Hydrogen and Fuel Cell Technologies Office Update

Dr. Sunita Satyapal, Director, Fuel Cell Technologies Office

Hydrogen and Fuel Cell Technical Advisory Committee (HTAC) Meeting
March 9, 2020– Washington DC
Agenda

• HTAC Scope
  – Membership
  – Energy Policy Act (EPACT) 2005 Title VIII

• Program Updates
  – Budget, solicitations and recent highlights
  – Requests for input and discussion- Multiyear Plan, Center for Hydrogen Safety, National Lab Facilities

• Additional Information
  – Responses to HTAC recommendations, Congressional language, Organizational updates
## 2020 HTAC Membership

<table>
<thead>
<tr>
<th>HTAC Member and Affiliation</th>
<th>Expertise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freese, Charles F. (Chair) General Motors Company</td>
<td>Automotive Companies</td>
</tr>
<tr>
<td>Hebner, Robert University of Texas at Austin</td>
<td>Advanced power and energy technology R&amp;D, government-industry partnerships, and tech-to-market strategies</td>
</tr>
<tr>
<td>Irvin, Nick Southern Company</td>
<td>Utilities/Advanced Energy Systems R&amp;D</td>
</tr>
<tr>
<td>Koyama, Harol H2 PowerTech</td>
<td>Stationary Power and Markets</td>
</tr>
<tr>
<td>Leggett, Paul Mithril Capital Management, LLC</td>
<td>Venture Capital / Investment</td>
</tr>
<tr>
<td>Leo, Anthony FuelCell Energy</td>
<td>Stationary Fuel Cell and Hydrogen Production Technology Manufacturing</td>
</tr>
<tr>
<td>Markowitz, Morry Fuel Cell and Hydrogen Energy Association (FCHEA)</td>
<td>Hydrogen and Fuel Cells Industry Association</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>HTAC Member and Affiliation</th>
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<tbody>
<tr>
<td>Marsh, Andrew Plug Power</td>
<td>Stationary and Transportation Fuel Cell Technology Manufacturing</td>
</tr>
<tr>
<td>Mount, Robert Power Innovations</td>
<td>Power management technology and integration</td>
</tr>
<tr>
<td>Nocera, Daniel Harvard University</td>
<td>Hydrogen Production R&amp;D</td>
</tr>
<tr>
<td>Novachek, Frank Xcel Energy</td>
<td>Utilities (Electricity and Natural Gas)</td>
</tr>
<tr>
<td>Powell, Joseph (Vice Chair) Shell Global Solutions</td>
<td>Fuels Production and R&amp;D</td>
</tr>
<tr>
<td>Rogers, Paul The Adjutant General of the Michigan National Guard and Director of Military and Veterans Affairs</td>
<td>Military Hydrogen and Fuel Cell Applications / R&amp;D</td>
</tr>
<tr>
<td>Rumsey Jennifer California Energy Commission</td>
<td>Medium- and heavy-duty engine design and manufacturing</td>
</tr>
<tr>
<td>Scott, Janea California Energy Commission</td>
<td>State Energy Policies and Regulations</td>
</tr>
<tr>
<td>Thompson, Levi University of Delaware</td>
<td>Catalytic and Absorbent Materials R&amp;D</td>
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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 fuel cells and technologies to produce, distribute, deliver, store or use hydrogen energy

3. The DOE Hydrogen & Fuel Cells Program Plan
Title VIII Sec. 802- Purposes

1. Enable and promote comprehensive development, demonstration, and commercialization of H₂ 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 H₂ 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
Examples of Applications

- **>500MW**
  Stationary Power

- **>30,000**
  Forklifts

- **>30**
  Fuel Cell Buses

- **>45**
  H₂ Retail Stations

- **>8,300**
  Fuel Cell Cars

Hydrogen Production Across the U.S.

- 10 million metric tons produced annually
- More than 1,600 miles of H₂ pipeline
- World’s largest H₂ 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**
**Key Programmatic Area: H2@Scale**

**H2@Scale:** Enabling affordable, reliable, clean, and secure energy across sectors

Includes early stage R&D: Funding Opportunity Announcements (FOAs) for industry, universities and national labs, including consortia

And includes later stage RD&D:
- Leverages private sector for large-scale demos
- New H2@Scale demonstration projects announced
- Texas, Florida, Midwest, complements California deployments
Funding and Impact

Examples of Accomplishments

Innovation

**Approx. 960 patents enabled by FCTO funds**

**Approx. 37% of H₂ and fuel cell patents come from National Labs**

Market Impact

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

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

EERE Fuel Cell Technologies Office Funding

**FY 2013 – FY 2019**

**From 2013 to 2019 Covering H₂ and Fuel Cell Activities in $649 M 37 states and DC**

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

1Prime recipients only
### Fuel Cell Technologies Office (FCTO) within Energy Efficiency and Renewable Energy (EERE)

<table>
<thead>
<tr>
<th></th>
<th>FY 2018</th>
<th>FY 2019</th>
<th>FY 2020</th>
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<tbody>
<tr>
<td>Fuel Cell R&amp;D</td>
<td>32,000</td>
<td>30,000</td>
<td>26,000</td>
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<tr>
<td>Hydrogen Fuel R&amp;D</td>
<td>54,000</td>
<td>39,000</td>
<td>45,000</td>
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<tr>
<td>Hydrogen Infrastructure R&amp;D*</td>
<td>-</td>
<td>21,000</td>
<td>25,000</td>
</tr>
<tr>
<td>Technology Acceleration</td>
<td>19,000</td>
<td>21,000</td>
<td>41,000</td>
</tr>
<tr>
<td>Safety, Codes, and Standards</td>
<td>7,000</td>
<td>7,000</td>
<td>10,000</td>
</tr>
<tr>
<td>Systems Analysis</td>
<td>3,000</td>
<td>2,000</td>
<td>3,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$115,000</strong></td>
<td><strong>$120,000</strong></td>
<td><strong>$150,000</strong></td>
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*Will be moved under Hydrogen Fuel R&D in FY 2021

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### DOE Hydrogen and Fuel Cells FY 2020 Appropriations

**DOE Office**

<table>
<thead>
<tr>
<th>Funding (in thousands)</th>
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<tr>
<td><strong>EERE (FCTO)</strong></td>
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<tr>
<td><strong>Fossil Energy (SOFC)</strong></td>
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<tr>
<td><strong>Nuclear Energy</strong></td>
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<td>(coordinated with FCTO)</td>
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</table>

- Office of Science, Basic Energy Sciences Funding for projects relevant to H₂ and fuel cells (e.g. catalysis, etc.) was $20.5 M in FY 19, TBD in FY 20
- ARPA-E- Funding is based on specific program selected each year: TBD in FY 20

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### Fuel Cell Technologies Office

**Hydrogen and Fuel Cells Breakdown FY 2020**

- Fuel Cell R&D, $26M
- Hydrogen Fuel R&D, $45M
- Hydrogen Infrastructure R&D*, Technology Acceleration, $41M
- Systems Analysis, $3M
- Safety, Codes, and Standards, $10M

*Will be moved under Hydrogen Fuel R&D in FY 2021
## Up to $64M announced under H2@Scale New Markets Funding Opportunity

<table>
<thead>
<tr>
<th>Topic Area</th>
<th>Total Funding Level</th>
<th>Anticipated # of Awards</th>
<th>Max. Federal Funding per Award</th>
<th>Max. Project Duration (yrs)</th>
<th>Min Required Non-Federal Cost Share %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topic 1: Electrolyzer Manufacturing R&amp;D</td>
<td>$15M</td>
<td>Up to 4</td>
<td>$5M</td>
<td>3</td>
<td>20%</td>
</tr>
<tr>
<td>Topic 2: Advanced Carbon Fiber for Compressed Gas Storage Tanks</td>
<td>$15M</td>
<td>Up to 3</td>
<td>$9M</td>
<td>5</td>
<td>20%</td>
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<tr>
<td>Topic 3A: Fuel Cell R&amp;D for Heavy-Duty Applications</td>
<td>$4M</td>
<td>Up to 4</td>
<td>$1M</td>
<td>3</td>
<td>20%</td>
</tr>
<tr>
<td>Topic 3B: Fuel Cell R&amp;D for Heavy-Duty Applications - Domestically Manufactured Fuel Cells for Heavy-Duty Applications</td>
<td>$6M</td>
<td>2 to 3</td>
<td>$3M</td>
<td>3</td>
<td>20%</td>
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<tr>
<td>Topic 4: H2@Scale New Markets R&amp;D-HySteel</td>
<td>$8M</td>
<td>1 to 2</td>
<td>$8M</td>
<td>3</td>
<td>20%</td>
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<tr>
<td>Topic 5A: H2@Scale New Markets Demonstrations -Maritime Demonstrations</td>
<td>$8M</td>
<td>1 to 2</td>
<td>$8M</td>
<td>3</td>
<td>50%</td>
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<tr>
<td>Topic 5B: H2@Scale New Markets Demonstrations - Data Center Demonstrations</td>
<td>$6M</td>
<td>1 to 2</td>
<td>$6M</td>
<td>3</td>
<td>50%</td>
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<tr>
<td>Topic 6: Training and Workforce Development for Emerging Hydrogen Technologies</td>
<td>Up to $2M</td>
<td>1</td>
<td>$2M</td>
<td>5</td>
<td>0%</td>
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<tr>
<td><strong>Total:</strong></td>
<td><strong>Up to $64M</strong></td>
<td><strong>Up to 21</strong></td>
<td><strong>Total</strong></td>
<td><strong>Up to 21</strong></td>
<td><strong>Total</strong></td>
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U.S. DEPARTMENT OF ENERGY OFFICE OF ENERGY EFFICIENCY & RENEWABLE ENERGY FUEL CELL TECHNOLOGIES OFFICE
FOA Application Requirements (DE-FOA-0002229 posted online)

- Interested applicants are encouraged to submit application materials through EERE Exchange at [https://eere-Exchange.energy.gov](https://eere-Exchange.energy.gov), EERE’s online application portal
- Applicants needed to submit a **Concept Paper by 5:00pm ET Feb 25, 2020** to be eligible to submit a Full Application

<table>
<thead>
<tr>
<th>Criteria for Assessing Applications</th>
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<tbody>
<tr>
<td><strong>Criterion 1: Merit, Innovation, and Impact (50%)</strong></td>
</tr>
<tr>
<td>• Merit and Innovation</td>
</tr>
<tr>
<td>• Impact of Technology Advancement</td>
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<tr>
<td><strong>Criterion 2: Project Research and Market Transformation Plan (30%)</strong></td>
</tr>
<tr>
<td>• Research Approach, Workplan and SOPO (Statement of project objectives)</td>
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<tr>
<td>• Identification of Risks</td>
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<tr>
<td>• Baseline, Metrics, and Deliverables</td>
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<tr>
<td>• Market Transformation Plan (NOT applicable to Topic Area 6)</td>
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<tr>
<td>• Impact Assessment (applicable ONLY to Topic Area 6)</td>
</tr>
<tr>
<td><strong>Criterion 3: Team and Resources (20%)</strong></td>
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<tr>
<td>• Ability to address all aspects of project with high probability of success</td>
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<td>• Sufficiency of facilities to support the work</td>
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<tr>
<td>• Ability to facilitate and expedite further development and commercial deployment of deliverables</td>
</tr>
<tr>
<td>• Level of participation by project participants</td>
</tr>
<tr>
<td>• Reasonableness of the budget and spend plan</td>
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</table>
Opportunity for Funding through Nuclear Energy FOA

Nuclear Energy (DE-FOA-0001817)

• To apply, go to: https://www.id.energy.gov/NEWS/FOA/FOAOppORTunities/FOA.htm
• Frequently Asked Questions: www.id.doe.gov

*New cycle open – Application due June 30 2020

How Hydrogen and Nuclear Synergize

• Heat and electricity from reactors can produce hydrogen to be used as a fuel or industrial commodity, in energy storage, or for other industrial purposes
• Hydrogen can optimize nuclear production when generation exceeds load on the grid
• To learn more about synergies between hydrogen and nuclear, go to https://www.energy.gov/ne/articles/could-hydrogen-help-save-nuclear
Interagency Collaboration to Enable Technology in Emergency Relief

U.S. Department of Energy and U.S. Army Issue Solicitation to Develop H2Rescue

Press Release
https://www.energy.gov/eere/fuelcells/articles/us-department-energy-and-us-army-issue-solicitation-develop-h2rescue

Opportunity Number and Due Date to Apply to Solicitation
W81EWF20FOA0001 - March 31, 2020

• Example of interagency collaboration (DoD and DOE)
• Up to $1M (requires equal match of industry contributions)
• Truck to run on fuel cell/battery and hydrogen and provide power, heat and potable water

The $1M H-Prize Challenge Incentivized Innovation in Community H₂ Fueling

The prize-winning SimpleFuel® team developed an electrolyzer-based appliance capable of refueling a 700 bar fuel cell vehicle at a rate of 1 kg-H₂ in less than 15 minutes.

DOE, Hyundai and SimpleFuel collaboration will include:

- Data collection and validation on five Hyundai Nexo fuel cell cars
- Installation of SimpleFuel unit to support refueling and identify infrastructure R&D gaps
Importance of Data Collection and Analysis to Guide Maintenance by Known Equipment Type – Retail Station

Classical Reliability Engineering Curve Over Life of Equipment

Example from hydrogen infrastructure data collection, demonstrating challenges with dispenser, compressor, chiller, and gas management
Safety Incident Reports by Type

- Incident
- Near Miss
- Minor H2 Leak

Severity

Number of Reports

- Dispenser
- Dispensing Nozzle
- Hose
- Multiple Systems
- Not Defined
- Pipes, Fittings, Valves
- Sensors
- Thermal Management

An Incident is an event that results in:
- a lost time accident and/or injury to personnel
- damage/unplanned downtime for project equipment, facilities or property
- impact to the public or environment
- any hydrogen release that unintentionally ignites
- release of any volatile, hydrogen containing compound (including the hydrocarbons used as common fuels)

A Near Miss is:
- an event that under slightly different circumstances could have become an incident
- any hydrogen release sufficient to sustain a flame if ignited

A Minor H2 Leak is:
- an unplanned hydrogen release insufficient to sustain a flame, and does not accumulate in sufficient quantity to ignite

Contact:
techval@nrel.gov
-or-
fuelcells@ee.doe.gov
Significant number of ‘undetermined’
More root cause analysis required
Example of Insight on Hydrogen Components Safety

Pressure relief valve failure caused hydrogen release - led to safety concerns and evacuation

Type 440C Stainless Not Suitable For This Application
Cross-cutting Materials Compatibility R&D

H-Mat Consortium launched in FY18 to conduct early-stage R&D on hydrogen effects on polymers and metals.

Focus of current activities include:
1) Reduce expansion of seals in hydrogen by 50%
2) Enhance life of vessels by 50% through improved understanding of crack nucleation.
3) Enhance fracture toughness of high-strength (>950 MPa) steels by 50%.

For more information:
Website: energy.gov/eere/fuelcells/h-mat-hydrogen-materials-consortium
Email: h-matinfo@pnnl.gov
Example of Collaboration: Global Center for H₂ Safety (CHS)

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

www.aiche.org/CHS
Specific Areas of Input Requested

1) Center for Hydrogen Safety
   • Follow up planned through subcommittee

2) Plans/Roadmaps
   • Multiyear Program Plan under revision

3) Feedback on National Lab facility plans

4) 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 priorities
   • Prize concepts
   • Training and Workforce development
Multi-year Plan Will Include Applications Across Sectors

<table>
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<tr>
<th>Existing, growing demands</th>
<th>Chemicals and Industrial Applications</th>
<th>Power Generation and Energy Storage</th>
<th>Transportation Fuel</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Oil Refining</td>
<td>Back-Up Power and Distributed Generation (e.g. datacenters)</td>
<td>Material Handling/Forklifts</td>
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<td></td>
<td>Ammonia</td>
<td></td>
<td>Buses</td>
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<td></td>
<td>Methanol</td>
<td></td>
<td>LDVs</td>
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<tr>
<td>Emerging future demands</td>
<td>Steel</td>
<td>Hydrogen Blending</td>
<td>M/HDVs</td>
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<tr>
<td></td>
<td>Industrial Heat (e.g. cement)</td>
<td>Flexible Power Generation</td>
<td>Rail</td>
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<tr>
<td></td>
<td>Biofuels Upgrading</td>
<td>Seasonal Energy Storage</td>
<td>Maritime</td>
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<td></td>
<td>Synthetic Fuels</td>
<td></td>
<td>Aviation</td>
</tr>
<tr>
<td>Sector</td>
<td>Current Role of Hydrogen</td>
<td>Barriers</td>
<td>Opportunities/Benefits</td>
</tr>
<tr>
<td>------------------------</td>
<td>-----------------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Oil Refining</td>
<td>Used to remove impurities (e.g., sulfur) and upgrade heavy crude</td>
<td>Cost of diverse methods of hydrogen supply (e.g. beyond SMR)</td>
<td>Lowering point-source emissions</td>
</tr>
<tr>
<td>Chemicals</td>
<td>Essential feedstock in ammonia and methanol production, used in other smaller-scale processes</td>
<td>Cost of diverse methods of hydrogen supply (e.g. beyond SMR)</td>
<td>Innovative, scalable production technologies</td>
</tr>
<tr>
<td>Steel Production</td>
<td>Hydrogen-containing syngas used for iron refining</td>
<td>Cost of diverse methods of hydrogen supply (e.g. beyond SMR); Reliability and efficiency of existing processes that can use high concentrations of hydrogen</td>
<td>Innovative approaches to hydrogen use that enhance process efficiency; Domestic competitiveness; Emissions reduction</td>
</tr>
<tr>
<td>Industrial Heat</td>
<td>Limited to hydrogen-containing by-product gases used for process heat</td>
<td>Availability of cost-competitive hydrogen for heating; Availability of appliances that can operate on high concentrations of hydrogen</td>
<td>Reduce emissions from industrial processes; Use existing natural gas infrastructure for gigawatt-hours of energy storage</td>
</tr>
<tr>
<td>Synthetic Fuels</td>
<td>Fossil-based methods are well established (e.g., methanol synthesis)</td>
<td>Availability of low-cost hydrogen supply and cost-competitive, efficient production methods</td>
<td>High energy density applications (e.g. aviation); Potential as drop-in fuels leveraging existing infrastructure; Potential for emissions reductions</td>
</tr>
<tr>
<td>Sector</td>
<td>Current Role of Hydrogen</td>
<td>Barriers</td>
<td>Opportunities/Benefits</td>
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<tr>
<td>Back Up and Off Grid Power</td>
<td>Hydrogen primarily used in-situ (e.g., natural gas reforming for fuel cell back up power)</td>
<td>Footprint of storage infrastructure</td>
<td>Emissions reductions; resiliency</td>
</tr>
<tr>
<td></td>
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<td>Cost of hydrogen fuel</td>
<td></td>
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<tr>
<td>Hydrogen Blending</td>
<td>Up to 20% blending in ongoing tests and demonstrations in Europe</td>
<td>Availability of low-cost hydrogen supply; Higher percentage blends will require upgrades to infrastructure and end uses</td>
<td>Leverages existing natural gas infrastructure and/or turbines and appliances</td>
</tr>
<tr>
<td>(Flexible) Power Generation</td>
<td>&gt;200 MW of stationary fuel cell power shipped worldwide (though hydrogen typically produced in-situ)</td>
<td>Availability of low-cost hydrogen supply; Commercial availability of components that can be used to enable high percentages of hydrogen in combustion turbines</td>
<td>Supports higher penetrations of intermittent renewable energy on the grid by providing demand response and other grid services</td>
</tr>
<tr>
<td>Seasonal Energy Storage</td>
<td>Bulk storage technologies have been demonstrated in petrochemical buffering applications</td>
<td>Low round-trip efficiency</td>
<td>Supports higher penetrations of renewable energy on the grid</td>
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<td>Limited market for long-duration energy storage</td>
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</table>
### Challenges and Opportunities for Hydrogen as Transportation Fuel - Draft

<table>
<thead>
<tr>
<th>Sector</th>
<th>Current Role of Hydrogen</th>
<th>Barriers</th>
<th>Opportunities/Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material Handling Equipment</td>
<td>&gt;30,000 MHEs across the US</td>
<td>Investment in fueling infrastructure</td>
<td>Fast fill-time; Performance in warehouse environments (e.g., refrigerated conditions)</td>
</tr>
<tr>
<td>Buses &amp; M/HDV</td>
<td>&gt; 30 buses across the U.S.</td>
<td>High TCO relative to incumbent (diesel), due to cost of hydrogen fuel, cost of fuel cell stack, and cost of hydrogen storage onboard vehicle</td>
<td>Fast fill-times and long range</td>
</tr>
<tr>
<td>LDVs</td>
<td>Over 8,300 vehicles sold or leased; Over 40 retail stations in California</td>
<td>High TCO relative to incumbent, due to cost of hydrogen fuel, cost of fuel cell stack, and cost of hydrogen storage onboard vehicle</td>
<td>Range, energy density for advanced vehicles (e.g. ridesharing, autonomous capabilities)</td>
</tr>
<tr>
<td>Rail</td>
<td>Prototype demonstrations in Germany</td>
<td>Low-cost incumbent technology; Capital intensive</td>
<td>Clustering of demand with regional opportunities</td>
</tr>
<tr>
<td>Maritime</td>
<td>Ongoing demonstration projects for marine vessels and port-side equipment</td>
<td>Volumetric storage requirements on ocean-going vessels; high cost of hydrogen fuel compared to alternatives</td>
<td>Clustering of demand with regional opportunities; Regulatory requirement for desulfurization of marine fuels</td>
</tr>
<tr>
<td>Aviation</td>
<td>Prototypes under R&amp;D</td>
<td>Volumetric storage requirements on aircraft; high cost of hydrogen fuel compared to alternatives</td>
<td>Short flights, air taxis, drones</td>
</tr>
<tr>
<td>Sector</td>
<td>Approximate Range of Hydrogen Consumption Per Day Per Site/Facility</td>
<td>Hydrogen Supply Methods Possible</td>
<td></td>
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<td>-------------------------------------------------------------------</td>
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<tr>
<td>Established</td>
<td>Methanol 500-1,000 tonnes/day</td>
<td>On-site production, pipeline</td>
<td></td>
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<td></td>
<td>100-500 tonnes/day</td>
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<tr>
<td>Emerging</td>
<td>Biofuels 8 tonnes/day</td>
<td>On-site production</td>
<td></td>
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<td>Heavy-Duty Fueling 2-5+ tonnes/day</td>
<td>On-site production, pipeline, Liquid tanker</td>
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<td></td>
<td>Medium-Duty Fueling (e.g., bus depots) 1-5 tonnes/day</td>
<td>Liquid tanker, onsite production</td>
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<td>MHE Fueling at Warehouses 200 kg-1+ tonnes/day</td>
<td>Liquid tanker</td>
<td></td>
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<td></td>
<td>Light-Duty Fueling 180 kg-1+ tonne/day</td>
<td>Gaseous tube trailer, liquid tankers</td>
<td></td>
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</tbody>
</table>

[3] Based on ANL analysis of Chicago area
Hydrogen Supply by Sector – For Discussion

**Existing demands**

- Power Generation
- MHE/Forklifts
- Small Hydrogen Refueling Stations (<1,000 kg/day)
- Electronics
- Heat treating (e.g., metals annealing)

**Manufacturing** (e.g., float glass)

- Ammonia
- Methanol
- Oil Refining

**Potential future demands**

- Large Hydrogen Refueling Stations (L/M/HDVs)
- Aviation
- Maritime
- Rail
- Iron Refining
- Biofuels
- Synthetic Fuels
- Power Generation and Energy Storage

*Liquid delivery also employed for smaller consumers requiring high purity hydrogen (e.g., transportation applications)
†The use of hydrogen carriers depends more on distance (e.g., for international trade) than facility-level demand
Example: Fuel Cell Status vs Targets for LDV Case - to be completed for HDV and other applications - DOE updates underway

System Power Density
659 W/L | 850 W/L

Start from -20°C
< 30 s | < 30 s

Peak Energy Efficiency
60% | 70%

System Specific Power
640 W/kg
650 W/kg

System Cost
$50/kW
$30/kW

System Durability
4130 h | 8,000 h

2020 Status
Ultimate Target

Production Rate (systems/year)

Stack Cost (2016 USD)

Preliminary Waterfall Chart - updates underway

FC System Cost (2016$/kW_net) at 100,000 systems/year

Ultimate Target $30/kW
2030 Target $40/kW

2006 2010 2014 2018 Targets

Preliminary FC System Cost (2016$/kW_net)

2006 2010 2014 2018 Targets

Waterfall Chart - updates underway

1840 to 1,000 mW/cm² based on reduction in cell voltage from 0.769 to 0.74 vcell
2 Switch fans/Roots to Centrifugal Compressor with an Expander

$97
$6
$14
$13
$4
$60

$0
$20
$40
$60
$80
$100
$120
$140

2019 HDV System Cost at 100k sys/yr

Increase FC Power Density
Reduce Air Management System Cost
Reduce Pt Loading from 0.1 to 0.25 mg/cm²
Remove Excess Humidity

DSC Ultimate Target

U.S. DEPARTMENT OF ENERGY
OFFICE OF ENERGY EFFICIENCY & RENEWABLE ENERGY
FUEL CELL TECHNOLOGIES OFFICE
**ARIES Vision** (NREL, in collaboration with other labs and industry)

- Address the fundamental challenges of how to scale up the physical size of new energy technologies and the number of interconnected devices into larger systems.
- Determine how the integration of multiple diverse technologies into future energy systems can provide a range of benefits including improved efficiency, security, and resiliency, lower costs, and greater customer choice.

**Key Questions:**

1) What key benefits will this new capability provide to you and/or your organization?
2) What other R&D challenges should be addressed that will ensure success and impact for industry?
3) Are the capabilities described above relevant to stakeholders?
4) Is there an interest on the part of owners and operators of commercial or large-scale energy generation in partnering?
5) What other facilities, equipment, and capabilities may be required?
6) What technology innovations and advances can be envisioned with the availability of ARIES?
Student Internship Opportunities

Minority Educational Institution Student Partnership Program Internships (MEISPP)

- 8 – 10 week summer internships with DOE and national laboratories
- Helps students gain professional and technical career experience while working side-by-side with an assigned mentor
- Includes lodging, round trip airfare, and student stipends

EERE Student Volunteer Internship Program (SVIP)

- Internships throughout the year at its Washington, D.C. Headquarters (HQ) and the Golden Field Office (GFO) located in Golden, Colorado
- Academic credit and/or stipends for federal internships at some colleges and universities
- Does not include lodging, round trip airfare, and student stipends

For eligibility & instructions:

MEISPP
https://www.energy.gov/diversity/services/minority-education-and-community-development/minority-educational-institution-0

SVIP
https://www.energy.gov/eere/education/eere-student-volunteer-internship-program-svip
### Fellow roles in:
- Hydrogen storage (e.g. composite materials, carbon fiber)
- Hydrogen infrastructure R&D (e.g. materials compatibility)
- Hydrogen fuel R&D (e.g. hydrogen production)

### Areas:
- Engineering
- Chemistry, Materials
- Project Management
- Safety, codes, standards

### For More Info:
DOE Fuel Cell Technologies Office
fuelcells@ee.doe.gov

Oak Ridge Institute for Science and Education
https://orise.orau.gov/stem/internships-fellowships-research-opportunities/index.html

### Potential Career Opportunities in Hydrogen and Fuel Cells

<table>
<thead>
<tr>
<th>Opportunity Title</th>
<th>URL</th>
<th>Opportunity #</th>
<th>Org</th>
<th>Deadline</th>
</tr>
</thead>
</table>
### National Hydrogen & Fuel Cell Day
**October 8 or 10/8**

### Safety Information and Training Resources

#### H2tools.org

**INCREASE YOUR H2 IQ**

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

### Workshops enabling H2@scale

- **AMR**: May 19-21, Crystal City, VA
- **H2@Airports**: April 7-8, 2020 in Arlington, VA

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


### Learn more at:
[energy.gov/eere/fuelcells](energy.gov/eere/fuelcells)
Thank You
&
Additional Information

energy.gov/eere/fuelcells
## HTAC Recommendations Being Addressed

<table>
<thead>
<tr>
<th>Recommendations from 2019 HTAC Annual Report</th>
<th>Actions Taken (Examples)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enhance funding of systems modeling studies for H2@Scale to identify best opportunities for integration of hydrogen into the U.S. energy infrastructure for energy transmission, storage, and dispatch</td>
<td>Enhanced H2@Scale modeling and analysis activities, with plans to publish at least three reports including H2 supply and demand across sectors and H2 resource availability analysis. CRADA projects underway.</td>
</tr>
<tr>
<td>Conduct system analysis of future storage and vehicle cost to understand what infrastructure investments are warranted</td>
<td>Working through the U.S. DRIVE partnership to address the impact of advanced onboard hydrogen storage technologies and costs on future hydrogen infrastructure implementation.</td>
</tr>
<tr>
<td><strong>Continue to conduct R&amp;D programs to reduce the cost of fuel cells, hydrogen storage, and delivery, and improve durability for commercial applications</strong></td>
<td>FY 19 FOA selections provide more than $55 million to address H2@Scale. The FY 20 FOA announcement will provide up to $64 million for projects aimed at lowering electrolyzer costs, reducing cost of compressed hydrogen storage, lowering fuel cell manufacturing costs, and expanding hydrogen and fuel cell markets. FCTO continues to support national laboratory-industry R&amp;D projects through R&amp;D consortia (HydroGEN, HyMARC, ElectroCAT, and H-Mat) and CRADA calls.</td>
</tr>
</tbody>
</table>
## HTAC Recommendations Being Addressed

<table>
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<tr>
<th>Recommendations from 2019 HTAC Annual Report</th>
<th>Actions Taken (Examples)</th>
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<tbody>
<tr>
<td>Increase emphasis on development and demonstration of solutions for heavy duty transit, marine, and aviation applications that are not readily served by battery electric systems</td>
<td>FY 2019 and 2020 FOAs included topics specific to medium- and heavy-duty trucks and maritime and data center applications (more than $18 million awarded in FY 2019 to projects specifically targeting truck applications). Published R&amp;D targets for Class 8 trucks in December 2019.</td>
</tr>
<tr>
<td>Continue support for standardization of codes and best practices for safety system design and approvals.</td>
<td>FCTO continues to support standardization of codes and standards as well as global harmonization, including stable funding of approximately $7 million per year to conduct R&amp;D and provide national laboratory expertise to inform the development of consistent global standards and best practices. FY 2020 appropriations includes $10 million for safety, codes, and standards. International harmonization activities also underway through IPHE Working Group.</td>
</tr>
</tbody>
</table>
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
### FY 2020 Congressional Language

<table>
<thead>
<tr>
<th>HOUSE</th>
<th>SENATE</th>
<th>CONFERENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within available funds, the Committee recommends <strong>$35,000,000</strong> for Technology Acceleration activities, of which $5,000,000 is for industry-led manufacturing.</td>
<td>The Committee recommends <strong>$35,000,000</strong> for Technology Acceleration activities, including <strong>$3,000,000</strong> for manufacturing research and development, and <strong>$7,000,000</strong> for industry-led efforts to demonstrate a hydrogen-focused integrated renewable energy production, storage, transportation fuel distribution/retailing system, and fuel cell system deployment.</td>
<td>[House and Senate language stands]</td>
</tr>
<tr>
<td>The Committee recognizes the progress in breakthrough research and cost reduction for stationary, vehicle, motive, and portable power applications of fuel cell and hydrogen energy technology.</td>
<td>Funding is included to support fuel cell and hydrogen technical and workforce development and training programs.</td>
<td>Within Technology Acceleration funds, $5,000,000 is for industry-led manufacturing. [Senate language stands]</td>
</tr>
<tr>
<td>The Committee recommends not less than <strong>$7,000,000</strong> for safety, codes, and standards.</td>
<td>The Committee further recommends <strong>$10,000,000</strong> for Safety, Codes, and Standards to maintain a robust program and engage State and local regulatory and code officials to support their technical needs relative to infrastructure and vehicle safety. The Department is encouraged to engage on codes and standards for developing fuel cell and hydrogen markets such as heavy-duty trucks. The Department is also encouraged to continue coordination between U.S. and international standard bodies to ensure there is one set of open [non-proprietary] global standards for fuel cell and hydrogen technologies.</td>
<td>[Senate language stands, though ‘encourage’ is not considered directive language]</td>
</tr>
<tr>
<td>[Senate language stands]</td>
<td>The agreement provides <strong>$10,000,000</strong> for safety, codes, and standards.</td>
<td>[Senate language stands, though ‘encourage’ is not considered directive language]</td>
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</table>
**FY 2020 Congressional Language**

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</thead>
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<tr>
<td>Within available funds, $10,000,000 to cost share the Office of Nuclear Energy hydrogen demonstration project.</td>
<td>Within the amounts recommended, the Committee recommends <strong>$49,000,000</strong> for Hydrogen Fuel Research and Development 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.</td>
<td>The agreement provides <strong>$45,000,000</strong> for Hydrogen Fuel Research and Development.</td>
</tr>
<tr>
<td>Within available funds, $7,000,000 to enable integrated energy systems using high and low temperature electrolyzers with the intent of advancing the H2@Scale concept.</td>
<td>The Department shall continue to research novel onboard hydrogen tank systems, as well as trailer delivery systems to reduce cost of delivered hydrogen. Further, the Department is directed to support research and development activities that reduce the use of platinum group metals, provide improvements in electrodes and membranes and balance-of-plant components and systems.</td>
<td>Within available funds, the agreement provides $7,000,000 to enable integrated energy systems using high- and low-temperature electrolyzers with the intent of advancing the H2@Scale concept and $10,000,000 to cost share the Office of Nuclear Energy hydrogen demonstration project.</td>
</tr>
<tr>
<td>The Committee remains supportive of H2@Scale activities that enable wide-scale hydrogen production and use in the United States to enable resiliency of power generation and transmission.</td>
<td>[Senate language stands]</td>
<td>[Senate language stands]</td>
</tr>
<tr>
<td>The Committee encourages the Department to continue its work on high temperature electrolysis coupled with thermal systems.</td>
<td>[House language stands, language is not considered directive language]</td>
<td>[House language stands, language is not considered directive language]</td>
</tr>
</tbody>
</table>
The Committee directs the Vehicle, Bioenergy, and Hydrogen and Fuel Cell Technologies offices to continue to work closely to develop common metrics to evaluate and compare the costs and energy consumption of advanced transportation technologies with existing technologies.

The Committee encourages regular consultation with industry to avoid duplication of private-sector activities and ensure retention of fuel cell technology and systems development in the United States.

The Committee recommends $3,000,000 for Systems Analysis, including research on in-situ metrology for process control systems for manufacturing of key hydrogen system components.

Within the amounts recommended, $26,000,000 is recommended for Hydrogen Infrastructure Research and Development with emphasis on large-scale hydrogen production, including liquefaction plants, hydrogen storage, and development of hydrogen, including pipelines.

Further, the Department 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.

The Committee encourages the Secretary to work with the Secretary of Transportation and industry on coordinating efforts to deploy hydrogen fueling infrastructure.

The agreement provides $25,000,000 for Hydrogen Infrastructure R&D.
In FY 2021, the Hydrogen and Fuel Cell Program will support early stage R&D on novel hydrogen and fuel cell technologies to achieve application specific goals. For example: Medium and Heavy-Duty truck applications ultimate targets are:

- 30,000 hours fuel cell durability
- $60/kW for fuel cell cost
- $8/kW for onboard hydrogen storage costs

The program will continue to focus on the H2@Scale concept to enable affordable, reliable hydrogen generation, transport, storage and utilization across sectors with increased focus beyond light duty vehicles emphasizing diverse end uses including energy storage, transportation (trucks, marine, rail, aviation), chemicals (ammonia, synthetic fuels), backup power (emergency power, data centers), and industry (steel, iron making).

<table>
<thead>
<tr>
<th>Subprogram</th>
<th>FY 2020 Enacted ($K)</th>
<th>FY 2021 Request ($K)</th>
<th>FY 2021 vs. FY 2020 ($K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Cell Technologies (Formerly Fuel Cell R&amp;D)</td>
<td>26,000</td>
<td>8,000</td>
<td>-18,000</td>
</tr>
<tr>
<td>Hydrogen Technologies (Formerly Hydrogen Fuel R&amp;D in FY20)</td>
<td>45,000</td>
<td>23,000</td>
<td>-22,000</td>
</tr>
<tr>
<td>Hydrogen Infrastructure R&amp;D (Included in Hydrogen Technologies in FY21)</td>
<td>25,000</td>
<td>0</td>
<td>-25,000</td>
</tr>
<tr>
<td>Systems Development and Integration (Formerly Technology Acceleration in FY20)</td>
<td>41,000</td>
<td>10,000</td>
<td>-31,000</td>
</tr>
<tr>
<td>Safety, Codes and Standards (Included in Systems Development and Integration in FY21)</td>
<td>10,000</td>
<td>0</td>
<td>-10,000</td>
</tr>
<tr>
<td>Data, Modeling and Analysis (Formerly Systems Analysis in FY20)</td>
<td>3,000</td>
<td>1,000</td>
<td>-2,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>150,000</strong></td>
<td><strong>42,000</strong></td>
<td><strong>-108,000</strong></td>
</tr>
</tbody>
</table>
Fuel Cell Technologies Office Org Chart

Director
Sunita Satyapal

Operations
Priya Swamy (BTO)
Vacant

Administrative Support
Karen Dandridge

Ops & Systems Analysis
Shawna McQueen
Vacant (Ops Manager)

Senior Advisor
Eric Miller

Hydrogen Technologies Program Manager
Ned Stetson

Technology Managers
Vacant
Zeric Hulvey
Jesse Adams* (GO)
Katie Rudolph* (SO)
Neha Rustagi*

Fuel Cell Technologies Program Manager
Dimitrios Papageorgopoulos

Technology Managers
William Gibbons
Donna Ho
Greg Klein (GO)
Dave Peterson* (GO)

Technology Acceleration
Vacant
Acting: Dimitrios Papageorgopoulos

Systems Development & Integration
Technology Managers
Pete Devlin
Nancy Garland*
Jason Morcinkoski*
Michael Hahn (GO)
Brian Hunter (GO)

Safety, Codes & Standards
Technology Managers
Laura Hill

* Supports multiple Program areas

Contract staff
Golden Field Office staff
Detailees into FCTO
Detailees out of FCTO