Prize concepts
- Center for Hydrogen Safety – expand awareness, share info

Areas of Input: Center for Hydrogen Safety



MEMBERS

- DECHEMA Gesellschaft für Chemische Technik und Biotechnologie e.V.
- Astra Rocket Company
- Air Liquide
- Alakai Technologies
- California Energy Commission
- NREL National Renewable Energy Laboratory
- HySA Infrastructure Hydrogen South Africa
- SCEJ The Society of Chemical Engineers, Japan
- HySUT
- Protium
- Air Products
- Pacific Northwest National Laboratory
- Sandia National Laboratories
- Plug Power
- True Zero FirstElement
- Shell
- Toyota
- UL
- Washington State University

EXECUTIVE BOARD

- AIChE
- Air Liquide
- HySafe International Association for Hydrogen Safety
- California Energy Commission
- Shell

STRATEGIC PARTNERS

- Hydrogen Council
- California Fuel Cell Partnership – Driving for the Future
- IPHE
- U.S. Department of Energy – Energy Efficiency & Renewable Energy

Direct result of HTAC input and recommendations:

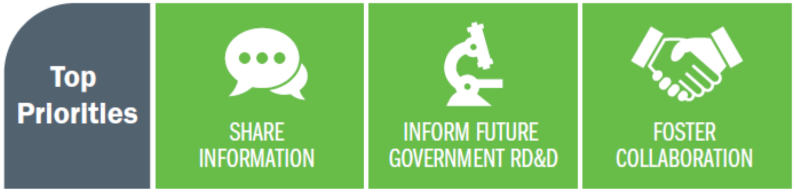
- **Leverages private sector**
- **Expands impact of safety panel**
- **Transitions key areas to industry for sustainable business model**
- **Supports IPHE, Hydrogen Ministerial, etc.**

Safety Conferences
Nov 2019 – CA, US
March 2020 – Japan
September 2020 - Germany

IPHE Background and Overview

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

Working Groups: Education & Outreach
Regulations, Codes, Standards & Safety



Elected Chair and Vice-Chair, 2018

Find IPHE on Facebook, Twitter and Linkedin

Follow IPHE **@The_IPHE**

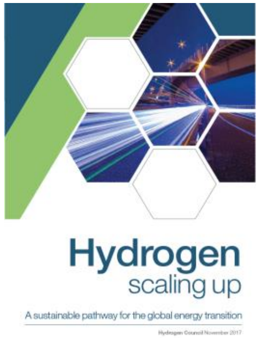
www.iphe.net

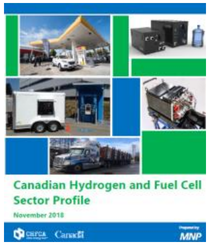
Supports other partnerships & activities: IEA, Mission Innovation, H_2 Energy Ministerial, Clean Energy Ministerial, etc.

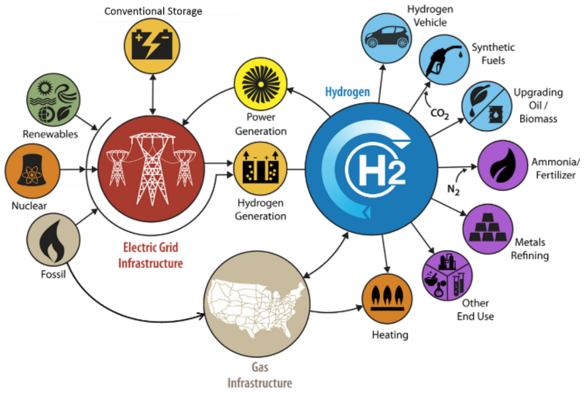
Formed 2003
19 Countries and EC

"Hydrogen – at Scale and Sector Coupling" – A Common Vision Across Multiple Regions in the World

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
From 10/19 IPHE meeting: Establish common definition of clean hydrogen to facilitate international trade

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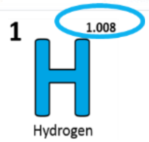
Stakeholder Engagement to support early stage R&D

National Hydrogen & Fuel Cell Day
October 8 or 10/8



Safety Information and Training Resources

H2tools.org

INCREASE YOUR H_2IQ

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

Workshops enabling H2@scale

- **H2Carriers:** Nov. 12-13 in Golden, CO
- **AMR:** May 19-21, Crystal City, VA
- **H2Airports:** April 7-8, 2020 in Arlington, VA

Sign up to receive hydrogen and fuel cell updates

www.energy.gov/eere/fuelcells/fuel-cell-technologies-office-newsletter

Learn more at: energy.gov/eere/fuelcells

Thank You
&
Additional Information

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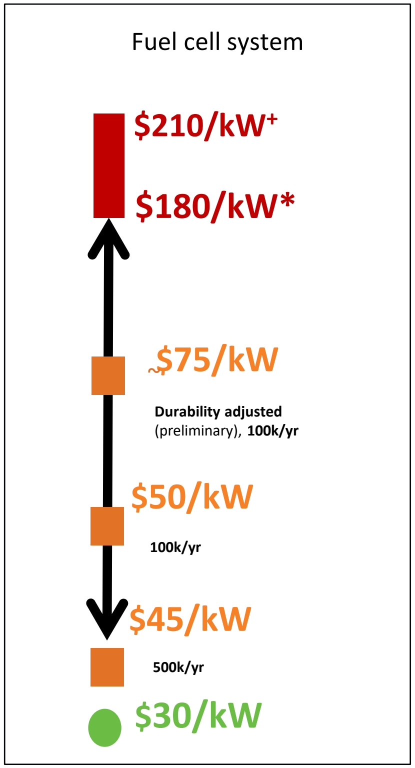
energy.gov/eere/fuelcells

Focus is on Affordability: DOE Targets Guide R&D

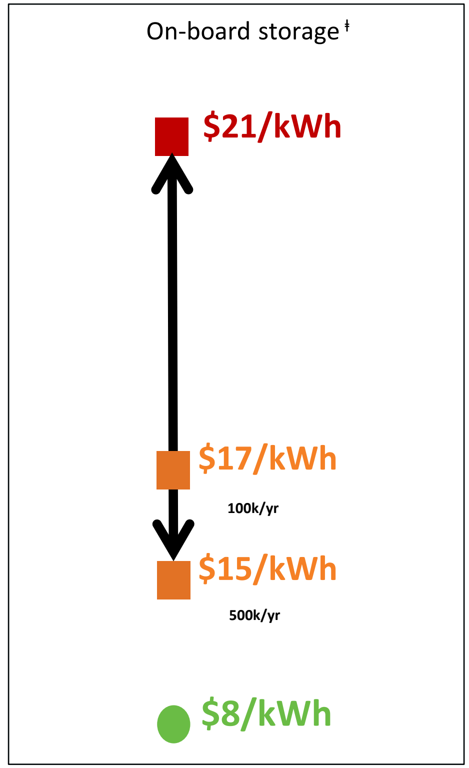
Fuel Cell R&D



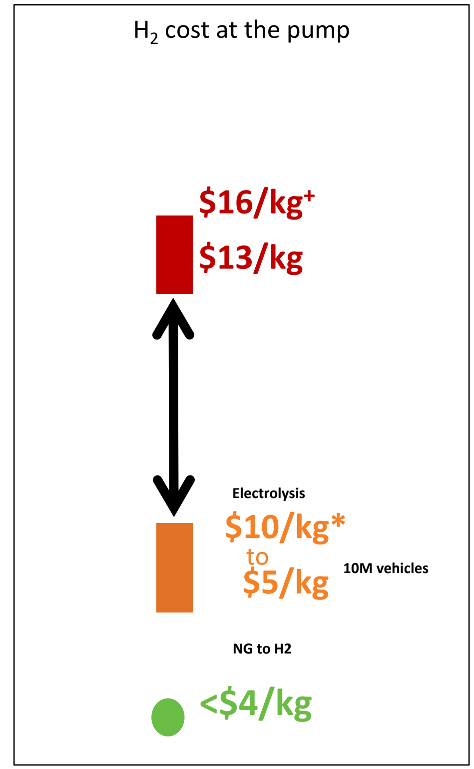
†Based on commercially available FCEVs

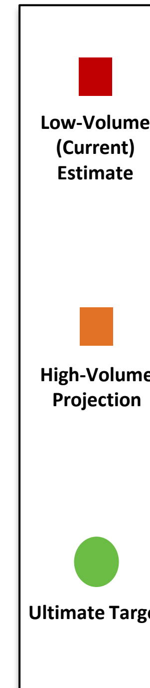
*Based on state of the art technology

Hydrogen R&D



ǂ Storage costs based on preliminary 2019 storage cost record

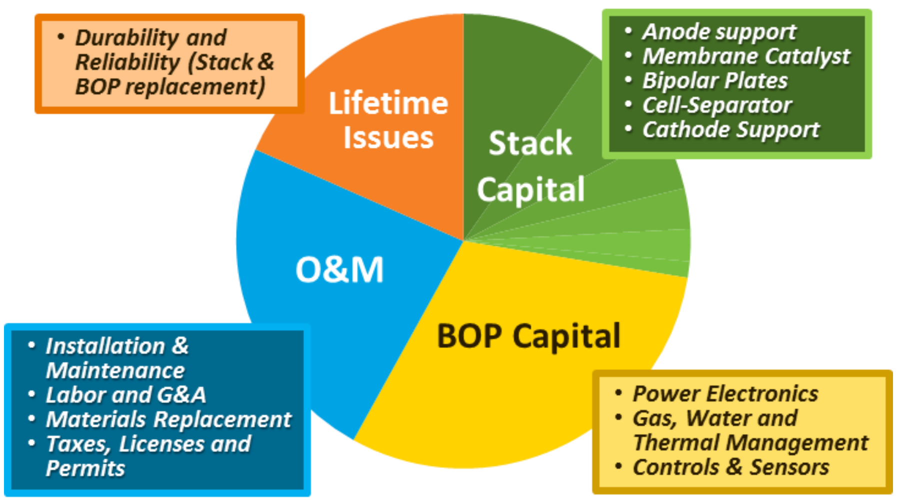




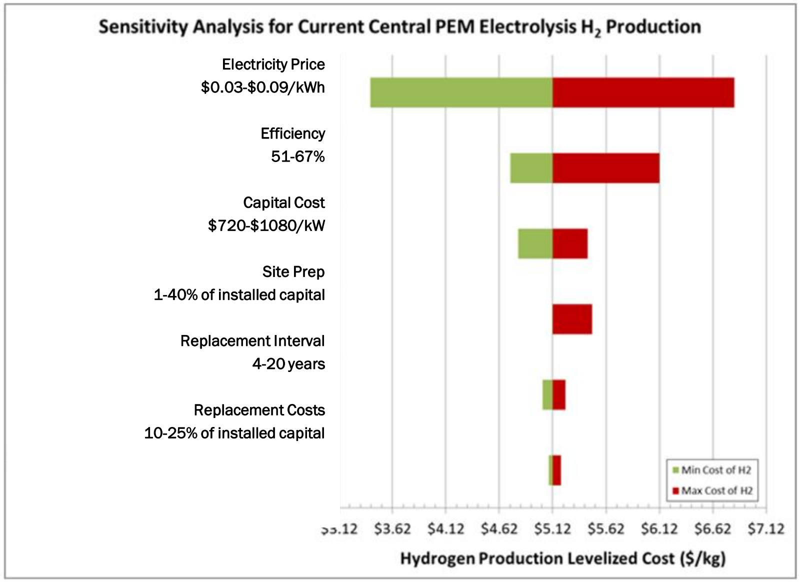
†For range: H2 production from natural gas (NG), delivered dispensed at today's (2018) stations (~180kg/d)
*For range: 1) H2 produced from electrolysis: $5/kg, H2 from NG at $2/kg; 2) Delivery and dispensing using advanced tube trailer or pipeline technologies ranges from $3-$5/kg, respectively; 3) Delivery and dispensing using current commercially available technologies at scale is $5/kg, assuming use of liquid tankers.
Assumes high volume: Electrolyzers manufactured at 700 MW/year; >10,000 stations at 1,000 kg/day capacity, to serve 10 million vehicles.

Low Temperature (PEM) Electrolysis Hydrogen Cost Challenges

Cases	Low Range ($/kg H_2)	Baseline Cost ($/kg H_2)	High Range ($/kg H_2)
Forecourt Current	$4.79	$5.14	$5.49
Forecourt Future	$4.08	$4.23	$4.37
Central Current	$4.80	$5.12	$5.45
Central Future	$4.07	$4.20	$4.33



Excludes electricity cost



H2@Scale Targets focus R&D

FCTO Focus: Developing application specific targets: Make, Move, Use, Store

MAKE
Increased Clean, Affordable Hydrogen Production

MOVE
More Efficient, Affordable Hydrogen Transport

USE
Low Cost Value-added Applications across Sectors

STORE
Flexible, Low-cost Storage Technologies

Application	Power (kW)	Cost ($/kW)	Durability (h)	Performance
Light-duty vehicles	80	30 75* 120*	8,000 5,000 4,100	70% efficiency, $\le 0.125\ mg_{PGM}/cm^2$ $\sim 0.35\ mg_{PGM}/cm^2$
Medium and Heavy-duty vehicles	160 to >360	60 92*	30,000 ---	72% efficiency $\le 0.2\ mg_{PGM}/cm^2$ $0.4\ mg_{PGM}/cm^2$
Stationary	1 to 1,000	1,000	80,000-130,000 40,000-80,000	>50% electrical efficiency

Green: target; black: lab-demonstrated tech; blue: on-road/installed tech
*Projected system cost for 100,000 units/year
**Technical targets under development

Targets are Application Specific- Examples

- H_2: $4/gge (including production, delivery, bulk storage and dispensing; untaxed)
- Fuel Cell System for FCEVs: $30/kW; 8,000 hrs
- H2 Onboard Storage for FCEVs $8/kWh, 2.2 kWh/kg, 1.7 kWh/L.

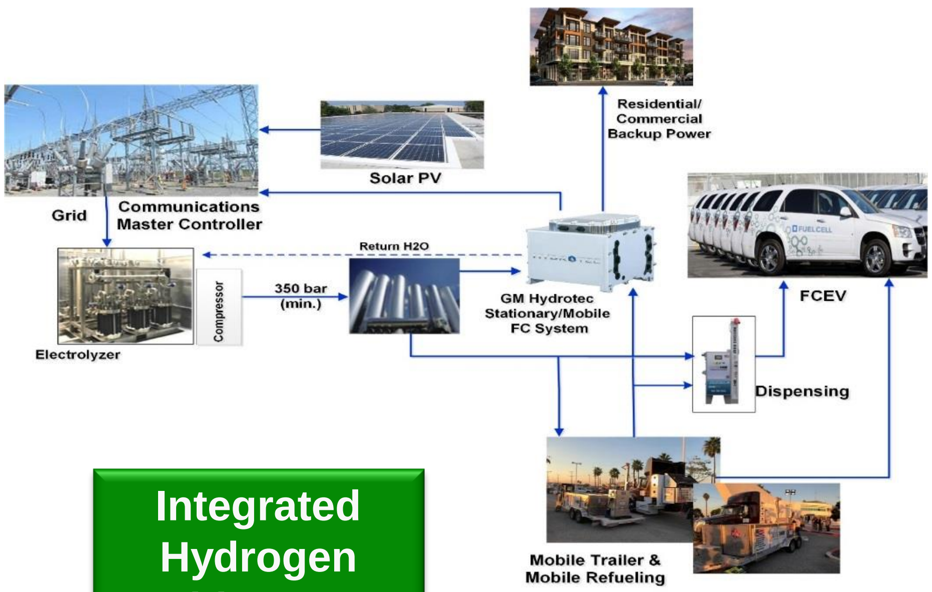
By 2025:

- $7/gge
- $40/kW, 5,000 hrs
- $10/kWh (FCEV storage), 1.8 kWh/kg, 1.3 kWh/L

Integrated Hydrogen Production and Consumption for Improved Utility Operations – Orlando, FL

Objectives

- Develop integrated system incorporating PEM-based electrolysis for H_2 production/storage and H_2-fuel for refueling of FCEVs
- Demonstration of electricity generation with site-specific PEM-based stationary fuel cells
- Develop/Optimize dispatch models based on grid-level optimization controls



Integrated Hydrogen Grid Assets

Program Summary

Partners: Giner ELX, Inc, Orlando Utilities Commission General Motors, OneH2, UCF-FSEC.

Period: 36 Months

Total budget: $8.48M

	Key Milestones & Deliverables
Year 1	• Develop utility control architecture to dispatch integrated Electrolyzer/Fuel Cell system • Complete/Optimize design(s) of individual system units (FC, Electrolyzer, PV Array, Storage, Dispensing)
Year 2	• Complete system unit assemblies • Integration of individual system units with Utility (OUC Utility)
Year 3	• Demonstrate integrated system dispatch with utility • Complete economic and market feasibility studies, establishing multiple value streams for hydrogen

Expected Outcomes

Grid-Integrated Hydrogen assets capable of leveraging intermittently available low-cost electricity to produce hydrogen for use in FCEVs, back-up power, and grid operational use cases

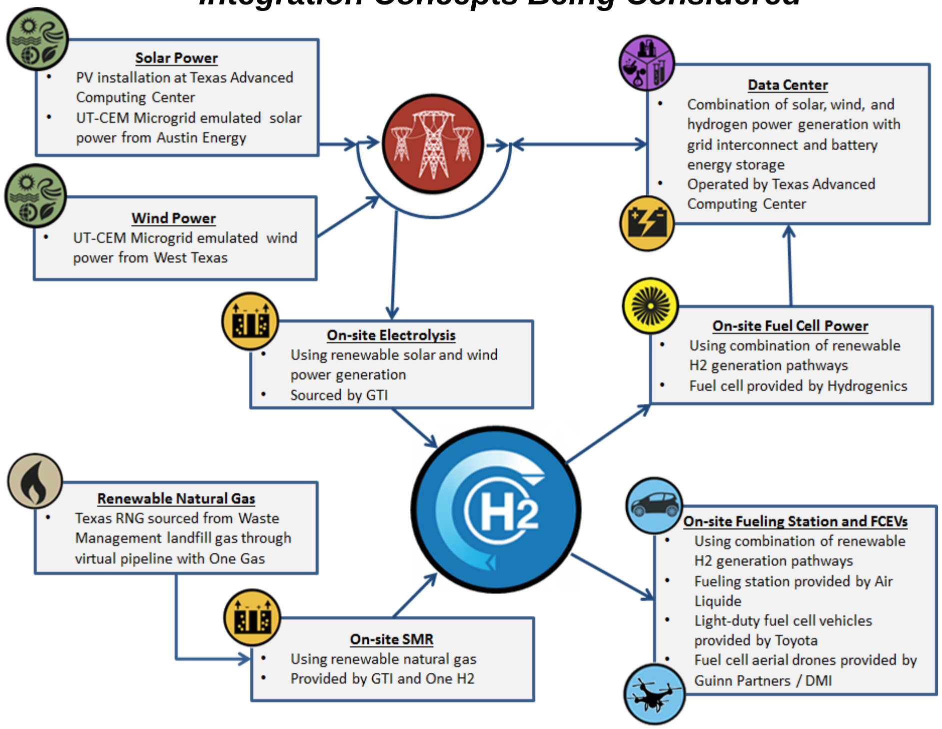
Based on summary slide from applicant. Award finalization underway

Demonstration and Framework for H2@Scale in Texas and Beyond

Objectives

- Demonstration of multiple renewable H_2 generation options, co-located with vehicle fueling and a large base load consumer
- Develop a framework for actionable H2@Scale pilot plans in Texas and the Port of Houston Gulf Coast region, including energy storage

Integration Concepts Being Considered



Program Summary

Partners: Frontier Energy, University of Texas at Austin, GTI, Toyota, Air Liquide, Waste Management, OneH2, Hydrogenics

Period: 36 Months

Total budget: $12.7M

	Key Milestones & Deliverables
Year 1	• Demonstration site planning and construction • Technoeconomic H2@Scale models in Texas
Year 2	• Commence demonstration activities • Complete framework for H2@Scale in Texas
Year 3	• Complete demonstration and assess ability to provide cost-effective hydrogen

Expected Outcomes

- Kick start renewable hydrogen infrastructure, storage, and fuel cell vehicles in the Texas, one of the country's top producers of hydrogen.
- Framework for hydrogen at scale in Texas and pathway for a cost-effective hydrogen economy

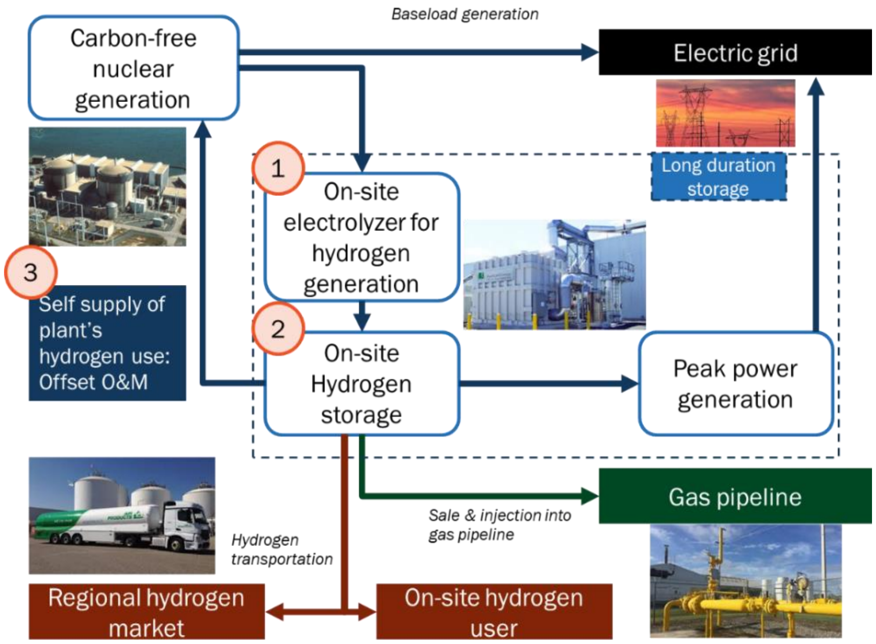
Based on summary slide from applicant. Award finalization underway

Electrolyzer Operation at Nuclear Plant and In-House Hydrogen Supply

Clean H2 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



Program Summary

Partners: Exelon & Nel Hydrogen, INL, NREL, ANL
Period: 36 months
Total budget: $7,238,122

	Key Milestones & Deliverables
Year 1	• Site selection, 30% engineering design • Simulation using prototype electrolyzer
Year 2	• 100% engineering design, decision to install • Complete manufacture, test of electrolyzer.
Year 3	• Start of steady state operation of electrolyzer • Simulation of scale-up electrolyzer operation • Demonstration of dynamic operation on site

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.

Based on summary slide from applicant. Award finalization underway