U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Fuel Cell Technologies Office Update

Dr. Sunita Satyapal, Director, Fuel Cell Technologies Office

Hydrogen and Fuel Cell Technical Advisory Committee (HTAC) Meeting

March 19, 2019– Washington DC

Agenda

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

2019 HTAC Membership

HTAC Member and Affiliation	Expertise
Aszklar, Henry Independent Energy Consultant	**Energy Project Development & Financing**
Ayers, Katherine Nel Hydrogen (Proton OnSite)	**Hydrogen Production Companies**
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**
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**

HTAC Member and Affiliation	Expertise
Markowitz, Morry Fuel Cell and Hydrogen Energy Association (FCHEA)	**Hydrogen and Fuel Cells Industry Association**
Marsh, Andrew Plug Power	**Stationary and Transportation Fuel Cell Technology Manufacturing**
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**
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**

Applications and Funding of Hydrogen and Fuel Cells

Examples of Applications in the United States

Over **>240MW** Backup Power

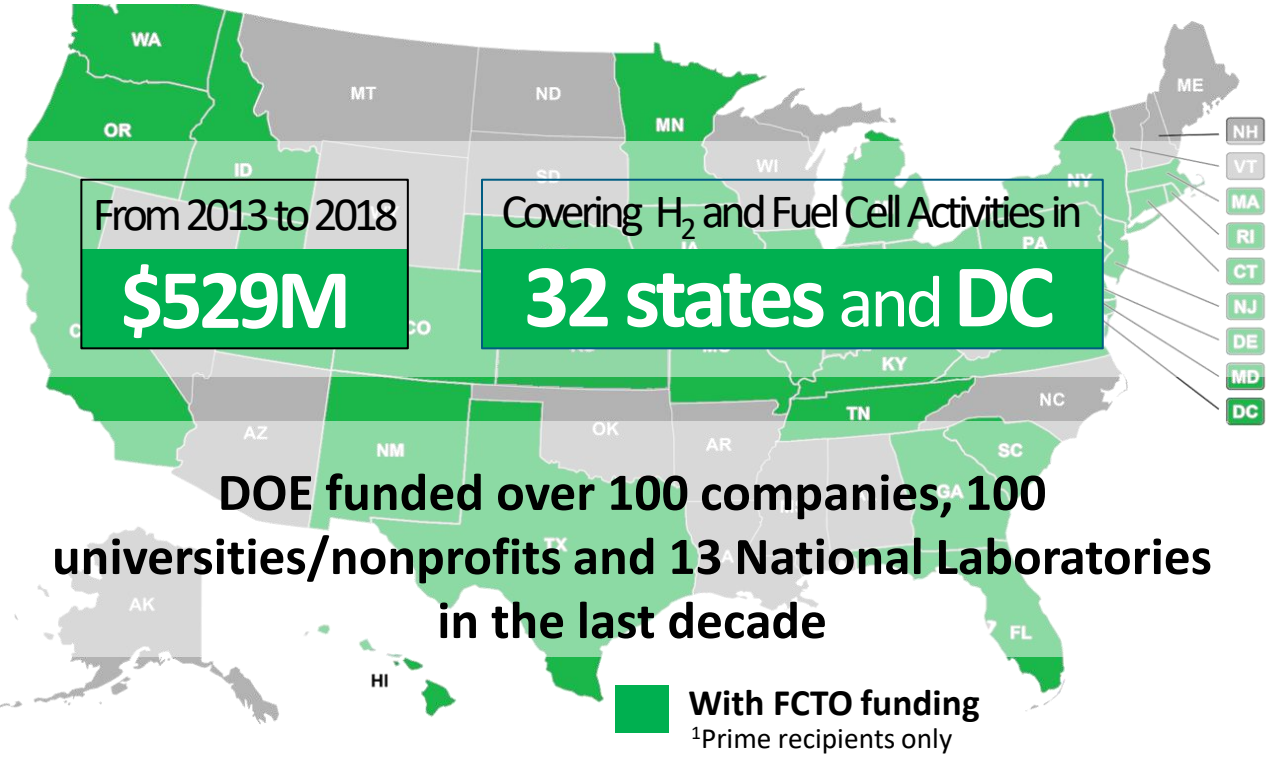
More than **23,000** Forklifts

More than **>30** Fuel Cell Buses

39 H_2 Retail Stations

Over **6,500** Fuel Cell Cars

EERE Fuel Cell Technologies Office Funding[1] FY 2013 – FY 2018



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

[1]Prime recipients only

Hydrogen Stations: Examples of Plans Across States

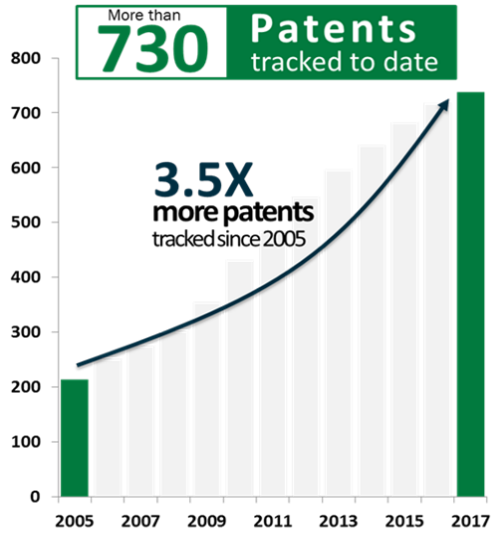
California
1,000 stations by 2030

Northeast
12 – 20 stations planned

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

DOE-funded Innovation Driving Impact

Innovation and Progress



In the last decade:

- **Reduced fuel cell and electrolyzer cost by >60%**
- **Quadrupled fuel cell durability**
- **Achieved world's firsts: Tri-gen, PEC, liquefaction, etc.**

Impact

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

and over **75** **with potential** to be commercial in the next 3-5 years

can be traced back to DOE R&D

Innovation to Market Technologies - Examples

Electrolyzers - Giner

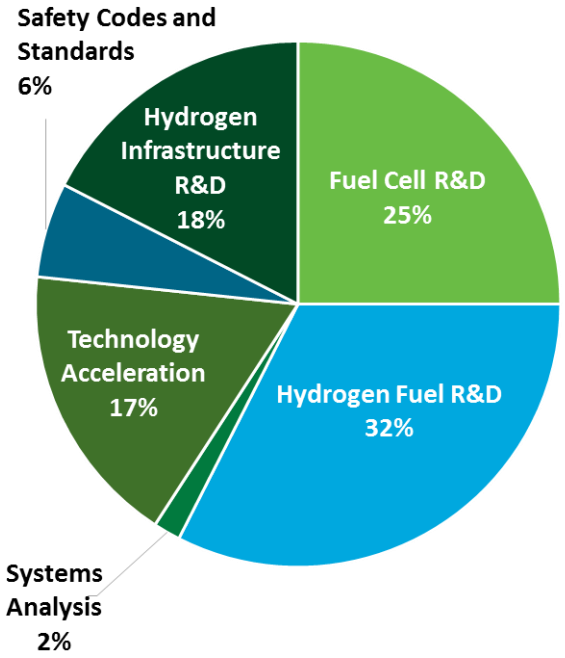
Fuel cell systems - Plug Power

Electrolyzers - Proton

Hydrogen Tube Trailers – Hexagon Lincoln

Funding

Distribution of FCTO FY19 Funding: $120 M



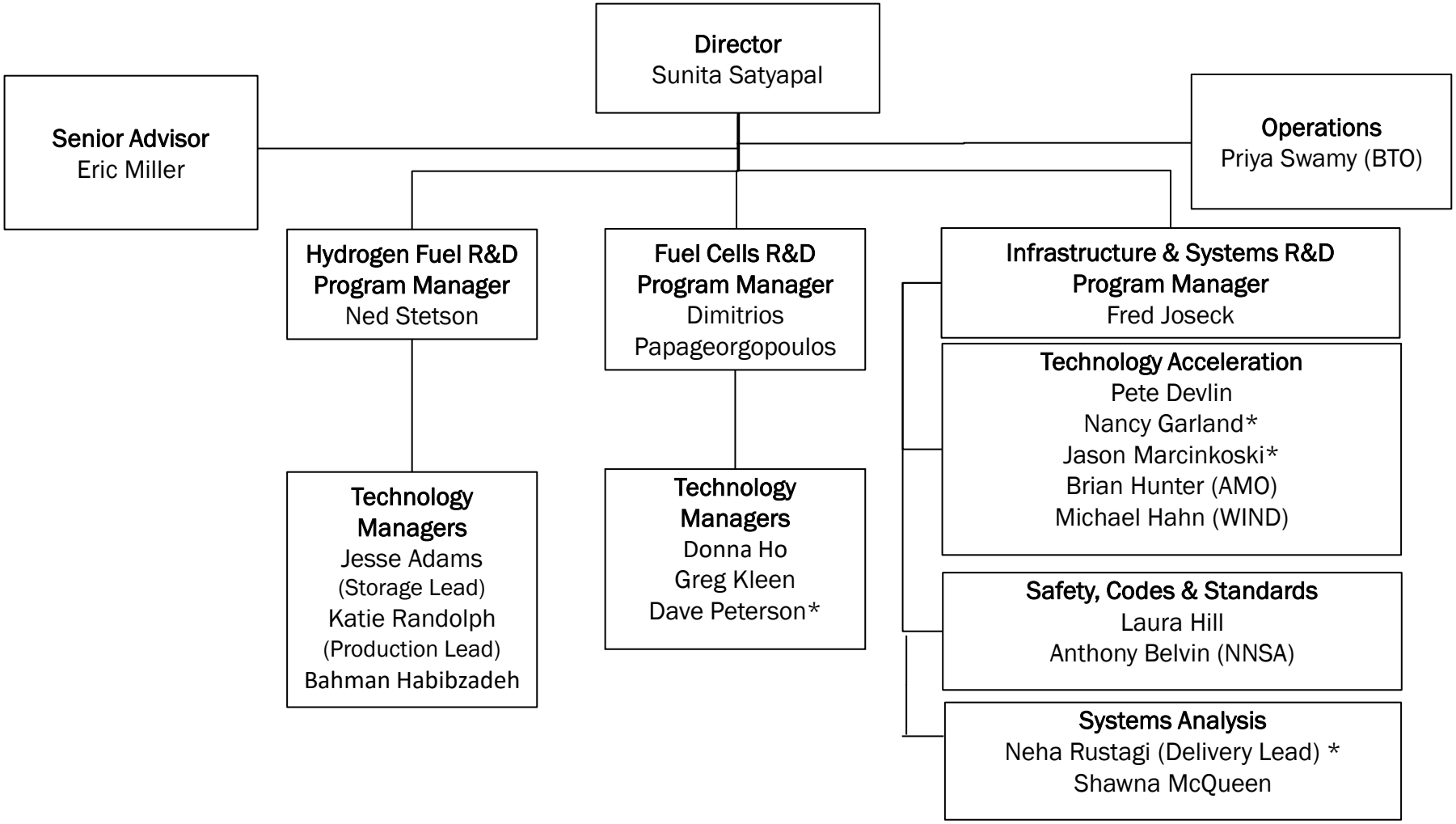
Office	FY 2018 ($ in thousands)
EERE (FCTO)	115,000
Science (Basic/xcut)	19,000
Fossil Energy (SOFC)	30,000
Total	~164,000

FCTO Appropriations

Key Activity	FY 2017	FY 2018	FY 2019
	($ in thousands)		
Fuel Cell R&D	32,000	32,000	30,000
Hydrogen Fuel R&D	41,000	54,000	39,000
Hydrogen Infrastructure R&D	-	-	21,000
Systems Analysis	3,000	3,000	2,000
Technology Acceleration	18,000	19,000	21,000
Safety, Codes and Standards	7,000	7,000	7,000
Total	101,000	115,000	120,000

FY19 Request: New Infrastructure R&D Subprogram in Budget

Update: Fuel Cell Technologies Office Org Chart



* Supports multiple Program areas

Update on FCTO Focus Areas

Early R&D Focus

Applied research, development and innovation in hydrogen and fuel cell technologies leading to:

- Energy security
- Energy resiliency
- Strong domestic economy

Early R&D Areas

Fuel Cells

- Cost, durability
- Components - catalysts, electrodes, etc
- Increase focus beyond LDVs

Hydrogen Fuel

- Cost of production across pathways
- Cost and capacity of storage, including bulk/ energy storage

Infrastructure R&D

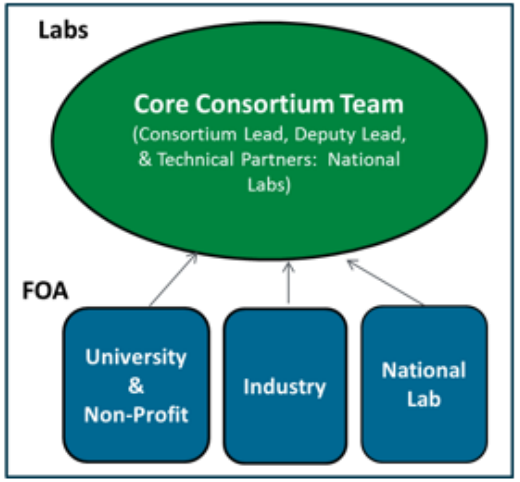
- Cost and reliability of infrastructure
- Delivery components, supply chain
- Safety

LDV: Light Duty Vehicle

Enabling

H2@Scale
U.S. Department of Energy

Leveraging industry and labs through the **Consortia Approach**



FCTO Strategic and Tactical Update

Lab-Based Consortia	Private Sector	Labs- Industry Bridge	International
HydroGEN Advanced Water Splitting Materials HyMARC Hydrogen Materials Advanced Research Consortium ElectroCat Electrocatalysis Consortium	• FOA projects • SBIRs • Prizes • State funding • Demos & Deployments • Partnerships • US National Roadmap (planned)	• H2@Scale Consortium • CRADAs • SPPs (WFOs) • L'Innovator • Technology Commercialization Fund	• IPHE • Mission Innovation • IEA • Ministerials • Leverage global efforts, harmonize codes & standards

H-Mat - H_2 materials R&D, enable codes & standards, reduce regulatory barriers

Safety – Lessons learned, best practices, enable safe infrastructure

Examples of Applications

- Rail
- MD/HD
- Marine
- Stationary
- Air

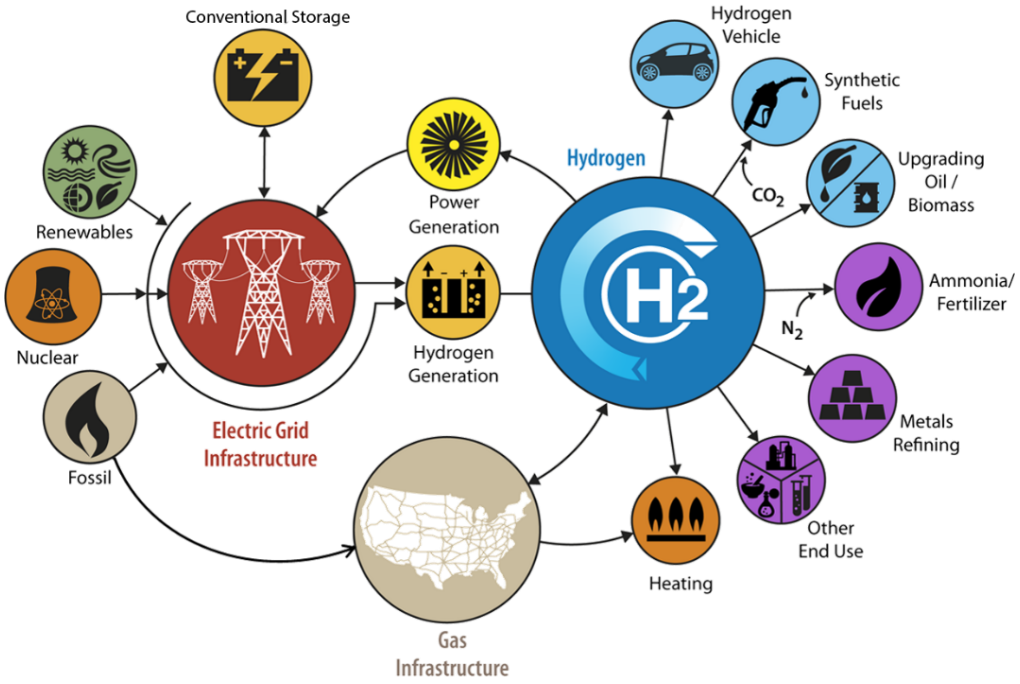
FY18 FOA Selections: 28 projects, ~$38M DOE Funding

(Note: Original selections below; award negotiations underway)

Awardee	DOE Share	Topic Area
Northeastern University	$1M	Topic 1: ElectroCat
Indiana University Purdue	$1M	
Vanderbilt University	$0.9M	
Pajarito Powder	$1M	
United Technologies Research Center	$1M	
Plug Power	$2M	Topic 2a: Production & Fueling
Equilon Enterprises LLC (dba Shell Oil US)	$2M	
Skyre, Inc.	$2M	
Giner ELX, Inc.	$1.7M	
3M Company	$1.9M	Topic 2b: Manufacturing
University of Tennessee Space Institute	$2M	
University of Connecticut	$2M	
Clemson University	$1.6M	
National Renewable Energy Laboratory	$1.2M	Topic 2c: Infrastructure Station Footprint
Washington State University	$1.7M	
Greenway Energy	$2.4M	
Gas Technology Institute	$2.5M	
Rensselaer Polytechnic Institute	$1M	Topic 3a: Fuel Cell Membranes
Pennsylvania State University	$1M	
Drexel University	$1M	
Vanderbilt University	$0.6M	
Xergy, Inc.	$1M	
Lawrence Livermore National Laboratory	$1M	
Lawrence Berkeley National Laboratory	$1M	Topic 3b: Liquid & Reversible Fuel Cells
Northwestern University	$1M	
Giner, Inc.	$1M	
Georgia Institute of Technology	$0.75M	
University of Kansas Center for Research, Inc.	$1M	

FOA Announced Mar '19: H_2@Scale

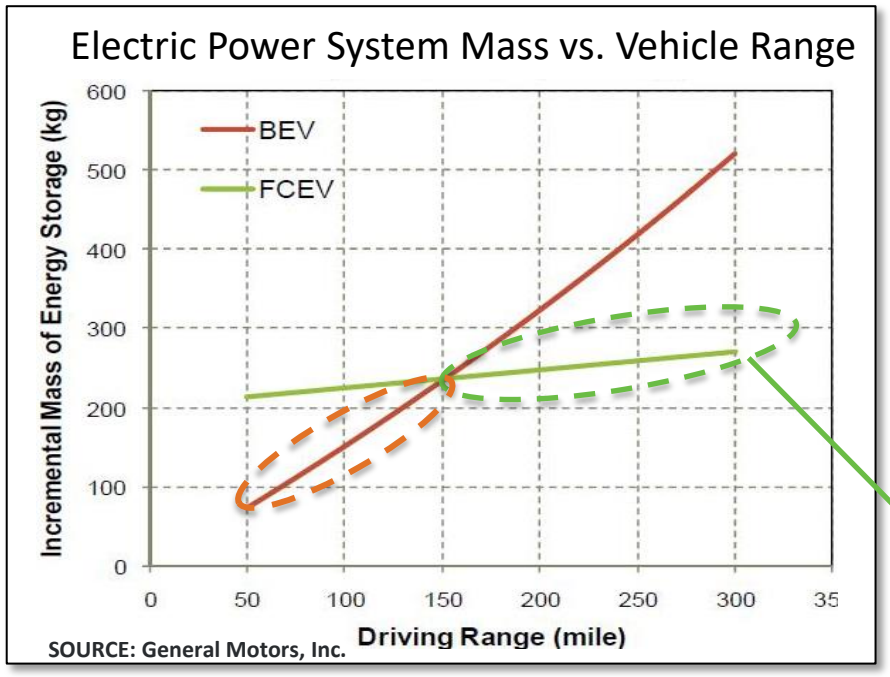
- Focus on **versatility, volume and value proposition**



- **FY 2019 H2@Scale FOA**
  - Approximately 30 awards (1-3 year awards). Topic 3 may be more than 3 years if warranted.
  - Total funding up to $31M
- **FOA Topics**
  - Early Stage H2@Scale-Enabling R&D
    1) Advanced H_2 storage & infrastructure R&D ($9M)
    2) Innovative concepts for hydrogen production & utilization ($12M)
  - H2@Scale Pilot Integrated Systems R&D ($10M)

- **Aligns with priorities: energy storage, systems integration, collaboration across Offices**

FOA Announced Mar '19: Medium/Heavy Duty Applications



- **Joint FY 2019 Truck FOA**
  - FCTO, VTO and BETO provide combined funding of approx. $51M
  - **Total FCTO funding: $15M**
  - Approx. **11-24 awards under FCTO** topics
- **Three H_2 and Fuel Cells Topics included:**
  - **Advanced storage for gaseous fuels** ($3M from FCTO, $3M from VTO)
  - **High throughput hydrogen fueling** technologies for trucks ($6M)
  - **Durable fuel cells with low platinum content** applicable to trucks and similar applications ($6M)

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

HTAC Recommendations Being Addressed

DOE Response to 2017 HTAC Annual Report (30 Nov 2018)
was delivered to the HTAC Chair in February 2019

Recommendation	Actions Taken Since Last Meeting (Examples)
Develop and validate value propositions and systems solutions for renewable energy to hydrogen for power, fuel, and grid-stabilization	H2@Scale analyses are continuing, e.g.,: • Hydrogen Market Size Potential across Applications • Comparative Costs of Energy Storage Continue work to demonstrate value of electrolyzers in providing grid services, and work with NE on hybrid energy systems.
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 (released March 4) includes topic for **H2@Scale Pilot** - integrated production, storage, and fueling systems (up to $10M) including innovative approaches that successfully integrate and optimize the complete system encompassing hydrogen production, storage, distribution, and use – *in addition….see below*
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 includes (1) **Advanced hydrogen storage and infrastructure R&D** (up to $9M) including novel materials/H_2 carriers and materials for H_2 infrastructure components and (2) **Innovative concepts for H_2 production and utilization** (up to $12M) 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

Recommendation	Actions Taken Since Last Meeting (Examples)
Make National Laboratory assets and funding available for collaboration with private industry	• FCTO is continuing to foster collaborative approaches to R&D, including through R&D consortia (**HydroGEN, HyMARC, ElectroCAT, and H-Mat**) and **CRADA** (Cooperative Research & Development Agreement) projects that include national lab, industry, and university partners (over 20 projects)
Conduct education and outreach to demonstrate the benefits and viability of fuel cells and hydrogen in different applications to a wide range of audiences	• The work of the HTAC's Outreach and Education Subcommittee, the "HTAC Outreach Modules," was published on the DOE-HTAC website in January 2019: https://www.hydrogen.energy.gov/pdfs/htac-outreach-modules.pdf • Leveraging IPHE Education & Outreach Working Group
Maximize the role of the Hydrogen Safety Panel (HSP) and maintain active DOE engagement in developing SCS	• **Spearheaded formation of the Center for Hydrogen Safety (CHS)** to provide the hydrogen and fuel cell industries and its stakeholders with hydrogen safety guidance (Direct HTAC output). • Continuing strong support on SCS (tunnels, etc.)

HTAC Recommendations Being Addressed

Recommendation	Actions Taken Since Last Meeting (Examples)
Continue efforts in material and process integration and technology acceleration to meet the 2020 EPACT Title VIII goals	• **Launched H-Mat consortium to focus on H_2 materials compatibility** • **Funded over 20 projects** to enable H2@scale ($11M with cost share) • March 4, 2019 – Issued **$31 million funding opportunity announcement** to advance the H2@Scale concept, with topics including system integration and materials R&D
Identify and support other federal and state agencies **Leverage the capabilities of public-private partnerships**	• **Signed DOD TARDEC MOU** to H_2 and fuel cell applications for military and civilian use • **January 2019 - MOU signed with Michigan Economic Development Corporation** to promote investment in hydrogen infrastructure and grow the domestic supply chain • Collaboration with **Federal Railway Administration** and States (H2@Rail workshop, Michigan, March 25-26) • Organized joint workshops (e.g. industry, labs, FCHEA) • **Leveraging and coordinating** with IPHE, Hydrogen Council, USDRIVE, State Partnerships, H2@Scale Consortium, etc.

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**
  - Input on Hydrogen Safety Panel and affiliation with AIChE
  - 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 circulated- feedback requested before AMR 4/29/19)
- "Dashboard" on metrics, status vs EPACT

2) Collaboration - Examples

- Tokyo Statement areas of collaboration and IPHE role
- MOUs and concrete collaboration opportunities (e.g. TARDEC-FCTO MOU, MEDC- DOE MOU)
- Center for Hydrogen Safety – expand awareness, April 1-2 launch
- Prize concepts

Hydrogen and Fuel Cell Technologies Program Plan

Program Strategic Plan required by EPACT
Hydrogen Posture Plan published in 2006
Last published Program Plan in 2011
New revision to be released in 2019

Preliminary draft complete
Release to HTAC, 3/19
Release to AMR program-level reviewers, 4/19
Final release ~ 6/19

1. Introduction

- Mission
- Program Benefits: Why Hydrogen and Fuel Cells
- H2@Scale
- Program Goals
- Strategy
- Program Accomplishments and Impact
- Barriers

2. Program Activities, Plans, and Milestones

- Make—Produce Affordable Hydrogen
- Move—More Efficient Hydrogen Transmission
- Use—Affordable Value Added Applications
- Store—Improved Hydrogen Storage Technologies
- Overarching activities
  - Safety, Codes, and Standards
  - Analysis
  - Technology Acceleration

3. Program Direction, Processes, and Stakeholder Input

- Organizations and Partnerships
- Program Implementation
- Federal, State, and International Collaboration and Coordination

Areas of Input: Center for Hydrogen Safety

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.**

AMR Program At Glance: Mon, April 29 – Wed, May 1

MONDAY APRIL 29 - General Plenary and Poster Session 1	
1:00 PM	Welcome and Keynote Speakers
1:30 PM	Industry/R&D Panel Session
2:00 PM	DOE Hydrogen and Fuel Cell Program Overview
2:45 PM	Break
3:15 PM	Subprogram Overviews and AMR Awards Ceremony
6:00 PM	Adjourn
6:30 - 8:00 PM	Poster Session

Plenary Speakers:

Alan Finkel, Chief Scientist, Australia
Andy Marsh, CEO, Plug Power

Tuesday (4/30) and Wednesday (5/1) will feature:

- **Oral technical sessions** (Fuel cell, Hydrogen Fuel, Technology Acceleration and Infrastructure R&D portfolios)
- **Interagency track**
- **Poster sessions**

Ride and Drive open to AMR Participants on Tuesday, April 30 – Lunch

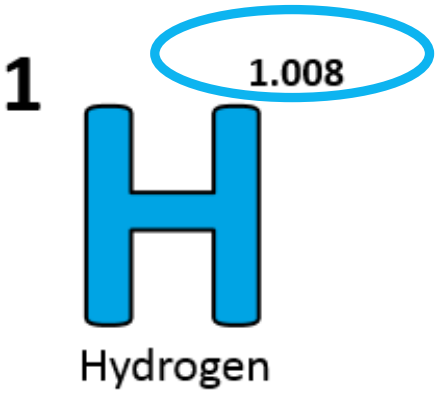


More info: www.annualmeritreview.energy.gov

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 H2IQ

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

Workshops enabling H2@scale

- **Datacenters:** March 20 in Seattle, WA
- **Rail:** March 26-27 in Lansing MI
- **Ports:** Sept 2019, San Francisco, CA (tentative)

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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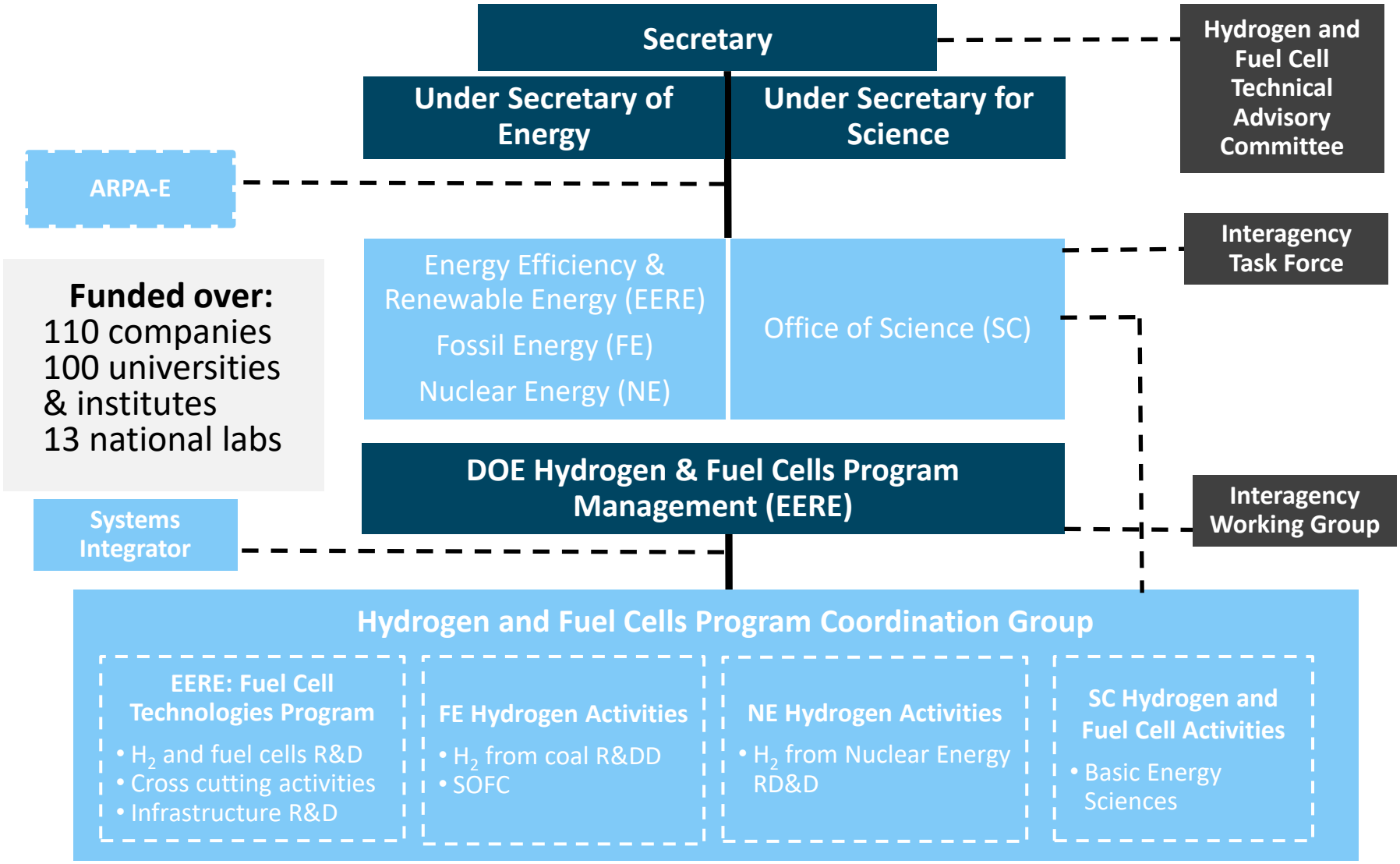
Fuel Cell Technologies Office
Sunita.Satyapal@ee.doe.gov

energy.gov/eere/fuelcells

The H_2 and Fuel Cells Program spans other DOE offices



Example of HTAC "Dashboard" Recommendation

Technology Areas		EPACT 2005, Title VIII – HTAC Review Responsibilities						
		DOE Hydrogen & Fuel Cell Programs	Technology Consequences			Energy Secretary Coordinated Plan[i] for Hydrogen & Fuel Cells – Potential to Achieve Section 805 Program Goals		
			Safety	Economics	Environment	Vehicles[ii]	Hydrogen Energy and Energy Infrastructure[iii]	Fuel Cells[iv]
Hydrogen								
Production	Fossil Fuels, Hydrogen Carrier Fuels Renewables, Nuclear							
Delivery	Transmission by Pipelines, Surface Transport; Fueling (Central Refueling Stations, Distributed Onsite)							
Uses	Commercial, Industrial & Residential Power Generation							
Advanced Vehicle Technologies	Engine & Emission Control Systems, Energy Storage, Electric Propulsion, Hybrid Systems, Automotive Materials, Other							
Storage	Hydrogen & Hydrogen Carrier Fuels, Development of Materials for Storage in Gas, Liquid or Solid Form at Refueling Facilities and On-Board Vehicles							
Fuel Cells								
Power Systems	Safe, Durable, Affordable, Efficient, Fuel Flexible							
Hybrid Technologies	U.S. Produced, Commercially Available, Competitive							
Manufacturing	High Temperature Membranes, Cost Effective Stack & System Reliability,							

Current H2@Scale CRADA Projects

Over 20 CRADA Projects Underway

HYDROGEN INTEGRATION WITH ENERGY GENERATION R&D

- Electric Power Research Institute
- Exelon
- Southern Company / Terrestrial Energy
- Pacific Gas & Electric
- TerraPower
- Southern / Xcel

HYDROGEN DISTRIBUTION COMPONENT DEVELOPMENT R&D

- California Go-Biz Office
- Frontier Energy
- HyET
- Honda
- NanoSonic
- RIX
- Tatsuno
- Shell

ADVANCED HYDROGEN PRODUCTION CONCEPTS R&D

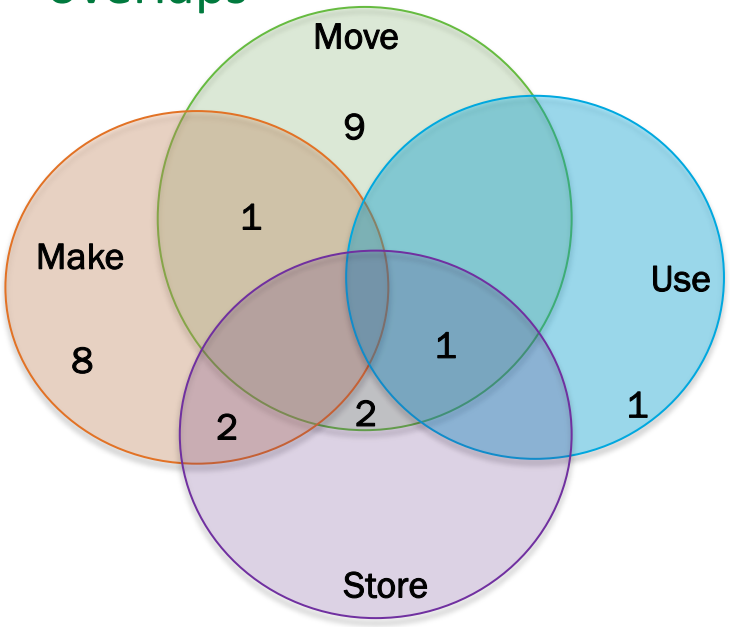
- Honda
- C4-MCP, Inc.
- GinerELX
- GTA, Inc.

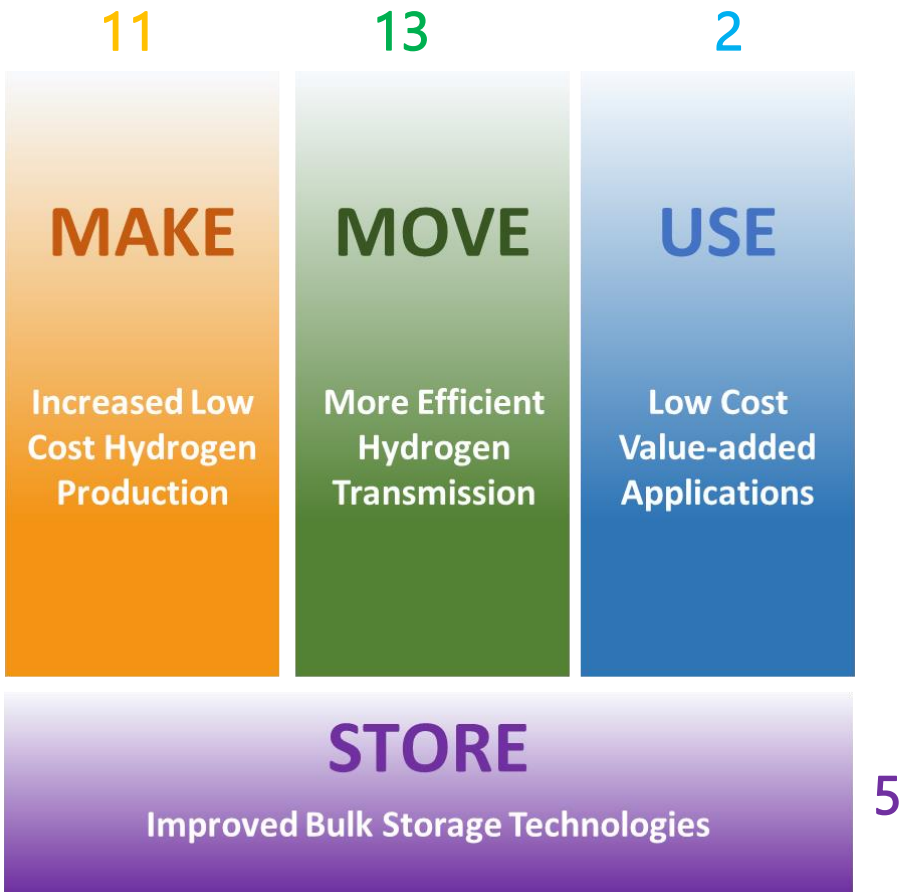
HYDROGEN QUANTITATIVE PERFORMANCE ANALYSIS AND OPERATION R&D

- Air Liquide
- California Energy Commission
- Connecticut Center for Advanced Technology
- PDC Machines
- Quong & Associates, Inc.

H2@Scale Focus Areas

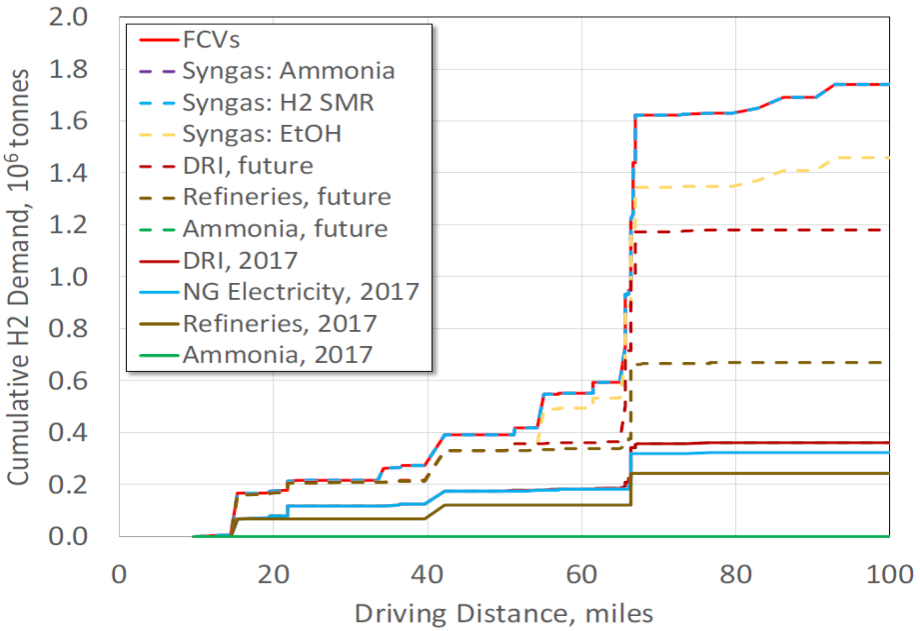
- H2@Scale consortium organized around 4 working groups which are linked to the FCTO Program Plan themes
  - "Make" WG launched in December 2018
  - CRADA participants can join multiple groups where project overlaps



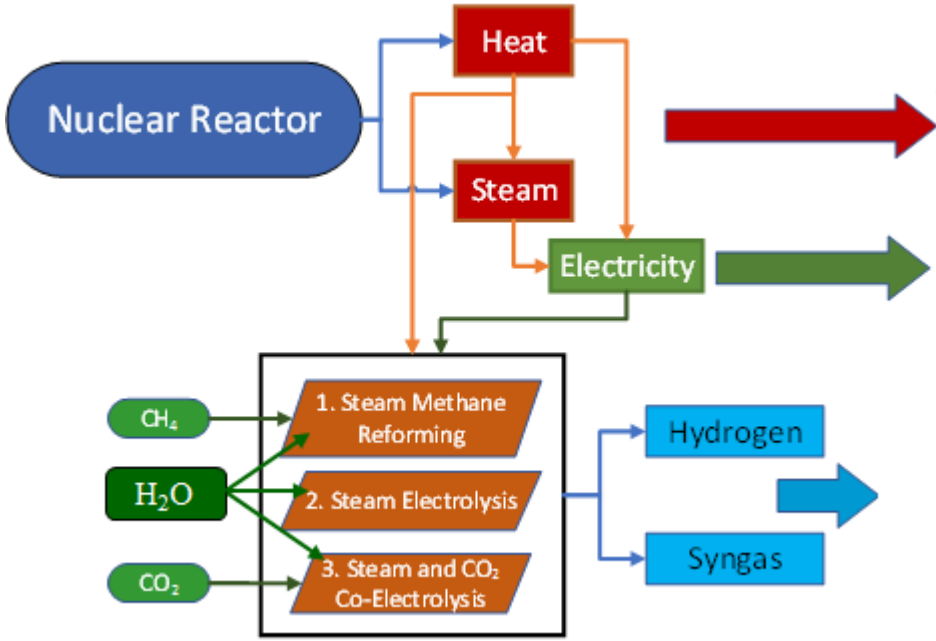


H2@Scale CRADAs: Four CRADA projects on integrated nuclear-hydrogen systems

Regional analysis to identify potential hydrogen demand near nuclear power plant



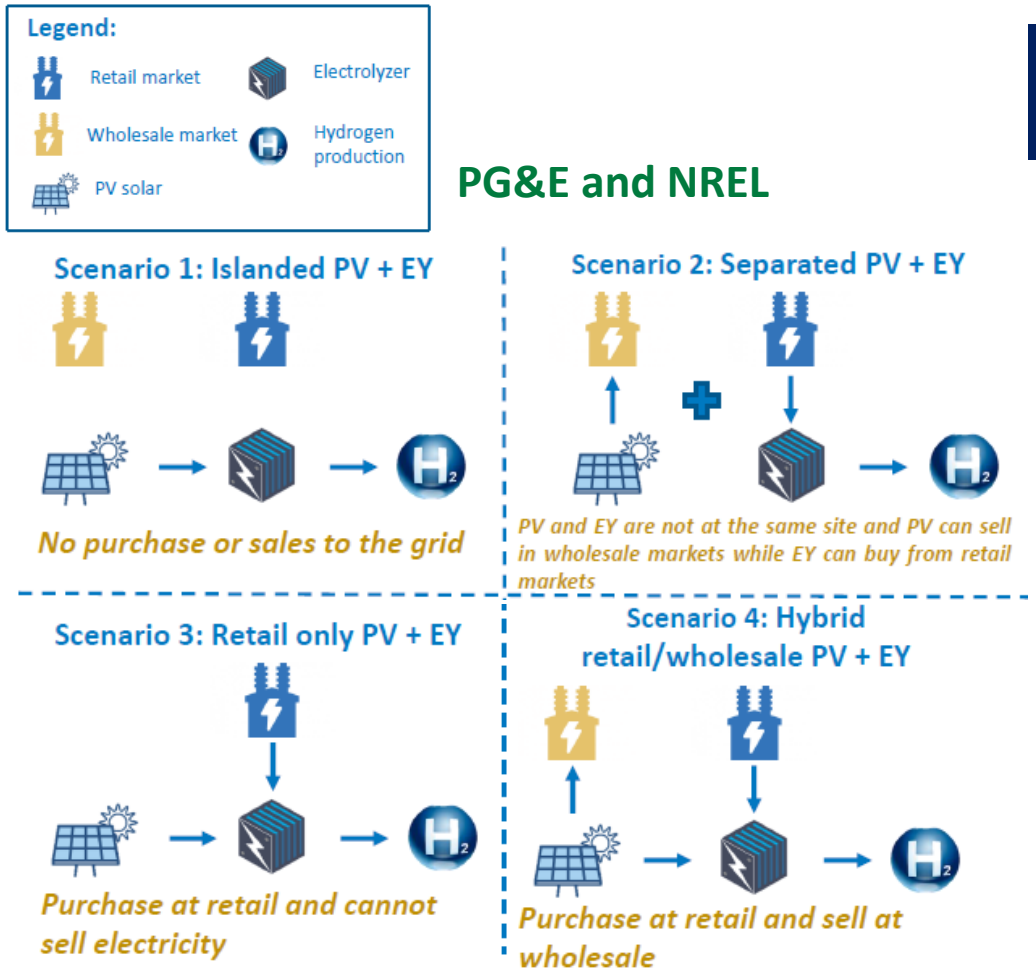
Modeling of alternative revenue streams for nuclear power plants



Industry Partners: Southern Company, Xcel, Exelon, TerraPower, FuelCell Energy, Terrestrial Energy USA

Lab Partners: INL, NREL, ANL, PNNL, SNL, SRNL

H2@Scale CRADAs: Analyzing grid integrated renewable-electrolyzer systems



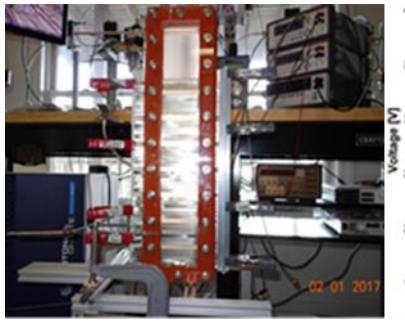
Analyzing breakeven cost for hydrogen production under various scenarios of producing hydrogen and/or electricity with solar

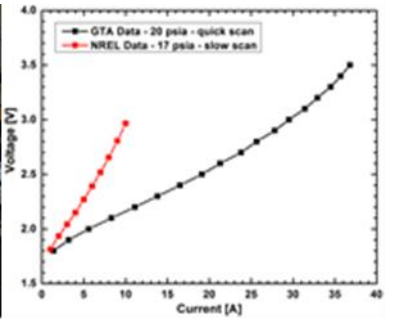
Purity and current-voltage studies for hydrogen production from offshore wind

- **Hydrogen purity as measured is 99.96681%**
- **H_2O, O_2, CO_2 are above stringent SAE J2719 fuel grade standard**
- **Removing H_2O, O_2, CO_2 would increase purity to above 99.999%**
- **Native H_2 purity (no purification): 99.68%**

Verification of Operation

- Large pressure impact observed due to NREL elevation: bubble size effect expected
- Only 5 psi gauge pressure available



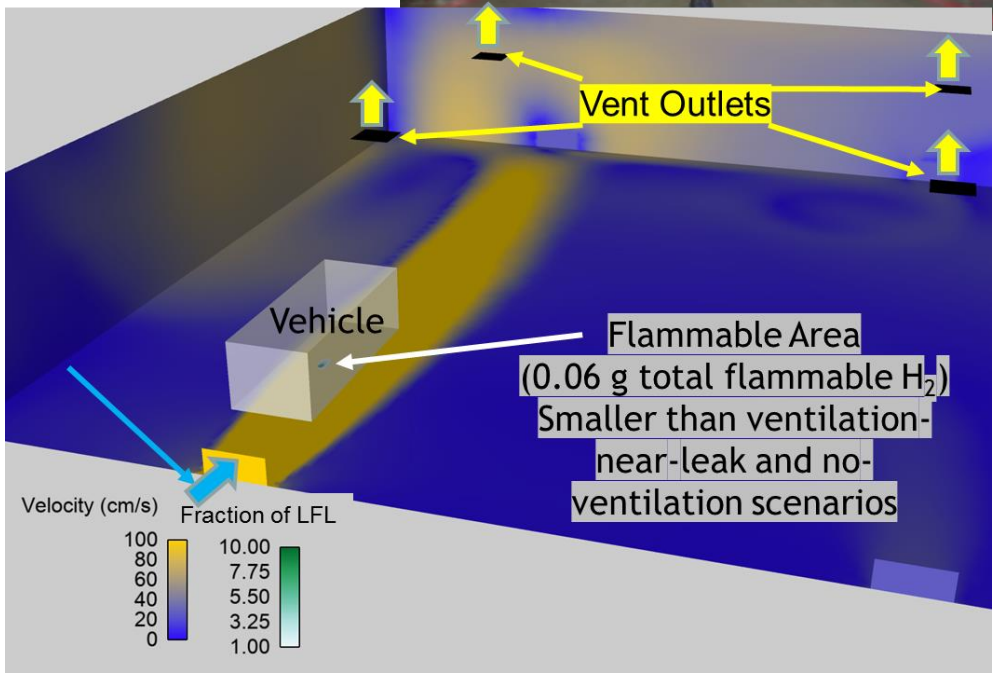


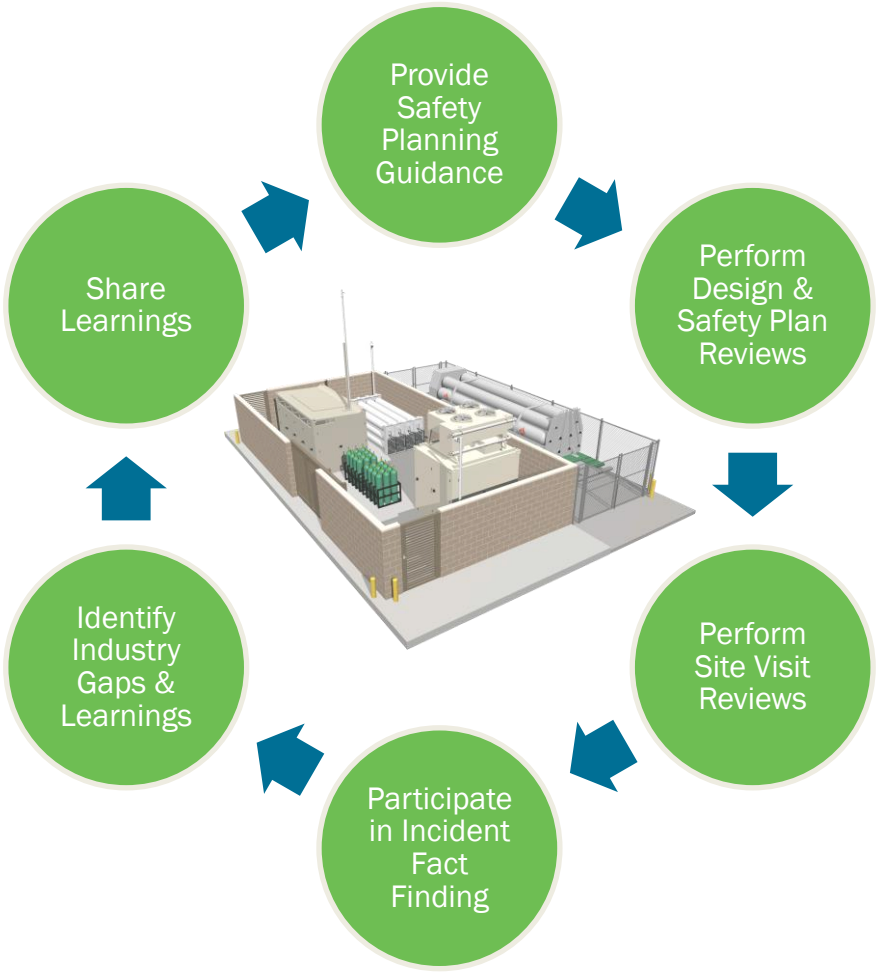
GTA, Inc. and NREL

H2@Scale CRADAs: Quantitative risk analysis and safety outreach

Identification of repair garage ventilation configurations to minimize flammability during leak scenario

Quong and Associates, Inc. and SNL





California Energy Commission and PNNL

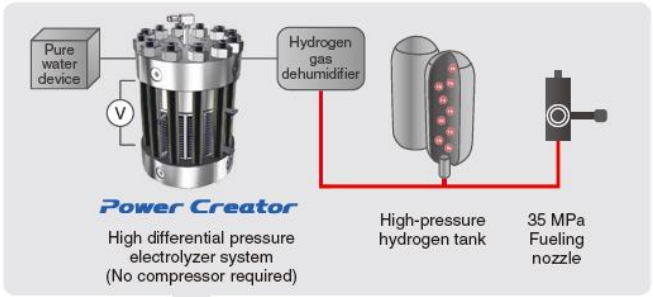
Providing recommendations pertaining to the safe handling and use of hydrogen

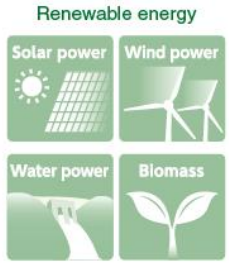
H2@Scale CRADAs: Electrochemical compression

Testing and characterization of high differential pressure electrolyzer system

Outdoor Test Area, Golden, CO

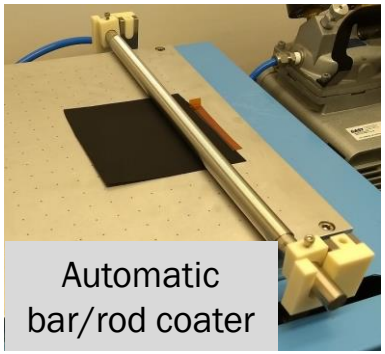
Honda R&D Americas and NREL



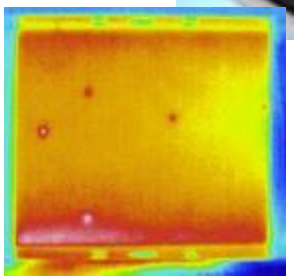


Development of real-time optical/areal quality inspection techniques for manufacturing automation technology for the electrochemical compression

HyET, NREL, and LBNL



Automatic bar/rod coater



Infrared imaging of electrode and MEA defects

FY 2019 Congressional Language

House	Senate	Conference
[No direction.]	The Committee recommends **$19,000,000** for Technology Acceleration activities, including **$3,000,000** for manufacturing R&D, and **$7,000,000** for industry-led efforts to demonstrate a hydrogen-focused integrated renewable energy production, storage, and transportation fuel distribution/retailing system. Regular consultation with industry is encouraged to avoid duplication of private-sector activities. The Committee encourages the Secretary to work with the Secretary of Transportation and industry on coordinating efforts to deploy hydrogen fueling infrastructure.	Within available funds, the agreement provides **$21,000,000** for Technology Acceleration activities, including **$3,000,000** for manufacturing research and development and **$7,000,000** for industry-led efforts to demonstrate a hydrogen-focused integrated renewable energy production, storage, and transportation fuel distribution/retailing system. *[Senate language stands.]*

FY 2019 Congressional Language

House	Senate	Conference
Within available funds, **$2,000,000 is for the EERE share of the integrated hybrid energy systems work with the Office of Nuclear Energy.** **$7,000,000** is to enable integrated energy systems using **high and low temperature electrolyzers** with the intent of **advancing the H2@Scale concept.**	**$39,000,000 for Hydrogen Fuel R&D** for efforts to reduce the cost and improve the performance of hydrogen generation and storage systems, hydrogen measurement devices for fueling stations, hydrogen compressor components, and hydrogen station dispensing components. The Department shall continue to **research novel onboard hydrogen tank systems, as well as trailer delivery systems to reduce cost of delivered hydrogen**. … directed to support R&D activities **that reduce the use of platinum group metals,** provide improvements in electrodes and membranes and balance-of-plant components and systems. …. **is directed to continue the H2@Scale Initiative**, which couples current research efforts within the program with new opportunities for using hydrogen to provide grid resiliency and advance a wide range of industrial processes for the production of fuels, chemicals, and materials.	**$39,000,000 for Hydrogen Fuel Research and Development** [Senate language stands.] Within available funds, the agreement provides **$4,000,000** for the EERE share of the integrated energy systems **work with the Office of Nuclear Energy** **$7,000,000** to enable integrated energy systems using **high and low temperature electrolyzers** with the intent of advancing the H2@Scale concept.

FY 2019 Congressional Language

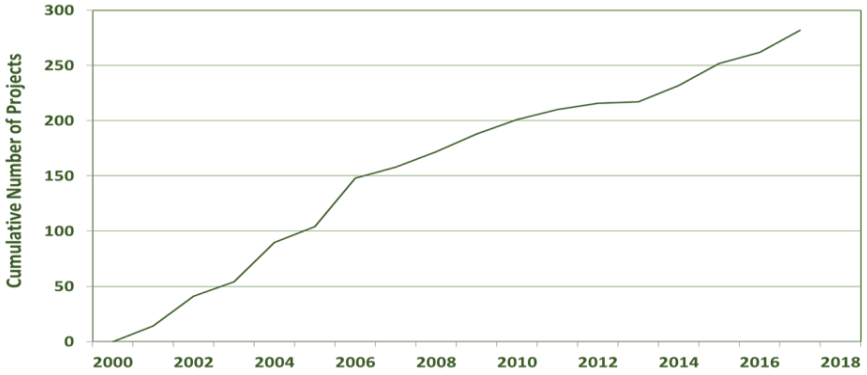
House	Senate	Conference
The Committee recognizes the need to support the development of alternative fueling infrastructure for U.S. consumers. Accordingly, the Department is encouraged to collaborate with the National Institute of Standards and Technology to allow accurate measurement of hydrogen at fueling stations.	The Committee further recommends $7,000,000 for Safety, Codes, and Standards to maintain a robust program and engage regulatory and code officials to support their technical needs relative to infrastructure and vehicle safety.	**$7,000,000** for Safety, Codes, and Standards. *[House language stands. "Encouraged" is not considered congressional direction.]*
The Department is encouraged to work with the Department of Transportation on coordinating supporting hydrogen fueling infrastructure.	Within the amounts recommended, **$19,000,000** is recommended for Hydrogen Infrastructure R&D.	[Senate & House language stands. In both cases, 'encouraged' and 'recommended' are not considered congressional direction]

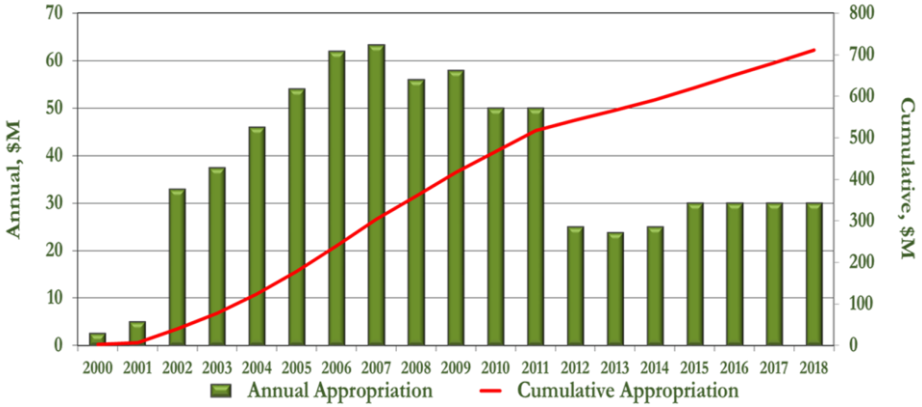
FY 2019 Congressional Language

House	Senate	Conference
The Committee recognizes the progress of the program and continues support for stationary, vehicle, motive, and portable power applications of this technology.	*[No direction.]*	*[House language stands. "Recognizes" is not considered congressional direction.]*
[No direction.]	The Committee recommends **$1,000,000** for Systems Analysis, including research on in-situ metrology for process control systems for manufacturing of key hydrogen system components.	*[Senate language stands. "recommends" is not considered congressional direction.]*

Additional Information- SOFC Program Funding History

- FY19 Appropriation: $30M
- Cumulative Funding (FY00 – FY18)
  - DOE ~$712M
  - Participant Cost Share ~$265M





- Total Number of Awards >290
- Total Number of Participants 116
  - Industry 66
  - Academia 40
  - National Labs/Agencies 10

Hydrogen Energy Ministerial Priorities: Summary

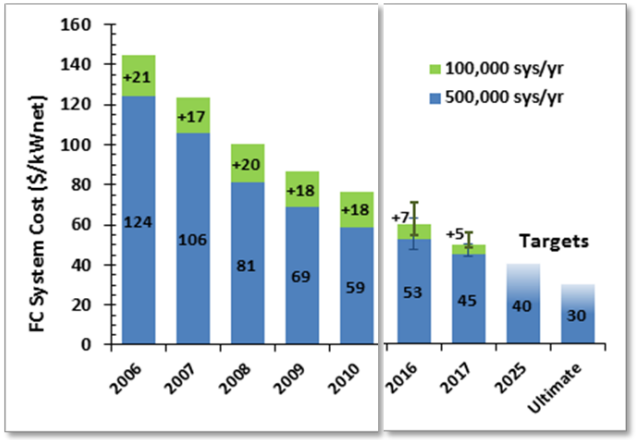
Action from Oct 23, 2018 Hydrogen Ministerial: Develop concrete actions that Agencies can undertake to address four priorities

Harmonization of Codes and Standards	Information Sharing, Safety, Infr. Supply Chain	Studies and Evaluations of Impact Potential	Communication and Outreach

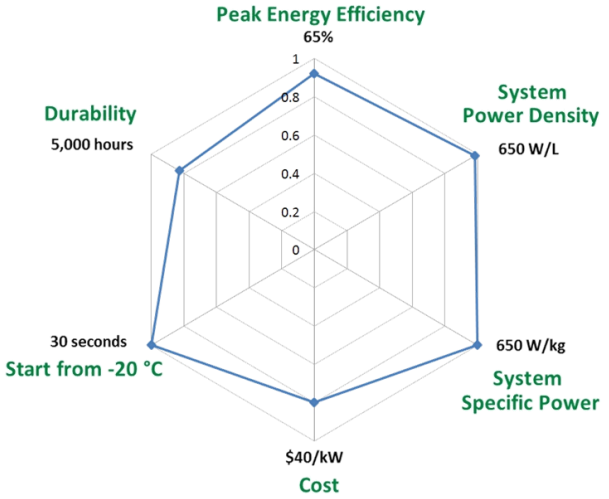
• Coordinate with industry to enable harmonization of relevant regulations, codes and standards such as those for:
  • refueling stations,
  • heavy duty transportation,
  • energy storage
  • technologies supporting sectoral integration,
  • maritime
  • other
	• Collaborate on relevant infrastructure R&D
	• Share safety lessons learned, best practices on hydrogen safety
	• Collaborate on R&D of risk assessment and mitigation to enable the safe and sustainable use of hydrogen technologies across applications.
		• Collect, analyze and share data and conduct studies
		• Assess impact potential for sustainable production of H2 across pathways
		• Develop business cases and models across value chain and integrated systems analysis across scenarios
			• Work together to promote appropriate outreach and awareness programs and initiatives to educate a broad range of stakeholder groups on H2 and fuel cell technologies
			• Develop 'train the trainer' programs, to build awareness of hydrogen solutions, especially on safety

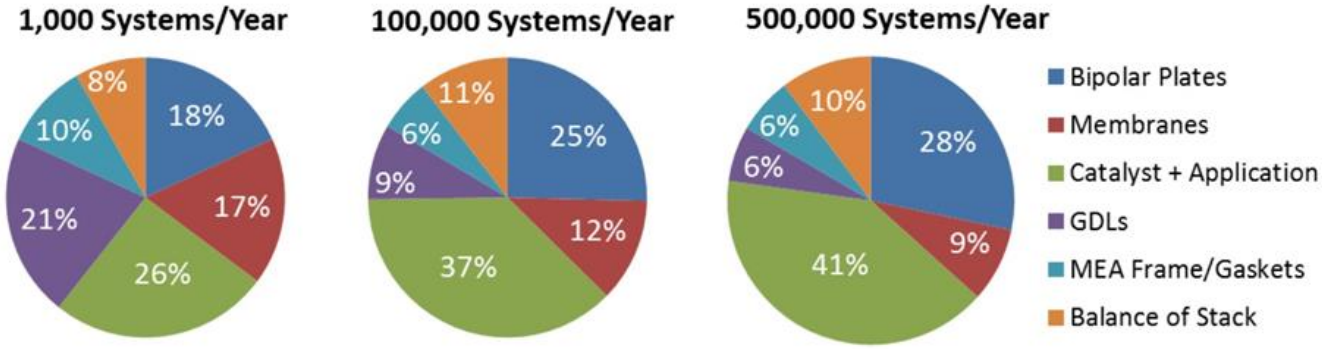
Fuel Cell Status vs. Targets

R&D has enabled > 60% cost reduction in the last decade

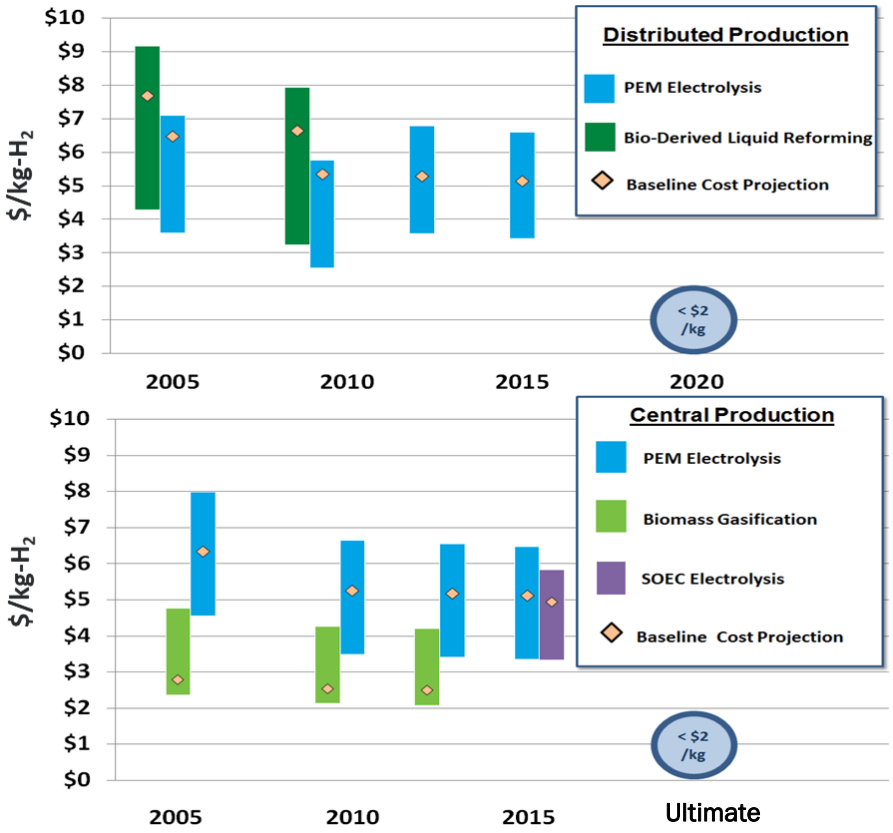


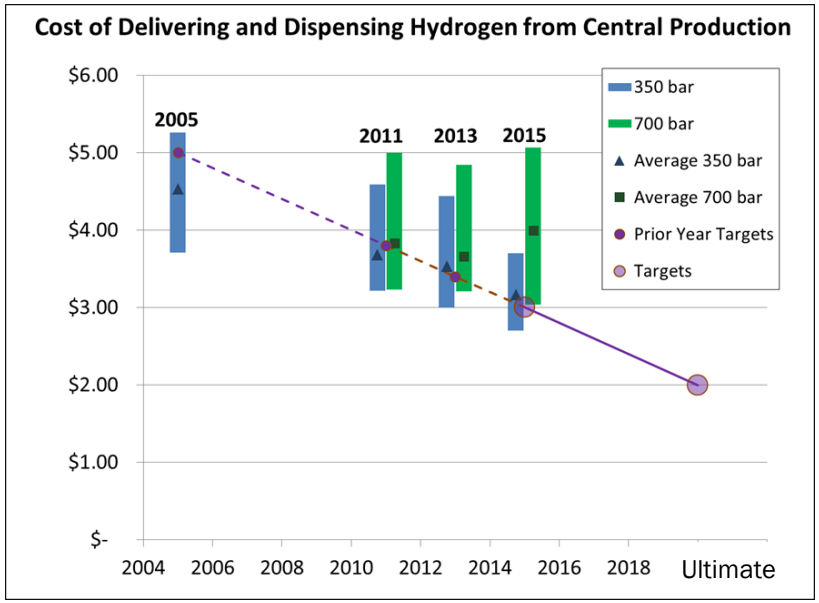
Some targets are met but fuel cell cost and durability must be addressed concurrently



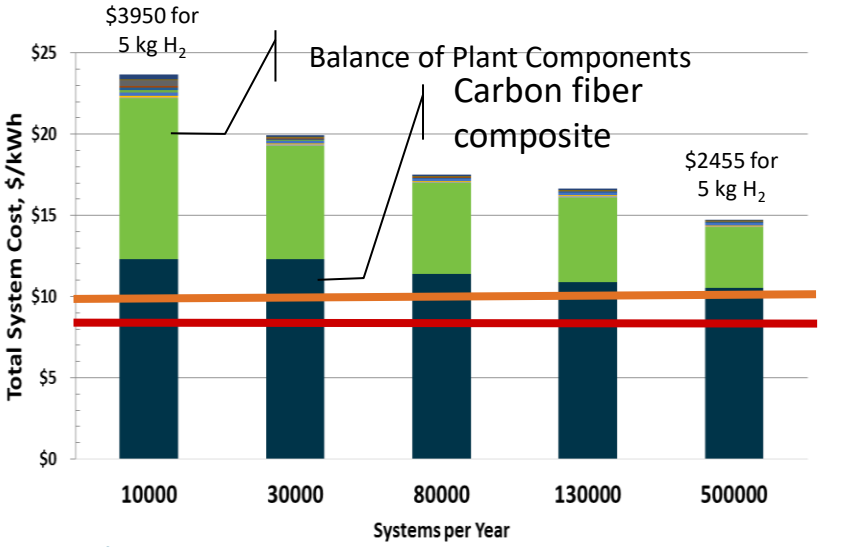


DOE Historical Analysis Examples with industry input

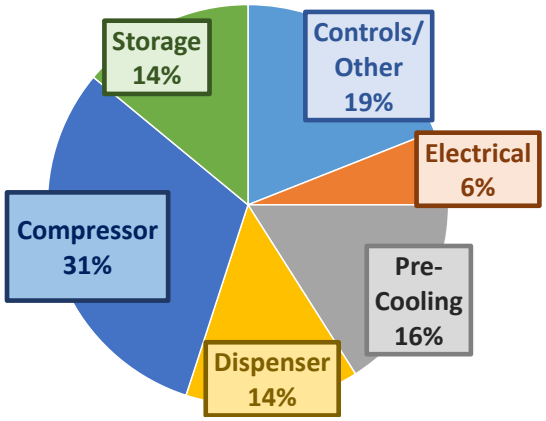




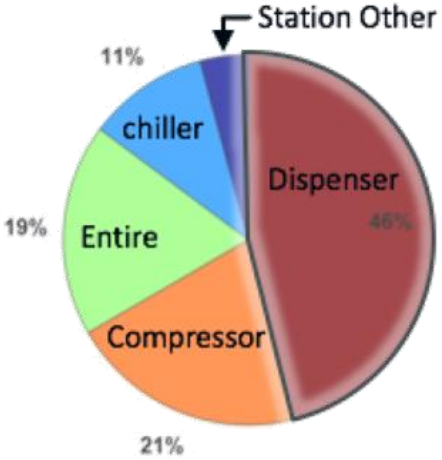
Examples of Cost and Reliability Data/Analysis



Analysis for a single tank design



Delivery Cost by Component Tube Trailer Delivery Example



Maintenance by Equipment Type
Retail Stations
Total Events: 4,663
Dispenser: 46% of Events

https://www.hydrogen.energy.gov/pdfs/15013_onboard_storage_performance_cost.pdf