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

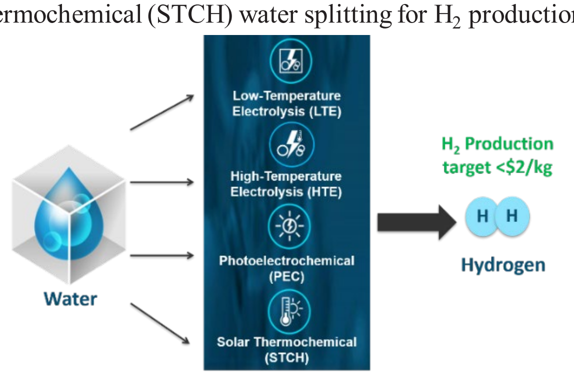
HydroGEN
Advanced Water Splitting Materials

CONSORTIUM
HydroGEN

HydroGEN is a consortium of five DOE National Laboratories working together to advance water-splitting (AWS) technologies for clean, sustainable hydrogen production. EERE's Hydrogen and Fuel Cell Technologies Office launched HydroGEN in 2016 to overcome R&D challenges in AWS and meet DOE's H_2 cost goal of less than $2 per kilogram. Producing H_2 from water using renewable electricity, nuclear power, or direct sunlight enables opportunities for large-scale energy storage, grid resiliency, and a clean, equitable energy future.

Collaborative Research Capabilities

As a collaborative effort among National Laboratories, academia, and industry, HydroGEN is addressing materials barriers associated with low-temperature electrolysis (LTE), high-temperature electrolysis (HTE), photoelectrochemistry (PEC), and solar thermochemical (STCH) water splitting for H_2 production.

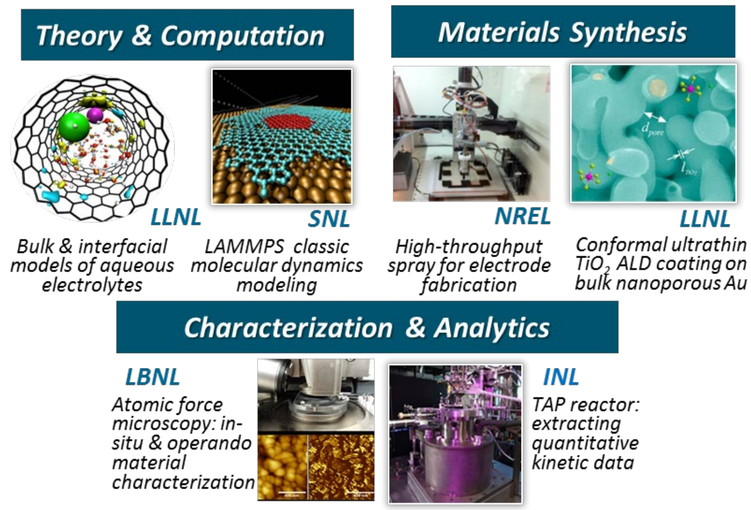


HydroGEN brings together a network of unique, world-class capabilities in materials theory and computation, advanced materials synthesis, characterization, and analysis to support:

- **30+** projects awarded through DOE funding opportunity announcements (FOAs)
- **5** collaborative multi-lab R&D projects
- **4** multi-agency projects with the National Science Foundation's Designing Materials to Revolutionize and Engineer our Future program

SUPPORTING UNIVERSITY & INDUSTRY LED R&D

HydroGEN provides academia, industry, and other national labs with streamlined access to world-class experimental and computational capabilities for accelerated materials discovery. Labs and project partners collaborate through personnel, capabilities, materials, and data sharing.



NATIONAL LAB-DIRECTED R&D

Collaborative multi-lab projects leverage HydroGEN capabilities and expertise to address specific research gaps critical to enabling low-cost H_2 through improved performance and durability. Efforts include theory-guided R&D where models and experimental testing are combined to analyze performance and durability. The consortium also aims to exploit similarities in technical challenges while leveraging simulation capabilities across all four AWS pathways.

INL Idaho National Laboratory · BERKELEY LAB · Sandia National Laboratories · Lawrence Livermore National Laboratory · NREL National Renewable Energy Laboratory

ACCOMPLISHMENTS

- Achieved 70% PEM electrolyzer cell efficiency, while improving durability and reducing cost
- Demonstrated metal-supported oxygen-conducting solid oxide electrolyzer cell (o-SOEC) with dramatically improved stability
- Scaled up baseline cell by 8X w/ 9% STH efficiency & 100-hour stability for an integrated PV-PEC system
- Discovered new STCH compounds with H_2 production capacities exceeding state-of-the-art at lower reduction temperatures

DATA HUB & BENCHMARKING

The HydroGEN Data Hub is a robust and secure resource for hosting experimental and modeling/simulation data that is searchable, shareable, usable, and freely leveraged by the community. HydroGEN is also engaging the research community in developing universal standards and best practices for materials benchmarking and reporting for all four advanced water splitting technologies.

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Projects

LOW TEMPERATURE ELECTROLYSIS - LTE	
Proton Energy Systems	High Efficiency PEM Water Electrolysis Enabled by Advanced Catalysts, Membranes and Processes
Northeastern University	Developing Novel Platinum Group Metal-Free Catalysts for Alkaline Hydrogen and Oxygen Evolution Reaction
Argonne National Lab	PGM-Free OER Catalysts for PEM Electrolyzer
Los Alamos National Lab	High-Performance Ultralow-Cost Non-Precious Metal Catalyst System for AEM Electrolyzer
Los Alamos National Lab	Scalable Elastomeric Membranes for Alkaline Water Electrolysis
Georgia Institute of Technology	High-Performance AEM LTE with Advanced Membranes, Ionomers and PGM-Free Electrodes
University of Oregon	Pure Hydrogen Production Through Precious-Metal-Free Membrane Electrolysis of Dirty Water
Chemours	Performance and Durability Investigation of Thin, Low Crossover Proton Exchange Membranes for Water Electrolyzers

HIGH TEMPERATURE ELECTROLYSIS - HTE	
University of Connecticut	Proton-Conducting Solid Oxide Electrolysis Cells for Large-Scale Hydrogen Production at Intermediate Temperatures
Northwestern University	Degradation Characterization and Modeling of a New Solid Oxide Electrolysis Cell Utilizing Accelerated Life Testing
UTRC	Thin-Film, Metal-Supported High-Performance and Durable Proton-Solid Oxide Electrolyzer Cell
Saint-Gobain	Development of Durable Materials for Cost Effective Advanced Water Splitting Utilizing All Ceramic Solid Oxide Electrolyzer Stack Technology
West Virginia University	Intermediate Temperature Proton-Conducting Solid Oxide Electrolysis Cells with Improved Performance and Durability
University of South Carolina	A Multifunctional Isostructural Bilayer Oxygen Evolution Electrode for Durable Intermediate-Temperature Electrochemical Water Splitting
Redox	Scalable High-H_2 Flux, Robust Thin Film Solid Oxide Electrolyzer
Nexceris	Advanced Coating to Enhance the Durability of SOEC Stacks

PHOTOELECTROCHEMICAL - PEC	
Rutgers University	Best-in-Class PGM-Free Catalyst Integrated Tandem Junction PEC Water Splitting Devices
Stanford University	Protective Catalyst Systems on III-V and Si-based Semiconductors for Efficient, Durable Photoelectrochemical Water Splitting Devices
University of Hawaii	Novel Chalcopyrites For Advanced Photoelectrochemical Water Splitting
University of Michigan	Monolithically Integrated Thin-Film/Silicon Tandem Photoelectrodes for High Efficiency and Stable Photoelectrochemical Water Splitting
University of California, Irvine	Development of Composite Photocatalyst Materials that are Highly Selective for Solar Hydrogen Production and their Evaluation in Z-Scheme Reactor Designs
Rice University	Highly Efficient Solar Water-Splitting Using 3D/2D Hydrophobic Perovskites with Corrosion Resistant Barriers
University of Toledo	Perovskite/Perovskite Tandem Photoelectrodes For Low-Cost Unassisted Photoelectrochemical Water Splitting

SOLAR THERMOCHEMICAL - STCH	
Colorado School of Mines	Accelerated Discovery of Solar Thermochemical H_2 Production Materials via High-Throughput Computational and Experimental Methods
University of Colorado	Computationally Accelerated Discovery and Experimental Demonstration of High-Performance Materials for Advanced STCH Hydrogen Production
Northwestern University	Transformative Materials for High-Efficiency Thermochemical Production of Solar Fuels
Arizona State University	Mixed Ionic Electronic Conducting Quaternary Perovskites: Materials by Design for Solar Thermochemical H_2
University of Florida	A New Paradigm for Materials Discovery and Development for Lower Temperature and Isothermal Thermochemical H_2 Production
University of California, San Diego	New High-Entropy Perovskite Oxides with Increased Reducibility and Stability for Thermochemical Hydrogen Generation

BENCHMARKING	
Proton Energy Systems	Benchmarking Advanced Water Splitting Technologies: Best Practices in Materials Characterization