Technology Acceleration Overview

Jesse Adams, HFTO - Technology Acceleration Program Manager
2021 Annual Merit Review and Peer Evaluation Meeting

June 7, 2021
Technology Acceleration Subprogram Overview

Technology Acceleration

Demonstrate Hydrogen Systems

Inform and Guide R&D and Analysis

End Uses

CHEMICALS & INDUSTRIAL PROCESSES
INTEGRATED CLEAN ENERGY SYSTEMS
TRANSPORTATION

Technology Validation

System Development & Integration

Commercial Readiness Assessment

Systems Analysis

IDENTIFY NEW MARKET OPPORTUNITIES

R&D

HYDROGEN TECHNOLOGIES
FUEL CELL TECHNOLOGIES

Enabling Activities

MANUFACTURING
SAFETY, CODES & STANDARDS
WORKFORCE DEVELOPMENT

U.S. DEPARTMENT OF ENERGY
OFFICE OF ENERGY EFFICIENCY & RENEWABLE ENERGY
HYDROGEN AND FUEL CELL TECHNOLOGIES OFFICE
Evolution of Technology Acceleration Subprogram & Priorities

Current Focus Areas

- **Integrated clean energy systems** including hybrid approaches and energy storage
- **Chemical and industrial processes** integrating H₂ technologies focusing on decarbonization
- **Transportation** and H₂ fueling demonstrations
- **Enabling activities** including manufacturing, safety codes & standards, and workforce development

Demonstrations of H₂ and fuel cell end uses that accelerate technology and reduce GHG emissions to enable H₂@Scale vision
Hydrogen Safety: An Overarching Priority

Enabling the safe deployment of hydrogen and fuel cell technologies

Codes & Standards

- **Goal**: 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
- **Approach**: Conduct RD&D to provide scientific basis needed to define requirements in developing codes and standards

Safety

- **Goal**: Support best safety practices for hydrogen and fuel cell deployments and ensure their use in DOE-funded projects
- **Approach**: Develop and enable widespread sharing of safety-related information resources and lessons learned with key stakeholders
Technology Acceleration Funding

FY21 budget supports focus on demonstration of novel H₂ end uses to enable H₂@Scale vision

Program Direction

- Decarbonize Ammonia / Steel
- Integration with Nuclear & Renewables
- Offshore Wind to Hydrogen
- SuperTruck III
- Safety, Codes & Standards
- Manufacturing

Note: $8M in FY20 funding for HySteel projects now managed under TA - Chemical & Industrial Processes
Technology Acceleration: Integrated Clean Energy Systems

- Conventional Storage
- Power Generation
- Transportation
- Synthetic Fuels
- Upgrading Oil / Biomass
- Ammonia / Fertilizer
- Metals Production
- Chemical/Industrial Processes
- Hydrogen
- Nuclear
- Fossil with CCUS
- Renewables
- Water
- Waste
- Electric Grid Infrastructure
- Gas Infrastructure
- Heat/Distributed Power
Demonstration of H2@Scale: Different Regions, Hydrogen Sources & End Uses

Frontier Energy – H2@Scale Demo in TX (TA037)

**Goals:**
- Minimize H₂ cost through multiple generation sources
- Co-locate H₂ end uses (stationary power & vehicle fueling)
- 5-year Plan for Port of Houston focused on H₂

**Key Accomplishments:**
- Site plans completed and undergoing final engineering
- Collected 1 year of load data from U. Texas Advanced Computing Center - modeled with H₂ and FC power
- Preliminary Port of Houston model with supply & demand hubs

Plug Power - Integrated H₂ Production & Consumption for Improved Utility Function in FL (TA030)

**Goals:**
- Develop grid-integrated H₂ assets to allow renewable penetration
- Develop H₂ end uses (stationary & vehicle fueling)

**Key Accomplishments:**
- Sizing of the storage system to meet H₂ delivery demands, including vehicular and stationary FC applications
- Site design, dynamic power simulations, & TEA underway
Technology Acceleration: Integrated Clean Energy Systems

Integration of Baseload Nuclear Energy with H₂ Production

Exelon – Demo of Electrolyzer Operation at a Nuclear Plant (TA028)

Goals:
- Install 1.2MW PEM electrolyzer at a nuclear power plant
- Provide low-cost supply of in-house H₂ used for cooling
- Simulate scaled-up operation of a larger electrolyzer in nuclear power markets

Key Accomplishments:
- Nine Mile Point (NY) selected as site
- Initial engineering design underway
- Completed acceptance testing of Nel electrolyzer – over 500 hours & degradation <0.1% (NREL)
- Conducted initial market demand for various sites (ANL)

FuelCell Energy – Solid Oxide Electrolysis System Demonstration (poster-TA039)

Goals:
- Integrate high temperature 250kW solid oxide electrolyzer (SOEC) with nuclear plant emulator
- Validate high efficiency & low-cost H₂ production from SOEC using electricity & waste heat from nuclear plant
- Increase operating flexibility & profitability by switching between power & H₂ generation

Key Accomplishments:
New project just underway
Technology Acceleration: Integrated Clean Energy Systems

High Temperature Electrolyzer Development and Testing

**INL - High Temperature Electrolysis Test Stand (TA018)**

*50kW test stand integrated w/nuclear power plant emulator*

**Goals:**
- Accelerate U.S. Solid Oxide Electrolyzer Competitiveness
- Independently validate stack performance
- Provide nuclear simulated integration/testing

**Key Accomplishments:**
- Validating commercial stack performance from Bloom, Nexceris, OxEon, FuelCell Energy, Haldor Topsoe (2 tested, 3 lined up)
- >4,000 hours testing on 25 kW stack; <0.5% degradation/1,000 hrs
- Great integration across EERE (H2NEW, HydroGEN), Fossil & Nuclear Energy Offices

**PNNL - Electrolyzer Stack Development & Manufacturing (TA043)**

*Goal:*
Work w/ industry to solve cost & degradation issues through MEA development, modeling, post-mortem analysis, AST development & manufacturing

**Key Accomplishments:**
- Developed process to produce 300 cm² SOEC cells
- Established stack repeat unit fabrication process
- Applied protective coating to metal interconnects to prevent corrosion and CR poisoning
**Technology Acceleration: Integrated Clean Energy Systems**

**Enabling & Demonstrating Integrated Hydrogen Energy Systems**


**Goals:**
- Integrate 1.25MW PEM electrolyzer, 600 kg H₂ storage & 1MW fuel cell
- Provide platform for RD&D in grid integration, energy storage, NG blending & scaling H₂ systems

**Key Accomplishments:**
- Overall site layout & safety reviews complete
- Most key pieces of equipment have been ordered
- Systems integration (controllable grid interface, thermal, water, gas, electrical) underway

**Caterpillar – Demonstration of H₂ Fuel Cell at a Data Center (poster - TA044)**

**Goals:**
- Install 1.5MW stationary fuel cell at a Microsoft data center in Washington state
- 48 hours of LH₂ onsite
- Increase confidence and comfort in H₂ & fuel cells for IT industry (document requirements and identify gaps)

**Key Accomplishments:**
- New project just underway
Technology Acceleration: Transportation

Diagram showing the integration of hydrogen and fuel cell technologies with various energy sources and processes. Key elements include:

- Conventional Storage
- Power Generation
- Waste
- Renewable Sources
- Nuclear
- Fossil with CCUS
- Electric Grid Infrastructure
- Gas Infrastructure
- Heat/Distributed Power
- Synthetic Fuels
- Upgrading Oil / Biomass
- Ammonia/Fertilizer
- Metals Production
- Chemical/Industrial Processes
Technology Acceleration: Transportation (Medium / Heavy-Duty)

Focused on M/HD Trucks with Demanding Drive Cycles & Range Requirements

**CTE – Fuel Cell Hybrid Electric Delivery Van (TA01)**

**Goal:**
Demonstrate hybrid electric delivery vans with fuel cell range extenders (75 to >125 mile range)

**Key Accomplishments:**
- 5 trucks built and undergoing testing
- 10 more trucks in assembly – to be completed by summer 2021
- Trucks to operate in disadvantaged community in CA

**SuperTruck III Funding Opportunity Announcement**
- Develop & demonstrate medium/heavy-duty electric trucks including H₂ fuel cells
- Up to $100M over 4 years; Released on April 15th (funded jointly by HFTO and VTO)


**Goal:**
Validate fuel cell electric bus performance & cost using real-world data

**Key Accomplishments:**
- Tracked 38 buses; 12 surpassed 25,000 hours & 1 over 32,000 hours
- ~9 mpdge (~2x greater than CNG or diesel); ~300 mile range (37.5 kg H₂)
- Status report: [https://www.nrel.gov/docs/fy21osti/75583.pdf](https://www.nrel.gov/docs/fy21osti/75583.pdf)

**Focused on M/HD Trucks with Demanding Drive Cycles & Range Requirements**

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**Technology Acceleration: Transportation (Maritime)**

**H₂ Can Reduce GHGs & Still Meet Maritime Performance Requirements**

**Hornblower – Marine Hydrogen Demonstration (poster - TA045)**

**Goal:**
First of its kind maritime H₂ refueling infrastructure on water (530 kg H₂ /day) - onboard a barge at the San Francisco Waterfront

**ANL - Total Cost of Ownership Analysis for Ferries (TA034)**

**Key Results:**
- Fuel cost dominates TCO
- H₂ fuel cell ferries likely to be cost competitive at fuel cell cost of $60/kW & LH₂ bunkered cost of $4.00/kgH₂ (Ultimate)
- Reducing onboard storage can yield lower TCO than diesel
Technology Acceleration: Transportation (Rail)

H₂ and Fuel Cells Offer Big Potential for Rail Applications

ANL - Total Cost of Ownership Analysis for Passenger Rail (TA034)

Key Results:
H₂ Electric Multiple Unit (HEMU) locomotives likely to be cost competitive at fuel cell cost of $60/kW & LH₂ cost of $3.50/kg (Ultimate)

CEC - H₂ Switcher Locomotive

Technical advisor for CEC’s FC-powered switcher locomotive demo project
**Electricore - High Pressure / Flow Rate Dispenser & Nozzle for HD Vehicles (TA049)**

**Goals:**
- Develop dispenser & nozzle (receptacle, hose, breakaway) for HD vehicles
- 100 kg in 10 mins at 70 MPa
- Demonstrate system at NREL

**Key Accomplishments:**
- Completed industry survey (27 organizations) to determine specifications
- Initial design work completed including component selection, CFD and FMEA analysis
- Partnered with WEH & Bennett

**Electricore – Advanced H₂ Mobile Fueler (TA017)**

**Goal:**
Develop a mobile fueler capable of fueling 20-40 vehicles / day (70MPa, T40, 3-5 min fill, 200 kg H₂)

**Key Accomplishments:**
Design, assembly, and initial testing complete; available soon for public fueling in Ontario, CA
Technology Acceleration: Transportation (New Uses)

HFTO Continues to Pursue New End Use Applications for H₂

H₂ HD Off-Road Equipment Workshop

Save the Date
September 22nd – 24th

Goal:
Develop & demonstrate disaster relief truck to provide victim aid, communication support, exportable power & potable water

Key Accomplishments:
- Developed vehicle design specifications w/ DOE-VTO, Army GVSC, DHS S&T (and FEMA) & Army Corps of Engineers

- Heavy-Duty Fuel Cell Truck Workshop, July 2018

- H2@Rail Workshop, March 2019
  https://www.energy.gov/eere/fuelcells/h2ports-workshop

- H2@Ports Workshop, September 2019
  https://www.energy.gov/eere/fuelcells/h2ports-workshop

- H2@Airports Workshop, November 2020
  https://www.energy.gov/eere/fuelcells/h2airports-workshop
Technology Acceleration: Industrial & Chemical Processes

- Conventional Storage
- Power Generation
- Transportation
  - Synthetic Fuels
  - Upgrading Oil / Biomass
  - Ammonia / Fertilizer
  - Metals Production
- Chemical/Industrial Processes

- Hydrogen
- Electric Grid Infrastructure
- Fossil with CCUS
- Renewables
- Nuclear
- Waste
- H₂O

- Gas Infrastructure
- Heat/Distributed Power
- CO₂
- N₂
Technology Acceleration: Industrial & Chemical Processes (Steel)

Decarbonizing Iron/Steel Production with Hydrogen (HySteel) – new projects

Missouri U. of S&T - Grid Interactive Steelmaking with H₂ (GISH) (poster TA053)

Goals:
• 1 ton/week iron production using variable H₂/NG content; scaled to 5,000 ton/day
• Demonstrate grid integrated steel production system combining:
  • H₂-Direct-Reduction furnace for ironmaking
  • Electric melting for steelmaking

U. of California Irvine - H₂ SOEC integrated with Direct Reduced Iron (DRI) plants (poster TA052)

Goals:
• 1 ton/week equivalent H₂-Direct-Reduction pilot system, scale-up design for a 2Mton/year DRI product capacity
• Demonstrate a thermally & chemically integrated Solid Oxide Electrolyzer system with a DRI plant
Technology Acceleration: Enabling Activities
**Technology Acceleration: Enabling Activities (Manufacturing)**

**Manufacturing is Key to Reduce Costs and Improve Durability at Large Volumes**

**NREL - MEA Manufacturing R&D (TA001)**

**Goals:**
- Develop quality inspection and defect threshold methods and understandings
- Focused on HD Fuel Cell and Low Temperature Electrolyzer (LTE) applications

**Key Accomplishments:**
- Validated membrane thickness imaging including impact of web speed
- Developed technique for reinforced & thick LTE membranes
- Developed thermal scanning for membrane thickness

**International Meeting on Membrane Electrode Assembly Quality Control for Electrolysis and Fuel Cells (May 2021)**

**Goals:**
- Review Prior Workshop Outcomes
- Add LTE MEA materials and compare to FC QC needs
- Prioritize QC needs for both FC and LTEs

**Key Outcomes:**
- Preliminary findings show:
  - FC industry expressed need to better understand features (material variations) vs. actual defects
  - Electrolyzer industry expressed need to review failure modes to inform QC needs

**Collaboration between U.S. (NREL - TA001), National Research Council-Canada and Fraunhofer ISE in Germany**
Technology Acceleration: Enabling Activities (Safety, Codes & Standards)

U.S. Federal Regulatory Map

Major Gaps Identified

- FERC for pipeline transmission, electricity production, and heating
- FHWA for bridges and tunnels
- FRA, USCG, and FAA for rail, maritime, and aviation use

Technology Acceleration: Enabling Activities (Safety, Codes & Standards)

SCS - Enabling Codes & Standards

**SNL - Materials Compatibility (SCS 005)**

**Goal:**
Provide scientific basis for codes & standards surrounding materials compatibility

**Key Accomplishments:**
- ASME Code Case 2938 enabled up to 3X longer life for Type I & II tanks
- Demonstrated Modal Acoustic Emission & Eddy Current techniques for vessel inspection in effort to define cycle parameters

**SNL - Hydrogen Behavior R&D (SCS 010)**

**Goal:**
Identify ways to reduce siting burdens for LH₂ deployment through R&D to enable a 40% reduction in station footprint

**Key Accomplishments:**
- Developed proposed science-based LH₂ exposure distances tables for NFPA 2
- Field validation of cryogenic H₂ behavior:
  - Confirmed H₂ is concurrent with visible plume
  - Demonstrated minimal effect of humidity on H₂ plume
Lab-Level engagement with FCH-JU projects:
- **PRESLHY** – liquid hydrogen R&D
- **PRHYDE** – protocol for heavy duty refueling

Technology Acceleration – Examples of International Collaboration

- Co-Chair of IPHE RCSSWG and E&O WG
- Coordinating efforts to identify regulatory gaps and prioritize efforts

• Strategic partnership with the Center for H₂ Safety
• Over 60 members & growing!
Technology Acceleration Program: Collaboration Network

Fostering technical excellence, economic growth and environmental justice

**DOE H₂ Program Collaborations**

- DOE AMO
- DOE VTO
- DOE WETO
- DOE ARPA-E

**DOE Cross-Cutting Initiatives**

- Energy Storage Grand Challenge
- Cybersecurity
- Advanced Manufacturing
- Grid Modernization Initiative

**Cross-Agency Collaborations**

- DOT (NHTSA, FRA, FHWA, MARAD, FAA)
- Army GVSC, DHS S&T, Army Corps of Engineers
- NASA WSTF
- IWG (15 government agencies including states)

**U.S. Regional and International Collaborations**

<table>
<thead>
<tr>
<th>Project Coordination across ~20 U.S. States</th>
<th>IPHE (RCSSWG)</th>
<th>FCH-JU</th>
<th>IA- HySafe</th>
<th>Mission Innovation - Shipping</th>
<th>Center for Hydrogen Safety</th>
<th>Bilateral Collaborations</th>
<th>National Research Council-Canada</th>
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**Industry Engagement**

- Center for Hydrogen Safety
- 21st Century Truck Partnership
- U.S. DRIVE
- FCHEA

**U.S. DRIVE**

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**21st Century Truck Partnership**

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**DOE AMO**

- DOE VTO
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- DOE ARPA-E

**Energy Storage Grand Challenge**

- Cybersecurity
- Advanced Manufacturing
- Grid Modernization Initiative

**Grid Modernization Initiative**

- DOE AMO
- DOE VTO
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**U.S. Regional and International Collaborations**

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<th>FY2019</th>
<th>FY2020</th>
<th>FY2021</th>
<th>FY2022</th>
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<tbody>
<tr>
<td>Released DOE H₂ and Fuel Cell Targets for Long-Haul Class 8 Trucks</td>
<td>Kicked Off H₂ Working Group as part of the 21st Century Truck Partnership</td>
<td>Awarded World’s first Large Scale Fuel Cell Powered Data Center (Caterpillar)</td>
<td>Focus on Integrated Offshore Wind to H₂ Demonstration</td>
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<td>Launched the Center for Hydrogen Safety (AIChE &amp; PNNL)</td>
<td>Kicked Off 2 Integrated Energy System Demonstration Projects Showcasing H₂@Scale Concept (Plug Power &amp; Frontier Energy)</td>
<td>Awarded World’s First Renewable H₂ Production Refueling Barge (Hornblower)</td>
<td>Focus on Decarbonizing Steel &amp; Ammonia through use of Green H₂</td>
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<td>H₂@Ports Workshop in Collaboration with DOT MARAD</td>
<td>Kicked Off a First-of-a-Kind Dynamic H₂ Production Demonstration at a Nuclear Plant (Exelon)</td>
<td>Kicked off 2 HySteel projects to Demonstrate using H₂ to Decarbonize Iron &amp; Steel Production (UCI and MS&amp;T)</td>
<td>Continue Collaborating with NE on H₂ Production from Nuclear</td>
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<td>H₂@Rail Workshop in Collaboration with DOT-FRA</td>
<td>Setup National Validation Lab for Large High Temperature (HT) Electrolyzers (INL)</td>
<td>Establishing an Integrated MW-scale H₂ Production, Storage and FC System at ARIES (NREL)</td>
<td>Select SuperTruck III Projects for M/HD H₂ Fuel Cell Trucks</td>
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<td>Setback Distances for GH₂ Storage Reduced 50% as a result of Codes &amp; Standards efforts</td>
<td>Performed Release of Cryogenic H₂ to support Reduced LH₂ Storage Separation Distances in NFPA 2 (SNL)</td>
<td>Initiated CRADA Project on High-Flow Fueling Protocol in Concert w/ International PRHYDE project (NREL)</td>
<td>Continued Collaboration and Alignment of 21CTP &amp; U.S. DRIVE</td>
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<td>Released HyRAM 2.0 (H₂ Risk Assessment) (SNL)</td>
<td>Enabled ~3x Longer Life for Type I &amp; II Storage Tanks through Testing to Enable ASME Code Case Revision (SNL)</td>
<td>Validated 2 High Temp Electrolyzers from Industry – including a 25kW stack that Surpassed 4,000 hrs with &lt;0.5% Degradation / 1,000 hrs (INL)</td>
<td>Test 250kW Integrated HT Electrolysis System using Fully Emulated Nuclear Integrated Test Stand</td>
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<td>H₂@Airports Workshop</td>
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<td>Kicked off H2EDGE Workforce Development Project (EPRI)</td>
<td>Utilize ARIES Capabilities to Advance Integration of H₂ Technologies in Future Energy Systems</td>
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<td>Hosted International Workshop on Quality Control for Electrolysis &amp; Fuel Cells w/ NRC (Canada) &amp; Fraunhofer ISE (Germany) (NREL)</td>
<td>Collaboration with International Mission Innovation – Shipping (Maritime)</td>
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<td>Released Federal Regulatory Map Report (SNL)</td>
<td>Perform SCS Gap Assessment for Large Scale H₂ Applications</td>
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<td>Utilize Bulk Cryogenic H₂ Behavior Validation Data to Enable Reduction of Separation Distances in NFPA 2</td>
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2021 H2@Scale CRADA Call – Supporting ARIES (Released Today!)

- Topic 1: H2@ARIES – Integrated Hydrogen Energy System Testing/Validation
- Topic 2: Applied Risk Assessment and Modeling for H2@Scale Applications
- Topic 3: Next-Generation Sensor Technologies (wide-area $H_2$ sensors)


- Total funding up to $12M over 3 years*
- $500k - $2M per project (dependent on topic area)
- Up to 14 projects total
- 30% Cost share including 10% cash in
- National Lab leads w/ partners from industry, state & local gov, universities, etc.

Proposals due July 19, 2021

*Pending Appropriations
Technology Acceleration Team – THANKS!

Jesse Adams
Technology Acceleration Program Manager
Jesse.Adams@ee.doe.gov

Technology Managers

Michael Hahn
Michael.Hahn@ee.doe.gov

Brian Hunter
Brian.Hunter@ee.doe.gov

Pete Devlin
Peter.Devlin@ee.doe.gov

Laura Hill
Laura.Hill@ee.doe.gov

Open position
Federal

Open position
Federal

Fellows and Contractors

Zachary Taie
Fellow
Zachary.Taie@ee.doe.gov

Open position
Fellow - TA

Open position
Fellow - SCS

Daniel Berteletti
Contractor
Daniel.Berteletti@ee.doe.gov

Karen Harting
Contractor
Karen.Harting@ee.doe.gov