U.S. DEPARTMENT OF
ENERGY

Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY

Infrastructure and Systems R&D and Safety Codes & Standards Overview

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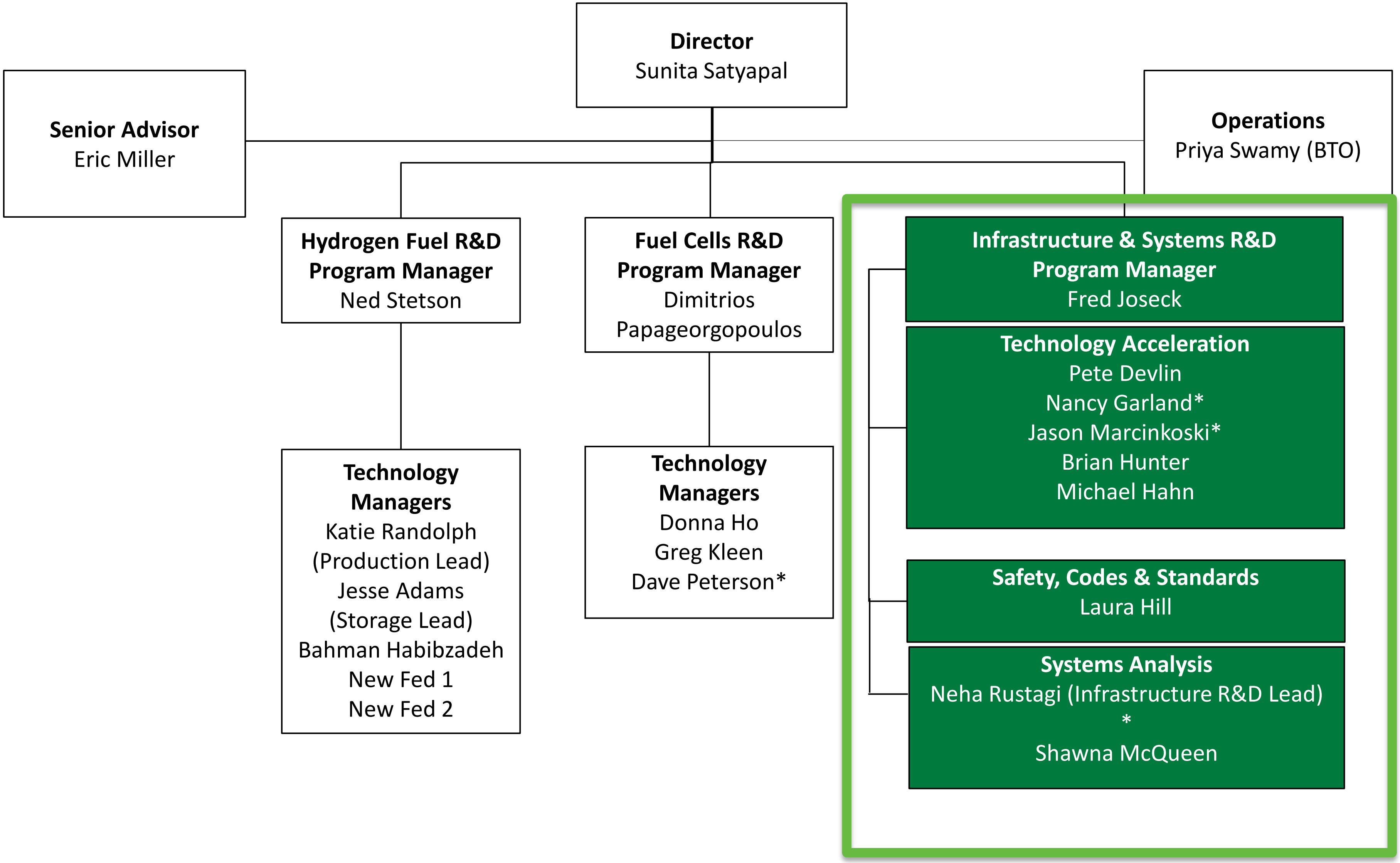
Infrastructure and Systems R&D Program Manager

Fuel Cell Technologies Office

2019 Annual Merit Review and Peer Evaluation Meeting

April 29, 2019 – Washington, DC


What's New in FY 2019: Organization



* Supports multiple Program areas

New Structure

Transformation of Infrastructure and Systems R&D and Safety, Codes & Standards from FY18 to FY19

INTERIM FY18
- TECHNOLOGY ACCELERATION R&D
- Manufacturing R&D
- Safety, Codes & Standards R&D
- Systems Analysis

FY19
- INFRASTRUCTURE R&D

FY19
- Systems R&D
- Systems Analysis
- Technology Acceleration

Safety, Codes & Standards

Infrastructure and Systems R&D Priorities

R&D Focus Areas

Hydrogen Transport

- Low-cost, high-efficiency **liquefaction, pipelines, chemical carriers, and tube trailers**

Refueling Station

- Low-cost and reliable **compressors, pumps, dispensers, and stationary storage**

+more
Integration with Energy Technologies

- **Grid integration of hydrogen production** and novel methods of manufacturing and improvements in durability

Cross-cutting analysis

- Overarching systems analysis to **inform R&D priorities** and determine impact

Goal

Less than $7/kg hydrogen fuel in early markets, including production, distribution, and dispensing

Early-Stage R&D to reduce cost of hydrogen storage, use and transport **to enable H2@Scale**

H2@Scale SM
U.S. Department of Energy

Safety, Codes & Standards (SCS) Goals & Objectives

Mission: Fund R&D needed to develop science-based codes and standards, thereby enabling the safe deployment of H_2 and fuel cell technologies

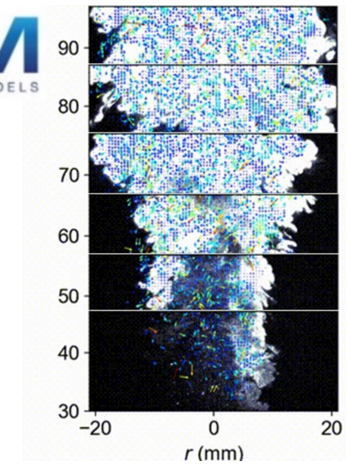
Codes & Standards

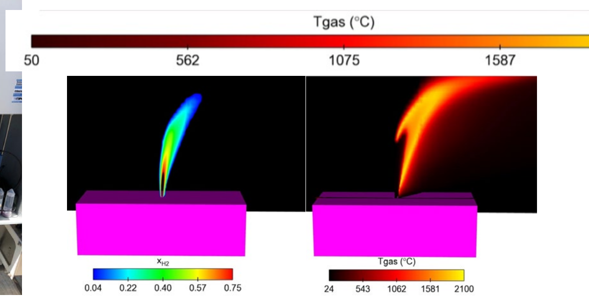
- Conduct **R&D to provide critical data** and information needed to define requirements in developing codes and standards.
- Support and facilitate development of **essential codes and standards** to **enable widespread deployment** of hydrogen and fuel cell technologies and completion of essential regulations, codes and standards (RCS).

Safety

- Ensure that **best safety practices** underlie activities supported through DOE-funded projects.
- Enable **widespread sharing** of **safety-related information resources** and lessons learned with key stakeholders.

HyRAM HYDROGEN RISK ASSESSMENT MODELS





Partnership with: CENTER FOR Hydrogen SAFETY

An AIChE Technical Community • A Global Resource On Hydrogen Safety

FY18-19 Budget

(Dollars in Thousands)		
Subprogram Distribution	FY 2018	FY19 Enacted
Total Appropriation/Requested Funding	115,000	120,000
Fuel Cell R&D	32,000	30,000
Hydrogen Fuel R&D	54,000	39,000
Infrastructure R&D	0	**21,000**
Technology Acceleration R&D	19,000	**21,000**
Systems Analysis	3,000	**2,000**
Safety, Codes and Standards (SCS)	7,000	**7,000**

$ 21M
FY19 Enacted

Infrastructure R&D Key Focus Areas

Examples:

- Refueling station R&D
- Innovative energy carriers R&D
- Materials compatibility R&D
- Integration with energy technologies R&D

$ 21M
FY19 Enacted

Tech Acceleration R&D Key Focus Areas

Examples:

- Grid integration & energy generation
- Medium/heavy-duty vehicle fueling
- New applications for hydrogen (e.g., rail & marine sectors)

Infrastructure and Systems R&D

and

Safety, Codes & Standards

Accomplishments

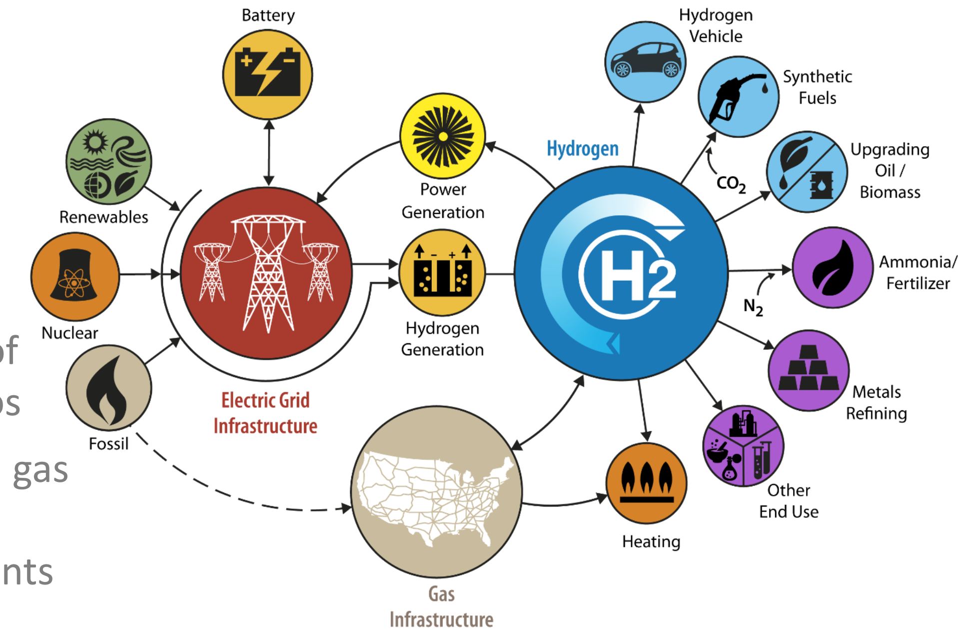
H2@Scale Analysis

Initial Step ✓ (Complete)

- Identify potential demand
- Examine supply resources
- Identify impact potential
- Identify infrastructure issues

In-Depth Analysis ✓

- Evaluated economic potential of hydrogen demand in 5 scenarios
  - Scenarios considered natural gas price, electricity price, grid integration, R&D advancements
- Performed stage-gate review



Regional & Economic Scenario Analysis (FY19)

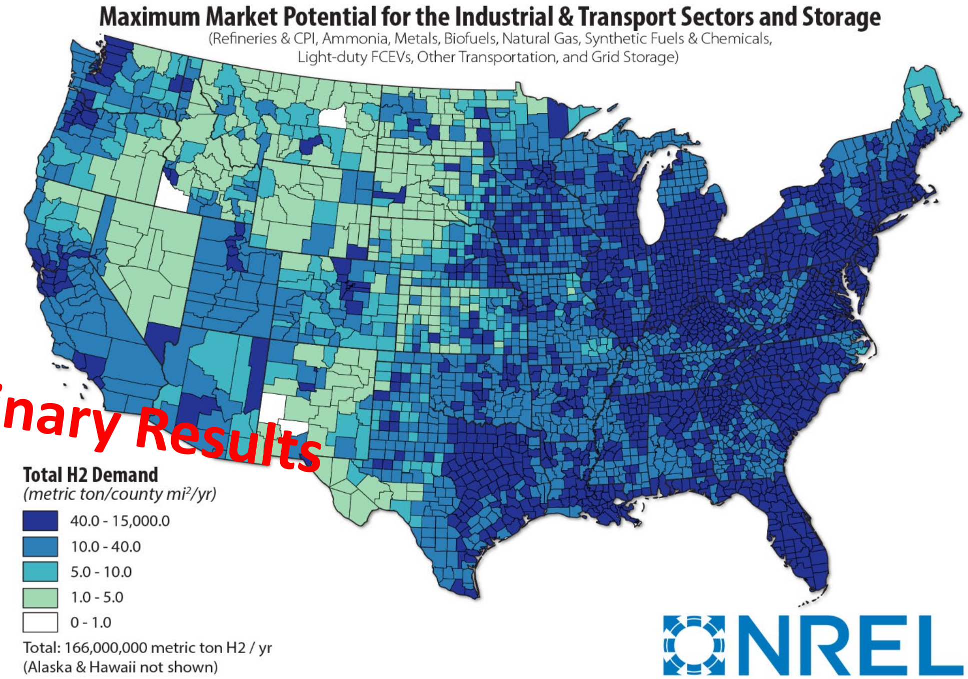
- Evaluating regional scenarios
- Examined economic inertia and externalities
- Performing spatial analysis

NREL National Renewable Energy Laboratory · Argonne National Laboratory · INL Idaho National Laboratory · Berkeley Lab · Lawrence Livermore National Laboratory · Pacific Northwest National Laboratory

H2@Scale Analysis: Estimated Maximum Scale for Hydrogen

Application	Maximum Scale (MMT* H_2 / year)
Refineries & CPI§	8
Metals	12
Ammonia	4
Synthetic Fuels and Chemicals	14
Biofuels	4
Natural Gas Supplementation	10
Light Duty (FCEVs)	57
Other Transport (Medium- & Heavy- Duty Fuel Cell Veh.)	29
Electricity Storage	28
Total	**166**

Maximum growth potential of hydrogen by 2050 is 16X.



Economic potential for hydrogen is estimated to be 15-50 MMT/yr in 2050

* MMT: Million metric tonnes

§ CPI: Chemical Processing Industry not including metals, ammonia, methanol, or biofuels

Light duty vehicle calculation basis: 190,000,000 light-duty FCEVs from http://www.nap.edu/catalog/18264/transitions-to-alternative-vehicles-and-fuels

Definition: The maximum scale is the estimated hydrogen demand constrained by the services for which society currently uses energy, real-world geography, and system performance, but not by economics.

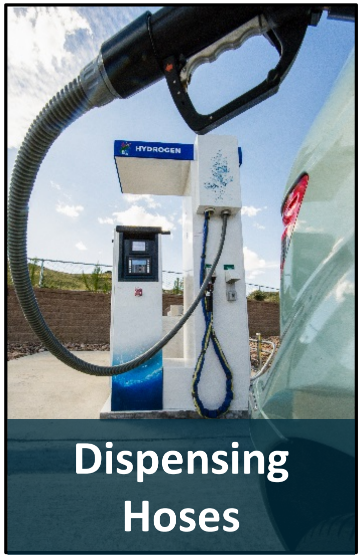
Infrastructure R&D Accomplishment: Launched R&D Consortium on Materials Compatibility

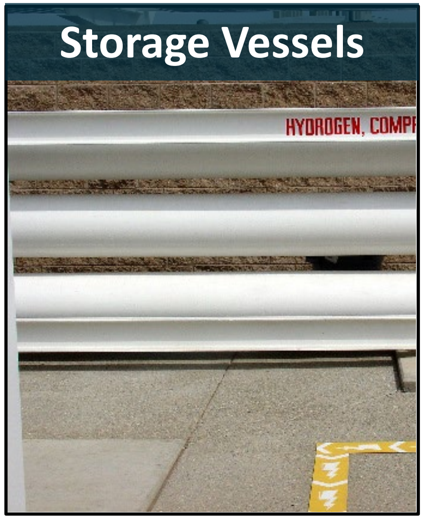
IN001

H-Mat Hydrogen Materials Compatibility Consortium SM

H-Mat R&D focuses on hydrogen effects on polymers and metals

(Joint effort between Infrastructure; Safety, Codes, & Standards; Hydrogen Fuel)





Focuses of current activities include:

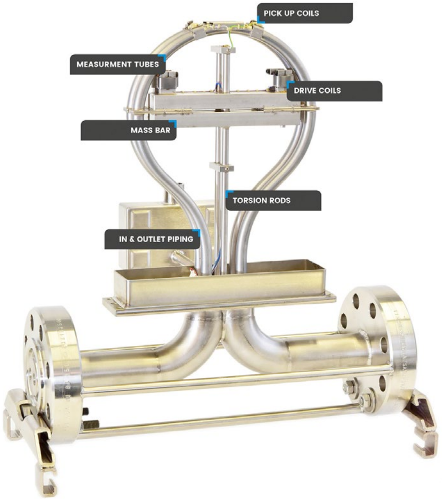
1) Reducing expansion of seals in hydrogen by 50%.
2) Enhancing life of vessels by 50% through improved understanding of crack nucleation.
3) Enhancing fracture toughness of high-strength (>950 MPa) steels by 50%.

For more information, please visit https://www.energy.gov/eere/fuelcells/h-mat-hydrogen-materials-consortium or contact h-matinfo@pnnl.gov

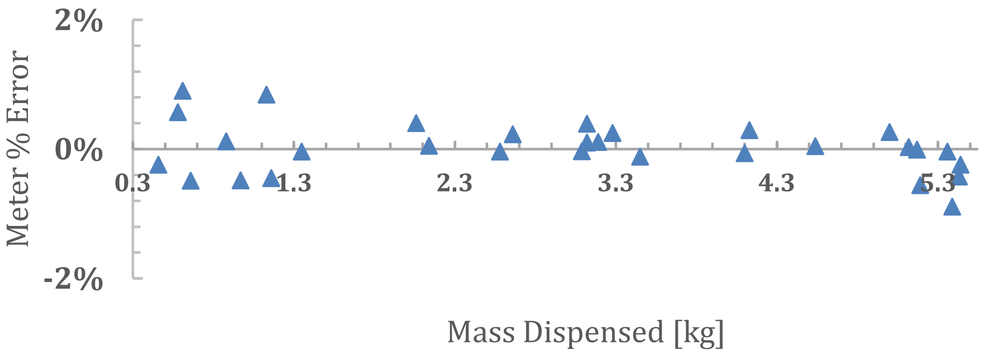
IN009

Dispenser Accuracy and Reliability

(IVYS Energy Solutions, Inc.; Rheonik GmBH, NREL)



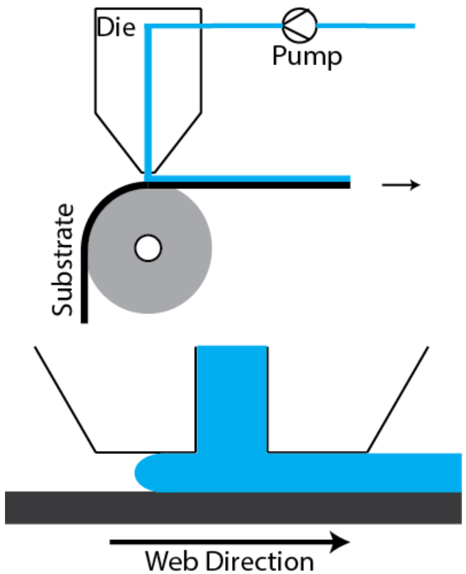
- Utilized Dedicated Short-Range Communication (DSRC) technology to enable **wireless communication** per SAE J2799 protocol.
- Developed Coriolis flow meters that achieve **2% accuracy** during SAE J2601 fills.



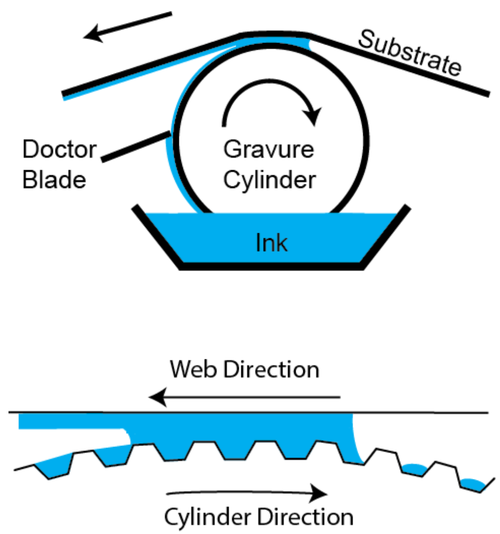
Technology Acceleration R&D Accomplishment: Comparison of MEA Fabrication Methods

TA008

Large-Scale Electrode Production: Roll-to-Roll

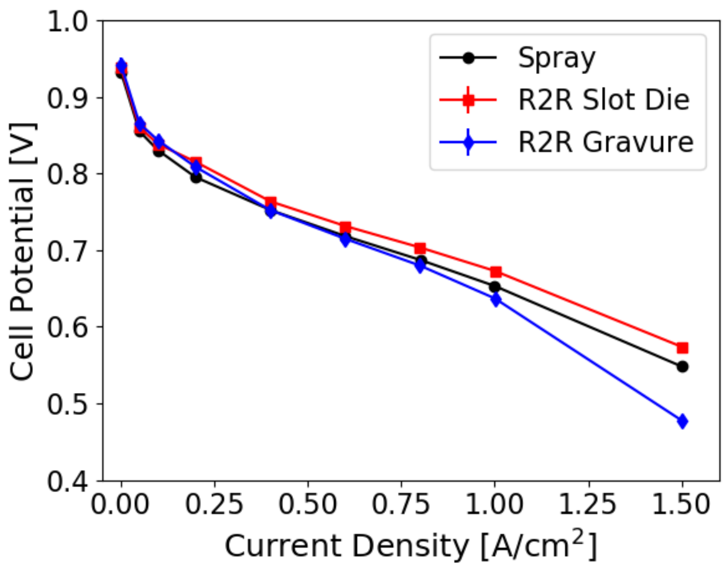


Slot Die Coating



Gravure Coating

Fuel Cell Performance



Slot Die vs. Gravure vs. Spray

R2R coated gas-diffusion electrode methods are >200x faster than spray coating and the MEAs perform as well.

Technology Acceleration R&D Accomplishment: High-Temperature Electrolysis Test Facility

TA018

Developed capability to simulate grid conditions (e.g. perturbations in frequency and voltage) to test response of high-temperature electrolyzers (HTE)

- Demonstrating HTE module **response rates** to support grid stability
- Conducting HTE stack degradation test with real-time measurement of stack performance
- Characterizing HTE **performance under dynamic grid conditions**

25 kW HTE Test Facility within the INL Energy Systems Laboratory

Technology Acceleration R&D Accomplishment: Demonstration of Fuel Cells for Medium-Duty Trucks

Fuel Cell Delivery Truck R&D
(FedEx Express, Plug Power, Workhorse)

Developed fuel cell hybrid electric parcel delivery van to extend battery-electric vehicle range **from 60 miles to >150 miles**.

First unit truck validation completed in Albany, NY

- **Fuel cell availability greater than 98%**
- **Over 15,000 miles logged**

TA011

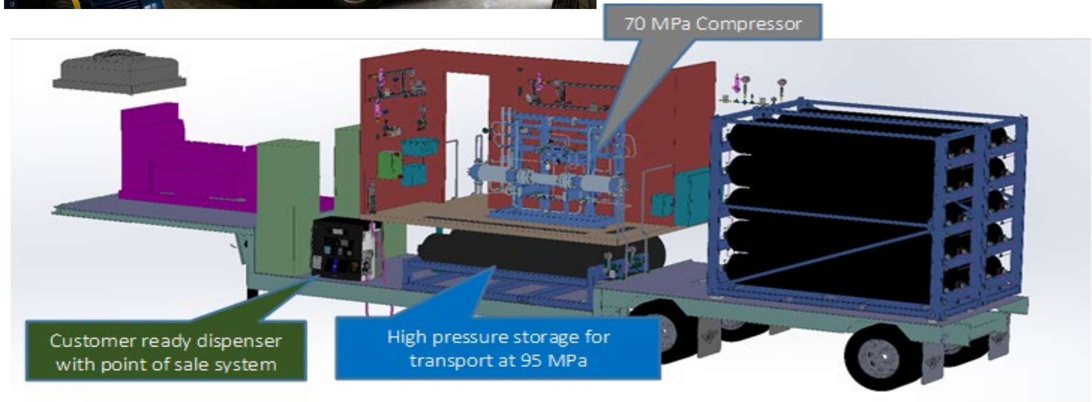
Fuel Cell Delivery Truck R&D
(CTE, UPS, CEM, UES, LiithiumWerks, Hydrogenics)

Developed fuel cell hybrid electric parcel delivery van to extend battery-electric vehicle range **from 75 to >125 miles**.

Completed first unit vehicle acceptance testing and began initial route operations.

TA016

Technology Acceleration R&D Accomplishment: Demonstration of Mobile Fueling and Auxiliary Equipment



Innovative Advanced Hydrogen Mobile Fueler
(Electricore, Air Liquide, HTEC, QAI, Manta)

Designed and developed advanced hydrogen mobile fueler (AHMF) capable of fueling approximately 20-40 fuel cell vehicles per day up to 70 MPa with -40 C cooling.

Design of AHMF is complete and assembly is currently underway.

TA017

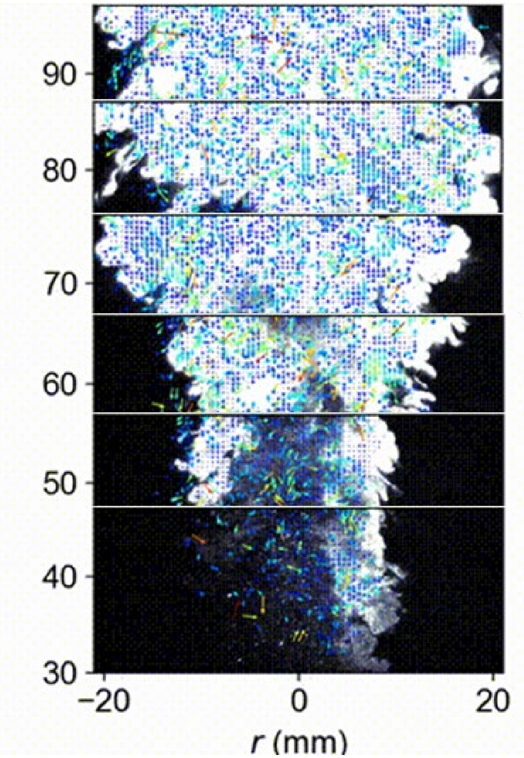
Fuel Cell Ground Support Equipment
(Plug Power, FedEx, Charlatte)

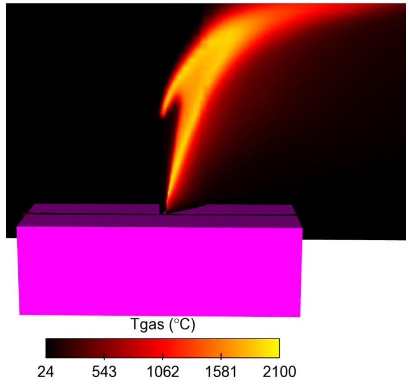
Developed and demonstrated fuel cell powered ground support equipment.

Two tuggers operating at Albany airport.

Hydrogen Safety is a Priority

Analysis & Validation	Measured scaling of flame length and heat flux at cryogenic temps and demonstrated means of large-scale release diagnostic
Risk Assessment	Expanded HyRAM flexibility in version 2.0 through updated methodology and open source availability
Sensors and Detectors	Developed preliminary guidance for indoor sensor placement; demonstrated detection of <1 ppm CO in field testing
Enabling Infrastructure	Performed R&D to support another 50% reduction in bulk gaseous H_2 storage requirements in the 2020 edition of NFPA 2
Partnership	Partnered with AIChE's Center for Hydrogen Safety to promote safe operation, handling, and use of H_2





SCS Accomplishment: Center for Hydrogen Safety

SCS019

PNNL and AIChE Partner to Establish the Center for Hydrogen Safety

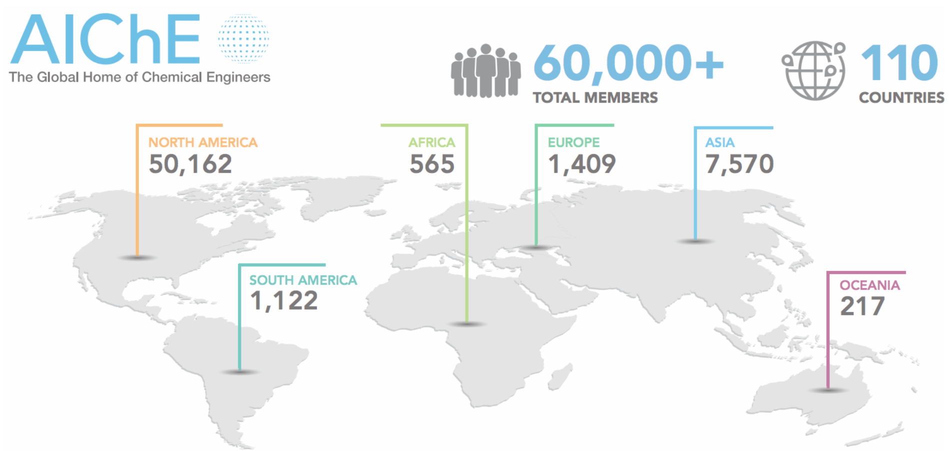
The CHS is a not-for-profit, global, membership organization within the American Institute of Chemical Engineers (AIChE) that promotes the safe operation, handling, and use of hydrogen and hydrogen systems across all installations and applications. The CHS identifies and addresses concerns regarding the safe use of hydrogen.

CENTER FOR Hydrogen SAFETY

An AIChE Technical Community • A Global Resource On Hydrogen Safety

Membership Benefits Include…

- Access to the U.S. Hydrogen Safety Panel (HSP) for reviews and support
- Education (continuing education units [CEUs]), training, and outreach materials
- Provide leadership and facilitation of hydrogen safety issues
- Conferences and networking opportunities



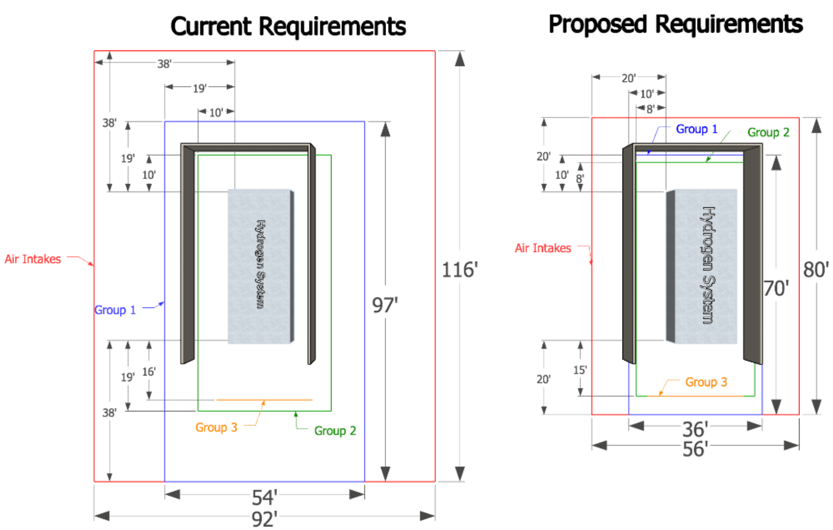
www.aiche.org/chs

SCS Accomplishment: Enabling Reduced Setback Distances

Pending changes to the NFPA 2 Hydrogen Technologies Code (2020 Edition) will result in further reduction in setback distances of up to 50% for gaseous hydrogen storage systems.

- **Risk-informed analysis** enabled an initial 50% reduction in bulk gaseous storage setback distances from 2005 to 2011*
- Further SCS efforts have enabled **new gaseous hydrogen setback distances** in the 2020 Edition of the NFPA 2 Hydrogen Technologies Code
- A newly completed rigorous analysis characterized footprint of conventional and potential future fueling station designs and identified technologies that can **enable up to 20% reduction in footprint area**

	NFPA 55 (2005)	NFPA 2 (2011, 2016)	NFPA 2 (2020)
	GH2 - ft (m)	GH2 - ft (m)	GH2 - ft (m)
Group 1 Exposures (lot lines, air intakes, openings, ignition sources)	50 (15)	34 (10)	16 (5)
Group 2 Exposures (exposed persons, parked cars)	15 (4.6)	16 (5)	13 (4)
Group 3 Exposures (buildings, flammable gas storage, combustibles, etc.)	15 (4.6)	14 (4)	13 (4)



Example gaseous storage footprint under the 2016 edition (left) and 2020 edition (right) of NFPA 2

*DOE Hydrogen and Fuel Cells Program Record #15006

Collaborations

Memorandum of Understanding (MOU)

ARMY GROUND VEHICLE SYSTEMS CENTER
H_2 infrastructure joint workshop
Cryo-compression research at ANL
Emergency relief truck research

DEPARTMENT OF TRANSPORTATION FEDERAL RAILROAD ADMINISTRATION
Fuel cell rail joint workshop
TCO analysis for rail applications

MARITIME ADMINISTRATION
Pier side power project siting
(Scripps Institute)

MICHIGAN ECONOMIC DEVELOPMENT CORPORATION
Infrastructure roadmap

Small Business Innovation Research Program (SBIR) & Funding Opportunity Announcements (FOAs)

DEPARTMENT OF ENERGY

OFFICE OF SCIENCE
SBIR Projects on fueling station technologies (e.g. dispensers, compressors, storage, contaminant detectors)
EPSCOR FOA on Materials Compatibility

OFFICES OF WIND ENERGY, SOLAR ENERGY, GEOTHERMAL ENERGY, NUCLEAR ENERGY, FOSSIL ENERGY, & ADVANCED MANUFACTURING
H2@Scale FOA - Integrated production, storage, and fueling system pilot

Cross-Cutting Work

CYBERSECURITY WORKING GROUP

U.S. DRIVE TECH TEAMS

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Thank You

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hydrogenandfuelcells.energy.gov

Panel Discussion

Potential Questions for Panel Discussion

1. What are some key changes in the program in FY19? **(Neha-Infras., Michael-TA, Laura-SCS, Fred-SA)**
2. Given the emerging interest in medium and heavy duty vehicles, can you explain your activities in this space? **(Brian)**
3. With the interest in fuel cells for these new transportation applications, how are you engaging and coordinating with stakeholders in industry, various government agencies, and international agencies? **(Pete)**
4. How are you increasing participation of the manufacturing industry as suppliers to the fuel cell industry. **(Nancy)**
5. Can you explain how you are broadening coordination with external stakeholders in other areas important to H2@Scale, such as utilities? **(Neha & Fred)**