U.S. DEPARTMENT OF ENERGY
Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

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

H2@Scale U.S. Department of Energy

What is H2@Scale?

The H2@Scale initiative, led by the U.S. Department of Energy's (DOE's) Hydrogen and Fuel Cell Technologies Office (HFTO) within the Office of Energy Efficiency and Renewable Energy (EERE), brings together stakeholders to advance affordable hydrogen production, transport, storage, and use while increasing revenue opportunities in multiple energy sectors. It includes DOE funded projects at National Laboratories and in collaboration with industry to accelerate hydrogen research, development, and demonstration activities.

How are H2@Scale CRADA projects informing pathways for cost-competitive hydrogen?[1]

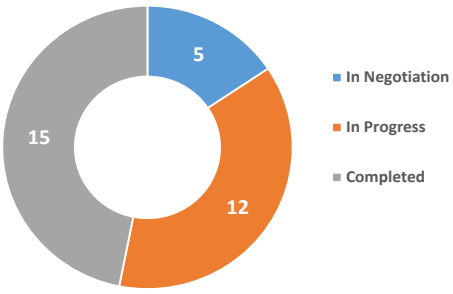
H2@Scale CRADA projects have developed multiple, free-to-access resources to inform hydrogen technology development, including:

- A report determining the cost of hydrogen production from electrolysis in six different integrations with electricity markets. (PG&E, NREL)
- An analysis characterizing the value proposition of high-temperature electrolysis integrated with nuclear power plants, relative to hydrogen demand, price points, and facility design. (Exelon, INL)
- H2FillS, a thermodynamic, mass flow model of the hydrogen fueling process for vehicles that can inform development of novel fueling methods. (Frontier Energy, NREL)
- A risk assessment and modeling analysis to inform fuel cell vehicle repair garage design. (Quong & Associates, SNL)

[1] Lead CRADA partner and national laboratory is shown. Complete list of projects and partners on p. 2-3.

HFTO, industry partners, and national labs working together to advance the H2@Scale initiative

Status of H2@Scale CRADA Projects



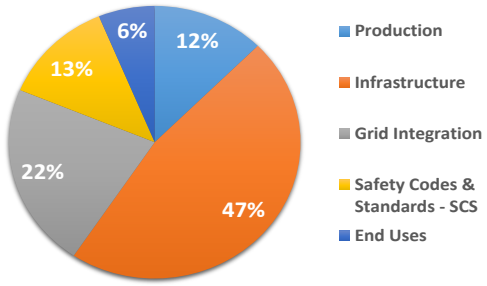
As of December, 2020

What are H2@Scale CRADA Projects?

DOE has issued two H2@Scale Cooperative Research and Development Agreement (CRADA) Calls since 2017 which have resulted in more than 30 CRADA projects with industry, academia, and non-profit organizations. Project focus areas include:

- Modeling and analysis
- Materials compatibility R&D
- Integration of hydrogen in the grid
- Safety and component R&D
- Co-generation of hydrogen and added-value products
- Technology performance verification

H2@Scale CRADA Focus Areas



H2@Scale CRADA Calls have targeted R&D on hydrogen fueling for medium- and heavy-duty vehicles, blending in natural gas pipelines, production, grid integration, and projects to inform safety, codes, and standards.

What H2@Scale CRADA projects are currently underway?

- Advancing the design and operating strategies of high throughput stations, supporting light-, medium-, and heavy-duty end use applications. (Shell, NREL)
- Developing a fully-integrated electrolyzer and bioreactor prototype, resulting in licensing of the technology by Southern California Gas. (SoCal Gas, NREL)
- Evaluating performance of conventional and emerging pipeline materials in hydrogen blends. (SoCal Gas, SNL)
- Designing hydrogen fueling and fuel cell systems for heavy-duty vehicles, stationary power, and resiliency at ports. (Port of Seattle, PNNL)

H2@Scale CRADA Projects & Partners		
Industry Partner	**Lab**	**Project Name**
Hydrogen Production		
C4-MCP, Southern California Gas Company, West Virginia University	PNNL	Methane Pyrolysis for Base-Grown Carbon Nanotubes and CO2-free Hydrogen over Transition Metal Catalysts
Giner ELX	NREL	MW-Scale PEM-based Electrolyzers for RES Applications
GTA, Inc.	NREL	Scalable Electrolytic Systems for Renewable Hydrogen Production
Honda R&D Americas	NREL	Validating an Electrolysis System with High Output Pressure
Hydrogen Infrastructure		
American Air Liquide, Inc, Chevron, DNV GL, Enbridge, Electric Power Research Institute, GTI, Operations Technology Development NFP (OTD), Hawaii Gas, Pipeline Research Council International (PRCI), Sacramento Municipal Utility District (SMUD), Southern Company, Stony Brook University, Tenaris, and 7 others	NREL, SNL, PNNL, ORNL, ANL, and NETL	HyBlend - focused on materials compatibility R&D, technoeconomic analysis, and life cycle to assess the feasibility of hydrogen blending in the US natural gas pipeline infrastructure
Air Liquide	SNL	Development, Validation, and Benchmarking of Quantitative Risk Assessment Tools for Hydrogen Refueling Stations
CA Governor's Office of Business and Economic Development (CA GO-Biz), CA Energy Commission (CEC), CA Air Resources Board (CARB), South Coast Air Quality Management District (SCAQMD)	SNL, NREL	Heavy-Duty Reference Station Design, Test Device Development, and Capacity Modeling
Chiyoda Corporation	ANL	Toluene-Methylcyclohexane as Two-Way Carrier for Hydrogen Transmission and Storage
Honda R&D Americas	NREL	Turboexpander: Alternative Fueling Concept for Fuel Cell Electric Vehicle Fast Fill
HyET Hydrogen B.V.	LBNL	MEMbrane Technology for the Electrochemical Compression of Hydrogen
HyET Hydrogen B.V.	NREL	Membrane Electrode Assembly Manufacturing Automation Technology for the Electrochemical Compression of Hydrogen
NanoSonic, Inc.	PNNL	Hydrogen Materials Compatibility of Low Cost, High Pressure, Polymer Hydrogen Dispensing Hoses
PDC Machines Inc.	ANL	Develop a Tool to Estimate the Benefits of Tube-Trailer Consolidation Scheme for Station Builders
Quong & Associates, Inc. (QAI)	SNL	Risk Analysis and Modeling to Improve Hydrogen Fuel Cell Vehicle Repair Garages
Tatsuno North America	NREL	Tatsuno Coriolis Flow Meter Development Testing in High Pressure Hydrogen
Frontier Energy, Inc.	NREL, ANL, SNL	Holistic Fuel Cell Electric Vehicle / Hydrogen Station Optimization Model
Nikola Motor Company	SRNL, SNL, ANL	Optimization of Pre-cooling at Heavy-Duty Stations and Cyber Vulnerability Analysis
Seattle City Light, Port of Seattle, Northwest Seaport Alliance, and PACCAR/Kenworth	PNNL	Design of Hydrogen Fueling and Fuel Cell Systems for Heavy-Duty Vehicles, Stationary Power, and Resiliency at Ports
Shell Oil Products US; Air Liquide Advanced Technologies U.S., LLC; Toyota Motor North America; Honda R&D Americas, Inc.	NREL	Innovating High Throughput Hydrogen Stations
Southern Company Services, Inc	SNL, PNNL, NREL, ANL	Hydrogen Blending into Natural Gas Pipelines
Safety, Codes and Standards		
CA GO-Biz, CEC, CARB, SCAQMD	NREL	California Hydrogen Infrastructure Research Consortium
CEC	PNNL	Hydrogen Safety Panel Evaluation of Hydrogen Facilities
Connecticut Center for Advanced Technology (CCAT)	PNNL	Hydrogen Safety Outreach by the Hydrogen Safety Panel to Expedite Hydrogen Fueling and Energy Project Deployment
Frontier Energy, Inc.	NREL	Development of High Flow 350-bar Hydrogen Fueling Method
Grid Integration		
Electric Power Research Institute (EPRI)	NREL	Valuation of Hydrogen Technology on the Electric Grid Using Production Cost Modeling
Exelon Corporation	INL, ANL, NREL	Merchant Hydrogen at Scale: A Technical-Economic Case Study of the Potential for Nuclear Hydrogen Production
Pacific Gas and Electric Company (PG&E)	NREL	Optimizing an Integrated Renewable-Electrolysis System

Southern Company Services, Inc; Terrestrial Energy US	SRNL, SNL	Hybrid Electrical/Thermal Hydrogen Production Process Integrated with a Molten Salt Reactor Nuclear Power Plant
Southern Company Services, Inc.; Xcel Energy; Exelon Corporation	INL, ANL, NREL	Region-Specific Merchant Hydrogen Market Assessment and Techno-Economic Assessment of Electrolytic Hydrogen Generation
TerraPower, LLC	INL, PNNL	Evaluate High Temperature Steam Electrolysis Coupled to PWR/MCFR/TWR for Hydrogen Production and Energy Storage
University of California, Irvine - Advanced Power and Energy Program	NREL	Electrolytic Renewable Fuel Production Optimal Operation Investigation
Hydrogen End Uses		
Southern California Gas Company	NREL	Reducing Capital Cost and Improving Efficiency of Water Electrolyzer Systems, While Improving the Production of Renewable Natural Gas in a Bioreactor